TETRAPLEGIA AND PARAPLEGIA

A GUIDE FOR PHYSIOTHERAPISTS

Ida Bromley

SIXTH EDITION

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Preface – 6th edition

The purpose of this book has always been to act as a manual for physiotherapists faced with the challenge of treating patients with tetraplegia and paraplegia. It is written particularly for those who have little experience in this field or who do not have the benefit of working in a spinal injuries centre. The text is therefore not exhaustive but suggests methods of treatment which have been used for many years and found valuable for a large number of patients.

The principles of treatment were originally laid down by Sir Ludwig Guttmann at the National Spinal Injuries Centre, Stoke Mandeville, in England where his interest in and enthusiasm for physiotherapy are well known. Unlike many other textbooks on this subject, this book outlines a rehabilitation programme from the day of the patient's admission as an acute lesion to the achievement of individual maximum independence and includes treatment for patients with incomplete lesions, those with lesions above C2 and the particular problems encountered in treating children.

The layout of the material may seem repetitious but it is intended to facilitate the use of the book for those who are involved in handling the patients and believe as I do that efficient treatment depends upon attention to detail. For clarity in the sections involving specific actions of patient and therapist, 'his' is always used for the patient and 'her' for the therapist. Both ordinal and metric systems of measurement have been given in this edition. The most commonly used system (such as that by the manufacturer) is placed first. The biomechanical principles of transferring have now been included as a basis for the chapters which follow in the hope that they may prove useful to both students and others.

Additions to this volume reflecting developments over the past few years include current approaches to repairing the spinal cord, ageing with spinal cord injury, pressure and related problems, with a detailed assessment of the posture of the seated patient and the latest in wheelchair design. The role of the patient as the centre of the rehabilitation team has been given greater emphasis.

I am deeply indebted to many people for their contribution to this and previous volumes. Without the support of my long standing colleagues and friends this edition would never have been published. I am doubly indebted therefore to Ebba Bergström, Susan Edwards,

Spinal cord injury

Spinal cord injury is not a notifiable disease and therefore figures for the annual incidence are inaccurate and may vary according to the source. The estimated incidence of spinal cord injury worldwide is between 11 and 53 cases per million inhabitants (Tator 2004). In general, road traffic accidents account for the largest number followed by falls, sports injuries and violence, although causes vary considerably according to the prevailing circumstances in the country in which they occur. The numbers are augmented by the group of people with spinal cord damage caused by disease or other forms of injury, e.g. stab wounds. The non-traumatic cases have a different demographic profile and a lower prevalence of many of the complications that affect those with traumatic lesions (New et al 2002).

Until Sir Ludwig Guttmann pioneered a positive approach to the treatment of spinal cord lesions at Stoke Mandeville Hospital in the mid-1940s, most people died of the resultant complications (Guttmann 1946). Regrettably this can still happen today where appropriate skills, knowledge and facilities are not readily available. Spinal injury units now exist worldwide and international symposia on the treatment of those with spinal cord lesions take place regularly.

The life expectancy of this group of people has steadily increased over the last six decades, and with constantly improving methods of treatment this trend should continue.

Patients with spinal cord injury are initially totally dependent on those around them and need expert care if they are once again to become independent members of the community. It is an exciting and rewarding challenge to be involved in and contribute to the metamorphosis which occurs when a tetraplegic or paraplegic patient evolves into a spinal man (Fig. 1.1).

In this book, maximum detail has been given in the sections dealing with the tetraplegic patient. Solutions to the majority of problems facing those with paraplegia have now been found, whereas many of the social, professional and industrial rehabilitation problems of those with tetraplegia have still to be solved. The tetraplegic patient needs a longer period of rehabilitation to achieve maximum independence and overcome the sometimes apparently insurmountable obstacles. With the increased expertise of paramedical personnel in the ambulance service, the lives of patients who have fractures as

Rehabilitation

Injury

Postural reduction
Correct positioning
Chest therapy
Passive movements

Fracture healed

Pressure consciousness
Strength
Balance
Mobility
Wheelchair management

Social activities
outside the hospital

Transfers

Standing

Chair
manoeuvres

Walking in bars

Bed   Bath   Toilet   Car   Walking on crutches

Home for
week-ends for
assessment

Dress   Wash   Bladder   Transport
                              and bowel
                              care

Institutional
care

Training for relatives   Self-care   Mobility in the
in patient care   environment

Community   **Home**   **Employment**

**Spinal man re-integrated
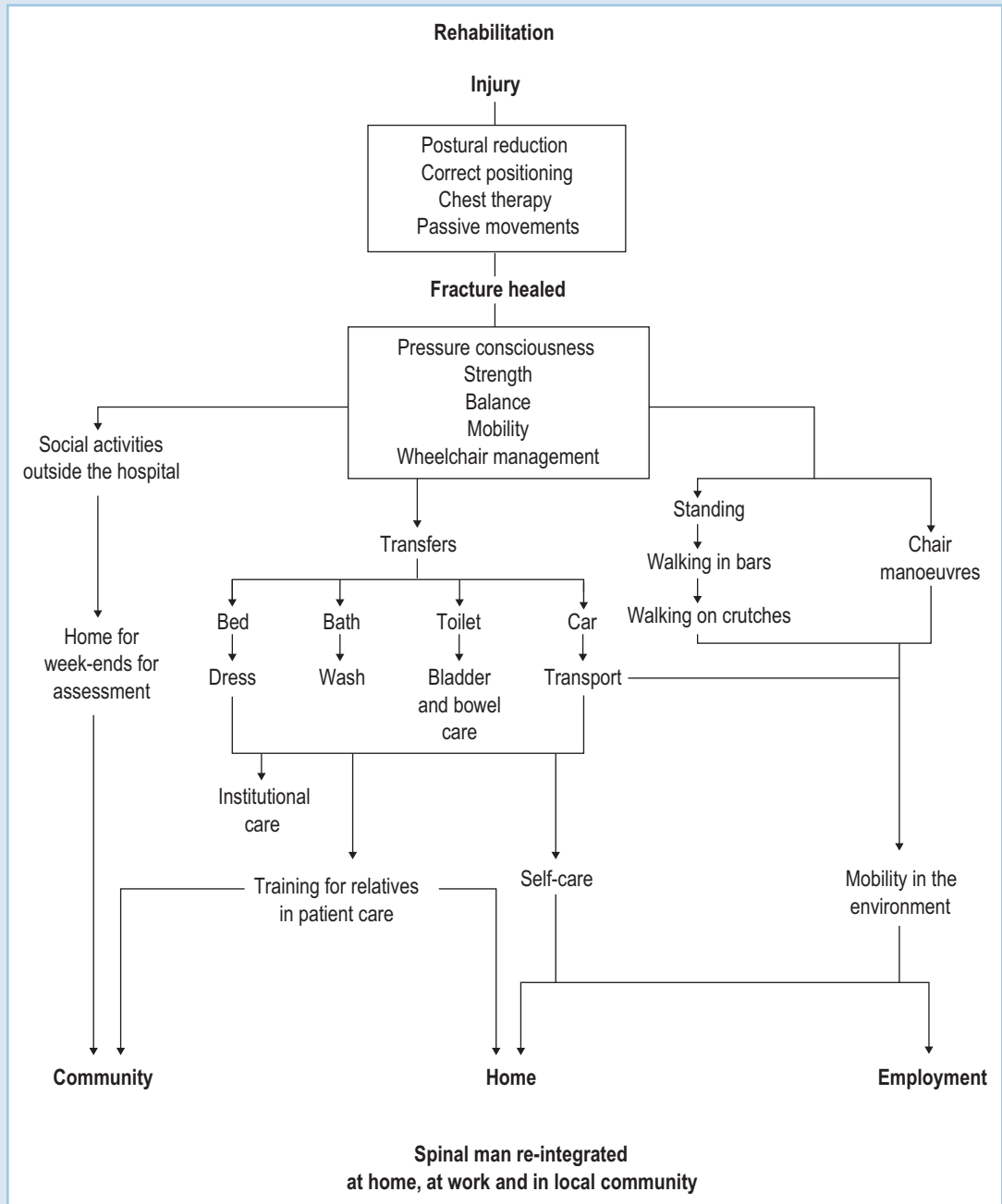at home, at work and in local community**

Figure 1.1 Dependence to independence.

high as C1/C2 are saved at the scene of the accident and they now reach hospital alive. Of the cases admitted to spinal units, the majority are traumatic, and about half of these involve the cervical spine.

The major causes of the approximately one-thousand new traumatic cases of spinal cord injury per year in the UK are road traffic accidents, industrial accidents, sporting injuries and accidents in the home. The majority of the traumatic cases are found to have fractures/dislocations, fewer than a quarter have fractures only, and a very small number are found to have involvement of the spinal cord with no obvious bony damage to the vertebral column, e.g. those with whiplash injuries. The most vulnerable areas of the vertebral column would appear to be:

- lower cervical, C5–C7
- mid-thoracic, T4–T7
- thoracolumbar, T10–L2.

The non-traumatic cases are mainly the result of transverse myelitis, tumours and vascular accidents. Thrombosis or haemorrhage of the anterior vertebral artery causes ischaemia of the cord with resulting paralysis.

Spinal cord damage resulting from either injury or disease may produce tetraplegia or paraplegia depending upon the level at which the damage has occurred, and the lesion may be complete or incomplete.

Tetraplegia. This term refers to impairment or loss of motor and/or sensory function in the cervical segments of the spinal cord due to damage of neural elements within the spinal canal. Tetraplegia results in impairment of function in the arms as well as in the trunk, legs and pelvic organs. It does not include brachial plexus lesions or injury to peripheral nerves outside the neural canal.

Paraplegia. This term refers to impairment or loss of motor and/or sensory function in the thoracic, lumbar or sacral (but not cervical) segments of the spinal cord, secondary to damage of neural elements within the spinal canal. With paraplegia, arm function is spared, but depending on the level of injury, the trunk, legs and pelvic organs may be involved. The term is used in referring to cauda equina and conus medullaris injuries, but not to lumbosacral plexus lesions or injury to peripheral nerves outside the neural canal. (Ditunno et al 1994)

DEFINITION OF THE LEVEL OF LESION

There are 30 segments in the spinal cord: 8 cervical, 12 thoracic, 5 lumbar and 5 sacral. As the spinal cord terminates between the first and second lumbar vertebrae, there is a progressive discrepancy between spinal cord segments and vertebral body levels.

All cervical nerve roots pass through the intervertebral foramen adjacent to the vertebra of equivalent number. Roots C1 to C7 inclusive leave above the appropriate vertebral body, whereas root C8 and the remainder exit below the appropriate vertebral body. The higher the root, the more laterally it is situated within the spinal cord. Although there is little difference between spinal cord segments and vertebral body levels in the cervical area, the nerve roots below C8 travel increasing distances in the canal before exiting.

The 12 thoracic segments lie within the area covered by the upper 9 thoracic vertebrae; the 5 lumbar segments lie within that covered by vertebrae T10 and T11; and the 5 sacral segments lie within T12 and L1 vertebrae.

Several methods of classification of the level of lesion are in use throughout the world. The system most often used in the UK is to give the most distal uninvolved segment of the cord together with the skeletal level, e.g. paraplegia, complete or incomplete, below T11, due to fracture/dislocation of vertebrae T9–T10 (Fig. 1.2). A lesion may not be the same on both sides, e.g. C5L/C7R. To give some idea of the neurological involvement in incomplete lesions, the most distal uninvolved segment is given together with the last segment transmitting any normal function, e.g. incomplete below C5, complete below C7. In this case, some motor power or sensation supplied by C6 and C7 is present.

MEASUREMENT SCALES

The inadequacy of the neurological level to define function and disability has long been recognized. The degree of paralysis, loss of sensation and the inability to perform activities of daily living demonstrate the severity of an injury, and in order to identify that level of disability measurements are required in all these areas. Such measures are necessary not only for the comparison of research results but also to facilitate communication between clinicians.

The International Standards for Neurological and Functional Classification of Spinal Cord Injury were published in 1994 (Ditunno et al 1994). These standards provide a tool to determine neurological level and to calculate a motor, sensory and functional score for each patient. They represent a valid, precise and reliable minimum data set.

The neurological levels are determined by examination of the following:

- a key sensory point within 28 dermatomes on each side of the body
- a key muscle within each of 10 myotomes on each side of the body. The sensation and motor power present are quantified, giving a final numerical score.

This is achieved by using the spinal cord injury scale of the American Spinal Injury Association (the ASIA scale) to grade impair-
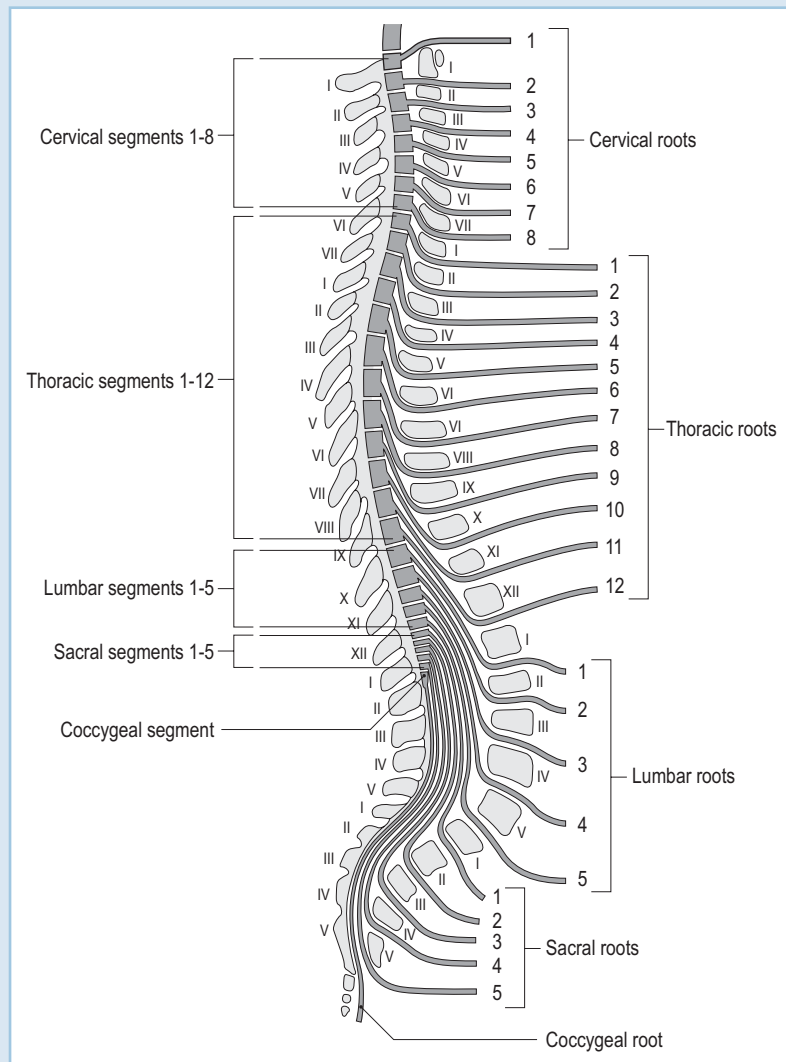
Figure 1.2 Topographical correlation between spinal cord segments and vertebral bodies, spinous processes and intervertebral foramina. (From Haymaker 1969.)

ment of sensation and motor power (Appendix 1), and the Functional Independence Measure (FIM) to measure disability and grade function (Appendix 2).

The ASIA impairment scale (Table 1.1; see also Appendices 1 and 2) is based on the Frankel scale (Capaul et al 1994) (Table 1.2). The letters A to E are used to denote degrees of impairment. The Frankel scale has broader bands than the ASIA scale, so unless there is marked improvement or deterioration it is more difficult to show change.

Table 1.1 The ASIA impairment scale

Grade	Description
A	Complete: no motor or sensory function is preserved in the segments
B	Incomplete: sensory (but not motor) function is preserved below the neurological level and extends through the sacral segments S4–S5
C	Incomplete: motor function is preserved below the neurological level, and the majority of key muscles below the neurological level have a muscle grade less than 3
D	Incomplete: motor function is preserved below the neurological level, and the majority of key muscles below the neurological level have a muscle grade greater than or equal to 3
E	Normal: motor and sensory function are normal

Table 1.2 The modified Frankel scale

Grade	Description
A	Complete
B	Sensory only
C	Motor non-functional
D	Motor functional
E	Recovered

The FIM, as its name states, is devised to measure function for any disability. Each area of function is evaluated in terms of independence using a seven-point scale. A total score from all these measures is calculated each time an assessment is carried out and progress can be readily seen.

Clinicians are using the ASIA scale and reporting that its accuracy is greater than the Frankel scale in classifying injuries and monitoring progress (Capaul et al 1994, Tetsuo et al 1996). Others suggested amendments (El Masry et al 1996).

The Spinal Cord Independence Measure (SCIM) (Catz et al 1997) (Appendix 3) was developed to provide a more sensitive measure than the FIM scale for assessing changes in function (Catz et al 2001a). The SCIM covers self-care, respiratory and sphincter management and mobility. A revised version, SCIM II, combines the scores on the ASIA and the SCIM scales (Catz et al 2001b).

Catz et al (2004) have developed the Spinal Cord Injury–Ability Realization Measurement Index (SCI-ARMI). The difference between the expected and actual function achieved is used to predict and assess the success of the rehabilitation programme.

Measuring the success of rehabilitation is extremely difficult. The Needs Assessment Checklist (NAC) has been developed to measure the outcome of rehabilitation and takes a much wider view of what is required than the other scales (Kennedy & Hamilton 1999). The outcome of the patient's rehabilitation is assessed on the goals the patient and the multidisciplinary team have set together. It is completed when the patient is first up in the wheelchair and again prior to discharge.

Indicators have been set in nine areas: activities of daily living, skin management, bladder management, bowel management, mobility, wheelchair and equipment, community preparation, discharge coordination and psychological issues. Questions in each area are

Table 1.3 The Ashworth scale

Grade	Description
0	Normal muscle tone
1	Slight increase in muscle tone, 'catch' when limb is moved
2	More marked increase in muscle tone, but limb easily flexed
3	Considerable increase in muscle tone
4	Limb rigid in flexion or extension

marked from 0 to 3. No distinction is made between verbal and physical independence, enabling each patient to have the potential to achieve 100% independence. Those with high level disability must be able to exert control, articulate their own needs and organize their programme of activities. It has so far proved to be clinically relevant and patient friendly (Berry & Kennedy 2003).

In addition to these measures, some therapists and other professionals are using the Ashworth scale of muscle spasticity (Table 1.3).

Therapists now have tools to measure the outcome of treatment and to identify landmarks in the recovery of patients with spinal cord lesions. Interesting data should be collected within units, both nationally and internationally, which will undoubtedly determine future therapy.

REPAIRING THE SPINAL CORD

The development of a nervous system is one of the most complex embryogenetic tasks, so it is not surprising that repairing any damage is extremely difficult (Fawcett 2002). Experiments have shown that features in the environment of the central nervous system (CNS) inhibit axon regeneration. This is particularly so when scarring has occurred in the spinal cord (Fournier et al 2001, Grandpre et al 2000). In addition, degeneration of cells occurs in the spinal cord after injury (Buss et al 2004).

To find a cure for spinal cord injury requires an extensive knowledge of the disorder in neuropathological terms and an appreciation of the complexity of the spinal cord (Kakulas 2004). Central axonal regeneration and restoration of normal function – motor, sensory and autonomic – is a massive task.

Nevertheless throughout the world innovative clinical approaches to the management of spinal cord injuries are being investigated with the aim of reversing or improving the neurological deficit. For example, research has been undertaken into the possibility of therapeutic roles in spinal cord injury using:

- neural stem cell biology
- grafted peripheral nerve tissue
- rerouting nerves from above the level of the lesion to the nerve root that controls the function to be restored below the lesion
- grafted tissue from the omentum
- reconstructive surgery to revascularize the injured cord
- medication to stabilize spinal cord trauma and overcome conductive deficits due to demyelination (Johnston 2001)
- therapeutic strategies designed to maximize adaptation in cortical plasticity to aid function (Hayes et al 2004).

Basic scientific research in animals has identified several procedures that may benefit humans with spinal cord injury. These inevitably fall far short of offering full repair (Raineteau et al 2002).

Grafts, transplants and cellular therapy are at the forefront of current research, offering hope for a cure by delivering cells to the damaged area which have the ability to differentiate and migrate.

For example:

- peripheral nerve transplants to deliver the myelin from the Schwann cells (Harvey & Plant 1995, Pearse 2004)
- bridging grafts using the hippocampus (Raisman 2003)
- olfactory ensheathing cells which continually replace nasal epithelial cells (Moreno-Flores et al 2002, Plant et al 2003)
- primitive bone marrow cells (Lemoine 2002, Hess et al 2004)
- embryonic stem cells (Lemoine 2002, Tai & Svendsen 2004).

It is not currently known which type of cells will ultimately be the most effective and each will need to be thoroughly evaluated in an animal model. The Cambridge Stem Cell Institute has been recently established at Cambridge University for research in this field.

It has been suggested that treatment leading to recovery of significant function may require a combination of approaches such as manipulation of nerve growth and inhibitory factors, insertion of bridging grafts and the deployment of cell types (Ramer et al 2005).

It is considered by many researchers that treatments which return function over two spinal segments would be of sufficient benefit to be worth offering to those with spinal cord injury. Initially interventions will probably be applied to the thoracic spine to minimize loss of any function which might occur from damage to surviving connections. Although major benefit over one or two segments would be most likely to occur in the cervical spine, should treatment cause further damage the consequences would be extremely serious. Treatments to the thoracic spine would be safer though the improvement more modest. In spite of this the trials will be worthwhile as a test for future treatment at cervical level. It is possible that trials in humans will start within a few years.

A satisfactory means of measuring recovery is required if the efficacy in humans is to be adequately assessed. Current systems of measurement are not sensitive enough to evaluate changes at segmen-

tal level. A range of clinical and physiological tests of sensory, motor and autonomic function, which are practical to administer, will be required to monitor recovery and function reliably.

A review of the progress made into improving methods for detecting change and recovery in spinal cord injury in humans has been undertaken by a group set up and financed by the International Spinal Research Trust. Though incomplete as yet a number of advances in techniques for assessment have already emerged (Ellaway et al 2004).

Charitable organizations have been promoting research that will cure paralysis associated with spinal cord injury for over 20 years. Now that encouraging signs are emerging many of these organizations have formed an alliance, the International Campaign for Cures of Spinal Cord Injury Paralysis (ICCP), to determine ways in which their collaboration can hasten progress (Adams & Cavanagh 2004).

The first ICCP international meeting on clinical trials was held in Vancouver in February 2004. The meeting brought together a variety of disciplines together with non-governmental organizations, foundations and representatives of the spinal cord injury community and introduced them to the progress in clinical trials and the complexities involved in effective clinical trial design. A working committee was set up to consider more detailed guidelines on how to develop the most accurate and effective spinal cord injury clinical trials (Steeves et al 2004).

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Physiological effects and their initial management

CLINICAL EFFECTS OF SPINAL CORD INJURY

Severe injury to the vertebral column can occur from any direction and result in dislocation, fracture or fracture/dislocation with or without resultant displacement. As a result, extensive trauma can occur to the spinal cord as it is compressed, crushed or stretched within the spinal canal (Hughes 1984). Yet there appears to be no absolute relationship between the severity of the damage to the vertebral column and that to the spinal cord and roots. A patient may sustain a severe fracture/dislocation and yet the spinal cord may be undamaged or only partially damaged. Another may exhibit no obvious vertebral damage on X-ray and yet have sustained an irreversibly complete tetraplegia.

The spinal cord conveys impulses to and from the brain, and through its various afferent and efferent pathways provides a vital link in the control of involuntary muscle. Transection of the cord will result in loss of:

- motor power
- deep and superficial sensation
- vasomotor control
- bladder and bowel control
- sexual function.

Frequently, at the actual level of the lesion there is complete destruction of nerve cells, disruption of the reflex arc and flaccid paralysis of the muscles supplied from the destroyed segments of the spinal cord. This segmental reflex loss is of little importance when the lesion involves the mid-thoracic region, but when the cervical or lumbar enlargements are involved, some important muscles in the upper or lower limbs are inevitably affected with flaccid paralysis. In the same way, a lesion at the level of the lumbar enlargement or cauda equina may destroy the reflex activity of the bladder and rectum and thus deprive the paraplegic person not only of voluntary, but also of involuntary (or automatic) control.

Lesions may be complete, where the damage is so extensive that no nerve impulses from the brain reach below the level of the lesion, or incomplete, where some or all of the nerves escape injury (see Ch. 15).

Immediately after injury the patient will be in a state of spinal areflexia. The nerve cells in the spinal cord below the level of the lesion (i.e. the isolated cord) do not function. No reflexes are present and the limbs are entirely flaccid. This depression of nerve cell activity can last for a few hours or days (particularly in young people), or up to 6 weeks. Gradually the cells in the isolated cord recover function, although they are no longer controlled by the brain. The reflexes return and the stage of spasticity ensues. If complications exist, the return of reflex activity can be delayed (Guttmann 1970). As the spinal cord terminates at the level of the lower border of L1, vertebral lesions below this level do not cause spasticity. The damage in these cases occurs to nerve roots only or is due to direct injury of the conus terminalis.

Occasionally a cord lesion of higher level may also cause sustained flaccidity. This is due to injury in the longitudinal as well as the transverse plane, or to longitudinal vascular damage.

Oedema or bleeding within the spinal cord may cause the level of the lesion to ascend one or even two segments within the first few days after injury. This is nearly always temporary, and the final neurological lesion will probably be the same as or even lower than that found immediately after injury.

Other skeletal or internal injuries are often present in addition to the spinal injury. Diagnosis of these injuries is rendered more difficult by the lack of sensation. The most common associated injuries are those of the long bones, head and chest. Head injuries are frequently found in conjunction with cervical fractures. Crush injuries of the chest with fractured ribs, pneumothorax or haemopneumothorax are commonly associated with fractures of the thoracic spine (Frankel 1968). Abdominal injuries also occur in some cases.

Early complications

Chest complications

The paralysis of the muscles of respiration, including the abdominal muscles, can give rise to serious problems (see Ch. 5).

Deep venous thrombosis

Deep venous thrombosis is recognized clinically by characteristic swelling of the leg. Erythema and low grade temperature may also occur. Unless contraindicated, patients are given prophylactic anticoagulant therapy (Silver 1975, Thumbikat et al 2002). Some advocate a combined approach using, in addition to anticoagulant therapy, pneumatic compression of the lower limbs for the first 30 days, plus elastic stockings (Aito et al 2002).

The swelling is frequently discovered by the physiotherapist when examining the limbs before giving passive movements. If a deep

venous thrombosis is diagnosed in either one or both legs, passive movements to both lower limbs are discontinued until the anticoagulation has been stabilized.

Pulmonary embolism

This usually occurs between the second and fourth week, occasionally later, but most commonly between the 10th and 15th days. If an undiagnosed deep venous thrombosis is present, it may give rise to an embolus when the physiotherapist begins to move the leg. Many patients have pulmonary embolism without prior evidence of deep venous thrombosis.

AIMS OF MANAGEMENT

In spinal cord injury centres, the aim of management is the simultaneous treatment of the spinal injury, the multisystems impairment and the non-medical effects of paralysis.

MANAGEMENT OF THE SPINE

The principles of management of the spine are to:

- enhance neurological recovery
- avoid neurological deterioration
- achieve biomechanical stability of the spine at the site of the fracture, preserving spared neural tissue until healing occurs.

Some neurological recovery is expected in patients with incomplete spinal cord lesions, provided the physiological instability of the spinal cord and the biomechanical instability of the spinal column are well controlled. Any major complications from the paralysis, such as pressure ulcers, septicaemia or hypoxia, can further destabilize a physiologically unstable spinal cord which has lost its blood–brain barrier and its autoregulatory mechanisms. This can result in lack of neurological recovery or further neurological deterioration (El Masry 1993).

In order to prevent further mechanical damage of the neural tissues due to displacement at the fracture site, it is important that the biomechanical stability of the spinal column is contained by either conservative or surgical means. If, however, biomechanical stability is to be obtained through surgery, it is important that the physiologically unstable spinal cord is not further destabilized by hypoxia hypotension during or after the surgical procedure.

Reduction of the spine can be achieved by conservative as well as surgical means and with or without traction depending on the type of injury. Oedema within the spinal cord is probably at a maximum

48 hours after injury. In view of this, some clinicians believe that it is dangerous to actively reduce the fracture dislocation after this time, especially in elderly people or in patients with degenerative changes in the spine. As some reduction of the size of the spinal canal is inevitable during the process of spinal reduction, the oedematous and swollen cord may be further damaged during the procedure. Early reduction is therefore particularly important. To date there is no evidence that realignment results in improvement of neurological recovery (Kakulas 2004).

Computerized tomography and, in particular, magnetic resonance imaging (MRI) now enable clinicians to assess impingement on the cord within the spinal canal and the longitudinal extent of cord pathology. MRI is a useful tool in determining and re-evaluating different management procedures for different patterns of injury (El Masry et al 1993).

Clinical trials have shown that corticosteroids (methylpred-nisolone) given in the acute phase conserve neurological function to a slight degree by limiting axonal damage. Bracken et al (1992) suggest it should be given within 8 hours of injury. Some spinal units are giving this treatment (Bracken et al 1992, Kakulas 2004). As it is not yet known if the benefit is sustained long term or whether there may be serious consequences, others are more cautious (El Masry & Short 1997, Quain et al 2005).

Postural reduction

Various surgical procedures are used to stabilize the fracture in spinal injury centres throughout the world. In other centres, the initial treatment of the fracture dislocation is usually conservative, i.e. by postural reduction (Guttmann 1945, Frankel et al 1970, Ersmarke et al 1990).

Postural reduction, with or without traction, is aimed at aligning the fractured vertebra and restoring and maintaining the normal curvature of the spine.

After the initial X-rays are taken, pillows and/or a roll are used to place the spine in the optimum position to reduce the dislocation and allow healing of the fracture. The majority of injuries are the result of acute flexion, flexion/rotation or extension of the spine, and the position has to be adjusted accordingly.

Control X-rays are taken over the next few days and weeks to check that the position is achieving the desired results. Plaster jackets or beds are never used because of the grave risk of pressure ulcers.

Fractured cervical spine

A firm, small roll made of wool and covered with linen or tube gauze is used to support the fracture. This roll is placed on top of a single

pillow which extends under the shoulders as well as under the head. If further extension is needed, the pillow is placed under the shoulders and the head is allowed to rest on a sheepskin pad on the bed. Two pillows are used to support the thorax and a single one is placed under the glutei and thighs, with a gap of approximately 8 cm (3 inches) in between the pillows to prevent pressure on the sacrum. A pillow is placed underneath the lower legs to avoid pressure on the heels by keeping them off the bed. A double pillow or several pillows bound together are set against the footboard to support the feet and toes in dorsiflexion.

If skull traction is necessary, as is the case in the majority of cervical injuries, the weights are moderate, i.e. 2.7–6.8 kg (6–15 lb) for 6 weeks on average.

Fractured thoracic or lumbar spine

Two pillows are usually sufficient to extend and support fractures of the dorsolumbar spine. Occasionally, a third pillow or a roll may be necessary to obtain the correct degree of hyperextension. Pillows have to be adjusted in such a way that the bony prominences are always free of pressure. The patient must be handled very carefully at all times. He must be lifted by four people or rolled in one piece with the fracture site well supported and the spine in correct alignment. Flexion and rotation particularly must be avoided.

There appears to be no difference in the outcomes of conservative or surgical treatment (Kakulas 2004) The complications can be greater following surgical intervention (Bravo et al 1996). In particular, there is less interference with the blood supply of the spinal cord using conservative methods. Avoiding the possibility of further neurological damage is crucial whatever method is used. Occasionally a late surgical stabilization procedure may be indicated where a spinal fracture remains unstable in both complete or incomplete lesions (Brooke et al 2003). Even when conservative management is preferred, there will be occasions when surgery is indicated, for example when further neurological deficit or gross bony displacement occurs which does not respond to conservative management in the first few days (Frankel et al 1987).

A person with spinal cord injury depends on spinal mobility in certain respects more than the able-bodied person. For example, a tetraplegic patient in a wheelchair relies on rotation of the neck to look behind. This requires approximately 67% rotation in normal subjects (Bennett 2002). To fulfil their potential in the activities of daily life all paralysed people require good spinal mobility. Wang et al (2003) suggest that surgical stabilization of more than two functional spinal segments in the mobile (cervical, thoracolumbar and lumbar) sections of the spine poses a high risk of restriction of spinal mobility and this needs to be borne in mind when planning major surgery.

Correct positioning of the patient

Correct positioning of the patient in bed (see Ch. 4) is important in order to:

- obtain correct alignment of the fracture
- prevent contractures
- prevent pressure ulcers
- inhibit the onset of severe spasticity.

Turning the patient

Patients are turned every 3 hours, day and night. The supine and side-lying positions are used for the acute lesion. In cervical and upper thoracic injuries, the prone position is unsuitable as it may cause further embarrassment to the respiratory system by inhibiting the excursion of the diaphragm. This can result in hypoxia. Immediately prior to discharge home, the turning interval may be increased to 4 and then to 6 hours.

MULTISYSTEMS IMPAIRMENT

The aims of treatment for the multisystems impairment are to:

- prevent death by resuscitation and maintenance of respiration (Ch. 5)
- prevent avoidable complications such as pressure ulcers (Ch. 6)
- institute a regimen of treatment for the care of the paralysed bladder and bowels.

Management of the bladder

Disturbance of bladder function can produce many complications which constitute a lifelong threat to the patient. Statistics have shown that renal disease was responsible for the majority of deaths among patients with spinal lesions. This is not now the case, but assiduous and continuing bladder care is essential if complications are to be prevented. Modern management of the bladder has successfully reduced renal related mortality in spinal cord injuries from 95% in the first half of the 20th century to 3% at the beginning of the 21st (Jamil 2001).

The acute lesion

The effect on the bladder depends upon the length of time after injury, as well as the level of cord injury and the degree of cord damage.

Paralysis of the bladder during the first few days after acute spinal damage is total and flaccid. During this period of spinal areflexia, all bladder reflexes and muscle action are abolished. The patient will develop acute retention, followed by passive incontinence due to overflow from the distended bladder. Treatment will be directed to:

- achieving a satisfactory method of emptying the bladder
- maintaining sterile urine
- enabling the patient to remain continent.

During the period of spinal areflexia, the bladder may be emptied in several ways, including:

- urethral catheterization
  – intermittent
  – indwelling
- suprapubic drainage.

For acute lesions from whatever cause – traumatic, vascular or viral – the treatment of choice at the Stoke Mandeville Centre and other centres throughout the world is intermittent catheterization (Frankel 1974, Green 2004). This method allows some distension of the bladder, which represents the physiological stimulus for micturition and triggers the appropriate impulses to the spinal bladder centre. This promotes return of detrusor activity. A long-term indwelling catheter is likely to be the source of bladder infection, vesical calculi, urethral strictures, diverticulae and fistulae, and periurethral abscesses. A fine-bore suprapubic catheter is often the most appropriate treatment for female patients during the first 2 months post-injury, and for tetraplegic patients they are sometimes left permanently.

Patients with total transection of the spinal cord no longer feel the specific sensations which indicate that the bladder needs emptying. Many patients, however, feel other sensations related to bladder filling and learn to interpret these as an indication that the bladder is full. The most common of the substitute sensations is a vague feeling of abdominal fullness which is the result of an increase in intravesical and/or intra-abdominal pressure.

Bladder training

As spinal areflexia wears off, which may take from a few days to several weeks, two main types of bladder condition develop:

- the automatic bladder
- the autonomous bladder.

The automatic (or reflex) bladder

This type of bladder develops in most patients with transverse spinal cord lesions above T10–T11. As reflex tone returns, the detrusor muscle contracts in response to a certain degree of filling pressure.

The returning power of the sphincter is overcome and micturition occurs. This reflex detrusor action may be triggered by stroking, kneading or rhythmic tapping over the abdominal wall above the symphysis pubis, or by stimulating other trigger points, e.g. stroking the inner aspect of the thigh or pulling the pubic hair.

With training, this reflex action will occur on stimulation of the trigger points and not at other times, so that the patient can learn to empty his bladder every 2 or 3 hours and remain dry in between.

The autonomous (or non-reflex) bladder

This bladder is virtually atonic and occurs where the reflex action is interrupted, i.e. with a longitudinal lesion of the spinal cord or a lower motoneurone lesion. There is no reflex action of the detrusor muscle. The patient is taught to catheterize himself to empty the bladder.

If the abdominal muscles are innervated the patient can raise the intra-abdominal pressure by straining, when the pressure on the kidneys is the same as that on the bladder. The disadvantage is that high pressure is also put on the rectum.

Both the automatic and autonomous bladders may be emptied provided their function is understood, gradual training takes place and active infection of the bladder is avoided.

When out of bed, the general increase in muscular activity, especially of the abdominal muscles if innervated, may make it more difficult to keep dry. Consequently, it may be necessary to express the bladder every hour at first.

Bladder training takes up a great deal of time and the patient may get discouraged, but it is important to persevere, for gradually the bladder will become trained and the time between emptying lengthened to 1, 2, 3 and in some cases even 4 hours.

The same training is carried out for both sexes, but it is essential for the female patient as there is no satisfactory urinal at present on the market. Pads and incontinence pants are the only protection in case of leakage between expressions or catheterizations. With encouragement, patience and perseverance, this method is successful for many patients and it is well worth the effort involved. Where bladder training is ineffective, the patient is taught to catheterize himself on an intermittent though not necessarily regular basis. Self-catheterization is most commonly used with female patients and children (Hill & Davies 1988).

Male urinals

There are several types of male urinals available. The best for any individual is that which he finds most convenient to use, but the following conditions must be fulfilled:

- it must not cause pressure ulcers
- it must contain a non-return valve
- if not disposable, it must be easily cleaned and sterilized.

Urinary sheath

The sheath is rolled onto the penis and an integral band, or collar, of non-irritant adhesive at the top of the sheath ensures that it remains in place. A non-return valve prevents a backflow of urine along the penile shaft, keeping the penis dry. A plastic tube connects the sheath to the leg bag which can have expandable side pleats. These allow outward expansion, enabling a greater volume of urine to be contained in a shorter bag (Fig. 2.1).

Condom urinal

Where a proprietary brand of urinary sheath is not available, the condom urinal can be used. This consists of the condom, a nylon connector, a piece of rubber tubing and a bag for drainage (Fig. 2.2).

The nylon connector is first placed inside the end of the condom and the connection tube is pushed over from the outside. This clamps the condom, which is then pierced where it stretches across the lumen of the connector. An orange stick is useful for this purpose. The shaft of the penis is smeared with a suitable adhesive and the condom sheath is rolled on and held in place for at least 30 seconds when the heat from the hand should ensure that the glue becomes effective. The condom should extend at least 2.5 cm (1 inch) beyond the end of the penis. A finger stall may be more suitable than a condom for young boys. The connecting tube is then attached to the urine bag, which may be strapped to the leg when the patient is up, and hung from the frame of the bed at night. Disposable bags can be used or the more durable suprapubic bag. If the suprapubic bag is used, each patient must have at least two and use them alternately so that each
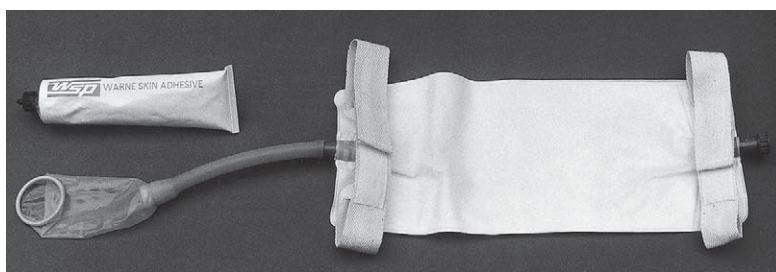

Figure 2.1 Urinary sheath.

Figure 2.2 Condom urinal.

can be thoroughly disinfected after use. The bag should be washed in warm soapy water, rinsed and soaked in, for example, Dakin's solution (16%) for 2 hours, rinsed well and hung up to dry for 12–14 hours.

Female pads

Incontinence garments with protective pads are available from many sources. When these are unavailable, pads can be made up by the patient. Size and thickness can be adjusted to suit individual needs, thin ones for use at home when the patient is in easy reach of the toilet, and thicker ones for travelling and visiting. The pads consist of 20 cm (8 in) gauze tissue, white wool and cellulose tissue, and are approximately 12–15 cm (5–7 in) wide and 30 cm (13 in) long.

To make up the pad, use the following procedure:

1. Cut the wool and cellulose to the required size and the gauze tissue approximately 15 cm (6 in) longer.
2. Open out the gauze tissue on a flat surface and ensure that it is free from creases.
3. Place the cellulose and the cotton wool, layered in that order, onto the gauze and fold the gauze over until the pad is completely enclosed.
4. Tuck the end of the gauze neatly into the layers of wool.

The pad is worn with the white wool side next to the skin.

Using an incontinence pad changes the distribution of pressure between the patient and the support surface. Folds or creases in the pad further increase the rise in pressure. This may be of clinical importance and the subject needs further investigation (Fader et al 2004).

Urinary hygiene

All patients must be taught urinary hygiene to avoid smell and must learn to watch for skin abrasions, redness and septic spots. If damage to the skin on the penis occurs, the urinal should not be worn until the lesion is fully healed. Severe pressure ulcers and fistulae can occur very rapidly if the urinal is applied over damaged skin. Difficult patches of adhesive may be removed with ether, but frequent use irritates the skin. Daily washing with soap and water and careful drying should be all that is required.

In order to have self-confidence, the incontinent patient must be prepared to cope either alone or with minimal help at all times, not only at home but also when a suitable toilet may not be available. For the female patient, receivers or bedpans can be useful and expression of the bladder can be successfully carried out on a suitable bedpan in a wheelchair. The incontinent female patient will find it essential to have a small travelling case containing:

- a plastic bedpan or receiver in a cover
- clean pads
- several plastic bags to receive soiled pads
- one plastic container of water for cleansing
- talcum powder.

Sacral anterior root stimulators

This is an alternative method of bladder stimulation for micturition. Radio-linked implants are successfully used to stimulate S2, S3 and S4. By activating these, the patient can empty the bladder at will. Resection of the posterior roots of S2, S3 and S4 has been found to improve the effectiveness of stimulation by amongst other things increasing the bladder capacity and preventing reflex action when it is not wanted. This form of treatment is prescribed for female patients who are unsuccessful with simpler methods such as regular toileting and self-catheterization (Brindley 1984, Brindley & Rushton 1990) and is particularly useful for female patients with upper motoneurone lesions.

In male patients, stimulation will produce erectile function but irreversibly abolishes reflex action including micturition. The procedure has become increasingly unpopular with patients in view of their hope that a cure might be found for spinal cord injury. Alternative approaches are being investigated such as the stimulation of sacral afferent nerves which modulate inappropriate reflex action and increase bladder capacity (Kirkham et al 2002).

Brindley (1994, 1995) found that 479 of the first 500 patients were still using their sacral anterior root stimulation implants (SARSIs) from 3 to 16 years after implantation. During the last 20 years over 2000 devices have been implanted worldwide (Popovic 2002).

Management of the bowels

Immediately after the onset of paralysis, fluids alone are given because of the danger of a paralytic ileus of neurogenic origin. The bowel training regimen is instituted once the patient is on a full diet.

Bowel training

The aim is to deliver the bowel contents to the rectum at the same time either daily or every second day and remove them by reflex defecation when the patient is prepared for it. This is achieved by:

- mild aperients in the evening, e.g. senna tablets (Senokot)
- two glycerine suppositories the following morning followed half an hour later by digital evacuation with a gloved finger
- correct diet and fluids.

Evacuation in bed

The previous evening senna tablets are given, 30 mg or as necessary depending on the results. Bulking agents may also be used.

The following morning, the patient is put on his left side and supported with sandbags and pillows. A plastic sheet and one or two disposable incontinence pads are placed under the buttocks. Two glycerine suppositories are inserted into the rectum as high as the gloved finger can reach. Care is taken to avoid overstretching the anus or damaging the rectal mucosa. The patient is kept warm and given a hot drink. Reflex defecation usually occurs within 20–30 minutes but may take up to an hour. If the bowel has not emptied or not emptied completely, digital stimulation may be indicated. A gloved finger is inserted into the rectum. The anus contracts when the finger is inserted. It then relaxes and the bowel empties. It may be necessary to stimulate the anus in this way during bowel training but subsequently it becomes unnecessary for most patients.

Toilet training

When the patient is out of bed, he is taught to do his own evacuation on the toilet, once he has sufficient balance in sitting and is able to transfer with assistance. A bar is needed beside the toilet so that the patient can support himself whilst leaning forwards.

Aperients and/or suppositories are continued as required. The development of a regular habit of bowel opening, usually every second day, is essential and with patience and perseverance it is possible to establish a satisfactory programme for all patients. Tetraplegic patients continue evacuations on the bed unless they can get onto a commode or toilet chair. Prior to the patient's discharge, the relatives or the community nurse are instructed in the procedure.

A patient with acute constipation may present with spurious diarrhoea, the impacted faeces allowing only liquids to pass through the gut. Although enemas as a routine are avoided, in this case they may be given before starting the bowel regimen.

SEXUAL DYSFUNCTION

Male

Male patients with high lesions often have priapism for hours or several days after injury. Subsequently all sexual function is abolished during the stage of spinal areflexia. Later return of function will depend upon the level and completeness of the lesion. For patients with complete lesions above the reflex centre in the conus, automatic erections occur in response to local stimuli but there will be no sensation during sexual intercourse. Patients with low cord lesions above the sacral reflex centre may have not only reflex erections but also

psychogenic erections if the sympathetic pathways are intact. Occasionally these may be accompanied by ejaculation. The seminal fluid will pass through the urethra only if there is an associated contraction of the internal bladder sphincter. Otherwise it refluxes into the bladder.

Mechanical assistive devices are now available, as well as various pharmacological agents which enhance erections.

Sexual function varies widely in patients with incomplete lesions, according to the degree of cord damage sustained. Any form of sensation on the penis may indicate some preservation of genital sex. Problems may remain in relation to locomotor and voluntary muscle activity.

Tests can be carried out to assess potency and fertility. Patients can now undergo semen procurement predictably and safely. However, most couples will need assisted pregnancy techniques such as intra-uterine insemination (Brindley 1984, Hirsch et al 1990).

Patients may benefit from attending a specialized fertility clinic, which offers a comprehensive approach with education, fertility assessment and a range of assisted reproductive options (Rutkowski 1999). This may be most appropriate up to 6 months after discharge during which time the major changes in sexual activity appear to occur (Fisher et al 2002).

Female

Menstruation

Interruption of the menstrual cycle occurs in the majority of women with complete or incomplete lesions who are not taking a contraceptive pill. This can last from a few months to more than a year. Eventually the menstrual cycle returns to normal.

Pregnancy

Apart from lacking genital sensation, sexual function is unimpaired for female patients with complete lesions.

Both paraplegic and tetraplegic women can become pregnant and have normal babies. These can be delivered vaginally or by caesarean section if indicated. Uterine contractions occur normally. Each uterine contraction in patients with complete lesions above T6 causes autonomic dysreflexia. Patients with complete lesions at T9 and below have uterine pain, but patients with complete lesions at T6, 7 or 8 may not be aware that labour has commenced, especially if it occurs during sleep. Therefore these patients should be kept under careful observation and are usually admitted to hospital before the expected delivery date.

A large number of women with spinal cord injury throughout the world now have children. A study evaluating how mothers and their

families adjust to the mother's disability showed no significant differences between the mothers or the children in each group. The individual adjustment of the children, their attitudes to their parents, self-esteem and gender roles did not appear to be affected by being brought up with mothers with spinal cord injury (Alexander et al 2002).

AUTONOMIC DYSREFLEXIA

The pathophysiology of autonomic dysreflexia is not fully understood. It is a vascular reflex which usually occurs in response to a stimulus from the bladder, bowel or other internal organ below the level of the lesion in a patient with a high lesion, i.e. above T6. Overdistension of the bladder caused by a blocked catheter can give rise to this reflex activity, which presents quickly and which, if not dealt with immediately, can rapidly precipitate cerebrovascular accident (Vallès et al 2005), epileptic fits and even death (Calachis 1992). It can also be caused by strong spasms and by sudden changes of position.

Degenerative changes of the lower spine are common amongst wheelchair users and in some patients changes progress to form Charcot's joints (Shwartz 1990). When autonomic dysreflexia occurs during changes in posture or transfers, Charcot's joints of the lumbar spine may be the cause (Thumbikat et al 2001, Selmi et al 2002). Selmi et al also suggest that heterotopic ossification can be responsible for autonomic dysreflexia, and Thumbikat et al that surgical procedures involving the vertebrae may have an effect on the formation of Charcot's joints in the lumbar spine. Three cases of autonomic hyperreflexia were reported in the USA in 1980 which were precipitated by passive hip flexion. This occurred in young men with lesions at C5, C6 and T1. It was suggested that this response was evoked by stretching the hip joint capsule or proximal leg muscles innervated by L4, L5 and S1 (McGarry et al 1982). Silver (2000) suggests that autonomic dysreflexia can occur during the period of spinal shock. Autonomic dysreflexia is perhaps more common than is realized. In a survey of 213 patients with lesions above T6 admitted to a spinal cord injury centre, 48% were shown to have experienced autonomic dysreflexia (Lindan et al 1980).

A scientific review of this syndrome was undertaken by Karlsson (1999) and includes valuable further information on all aspects of the syndrome, such as incidence and prevalence, triggering factors and treatment.

The physiotherapist must be alert to recognize the symptoms of autonomic dysreflexia, which are an outburst of sweating on the head, neck and shoulders, raised blood pressure, slow pulse and throbbing headache. Tilting the body with the head up will reduce the blood pressure until further treatment can be given. The treatment is to remove the cause; antihypertensive drugs may be given as a temporary measure.

Caution

All those involved in the care of patients with spinal cord lesions should be able to recognize the symptoms of autonomic dysreflexia and know what to do in an emergency.

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Patient-centred practice

Dot Tussler

INTRODUCTION

Traumatic spinal cord injury suddenly reduces an individual enjoying normal health and activity to a state of complete immobility and dependence upon others. There may be initial concern for his survival. He is precipitated into an unknown and unreal world full of fears, problems and multiple anxieties. He will experience pain, disorientation, lack of sleep, sensory deprivation, immobility and prolonged hospitalization. There will be stress from the effort to sustain relationships, manage finances, and prepare for an uncertain future whilst also coping with the demands of a physical rehabilitation programme and the challenges of relearning all basic care needs.

Existing attitudes, behaviour, beliefs, knowledge, skills, family support and coping strategies will be drawn on by the individual with spinal cord injury to define and manage this new situation, both in the immediate period following injury and in the ensuing months of rehabilitation and return to the community. The consequences of spinal cord injury will also affect family, friends and social network. Psychological support for the patient and his family throughout rehabilitation is essential. Knowledge and awareness of the psychological responses to spinal cord injury will affect the planning of care by the interdisciplinary team, the patient's participation in rehabilitation and future reintegration into the community. If rehabilitation is to be patient-centred it cannot just focus on the learning of physical skills.

BACKGROUND TO PATIENT-CENTRED REHABILITATION

Rehabilitation following spinal cord injury evolved historically from the disciplined approach to managing the physical consequences (Guttmann 1976). This medical model of management entailed the treatment of symptoms according to a defined set of principles of best practice determined by the healthcare professionals. However, this approach is limited when dealing with a long-term disability. This method can lead to dependence on the healthcare professionals as

the determiners of rehabilitation, as the attainment of independence is focused on physical goals and functions. Whalley Hammell (1995) proposes that independence should be seen in relation to decision-making and problem-solving skills. She states 'Independence is not so much a physical state but a state of mind – an attitude.' This view is of specific relevance to those individuals whose neurological level is such that physical goals are limited. She goes on to describe an educational approach to rehabilitation that is grounded in psychological theories and is based on dynamic interaction with the patient as an active participant learning to live with his disability in his own environment.

This is a vast and evolving subject and brief consideration only is given here.

ACUTE MANAGEMENT

The immediate consequences of spinal cord injury may focus on the life-threatening impact of a high level lesion or any associated injuries and complications, so the patient and his family may not consider the longer-term impact on the individual. This may appear as an inability to appreciate the condition and its consequences, and healthcare professionals caring for the patient may think that the individual is in denial of his disability.

In the early days following spinal cord injury the individual is exposed to numerous factors that will affect his judgement and rational thought and which may prevent him learning new information (Horn 1989). Disorientation, interrupted and reduced sleep, effect of medication, pain, anaesthesia and immobility can lead to sensory and perceptual deprivation, which will result in intellectual and cognitive impairment and intolerance to the present situation (Krishnan et al 1992). Anoxia from respiratory dysfunction or an associated head injury may also be present. It is important that healthcare professionals do not misunderstand ongoing hope expressed by the patient as the adverse response of denial. Consistent communication between all members of the team when dealing with the patient and his family is essential.

For most patients a superficial awareness and realization of their disability becomes apparent in the first week. This knowledge gradually deepens and the patient begins to realize the enormity of what the loss of movement and sensation, bladder, bowel and sexual function will mean in daily life. Involvement of family and friends from the outset has been shown to provide valuable support to the patient (Treischmann 1988). The emotional reaction and psychological responses in facing the disability will vary for each individual, and will be influenced by their pre-injury coping style and personal resources (Duff & Kennedy 2003). There is no 'right' way an individual will adjust. Some people find the situation hard to believe and so resist hearing the news that they will be paralysed: 'I just did not

believe it. It took a month of total disbelief.' Others just face up to it: 'This has happened. Let's get on with it' (Oliver et al 1991). For some there is a need to understand what has happened and to try and make sense of the situation.

INITIAL REHABILITATION

Mobilization in a wheelchair for the first time is often a difficult period for a newly injured patient. While on bedrest his care needs were undertaken by others and the extent of his physical limitations were restricted by his environment. Mobilization in a wheelchair can highlight the extent of his disability. For some this situation is overwhelming and engagement in rehabilitation is difficult. Support is needed at this time, with a consistent team approach to address the problem. The change in emphasis from caring to rehabilitation can be particularly difficult for nursing staff (Pellatt 2003). For other patients the time of mobilization represents the opportunity to start to resume control over the situation and acquire the skills and knowledge that will lead to independence. Nordholm & Westbrook (1986) identified that negative attitudes of healthcare professionals who consider the situation of an individual with spinal cord injury as intolerable, can adversely influence newly injured people who are seeking cues to define their disability. Studies have described staff's perception of the patients' situation to be worse than that reported by the patients themselves and as a consequence, optimism and positive attitude are disregarded. No member of the team must contribute to a sense of powerlessness or hopelessness in the patient (Whalley Hammell 1995). Each member of the team is responsible for their contribution to an atmosphere of hope and confidence in which the patient can learn to manage his disability and regain self-confidence. The expectations of the rehabilitation staff have a significant influence on this outcome (Bodenhamer et al 1983). The importance of a clinical psychologist as a member of the rehabilitation team should not be underestimated. The psychologist will assist the patient in utilizing effective coping strategies and personal resources, whilst supporting the staff in delivering effective rehabilitation.

The application of psychological theory to rehabilitation practice by all team members is essential in delivering outcomes that are purposeful and have value and meaning to the patient and his family.

The treatment of patients within a spinal injuries centre, where staff have learnt from a large number of patients, has enabled the development of expertise, skills and knowledge, contributing to the reduction of avoidable complications (Carvell & Grundy 1989) and improved outcome (Smith 1999). Such an environment provides the patient with visible evidence of what can be achieved by others in the same situation, but at a different stage of the rehabilitation process, or who are living at home. These positive characteristics seen in

others who are well adjusted can be beneficial to successful adjustment (Cushman & Dijkers 1991).

PERCEIVED PERSONAL CONTROL

Perceptions of control have been shown to be important in terms of management of healthcare and disability: 'Perceived control is defined as the *belief* that one can determine one's own internal states and behaviours, influence one's environment and/or bring about desired outcomes' (Wallston et al 1987). Rotter (1966) described people who believe that they have a high degree of personal control of events in their lives as having an *internal* locus of control. These are people who want more information and are hopeful of, and persevere in, attaining goals. He described those who believe they have little or no control over what happens to them as having an *external* locus of control. Outcomes are seen as random occurrences controlled by fate, chance or powerful others. This may lead to the belief that their own efforts in rehabilitation will not be successful. It is not the actual reality of the extent of control that has been shown to be important, but rather the person's belief about his control over events (Whalley Hammell 1995). Even though a person may have a high lesion and little physical control over his immediate circumstances, this does not necessarily change his perception of the extent of the control he has over his life (Treischmann 1988). This belief is associated with the ability to influence others in order to achieve one's own ends (Johnson et al 1970).

The background to the concept of perceived personal control initially came from social learning theory research and has received a significant amount of attention in behavioural research (Wallston et al 1987), and more recently in the healthcare field. It is a complex subject and is mentioned because the patient's perceptions and beliefs are an integral part of his learning in rehabilitation, and health professionals need to take account of them in planning rehabilitation programmes (Whalley Hammell 1995). Patient compliance with externally imposed routines is highly rated by professionals but does not facilitate independence and problem-solving skills (Tucker 1984). Independence encompasses thinking and acting for oneself as well as the performance of physical skills. Those patients who believe that they are as physically independent as possible have more positive self-concepts than those who perceive themselves as less independent than they are capable of being (Green et al 1984). Rehabilitation is an intensive process with a great deal for the patient to learn. If learning is to be effective, patients need to define their own problems, decide on the actions to be taken and evaluate the consequences of their decisions (Whalley Hammell 1995). Banja (1990) offers the idea of empowerment as a key concept. Patients will differ in their desire for personal control and in the extent to which they believe they have

it. The concept of perceived personal control forms the basis for psychological interventions that are used within many rehabilitation programmes. Here the focus is on identifying and recognizing fears, distress and loss and challenging an individual's beliefs and attitudes to their situation, so that the person with spinal cord injury can acquire the knowledge, skills and strategies for optimal physical, psychological and social functioning (Duff & Kennedy 2003).

ADJUSTMENT MODEL FOLLOWING SPINAL CORD INJURY

Previous psychological theories proposed that following a spinal cord injury individuals underwent a staged process that required them to sequentially experience depression, anger, confusion and withdrawal before acceptance of the situation could be achieved. Little evidence existed to support these views (Treischmann 1980), although it is acknowledged that these emotional responses may occur at any time as a normal response to the stress encountered (Duff & Kennedy 2003). Current research proposes models of adjustment based on individuals' response to stress and the coping strategies that are subsequently utilized. Duff & Kennedy (2003) provide a comprehensive review of the development of these theories encompassing the area of perceived personal control.

The principles of an adjustment model post-injury are particularly useful in that they are concerned with the recognition of strategies that facilitate coping and also those that lead to distress and dysfunction. These can lead to easier identification of interventions that can support the individual in managing his situation. It can also clarify the direction of the rehabilitation team in understanding the changing needs of the patient.

The components of a model such as that proposed by Duff & Kennedy (2003) are developed from the cognitive model of stress and coping (Folkman et al 1991). This model identifies relevant pre-injury factors pertinent to an individual such as:

● emotional history and previous vulnerabilities
● beliefs about self, world and coping
● beliefs about disability
● environmental factors
● biological factors
● social support.

On encountering the challenge and stress of the spinal cord injury, the individual conceptualizes the impact of its consequences and the perceived threat he faces, along with his perceived ability to cope. A subsequent appraisal assesses the effectiveness of resources the patient has available to cope with the challenge, along with a perception of his potential to manage or accommodate the situation.

If the patient regards the challenge as being manageable, positive coping skills can be engaged, based on his perception of his influence and control. This is described by Duff & Kennedy (2003) as approach-focused coping and includes 'thinking about the injury, acceptance, planning and problem-solving'. This can result in new goals and opportunities, a sense of mastery and self-efficacy, post-traumatic growth, personal development, life satisfaction, development of coping beliefs and the ability to face further challenges. However, if the stress of the injury is perceived as being unmanageable, avoidance coping strategies are employed. These have an emotional impact and can lead to anxiety, depression, a sense of helplessness and hopelessness, accompanied by withdrawal and disengagement. Further appraisal may serve to reinforce the perception of an unmanageable situation, leading to an escalating downward spiral of dysfunction and secondary complications arising from the emotional impact. These may include self-neglect, severe stress reaction, long-term emotional difficulties, anxiety and depression, and potential alcohol and drug abuse.

An adjustment model of coping is not time limited and can be utilized across the lifespan of the individual as new challenges and situations are encountered, as well as dealing with specific elements such as mobility, relationships etc.

This model represents a dynamic and evolving concept of adjustment and provides a useful reference for staff to consider both in the acute and the rehabilitation setting, as well as over the lifespan. It can identify relevant points for intervention at any time post-injury.

Adjustment to spinal cord injury is a lifelong process in which constant changes occur both in the patient and in his circumstances. It may be that a minimum of 2 years is needed to achieve some stability in life, although this will vary from person to person (Craig et al 1994). It must also be acknowledged that social networks and relationships that offer support and reassurance of worth will enhance adjustment and self-esteem (Elliott et al 1992).

A variety of responses and coping strategies utilized by individuals when learning to live with a spinal cord injury have been mentioned, but some patients have a pre-existing psychological or psychiatric history. A spinal cord injury can result from a suicide attempt. This group of patients has particular problems and require special care and psychological support.

Cognitive dysfunction arising from concomitant head injury, alcohol and substance abuse, or other causes of cerebral damage has been reported by various authors to be present in 10–60% of patients with acute traumatic spinal cord injury. Resultant problems with inattention, poor memory, reduced concentration, inappropriate social behaviour and poor problem-solving skills all complicate adjustment. Assessment of cognitive dysfunction is recommended to identify appropriate strategies to be utilized within the rehabilitation programme.

REHABILITATION AND GOAL PLANNING

Goal planning provides a systematic framework for incorporating behavioural change principles into the rehabilitation process, that is, positive coping strategies that encourage the adjustment-focused coping described earlier (Duff & Kennedy 2003). It aims to place the patient at the centre of his rehabilitation programme and in a situation to optimize his perceived personal control, whilst increasing his engagement in rehabilitation activities (Kennedy et al 1991). Goal planning is based on patient involvement as an active participant in patient and not therapist-led practice, with the recognition and the utilization of the patient's strengths to meet identified needs significant to the patient in regard to his perception of his spinal cord injury. Goals are then set within the rehabilitation team with specific, measurable and realistic targets to be achieved in an agreed time. Regular review and monitoring success can become an empowering process. Areas of unmet need can be recognized and addressed and the roles and contribution of the various healthcare professionals clarified. Goal planning provides a strategy for approach-focused coping as highlighted in the adjustment model following spinal cord injury in which the targets set will be directed to behaviour that has relevance to the patient's perception of the needs that have arisen from his injury. Collaborative working and the opportunity to learn what is significant to the patient is important to each member of the inter-disciplinary team and has been shown to be of positive benefit (MacLeod & MacLeod 1996).

The need to address all areas affected by the spinal cord injury throughout rehabilitation is essential if the process is to be considered one of learning and developing new skills and knowledge. The opportunity to discuss any topics should be encouraged and facilitated. This should be an integral part of every interaction with each healthcare professional. The use of specific educational programmes also has been found to be successful. These can take various forms depending on the organization and patient group. The learning style should be considered. Appropriate individual sessions, group lectures or focus groups along with supporting material are in frequent use within spinal injury centres in the United Kingdom. Information is also readily available on a variety of appropriate websites. Lifelong learning programmes have been developed by individuals with spinal cord injury and have been proved to be of benefit in continued information sharing long after the initial rehabilitation has been completed (Spinal Injuries Association 2004).

The opportunity to discuss issues of sexual dysfunction might need to be specifically raised by the healthcare professional in a timely and personal manner along with appropriate evaluation of function and information pertinent to each individual. Relatives and friends also need educational programmes and individual teaching about the consequences of the injury to meet their own need for information and to enable them to give appropriate support to the patient.

RETURNING HOME

Returning to the community, whether for the first weekend home or for discharge from hospital, is a challenging time for the patient. The security of the hospital environment with the reassurances of healthcare professionals' knowledge and skills to manage physical concerns and the familiarity of other wheelchair users is replaced by a world where disability and the needs of a wheelchair user may be unfamiliar. Anxieties about home and family life, relationships, access, employment, care provision, finance, attitudes and isolation are all real threats. The patient should be prepared for the transition from the hospital to the community as a continuation of their rehabilitation goals. Review of access in the home environment, frequent community visits, continued social networking, links with local peer groups and community services, awareness and preparation of social support systems and provision of written material and information may be of benefit (Whalley Hammell 1995).

CONCLUSION

Successful rehabilitation is hard to define. This chapter has tried to emphasize that rehabilitation must be patient centred. The psychological impact of and responses to spinal cord injury need to be considered throughout rehabilitation and lifespan by all members of the interdisciplinary team. 'The aims of the rehabilitation team should not only focus upon the acquisition of skills to enable a person to get out of bed in the morning, but to assist him in finding a reason for so doing' (Treischmann 1988).

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Websites with educational information for people with spinal cord injuries

http://www.craig-hospital.org
http://www.metrohealth.org
http://www.spinal.co.uk
http://www.spinalcordinjury.co.uk
http://www.spinalnet.co.uk
http://www.tbi-sci.org

The acute lesion

EXAMINATION OF THE PATIENT

For the therapist to gain maximum information regarding the patient, she should be present at the initial neurological examination carried out by the doctor in charge of the case. In this way she will gain information regarding:

- the patient's injury
- general condition
- the site and condition of the fracture, if any
- the presence of associated fractures or injuries, including any skin lesions
- condition of the chest, including the results of lung function tests
- motor function
- sensory function
- presence or absence of reflexes
- previous medical history and current medical conditions, e.g. ankylosing spondylitis, rheumatoid arthritis, diabetes
- occupation
- family history
- diagnosis of the level of the lesion
- immediate medical treatment.

The therapist will subsequently wish to make her own examination, adding to the above information her assessment of:

- respiratory function (see Ch. 5)
- the range of motion of all joints involved and the presence of contractures
- the strength of innervated muscles with particular regard to
  – completely paralysed muscles
  – unopposed innervated muscle groups
  – imbalance of muscle groups
- the degree of spasticity, if present
- the presence of oedema.

When the doctor and therapist discuss the treatment required, factors such as the following will be given special attention:

- respiratory therapy, especially in relation to the treatment of patients on ventilators
- the danger of muscle shortening due to unopposed muscle action and the required positioning of the joints involved
- severe spasticity and the positioning required to reduce tone
- the necessity for splinting.

After her own initial assessment, the physiotherapist will need to discuss treatment with the other members of the multidisciplinary team.

Physiotherapy programme

On the basis of the physiotherapist's examination and assessment, the patient and therapist together set short- and long-term goals and plan the treatment schedule to achieve the initial short-term goals (Ch. 3).

Detailed records are kept of the initial assessment, treatment and progress of the patient. Everyday incidents are also noted, such as the occurrence of bladder infections, slight injury or pressure marks, the first outing and the first weekend home.

TREATMENT OF THE PATIENT IN BED

From the outset, the combined efforts of everyone are concentrated on assisting the patient to achieve maximum independence. When the patient cannot do something for himself, he must learn how to teach others to do it for him. Gaining knowledge and accepting responsibility both start whilst the patient is in bed. He must know where others can find his belongings in the locker and when, for example, he needs more soap or toothpaste.

The patient with a spinal fracture will be in bed from 6 to 8 weeks. Those paralysed from other causes or who have had surgery will spend considerably less time in bed and may even be up in a few days.

Correct positioning of the patient

Correct positioning in bed is vitally important not only to maintain the correct alignment of the fracture, but also to prevent pressure ulcers (Ch. 6) and contractures, and to inhibit the onset of extreme spasticity.

The supine position (Fig. 4.1A)

When supine, the patient is positioned in the following way.
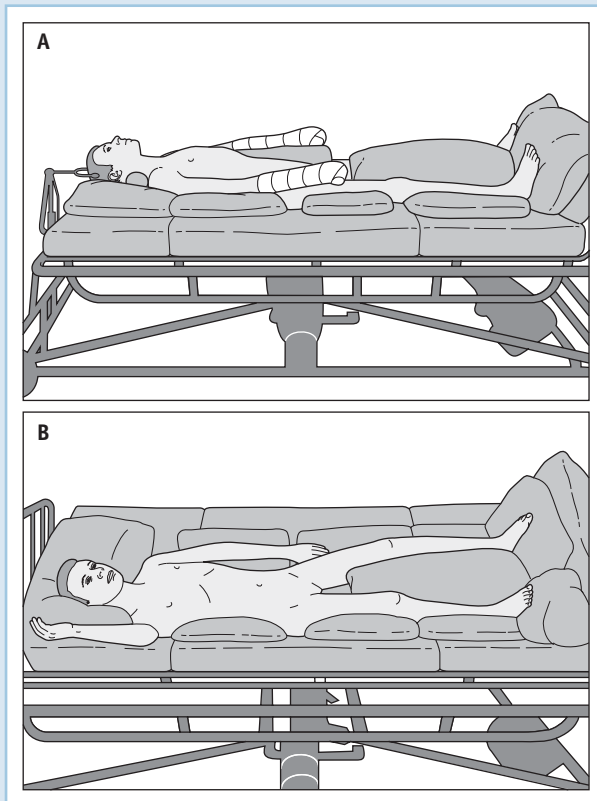
Figure 4.1 A: Supine position of a patient with a cervical fracture (right arm pillow was removed for clarity). The patient is lying on an Egerton–Stoke Mandeville 'electric turning bed'. B: Lateral position of a patient with a low thoracic fracture.

Lower limbs

- Hips – extended and slightly abducted
- Knees – extended but not hyperextended
- Ankles – dorsiflexed
- Toes – extended.

One or two pillows are kept between the legs to maintain abduction and prevent pressure on the bony points, i.e. medial condyles and malleoli.

Upper limbs (for patients with tetraplegia)

- Shoulders – adducted and in mid-position or protracted, but not retracted

- Elbows – extended; this is particularly important when the biceps is innervated and the triceps paralysed. If the biceps is overactive, extension can be maintained by wrapping a pillow round the forearm, or by using a vacuum splint or making an individual splint of suitable material.
- Wrists – dorsiflexed to approximately 45°
- Fingers – slightly flexed
- Thumb – opposed to prevent the development of a 'monkey' hand, which is functionally useless.

The arms are placed on pillows at the sides. The pillows should be high enough under the shoulders to ensure that the shoulders are not retracted, when damage to the anterior capsule can occur. If the shoulders are painful and protraction is required, a small sorbo wedge can be placed behind the joint on either or both sides. If necessary, two pillows should be used under the forearms and hands, as it is important that the hands are kept higher than the shoulders to prevent gravitational swelling in the static limbs.

The side-lying or lateral position (Fig. 4.1B)

When lying on the side, the patient is positioned in the following manner.

Lower limbs

- Hips and knees – flexed sufficiently to obtain stability with two pillows between the legs and with the upper leg lying slightly behind the lower one
- Ankles – dorsiflexed
- Toes – extended.

Upper limbs

- Lower arm – shoulder flexed and lying in the trough between the pillows supporting the head and thorax to relieve pressure on the shoulder
- Elbow – extended
- Forearm – supinated and supported either on the arm board attached to the more sophisticated beds or on a pillow on a table
- Upper arm – as in the supine position, but with a pillow between the arm and the chest wall.
  For the hipflick position see page 75.

The hand

If the hand is to be functional even when paralysed, the maintenance of a good position in the acute phase is essential. The hand must

remain mobile as subsequently it will be used in different positions and also should surgery be contemplated later on, a supple hand is a prerequisite (Forner-Cordero et al 2003). Gravitational swelling must be avoided. If it is allowed to occur unchecked, contractures easily develop. 'If length can be maintained by stretching the soft tissues during the acute phase, deformity can be prevented; otherwise the deposited collagen becomes converted into strong fibrous tissue and a fixed deformity results' (Cheshire & Rowe 1971). Swelling can be prevented if the collateral ligaments of the metacarpophalangeal joints are kept at their maximum tension, i.e. when the joint is kept in 90° flexion. In order to maintain a good functional position Cheshire developed the 'boxing glove' splint. It consists of a light, well-padded, cock-up splint (Fig. 4.2) and a palmar roll. The wrist is maintained at 45° dorsiflexion, the metacarpophalangeal joints at 90° flexion, the interphalangeal joints at 30° flexion and the abductor web of the thumb in full stretch with opposition of the thumb. A layer of wool is placed over the dorsum of the hand and fingers and the whole is bandaged as for an amputation. The splint is removed several times a day for washing, physiotherapy and occupational therapy, and the skin is checked for pressure marks. It is used constantly until the patient is using his hands and then is applied at night only.

If the boxing glove splint is not employed, the hand can be kept in a useful functional position with a small palmar roll. Light straps keep the fingers in flexion and the thumb in opposition around the
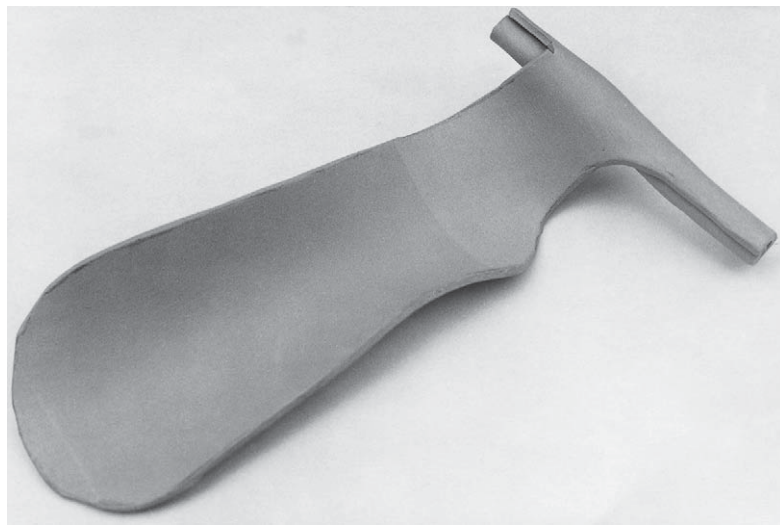
Figure 4.2 Unpadded wrist support for the boxing glove splint.

roll. A wrist splint with a suitably padded cover for the dorsum of the hand with tapes to hold the fingers in flexion can also be used. A palmar resting (paddle) splint may be useful for patients with ultra-high lesions depending on the presenting problem and the level of the lesion. These splints are usually worn at night.

PHYSIOTHERAPY

During the period in bed, the following treatment is given:

- respiratory therapy – to maintain good ventilation (as the need for respiratory care may extend throughout life, this is dealt with separately in Ch. 5)
- passive movements – to assist the circulation and to ensure full mobility of all paralysed structures
- active movements – to maintain or regain muscle strength.

Passive/active movements

Animal studies point to the remarkable ability of the damaged central nervous system to undergo plastic changes (Dunlop & Steeves 2003). Neuronal plasticity, described as simply as possible, is said to be the neuron's capacity to reduce the effects of lesions through structural functional changes (Pascual-Castroviejo 1996). It would appear that plasticity can occur in other parts of the central nervous system as well as the brain, including the spinal cord and possibly the isolated spinal cord. As the damaged nervous system has an innate capacity to undergo changes the question arises as to whether plasticity can be harnessed to improve function (see Ch. 14).

In view of this and of the fact that 'movements are planned before they are produced and there is a slight delay period between the two events' (Dunlop & Steeves 2003), movements to the paralysed limbs should be given in such as way as to promote active movement. Passive/active movements of the paralysed limbs are essential to preserve full range of movement in joints and soft tissues and to encourage active movements to return. During these movements it is important that the patient is involved, concentrates on the movement and tries to perform it as the physiotherapist moves the limb. Verbal instructions are given to ensure that the patient knows what is happening and can think about the movement even if he cannot see his limbs. Treatment is commenced the first day after injury or when anticoagulant therapy has started and the prothrombin times are within the therapeutic range (El Masry & Silver 1981). During the period of spinal areflexia, i.e. for approximately 6 weeks, treatment is given twice daily. Movements are continued once a day until the patient is mobile and capable of ensuring full mobility through his own activities.

In addition to movements of the whole limb, each joint – starting proximally and working distally and including the metatarsal and metacarpal joints and those between radius and ulna – is moved several times through its full range, and appropriate movements are given to prevent muscle shortening. The patella should be mobilized before moving the knee. The movements are performed slowly, smoothly and rhythmically to avoid injury to the insensitive, unprotected joints and paralysed structures. Any limitations imposed by previous medical history and/or age must be taken into consideration.

When reflex activity returns, the limb must be handled with extreme care, so as not to elicit spasm and reinforce the spastic pattern. A pinch grip or any sudden brisk movement must be avoided. If a spasm occurs during a movement, the therapist holds the limb firmly and waits for the spasm to relax before completing the movement. Forced passive movements against spasticity may cause injury or even fracture of a limb. Sometimes, however, the only way to overcome ankle clonus is to completely dorsiflex the ankle, against the spasm, and hold it until the foot relaxes. The movement must be performed firmly but gently. Before moving any limb when tone is increased, the other limbs should be placed in positions which oppose their spastic pattern. For example, the lower limbs can be placed in the 'frog position' where the hips are abducted, laterally rotated and flexed to 40° before moving the upper limbs.

The importance of detail when giving passive movements cannot be overemphasized if the functional range in all structures is to be maintained.

If the patient has not had any passive movements for a week or more since being injured, the movements should be commenced extremely cautiously, avoiding full range for a few days. It is possible that minor contractures are present which, if torn, may give rise to heterotopic ossification (Silver 1996) or the patient may have a deep venous thrombosis.

Cautions

1. *Extreme* range of movement must be avoided, particularly at the hip or knee, as the tearing of any structures may be a predisposing factor in the formation of heterotopic ossification.
2. Only 45° abduction is given, to avoid tearing any structures on the medial side of the thigh. The medial side of the knee must always be supported to prevent stretching the medial ligament.
3. Flexion of the hip with the knee flexed is cautiously carried out where there is a fracture of the lower thoracic or lumbar spine to ensure that movement does not occur around the fracture site. If pain occurs on movement, flexion is limited to the pain-free range. The movement is gradually increased as the pain diminishes. When the patient is supine, full flexion of the knee can only be obtained by combining knee flexion with lateral rotation of the hip.

4. Straight leg raising is carried out with extreme caution because of the danger of putting a stretch on the dura mater. Hamstring extensibility varies with the individual. Harvey et al (2003) suggest that some physiotherapists apply stretch torques well in excess of those tolerated by individuals with normal sensation. In this study 'the stretch applied by different physiotherapists to any one subject varied by as much as 40 fold'. Further work is needed to determine optimal stretch torques. In the meantime physiotherapists should be guided by the subjective 'feel' of tautness in the patient's hamstring muscles and their own interpretation of what constitutes a 'reasonable' stretch.

5. Combined flexion of the wrist and fingers is never given. This movement can cause trauma of the extensor tendons, resulting in loss of mobility and function.

Maintenance of muscle length

Gross contractures occur when a paralysed limb is not moved, but contractures can also occur in individual muscles or muscle groups in a limb that is receiving daily treatment. For example, contractures readily occur in the following situations:

- where the muscle on one side of a joint is innervated and the opposing muscle is paralysed
- where a paralysed muscle passes over more than one joint – in this case, individual joint movements are insufficient to maintain the muscle length
- when the patient lies with the spine in hyperextension to heal a fracture, the degree of hyperextension necessary to correct fracture dislocations of the lower thoracic and lumbar spine inevitably produces slight flexion of the hip joints
- where the cervical spine is fractured, the shoulders are held in elevation and retraction due to gravity and unopposed muscle pull.

For these reasons, the following movements should be given in addition to the full range of passive movements.

The shoulder girdle

Particular attention needs to be given to the shoulder girdle. It is so freely movable that its habitual position depends upon the relative tension in the following six muscles which act indirectly on the shoulder girdle through the arms:

- trapezius – cranial 11, C3, C4
- levator scapulae – C3, C4, C5
- rhomboids – C5
- serratus anterior – C5, C6, C7
- pectoralis minor – C8, T1
- subclavius – C5, C6

together with the tension produced by:

- pectoralis major – C5, C6
- latissimus dorsi – C6, C7, C8.

The mobility of the shoulder girdle is largely maintained through adequate unilateral and bilateral passive movements to the arms, which will prevent shortening of these muscles.

The scapula

Mobility of the scapula must be maintained. Movements are performed passively in lying or side-lying with the elbow well supported by the therapist.

Passive depression is particularly important where the muscles of elevation are innervated and unopposed.

In situations where passive movements of the limbs are impractical, accessory gliding techniques should be applied locally to the joints involved to maintain mobility.

To prevent shortening of the following

Rhomboids. With the arms in horizontal flexion, adduct both shoulders at the same time. Both elbows are flexed and each hand moves towards the opposite shoulder.

Long head of triceps. With the arm held in elevation, flex the elbow.

Pectoral muscles. With the opposite shoulder lying in abduction to 90° outward rotation and extension and supported on a padded board, abduct and extend the shoulder with the elbow and wrist extended and with the forearm supinated. The arms can be placed in the cruciform position whilst giving passive movements to the lower limbs but care must be taken not to traumatize the shoulder joints.

Biceps. Pronate and supinate the forearm with the elbow flexed and with the elbow extended. (Pronation is particularly important for patients with lesions at C5, since biceps pulls the forearm into supination, which is not a functional position.)

Flexor tendons of the fingers. Extend the wrist and fingers together.

Flexor muscles of the arm. Elevate and laterally rotate the arm with the forearm supinated and the elbow, wrist and fingers extended and with the arm held close to the side of the head.

Hip flexors, quadriceps and anterior fascia of the thigh. In side-lying, extend the hip through the last 15° of movement, keeping the knee flexed. The posterior aspect of the hip must be well supported to prevent movement occurring in the spine.

Tensor fascia lata. Adduct and medially rotate the leg beyond the midline.

Tendo Achillis. Dorsiflex the ankle with the knee extended.

Flexor muscles of the toes. Extend the toes, dorsiflex the ankle and extend the knee. Clawing of the toes occurs easily and not only hinders walking and increases spasticity but may lead to pressure sores on the dorsal and/or plantar aspect of the toes.

Careful attention must also be given to movements involving rotation and flexion of the limb. For example, flexion and lateral rotation of the hip with flexion of the knee are important for self-dressing.

Inspection of the lower limbs

Before commencing treatment, the therapist examines the legs for signs of swelling or pressure. Deep vein thrombosis is a common complication during the early weeks after injury, and the possibility of pressure ulcers is an ever present danger. If a deep vein thrombosis is diagnosed, movements to both lower limbs are discontinued because of the possibility of causing a pulmonary embolus. Movements are recommended when the anticoagulation therapy is successful.

Active movements

Cervical cord lesions

Gentle, assisted, active movements are given to all innervated muscles from the first day after injury. Progression is made to unassisted active exercises and the patient is encouraged to move his arms independently and functionally.

Where possible, the following movements are taught.

Extension of the elbow without triceps. The patient laterally rotates and protracts his shoulder, relaxes biceps and allows gravity to extend the elbow. Independence in this movement should be achieved as soon as possible to prevent shortening of the biceps tendon.

Flexion of the shoulder without flexion of the elbow. The patient is encouraged to lift the arm off the bed, allowing gravity to keep the elbow extended. Lateral rotation of the shoulder may be necessary initially.

Grip without finger movements – wrist extension grip or tenodesis grip (see Ch. 8). The grip is obtained by first allowing gravity to flex the wrist when the fingers and thumb fall into extension. The hands or the first finger and thumb are placed over the object to be lifted. Extension of the wrist by extensor carpi radialis places passive tension on the flexors and enables a light object to be held in position. If the object is heavier, the pull of gravity can be partially overcome by supinating the forearm.

Although the efficacy of the wrist extension grip can be augmented by allowing some shortening of the finger flexor muscles, not all

therapists agree with this approach. Of those who do, some advocate that this shortening should be allowed to develop from the outset, while others believe that it should be allowed to occur only when there is no further hope of functional recovery. To prepare the hand for future function one needs to bear in mind what the future might hold. If the lesion is to remain complete the patient will need slight tension in the finger flexors to give him a stronger wrist extension grip. If the lesion is to become incomplete the need is to maintain full range of movement in the finger extensors and not allow the tenodesis grip to become too strong (see Ch. 15). The lesions of many of the patients in spinal units are, or become, incomplete. A middle way is to give full range movements, including wrist and finger extension together, for the first 6 weeks unless the lesion becomes incomplete before then. For the patient with a complete lesion the degree of shortening (or contracture) needs to be carefully controlled. Only a small loss of range of the finger flexor muscles is required to provide slight curve of the fingers. Too great a contracture will prevent the patient from putting his hand around a large object, such as a glass or placing his hand flat when transferring.

Resisted movements

Gentle resisted movements can be gradually introduced as indicated. Strong unilateral exercise for the whole arm involves head movement and is therefore completely avoided until the fracture is healed. All movements must be given with carefully graded resistance, avoiding any neck movements.

Neck exercises

Gentle static neck exercises are given 6 weeks post-injury if there are no contraindications.

Thoracic cord lesions

Patients with thoracic cord lesions are given frequent resisted arm exercises, manually or by using a chest expander of suitable strength, hand weights or other equipment. All movements are given bilaterally and in a controlled manner when the patient is supine, so that resistance is constant and there is no unequal pull on the unstable spine.

Functional electrical stimulation

As functional electrical stimulation is known to increase muscle bulk (Scremin et al 1999), it is used by some physiotherapists in the hope of contributing to the recovery of muscle strength. Weak muscles with strength 1 or 2 on the Oxford scale are treated daily for 6 weeks or in bursts of 2 weeks at a time.

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Respiratory therapy

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When the spinal cord is damaged, the respiratory muscles innervated below the level of the lesion become paralysed. This interferes with the power and integration of the remaining muscles and reduces their ability to drive the chest wall efficiently. Patients with injuries to the cervical spine have serious problems, whilst those with lower thoracic and lumbar lesions have very little impairment of lung function. All acute lesions need prophylactic respiratory therapy as all are subject to hypostatic pneumonia. The patient with partial or complete paralysis of any of the muscles of respiration will need special care.

FUNCTION OF THE CHEST WALL AND RESPIRATORY MUSCLES

The current view of the action of the respiratory muscles on the chest wall is that an integrated activity of many muscles is probably required to expand the ribcage in the most efficient way.

The respiratory muscles comprise three main groups: the diaphragm, the intercostal/accessory muscles and the abdominal muscles. These muscles act upon the chest wall either as prime movers or to strengthen the ribcage and facilitate the action of the others.

Diaphragm – innervation C3, C4, C5

The diaphragm is the main muscle of inspiration. As the diaphragm contracts, the central tendon is pulled downwards and forwards, pushing before it the abdominal viscera. It expands the ribcage, using the abdominal viscera as a fulcrum. The efficiency of the diaphragm depends on this balance of both ribcage and abdominal compliance.

In patients with spinal cord lesions above C5, the diaphragm may be partially or completely paralysed. Its function can be assessed by inspecting or palpating the upper abdomen during inspiration. When the diaphragm's function is impaired, the negative intrathoracic pressure during inspiration sucks the diaphragm up into the chest

and the upper abdomen will move inwards. The findings of Sinderby et al (1992), who investigated eight tetraplegic patients, imply that the diaphragm acts as a trunk extensor in addition to its respiratory function in these patients.

Intercostal muscles – innervation T1–T7

The internal and external intercostal muscles have both inspiratory and expiratory action. At lower lung volumes, their function is inspiratory and at higher volumes it is expiratory. When breathing is stressed, the intercostals may alternate with other inspiratory muscles; for example, when the diaphragm becomes fatigued, the intercostals may take over as the main inspiratory muscle until the diaphragm recovers. The reduction in respiratory muscle reserve makes fatigue and failure more likely. The intercostal muscles also stabilize the chest wall; in full inspiration they contract to prevent the intercostal spaces being sucked inwards by the negative intrathoracic pressure generated by contraction of the diaphragm. When the intercostal muscles are paralysed, paradoxical movement of the intercostal spaces on inspiration may occur.

Accessory muscles – innervation C1–C8

Scaleni

The scaleni muscles are now considered to be primary respiratory muscles. They lift, expand and stabilize the ribcage from their insertion on its upper part.

Sternomastoid and trapezius

The sternomastoid and trapezius are inspiratory muscles and contribute to inspiration only during exercise or stress. Usually they are incapable of providing long-term ventilation. In complete lesions above C3 where there is paralysis of the diaphragm, the accessory muscles become the main inspiratory muscles and can produce a vital capacity of 700 ml, particularly the sternomastoid and trapezius (Danon et al 1979). Diaphragmatic pacing may be considered if indicated in these situations (Glenn et al 1986). Clinical observation of the hypertrophy of the accessory muscles demonstrates their inspiratory role in tetraplegic patients (Short et al 1991).

De Troyer & Estenne (1991) attribute an expiratory function to the clavicular portion of pectoralis major in patients with lesions between C5 and C8. With the arms fixed, contraction of the clavicular portion on both sides of the chest pulls the clavicle and manubrium sterni downwards, taking with them the upper part of the ribcage. The anteroposterior diameter of the upper ribcage is thus

reduced. This action was associated with a rise in intrathoracic pressure, which was transmitted through the diaphragm to the abdominal cavity. The anteroposterior diameter of the abdomen increased. It is suggested that latissimus dorsi and teres major (C5, C6, C7) fix the humerus and prevent pectoralis major from shortening excessively. Thereby, they facilitate the action of pectoralis major in pulling down the manubrium sterni. It is also suggested that cough is active and not passive in patients with lesions at this level.

Abdominal muscles – innervation T6–T12

The internal and external recti, oblique and transversus abdominal muscles are the most important muscles of expiration (De Troyer et al 1983). In quiet breathing, expiration is usually a passive process achieved by relaxation of inspiratory muscles. In forced expiration, e.g. coughing or sneezing, the abdominal muscles contract strongly. The action of the abdominal muscles is also important in maintaining the position of the diaphragm and hence its efficiency. In the erect posture, the abdominal muscles contract to maintain the diaphragm in the dome-shaped position above the lower ribs by pressing on the abdominal contents and raising intra-abdominal pressure (De Troyer et al 1983).

Paralysis of the abdominals, as in high thoracic or cervical cord injuries, results in severe impairment of forced expiration. Sputum retention may occur, causing microatelectasis, major segmental, lobar or lung collapse and an increased susceptibility to infection. Microatelectasis may result in ventilation and perfusion mismatching, causing hypoxia (usually with a normal or low CO_2). This can cause additional damage to the spinal cord.

During the period of spinal shock, when there is an absence of tone in all muscles below the level of the lesion, the distensibility of the ribcage and abdominal wall prevents the diaphragm from inflating the lungs in the most effective way. When the period of spinal areflexia is over, the reflexes return and the degree of tone in the intercostal muscles will, in general, improve the stability of the ribcage. It also provides some resistance in the abdominal muscles, thus rendering the action of the diaphragm more effective (Guttmann & Silver 1965, Silver & Moulton 1970).

The fall in vital capacity below the value that would be expected from the loss of motor power alone, and the rise which often occurs even in the absence of neuromuscular activity reflect the distortion of the ribcage and its later improvement as tone returns to the intercostal muscles and the ribcage joints stiffen (De Troyer et al 1983, Morgan & De Troyer 1984).

As a result of the paralysis of the respiratory muscles:

- The patient is unable to perform active, expulsive expiration.
- Total ribcage and lung inflation is impossible.

- The partial loss of inspiratory muscle function allows the pleural pressure generated by the diaphragm to distort the ribcage, which results in paradoxical motion. This can be seen in the absence of tone when the intercostal spaces are indrawn during inspiration. This increases the work of breathing and reduces the effectiveness of the action of the diaphragm.
- Without active abdominal muscles, the patient is unable to cough.
- The inability to inflate parts of the lung and to clear secretions tends to produce microatelectasis with subsequent fibrosis of lung tissue.
- Immediately after injury, small areas of collapse interfere with ventilation and may result in transient hypoxaemia.
- The reduction in available muscle power and the increased load placed on the remaining muscles of respiration increase the likelihood of respiratory muscle fatigue and failure (Morgan et al 1984).

EFFECT OF POSTURE ON RESPIRATION

In the supine position, the action of the diaphragm is aided by the weight of the abdominal viscera displacing the diaphragm cranially and assisting inspiration.

Paralysed abdominal muscles allow the abdominal viscera to fall downwards and forwards when the patient is erect. The diaphragm then descends lower into the abdominal cavity and may lie below the lower ribs at the start of inspiration. When the diaphragm contracts, the lower ribs are pulled inwards, reducing the lateral diameter of the lower chest instead of, as is usual, lifting the lower ribs and increasing the lateral diameter.

Research has shown that the vital capacity of the tetraplegic patient improves by 6% when the patient is tipped 15° head down from the supine position, and falls by approximately the same amount when the head is tipped up 15°. The vital capacity may fall by as much as 45% when the patient is tilted towards the standing position.

The use of abdominal binders can lessen the change of vital capacity in the upright position. Care must be taken that they do not restrict the movements of the ribcage (Goldman et al 1986).

GENERAL PRINCIPLES OF RESPIRATORY PHYSIOTHERAPY

Respiratory physiotherapy plays a significant role in the care of patients with spinal cord injury and physiotherapists need to be aware that patients with high lesions and respiratory insufficiency have varying degrees of dysphagia (Wolf & Mainers 2003). When

there is respiratory muscle paralysis, the inspiratory force and volume are reduced and the ability to produce a forced expiration with raised intrathoracic pressure may be absent. The vital capacity can be as low as 30% after injury and may fall further after the first few days, largely due to ascending oedema within the spinal canal (Ledsome & Sharp 1981). It then improves quite rapidly for the first 3–5 weeks, with further slow improvement up to 5 months. The improvement is due to resolving oedema, increased spasticity of the intercostal muscles reducing paradoxical movement, and possibly some reinnervation. Patients may also become hypoxic due to the reduced respiratory function and sputum retention. Respiratory muscle fatigue may occur. The vital capacity of tetraplegic patients decreases with age and also with years post-injury, declining more rapidly after 20 years as a paralysed person (Tow et al 2001).

The principle of respiratory treatment is to replace the function of the paralysed respiratory muscles, and the aim is to maintain respiratory function by:

- promoting sputum mobilization and expectoration
- reducing airway obstruction
- improving ventilation and gas exchange.

It is important to maintain continuity with the patient by having one physiotherapist in charge of his care and, where possible, to educate and support helpers, medical and nursing staff and family in the patient's respiratory care.

Prophylactic treatment

Frequent respiratory assessment is essential for an effective treatment programme, which needs to be constantly modified.

The assessment will include:

- history of present and relevant associated injuries
- past medical history, in particular respiratory or cardiovascular problems
- inspection of movement, using vision or palpation to assess paradoxical movement and diaphragmatic function
- strength and efficiency of cough
- auscultation, in particular listening for uniform air entry, crackles or wheezes in all lung areas
- vital capacity measurements (care should be taken not to tire the patient)
- blood gases
- chest X-rays.

Breathing exercises

Breathing exercises can be useful in maintaining lung expansion in all areas. Treatment should begin as soon as possible to minimize

respiratory muscle wasting. Apical, basal, lateral and diaphragmatic breathing exercises are usually taught twice daily. The emphasis is on relaxed comfortable breathing without excessive effort. The aim is to improve strength and endurance and to postpone fatigue and enable the patient to deal more effectively with respiratory problems.

Training programmes for the respiratory muscles using various methods of resistance, e.g. incentive spirometry, are given in some spinal units. Biofeedback can also be used. After inspiratory muscle training using functional magnetic stimulation with tetraplegic patients with lesions from C3 to C7, Uijl et al (1999) found that endurance was increased but there was no measurable increase in strength. Three of the nine patients had complete lesions and the rest were incomplete A non-invasive technique using functional magnetic stimulation to train expiratory muscles of respiration was found by Lin & Hsiao (2001) to improve strength in the eight patients in the study. The strength decreased sharply to baseline 2 weeks after conclusion of the programme. This subject continues to be investigated.

Positioning and postural drainage

The frequent repositioning to prevent prolonged pressure is also beneficial for respiratory care. Postural drainage, using gravity to free secretions from the peripheral airways, can be used if the patient's condition is stable, and where necessary the traction can be maintained. Padded head supports can be used when turning the patient from side to side to maintain alignment of the cervical spine.

Forced expiration

Patients with paralysis of their abdominal muscles are unable to cough, and assistance to do so is required to prevent sputum retention and lung collapse.

Normal cough

A single cough consists of a rapid maximal inspiration with a closed glottis followed by contraction of the intercostal and abdominal muscles with sudden opening of the glottis producing forced expiration. The effectiveness of the cough depends on the linear velocity of the gas in the airways. At high lung volumes, the cough is effective in clearing secretions from the large airways. At low lung volumes, it becomes more effective in the small airways (Macklem 1974).

Spinal patients are unable to achieve high lung volumes. They are able, provided the vital capacity is not too severely affected, to bring sputum from the small to the large airways and they then need assistance with coughing to expectorate (Cheshire & Flack 1979). The forces generated in a cough are not due to active contraction of

muscle but are the result of elastic recoil of the lung and thoracic tissue generated by the previous breath.

Assisted coughing

The patient with partial or complete paralysis of the abdominal muscles is unable to cough effectively. The therapist can replace the function of the paralysed abdominal muscles by creating increased pressure underneath the working diaphragm (Linder 1993).

Methods of assisting the patient to cough

When the patient is supine, there are two main methods by which one therapist can assist the patient to cough:

Method 1. One forearm is placed across the upper abdomen of the patient with the hand curved around the opposite side of the chest. The other hand is placed on the near side of the chest. As the patient attempts to cough, the therapist simultaneously pushes inwards and upwards with the forearm, stabilizing and squeezing with the other hand (Fig. 5.1).

Method 2. The hands are spread anteriorly around the lower ribcage and upper abdomen, and with elbows extended the therapist pushes inwards and upwards evenly through both arms as the patient attempts to cough (Fig. 5.2A, B).

As it is essential for the effectiveness of method 2 that the therapist's arms are kept extended, this method may prove impractical when the patient is on a high bed. With the patient in the lateral position, method 1 may be preferable.

Figure 5.1 Assisted coughing. Method 1 using one therapist.
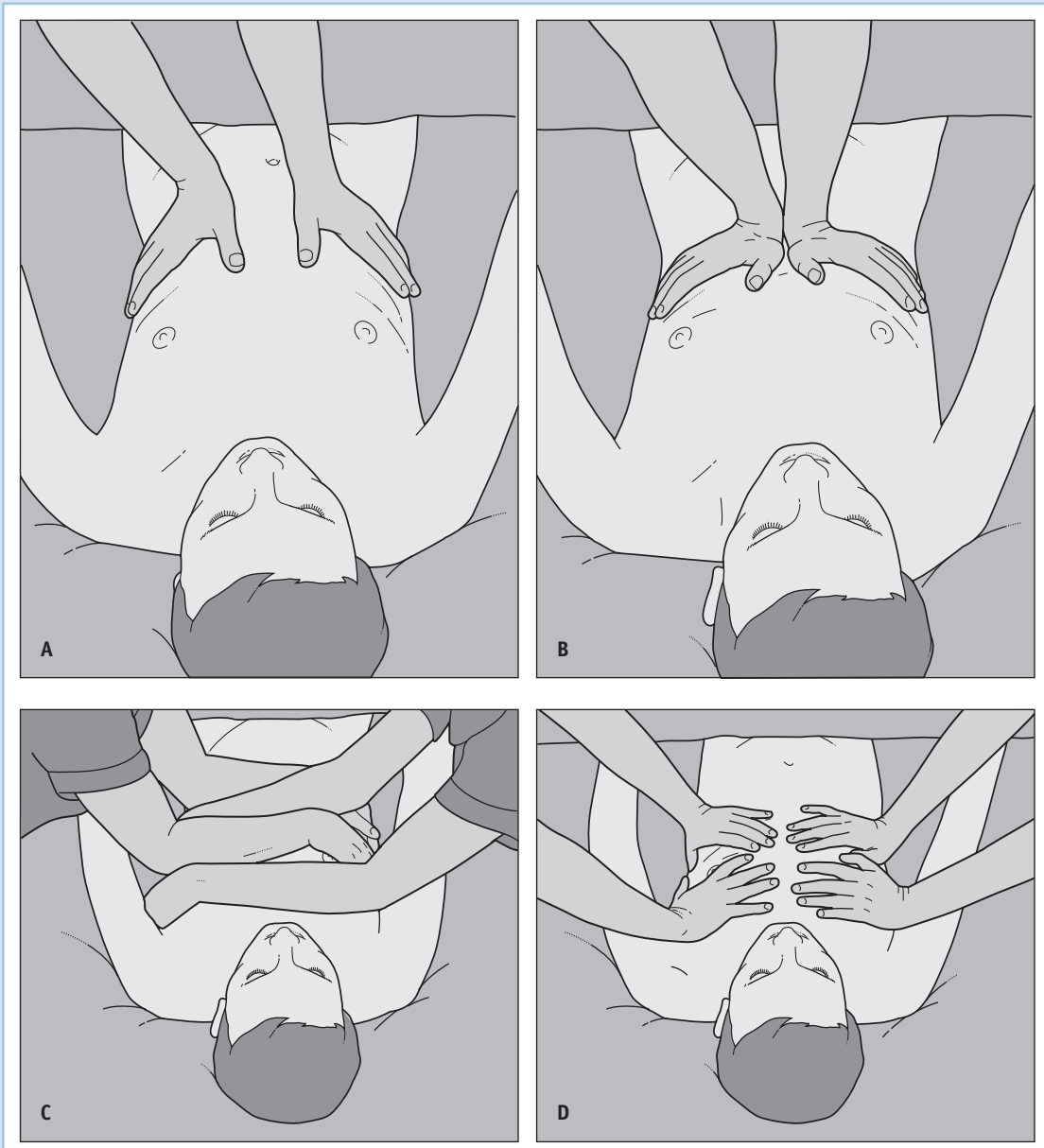
Figure 5.2 Assisted coughing. A, B: Method 2 using one therapist. C: Method A using two therapists. D: Method B using two therapists.

One therapist may not be able to give the necessary pressure to produce a cough, if, for example, the sputum is tenacious or the patient has a large thorax or is easily exhausted. In this case, two therapists working together are usually effective, using one of the following methods:

Method A. Standing on either side of the bed, the therapists place their forearms across the chest with the hands curved around the opposite side of the chest wall. The arms are placed alternately with the lowest arm across the diaphragm. When the patient attempts to cough, the therapists simultaneously squeeze the chest (Fig. 5.2C).

Method B. Standing on either side of the bed, each therapist spreads their hands over the upper and lower ribs of the same side with the fingers pointing towards the sternum. When the patient attempts to cough, the therapists simultaneously push on the chest wall (Fig. 5.2D).

Whichever method is used, the pressure must be even and firm with the weight of the therapist's body behind the 'push'.

The effectiveness of the cough depends on the simultaneous effort of the patient and therapist(s). For maximum effect, the pressure behind the push should be held until the very end of expiration and the force applied should be sufficient to deliver the sputum to the mouth. The sound of the cough produced is usually a good guide to the force needed.

Both functional electrical stimulation to the abdominal muscles and manually assisted coughing increase maximum expiratory pressure and therefore enhance the cough (Linder 1993, Zupan et al 1997). By increasing the maximum expiratory pressure, functional electrical stimulation to the abdominal muscles can enhance the cough in tetraplegic patients (see p. 260).

It is essential to teach the techniques of assisted coughing to medical and nursing staff involved in the care of the patient, as well as to relatives, since the same techniques can be used if the patient is choking. Once up in his chair, the patient will need to be shown how to cough by himself or be assisted by another person.

Caution

Great care must be taken to avoid causing any movement or pain at the fracture site. Pressure on the abdominal wall alone must be avoided, as a patient with an acute lesion may have a paralytic ileus, internal damage or a bleeding gastric ulcer. Extreme care must be taken when assisting the patient to cough in the presence of any of these complications. The methods described above involving two therapists may be preferable under these circumstances.

Coughing in a wheelchair

To cough unaided, the patient himself must produce the pressure usually provided by the abdominal muscles. This can be done in the following ways:

- Hold one armrest or wheel rim, press the other arm against the abdomen and lean well over it.

- Flex one elbow behind the chair back or chair handle; those with wrist flexors can hold the wheel. Press the other arm against the abdomen and lean over it (Fig. 5.3).
- Hold both armrests or flex the elbows behind the chair handles and lean over until the chest is pressing against the thighs (Linder 1993).

To assist a patient to cough in a wheelchair

The therapist stands behind the chair and, linking her hands in front of the patient, pulls back against the upper abdominal wall and lower ribs (Figs 5.4 and 5.5). Should a second therapist be required, she stands in front of the patient and pushes on the upper thorax. If it is not possible to assist the patient from behind, the methods described on pages 59 and 60 may also be used with the therapist standing in front of the patient.

Caution

When using these methods with the patient sitting, it is essential to stabilize the wheelchair either by anchoring the rear wheels against a wall or with an assistant holding the chair from behind.

Frequency of treatment

It is important that the patient coughs several times a day to clear the throat even though the chest appears to be free from secretions. Patients with high lesions cannot clear the nose or throat unaided, and the normal amount of debris delivered daily from the lungs collects in the upper trachea. Although this will not cause distress for
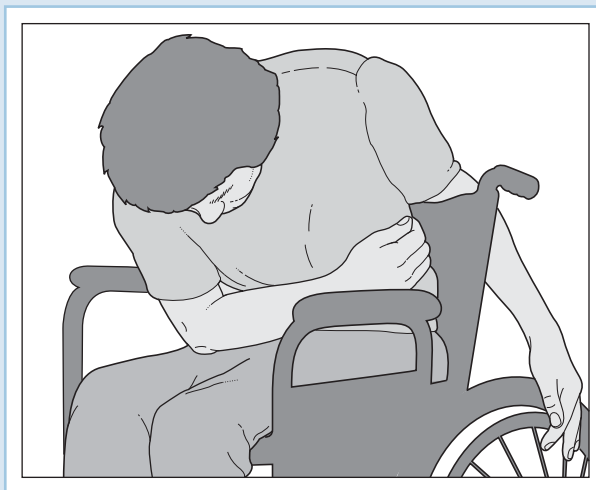
Figure 5.3 Independent coughing. Patient with a complete lesion below C7.

Figure 5.4 Assisted coughing in a wheelchair.

Figure 5.5 Assisted coughing in a wheelchair.

the first 2 or 3 days, towards the end of a week the patient will begin to experience some difficulty in breathing. Inspiration becomes slightly laboured and finally the debris is pushed down into the bronchial tree. At the end of the week, a patient with a previously clear chest may suddenly develop a high temperature and be found to have pneumonia or collapse of a lung.

This can be prevented by prophylactic treatment given three or four times a day for the first 2 weeks at least. Treatment is subsequently given once a day until the patient is up in a wheelchair and able to clear his secretions unaided. Tetraplegic patients also need prophylactic postural drainage at least once a day. If a mobile cervical patient with a lesion at or above C5 gets a heavy cold, he should return to bed for 24 hours. This prevents the nasal secretions dropping down into the chest and causing congestion. He will need assistance to blow his nose and clear his throat.

Physiotherapy for respiratory complications

Respiratory complications, such as retained secretions, collapse of lobe or segment, and infections, require careful and more frequent treatment. The frequency of treatment depends upon the severity of the chest infection. 'Little and often' is a good maxim. If the patient tires quickly and has copious sputum, it may be necessary to treat him every hour, day and night for 24 hours. For less severe cases, treatment at each turn will be sufficient.

Assessment

Treatment is directed at the particular area affected. Regular assessments are important to initiate or change treatment.

Oxygen therapy

If the blood gases are abnormal, e.g. low Po_2, oxygen may be required, which can be given via mask, nasal spectacles, minitrac or tracheostomy.

Humidification

Secretions may be thick and difficult to expectorate, and in addition there may be some difficulty with blocked nasal passages. Humidification can be given via ultrasonic or jet nebulizers with saline. It may be necessary to warm the saline.

Drug therapy

The effect of these complications can be reduced where appropriate by the use of drugs, e.g. bronchodilators, antibiotics or steroids for

asthma and chest infections. Coordinating the time of treatment with therapy produces the best results.

Sputum mobilization

Chest mobilization

Shaking and vibration on expiration may assist in loosening secretions in peripheral airways to allow drainage to the main bronchus, provided the movement does not compromise the stability of the fracture.

Postural drainage

Gravity can also assist in the removal of secretions. Unless contraindicated, postural drainage may be given to any lesion. Care is taken to gain the correct drainage position for the area affected within the limits imposed by the hyperextended position and the type of bed in use. It is important to give postural drainage before as well as after the turn, and essential when treating high lesions. If both lungs are congested and the uppermost lung is not cleared before the turn, as the patient is moved secretions may drain into the trachea, completely blocking it and choking the patient. This can be prevented if the uppermost lung is cleared before the patient is moved. The therapist should wait whilst the patient is turned and treat him immediately in the new position, before the sputum has a chance to settle.

Continuous positive airway pressure (CPAP) and positive expiration pressure (PEP)

CPAP may be useful in the prevention of alveolar collapse (Harvey & Ellis 1993). PEP may also be used.

Intermittent positive pressure breathing (IPPB)

IPPB can also be used, the objectives being to open small airways, reduce airway collapse and improve ventilation and perfusion. Although improvements in lung volume during IPPB seem to be of sufficient magnitude to be of clinical value, the vital capacity changes immediately post-treatment are of such small magnitude that their clinical value would be less certain (Stiller et al 1992). This area is yet to be evaluated. If, as the evidence from this study suggests, IPPB does not have a clinically significant sustained effect on lung volume, it may have to be given at frequent intervals to have any beneficial effect on respiratory function. Furthermore, if the inspiratory breath can be increased by using IPPB then the elastic recoil of the lung is increased and this can improve expiratory flow, assisting in the clearance of secretions (Jackson 1983). In stable tetraplegic patients, lung volume expansion alone has no major effect on lung function, and

Rose et al (1987) suggest that it may be more useful in combination with respiratory muscle training. If the expansion of the ribcage is achieved by mechanical means, then full range of movement may be maintained by the remaining inspiratory muscle action. Loaded expiration or incentive spirometry may be useful in increasing the strength of the inspiratory muscles. IPPB should be used with care due to the potential hazards. Positive intrathoracic pressure can reduce venous return to the heart and can therefore reduce cardiac output. IPPB can generate high intra-alveolar pressure, which can result in damage to the lung and may cause an increase of bronchospasm in patients with asthma or similar conditions. Therefore, it should be used with care in patients with unstable cardiovascular systems and asthmatics and is contraindicated in patients with a pneumothorax (Webber & Pryor 1995). In view of this, treatment should not exceed 10 minutes in duration, including rest periods, but should be repeated several times a day. Severely ill patients may tire very easily and clear instructions to the patient and patience on the part of the therapist are vital for the success of this treatment.

Various machines are available which assist the clearance of secretions from the lungs. The Cough Assist is one of these. It inflates the lungs and subsequently sucks the air out again, thus aiding the movement of sputum. As with all these respiratory machines it should be used with care and in compliance with the instructions for use.

Respiratory physiotherapy in ventilated patients

Despite efforts, some patients may require ventilation because of deterioration in their condition. The criteria for this are determined by the medical staff. Respiratory failure occurs especially in patients with high spinal injury who may become fatigued, have extensive secretions which may be difficult to remove, and have fractured ribs with flail segments. These patients will have blood gas and chest X-ray changes and their general condition will have deteriorated.

Assessment

It is important to establish whether or not the patient's cardiovascular system is stable.

Caution

Physiotherapy may be contraindicated when the cardiovascular system is unstable.

Bagging

Bagging is manually inflating the patient via a 2 L water bag, or, if the patient is on peak end-expiratory pressure (PEEP) whilst on the

ventilator, an Ambu bag with an Ambu PEEP valve can be used. Bagging is used to stimulate a cough and to mobilize secretions by increasing the expiratory flow and lung expansion. Treatment should not exceed 15–20 minutes. The following techniques should be used to avoid precipitating bronchospasm: following a slow inspiration, given via the bag, the breath is held for a few seconds to allow the poorly ventilated parts of the lung to be aerated, and then the bag is released quickly and expiration occurs, producing a high expiratory flow rate which will help to move the secretions. Chest mobilizations are used on expiration to further assist in draining secretions.

Drug therapy

It may be necessary for the patient to be sedated so that an effective treatment can be tolerated. Adequate pain control may also be required. If there is evidence of bronchospasm, bronchodilators or other drugs can be given prior to treatment.

Suctioning

To prevent bradycardia occurring during suction, it is best to preoxygenate the patient, to use catheters whose size should be no more than half the diameter of the endotracheal tube, and to be as quick as possible. Whilst suctioning the patient, the physiotherapist can use the assisted coughing technique to help mobilize the secretions by increasing expiratory flow.

Caution

Pharyngeal suction can excite parasympathetic nerves, e.g. the vagus nerve, and as this cannot be compensated for by increased sympathetic activity, a profound bradycardia and even cardiac arrest may result. Atropine should be available by the patient's bed, to be given intravenously by the nursing staff or doctor. Atropine may cause secretions to become thicker and therefore more difficult to remove.

Tracheostomy

It may be necessary to perform a tracheostomy to maintain a clear airway. A tracheostomy reduces the respiratory 'dead space' by approximately one-half. In consequence, each breath becomes more effective in oxygenating the blood and removing carbon dioxide. It facilitates the removal of secretions from the lungs and the control of oxygen administration. Initially a cuffed tracheal tube is used, as this provides an effective seal for the lungs against secretions or inhaled substances and will readily connect with the tube from the ventilator. Overinflation of the cuff for long periods can cause excessive pressure on the tracheal mucosa and lead to necrosis, sloughing

and in due course stricture. This is prevented by inflating the cuff just enough to make the seal and by deflating the cuff at regular intervals for a short time. The tube should be changed frequently as the lumen can become blocked by encrusted, dried secretions. Speaking tubes can be used prior to complete weaning off the ventilator. If the removal of secretions is the only problem and the patient does not require ventilation a mini-tracheostomy may be useful. A small bore tube is inserted into the trachea through the cricothyroid membrane, facilitating the removal of secretions (Gupta et al 1989).

Weaning

Once the patient's respiratory condition has stabilized or improved, weaning may be considered. Sedation is usually stopped, and the patient is disconnected from the ventilator for short periods several times a day. A spirometer can be used to measure tidal volume and vital capacity, and a graph to show time off the ventilator can be a useful incentive. During the weaning period, which may take several weeks, the patient will need a great deal of encouragement. As patients on ventilators cannot talk and communicate, all feel insecure. Anxiety and/or fear, sometimes amounting to panic, is experienced during treatment (Bergborn-Engberg & Haljamae 1989). These anxieties are exacerbated when the ventilator is being removed. The patient should be told exactly what to expect and be warned against being too disappointed when improvement is slow, or when there appears to be no improvement at all for a time. The ventilator should be replaced whenever the patient asks for it, otherwise he may become afraid of having it disconnected again. During these periods off the ventilator, the therapist encourages the use of the diaphragm and the accessory muscles of respiration. Initially, 1, 2 or 3 minutes only may be tolerated, but as the diaphragm becomes stronger, longer periods are gradually achieved. Sleeping without the ventilator is usually very difficult, a problem that can sometimes be due to fear alone, but this can gradually be overcome. CPAP and nasal intermittent positive pressure ventilation (NIPPV) can offer useful respiratory support during this period.

Long-term ventilation

Patients with high cervical lesions, e.g. lesions above C4, may require long-term ventilation. For the patient to have some mobility and independence, all the necessary equipment, such as ventilator unit with a back-up system, mobile suction equipment, manual hyperinflation bag, suction catheters, gloves etc., must be attached to the chair and easily available at all times. Close liaison with those providing care in the community is essential if these patients are to be safely discharged to the home (see Ch. 14).

Diaphragmatic pacing

The development of the phrenic nerve stimulator has given some patients, who would otherwise be totally dependent on a life support system, a new independence (Collier & Wakeling 1982). A paralysed diaphragm may be electrically stimulated if the lower motoneurones in the phrenic nerve are intact and the cell bodies in the C3, C4 and C5 segments are viable. Some or all of the phrenic nerve cell bodies or lower motoneurones may have been destroyed. The viability is first established by percutaneous stimulation of the phrenic nerve. Contraction of the diaphragm is estimated by X-ray screening, ultrasound or palpation. Surface electrodes in the lower intercostal spaces may be used to measure the phrenic nerve conduction time. If the results are satisfactory, electrodes are placed on the phrenic nerve, in either the neck or the thorax, and connected to a receiver embedded in the skin of the anterior chest wall. A radio transmitter is placed on the skin surface over the receiver and the phrenic nerve is stimulated (Glenn et al 1984). The aim is to enable the patient to breathe via the stimulator initially during the day, and eventually, for 24 hours if possible.

Patients with diaphragmatic pacers are discharged from hospital earlier, are able to communicate more naturally and are better at manipulating the power drive wheelchair than are patients on mechanical ventilation (Esclarin et al 1994).

Where diaphragmatic pacing is not a viable option (the phrenic nerves are not intact or the patient does not want the necessary surgery), Di Marco (2001) suggests that intramuscular diaphragmatic stimulation may be a useful alternative. Electrodes are implanted laparoscopically directly into the diaphragm and activate the phrenic nerve.

In a retrospective review of 107 patients with high tetraplegia, Oo et al (1999) found that seven patients were able to be weaned off the ventilator between 96 and 430 days after injury, suggesting that phrenic nerve recovery can take place and that the nerve should be tested at 3-monthly intervals for the first year post-injury. Fewer than 5% recover after the first year.

OTHER CONDITIONS AFFECTING RESPIRATORY FUNCTION IN THE SPINAL PATIENT

Patients with spinal cord injury may have associated injuries or conditions and treatment must be adapted accordingly.

Paralytic ileus and gastric dilation

The initial signs of this complication, often first noticed by the physiotherapist, are distension of the abdomen and/or complaints by the patient of difficulty in breathing. This can be particularly dangerous

for the tetraplegic patient with his already compromised respiration. Assisted coughing must be given with great care to avoid regurgitation, vomiting or aspiration. If such a patient is likely to vomit, he is turned from side to side only until the danger is past.

Head injuries

Physiotherapy may have to be adapted to prevent a further increase in intracranial pressure in patients with head injuries, e.g. turning, tipping, bagging, coughing and suctioning. Priorities in treatment must be discussed with the medical staff. The failure of the patient to understand or cooperate with treatment may cause problems. Sedation may depress respiration.

Fractured ribs

Special care must be taken when treating patients with fractured ribs to avoid further damage to the chest, including pneumothorax. A flail segment of rib may cause paradoxical movement of part of the chest wall.

Fat embolus

A fat embolus can follow a long limb fracture and is diagnosed by increased confusion, altered blood gases, petechial rash and retinal haemorrhages. Oxygen therapy and steroids are used in treatment.

Adult respiratory distress syndrome

Spinal patients can develop adult respiratory distress syndrome. Careful consideration is required as to whether physiotherapy should be given in such cases because of the pulmonary oedema.

Other respiratory complications

Underlying respiratory pathology may be present in patients who receive a spinal cord injury. Such problems may increase with a cervical injury, e.g. the symptoms of asthma. Prophylactic management may be required.

Cardiovascular conditions

Any circulatory problem can be complicated further by a spinal cord injury and treatment should be altered accordingly.

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Pressure – effects and prevention

Lone Rose

There are many factors that contribute to the development of a pressure ulcer (Graham 1997) but pressure remains the main and most direct cause of tissue breakdown. It cannot be overemphasized that pressure ulcers are caused in bed or in the chair through prolonged pressure, which prevents adequate circulation to the area. Despite the development of increasingly sophisticated pressure relief devices, pressure ulcers continue to feature as a common complication in both acute and chronic spinal cord injury (Yarkony & Heinemann 1995). Ulcers develop mainly over bony prominences which are exposed to unrelieved pressure in the lying or sitting position. The most vulnerable areas are the sacrum, trochanters, ischial tuberosities, knees, fibulae, malleoli, heels and fifth metatarsals. The occiput, scapulae and elbows are also at risk in patients with cervical cord lesions. If the patient is placed in a plaster cast, ulcers may develop over the ribs, spinous processes, and anterior and posterior superior iliac spines. Pressure ulcers readily occur under splints, plasters, calipers and braces applied over anaesthetic areas.

Contributory factors in patients with spinal cord injury

The individual with spinal cord injury is at particularly high risk of developing pressure ulcers due to the following contributory factors.

Loss of sensation and voluntary movement

The body's normal response to prolonged pressure is a feeling of discomfort or pain. The reaction to this warning signal is an automatic change of position. Not only will the loss of sensation prevent the patient with a spinal cord injury from receiving these warning signals but the paralysis will make it harder or impossible for him to shift his position to relieve it.

Loss of vasomotor control

The impairment of the circulation produces a lowered tissue resistance to pressure. Ischaemia due to local pressure therefore occurs

more readily. The vasomotor paralysis is most extreme immediately after injury, and severe ulcers can be produced very rapidly. Although the vasomotor system is never subsequently normal, some improvement does occur when reflex activity returns to the isolated cord.

Pathology

There are currently in excess of 30 pressure ulcer grading tools to help classify the degree of tissue damage. The 'Stirling' scale is the one used at the National Spinal Injuries Centre, Stoke Mandeville Hospital (Reid & Morrison 1994). It describes four stages of pressure ulcer development, which may be summarized as follows.

Stage 0 (pre-ulcer stage)

Normal intact skin, healed skin with scarring or an area of erythema and slight oedema caused by transient circulatory disturbance. When pressure is relieved, this inflammation disappears within 48 hours. This is not classified as a pressure ulcer.

Stage 1

There is permanent damage to the superficial layers of the cutaneous tissues. Vascular stasis occurs, and reddening and congestion of the area do not disappear on digital pressure. The skin is discoloured blue/purple/black.

Stage 2

There is abrasion of the skin or formation of blisters. This may be followed by superficial necrosis and the formation of a shallow ulcer without undermining adjacent tissues.

Stage 3

There is full thickness skin loss involving damage or necrosis of subcutaneous tissue but not extending to underlying bone, tendon or joint capsule.

Stage 4

There is full thickness skin loss with extensive destruction and tissue necrosis extending to underlying bone, tendon and capsule. If the infection extends to the bone, periostitis and osteomyelitis will develop, which may result in the destruction of joints and the formation of ectopic bone. If unchecked, these major lesions may lead to general septicaemia and death.

Development of bursae

A bursa can develop, frequently over the ischial tuberosity, due to prolonged sitting. The surrounding tissues are rapidly involved if infection occurs, and a very small skin opening may be the only visible sign of a deep cavity reaching down to the infected bursa, and usually to the bone.

PREVENTION OF PRESSURE ULCERS

As Sir Ludwig Guttmann used to say, 'Where there is no pressure, there will be no sore.'

Prevention therefore depends primarily upon the frequent relief of pressure in conjunction with the correct positioning of the patient (see Ch. 4). In order to establish the most appropriate routine of pressure relief and positioning for each patient, it is essential that an assessment of risk is carried out on admission by an experienced nurse and at regular intervals throughout the rehabilitation. The degree of risk of developing a skin problem will vary from individual to individual and will largely depend on age, sex, body build, level and completeness of injury, degree of incontinence and general health. Other factors such as smoking, anaemia and diabetes will further increase the risk. There are several scales that can be used to document and monitor the level of risk of developing a skin problem. One example is the Waterlow scale (Waterlow 1991).

Turning the patient

Newly injured patients are turned every 3 hours, day and night, using the supine and side-lying positions. Besides preventing the effects of prolonged pressure, regular turning also aids renal function by preventing stagnation in the urinary tract. For patients who are unable to tolerate the traditional side-lying position (e.g. because of shoulder pain or halo traction), the 'hipflick' position can be used. In this position only the lower half of the trunk is rotated to the side together with the lower limbs, flexed at the hips and knees. A small pillow or rolled up towel should be placed in the lower back to ensure that the sacrum stays free of pressure. A pillow is placed between the knees to prevent pressure areas developing on the medial sides of the knees. The flexed knees should be supported on a pillow if full rotation cannot be achieved. Feet should be placed on pillows as necessary to prevent pressure areas on the malleoli and borders of the feet. The hipflick position should not be used where there is a risk of causing movement at the site of the fracture (low thoracic and lumbar fractures). Special attention should be given to inspection and protection of potential pressure areas on the occiput and shoulders if the hipflick position only is being used.

The most susceptible areas, i.e. where bony points are close to the skin, must be kept free of any pressure by adjusting the pillows accordingly. At each turn, all such areas are inspected, the skin is checked and all wrinkles and debris are removed from the bed linen. Any evidence of local pressure, however minor, is an urgent warning. Redness that does not fade on pressure, septic spots, bruising, swelling, induration or grazing indicates an impending pressure ulcer. All pressure must be relieved from any area thus affected until it is healed. For example, if the sacrum shows signs of redness, the left and right lateral positions only should be used until the mark has completely disappeared.

An 'electrical turning and tilting bed' can be used to facilitate the 3-hourly turning of patients (Huntleigh Healthcare Ltd, UK; Pegasus Ltd, UK). This type of bed is divided longitudinally into three sections. On pressing a button, two of these sections elevate to 70°. The remaining third can be slightly raised to maintain the patient in position. The head and foot of the bed will tilt down to 15°. A head traction unit can be attached when skull traction is required. This unit enables constant cervical traction to be maintained when turning the patient. A face-piece supports the head in the lateral position. A detachable armrest enables the upper limb to be positioned with the elbow fully extended and the shoulder abducted. All turns should be supervised by an experienced nurse who organizes each turn and ensures that correct spinal alignment is maintained whilst the patient is moved.

If a turning/tilting bed is not available, the patient can be positioned on a bed with sorbo rubber packs. The space between the packs is altered to suit the position and stature of the patient, so that the bony prominences are free from pressure. The prone position is particularly useful for the non-acute lesion if the sores are on the sacrum, trochanters or ischii, or on all three sites. In this position, care must be taken to ensure that the toes, knees, iliac crests and genital areas are clear of pressure (Fig. 6.1). Support to the back is given by sandbags or firm pillows when in the side-lying position.

If sorbo packs are not available, pillow packs can be used. These are made by tying five or six pillows tightly together.

For the non-acute patient the intervals between turns can gradually be increased but will always be guided by the individual's specific needs at any one time. It is important to remember that an individual's tolerance to pressure can alter due to simple factors such as body temperature and general well-being.

There is a large variety of mattresses and mattress overlays available designed to help in the prevention of pressure ulcers. Body support systems are constantly being developed to facilitate the healing of pressure ulcers. Ultimately the type of bed and mattress used has to meet the needs of the individual patient as identified by the risk assessment at that time.
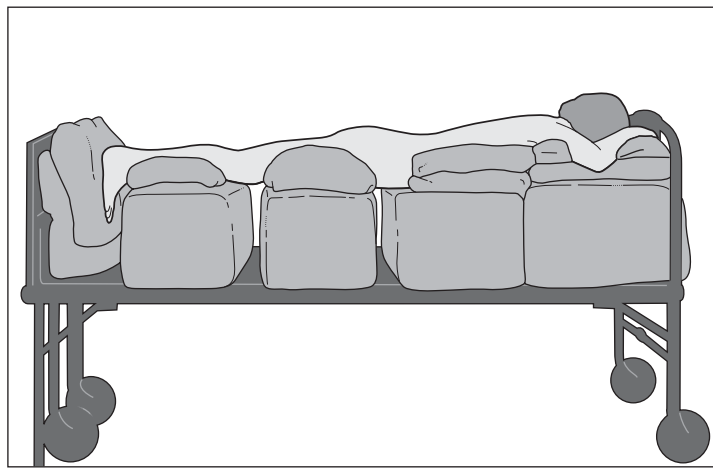
Figure 6.1 Prone position of patient on a pack bed.

Care of the skin

The emphasis is on cleanliness and dryness. Intact skin is kept clean by the normal use of soap and water. No local applications of methyl alcohol etc. are used. Dead epithelium tends to collect, through disuse, on the soles of the feet and palms of the hand. It can be prevented and removed by thoroughly washing and towelling these areas and then massaging an emollient into the skin.

POSTURE AND SEATING

Any wheelchair user needs a well-fitting wheelchair with an effective cushion if the dangers of prolonged pressure and poor posture are to be minimized. Even the most sophisticated cushion cannot work optimally if it is not adequately supported by the wheelchair. It is therefore essential when assessing a wheelchair user that the wheelchair and cushion are considered as one unit. On completion of the assessment and prescription, the seating must be fitted properly to the individual as otherwise it may itself become the cause of tissue trauma (Batavia & Batavia 1999).

The purpose of the seating is to offer the user a stable and comfortable base from which he can function at his full potential with maximum efficiency and minimum effort. It should also promote a symmetrical posture and provide adequate skin protection. If the position of the patient is not stable on the seat, the patient will tend to slide on the seat, causing friction, which is more damaging to the

skin than pure pressure. Regular friction may be indicated by the reduction in hair growth in patches over the ischii. The seating system should be supportive but not restrictive. Normal posture is dynamic – the patient recently out of bed should be encouraged to change his posture frequently in the chair but also know how to return to a symmetrical upright posture.

Posture

Most patients with a recent spinal cord injury will need some encouragement and support to adopt the correct position in the wheelchair. Due to the lack of, or altered, sensation below the level of the lesion, the patient will not receive the normal sensory input to tell him when he is adopting a normal posture in the chair. He needs time to learn to recognize when he is positioned correctly by using the sensory input from the unaffected parts of the body. To achieve this, it is crucial that this sensory stimulus is that of normal postural alignment from the first day out of bed, and this should be carried on throughout the 24 hour period, not just when the patient is up in the wheelchair. Attention to detail and a consistent approach to positioning in the early days of rehabilitation will soon show the benefit. The therapist needs to take a very active role in guiding and supporting not only the patient but also all other professionals involved with positioning the patient, whether in the wheelchair or in bed. This is particularly the case with patients who have high tone, asymmetrical neurological deficit or incomplete lesions. The patient's position in bed needs to address the postural problems observed in sitting without compromising the skin integrity of the patient. A commonly used and very effective position in bed for patients with a scoliosis or increased kyphosis is the hipflicked position as described earlier. This position is very effective in breaking up high tone patterns, stretching the side flexors of the trunk, and it encourages trunk extension if positioned well.

After the prolonged period of bedrest, the postural muscles unaffected by the spinal cord injury will inevitably be weak. It is beneficial if static neck and back extension exercises can be initiated during the last 2 weeks prior to getting up and carried on during the initial rehabilitation phase.

When the patient is positioned in the wheelchair he should sit with the bottom right to the back of the seat, the trunk and head symmetrical, all four limbs resting in normal alignment, the weight distributed evenly over as wide an area as possible and the anatomical curves of the spine maintained.

In order to achieve this it is essential that the wheelchair used when mobilizing the patient is a good fit.

Seat width – it should be possible to just slide a hand between the widest point of the hips and side of the chair. Recent weight gain or weight loss must be considered.

If the seat is:

1. Too narrow – there is danger of excessive pressure on the hips (trochanters). If the trunk cannot be accommodated comfortably within the back uprights the user will tend to rotate with one side comfortably within the backrest and the other on top of the backrest upright.
2. Too wide – this is likely to lead to asymmetrical pelvic posture as the patient tends to place the hips to one side or the other for stability. This in turn will lead to pelvic obliquity and scoliosis with increased risk of developing a pressure area on the lower ischium and possibly also on the side of thorax resting against the side support of the backrest.

Seat depth – the whole length of the thighs should be supported to within 5 cm (2 inches) (maximum) of the popliteal fossa.
If the seat is:

1. Too long – the patient will not be able to get to the back of the seat and will slump and gradually slide forwards. This will create excessive pressure and friction on the sacrum.
2. Too short – the area over which the weight can be distributed will be decreased, thereby increasing overall pressure on the remaining contact area.

Footplates – must be adjustable to allow the thighs to be in contact with the full length of the cushion.
If the footplates are:

1. Too high – the area over which the weight is distributed is reduced and the pressure will be increased over the remaining contact area.
2. Too low – increased pressure on the distal part of the thigh will reduce venous return and increase the risk of oedema to the lower legs and feet. The downward drag of the feet will make it harder for the patient to lift fully back onto the seat.

Backrest height should be high enough to give adequate support without interfering with the shoulder girdle and upper limb function when propelling the wheelchair. For patients with levels above T6 the backrest should be no higher than the inferior angle of the scapulae. For paraplegic patients with levels below T6 the backrest should be no lower than the level of sensation.
If the backrest is:

1. Too high – the patient will feel as if he is being pushed forward and will frequently ask to have his hips pulled forwards to compensate, resulting in a slumped position. This will encourage the body to gradually slide further forwards on the seat with ever increasing trauma to the sacrum. Furthermore the loss of lumbar lordosis will lead to gradually increasing thoracic kyphosis and increased cervical lordosis often associated with neck pain.

2. Too low – if the backrest does not offer sufficient support the newly injured patient will typically tend to arch over the backrest with an anteriorly tilted pelvis. In order to compensate and gain increased trunk support they will lower themselves in the chair by bringing their hips forward. This results in posterior tilt of the pelvis and increased thoracic kyphosis. A temporary back extension may help until the patient's balance and postural control have improved.

Backrest angle should be as close to vertical as the patient can tolerate. If the patient needs to be tilted back it is important to maintain a minimum of 90° hip flexion to prevent sliding forward and losing the lumbar curve. This may be achieved either through independent adjustment of back/seat angle or by reclining the backrest with simultaneous ramping of the cushion at the front by inserting a wedge under the first third of the cushion. If the wedge goes further under the cushion, the patient tends to be raised overall in the seat and the effect is lost.

Maintaining the normal curves of the spine can be very difficult to achieve in a standard slingback style backrest. A tension adjustable backrest (see Fig. 11.3) provides the most effective and comfortable way of sculpting the backrest to the contours of the individual. Most newly injured patients tend to be very stiff in the lumbar spine when first mobilizing out of bed. The tension adjustable backrest can be altered regularly as the spine becomes more flexible.

Armrests will assist newly injured patients to maintain their balance in the chair. Being able to rest on armrests occasionally will help to alleviate fatigue of the postural muscles of the trunk. As they make it easier for patients to alter their position in the chair, armrests also encourage a more dynamic posture. Armrests should ideally be height adjustable for optimum support.

If the armrests are

1. Too high – the shoulders will be elevated and may lead to shoulder/neck pain.
2. Too low – the patient will have to stoop to rest on them, which will encourage kyphotic trunk posture. There may also be drag on the shoulder joint leading to shoulder pain.

For more detailed description of wheelchair options and adjustments, see Chapter 11.

Assessment of posture

For posture to be functional it must be dynamic. Even tetraplegic patients with very high lesions can develop the ability to shift their posture by shrugging their shoulders or moving their head. It is important that the therapist takes time during the assessment process

to observe these movements, which are often automatic rather than conscious, as they may have a bearing on how to interpret the assessment findings. These habits develop over time and are more pronounced in patients in the final stage of rehabilitation or readmission and outpatients.

The posture is usually assessed first in the habitual sitting position in the user's present seating system, then in supine to check joint ranges and if any tightness can be corrected with gravity eliminated and finally in a corrected sitting position. The order in which the assessment is carried out can vary from therapist to therapist but the postural assessment usually starts with the orientation of the pelvis as this determines the position of the legs, trunk and head.

Assessment in the habitual sitting position – frontal view

With the therapist looking at the patient from the front the pelvis is checked for obliquity (i.e. level horizontally), rotation and tilt (anterior/posterior).

Pelvic obliquity

This is assessed by palpating the anterior superior iliac spines (ASIS) and observing whether one is lower than the other. If there is a pelvic obliquity, the main area at risk of pressure will be the ischial tuberosity on the lower side of the pelvis. Where an obliquity can be observed clinically, a more objective way of measuring it may be required to monitor any future deterioration. An anthropometer or slide rule can be used to measure the distance from the floor to the top of the iliac crest on right and left sides. The difference between the two sides will give the absolute obliquity in any given posture or seating system.

Pelvic rotation

The rotation of the pelvis is determined by palpating both ASIS and observing whether one is forward in relation to the other. Provided there is no history of orthopaedic problems with the hips and thighs, the alignment of the knees may assist in determining whether the pelvis is rotated. The rotation can either be described according to the side it is rotated towards (e.g. 'pelvis rotated to the left') or according to its orientation on the down side if an obliquity is present (e.g. 'pelvis down and rotated back on the left'). As in the case of the obliquity, an anthropometer or slide rule can be used to monitor more accurately the rotation by measuring the distance from the ASIS to the backpost of the chair on both sides. The difference between left and right denotes the measure of rotation.

Pelvic tilt

The normal tilt for the pelvis in the seated position is neutral, i.e. when the anterior superior iliac spines (ASIS) are level with the posterior superior iliac spines (PSIS). The pelvis is said to be in posterior tilt if the ASIS is higher than the PSIS and in anterior tilt when the ASIS is lower than the PSIS. For the pelvis to be in neutral, the femora need to be at true 90° in the hip joint. This is not usually achieved on a flat seating surface. The thigh is thicker proximally than distally and therefore the femur will effectively slope downwards and not be parallel to the surface, making the angle at the hip joint <90°. Any seating system with a ramped effect, e.g. a posteriorly inclined seat or a cushion which is thicker at the front, will promote a neutral pelvic position. A quick guide is to imagine the patient sitting with a tray on his lap. It should neither slope away from him nor towards him. As it can be very difficult to palpate both ASIS and PSIS simultaneously helpful clues may be picked up from other parts of the body.

Posterior tilt of the pelvis is characterized by a flattened lumbar spine with a characteristic long 'C' kyphosis and compensatory increased cervical lordosis in order to maintain horizontal vision ('poking chin' posture). Main areas at risk of pressure are the sacrum and coccyx and the spinous processes of the spine. The legs will typically be abducted and externally rotated.

Anterior tilt of the pelvis is usually associated with adduction and internal rotation of the legs. The lumbar spine will be hyperlordotic with compensatory thoracic and cervical curves. If severe, pressure areas may appear in the perineal area as well as on the coccyx where it comes into contact with the back of the chair. Frequently the patient with anteriorly tilted pelvis does not use the backrest for support or has to extend back to be able to reach it.

With either posterior or anterior tilt of the pelvis, the range of rotation in the trunk will be restricted and therefore function will be affected.

Lower limbs

The greater trochanters are palpated to ensure that the whole of the pelvic/hip girdle is supported within the perimeter of the cushion. When palpating the hips it is important to be alert to the possibility of a dislocated or subluxed hip in sitting. The hips, knees and feet should be in line with one another. If the knees are adducted and the feet placed far apart there is the potential for medial knee strain. If the knees are abducted and the feet are placed close together, the lateral side of the lower leg is likely to be in touch with the frame of the wheelchair with the subsequent risk of pressure problems. The thighs should be in contact with the full length of the cushion and the feet should be weight-bearing on the soles of the feet. There is no standard formula for the correct angle of the hips, knees and

ankles in sitting. This should be determined by careful examination of the free range of movement in each joint, which should be carried out in supine.

Trunk, upper limbs and head

Working up from the pelvis the shoulders should be level and the head in the middle. The trunk should be central in the wheelchair with an equal amount of backrest showing on each side. Pelvic obliquity inevitably leads to a compensatory scoliosis as the spine curves to enable the head to align itself for upright posture. Often the head will be tilted to one side with one shoulder higher than the other. If the scoliosis is severe, upper limb function may be affected as one or both hands may need to be used in order to maintain balance and upright posture.

If armrests are used for support, the upper limbs should rest comfortably on them without elevating the shoulders or having to stoop to rest on them.

Assessment in the habitual sitting position – lateral view

Looking at the patient from the side, the lumbar, thoracic and cervical curves are described as well as the head position. In normal upright posture the shoulder is vertically above the hips with the head between the shoulders. This can be difficult to achieve when the patient first gets up but should always be the ultimate aim. As the head will always try to stay above the pelvis, the further back the trunk is tilted, the further forward the head will flex. This posture will eventually lead to neck and shoulder pain. In order to achieve sufficient stability while using their arms, tetraplegic and high paraplegic individuals will often sit with the shoulders slightly behind the hips. The normal curves of the spine should still be maintained by using a well-adjusted back canvas.

Assessment in the habitual sitting position – posterior view

Standing behind and with the patient leant slightly forward the spine is palpated for any sign of scoliosis. The profile of the trunk and skin creases will often give away any tendency to scoliosis. When assessing for scoliosis it is important that clothes are removed and that the patient is sitting as close to upright as possible to get the maximum effect of gravity in the usual sitting position. It is important that the patient is assessed for scoliosis in his habitual posture to get an impression of the effect of the seating on the posture. Rotation of the trunk can most clearly be assessed by observing the patient from above.

Assessment in supine on a firm surface

After assessing the position of the pelvis, trunk, head, upper and lower limbs in the habitual sitting position, it is essential to establish whether any abnormal posture identified is fixed or correctable as this will determine the appropriate intervention. This can most effectively be done by assessing the patient in supine, where the effect of gravity can be eliminated. This part of the assessment can be difficult to carry out for the therapist, especially with heavy individuals or those with high tone. Proper attention must be paid to back care at all times.

Pelvis/trunk

It is helpful to observe the posture that the individual adopts when first positioned in supine before correcting the alignment. Trunk extension should be observed with only the minimum of support under the head. With the knees and hips flexed to allow the pelvis to move freely, the therapist checks the range of movement in the pelvis in terms of obliquity, rotation and tilt. This will also test the correction of any scoliosis. It may be necessary to have assistance to stabilize the shoulders or help to take the weight of the legs.

Lower limbs

Passive hip flexion is tested whilst fixing the pelvis with one hand. The degree of hip flexion achieved before the pelvis starts to roll posteriorly will determine the maximum seat/back angle of the wheelchair. If the seat/back angle of the seating system places the user in more flexion at the hips than is freely obtainable, a posteriorly tilted pelvis will result.

With the hip flexed the lower leg is then raised to test the range of knee extension. Tight hamstrings is one of the most common causes of posterior tilt of the pelvis so it is important that the legrests of the wheelchair place the leg in sufficient knee flexion to release tension in the hamstrings and allow free upright position of the pelvis.

Passive range of movement in the foot and ankle is also checked for any restrictions which may affect the position of the feet on the footplates.

Head and upper limbs

It may be necessary to check the range of movement in the neck and shoulder girdle if problems have been observed in the upright posture.

Finally the patient may need to be assessed in short-sitting on a firm surface to assess the potential for correction of any abnormal posture against gravity. The procedure is the same as for habitual upright posture.

Following the assessment, changes are made to the seating system according to the findings. Frequent reviews and adjustments to the seating are recommended as the posture usually changes as the patient progresses through the rehabilitation.

If the patient is struggling to maintain an upright and symmetrical posture, a body brace may be used (see Fig. 7.1). This is usually only necessary in the short term for patients undergoing initial rehabilitation. For some patients with established postural problems, it may be an effective long-term solution. Similarly foot orthoses may be required to ensure a good position on the footplates/footbar.

Assessment of body–seat interface pressure

Poor posture in the wheelchair will not only affect the patient's function and comfort, it will also affect the distribution of pressure and thereby increase the risk of pressure problems.

Apart from meeting the patient's need for postural support, the cushion must also be able to distribute the pressure over as wide an area as possible. The more the cushion can conform to the body's contours, the better it will achieve this. Measurements of the pressure between the patient's body and the seating surface in sitting can be taken by using either simple hand-held pressure transducer systems as described by Rothery (1989) and Dover et al (1992) or more sophisticated (and more accurate) computerized systems as described by Bar (1991), Henderson et al (1994) and Bogie et al (1995). Single cell transducers can help to identify peak pressures. However, interface pressure monitors which are able to map the entire seating area via a series of interconnected cells will give a more complete impression of the distribution of pressure. The cushion should distribute the pressure evenly throughout the contact area with no peaks and troughs. The pattern of distribution is of primary interest, not merely the absolute value of pressure measured at a certain point. Capillary closure pressure of 32 mmHg is frequently quoted as a threshold for tissue viability and hence interface pressures above this level are thought to produce ischaemia (Kosiak 1961, Daniel et al 1982). However, the length of time that an individual can withstand a certain pressure over bony prominences varies greatly from person to person. A guideline is given by Reswick & Rogers (1983). If shearing forces, e.g. through bad posture or transferring, as well as vertical pressure are applied to the tissue, the process of tissue necrosis will be accelerated. More recent studies show that deeper tissue such as muscle is more susceptible to pressure and that deep ulcers, e.g. as a result of bruising after a bad transfer or a fall, can develop very fast without significant superficial signs of tissue breakdown (Bouten et al 2003).

Whatever system is used, it is important that the therapist takes into consideration the degree to which the pad used to measure the pressure may interfere with the pressure-distributing properties of the cushion being assessed. Interface pressure measurements are an

extremely useful adjunct to a full clinical assessment, but as most only demonstrate the pressure distribution at the moment of use, they should never be used as the sole indicator of a cushion's suitability.

Cushions

A wide variety of cushions is available worldwide ranging from simple easy-to-use cushions to highly sophisticated ones. No one cushion will be appropriate for every patient, but all wheelchair users must have at least a foam cushion. Where there is a choice of cushions other than foam, the therapist will need to examine and assess not only the patient's posture and skin care needs, but also comfort, the method of transfer, the patient's balance and stability in sitting and his degree of independence. Some cushions, for example, may cause difficulties when transferring, may be too heavy for the patient or relatives to handle, or may not be available in the appropriate size. The climate in which the cushion is used can also affect the durability of the cushion. A hot, humid climate will make certain types of foam deteriorate faster. The patient and anybody involved in his care after discharge need to understand how the cushion works and how to look after it. Where the patient has more than one wheelchair, it may be necessary for the cushion to be used in both. This also applies to any special back supports which may be used. Trial periods with more than one cushion may be necessary.

Cushions are made from different substances, including foam and gel emulsion. Some are a combination of a contoured, firm base with a fluid-filled pad on top, such as the Jay (Fig. 6.2) and Flo-tech ranges. Some are air-filled, e.g. the Roho dry flotation cushion (Fig. 6.3) and

Figure 6.2 Jay 2 base and Flolite pad separated.
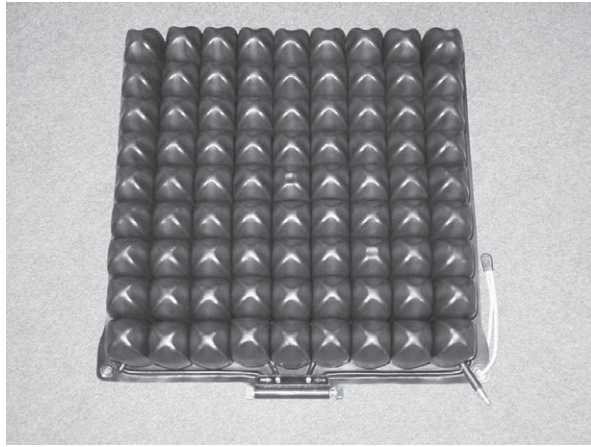
Figure 6.3 *(left)* Roho Quadtro cushion. It has four intercommunicating compartments, allowing for greater stability and postural control.

Figure 6.4 *(right)* Range of Vicair cushions.

Vicair (Fig. 6.4), or a combination of air and foam, e.g. Varilite. Many cushions are now contoured and designed to lower the ischial tuberosities into the cushion while lifting the distal end of the femur, promoting a more upright position of the pelvis (Green & Nelham 1991). This design of cushion also helps to reduce the interface pressures under the ischial tuberosities (Gilsdorf et al 1990). Cushions that are in sections (right/left, front/back) tend to offer greater stability and postural control. The Jay range of cushions has several options for modifications (Fig. 6.5) which can be employed either for assessment or for permanent use. Depending on the material of the cushion and the way it is used, it may last for anything from 6 months to several years. The patient must know the likely lifespan of the cushion, how to assess the wear and how to organize a replacement. Most cushions come supplied with an outside cover. Although the cover needs to be well-fitting, it must not detract from the conforming properties of the cushion, as the patient will then be supported by the cover rather than the cushion itself. This is a common problem with PVC-type covers. The best material for a cover is a two-way stretchy cotton based material, e.g. terry towelling.

Where access to a range of cushions is limited, the use of what is available and some imagination can go a long way to make a relatively simple cushion more effective. A foam cushion with ischial cut-outs filled with bags of air or water will offer a far greater degree of pressure relief than the foam on its own. A cushion made from

Figure 6.5 Jay box of modifications.

bicycle inner tubes and plastic balls has been described as being more effective than a foam cushion (Guimaraes & Mann 2003).

Whatever the sophistication of the cushion used, the need for regular pressure relief and checking of skin must never be forgotten.

Posture and seating clinics

The value of using posture and seating clinics as an integral part of the rehabilitation programme is well documented (Noble 1981, Rothery 1989, Dover et al 1992). They serve not only to facilitate early identification of problems through continual assessment of the individual seating needs of the patient, but also to create an important focus for education on matters relating to skin care and posture for patients as well as carers and staff. This type of assessment is

valuable not only for newly injured patients but also for readmission and outpatients. Patients usually attend for an initial assessment for wheelchair and cushion, and advice on posture and pressure prevention, as soon as they are out of bed. The patients continue to be seen regularly whilst in hospital and after discharge at follow-up outpatient attendances. Attempts are made to evaluate the quality of life of each patient, as social and psychological factors influencing behaviour inevitably have an effect on the incidence of pressure ulcers (MacLeod 1988, Rothery 1989).

The long-term effects of ill-fitting seating should not be underestimated. It will reduce the patient's function and increase pain and discomfort. The function of the inner organs may be compromised. The risk of contractures and deformities will increase as will the risk of pressure ulcers. If an ulcer develops, the cost to the patient can be catastrophic in terms of social isolation, poor psychological well-being and financial hardship, as prolonged enforced bedrest may put employment at risk.

PRESSURE CONSCIOUSNESS: RE-EDUCATION IN SELF-CARE OF THE DESENSITIZED AREAS

Whilst the patient is in bed, the prevention of pressure ulcers is the responsibility of the multidisciplinary team. As soon as he is mobile, this responsibility must be transferred to the patient if he is to remain free from pressure ulcers in the future.

Pressure relief

To allow adequate circulation to be maintained in the areas of maximum pressure, relief of pressure at regular intervals is essential, regardless of the type of cushion used. In the upright sitting position, maximum weight is taken on the ischial tuberosities. Therefore as soon as the patient sits in the wheelchair, the therapist must teach him the most practical method of pressure relief – by leaning side to side, leaning forward or tilting the chair.

Traditionally patients have been instructed to relieve pressure by lifting every 10 minutes for 10–15 seconds. However, studies of transcutaneous oxygen flow carried out at the National Spinal Injuries Centre, Stoke Mandeville Hospital, indicate that the oxygen levels take a lot longer to recover than 10–15 seconds. By placing an oxygen sensor over the ischial tuberosity with the patient in side-lying, a baseline reading of transcutaneous oxygen is established, as described by Bogie et al (1995). The sensor stays in place while the patient is transferred to the wheelchair and cushion currently being used and adopts his usual posture. As the ischial tuberosity is now weight-bearing, the effect of loading on the transcutaneous oxygen levels can be monitored. As the level of oxygen displayed on the

monitor is visible to the patient, the educational benefit of this procedure is considerable (Kennedy et al 2003). Inevitably the oxygen level will drop during loading. While carrying out pressure relief, the patient is encouraged to time how long it takes for the oxygen to return to unloaded levels. Usually this takes between 1.5 and 2 minutes. Few patients at the early stages of rehabilitation will have the strength or stamina to perform the traditional lift on the wheels or armrests for that length of time. An increasing body of evidence shows that upper limb pain is a fact of life for many long-term manual wheelchair users (see Chs 17 and 18). This evidence combined with the findings relating to oxygen recovery has prompted the search for alternative methods of pressure relief which are less stressful on the upper limb but equally effective (Coggrave & Rose 2003). For most patients, leaning forward is the most practical, either onto the elbows (Fig. 6.6A) or completely forward with the chest resting on the knees (Fig. 6.6B). For those patients unable to relieve pressure independently, leaning forwards may be the most suitable method, as a helper can easily provide the necessary assistance (Fig. 6.6C). The helper can stand either by the side or in front of the patient. If the patient is unable to tolerate leaning forwards or is anxious in this position, leaning sideways may be an alternative.

None of these methods may be practical for patients who have a lot of pain or who are ventilated. An alternative may be to tilt the chair backwards as long as the tilt is sufficient (65°), although this is not as effective as leaning forwards (Henderson et al 1994). To minimize the strain on the person assisting in this method, the assistant should be seated behind the patient with the wheelchair tilted back, resting against the knees. At each assessment, the method of pressure relief is reviewed. To give the patient more choice in adopting the most appropriate method in any given situation, he will be taught several methods if possible.

All patients are instructed to relieve pressure for 1.5–2 minutes once every half-hour, including during mealtimes and when out socially, e.g. visits to the cinema. In many cases the interval will gradually extend to once every hour. Pressure relief will eventually become second nature and the patient will do it automatically. Until that time, he will need to be frequently reminded and encouraged. If required, various pressure gauges with alarm systems are available to assist the patient to remember to lift.

Turning at night

The patient must also become responsible for the prevention of pressure occurring during the night. He must learn to turn himself regularly in bed, to reposition the pillows between the legs and to ensure as far as possible that he is not lying on any creases in the bed linen. The interval between turns will depend on the condition of the skin and the type of mattress used.
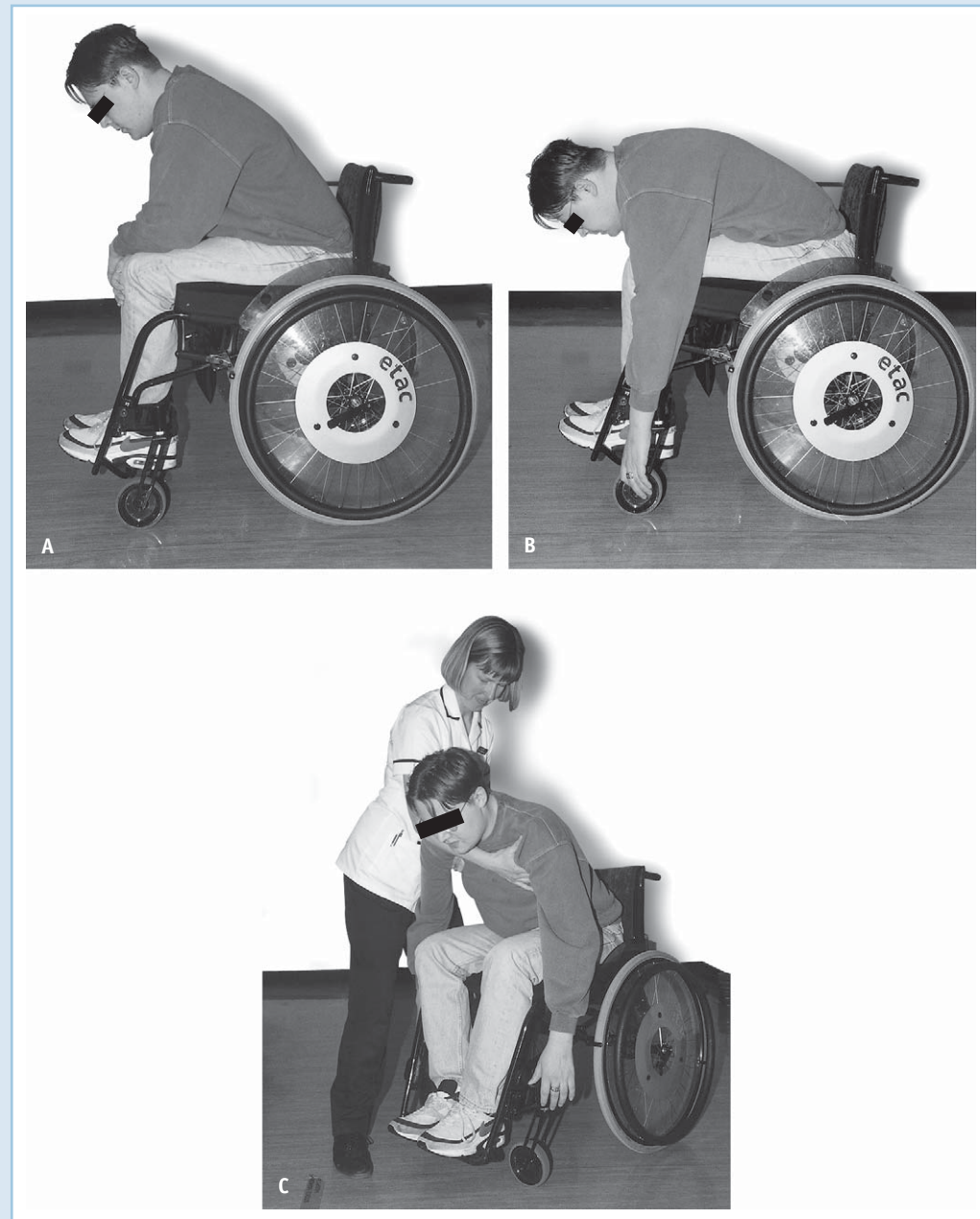
Figure 6.6 A: Forward lean onto elbows. B: Full forward lean. C: Assisted forward lean.

Inspection of the skin

Care of the desensitized and paralysed areas of the body must form an integral part of the patient's daily life. He must learn to inspect his skin night and morning for pressure marks, abrasions and septic spots. It is important to recognize that the night inspection will show problems related to activities during the day, usually associated with sitting in the wheelchair. The morning inspection will alert the individual to problems which may have arisen during the night. Special attention should be given to the most vulnerable areas, i.e. the sacral, ischial and trochanteric areas, plus the knees, malleoli and toes. A mirror is used to inspect any areas the patient cannot view directly. A long-handled mirror can be adapted for tetraplegic patients or those with restricted mobility. Those patients who are unable to inspect their own skin must be responsible for requesting that this is done. If a mark is discovered, the cause of it must be determined in order to prevent it happening again. The length of time that it takes for the mark to disappear provides important information regarding the severity of the trauma.

The paralysed limbs

Great care must be taken in lifting the limbs whenever the patient transfers. A bruise sustained by knocking the malleolus against the footplate, for example, can become a deep sore and take weeks and even months to heal. Bruises devitalize the overlying skin and should be treated as pressure marks. As the vasomotor system does not allow adjustments of the circulation, care must be taken also to ensure that the desensitized areas are protected from excessive heat or cold.

Do's and don'ts

The patient is taught the following list of simple do's and don'ts when he first gets out of bed:

- *Do* relieve pressure in the chair for 1.5–2 minutes every half-hour.
- *Do* lift the paralysed limbs when transferring.
- *Do* little lifts when using a transfer board or use a sliding sheet to reduce friction.
- *Do* cover the tyre of the rear wheel when transferring whilst undressed.
- *Do* use a mirror to detect marks, abrasions, blisters and redness on buttocks, back of legs and malleoli.
- *Do* watch for marks on the penis if using a sheath.
- *Do* protect the limbs against excessive cold.
- *Do* have the bath water ready and not too hot.

- *Don't* force the transfer board under the bottom, lean over to the side before placing it.
- *Don't* allow the clothes to be pulled to be repositioned.
- *Don't* open the hot tap when having a bath in case hot water drips on the toes.
- *Don't* have a hot water bottle in bed.
- *Don't* expose the body to strong sunlight; tetraplegic patients must wear a hat.
- *Don't* knock the limbs against any hard object.
- *Don't* carry hot drinks on the lap.
- *Don't* rest the paralysed limbs on hot water pipes or radiators.
- *Don't* sit too close to the fire.
- *Don't* leave the legs, particularly the feet, unprotected against car heaters.

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Initial physical re-education

As soon as the spine has consolidated for those treated conservatively, or when the surgeon permits, the patient is allowed to sit up in bed prior to sitting in a wheelchair. A support is usually worn for 2 or 3 weeks to prevent acute flexion until the spinal musculature becomes stronger. A padded, metal-framed brace with three-point support on the pelvis, the sternum and the midpoint of these two at the back is used for patients with thoracic lesions (Fig. 7.1). If a firmer support is required, a corset can be supplied by several firms. Those with cervical lesions use an anterior collar, which holds the neck in the anatomical position. Both thoracic and cervical supports can be made to measure or obtained commercially.

Programme for patient's activities

Once out of bed the patient, relevant members of the rehabilitation team and especially the nurse in charge liaise to work out a programme of increasing activity according to the patient's individual needs. For rehabilitation, the patient needs to wear loose clothing that is comfortable and easy to clean, and flat, lace-up shoes.

Initially the patient will attend the physiotherapy and occupational therapy departments for only a short period, approximately 1 hour in each department. Gradually, as the patient is able to stay up for longer, the programme is increased. As always, this will depend upon the patient's age, general state of health and previous medical history.

Assessment for a suitable wheelchair and cushion is undertaken as soon as possible.

IMPORTANT PHYSICAL FACTORS INFLUENCING THE RESTORATION OF INDEPENDENCE

As with all patients, age, sex, medical history, current associated problems and previous lifestyle play a part in successful rehabilitation. The majority of patients incurring injuries to the spinal cord are young males, for whom expectations for the achievement of independence should be high.

Figure 7.1 Three-point brace.

Previous employment and leisure activities inevitably affect the existing strength of shoulder and shoulder girdle muscles. A coal miner will have greater strength in the shoulders and be more used to using his muscles than an office worker. Similarly, a trained athlete, horseman or squash player has greater coordination and visuospatial appreciation than a patient who has never used his body in these ways.

The degree of motor function, the amount of spasticity present and the height and weight of the patient inevitably influence the restoration of independence. Physiotherapists generally think that the length of the arms in relation to the length of the trunk is also a factor, although this was not found to be the case by Bergström et al (1985).

Motor function

The degree of motor function, which depends upon the level of the lesion, is obviously a crucial factor in determining the independence finally achieved: 'Very considerable variations exist in the segmental supply of muscles which may influence the clinical presentation' (*Gray's Anatomy* – Williams et al 1995). An easy reference guide to the major segmental innervation of the most important muscles of the upper and lower limbs is provided in Appendices 4 and 5.

A chart of progressive attainment in the four broad areas of daily living activities – personal independence, wheelchair manoeuvres, transfers and gait – is given in Appendix 6. Each activity is listed at the highest segmental level at which it is currently attainable.

Physical proportions of the patient

The physical proportions of the patient influence the ease and speed with which independence can be achieved. Height, weight and the length of the arms in relation to the length of the trunk appear to affect the rehabilitation of all patients with spinal cord injury, but particularly those with lesions complete below C6.

The most intrepid patients having led the way, therapists have gradually come to expect a greater degree of independence for these patients (Yarkony et al 1988). Achieving it, however, is expensive in effort and time for both the patient and the therapist and may incur extended hospitalization.

In order to identify those patients most likely to benefit from extended rehabilitation, it is necessary to determine the factors that differentiate between the successful and unsuccessful groups.

Physical ability in relation to anthropometric measurements in persons with lesions at C6

A study was undertaken at the National Spinal Injuries Centre, Stoke Mandeville Hospital, in the UK in 1985 (Bergström et al 1985) to assess which anatomical and anthropometric characteristics of the

patient with tetraplegia complete below C6 could be of value in predicting which patients would learn to transfer independently.

The 36 chronic patients were restricted to those with a transverse spinal cord syndrome complete below C6 where extensor carpi radialis was present and the triceps muscle was absent or graded 2 or less on the Oxford scale. There were 33 males and 3 females and the ages ranged from 18 to 52 years. 23 anatomical and anthropometric variables were selected in order to give as complete a picture of the patient as possible. Spasticity, although difficult to quantify, was included, as it was felt that, if severe, it could prevent patients from transferring independently. Two groups of patients were defined: those who could transfer independently from a wheelchair to a surface of similar height (T) and those who could not (NT).

Table 7.1 shows the results for the total group of 36 patients, and for the subgroups representing transfer and non-transfer ability. It is interesting that the data does not show the 'monkey syndrome' (long arms and a short trunk) to be statistically significant for the ability to lift, although this is the subjective impression of therapists working in this field. Although not significant, functional arm length was greater in the T group.

The largest significant difference between the two groups was in the base triangular measurement. This measurement was devised to obtain an impression of how much the subject leans forward in sitting and lifting (Fig. 7.2). The 'triangle' was formed from:
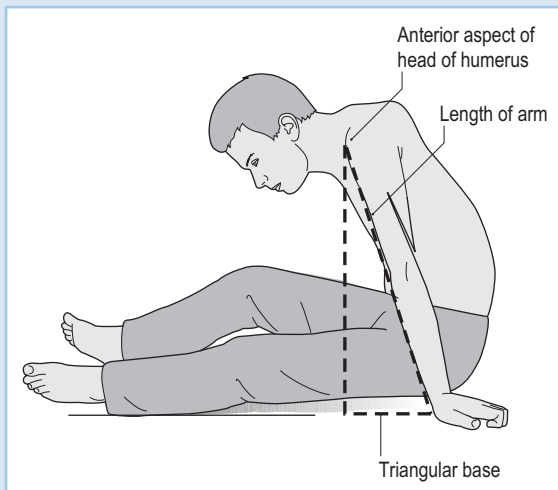
Figure 7.2 Triangular base

Table 7.1 Means and standard deviations of all the measured and predictor variables for the total group and the subgroups (T, NT). The Student's *t*-value and its level of significance for the difference between NT and T groups are also shown

Variables	Units	Total group (n = 36)		NT group (n = 25)		T group (n = 11)		*t*-value	Level of significance
		Mean	SD	Mean	SD	Mean	SD		
Age	years	28.4	7.9	29.1	9.0	26.7	4.8	1.0	ns
Weight	kg	65.7	14.3	68.4	15.0	59.6	11.0	2.0	ns
Stature	cm	176.1	9.2	176.3	9.3	175.5	9.4	0.2	ns
Sitting height	cm	93.1	4.5	93.4	4.3	92.2	5.0	0.7	ns
Cervicale to datum[a]	cm	66.3	3.6	66.6	3.3	65.8	4.2	0.5	ns
Right shoulder flex	cm	10.6	1.8	10.3	1.6	11.1	2.1	1.1	ns
Left shoulder flex	cm	9.9	1.7	9.7	1.5	10.5	1.9	1.3	ns
Biacromial width	cm	38.5	2.5	38.4	2.5	38.9	2.6	0.6	ns
Bitrochanteric width	cm	34.4	2.4	38.8	2.1	33.5	2.7	1.4	ns
Functional arm length[b]	cm	60.6	3.8	60.3	3.4	61.1	4.5	0.5	ns
Acromion to floor static	cm	59.0	4.2	59.1	3.5	58.8	5.7	0.2	ns
Acromion to floor lifting	cm	59.0	3.9	59.2	3.4	58.4	4.9	0.5	ns
Triangular base static	cm	12.5	5.6	11.6	4.0	14.4	8.1	−1.1	ns
Triangular base lifting	cm	13.0	5.4	11.0	4.3	17.1	5.4	−3.3	P < 0.005
Head circumference	cm	57.9	1.8	57.8	1.8	58.1	1.8	−0.4	ns
Spasticity	Grade	4.6	0.6	4.5	0.7	4.7	0.4	−1.3	ns
Σ4-skinfolds	mm	44.1	23.4	50.3	25.1	30.0	9.3	3.5	P < 0.001
Fat (% of body weight)	%	17.9	6.6	20.1	6.3	12.9	4.1	4.1	P < 0.001
Fat mass	kg	12.3	6.5	14.2	6.7	8.0	3.5	3.6	P < 0.001
Fat free mass	kg	53.4	9.4	54.2	10.0	51.6	8.2	0.8	ns
Functional arm length/ stature	Ratio	0.3	0.01	0.3	0.01	0.3	0.01	1.3	ns
Functional arm length/ sitting height	Ratio	0.7	0.03	0.6	0.03	0.7	0.04	−1.4	ns
Functional arm length/ cervicale to datum	Ratio	0.9	0.05	0.9	0.05	0.9	0.05	−1.3	ns

ns = not significant.
[a] C7 to ischium.
[b] Anterior aspect of head of humerus to base of palm.

the perpendicular from the anterior aspect of the head of the humerus

the distance along the floor to the hand

the length of the arm.

The subjects with transfer ability leaned further forwards when lifting. This gives greater mechanical advantage as it balances the body more accurately over the acromial point which is the fulcrum for the lift.

There was a significant difference between the two groups in the data on total body fat. This indicates that additional weight as fat is detrimental when attempting to lift and transfer.

The NT group had considerably broader hips. This forces the subject to place the arms further away from the sides, which effectively reduces arm length and minimizes any mechanical advantage. Morphologically, females have narrower shoulders and broader hips than males. This data confirms the clinical impression that tetraplegic women do not lift as well as men and that fewer can transfer.

As 23 variables were considered to be too many for practical use, an analysis was carried out on these variables to assess the extent to which a smaller number of anatomical and anthropometric data could predict the final ability to transfer. Nine variables were finally selected:

- biacromial width
- body weight
- cervicale to datum
- fat percentage
- head circumference
- shoulder flexibility
- sitting height
- spasticity
- triangular base lifting.

Using these variables, it is possible to predict into which group (T or NT) a patient will fall with an accuracy of 90%.

However, this result is tentative due to the small size of the sample. Data needs to be collected from a further sample of patients, and the present results used to classify patients into the T or NT group, in order to assess the validity of the process. (Bergström et al 1985)

Spasticity

There is no doubt that severe spasticity is one of the most incapacitating complications of spinal cord injury and can seriously curb rehabilitation, in some cases preventing even a minimal degree of self-care. Early positioning of acute lesions has a great influence on the development of reflex patterns of spasticity in both complete and

incomplete lesions. With adequate early treatment, the majority of patients are left with a degree of spasticity which is useful to them in many ways and which does not inhibit daily life. Some patients, however, develop incapacitating spasticity in spite of treatment.

The problems arising from severe spasticity are dealt with in the relevant sections of subsequent chapters.

AIMS OF TREATMENT

The ultimate aim of rehabilitation is to achieve the highest degree of fitness, independence, balance and control that the patient's lesion permits. This is to be achieved by re-education and the fullest possible use of each muscle over which the patient has voluntary control. The immediate aims of treatment therefore are:

- readjustment of vasomotor control
- re-education of postural sensibility
- the re-education and hyperdevelopment of the normal parts of the body to compensate for the paralysed muscles; the fulfilment of these aims is the foundation for restoring independence (Guttmann 1946) (Figs 7.3 and 7.4)
- the education of the patient in self-care of the desensitized areas (see Ch. 6).

Those patients who have had some form of surgical intervention and spend less time in bed will follow the same overall programme of rehabilitation. Certain elements may have to be curtailed initially and progression will vary depending upon the procedure undertaken.

VASOMOTOR DISTURBANCE

Postural hypotension is particularly common in patients with cervical or high thoracic lesions. This is due primarily to loss of vasomotor control in the splanchnic area. The blood vessels in the viscera are unable to constrict when the body is raised from the horizontal to the vertical position. The vasomotor control that is lost cannot be regained, but the patient can overcome this by developing other vascular reflexes which are still intact.

The reflexes are trained in a variety of ways, by means of deep breathing exercises, tilting exercises in bed, frequent changes of position and graduated balance exercises in the sitting and standing positions.

Before sitting out in the wheelchair, the patient is tilted in the bed. Gradual progression is made from the initial 30° until the patient can sit at 90° without feeling faint.

Houtman et al (2000) found that, compared with able-bodied people, a greater fall in arterial pressure and stroke volume occurs in patients with lesions above T4 when the patient is tilted head-up.
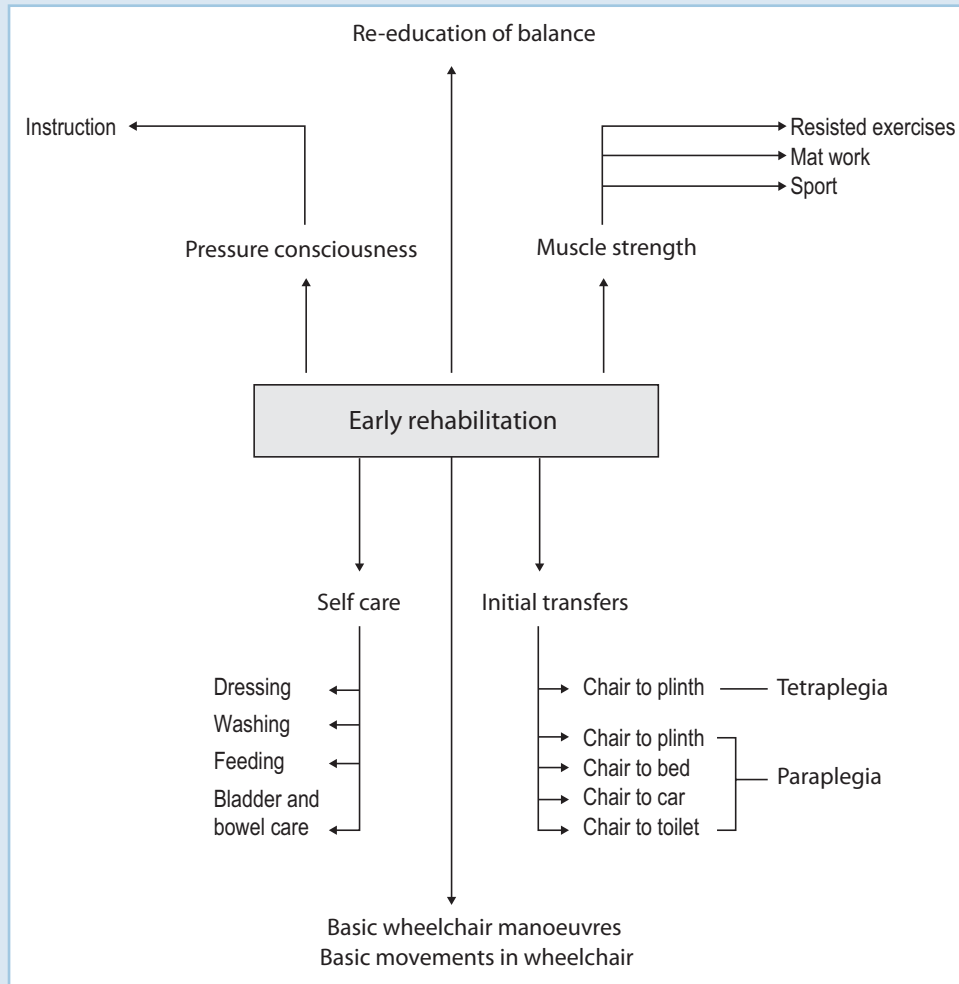
Figure 7.3 Early physical rehabilitation.

The alterations in cerebral oxygenation, however, were the same in both groups. The mechanism by which this is achieved remains obscure. Deep breathing exercises are given in each position. The time in the tilted position is lengthened gradually from 10 to 15 minutes to 3 hours over approximately a week. The skin over the ischia and coccyx is not accustomed to weight-bearing. Constant inspection is necessary as a pressure ulcer can easily develop.

Whilst sitting, the paraplegic patient should practise lifting his body weight on his hands. He can either push down on the bed or use wooden lifting blocks if available. This exercise helps to establish the vascular reflexes, increases the strength of latissimus dorsi and relieves some pressure on the buttocks.
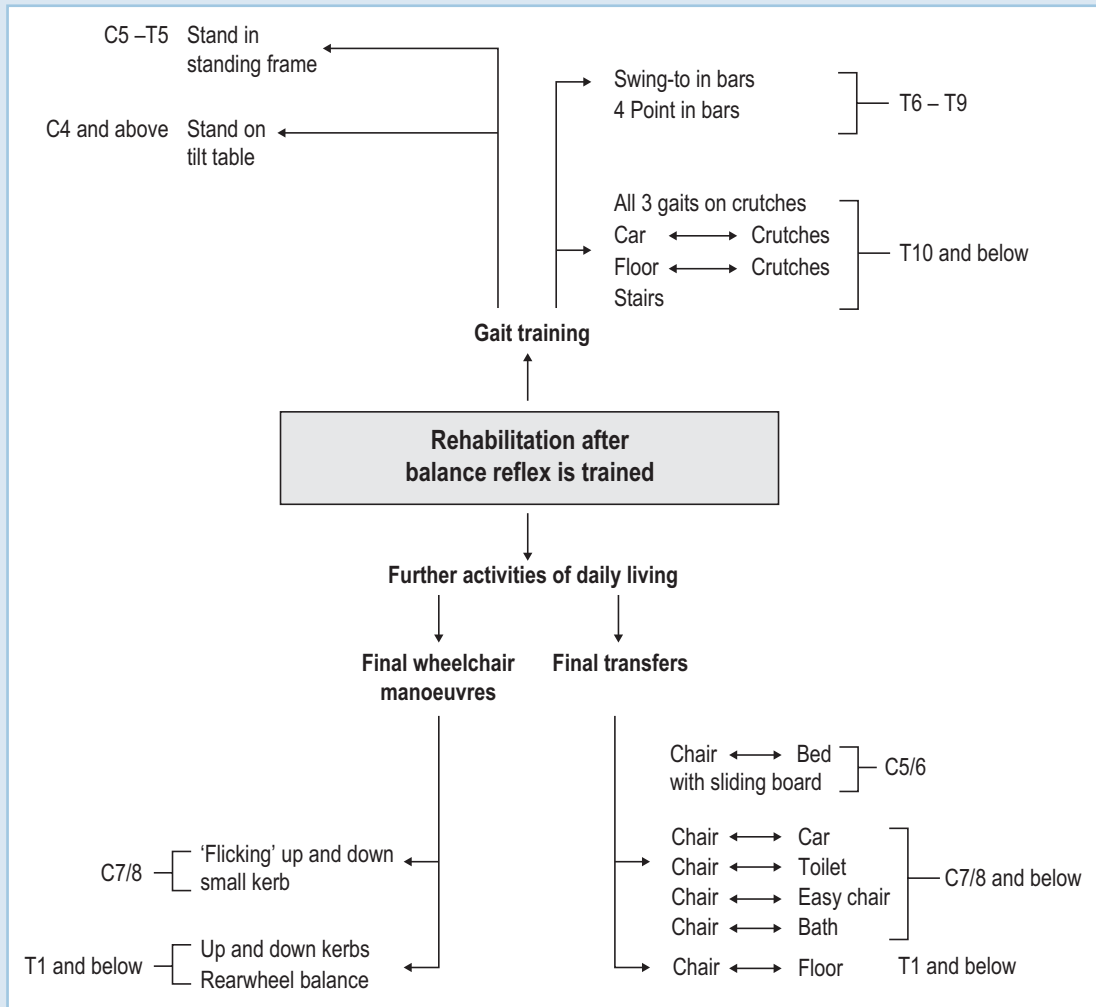
Figure 7.4 Independence expected according to the level of the lesion.

When vasomotor control is established in the bed, training is commenced in the wheelchair, initially for a few moments at a time. The process of gradually and regularly extending the time is repeated. Functional electrical stimulation to the leg muscles increases blood pressure and may prove useful in treating orthostatic hypotension if this remains a problem (Sampson et al 2000). A fixed dose up to a certain stimulation can be given and controlled by the patient.

Active rehabilitation in the various departments begins when the patient can tolerate 1.5 hours in the wheelchair. At first the patient will need to be pushed to the departments. As he has not experienced motion of any kind for several weeks, even relatively slow speeds will

seem alarmingly fast. As soon as possible, the patient should push himself and be responsible for keeping his own appointments.

Fainting

As fainting can occur, it is advisable not to leave the patient alone during the early days of vasomotor training in the wheelchair.

If the patient complains of feeling faint or dizzy, has blurred vision or appears white and sweaty, the legs must be elevated immediately and the chair tipped onto its rear wheels. Deep breathing is encouraged by giving pressure during expiration over the lower ribs and upper abdomen. Should loss of consciousness occur with no signs of recovery within a minute, the patient should be placed flat.

The vasomotor problem must be explained to the patient. Instructions should be given on how to aid the circulation when feeling faint by brisk movements of the arms and deep breathing. Encouragement is essential, as once a patient has fainted, fear of a recurrence may inhibit his activity.

POSTURAL SENSIBILITY

The patient with a complete spinal cord lesion has lost not only sensibility to touch, pain and temperature, and motor power of the trunk and limbs, but also his postural or kinaesthetic sense, below the level of the lesion.

Kinaesthesia is the perception of the position and movement of one's body parts in space. It also includes perception of the internal and external tensions and forces tending to move or stabilize a joint (Rasch & Burke 1971).

In complete lesions above T12 where postural sensibility in the hip joints is abolished, the patient has difficulty in keeping his balance in the unsupported upright position. The development of a new postural sense is a major objective in the rehabilitation of these patients. It is the foundation for all daily living activities.

Postural control is achieved largely through those muscles that have a high innervation and low distal attachment. These muscles form a bridge between the normal parts of the body, including of course the brain, and the paralysed areas. The most important of these muscles is the latissimus dorsi. It has a high segmental supply (C6, C7, C8) and an extensive attachment to the spine and pelvis. Therefore, in all lesions below C7, it bridges the paralysed and nonparalysed parts of the body and allows patients with high thoracic and low cervical cord lesions to regain a high degree of balance and control.

Proprioceptive impulses arising from any movement of the pelvis are transmitted centrally along the afferent nerve fibres of these

normally innervated muscles and thus reconnect the insensitive part of the body with the cerebral and cerebellar centres promoting appropriate efferent postural responses to the paralysed area ... Eventually a new pattern of postural sensibility develops along the nerve supply of the trunk muscles. (Guttmann 1976, p. 582)

Latissimus dorsi is important both in the restoration of the paraplegic patient's upright position and in future gait training. The function of this muscle is greatly assisted by other trunk and shoulder girdle muscles, particularly trapezius, because of its dorsal attachment as low as T12, and the abdominal muscles with their insertion on the pelvis.

The patient develops his new postural sense primarily by visual control. He performs exercises sitting in front of a mirror where he can see the position of his body and limbs. This visual-motor feedback helps him gradually to develop more acute sensory impressions, i.e. interpreting the muscle stretch sensations of the latissimus dorsi and other trunk muscles, and a new sensorial pattern becomes established. He will then perform movements without the aid of a mirror, and eventually functional activity without conscious effort to balance.

Balance exercises in the sitting position

These exercises are primarily carried out sitting on the plinth in front of the mirror, though some patients may need to begin their exercises sitting in the wheelchair .

Position of the patient

The patient sits on a low plinth in front of a long mirror. A pillow is placed under the buttocks to guard against excessive pressure.

The thighs and feet are well supported so that a right-angle is formed at the hips, knees and ankles.

Role of the therapist

- The therapist stands behind the patient so that she can watch his movements in the mirror and have control should he lose balance.
- Her hands initially support the patient either over the shoulders or around the thorax. Her hands should be visible to the patient. Should she put them where he cannot feel, he will be unaware of the support and lose confidence.
- Assurance is given that the therapist will not move away. The fear of falling, especially backwards, is very marked. The therapist should never leave her position unless the patient has some form of support, as he can easily overbalance and fall off

the plinth. The position is obviously more dangerous for those with severe spasticity.

- The therapist can, to a large extent, control the speed of the patient's activity by her voice and her general handling of the situation. Her voice should be quiet and confident and, most important of all, unhurried since all exercise involving balance must be performed slowly.
- She should give constant direction and encouragement.
- When the patient overbalances, the therapist should allow a gross movement to occur before restraining him, otherwise he may not be aware of the movement that has taken place.

Progression of exercises

Self-supported sitting

Watching himself in the mirror, the patient learns to support himself in as upright a position as possible, with his hands first on the plinth at his sides and then on his knees. If the lesion is high and the arms are short in relation to the trunk, it may help to have a pillow at each side of the patient to support the hands. Time and trouble should be taken to teach the patient to hold the correct sitting position before commencing exercises involving motion.

Single arm exercises

Always watching himself closely in the mirror, the patient raises one arm first sideways, then forwards and lastly upwards whilst supporting himself with the other hand on his knee. A small degree of movement of the head and trunk to the side of the supporting hand will be necessary to compensate for the weight of the moving arm. Single arm exercises are not found to be helpful for patients with lesions at C6 or above, since without triceps the supporting arm is ineffective.

Bilateral arm exercises

Larger compensatory movements of the head and trunk will be necessary when moving both arms in the unsupported sitting position. The patient first tries to lift the hands from the knees to the arms bend position and then progresses to raising both arms sideways, forwards and upwards (Fig. 7.5).

The sideways stretch position presents little difficulty since the centre of gravity is barely altered.

In the forwards stretch position, the patient must lean his head and body backwards to counteract the line of gravity which would otherwise fall in front of the hip joints.

The upwards stretch position is particularly difficult for patients with high lesions, since the centre of gravity is raised and the patient has no abdominal muscles to help him to maintain his equilibrium.

Bilateral arm exercises without the mirror

When the patient has mastered the basic positions and exercises, bilateral exercises are performed without the mirror and with the eyes closed.

Other exercises

Balance can be further improved by, for example, asymmetrical work, altering the rate of movement, resisted trunk exercises, stabilizations and ball throwing.

Duration and frequency of treatment

These exercises are physically and mentally exhausting. Treatment is given daily for only 5–10 minutes initially, progressing gradually to half an hour. Frequent rests should be given during treatment by allowing the patient to lean back against the therapist for a few moments. Tetraplegic patients need to rest the head to allow the neck extensors to relax. Balance training requires constant practice and it is valuable to treat patients with thoracic lesions twice daily.
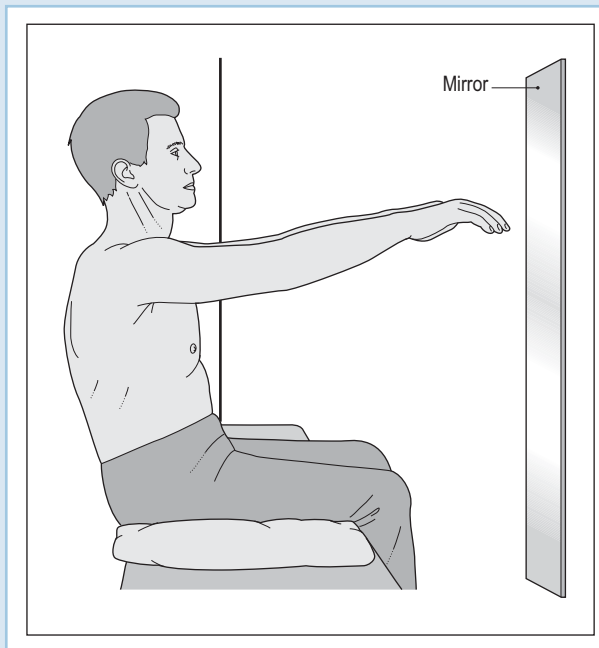
Figure 7.5 Balance position of a patient with a complete lesion below T6.

Balance in the wheelchair

Balance exercises are commenced in the wheelchair for the following reasons:

- Poor posture when sitting on the plinth. This occurs:
  - with high cervical lesions, C5 or above, where the head pokes forward and the patient is unable to extend the neck
  - with some thoracic lesions where the trunk is flexed due to weak extensor muscles. It may be necessary for such patients to concentrate on back extension exercises for a week, balancing only in the wheelchair. When the general muscle tone has improved the patient can return to balance exercises on the plinth.
- General debility. The patient may not be fit to be moved in and out of the chair.
- Recently healed ulcers. The scar tissue may be delicate. Movement in and out of the wheelchair may constitute a potential danger until the scar tissue becomes stronger.

Exercises in the wheelchair are carried out in front of the mirror as described above, first leaning against the back of the chair and progressing to sitting away from the backrest. As soon as possible, balance on the plinth should be commenced or resumed.

Posture

Although the aim is to achieve as upright a position as possible, this will vary according to the level of the lesion.

The low thoracic lesion (with abdominal muscles) should have a straight back.

The upper thoracic lesion (without abdominal muscles) has a typical posture with increased kyphosis and lordosis.

The low cervical lesion usually has a good, straight posture providing trapezius is strong and the patient has not been allowed to sit on his sacrum for several weeks or months, producing a long kyphosis.

The high cervical lesion may have a poor posture with poking head and flexed spine or, where the neurological deficit is asymmetrical, a scoliosis.

Sport

Archery and table tennis are useful activities in training postural control.

MUSCLE RE-EDUCATION

To establish a satisfactory compensatory mechanism to cope with the paralysed limbs, all innervated muscles need to be as strong as possible (Guttmann 1976, p. 577). For patients with complete lesions, it is particularly important where possible to hypertrophy the following:

- latissimus dorsi
- shoulder and shoulder girdle muscles, particularly adductors
- arm muscles
- abdominal muscles.

The choice of technique for strengthening these muscles belongs to the individual patient and therapist. Methods currently used include:

- manual resistance, including proprioceptive neuromuscular facilitation (PNF) techniques (Knott & Voss 1968)
- spring and sling suspension therapy
- weights – tetraplegic patients can use weighted cuffs round the wrists
- weights and pulleys
- all types of multi-gym (Nash et al 2002)
- sport.

PNF is particularly useful for:

- patients with incomplete lesions with very little spasticity
- strengthening the trunk muscles
- strengthening the arms of patients with cervical lesions.

In the absence of more sophisticated systems, bilateral strengthening exercises for latissimus dorsi and the pectoral muscles can be carried out by paraplegic patients using a simple system of weights and pulleys (Fig. 7.6). With the pulley handles at shoulder level, the patient pulls down to the chair wheels keeping the elbows straight. If the elbows are allowed to flex, triceps will be strengthened and not latissimus dorsi as desired.

Body weight is useful as resistance in free exercises such as press-ups and lifting up on blocks.

Progression

In all exercise programmes, progression must be carefully graded both for strength and endurance and for the effect on cardio-respiratory function. It is often helpful for patients to watch in a mirror when performing exercises so as to have some visuospatial feedback.

Biofeedback can be useful in muscle re-education. It assists the patient to strive for maximum effort and enables him to measure his achievement.
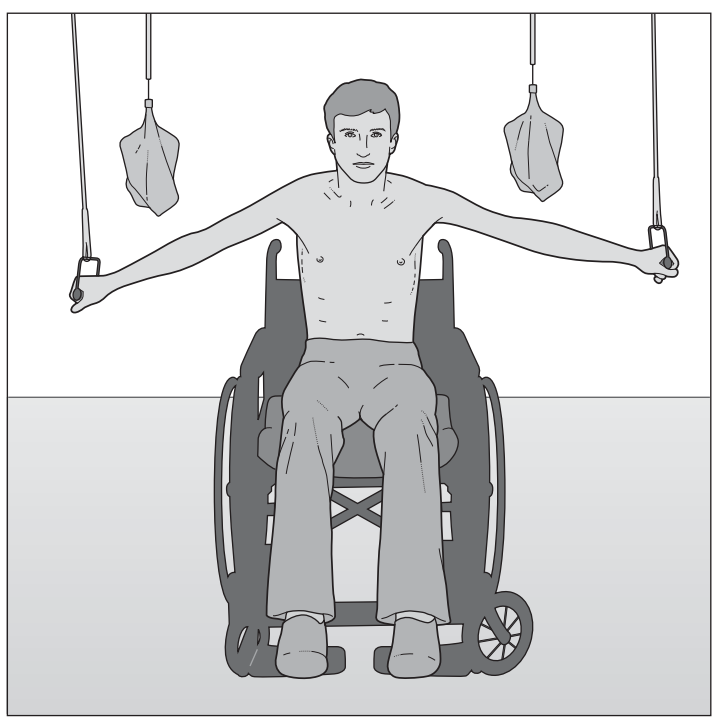
Figure 7.6 Weights and pulleys used to strengthen latissimus dorsi.

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Personal independence

CHAPTER

8

Close cooperation between the occupational therapist and the physio-therapist is essential in planning the patient's rehabilitation pro-gramme. The work of the two disciplines complement one another and in many areas overlap.

All but those with the highest lesions need to learn to dress, and in addition tetraplegic patients must learn to eat and drink, brush their hair, clean their teeth, and wash and shave. All need to be able to instruct others how to undertake those tasks they cannot do for themselves.

PATIENTS WITH LESIONS AT C1–C4

Patients with lesions between C1 and C3 have varying degrees of head control and no other movement and will need assistance with respiration. In addition to head movement those with lesions at C4, have an innervated trapezius which allows them to shrug the shoul-ders and thereby learn to move their upper body very slightly in the wheelchair (see p. 264).

The range of equipment to enable patients with disabilities, includ-ing those with ultra-high spinal cord lesions, to access computers and control their environment is constantly increasing. The environmen-tal control systems are adapted to meet the needs of the individual and usually include at least the operation of the computer, television and video, lights, front door and curtains. Patients can use breath, eye blinks, voice, head movements or equipment mounted on the head or held in the mouth to operate the controls.

Many systems are now available to facilitate computer control. For example operation can be achieved through:

- a wire-free light device mounted on the head and controlled by head movements in two axes
- head-mounted laser pointer
- voice control with the words dictated at a normal speaking rate
- a switching device which recognizes the increase in alpha waves as the eye closes (Craig et al 2002)
- head-mounted or mouth-held stick with a rubber capped tip.

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The light-sensitive or touch screen monitors can have overlays which allow the individual to create his own keyboard on screen. Words or pictures can be used if required.

For those with lesions at C4 who can, and choose to, use a mouth-stick, various adaptations to the keyboard can be made. There are keyboards with large letters, or with guards around the whole, or on one side of each letter, light touch and left hand keyboards. The mouth stick can also be used to turn pages, paint and play board games with suitably adapted pieces.

For patients with incomplete lesions there are various adaptations in mouse design, for example larger than normal rollerball, joystick, touch mouse and an ergonomic mouse which can be held in the hand. These can be used with a variety of wrist rests. Scanners are available which turn documents into speech.

PATIENTS WITH LESIONS AT C5

These patients have good functioning deltoids and biceps but no muscle control at the wrist. A light cock-up splint is used to stabilize the wrist joint. This contains a slot in the palmar surface to hold simple gadgets such as a spoon, fork or typing stick (Fig. 8.2e). With practice, most patients with lesions at this level learn to eat, type, move papers and operate a computer using a stick with a rubber cap, and to play games such as draughts, chess and dominoes with specially adapted pieces.

Mobile arm supports may be of use to patients with weak shoulder and/or elbow muscles.

The Handmaster is a device for improving hand function (Uzerman et al 1996). It may be useful for patients with lesions at C5 who have shoulder and elbow movement. It uses non-invasive functional electrical stimulation with wrist and forearm support to restore some function to the hand by providing a key grip and release, palmar grasp and release, and a static open hand position. It can also be used to exercise relevant muscles (Allen & McBride 2003).

PATIENTS WITH LESIONS AT C6

These patients have an active brachioradialis and extensor carpi radialis. Patients with lesions at C7 without finger movement can be included in this group, although the active elbow extension and wrist flexion give greater dexterity in all activities.

Wrist or tenodesis grip

The non-paralysed hand is a multifaceted tool for independence. For example, it can hold a pen with thumb and two fingers or use all

fingers splayed to pick up a circular object such as a jar lid. It can pick up objects as small as money or as big as a plate, hold a tumbler and use instruments of various sizes.

In the paralysed hand key pinch grip has been described as the primary hand function to restore to people with tetraplegia (Moberg 1975). This is known as the wrist or tenodesis grip (see p. 50) where the wrist posture determines the position of the fingers and thumb allowing the thumb to come into contact with the finger(s) (Fig. 8.1A, B). The grip is achieved through the combined control of the unaffected muscles with the passive tension in the finger and thumb muscles. To produce an effective grip in this way the strength in the wrist extensors must be able to overcome the wrist flexor tension imposed by the weight of the hand and the structures crossing the wrist (Johanson & Murray 2002). Due to the forces present in the
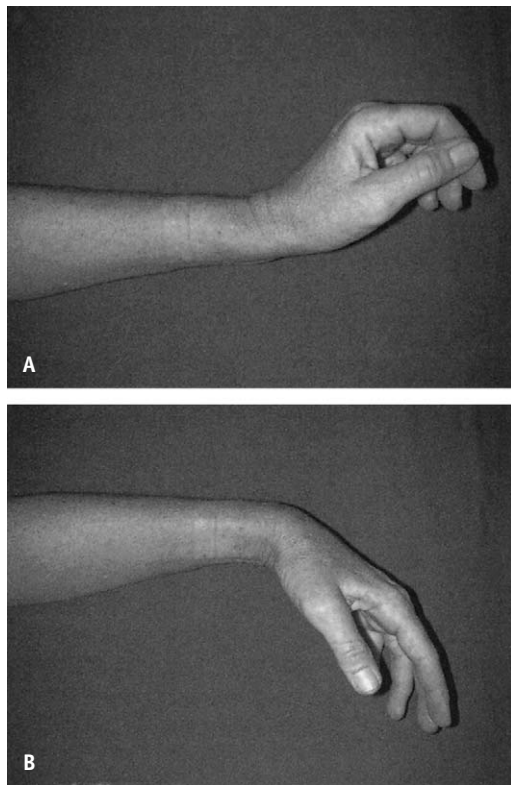
Figure 8.1 The tenodesis grasp used for hand closing (A) and hand opening (B). In the absence of active forces from muscles under voluntary control, wrist posture determines the position of the fingers and the thumb. (From Johanson & Murray 2002. Courtesy of V.R. Hentz MD, Palo Alto, CA.)

hand the grip tightens as wrist extension is increased. With practice the patient is able to pick up light objects and, using small straps, learn how to use small gadgets to eat, write, clean the teeth, use an electric shaver etc. (Fig. 8.2). Patients develop compensatory strategies to maximize the use of their hands and use the effect of gravity to augment the grasp. For example, if the object to be lifted is too heavy for the grip, supination allows the patient to 'cradle' the object in the hand. Most patients with lesions at C6 and C7 attain a high level of hand function in the long term and many no longer use any gadgets (Harvey & Bally 2001).

A number of wrist/hand orthoses are available to increase the function of weak wrist muscles and produce grip. The flexor hinge splint, which utilizes extensor carpi radialis to produce a pincer grip, can be a useful asset to some patients, especially those who return to work. Modular kits are available which enable the splint to be fitted and in use within a few days.

Figure 8.2 a: Finger splint to hold pen. b: Rubber tipped finger splints for using computer. c: Strap with slot for holding gadgets. d: Strap with slot and toothbrush. e: Wrist support with strap for fork. f: Pushing glove. g: Hairbrush. h: Mouthsticks, with dental bite and without.

Procedures to augment arm and hand function

If surgery is to be considered the hand needs to be supple. Patients with stiffness, severe spasticity or pain in their hands may be excluded from consideration (Forner-Cordero et al 2003).

Surgery to produce a grip and improve hand function in tetraplegic patients began over 30 years ago (Zancolli 2002). The goal of any surgery is to make the patient more independent and various procedures have been employed. The early emphasis was on stabilizing joints and transferring tendons (Bryden et al 2004). More recently attention has been focused on neuroprostheses often combining tendon transfers with functional electrical stimulation of appropriate muscles. Surgical procedures are not normally considered until 12 to 18 months after injury. The process is usually long and independence is curtailed as one arm is immobilized during this period. The assessment of the patient, both physical and psychological, must be comprehensive and detailed. The patient must be well informed and have a precise and realistic need for the reconstruction, such as greater independence in relation to bladder management, or more dexterity for work. Unsatisfactory results can come from inappropriate patient selection.

Elbow extension

The inability to extend the elbow actively hinders many of the tasks of daily living, as the patient has to rely solely on the weight of the forearm for stability. Transferring some fibres from the posterior deltoid muscle to triceps on the same side provides the patient with stable elbow extension (Moberg 1975). The strength of the other shoulder muscles needs to be considered in addition to the strength of deltoid, as other weakness may affect the outcome of surgery. Independence is increased as the patient can reach an object from a high shelf, use his hand in the supine position and finds it easier to steer the wheelchair and drive a car. Other procedures are also used and some combine elbow surgery with the provision of a tenodesis grip or even with finger movements. Wuolle et al (2003) in a study of 67 patients (involving 107 arms) found that 70% of the patients were generally satisfied with the results and 66% had improved independence. In a separate study Rothwell et al (2003) found that the levels of improved function after surgery were generally maintained 10 years later.

'Freehand system'

The neurocontrol 'Freehand system' is an upper extremity neuroprosthesis using functional electrical stimulation to increase hand function for patients with spinal cord injury at C5. It was designed at Case Western Reserve University, Cleveland, Ohio in 1987 (Keith et al 1989). A programme was started in 1995 at the Salisbury

District Hospital, in England, which is the European Training Centre for Neurological Control (Kilgore et al 1997).

The system is designed to provide the patient with two hand grasps: the palmar or power grasp, where the fingers flex towards the abducted thumb, used for holding a glass and picking up large objects; and a lateral prehension grip, where the thumb adducts to the flexed fingers, used for small objects such as a key. The ability to open and close the hand allows the patient to have more control over everyday tasks such as eating, writing, using a telephone and inserting a computer disk.

A pacemaker-type stimulator is implanted in the upper chest on the side of the hand to be controlled, and from it electrodes control eight muscles in the hand, enabling the fingers to flex and extend and the thumb to abduct and adduct with the fingers in flexion.

An external transmitter is placed over the chest implant and connected to a microprocessor which can be attached to the wheelchair. A small, light metal stick with a ball-bearing joint at one end and a disc at the other (a joystick) is fixed to the upper sternum. The disc end is located on the shoulder on the opposite side to the hand to be controlled. Signals pass from the joystick via the microprocessor to the external transmitter over the implant site. Small movements of elevation, depression, protraction and retraction of the shoulder then control the opening and closing of the hand. The grasp can be locked and unlocked by a strong, quick movement into elevation at the shoulder so that the grasp can be maintained as long as required.

To enhance the usefulness of the implanted system, the patient may also have the posterior fibres of deltoid transplanted into triceps to provide elbow extension and extend the range of movement of the arm. Both surgical procedures, implanting the neuroprosthesis and transplanting the muscle, can be carried out at the same time.

As with the implantation of all functional electrical stimulation systems, the team approach is essential and the surgeon, clinical engineer and occupational therapist need to be involved from the outset. A comprehensive assessment of the patient, including both physical and psychological aspects, is also essential if the patient is to be successful. It is important that the patient identifies his goals for having the system implanted and these can be used subsequently to judge its success.

A training programme involving surface stimulation for the muscles to be used is undertaken by the patient prior to operation. Postoperatively the patient has his arm in plaster for 2–4 weeks, and after that a phased programme to use the system is started.

The system provides an active grasp with strength which increases independence and quality of life (Peckham et al 2001, Taylor et al 2002).

Marketing the Freehand neuroprosthesis was halted in September 2001 after 300 devices had been implanted. A second generation of neuroprostheses which benefit from the outcomes of the first group may be produced (Keith & Hoyen 2002).

In order to determine if further independence has been achieved through the surgery a classification system for hand function which is sensitive to small changes is required. The ASIA scale (Appendices 1 and 2) is not sufficiently detailed. Two different measures have been developed. It is hoped that the Southampton Hand Assessment Procedure (SHAP) will enable clinicians to compare and monitor hand function (Light et al 2002); the Canadian Occupational Performance Measure (COPM) is a tool primarily designed to measure the patient's satisfaction in achieving the goals he had set himself (Law et al 1998, Samuelsson et al 2004).

Splinting

Each patient is assessed individually and a hand regimen instituted. When a patient requires a splint the occupational therapist and the physiotherapist treating the patient should discuss the case so that the patient benefits from the expertise of both. To be effective a splint needs to be appropriate for the purpose and applied correctly. All splints should be worn for short periods initially so that the skin can be checked for excessive pressure. Patients do not wear their splints for a variety of reasons: because the splint does not solve the problem, cannot be put on easily, is uncomfortable, ugly or impractical, or they do not understand why they need it (Taylor et al 2003). If the splinting is to be successful close cooperation between ward staff and therapists is essential.

Splints are usually required to maintain position, correct a contracture or to encourage function, and can be made from several materials, e.g. plaster of Paris, synthetic plaster materials, thermoplastics or neoprene. Some patients require two splints: one may need to be worn at night to maintain hand position and another during the day to aid independence.

Some examples of the ways in which splints may be used:

- Long paddle splint (from forearm to finger tips with the fingers slightly flexed) for a patient with a lesion at C4 or above to maintain the hand in a good position and give some control over the arm.
- Wrist extension splint for a patient with a lesion at C5 to inhibit lengthening of the extensor tendons and allow the hand to be used with simple gadgets.
- A patient with a lesion at C6 with wrist extensors less than grade 3, as for C5 above but may also need tapes over the fingers to hold them in flexion to encourage the tenodesis position.
- A knuckle duster splint to inhibit metacarpophalangeal hyperextension for a patient with a lesion at C7.
- A splint to encourage opposition of the thumb may be needed by a patient with an incomplete lesion or one at C7.

Activities for patients with lesions at C6

Feeding

Patients start to eat by using a strap which has a slot in the palmar surface to hold the fork (Fig. 8.2c) or spoon and then by extending and relaxing the wrist. After some practice the strap is usually discarded and the fork held by balancing it over the thumb and against the palm of the hand or over the little finger. A plate guard may be helpful initially.

Drinking

A cup or mug with a large handle is held by hooking the thumb through the handle and extending the wrist. A glass without a handle can be lifted by sliding the fingers and thumb around the glass with the wrist extensor relaxed and then extending the wrist to produce the necessary grip.

As the hands are insensitive and the movements slow and clumsy, insulated mugs are preferred whilst training. Standard cups are used later by most dextrous patients.

Cleaning the teeth

The toothbrush is used in the strap (Fig. 8.2d) or laced between the fingers. To unscrew the cap from the toothpaste tube, the cap can be held by the teeth whilst both hands rotate the tube. The teeth can also be used to squeeze out the paste. Toothpaste dispensers can be obtained from companies specializing in products for disabled people.

Brushing the hair

Most patients find a shampoo brush with a wide handle easy to use (Fig. 8.2g).

Shaving

To enable the patient to shave unaided, a soft leather jacket can be sewn around the electric shaver and a strap attached to fit over the dorsum of the hand. Many patients learn to use the razor without the jacket. The patient manoeuvres the razor into position between the fingers and palm of the right hand, with the head of the razor projecting between the thumb and first finger. He then places his left hand round the other to strengthen the grip. By pressing the two hands together the grip is maintained.

Bladder, bowel and skin care

The care of the bladder and bowels is dealt with in Chapter 2 and re-education in self-care of desensitized areas in Chapter 6.

Computers

Computers and word processors can be used for both work and leisure activities. Most patients use a small, rubber-tipped stick on an extension splint on the first or second finger (Fig. 8.2b). Where possible, both hands are used.

Using the telephone

A telephone can be adapted to allow the patient with an ultra-high lesion to make independent calls. If these adaptations are not available the receiver can be mounted on a retort stand and a simple wooden bar with a firm handle placed across the receiver rest. A mouth stick can be used to dial and to remove and replace the wooden bar. Some environmental control systems have the facility to use a phone.

Writing

Several gadgets are available for use with a pen or pencil. Small splints supporting finger and thumb can easily be made for the individual patient (Fig. 8.2a). Some tetraplegic patients give up the gadget in time and either lace the pen through their fingers or hold it in one hand, putting the other hand on top to reinforce the grip.

Housework

Both low tetraplegic and paraplegic patients prepare for their return to housekeeping in the occupational therapy department kitchen and in the ward. They dust, cook, wash up, make their beds and do their laundry, as appropriate to their home surroundings. They have the opportunity to discuss ways and means to overcome individual problems in the home and in this way gain the necessary confidence to return to their family responsibilities.

DRESSING FOR ALL PATIENTS WITH LESIONS AT C6 AND BELOW

Dressing begins as soon as the spine is stable. Upper extremity dressing refers to the ability to put on and remove clothing over the upper limbs. Lower extremity dressing refers to the ability to put on and remove clothing over the lower limbs. Total dressing refers to the ability to achieve both the foregoing.

Although most paraplegic patients will finally achieve total dressing both on the bed and in the wheelchair, they are initially taught to dress on the bed. Tetraplegic patients need to gain some sitting balance before attempting to dress, and it is usual to begin with upper extremity dressing in the wheelchair. Each patient, having learnt the

basic methods, will find an individual way which best suits his requirements and daily schedule. Dressing techniques are described later.

Caution

Training is delayed where there is:

- instability of the spine at the site of the injury
- a need to avoid rotation after surgical intervention
- delicate scar tissue which might easily break down during rolling or through friction.

Clothing

All clothing should be loose-fitting. The trousers need to be at least a size larger than normally worn to accommodate the urinal and avoid trauma due to friction. Zips in a side seam of the trouser leg are also helpful if wearing a urinal or calipers. A wrap-over skirt and protective pants with a front fastening may be helpful for female patients who find difficulty in removing clothing for toilet purposes.

Shoes that are one size larger than those worn prior to the paralysis are usually required to avoid pressure and accommodate for any oedema or spasticity. They should have smooth inside seams, must remain in position when the legs are lifted and should be selected according to the patient's needs.

For tetraplegic patients, zips or Velcro fastenings are the most easily managed. Since the thumb is used as a hook on many occasions, loops or split rings on the zipper pulls may be helpful. Brassières should have stretch straps and should not be boned, because of the danger of pressure marks.

Loose woollen socks are easier to put on initially. Progression can be made to synthetic socks later if desired. Clip-on ties may be useful for some patients with cervical lesions.

Level of lesion in relation to dressing

Total dressing should be achieved by patients with lesions as high as C7, i.e. patients with active flexion and extension of elbows and wrists.

Total dressing may be achieved by patients with lesions at C6 both with or without triceps, but lower extremity dressing for these patients, though useful in emergency, is usually so costly in time that it is not practical. Upper extremity dressing should be achieved by patients with lesions at C5–C6 except for the following activities:

- putting on a brassière
- tucking the shirt tails into the trouser band
- fastening buttons on cuffs and shirt fronts.

Patients without finger movement cannot usually manage to put on the urinal.

As always, these objectives are only possible within the limits imposed by the previous medical history, age and physical proportions of the patient.

Dressing techniques

In most movements, two actions are involved:

- moving the garment
- moving the body, i.e. wriggling into or out of the garment.

Balance

Those tetraplegic patients who can lift in the chair during dressing should put the stronger hand towards the back of the armrest, with the forearm braced against the backrest support and the weaker hand towards the front of the armrest. This arrangement gives more stability anteroposteriorly and allows wriggling movements forwards and backwards as well as from side to side.

Patients who have difficulty in maintaining balance whilst using both arms are more stable if the buttocks are brought a few inches forward in the chair.

Spasticity

Increased tone may be an advantage in flexing and extending the lower limbs. Uncontrollable muscle spasm in the lower limbs may render independent dressing impossible. Sitting cross-legged for 15–20 minutes may help to reduce severe extensor spasticity before attempting to dress.

As it is easier to achieve, the tetraplegic patient is taught to undress first. However, for clarity, in the following section the method for putting the garment on is described first. This procedure is usually reversed when taking it off.

Dressing in the wheelchair

Upper extremity dressing in the wheelchair

As upper extremity dressing provides no problem for low lesions, i.e. those with abdominal muscles, reference in this section is to patients with cervical and high thoracic lesions.

Putting on a garment of soft material with or without a front fastening

This method can be used for blouses, vests, sweaters, skirts and dresses that open down the front. If it is found easier and the garment

is large enough, the buttons can be left fastened. Many tetraplegic patients without a grip can learn to fasten buttons by using a button hook.

1. Position the garment on the thighs, with the neckline towards the knees.
2. Put both arms under the back of the garment and through the armholes.
3. Push the garment past the elbows.
4. Using the wrist extension grip, hook the thumbs under the garment and gather the material up from the neck to hem.
5. Using adduction and lateral rotation of the shoulders and flexion of the elbows and neck, pass the garment over the head.
6. Relax the shoulders and wrists and remove the hands from the back of the garment. Most of the material will be gathered up at the back of the neck and under the arms.
7. There are several ways in which the garment can be worked down into place:
   a. shrug the shoulders and/or elevate and laterally rotate the shoulders with the elbows extended to get the material down across the shoulders
   b. hook the wrists into the sleeves and pull the material free at the axilla
   c. using two hands pull down on each side of the front
   d. hook one hand in the material at the neck, lean on the opposite forearm on the armrest and pull the garment down.

Taking the garment off

1. Hook the thumb in the back of the neckline, extend the wrist and pull the garment over the head, turning the head towards the side of the raised arm. Maintain balance by either:
   a. leaning on the opposite forearm
   b. pushing on the thigh with the extended arm.
2. Hook the thumb in the opposite armhole and push the sleeve down the arm. Pull the arm out of the garment.

Putting on a jacket

1. Put the weaker arm in the armhole and push the sleeve up the arm.
2. Maintain balance by leaning on and over the forearm resting on the armrest.
3. Put the other arm in the armhole behind the back.
4. Elevate the arms and shrug the shoulders to get the jacket over the shoulders.

Removing a jacket.

Reverse the above procedure.

Putting on a brassière with fastening at the back

1. Powder under the breasts and round the chest wall, especially if subject to sweating attacks.
2. Place the bra on the knees, inside out and upside down, i.e. with the lower edge of the bra towards the knees.
3. Balance on the weaker elbow. Hold the middle of the bra with the strong hand, take behind the back and bring the fastening to the front.
4. Fasten the hooks or Velcro at the front. It may help to lift slightly on the forearms.
5. Wriggle the bra round to the back. Powder again if necessary.
6. With the thumbs in the strap pull up over breasts.
7. Place one arm at a time in the appropriate shoulder strap. Hook the thumb under the bra strap, lean to the opposite side and put the strap over the shoulder. Repeat for the other arm.
8. Look in the mirror to see that the bra is not wrinkled. (Note: adjust the length of the straps when the bra is off)

Taking off the brassière

1. Hook the thumb under the opposite strap, and push down whilst elevating the shoulder.
2. Pull the arm out of the strap.
3. Repeat on the other side.
4. Push the bra down and turn it round to bring the fastening to the front.
5. Undo the fastening.

Lower extremity dressing in the wheelchair

When dressing the lower extremity, the socks should be put on before the trousers to avoid catching the toes and causing trauma.

Putting on and removing socks and shoes

Whether in the chair or on the bed, maximum control is achieved when putting on and taking off socks and shoes by crossing one ankle over the opposite knee. The tetraplegic patient uses the wrist extension grip and the palm of the hands in a patting movement to pull on the socks.

Putting on trousers

1. Lift the right leg with the right wrist behind the knee and the forearm on the armrest. Put the trouser leg over the foot. Repeat with the left leg.

Alternatively, cross the right ankle over the left knee, put the trousers over the foot and pull up to knee height. Replace the right foot on the footplate. Repeat with the left leg.

2. Pull the trousers well up over the knees and under the thighs, lean on the left forearm and lift the right knee with the left wrist to pull the trousers up the thigh.

3. Hook the right fingers or thumb inside the back of the waistband, lean over to the left and lift on the left hand and forearm. Repeat from side to side. At each lift, wriggle forwards and backwards whilst the buttocks are in the air.

Alternative method to pull the trousers over the buttocks for paraplegic patients:

1. Lean forward on the forearms on the armrests, depressing the shoulders and lifting the buttocks, and pull the trousers up.

2. Lean well back taking the weight on the top of the backrest, wriggle the buttocks forward and at the same time pull up the trousers.

Dressing on the bed

Upper extremity dressing on the bed

This presents no real problems for paraplegic patients. Tetraplegic patients have more stability for upper extremity dressing in the wheelchair and rarely do it on the bed.

Lower extremity dressing on the bed

Putting on trousers

1. Put the trouser legs over the feet as for the socks.
2. Flex the knee with the hand, wrist or forearm and pull the trousers up over the thighs. Lean on the elbows if necessary.
3. Repeat for the other leg.
4. Lean to the right on the right elbow, and pull the trousers over the left buttock.
5. Lean to the left and pull the trousers over the right buttock. Repeat this as often as necessary.

A monkey pole may be necessary for patients with high thoracic lesions to lift onto the side at the commencement of training.

The trousers may be removed by reversing the procedure.

Alternative method for putting on trousers for tetraplegic patients:

1. Sit up, hook the right hand under the right knee and pull the knee into flexion.
2. Put the trousers over the right foot.

3. Repeat for the left foot. It may help to have both legs slightly flexed and laterally rotated at the hips.
4. Work the trousers up the legs by alternately flexing the knees and using a patting sliding motion with the palms of the hands.
5. Lie down and pull the right knee onto the chest.
6. Stay supine and hold the right knee with the left forearm or roll into left side-lying. Throw the right arm behind the back, hook the thumb in the waistband or belt loops, or the hand in the trouser pocket, and pull the trousers over the right buttock.
7. Repeat for the other side. These steps may need to be repeated several times until the trousers are in place over the hips.
8. Fasten the trouser placket by hooking the thumb in a loop on the zipper pull.

If the patient cannot cross one ankle over the other, the trousers, socks and shoes have to be put over the feet in long-sitting. This is more difficult since the heels are resting on the bed.

ACCOMMODATION

The two major practical problems in resettlement are obtaining suitable accommodation and employment. Paraplegic patients, except for those handicapped by age or other illness, are usually able to return to live independently in the community. The majority of tetraplegic patients do return to their own homes, although often with maximum support from the social services and the family. Over the last decade organizations and governments have placed increasing emphasis on housing for people with disabilities.

The home may need to be adapted or to have an extension, or it may be totally unsuitable, in which case the only solution is for the patient to be rehoused in a flat or bungalow.

Accommodation for patients who are unable to return home may be found in units for young disabled people, voluntary institutions or hostels with sheltered workshops.

Adaptations

The need for adaptation to the home varies considerably in relation to the level of the patient's lesion and to his age and sex. Those adaptations most frequently necessary are to the bathroom facilities, which are usually too small, and to the kitchen. Access for the wheelchair to the toilet and bath or shower is necessary for those patients capable of independent transfer. To cook without unnecessary danger may necessitate adaptations to cupboards, cooker and working surfaces in the kitchen.

Free access to the house from outside is essential and those able to drive will need a garage wide enough to accommodate the wheelchair beside the car for independent transfer.

Although adaptations are necessary to enable access to, and independence within the home, a number of problems have been noted during the adaptation process. These include restriction of choice in the selection of adaptations, the length of the process and the appearance of the home subsequently. The value and meaning that the individual and his family attach to their home can be affected and these issues need to be dealt with sensitively (Hawkins & Stewart 2002).

Equipment

Some patients will need very little, if any, special equipment in the home; others may need a great deal. A bed, special mattress, hoist, and home nursing equipment, as well as a telephone and environmental control system, may all be necessary for a patient with a high cervical lesion.

EMPLOYMENT

Future employment is discussed with the patient as early as possible. Many patients are unable to return to their former employment as most are manual workers. Unemployment rates amongst registered disabled persons are higher than in the working population as a whole. Krause et al (1999) found that 50% of people with spinal cord injury were unemployed one year post-injury. Assessment at an industrial rehabilitation unit may be necessary, followed by retraining at a day or residential training establishment for disabled people. Some patients undertake new studies and embark on a second career and others, already in professions or business, return to all types of work. The internet is proving an asset to many who find travelling to work difficult.

Countries will differ in their ability to provide the necessary equipment and facilities to enable people to be re-employed and also in the way people with spinal cord injury receive financial support after their injury. Noreau et al (1999) in a Canadian study with 418 subjects confirm the significance of education and transportation in the ability of people to return to work or to enjoy leisure pursuits or contribute to community organizations. In a recent study of 236 people with spinal cord injury in Denmark (193 men and 43 women, 126 with paraplegia and 110 with tetraplegia) over 86% had a passenger van or another car (Biering-Sorensen et al 2004). Tomassen et al (2000) in the Netherlands found that only 37% of the 234 people with spinal cord injury in their study were gainfully employed and suggest that long-term support to find jobs is necessary if more people are to return to work.

CANINE PARTNERS FOR INDEPENDENCE

In Australia and the UK in recent years the Canine Partners for Independence have placed many dogs with disabled people including those with spinal cord injury. The dogs are trained to assist the owner with everyday tasks such as picking things up from the floor, assisting with the washing machine and dressing. These dogs not only provide functional assistance and relieve carers but are also great companions.

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The biomechanical principles used in transferring

Roger Ellis

Most people who suffer from a spinal cord injury will in time devise their own technique for transferring. Transfers need to be modified to the environment by the individual using all the knowledge and skill that the physiotherapist can impart. Once the basic principles have been established, the physiotherapist should allow the patient to solve his own problems.

The correct training for transfers is essential because they are a large proportion of the skills that are needed to develop independence. Therefore the mechanics of transferring need to be understood by the physiotherapist who, in turn, will teach them to the patient.

To be successful at transferring requires appropriate training in strength and skill until a safe technique is established. It has been shown in stroke patients who did exercises to increase strength that they were more independent at one month than those who only received functional training (Inaba 1973). This principle also applies to patients with spinal cord injury, where the physiotherapist is responsible for combining appropriate exercise with functional training to achieve a result.

The following section is intended to assist the physiotherapist to understand the theory behind preparing a patient to transfer independently. It is a useful exercise for the therapist to identify the changing order of levers during the various stages of each transfer as they rarely remain the same throughout the manoeuvre.

Elements of safe, efficient transfers

Three elements are basic for efficient and safe transfers:

1. *Mobility.* Before starting to teach transfers the patient should develop the ranges of movement necessary to achieve a triangular base as shown in Figure 7.2. The position is known as the 'the vital triangle'.
2. *Balance.* As soon as possible the physiotherapist has to work with the patient to develop balance and stability commensurate with injury level.
3. *Strength.* The level of neurological trauma will decide the pattern of muscle strength available to successfully clear the surface from

which transfers are being made. Paraplegic patients with normal upper limb power would be expected to perform all transfers, depending on their age, weight and sex. Tetraplegic patients with selective power will rely on their remaining strength distribution as described in Chapter 12.

Therefore:

> Mobility
> Balance + Technique = Safe efficient transfers
> Strength

Skin safety and the prevention of sores is the overriding message that all patients should understand when transferring. Poor transfers performed regularly result in eventual skin breakdown with more time spent on bedrest.

Levers

The physiotherapist must have a clear understanding of the mechanical principles involved when teaching transfer techniques.

> A lever is a rigid bar; capable of moving around a fixed point called a *fulcrum* (F). Work is done when force or *effort* (E) applied at one point on the lever, acts upon another force or *weight* (W), acting at a second point on the lever. The perpendicular distance from the fulcrum (F) to the effort (E) may be called the *effort's arm*. And that from the fulcrum to the weight (W) as the *weight's arm*. (Gardiner 1963)

There are three orders or classes of levers, which are determined by the relative positions of the fulcrum, effort and weight. Each of these can be relevant at some point during the transfer.

First order

The fulcrum is situated between the effort and the weight (Fig. 9.1).

Example

The use of this class of lever can be found during the initial stages of some transfers. The patient first assumes a stable sitting position by leaning back in the wheelchair before lifting one leg to place it into the bath, onto a plinth/bed or into a car. The sacrum is acting as the fulcrum (F); the arm is the effort (E), lifting the leg the weight (W). This order can be found at certain points when legs are being lifted and the effort from the arms is behind the fulcrum. However, the type of lever may change throughout this transfer.

Second order

The weight is situated between the fulcrum and the effort (Fig. 9.2).

This class of lever is found during reverse transfers (patient moving backwards). The patient is in the long sitting position with the arms behind the trunk The effort (E) is through both arms. Legs and truncal mass are the weight (W). Once the lift has started the heels become the fulcrum (F).

Examples

- Reverse transfers from bed to chair, plinth or bath
- Tetraplegic person lifting backwards in a wheelchair to reposition himself using the wheels of the wheelchair to gain lift.
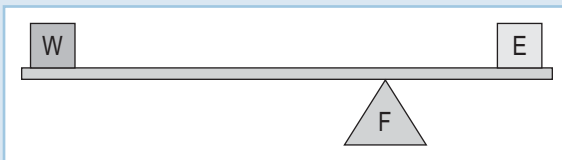
Figure 9.1 First-order fulcrum.
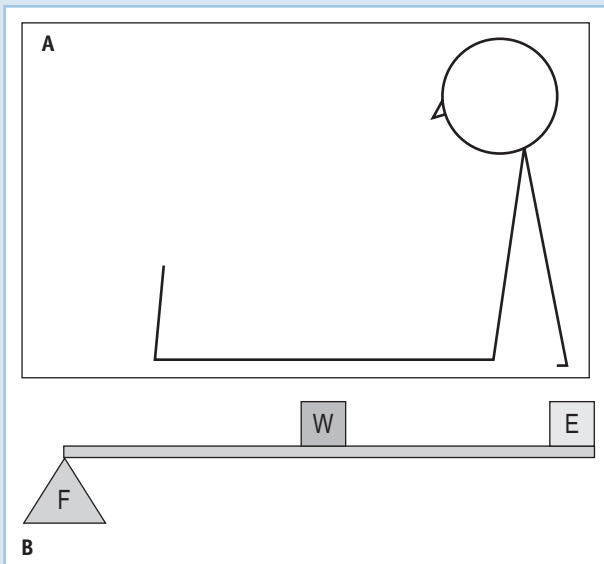
Figure 9.2 Second-order fulcrum.

Third order

The effort is between the fulcrum and the weight (Fig. 9.3).

This is the most common lever used during transfers. For it to be successful the 'vital triangle' must be achieved before the techniques can be taught.

Examples

- Surface transfers
- Bed-to-chair transfers
- Transferring into a car, from chair to toilet, or chair to bath through 180°.

During most transfers the order of leverage changes and will depend on the body mass of the patient, position of the effort arm and the transfer technique to which the patient is most suited.
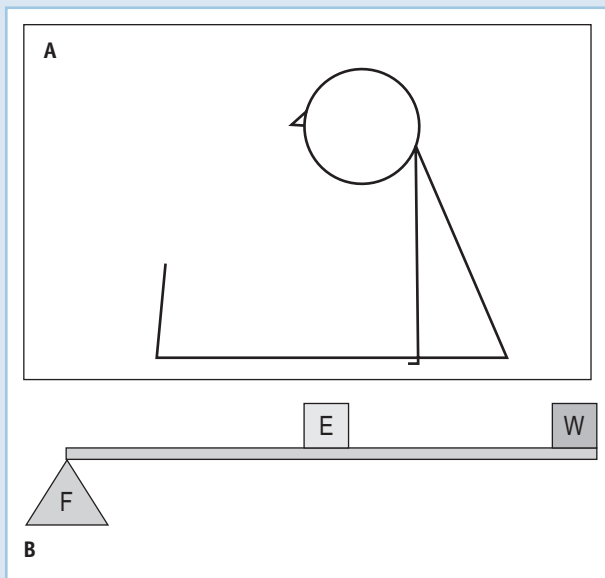
Figure 9.3 Third-order fulcrum.

Factors that make transferring easier

- Low body weight
- Upper limb strength commensurate to injury level
- Joint flexibility and full forward mobility to achieve at least the vital triangle position
- Good balance
- Buttock clearance
- Patient ability to solve problems
- Daily practice
- A longer arm to trunk length ratio (monkey syndrome). Thought to be a factor by physiotherapists although not proved to be so in Bergström's research – see p. 97)
- Use of the extended wrist, which adds 5 to 7cm (2 to 3 inches) to the height of the lift
- Placing one leg on the wheelchair footplate, which can offer greater trunk mobility for the transfer
- Knowledgeable teaching by the physiotherapist.

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Basic functional movements

MOBILIZATION AND STRENGTHENING OF THE TRUNK AND LIMBS

Some degree of stiffness in the trunk will result from the weeks of immobility in bed. In addition, there will be some shortening of the hamstring muscles. If the activities of daily living are to be mastered, good mobility is essential.

Therefore, mobilization of the trunk in all directions and stretching of any tight muscle groups form an essential part of early rehabilitation. Active assisted, active and resisted work are given as indicated for trunk, shoulders, shoulder girdle and head. The use of the head and shoulder girdle in flexion and rotation is essential in many functional activities, especially for patients with cervical or high thoracic lesions.

Caution

As the fracture is recently healed, mobilization of the trunk must be undertaken very gradually and with extreme care. Forced movements, particularly forced flexion, must be completely avoided. Initially only free active flexion is given.

PRELIMINARY TRAINING FOR FUNCTIONAL ACTIVITIES

To give the patient confidence, these activities need to be undertaken on a wide plinth.

Lifting the buttocks by pushing on the arms is the basis of most of the activities of daily living. An effective lift depends upon balance and strength and upon knowing exactly where to place the hands and how to hold the head, shoulders and trunk. The following comments apply primarily to patients with cervical and high thoracic lesions. Where the abdominal muscles are innervated, trunk control will be adequate and all lifts will be relatively easy.

Basic principles (see also Ch. 9)

In order to maintain balance whilst moving, the first principle of body mechanics must be observed, i.e. the line of gravity must remain inside the base of support. To achieve this in the sitting position with no muscle power around the hips, the head and shoulders must be kept forward of the hip joints. When lifting the trunk with the hands just in front of the hip joints, the head, trunk and hips *must be flexed as much as possible*. This position gives a mechanical advantage so that the same strength achieves a higher lift. An optimum degree of flexion will be reached beyond which the lift becomes impractical for those without triceps, because the elbows will be flexed.

All patients start lifting themselves with extended elbows. Many patients with triceps later progress to lifting with the elbows flexed, when the mechanical advantage increases as the degree of hip flexion increases.

In all movements the head acts as a weight to assist or resist any movement. When the arms are short or when there is extra weight around the hips, lifting is more difficult (see Ch. 8).

The following manoeuvres provide the basis for functional activities such as dressing, turning in bed and transfers:

- lifting and moving
- moving the paralysed limbs
- sitting up and lying down
- rolling prone and turning onto the side.

The therapist is behind, at the side of or in front of the patient as required to assist or resist each component of the movements involved. Clear instructions should be given at every step. Initially assistance will be necessary to maintain sufficient flexion of the head and trunk as patients generally feel that they need to extend the trunk in order to lift. The therapist should never try to assist the patient in functional activities by lifting under the axillae. This action entirely negates any effort by the patient to lift by depressing the shoulders.

LIFTING

The therapist. The therapist is behind the patient and, as well as maintaining the necessary flexion, may need to aid the lift with her hands under the buttocks. Later, where possible, stabilizations are given in the lifted position.

Action of the patient
1. To balance in long-sitting, flex the head, shoulders and trunk so that the line of gravity is kept in front of the hip joints. With the arms close to the sides, place the hands on the plinth slightly forward of the hips and preferably with the palms flat and fingers

extended. If the arms are short in relation to the trunk a higher lift may be obtained by lifting on the clenched fist. Where triceps is paralysed, lateral rotation of the arms assists stability at the elbows.

2. Lean forward with the head and shoulders bent over the knees. A greater degree of flexion is needed by tetraplegic patients. When innervated, the abdominal muscles will flex the trunk and the movement of the head and shoulders becomes less important.
3. With the elbows extended, push down on the hands.
4. Depress the shoulders and lift the buttocks off the plinth. At the moment of lift, raise the head. This will prevent the trunk collapsing forward.

To lift and move sideways

The therapist. In addition to the factors already mentioned, the therapist may need to encourage rotation.

Action of the patient
1. Place the right hand on the plinth close to and slightly in front of the hip.
2. Place the left hand at the same level but approximately a foot away from the body. This distance will depend on the length of the arm in relation to that of the trunk. The elbows are extended and the forearms supinated, or in mid-position (Fig. 10.1A).
3. Flex further forward over the knees and lift the buttocks. At the same time twist the head and shoulders to the right, bringing the left shoulder forward and the right shoulder back (Fig. 10.1B). Where latissimus dorsi is innervated, it will pull the pelvis forward towards the arm which is away from the side.
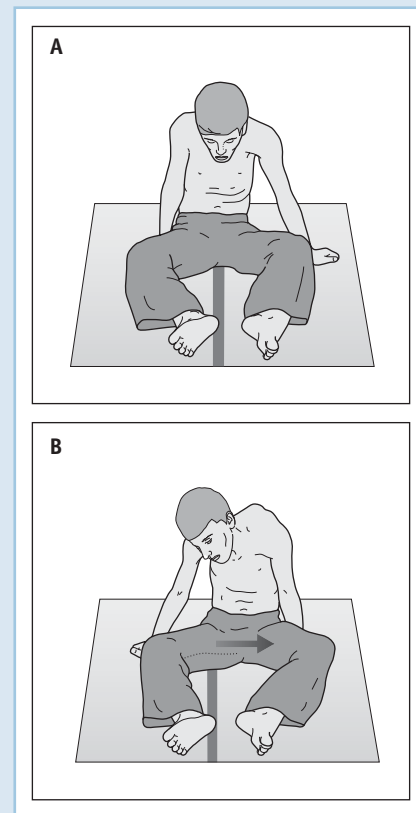
Figure 10.1 Lifting sideways. Patient with a complete lesion below C6 without triceps and with the clavicular portion of pectoralis major only.

To lift and move forwards

Action of the patient. The legs need to be in lateral rotation and free to flex at the knee:

1. Lean well forward, with the head over the knees (Fig. 10.2A).
2. Place the hands on the plinth a little in front of the hip joints and close in to the sides. The elbows are extended and forearms supinated.
3. Lift the buttocks (Fig. 10.2B).
4. Keep the head flexed and the buttocks will move forward. Once beyond the point of balance, the patient will collapse forward (Fig. 10.2C).

MOVING THE PARALYSED LIMBS

In order to perform the activities of daily living, the patient will need to lift and move his paralysed limbs.

The paraplegic patient will accomplish this quickly and easily, almost automatically. The tetraplegic patient will need intensive training and practice, and must not be disheartened if success is delayed.

It is necessary to be able to:

- move the legs along the plinth
- cross one ankle over the other
- cross one ankle over the opposite knee
- flex the leg in sitting and side-lying.

A method for tetraplegic patients to flex and lift the leg is described on page 146.

Balance can be maintained whilst moving the legs by leaning forward on one or both elbows. This position leaves the hands free to lift, push or pull the leg. The pelvis must be straight and the patient leans a little to one side, as well as forward, to keep the body weight over the static leg.
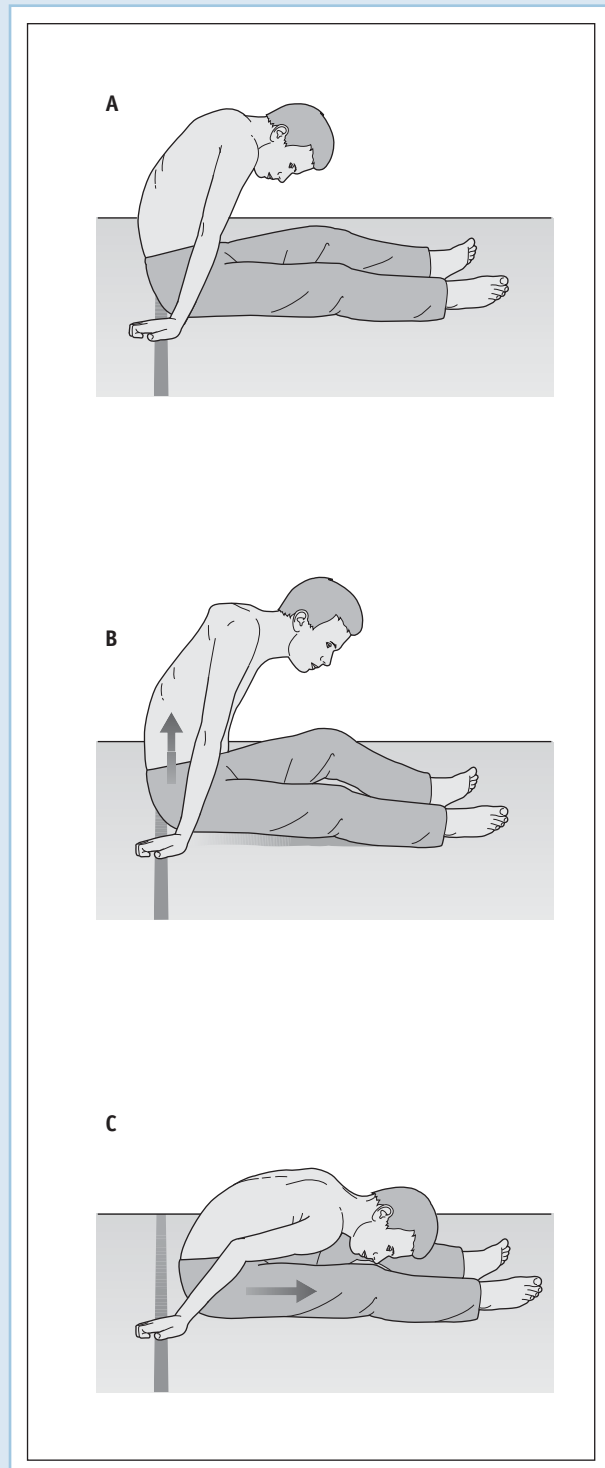
Figure 10.2 Lifting forwards. Patient with a complete lesion below C6 without triceps and with the clavicular portion of pectoralis major only.

SITTING AND LYING

These movements can be achieved without any equipment or using a monkey pole.

To sit from the supine position without using a monkey pole

Action of the patient
1. In one brisk movement throw the right arm over to the left, flex the head and shoulders and twist them to the left. This will rotate the upper part of the trunk (Fig. 10.3A, B).
2. Balance on both elbows (Fig. 10.3C).
3. Take the weight on the right elbow and bring the left elbow closer to the trunk.
4. Balance on the left elbow and, holding the head forwards and protracting the shoulders, transfer the right arm to the right side of the body and balance on both elbows (Fig. 10.3D).
5. Lean over on the left elbow, outwardly rotate the right arm and extend it behind the body (Fig. 10.3E).
6. Adjust the position until the weight can be taken on the right arm and extend the left arm in a similar manner (Fig. 10.3F).
7. Slowly bring the hands forward alternately, a few inches at a time, until the weight is over the legs (Fig. 10.3G).

Where possible, step 4 can be omitted.

Alternative method for steps 1–4

1. With the arms in pronation by the sides put the wrists under the buttocks.
2. With the elbows on the plinth strongly extend the wrists.
3. Flex the head, protract the shoulders, and with the elbows as the pivot-point pull the weight of the head and upper trunk onto the elbows.
4. Move each elbow backwards a few inches at a time.

Continue as in the previous method, steps 5, 6 and 7. If the patient finds difficulty with the hands under the hips, the thumbs can be hooked in the trouser pockets initially to enable him to get the feel of the movement.

Alternative method from step 2

From the position where the weight is on both elbows (Fig. 10.3C), the patient can 'walk' on his forearms along the plinth to achieve the sitting position (see Fig. 16.14).
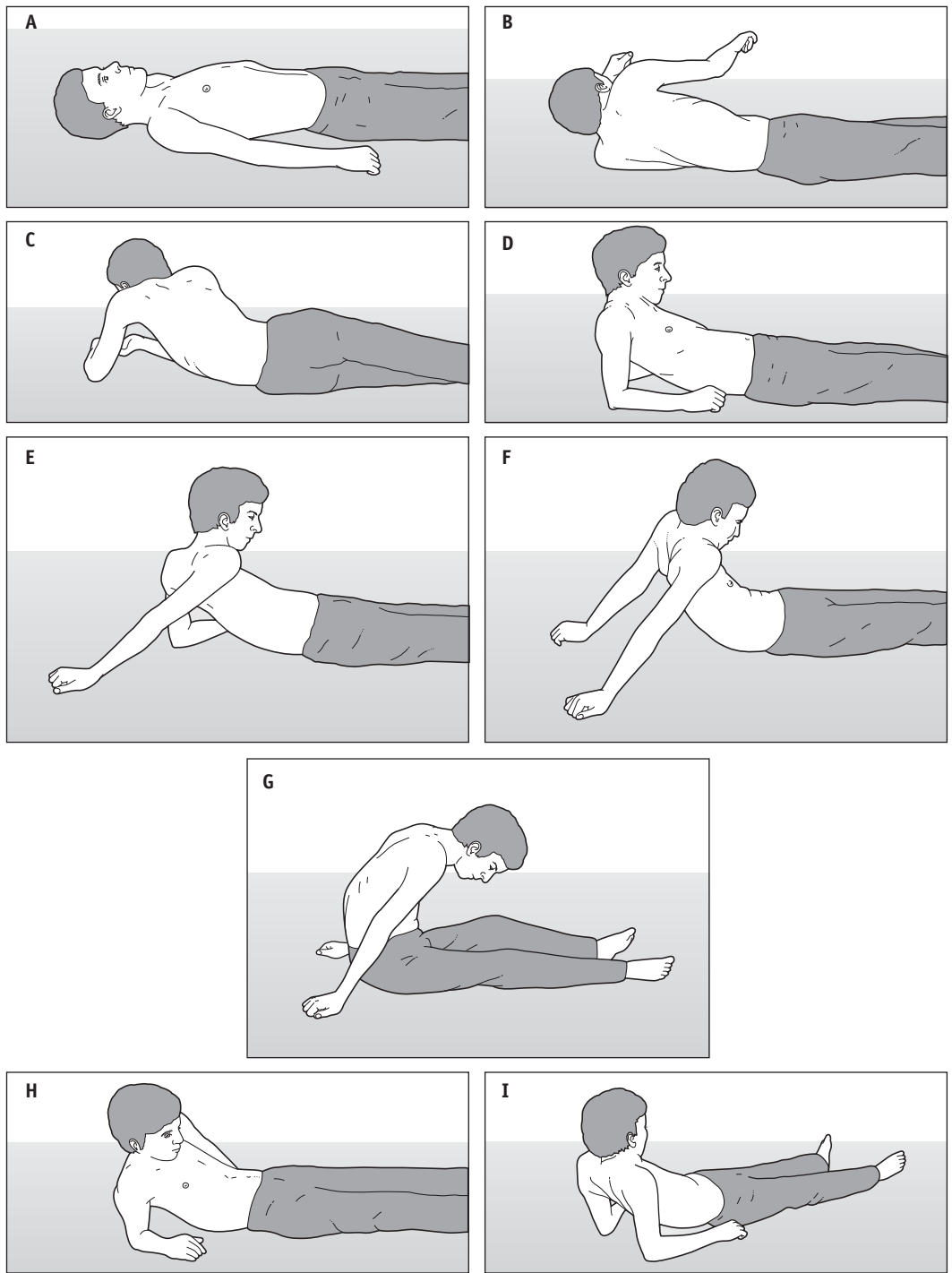
Figure 10.3 A–G: Sitting up. H, I: Lying down. Patient with a complete lesion below C6 without triceps and with the clavicular portion of pectoralis major only.

To lie down from the sitting position

Action of the patient
1. Keeping the head flexed and shoulders protracted, lean over to the right and drop the weight onto the right elbow (Fig. 10.3H).
2. Balance on the right elbow.
3. Flex the left arm and transfer half the weight onto the left elbow.
4. Still keeping the head and shoulders forward (Fig. 10.3I), straighten one arm at a time until lying flat.

To sit from the supine position using a monkey pole

Position of the monkey pole
The point of suspension for the monkey pole is over the midline of the body or slightly beyond midline towards the side of the supporting arm and approximately level with the xiphisternum. The handle should be just within the reach of the patient's extended wrist.

*Action of the patient.*To lift onto one elbow:

1. Extend the right arm and hook the extended wrist over the monkey pole (Fig. 10.4A).
2. Pull the body towards the monkey pole and lean on the left elbow (Fig. 10.4B).
3. Flex the right elbow over the monkey pole and hold the body weight whilst bringing the left elbow closer to the trunk.
4. Support the body weight on the left elbow (Fig. 10.4C).

To get up on two extended arms, proceed with either of the following methods.

Method 1

5. Lean on the left elbow.
6. With the elbow flexed flick the right arm into lateral rotation and hold the wrist against the monkey pole chain (Fig. 10.4D).
7. Hold the body weight with the right arm, outwardly rotate the left shoulder and extend the arm behind the body (Fig. 10.4E).
8. Lean well over the left arm, release the monkey pole and extend the right arm behind the body.
9. Move the hands forward alternately, a few inches at a time, until the weight is over the legs (Fig. 10.4F).
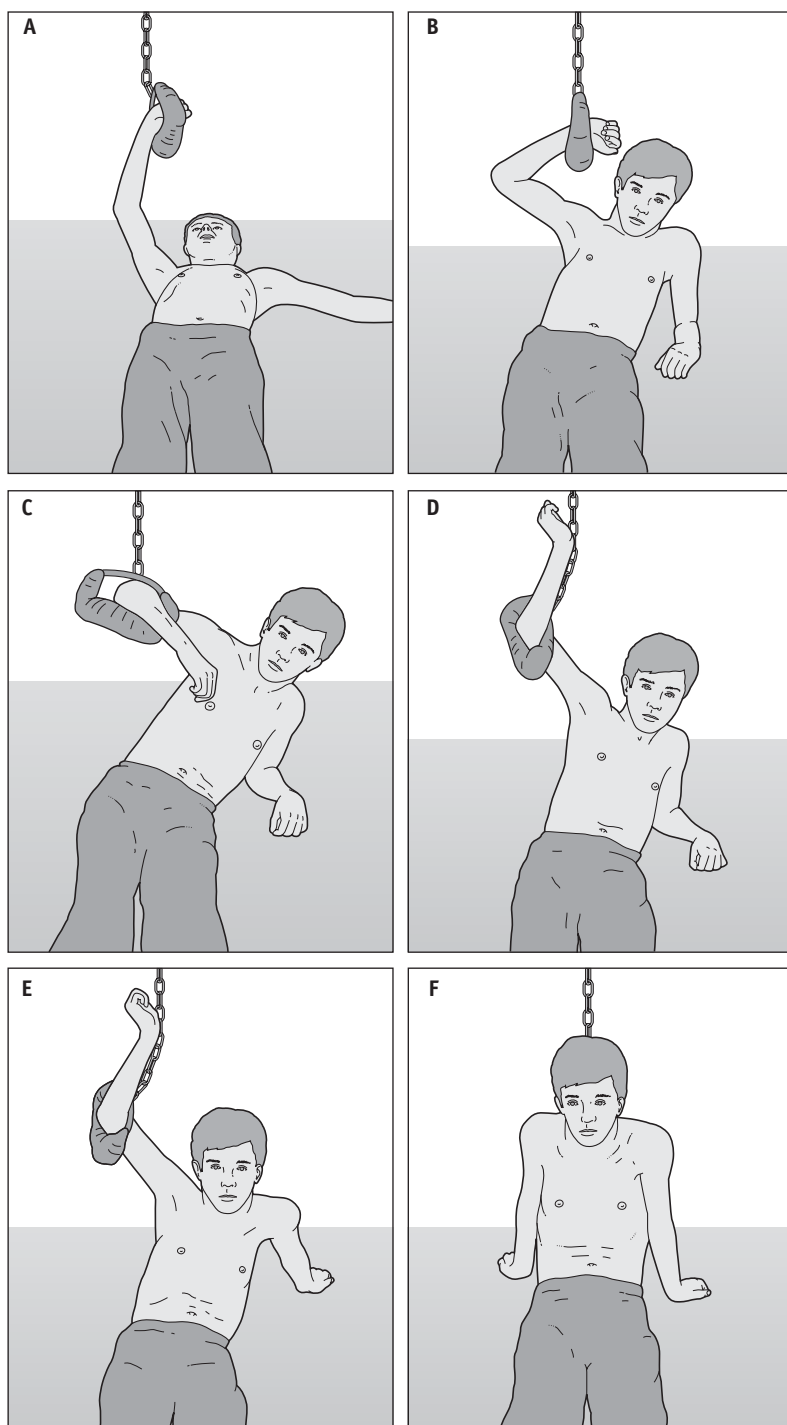
Figure 10.4 Sitting up using a monkey pole. Patient with a complete lesion below C6 without triceps and with the clavicular portion of pectoralis major only.

Method 2

5. Lean well over to the left and balance on the left elbow.
6. Take the right arm out of the monkey pole, outwardly rotate the shoulder, and extend the arm behind the body.
7. Transfer most of the weight onto the right arm and push the left arm straight.
8. Move the hands forward alternately, a few inches at a time until the weight is over the legs.

Patients without pectoral muscles, or with the clavicular head of pectoralis major only, may find method 1 to be the easier of the two. Patients with good hand function grasp the monkey pole with one hand and lift onto the opposite elbow. From there, the procedure is the same as method 2.

Occasionally a paraplegic patient may need to use a monkey pole for one of the following reasons: age, overweight, ossification around the hip joints or a previous medical history of heart or lung disease.

To roll prone from the supine position

Action of the patient. To roll to the right:

1. Flex the head and shoulders and fling the arms over to the left, so that the necessary momentum can be gained in step 2 (Fig. 10.5A).
2. In one brisk movement, flex the head and shoulders and fling the arms from left to right. As this movement is completed, the right shoulder is pulled back as far as possible (Fig. 10.5B).
3. The momentum of the arms is transferred to the trunk and legs and the lower half of the body will roll prone (Fig. 10.5C).
4. Place the left forearm on the plinth and take the weight on it.
5. Pull the right shoulder back and take the weight on both forearms (Fig. 10.5D).
6. Lie flat and put the arms by the sides.

To turn onto the side

Action of the patient
1. Sit up with or without the monkey pole as described.
2. Lean on the left extended arm.
3. Hook the extended right wrist under the right knee and flex the leg.
4. Facing the left, lean down on the left elbow and at the same time pull the right leg into further flexion and cross the right knee over the left leg.
5. Place the right forearm on the plinth and take the weight on it.
6. Lower the trunk into side-lying.
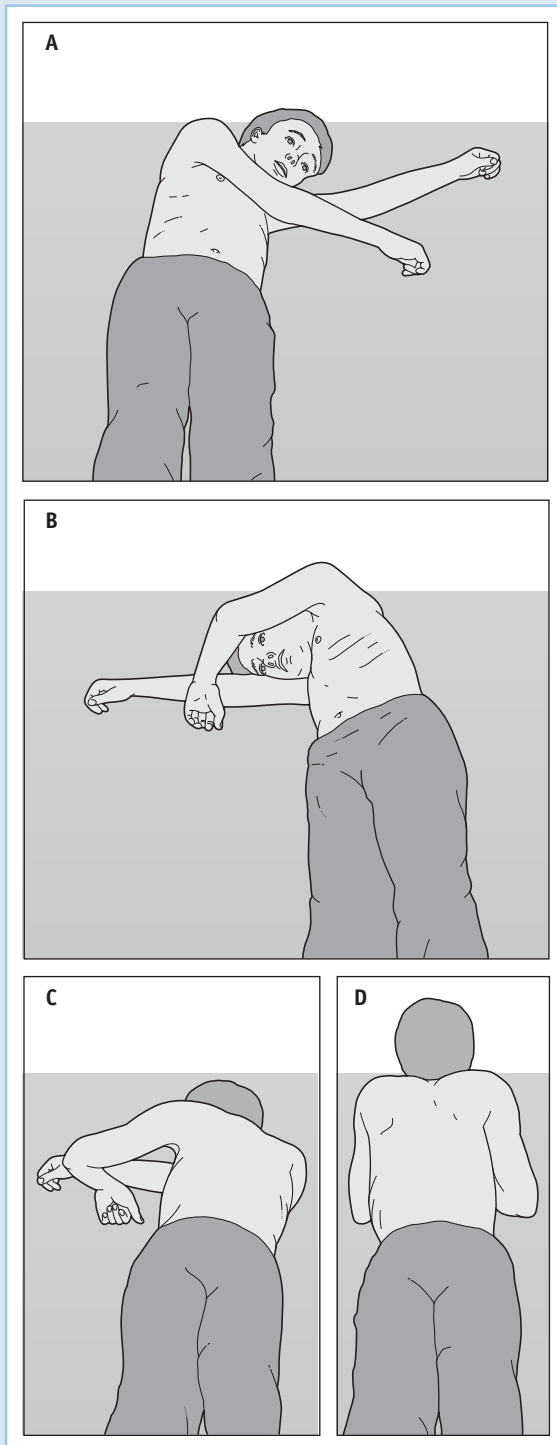
Figure 10.5 Rolling. Patient with a complete lesion below C6 without triceps and with the clavicular portion of pectoralis major only.

To turn in bed

When the patient is able to turn on the mat and to move and position his legs, progression is made to turning in bed.

Action of the patient. To turn from supine to right side-lying:

To sit up, either of the two ways already described can be used, or the patient can sit up using a bed loop. The loop is attached to the end of the bed and is just long enough to hook on the forearm:

1. Put the left forearm through the loop and flex the right elbow, extending the wrist to 'grip' the edge of the mattress (Fig. 10.6A).
2. Pull on the loop with the left arm and transfer the weight onto the right elbow (Fig. 10.6B).
3. Release the strap (Fig. 10.6C).
4. Extend the left arm behind the body and take the weight on it (Fig. 10.6D).
5. Extending the right arm take the weight on both arms. Move the hands forward until the weight is over the legs (Fig. 10.6E).

To position the pillow:

6. Flex the left knee with the extended left wrist and push the pillow under the knee (Fig. 10.6F).
7. Keeping the weight well over the right hip, lift the lower leg onto the pillow with the right arm (Fig. 10.6G). Adjust the position of the pillow and legs.
8. Turn the upper trunk to the right and take the weight firstly on the right and then on both elbows.
9. Lean forward and take the maximum weight on the left elbow and forearm. Rock onto the left elbow and pivot the buttocks backwards across the bed (Fig. 10.6H).
10. When adequate movement backwards has been achieved, adjust the head pillow for individual comfort.
11. Take the weight onto the left elbow and lower the weight onto the right shoulder, lying down on the side (Fig. 10.6J).
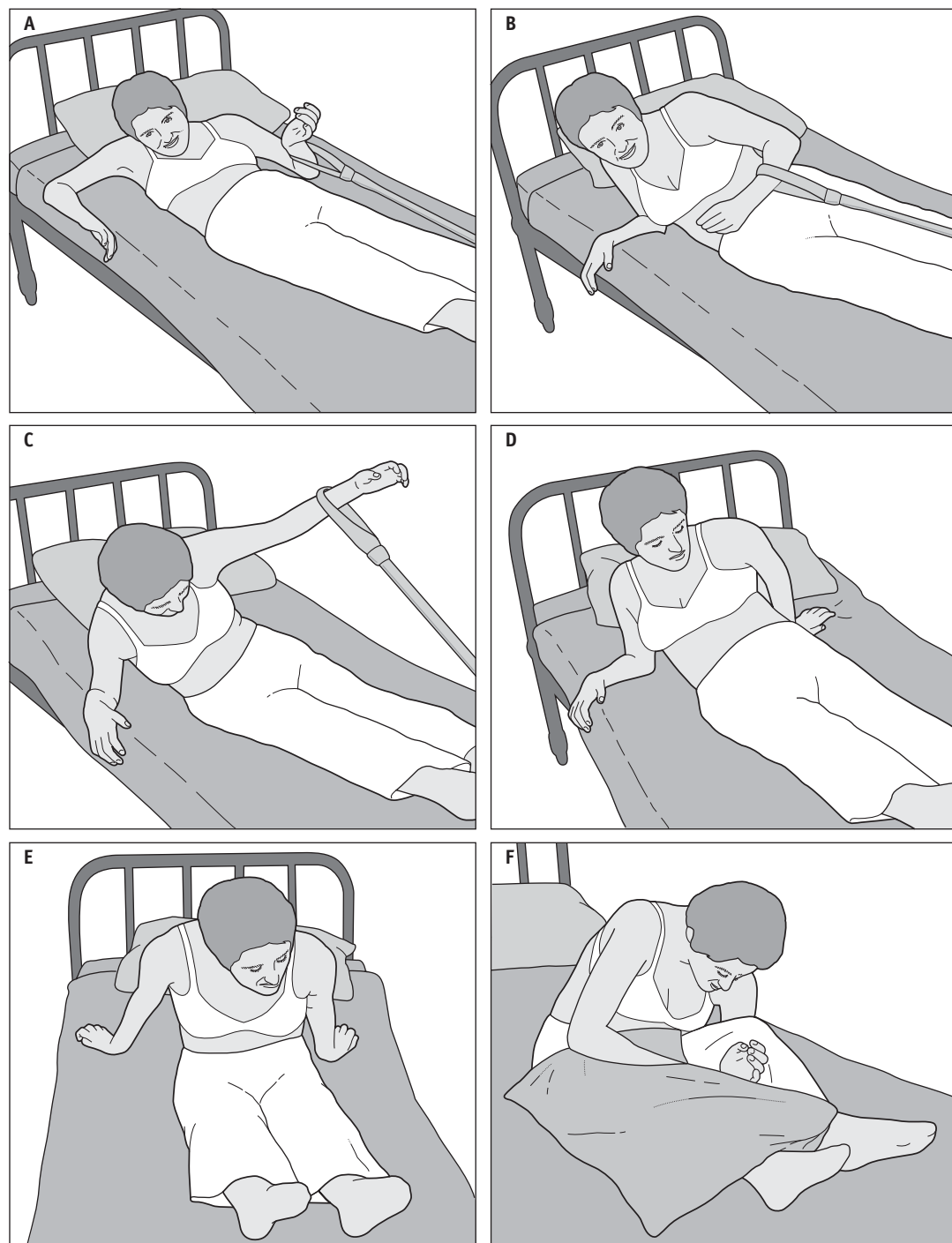
Figure 10.6 Turning in bed. Patient with a complete lesion below C7 with wrist control only.
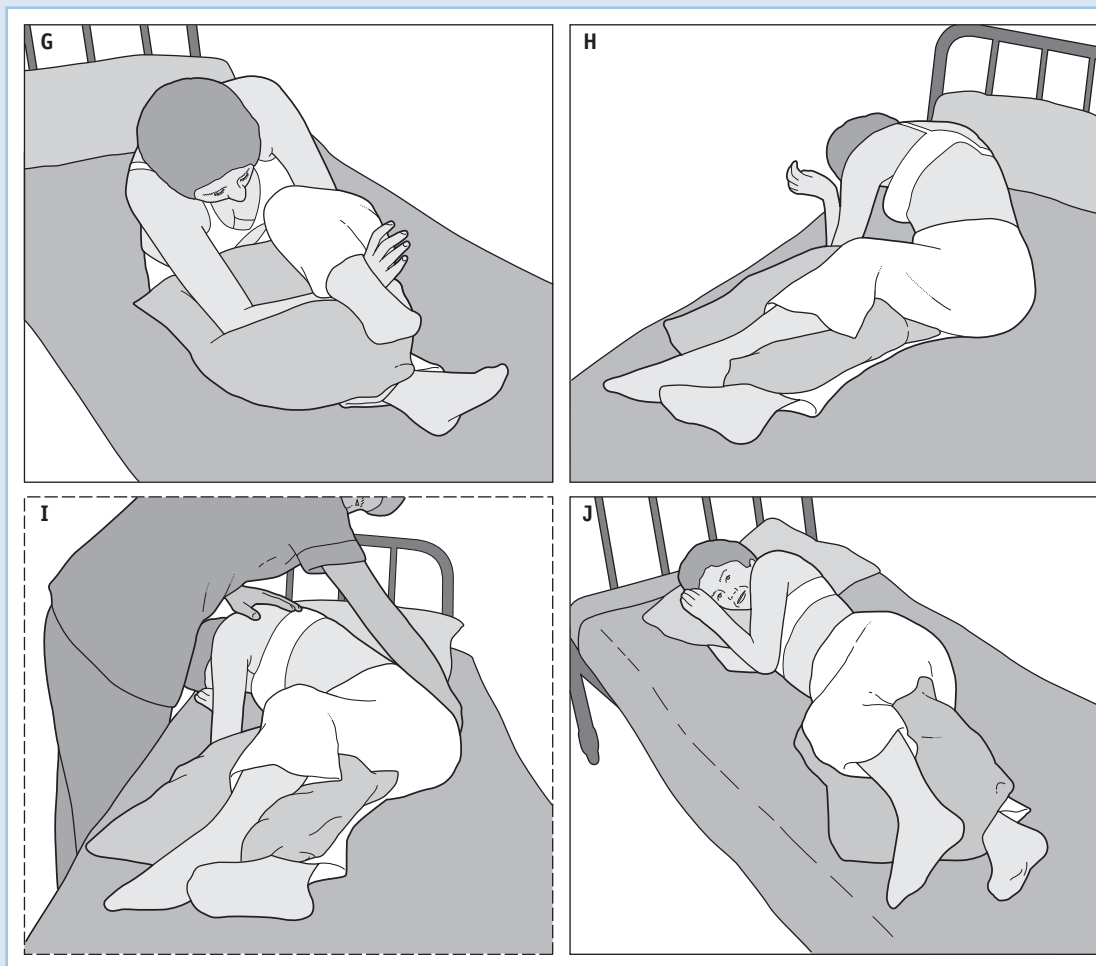
Figure 10.6 cont'd

Initially the therapist may need to assist the patient to achieve the rocking movement by pressing down over the patient's left shoulder girdle with one hand and lifting under the right buttock with the other (Fig. 10.6I).

When the patient can turn himself in bed and position the pillows correctly he will be encouraged to take responsibility for turning himself at night with supervision from ward staff.

Wheelchairs and wheelchair management

Ida Bromley, Lone Rose

Guide to wheelchair selection

With advances in technology has come a revolution in wheelchair design, both manual and powered. In many parts of the world the range of wheelchairs is now vast. This increase in choice has made selection more complex both for the professional and for the user. With the number of options and the continuing development of these chairs, expert advice is required to select an appropriate chair for each individual. The following considerations may assist in shortening the list of potentially suitable wheelchairs to be tried.

Use of wheelchair

- The environment in which the wheelchair will be used most of the time will particularly have a bearing on the durability and types of wheels selected. If mainly used indoors, the wheelchair needs slimmer tyres to reduce friction, whereas if used mainly outdoors, a strong frame and thicker tyres with better grip would be preferable. For some users a manual self-propelling chair may be adequate for use indoors whereas a powered chair may be required for outdoor use.
- The type of use whether general purpose or specific such as sport, work or leisure.
- If the wheelchair is not going to be controlled by the user, special attention must be paid to how the user will be assisted.
- If the wheelchair is not going to be used full-time, storage needs to be considered.

Mode of transfer

- Transfers through standing require the footplates to be able to flip-up and/or swing safely out of the way.
- Sideways transfers with or without a transfer board require sufficient space to clear the large rear wheel or other obstacles to avoid tissue trauma.
- Where hoisting is required, sufficient access for the caregiver to place and remove the hoist sling must be taken into

consideration. The style of front end of a wheelchair and height off the floor of footplates can affect access with a hoist.

Transport

- If the wheelchair has to be lifted in/out of a vehicle the overall weight of the wheelchair as well as the weight distribution (balance when lifted) becomes particularly important.
- The room available in a particular vehicle may determine the type of wheelchair in terms of compactness when folded.
- If the user stays in the wheelchair whilst travelling, the wheelchair must be compatible with adequate clamping systems to firmly secure it to the floor of the vehicle. The user will need separate seatbelt and headrest systems.

The user

- Although most wheelchair manufacturers offer a wide range of sizes (width and depth), individuals of exceptional stature (either very tall or very short) may have a limited range of wheelchairs to choose from.
- All manufacturers state maximum user weight for each type of wheelchair. An increasing number of wheelchairs are becoming available for larger individuals.
- Special back support and cushions may be required for the wheelchair due to the special postural needs of the user.

Rehabilitation is wasted if appropriate equipment is not provided at the end of it, i.e. equipment that will enable the individual to continue to use and progress the skills learnt during rehabilitation.

TYPES OF WHEELCHAIR – MANUAL

The drive behind the revolution in manual wheelchair design over the last 20 years has been the desire to develop a lighter and more manoeuvrable wheelchair, which would enable the wheelchair to be fitted to the needs of the user rather than the other way round. Postural stability, efficiency of propulsion and manoeuvrability are all improved, facilitating the use of the chair, e.g. in rear wheel balance, which is the key to wider mobility in the environment. The key features in this new design are the use of lighter materials and greater adjustability in the wheelchair itself.

Weight

- The terms 'lightweight' and 'ultra light' are used freely in the context of manual wheelchair design today. The weight of any

wheelchair is largely dependent on the materials used and the number of individual parts. Traditionally wheelchairs were made from steel and weighed 25 kg (55 lb) Steel is still used in some wheelchairs, but most wheelchairs are now made from aluminium, titanium, carbon fibre or a combination of these materials. All wheelchairs today are therefore much lighter than the traditional wheelchair used 20 years ago. For the same size of wheelchair the weight can vary from 7 to 15 kg (15.4 to 33 lb) depending on style of chair. Custom-made wheelchairs with minimal adjustability are lightest of all.

- Frame style. The traditional design with a vertically folding frame (Fig. 11.1) tends to be heavier as the cross frame design requires more metal to achieve the required strength. The rigid, horizontally folding frame design (Fig. 11.2) is stronger as well as lighter as there are fewer movable parts in it. The rigid frame design also tends to be more efficient as no energy is lost in the movement of individual frame parts. Some users find that the slight movement of the frame in a folding frame design is more comfortable. Some wheelchair manufacturers offer a rigid frame chair with an 'ergonomic' seat unit for optimal positioning (see p. 156). Most manufacturers offer a wide choice in both seat widths and depths, usually in 2 cm (0.8 in) increments. For correct sizing of the seat, see Chapter 6.
- Most wheelchairs now have detachable rear wheels, which not only reduces the weight when stowing the chair in a car but also makes the 'package' to be lifted much more manageable.

Backrest

- Many manual wheelchairs have adjustable backrest height as standard.
- Rigid frame wheelchairs have the facility to independently adjust the backrest angle in relation to the seat. Some folding frame wheelchairs offer this as an optional extra.
- Sling back canvasses tend to offer very poor postural support. Most manufacturers offer a tension adjustable backrest as an optional extra. This consists of adjustable bands between the two upright struts. These are adjusted by means of Velcro so that the spine can be supported wherever the support is needed (Fig. 11.3) (see Ch. 6).
- Some manufacturers of custom-made chairs are beginning to recognize the difference in the male and female body shape and have started to offer 'female backrests'. Frequently women have the dilemma of requiring a wider chair at the hips than at chest level, which leads to the backrest interfering with the pushing action. The 'female back' is the same width as the seat at the base but tapers in above the pelvis.
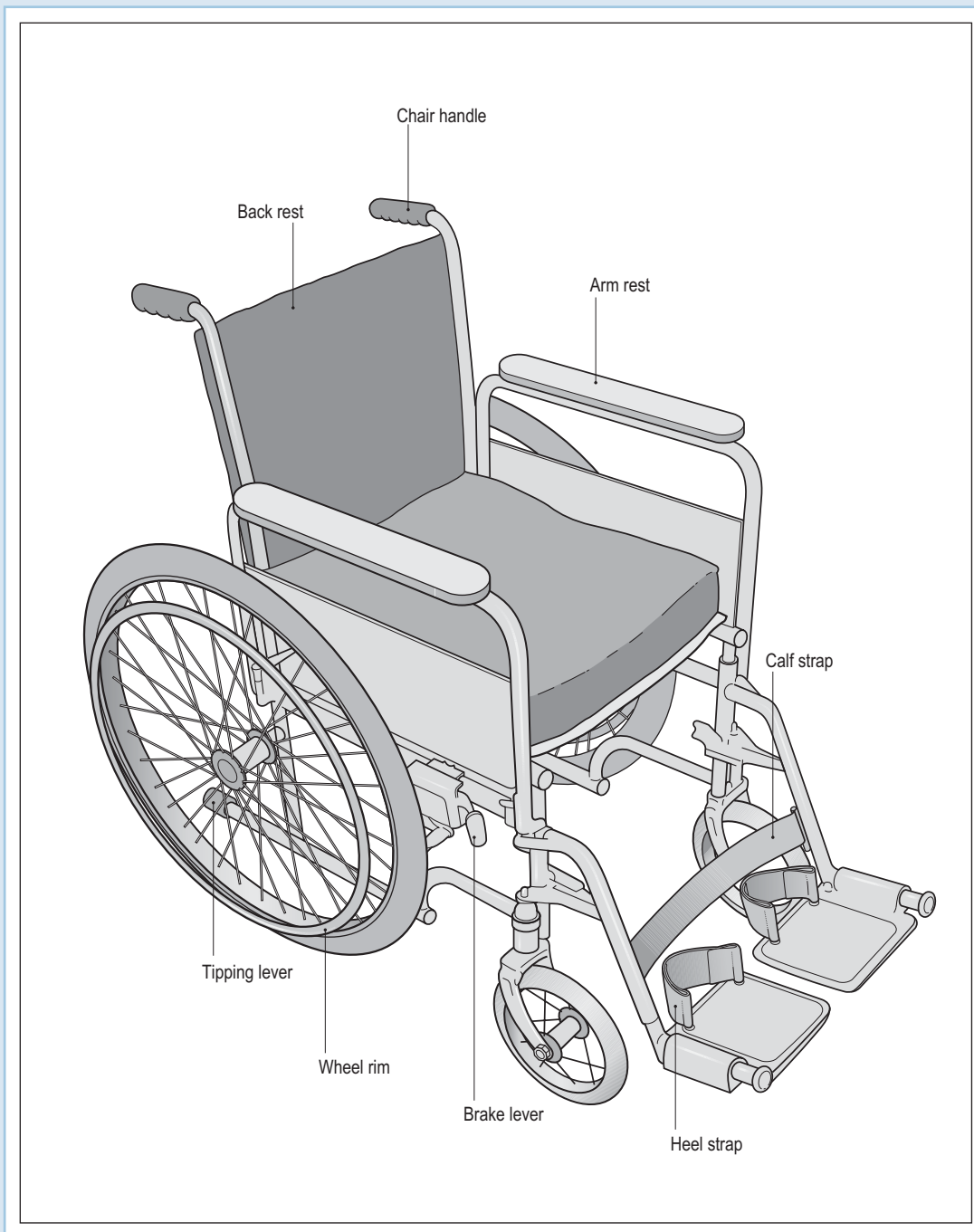
Figure 11.1 Example of standard folding frame wheelchair.

Figure 11.2 Example of high performance rigid frame wheelchair.

Figure 11.3 Tension adjustable backrest.

Rear wheels

- Standard size for a self-propelling wheelchair is 24 in (60 cm) but wheel sizes from 20 to 26 in (50 to 65 cm) are available. If attendant controlled, some manufacturers offer rear wheel sizes of 10 to 12 in (25 to 30 cm), known as transit wheels. The larger the rear wheel, the less effort is involved in pushing the chair whether by the occupant or the assistant.
- The tyres can be pneumatic with pressures from 60 psi to 100 psi or solid. Some manufacturers offer an extensive choice of tyres from smooth, slim, low profile racing bike styles to very high profile, chunky mountain bike style tyres. The type of tyre used will affect friction when pushing – a softer, broader pneumatic tyre will increase friction but gives a softer ride. A slim, high pressure or solid tyre will reduce friction, but gives a harder ride. Puncture proof inserts are available for most pneumatic tyres. For optimal performance pneumatic tyres must be kept at the recommended pressure.

Front castors

- Sizes range from a few inches in diameter to the traditional 8 in (19.8 cm) castor. A larger castor will make it easier to roll over rough ground but makes it heavier to turn the wheelchair. Large castors are more likely to interfere with the feet on the footplates when turning the chair. Small castors require greater skill from the user when pushing outdoors as the weight has to come off the castors when pushing over soft or rough ground to prevent getting stuck.
- Castor tyres can be solid or pneumatic, slim or chunky. The same principles for comfort and rolling resistance apply as for the rear wheel.
- Some wheelchairs can have quick-release castors.

Legrests and footplates

- The angle of the legrests (sometimes described as 'foothangers') affects the overall length of the wheelchair and therefore the turning radius. The traditional standard wheelchair had legrests at 60° knee flexion. This is now rare in modern design. The most common legrest angle is 70° or 80° and some manual wheelchairs have 90° front ends. The range of movement in the hamstrings and degree of knee flexion determine the limitation of the angle of the legrests (see Ch. 6). Leg length will also affect choice of angle as people with long legs will have to be higher off the ground if wanting 90° front end to their chair, which in turn may affect their ability to get under tables.
- Legrests can either be swing-away detachable or integral to the frame of the chair. Folding frame chairs tend to have swing-away

detachable legrests whereas the rigid frame manual wheelchairs tend to have integral ones. Some legrests are tapered to make them narrower at the bottom. This feature helps to reduce the turning circle of the chair.

- Footplates can be flip-up style which can be adjusted independently for right and left leg or can be a single flip-up footplate. Integral legrests can have a footbar or a single fixed footplate. Some footplates are angle adjustable.
- Footplates can be fitted with heel loops to prevent the feet slipping back off the footplate. Some heel loop designs are quite short and users with large feet will tend to have only the middle of the foot supported on the footplate. A calf strap can be used as an alternative. For some users with excessive spasticity both may be necessary.

Adjusting the manual wheelchair to suit the user

The correct position of the patient in his wheelchair is important if pressure ulcers and deformities are to be avoided and if the patient is to have maximum stability for independent activity (see Ch. 6). The majority of patients are apprehensive and unstable when first sitting up in a wheelchair. Their primary need is to feel safe in their wheelchair. Having a wheelchair with minor but essential adjustability available makes it possible to adjust the wheelchair to give the user the benefit of a more manoeuvrable chair and still reflect the greater need of stability over mobility. The seating system needs to support the user in a good posture whilst at the same time allowing him to be dynamic. The following section describes the advantages and disadvantages to the user of the adjustments, which will affect the biomechanics of the wheelchair. For more detailed description of wheelchair ergonomics, see Engström (2003).

Rear wheel position – forward/backward

Pushing efficiency is directly linked to the axle position of the rear wheel – the further forward the rear wheel is placed under the user, the more manoeuvrable the chair becomes as more weight is placed over the rear wheel (Boninger et al 2000). Wheelchairs with several forward position options are often referred to as 'high performance wheelchairs'. Advantage to function is that it improves manoeuvrability and pushing efficiency, shortens the turning radius and makes backwheel balance easier. Disadvantage to the user may be that it makes the chair tip backwards more easily and may interfere with sideways transfers. When adjusting the chair to the user the balance is between stability and mobility. The optimal rear wheel position will vary according to the progress of the individual's skill (at a given point in time) as well as from individual to individual. At the beginning of rehabilitation the first time user will primarily need stability
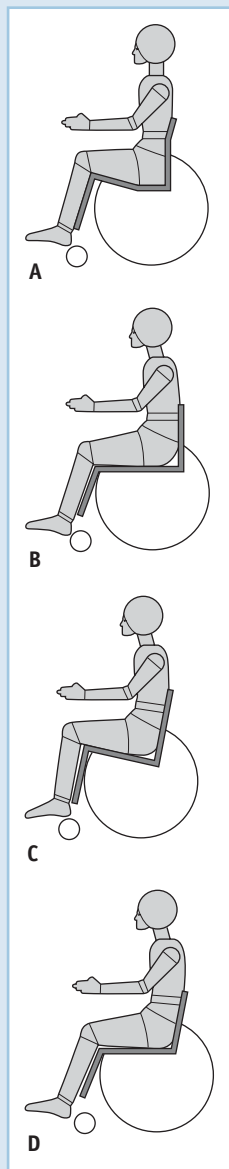
Figure 11.4 A: Ergonomic seat frame. B: Standard seat unit – seat horizontal, backrest vertical. C: Tilted seat unit – seat/back angle = 90°. D: Reclined seat unit – seat/back angle >90°.

in order to be able to learn new skills. As confidence and skills grow greater mobility becomes more important. For the more timid individual with limited potential for advanced wheelchair skills the rear wheel may only be moved safely forwards in small increments up to a maximum of 4–5 cm (2 in) whereas the more skilled user over time may choose to have the rear wheel forward by 10 cm (4 in) or more. Conversely the rear wheel may be positioned rearwards if the user needs greater stability due to partial or full amputation of one or both lower limbs.

Rear wheel position – up/down

This alters the seat angle in relation to the rear wheel and will determine how deep the user sits between the wheels. Combining adjustment of the seat angle with the backrest angle will create three basic seat unit positions: standard, tilted and reclined (Fig. 11.4). A hybrid position of the standard and the tilted is referred to as the 'bucket' position, i.e. seat tilted but backrest vertical. The optimal position is considered to be when the user can reach the centre of the hub of the wheel with the tips of the middle fingers when sitting in an upright position. If the correct arm position in relation to the wheel is reached without achieving the desired seat angle, further raising of the front end of the seat can be achieved by either ramping the cushion or extending the castor forks. As the seat slopes down towards the back of the chair, gravity will assist the user in achieving and maintaining his position towards the back of the seat. However, a sloping seat may affect transfers as it necessitates moving uphill in preparation for a transfer out of the chair. Most users who are able to transfer independently or with minimal assistance are able to cope with a difference in floor to seat height of 5 cm (2 in) from front to back. A severely sloping seat will also increase subischial pressures and can interfere with urinary drainage if leg bags are used as the urine has to drain uphill.

Rear wheel position – camber

Cambering – angling the rear wheels in relation to the frame of the chair – greatly improves directional stability, making it easier to maintain a straight line on uneven ground and facilitating turning the chair. It brings the wheels closer to the body, improving pushing efficiency. It does, however, make the wheelbase wider, which may affect access through doorways.

Front castors

By moving the rear wheel forward the wheelbase is shortened, which may result in making the wheelchair unstable forwards, if the user reaches forward. To counteract this, the castors usually have the

facility to be moved forwards by one or two positions. Having a very short wheelbase also requires greater skill when mounting a kerb.

If the angle of the seat is altered through moving the rear wheel up or down on the frame, the castor housing needs to be adjusted accordingly. The castor housing should always be perpendicular to the floor to avoid castor flutter.

Footplates

Footplates should be adjusted to take the weight of the leg and offer support throughout the length of the thigh (see Ch. 6).

The feet should be supported in plantargrade or slight dorsiflexion.

Backrest

The height of the backrest should be sufficient to fully support the posture without interfering with function.

Backrest angle should be as close to vertical as the user can tolerate without losing balance. The tension adjustable backrest should be adjusted according to the principles for posture laid out in Chapter 6.

Seat canvas

Some wheelchairs tend to have a sag in the seat canvas. As most cushions are designed to be supported on a flat surface it is important to eliminate the sag by using a solid seat insert made of wood, solid plastic or shaped foam.

TYPES OF WHEELCHAIR – POWER-DRIVE

For users who are unable to self-propel or who find it difficult to use a manual chair all the time, the power-drive chair provides the ideal solution. Most power-drive users will have a manual wheelchair for back-up. As for the manual wheelchair, the range of power-drive chairs has greatly increased in recent years and they too are available in a wide range of sizes. The power-drive chair is classified as indoor, indoor/outdoor, outdoor/indoor or outdoor. This classification is largely dependent on the power of the motor and the combination of front and rear wheels.

- The indoor power-drive chair tends to have four solid tyres.
- The indoor/outdoor power-drive chair has pneumatic rear tyres with solid front tyres.
- The outdoor/indoor and outdoor power-drive chairs tend to have pneumatic tyres on all four wheels to be able to cope with rugged terrain.

Power-drive chairs can be either front- or rear-wheel drive. The front-wheel drive has the advantage of being able to turn on its own axis.

Control unit

This determines the power sent from the battery to the motor. The control unit can be adjusted for speed and sensitivity to suit the individual's need. Controlling the chair can be by hand via a joystick which can be individualized depending on hand function. Other types of controls are chin or head controls, i.e. sip/puff, head switches, or the chair can be attendant controlled.

Seat unit

The style of seat unit varies from a standard sling-seat/back to well-upholstered, contoured seats and backrests, reminiscent of a car seat. However, it is possible to use independent back systems and cushions with most chairs. It is usual and indeed recommended that users with spinal cord injury will use their own pressure-relieving cushion. Backrests tend to be taller than in manual chairs for added stability, particularly in the chairs intended for outdoor use.

Some power-drive chairs have the facility to recline or tilt-in-space (whole seat unit tilts without altering back/seat angle). This function offers the user the opportunity to change position in the chair and can be controlled either manually or electrically. The degree of tilt offered by most manufacturers will not be sufficient for adequate pressure relief (see Ch. 6) but will still provide increased comfort to the user through a change in position. Tilting the seat unit is usually preferable to reclining as the pelvic/hip posture remains unaltered. When using the recline facility, shear forces on the back are greatly increased when bringing the backrest back to upright. This can be reduced by leaning the user forward (Gilsdorf et al 1990).

Headrest

All power-drive chairs that are being transported with the user in them must be fitted with headrests for safety purposes. Headrests are essential in chairs that recline or tilt. They should be adjustable in all directions for maximum comfort and may have to be altered for different seat positions.

Caution

Where the user's head extends to rest on the headrest, care must be taken when feeding as this position opens the airways and food may go into the respiratory tract.

Leg support

Legrests tend to be swing-away with flip-up footplates, which in some cases are angle-adjustable.

Elevating legrests can be raised or lowered either manually or electrically.

Kerbclimber

This device enables kerbs of up to 13 cm (5 in) to be mounted in a power-drive chair. The action of the kerbclimber lifts the chair over the kerb and it is not advisable to use this with any head control system. The kerbclimber needs to be positioned relatively close to the ground to be effective, which may cause it to activate whilst going over small obstacles on the ground when the user does not expect it. Careful training of the user is required.

Armrests

All are detachable or swing-away and in most cases also height adjustable. Special contoured arm supports are frequently used on top of the armrest.

Batteries

Most power-drive chairs have gel batteries, which are maintenance free apart from charging. They are safer to transport than wet batteries, especially on planes, are more expensive, tend to have a shorter lifespan (2 years +) and may take longer to charge. Although still heavy, batteries have reduced in weight as well as in size over the years.

Most power-drive chairs can be fitted with systems that can be used with environmental control units as well as computer systems, giving the user greater independence once up in the chair.

More sophisticated power-drive chairs have got stand-up modes and/or variable seat height. In some chairs it is possible to continue to manoeuvre the chair whilst using these functions.

OTHER TYPES OF WHEELCHAIR

Hybrid power/manual chairs

Several systems are available whereby a manual wheelchair with quick release rear wheels can be converted to a power-drive chair or power-assisted manual propulsion. Manual propulsion can also be assisted by adding a fifth central rear wheel. The power-assist systems have been shown to be effective in reducing the strain of manual

wheelchair propulsion and are ideally suited to the person with or at risk of upper limb joint degeneration, or with reduced exercise capacity or who has marginal strength and endurance for manual wheelchair propulsion (Cooper et al 2001, Levy et al 2004). These systems are heavy and would make independent car mobility very difficult. Some systems add considerable extra width to the wheelchair and may make some access difficult. A growing number of systems are available, e.g. the E-Fix and F16 (power-drive), the E-motion and i-Glide (power-assist) and the Samson Jockey (fifth wheel power-assist).

Reclining/tilting manual wheelchairs

Some chairs only allow the backrest to recline; others have both a reclining and a tilt facility. The effect of both these functions on posture is described in Chapter 6. This style of chair is intended for the user who is unable to maintain upright posture against gravity and is unable to control the wheelchair himself. In order to maintain stability through the full range of adjustments of this style of chair, the wheelbase has to be longer. This can make the chair difficult to manoeuvre in a confined space. Traditionally these chairs have had small rear wheels but newer models can be supplied with large rear drive wheels which will make it easier for the attendant to push, especially up and down kerbs or on sloping surfaces. Separate seat and back systems can be used with most chairs and some chairs can also accommodate ventilators.

The stand-up chair

This chair (Fig. 11.5) enables the patient to raise himself to the standing position to perform an activity and to sit down again independently. The seat of the chair is raised slowly to the required height either manually or electrically. The movement can be interrupted or reversed at will. Several models and mechanisms are available.

Sports chair

Highly specialized wheelchairs are now designed for specific sports, e.g. basketball, tennis, wheelchair rugby and racing. Hand bike attachments can be used with a range of manual wheelchairs.

Paediatric wheelchairs

The range of wheelchairs both manual and power-drive for children has experienced the same expansion and technological advances as for the adult user. The biomechanical principles applied to adults

regarding pushing efficiency can equally be applied to children as children essentially propel their wheelchairs in the same manner as adults (Bednarczyk & Sanderson 1994). Some special points need to be considered when selecting a wheelchair for a child.

- Larger rear wheels on a manual wheelchair will be very efficient but may place a young child much higher than its peer group for play and education.
- Postural management of the spinal cord injured child is of paramount importance (see Ch. 16) but the natural instinct of most children to be active must also be considered. A balance between dynamic activity and postural control must be found for the full 24-hour period.
- Normal developmental milestones must be respected and the disabled child needs equipment that will enable him to reach these. This has implications for the age at which a child can be provided with a wheelchair that he himself can control to explore his wider environment. Very young children (12 months+) can learn to propel a manual wheelchair safely. If a power-drive chair is required the child's cognitive skills must be assessed carefully for obvious safety reasons. With paediatric power-drive chairs an adult should always have a remote cut-out switch, which can instantly immobilize the chair (similar to a car key fob).
- All children want to feel part of a peer group. The colour, speed and cosmetics of their wheelchair are probably the most important criteria for them. It is essential to involve the child actively in the selection of the chair.

Figure 11.5 Example of stand-up chair.

LATEST TRENDS

New technologies are being developed all the time. Recent designs have seen the development of highly sophisticated chairs like the iBOT Mobility System, which is able to climb kerbs and stairs and manage very rough terrain. Through a system of gyroscopes it is able to balance on two wheels and still be fully mobile (http://www.independencenow.com). The quest to reduce the weight of manual wheelchairs continues as does the drive to find new ways of collapsing wheelchairs into ever smaller, more compact and more transportable packages. Development of power-drive chairs and cars that can be controlled by voice continues.

Keeping up with new development can be difficult for the busy clinician but in this technological age the internet offers quick access to all the main manufacturers' websites. Attending equipment exhibitions is preferable whenever possible as it gives the opportunity to try new equipment and discuss with the manufacturers and agents. It is important for clinicians and users to feed back their experiences if future advances are to reflect the clinical and not merely commercial need.

WHEELCHAIR ACCESSORIES

There are various accessories which can be obtained with most models when necessary.

Anti-tipping levers

These levers are designed to prevent the chair and patient overbalancing backwards. They can be adjustable and are removable, and it is possible to mount small kerbs with them in situ, thus increasing independence for children and patients with cervical lesions.

Armrests

There are several models, all detachable:

- standard
- desk arms – the front upper quarter is cut away to allow the chair to be wheeled closer to a desk or table
- height adjustable
- lift-up
- swing-away tubular.

Most detachable armrests have automatic locking devices.

Backrests

These are available in a number of sizes to provide sufficient support without impeding mobility. The angle of the backrest is adjustable, which permits patients, particularly those without abdominal muscles, to recline a few degrees from the vertical, allowing greater freedom to use the arms. Some have fixed or swing-away lateral supports for increased postural control.

Brakes

These can be push/pull or scissor type, which can be mounted high or low on the frame of the chair. Some push/pull brakes are designed to swivel away underneath the seat like the scissor style brake. Some manufacturers are bringing out brake designs that are located in the hub of the wheel.

Brake extensions

These are sometimes necessary to enable patients with cervical lesions to reach the brakes without falling forward. For patients with weak grip the brake extensions give added leverage.

Caddy

These are small levers which attach to the legrests of the wheelchair. When folded down they are perfect for carrying a briefcase. When not in use they simply fold up parallel to the legrest.

Capstans and pushrims

Capstans are rubber-capped projections spaced at regular intervals around the rim of the wheel. These help some patients with high cervical lesions to get a purchase on the wheels when pushing the chair. Friction-coated or specially designed hand rims increase the effectiveness of the push for weaker users.

Carrying bag

This hangs under the seat of the chair to hold personal belongings. Bags should not be carried on the backrest of a manual wheelchair as it alters the balance point of the wheelchair and will eventually ruin the back canvas.

Castor locks

Castor locks contribute to sideways stability of the chair for transfers.

Crutch or walking stick holder

This consists of a small platform attached to the tipping lever and a strap on the upper part of the backrest to carry the crutches.

Cushions

See Chapter 6.

Elevating legrests

These increase the overall length of the chair by 10 cm (4–5 in) and its weight by approximately 1 kg (2.2 lb) They are useful for:

- patients with high lesions with vasomotor problems
- any patient with a leg injury.

Frogslegs

Suspension in the front castor fork makes it easier to push over small lips and ridges.

Guards

Side guards

The intrinsic stability of the chair is high, so that even patients with cervical lesions may not need armrests. In this case, side guards may be required to protect the clothes.

Spoke guards

Guards on the outside of the wheels protect the fingers, especially of patients with cervical lesions.

Mobile arm support

A splint supports the weight of the arm and on a pivot, allowing maximum performance from minimum motor power.

Push handles

These can be integral to the backrest or detachable. Some are height adjustable, which is particularly relevant for users who require regular assistance from a tall person or from a range of people of varying heights. Some wheelchairs can be supplied with stroller handles which angle away from the back of the chair and make it more comfortable for the person pushing.

Restraining or safety strap

This is attached to the supports for the backrest on each side and fastens with Velcro or a buckle across the abdomen. All patients with cervical lesions use them when first mobile and those with lesions at C4–C5 and above may continue to use them.

Stepper tube

This is a small metal lever that assists an attendant when tipping the chair back to go up and down kerbs.

Suspension

Several manufacturers offer suspension on both manual and power-drive chairs.

Tetra clip

This helps people with restricted or weak hand function to release the hub of a quick release wheel.

Tray

The tray clips on to the armrests and provides a useful surface for many activities. It is also useful, when well padded, as a support for the arms for patients with high cervical lesions.

Tyres

High pressure, pneumatic and solid tyres are available.

Wheels

There is a range of sizes from approximately 12 to 26 in (30 to 65 cm) in diameter.

Zipper backrest

This can be fitted to permit entry and exit from the rear of the chair.

Following assessment it is essential that the user is given the opportunity to try the wheelchair in circumstances he will encounter in daily life. It may be necessary to try more than one before being able to decide which is the most suitable. Rarely does one wheelchair meet all the requirements of the user – just as one pair of shoes does not meet all the needs of an able-bodied person. However with the ability to configure very easily it is now possible to have one wheelchair with different sets of rear wheels for different purposes, e.g. slim, low profile tyres for easy pushing indoors and pneumatic, puncture proof, high profile ones for outdoors.

Evidence from a survey of wheelchair provision to people with spinal cord injury (Rose & Ferguson-Pell 2002) indicates that it takes time for people to adjust to life after discharge from the spinal unit. As the person settles into a new routine, so the requirements of the wheelchair become clearer. The benefits to the user of being provided with a wheelchair that can be adjusted to the change in skills and confidence over time cannot be stressed enough. The wheelchair system needs to be flexible enough to allow the user access to frequent reviews, advice and change of wheelchair if wheelchair provision is to meet the needs of the user over time.

Mobility needs continue to change. The special needs of the person growing old with spinal cord injury are described in Chapter 17. Problems with pain from degenerative changes and repetitive strain in upper limbs are not confined to the older person in terms of chronological age but can also be seen in the person who has lived with spinal cord injury for 20+ years. For example, a person injured at the age of 17 will still only be 37 years old at 20 years post-injury, so he will be 'old' in spinal cord injury terms, but most people would still consider themselves 'young' at the age of 37! Provision needs to reflect the requirements of the individual who has lived for a long time with disability but still has the expectation of living the active and fulfilling life of his peers. Whereas many people used to subscribe to the motto of 'use it or lose it' more recent evidence promotes 'conserve it to preserve it'.

WHEELCHAIR MANOEUVRES

In recent years several manual wheelchair training guides and wheelchair skills programmes have been published (Axelson et al 1998, Kirby 2005). The Spinal Injuries Association in the UK has produced a wheelchair skills video called 'Turning the corner' (Spinal Injuries Association 2003). All recognize the need amongst professionals as well as users for practical advice on how to become a proficient

wheelchair user. The value of a specifically targeted wheelchair skills programme as part of a rehabilitation programme has been documented by MacPhee et al (2004).

The basic movements of the patient within the wheelchair and the initial wheelchair manoeuvres described below are written for tetraplegic patients without a grip. The basic safety measures, such as holding on with one elbow or wrist, become progressively unnecessary as the level of the lesion descends. The advanced wheelchair manoeuvres are divided into sections, since some activities are unsuitable for patients with cervical lesions. Adaptations in technique may have to be made for chairs of a different design.

BASIC MOVEMENTS WITHIN THE WHEELCHAIR

- To manipulate the brakes
- To remove the armrest
- To pick up objects from the floor
- To reach down to the footplates.

Whenever the patient prepares to move within the wheelchair or to move into or out of it, he must first position the wheelchair itself. To give maximum stability, the small front wheels must point forward, as this prevents the chair tipping onto the footplates, and the brakes must be applied. If the patient is going to lean out of the chair in any direction, the buttocks must be well back in the seat.

To manipulate the brakes

To reach the right brake:

1. Hook the left elbow behind the left chair handle.
2. Lean forward and to the right, allowing the left biceps to lengthen as the trunk movement occurs.

To release the brake, use flexion of the elbow and shoulder to push the lever forward with the palm of the hand or the lower part of the supinated forearm (Fig. 11.6A, B). To apply the brake, pull the lever back using the right biceps and either the extended wrist or the supinated forearm (Fig.11.6C, D).

To remove the armrest

Most armrests now tend to be either flip-up or swing-away as well as detachable. The technique for swinging them out of the way varies greatly depending on type but all tend to be easier to manipulate than the traditional detachable style. For tetraplegic patients strong wrist extension is essential if they are to manipulate the armrest independently.
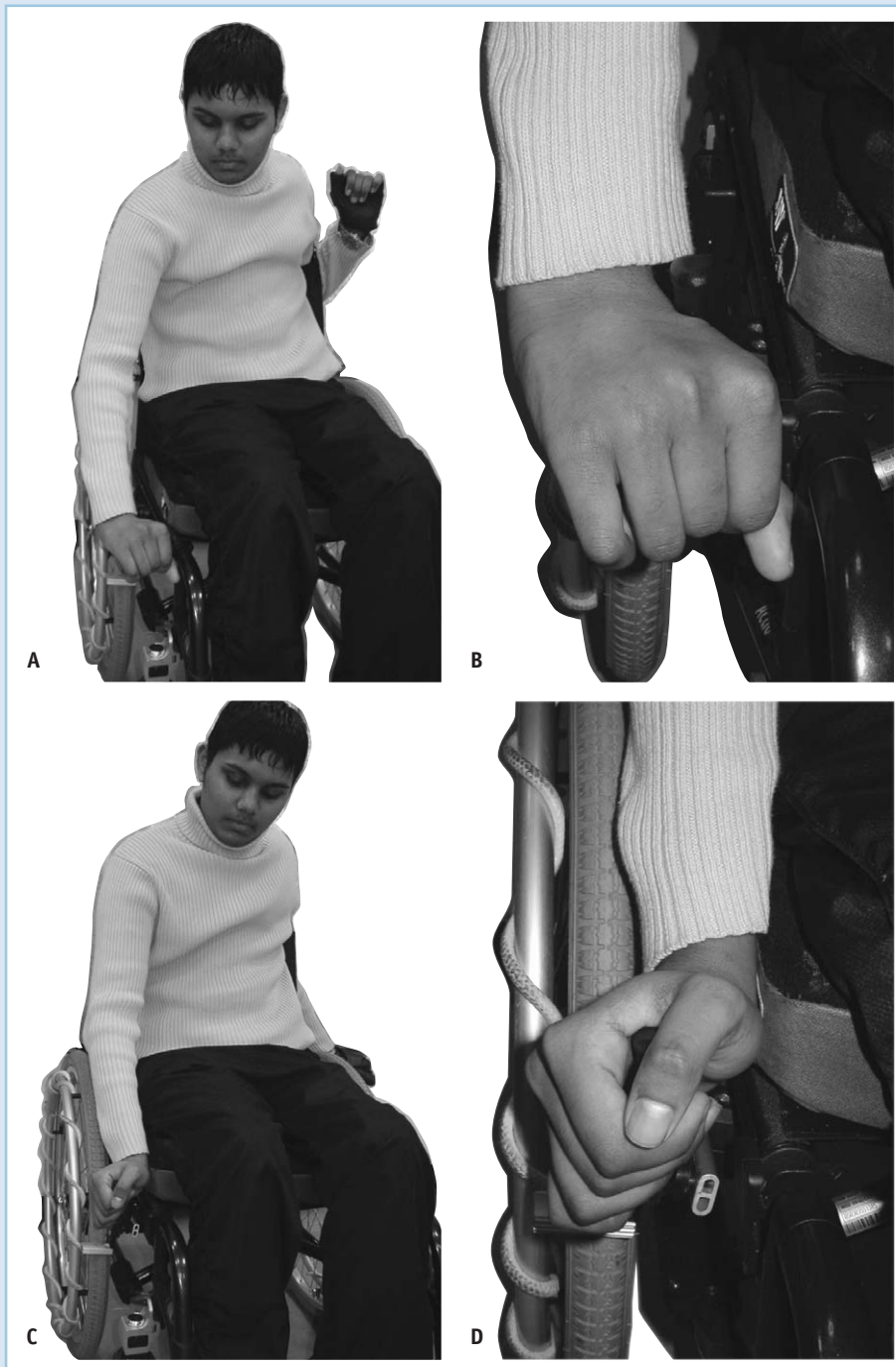
Figure 11.6 A, B: Brake off. C, D Brake on. Patient with a complete lesion below C6 without triceps.

To pick up objects from the floor

Objects are picked up by leaning sideways out of the chair, and not by leaning forward over the footplates; the forward position is unstable and therefore dangerous.

To lean to the left

Position the chair sideways in relation to the object. Hook the right elbow behind the right chair handle and lean over the left armrest.

To avoid excessive pressure on the ribcage, maintain this position for only a few seconds at a time. The armrest can be removed to allow shorter patients the necessary reach.

To regain the upright position, pull up with the right elbow. When triceps is innervated, the extended wrist can be used under the outer rim of the armrest to maintain balance and regain the upright position.

To reach down to the footplates

This position will be necessary to adjust the footplates, to empty the urinal or for adjustments when dressing:

1. Lean forward on the elbows on the armrests.
2. Change the position of the arms one by one and lean on the forearms on the thighs.
3. Put one hand at a time down to the feet, leaning the chest on the thighs.

To regain the upright position, patients without triceps must (1) throw the stronger arm back over the backrest and hook the extended wrist behind the chair handle, and (2) pull the trunk upright by strongly extending the wrist and flexing the elbow.

Patients with good functioning triceps pull the trunk upright by hooking one or both extended wrists underneath the upper, outer edge of the armrest(s).

INITIAL AND ADVANCED WHEELCHAIR MANOEUVRES

When putting the wheelchair in motion in any direction, the position of the head and shoulders is important. They are used to reinforce the action of the arms, whether to gain greater momentum or to act as a brake.

Patients start moving the chair by pushing on the tyres. Paraplegic patients may progress to using the wheel rims, particularly outside, but many patients with tetraplegia continue to use the tyres because they find the purchase easier and the push more effective. Pushing gloves (see Fig. 8.2f) are used by tetraplegic patients to protect the skin from callus formation and abrasions due to friction or injury.

Those designed with the thumb portion set in opposition may assist in encouraging the tenodesis grip. Specially designed pushrims, temporary capstans or using rope or rubber tubing wrapped around the wheel may help older patients and tetraplegic patients to learn to push the chair.

Many of the initial wheelchair manoeuvres can be taught in a group where patients learn from and encourage each other. Competition over slalom courses where the obstacles include ramps and turns in narrow confines is also useful. Penalties are given for touching as well as moving any of the marker buoys.

Initial manoeuvres

- To push on the flat
- To use the chair on sloping ground
- To turn the chair.

To push on the flat

When wheeling on the flat, the push forward with the arms is reinforced if accompanied by strong flexion of the head and shoulder girdle. Momentum is gained because there is a general thrust forward with the upper part of the body. Significant differences were observed by Boninger et al (2002) between the ways in which patients pushed their manual wheelchairs, and the stroke pattern was not always the same on both sides. It is suggested that a semicircular motion where the hand falls below the pushrim during the recovery phase produces the most work for the least effort. With this motion more time was spent in the push phase at a given speed.

To reverse on the flat

1. Put both arms over the backrest between the chair handles.
2. Place the hands on the wheels with the elbows extended and shoulders elevated.
3. Leaning backwards, depress the shoulders and thrust downwards, with as much weight as possible over the arms. Slopes can be ascended in reverse in this way if the patient is unable to push up forwards.

To use the chair on sloping ground

To push up a slope

1. Leaning forward, place the hands towards the back of the top of the tyre (Fig. 11.7).
2. Push forward using flexion of the elbows and flexion and adduction of the shoulders. The chair can be held on a slope by turning the wheels across the incline.

Figure 11.7 *(left)* Pushing up a slope. Patient with a lesion at C6.

Figure 11.8 *(right)* Turning. Patient with a lesion at C6.

To slow down when going down a slope

Extend the head and shoulders and brake either with both hands towards the front of the tyres or with the first metacarpals under the wheel rims and the wrists extended.

To turn the chair to the left

1. Place the left hand towards the back of the tyre with the arm over the backrest, behind the chair handle.
2. Laterally rotate the left arm and with the body weight over the hand push backwards on the inner side of the wheel (Fig. 11.8).
3. Push forward with the right hand.

Advanced manoeuvres: tetraplegic patients

To push the chair over a 5 cm (2 in) step

This manoeuvre can be accomplished by patients with lesions at C6 without triceps, and may be necessary to get over a draught excluder or similar obstacle:

1. Place the palms on top and to the outer side of the tyre with the fingers down over the rim and the thumb between the rim and the tyre.
2. Push the chair backwards.
3. Then push briskly forward, leaning the body weight forward at the same time.

Advanced manoeuvres: paraplegic patients

- To balance on the rear wheels
- To mount and descend a kerb
- To 'jump' the chair sideways
- To mount and descend a flight of stairs in a high performance wheelchair
- To transfer a wheelchair into a car.

To balance on the rear wheels

Balance and movement on the rear wheels are useful to facilitate independent travel over rough ground, e.g. over grass, sand or shale, and also in negotiating kerbs or a step. This technique is safe only for patients with a good grip, i.e. for patients with lesions at T1 and below. In a well-adjusted lightweight wheelchair patients with lesions at C6 may also manage it. Anti-tipping levers are used initially. There are three manoeuvres involved:

- To tilt the chair onto the rear wheels
- To balance the chair on the rear wheels
- To move and turn the chair on the rear wheels.

Action of the therapist
The therapist always stands behind the patient in step-standing, with the thigh of the forward leg ready to support the chair if control is lost. She holds the chair handles loosely (Fig. 11.9d). Assistance is given to tilt the chair by pressing down on the chair handles, and to find the balance point by giving pressure in each direction as necessary.

The therapist's hands must be very sensitive to the movement of the chair, correcting it only when the patient is out of control. She must allow enough scope for the patient to be really aware of each movement that occurs, so that the patient can become familiar with the 'feel' of the chair in the balance position.

Caution

The therapist's hands must remain on the chair handles until the patient has complete control, as it is all too easy for the patient to overbalance backwards and injure himself. Much practice will be needed. Not until the therapist is entirely satisfied that the patient is completely competent should he be allowed to balance without her behind him as a safeguard.

Action of the patient
To tilt the chair onto the rear wheels

1. Place the hands on the wheels approximately in the 10 o'clock position, holding the tyre and the rim or the tyre only, whichever is most comfortable.
2. Slightly extend the head, and put pressure on the wheels as though moving backwards (Fig. 11.9A).
3. Push forward quickly and forcefully, and the front wheels will lift off the floor (Fig. 11.9B). The height of the lift depends upon the force of the push.

To balance on the rear wheels

The balance point is much further back than most patients realize. It is found by playing the wheels forwards and backwards and using the head and shoulders as a counterweight. When overbalancing forwards, push the wheels forwards. When overbalancing backwards, push the wheels backwards. Control may be easier when holding the rims or the wheel and rim (Fig. 11.9C).

To move and turn on the rear wheels

Once balance is achieved, it is not difficult to move on the rear wheels. The technique is the same as with the front wheels down.

To mount and descend a kerb

This activity can be accomplished by patients with a normal grip, i.e. those with lesions at T1 and below.

To push up a kerb

1. Tilt the chair onto the rear wheels.
2. Push forward until the front wheels hang over the kerb (Fig. 11.10A) and lower them gently.
3. Leaning forward, push forward forcefully to bring the rear wheels onto the pavement.

If the patient is unable to tilt the chair onto the rear wheels, he should 'flick' the front wheels high enough to mount the kerb. The flick up

is achieved in the same way as the tilt but requires less strength and balance. Patients with lesions at C7–C8 with good hand function may mount low kerbs in this way and some patients with lesions at C6 in a high performance wheelchair may also be able to do it.
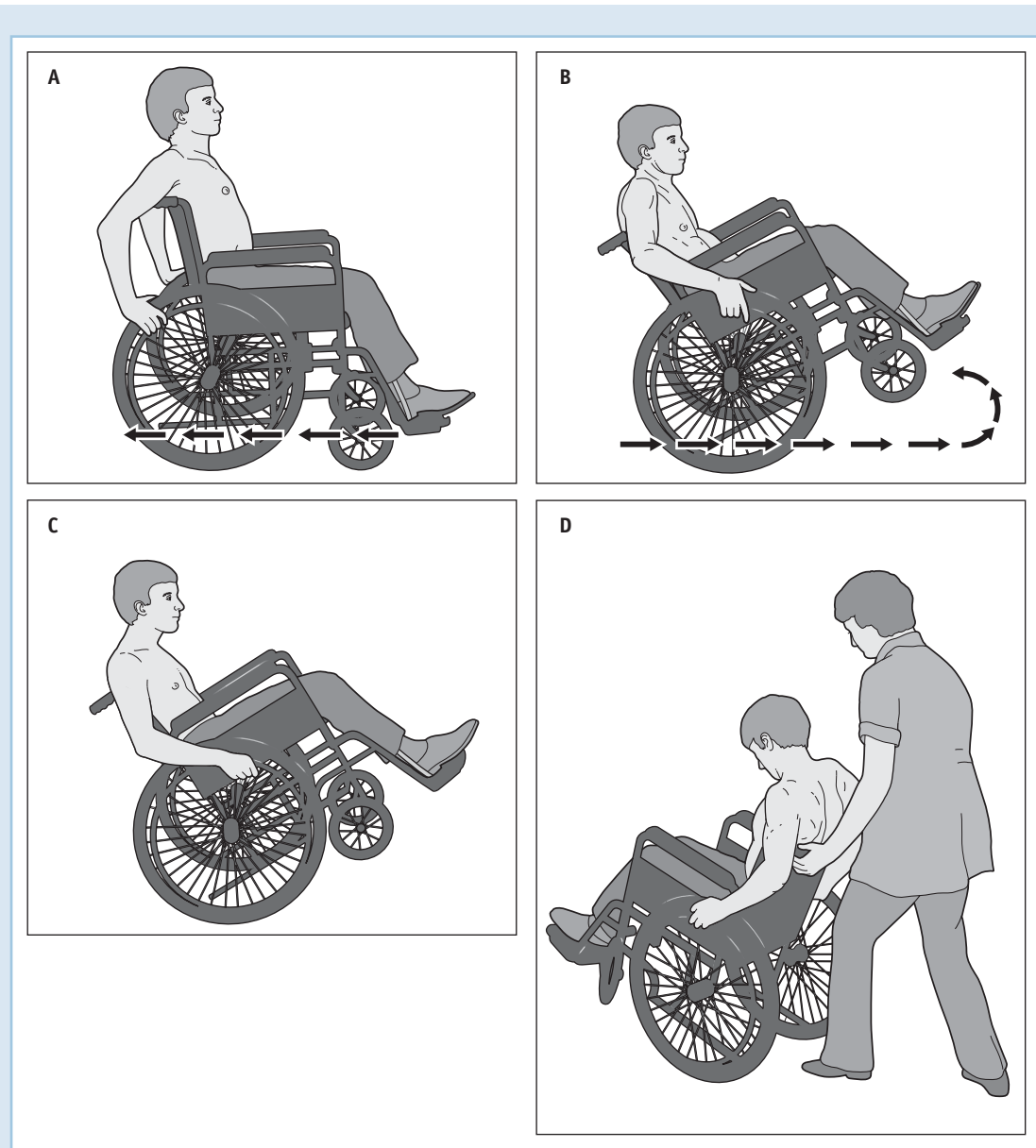
Figure 11.9 Rear wheel balance.
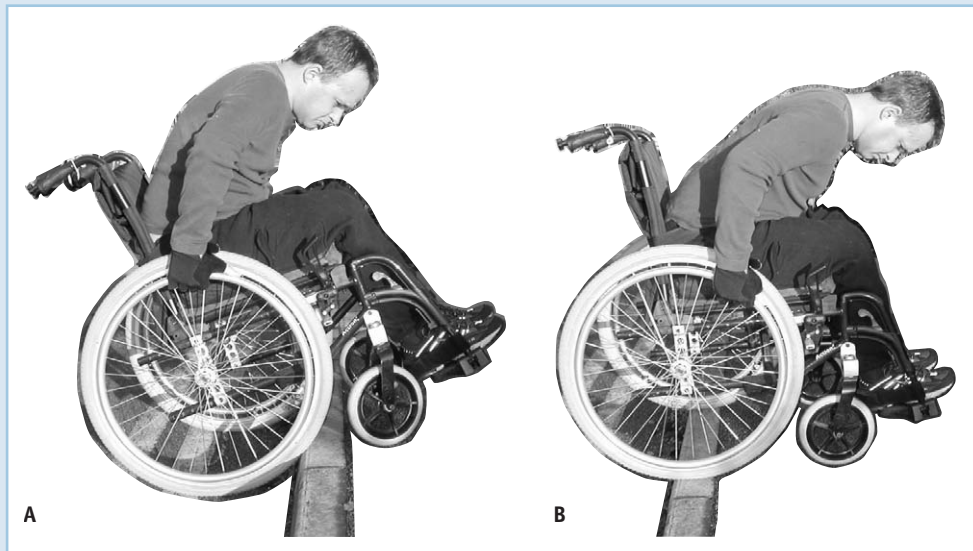
Figure 11.10 A: Pushing up a kerb. B: Descending a kerb. Patient with a lesion at T6.

To descend a kerb

With the back to the kerb, lean well forward and push slowly backwards until the rear and then the front wheels roll down the kerb (Fig. 11.10B).

To 'jump' the chair sideways

This manoeuvre can be useful when turning into a doorway from a narrow passage:

1. Apply the brakes.
2. Lean away from the back of the chair.
3. Grip the highest point of the wheel rims.
4. Lift the buttocks off the chair.
5. Quickly lift the wheels up and sideways before the buttocks descend again to the seat.

To mount and descend a flight of stairs in a high performance wheelchair

To go up and down a flight of stairs, each step must be deep enough to accommodate the weight-bearing section of the wheel. Within normal limits, the height of the step is not a limiting factor. This manoeuvre is only taught to patients who have already mastered all other activities in the wheelchair and who are willing to undertake the risks involved in learning the procedure.

To go up a flight of stairs with the rail on the right

Action of the therapist. The therapist can assist using either of two methods:

● Stand behind the patient, holding the chair handle with one hand and grasping the stair rail with the other to anchor both herself and the patient (Fig. 11.11A). For wheelchairs without handles, a strap secured to the back-strengthening bar can be used.
● Stand on one side of the patient and control the twist of the chair by holding the wheel on the step whilst the patient alters the position of his arms to pull up to the next step (Fig. 11.11B). Should assistance continue to be required this method can be taught to relatives or friends to enhance mobility in the community.

Action of the patient
1. With the chair close to the rail and the rear wheels against the step, stretch the right arm back and grasp the stair rail (Fig. 11.12A).
2. Lean back and balance on the rear wheels.
3. Grasp the right wheel rim with the left hand as far down the wheel as the patient can reach.
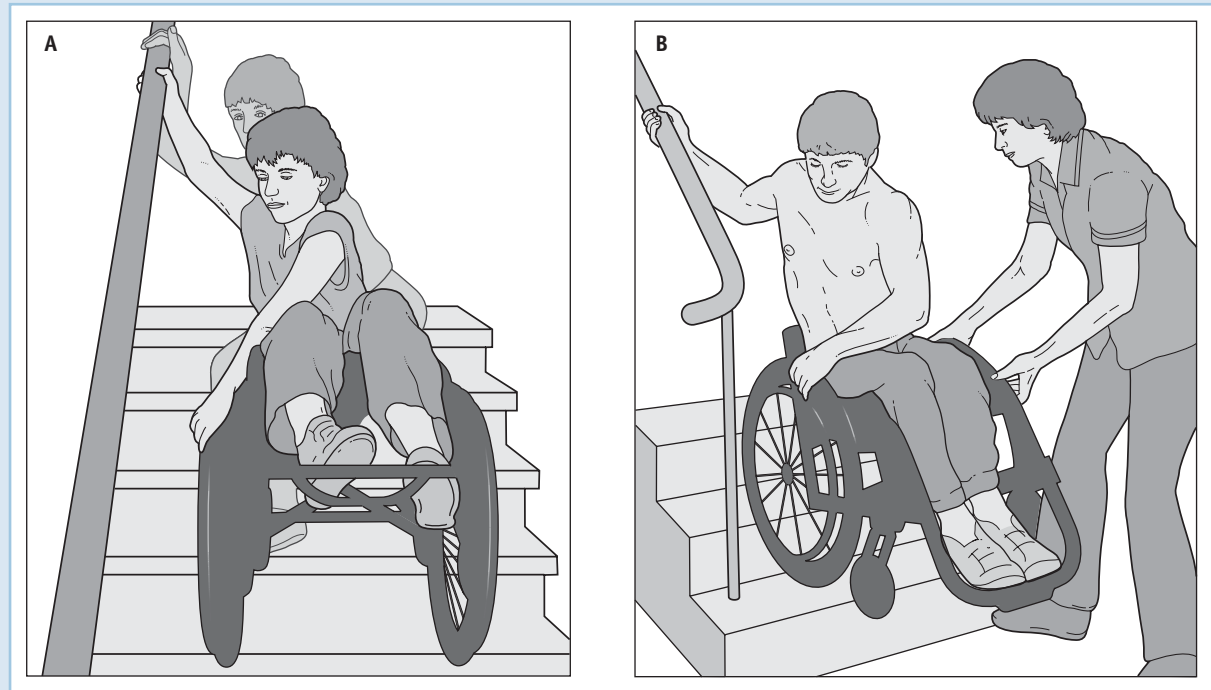
Figure 11.11 A: Ascending a flight of steps with assistance from behind. Patient with a complete lesion below T11. B: Ascending a flight of steps with assistance from below. Patient with a complete lesion below T12.

4. Pull the arms towards each other and ascend the step (Fig. 11.12B).
5. Hold the right wheel firmly against the next step with the left hand and slide the right hand up the rail.
6. Move the left hand down the wheel.

Repeat steps 4–6 to ascend each subsequent step.

To go down a flight of stairs

The steps are descended backwards.
   Method 1 (using a rail on the left):

1. Position the chair close to the rail.
2. With the left hand, grasp the rail approximately level with the shoulders.
3. With the right hand, grasp the top of the right wheel and/or wheel rim.
4. Lean forwards and allow the chair to move backwards down the step, controlling it with the right hand (Fig. 11.13).
5. As the wheel descends onto the step, sit a little more upright and stabilize the chair. Lower the left hand on the rail and
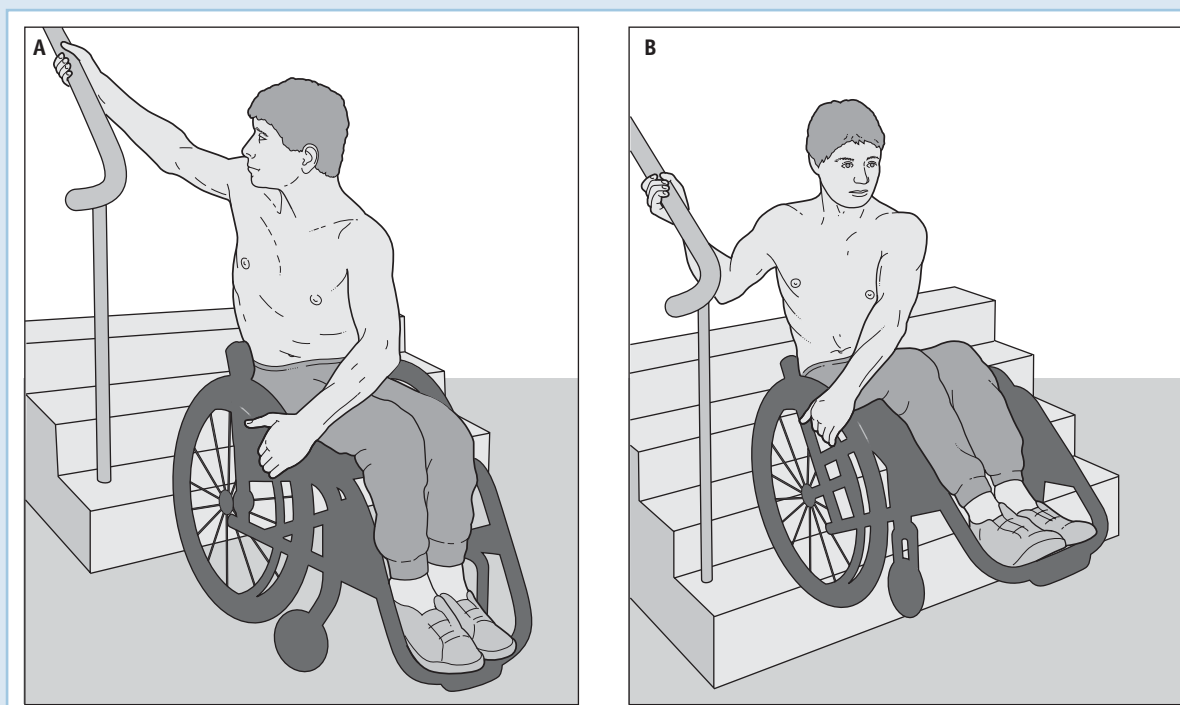
Figure 11.12 Ascending a flight of steps. Patient with a complete lesion below T12.
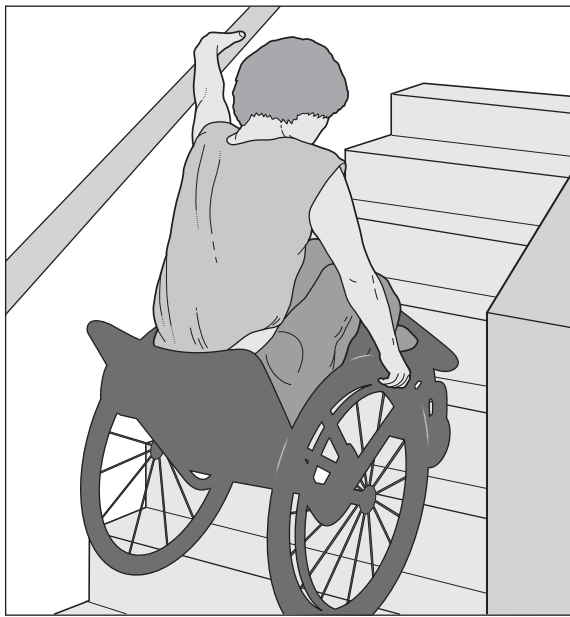
Figure 11.13 Descending a flight of steps holding rail and wheel. Patient with a complete lesion below T10.

repeat 4 to go down the next step. (The footplates may bump onto the upper step as the chair descends.)

6. The left arm moves gradually down the rail with the chair. There is a tendency for the chair to twist as it descends.

Method 2 (using a rail on the right): Those patients who are both exceptionally skilled and strong may descend steeper steps in the following way:

1. With the left forearm held close to the chest, grasp the rail with the left hand.
2. Rotate the upper trunk and grasp the rail approximately midway between the top and next step with the right hand (Fig. 11.14A).
3. Lean on the rail to take some of the body weight; great care must be taken not to pull the body out of the wheelchair.
4. In quick succession, let first one wheel and then the other descend the step. The chair twists during this manoeuvre and it is difficult to hold it with only one wheel on the step (Fig. 11.14B, C).

The safest and easiest way to descend a flight of stairs backwards is to use two rails if both can be reached comfortably. The wheelchair is lowered one step at a time as in method 1.
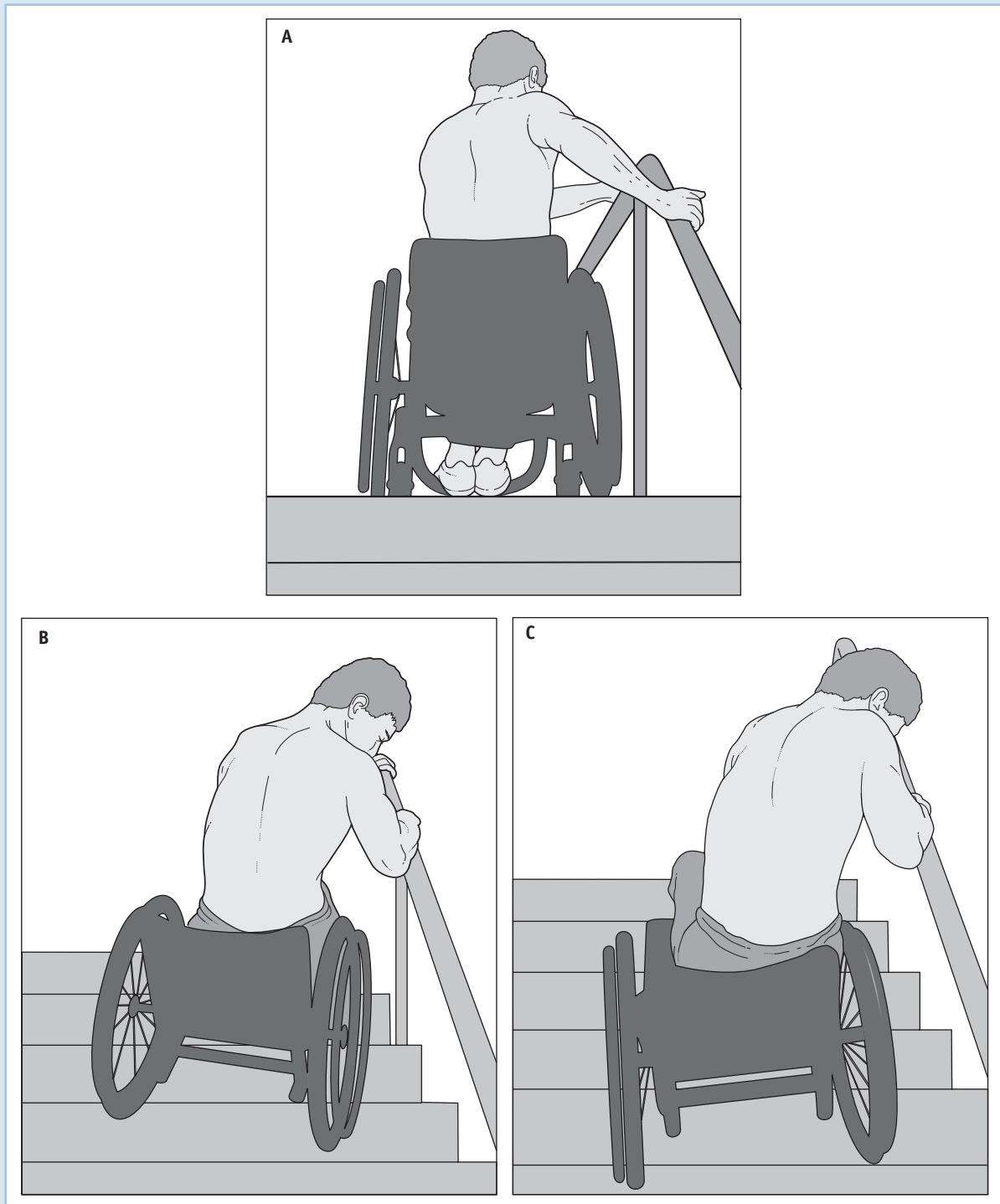
Figure 11.14 Descending a flight of steps holding only the rail. Patient with a complete lesion below T12.

In either method, the therapist stands behind the chair, controlling its descent as necessary.

To descend shallow steps in a high performance wheelchair

Tip the chair onto the rear wheels and lower the chair onto the next step as in going down a kerb. Stop on each step to ensure continued control (Fig. 11.15).

To transfer the high performance wheelchair into the car

Action of the patient
1. Move the driver's seat as far back as possible and recline the back of the seat.
2. With the rear wheels towards the driver, tip the chair onto the front wheels (Fig. 11.16A).
3. Rest the top of the backrest against the open door.
4. Remove the left wheel (Fig. 11.16B).
5. Pull the chair towards the car and remove the right wheel (Fig. 11.16C).
6. Turn the chair until the seat faces the driver.
7. Grasp the front of the seat with the right hand and hold the top of the backrest with the left hand (Fig. 11.16D).
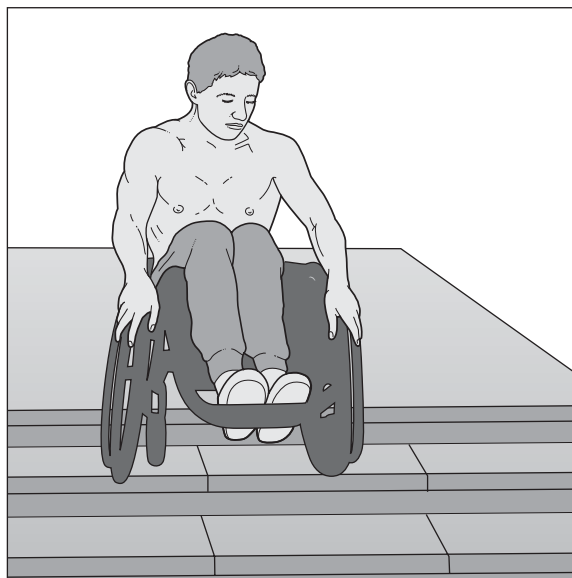
Figure 11.15 Descending shallow steps without a rail in a high performance wheelchair.
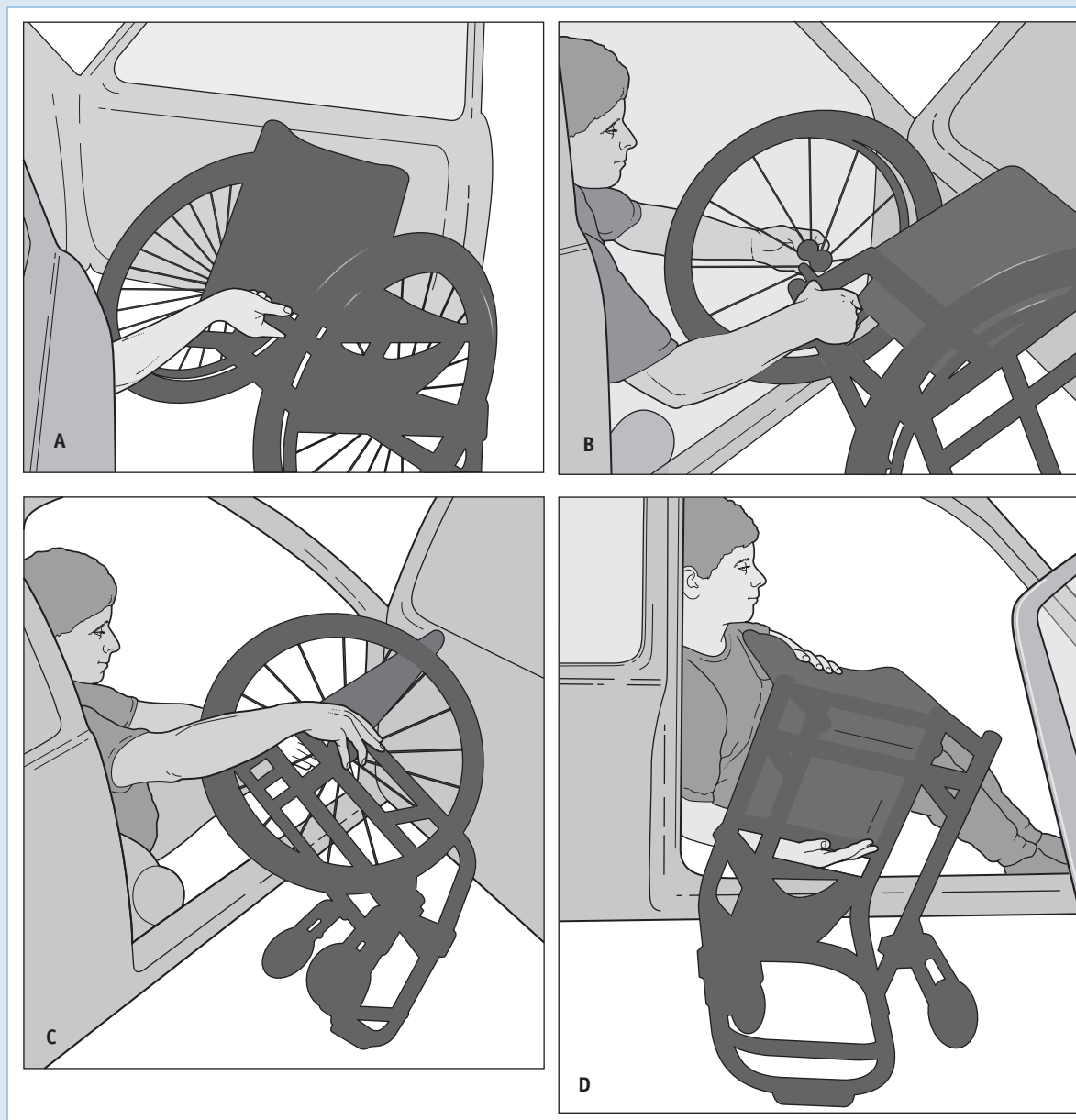
Figure 11.16 Transfer of a high performance wheelchair into a car. Patient with a complete lesion below T12.

8. Lean against the back of the car seat and lift the chair across the body and into the back of the car (Fig. 11.6E, F).

Reverse the procedure to take the chair out of the car.
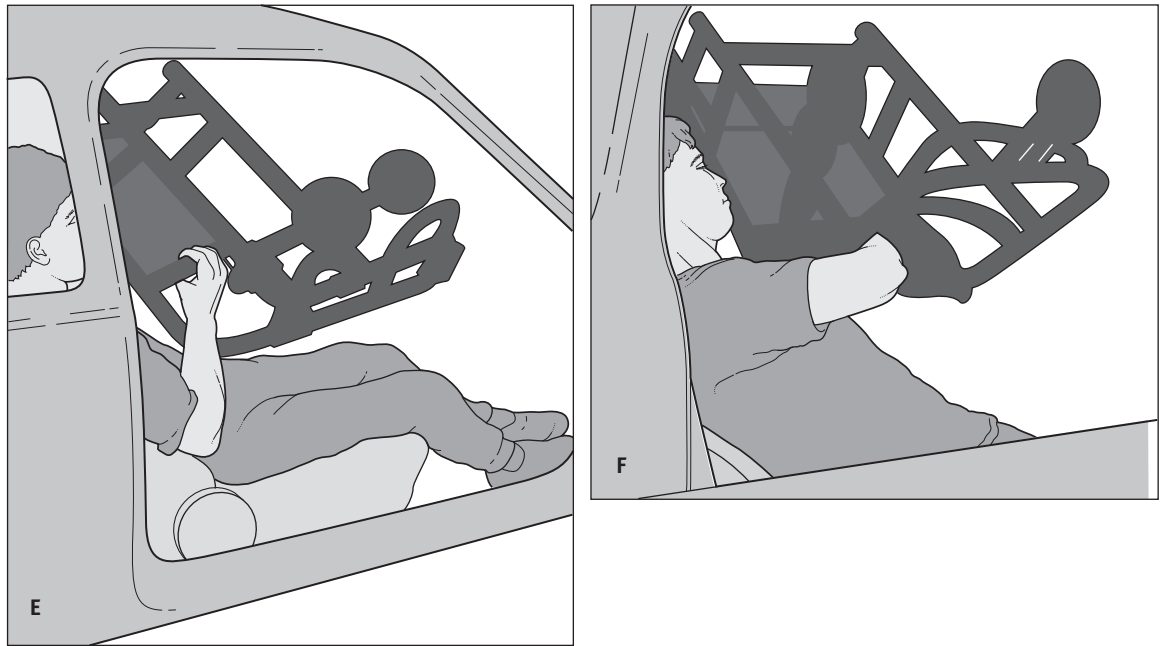
Figure 11.16 cont'd

To transfer wheelchairs without removable wheels into a car

Patients can transfer the wheelchair into the car through the front passenger door. The chair is accommodated either in front of or behind the seat, which is adjusted accordingly.

Method 1

1. Transfer into the car through the passenger door.
2. Fold the wheelchair, leaving the brakes off.
3. Lift the front wheels of the chair into the car.
4. Transfer to the driver's seat.
5. Pull the chair into the car.

Method 2

Alternatively, after step 2 of method 1:

3. Transfer to the driver's seat.
4. Lean across the passenger seat and tip the chair onto its rear wheels.
5. Pull the chair, rear wheels first, into the car.

The efficiency of either method depends largely upon the physical proportions of the patient, and the best way should be found by trial and error. To get the chair out of the car, the procedure is reversed. It is easier to push the chair out when the rear wheels are adjacent to the door, i.e. using method 1.

Some cars can be adapted with a sliding door in place of the passenger door, and a hoist for loading the wheelchair.

TRANSPORT

Both paraplegic and tetraplegic patients can have their own cars converted to hand controls. A patient with a lesion as high as C5 can drive a car providing it has automatic transmission. Adaptations for patients with special needs, e.g. those with incomplete lesions, are developed on an individual basis. Patients with paralysis of both lower and one upper limb can drive (Dollfus et al 1983).

Many spinal units have facilities for driving assessment. Most patients learn to drive through national organizations.

Some makes of cars and vans can be adapted with a ramp or hoist to give access to the driving position for the patient in his wheelchair. This is particularly useful for those who are able to drive but unable to transfer, e.g. those in electrically powered chairs.

Some car rental firms have adapted vehicles for disabled users. Automatic rented cars can be quickly adapted to accommodate a paraplegic driver, enhancing the possibilities of independent travel (Dollfus et al 1983).

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Transfers

For patients with spinal cord injury, transfers fall broadly into three groups:

1. those in which the feet are lifted and the trunk moves horizontally, e.g. transfer to plinth or bed
2. those in which the feet are at floor level and the trunk moves horizontally, e.g. transfer to toilet or easy chair
3. those in which the feet remain on the floor and the trunk moves vertically, e.g. transfer to bath or floor.

The first group is the most stable. The second requires skilled balance. The third requires considerable strength.

These factors explain the division of the transfers into initial and advanced for both tetraplegic and paraplegic patients. All patients commence with the transfers in group 1. Tetraplegic patients without triceps progress only to the easiest of those in group 2. To lift without triceps, the patient must have a strong deltoid to hold the shoulder joint in three planes, an elbow joint capable of being locked in hyperextension, and sufficient mobility in the wrist joint to allow weight to go through the arm with the palm on a flat surface. As can be seen in the following list, advanced transfers for the most active tetraplegic patient with triceps and wrist control only reach group 3 with the bath transfer, whereas advanced transfers for paraplegic patients are in group 3 exclusively.

For patients with tetraplegia

- *Initial transfers*
  – chair to plinth
  – removal of footplates
- *Advanced transfers*
  – chair to bed
  – chair to car
  – chair to toilet
  – chair to easy chair
  – chair to bath.

For patients with paraplegia

- *Initial transfers*
  - chair to plinth or bed, sideways and forwards
  - chair to car
  - chair to toilet, sideways and backwards
  - chair to easy chair
- *Advanced transfers*
  - chair to bath
  - chair to floor.

TECHNIQUE

The techniques described are those most commonly used for the various transfers. Slight variations will occur depending upon the individual height, weight, agility and age of the patient, and the level of the lesion.

All transfers, except for that from the chair to the floor, are described for the tetraplegic patient. It is a simple matter to adapt the transfer for a patient with a lower lesion. The patient is always to lift, and not drag, his body to avoid knocking his limbs on the furniture or his buttocks on the wheel.

Whilst transferring the buttocks, the head, shoulders and trunk must be flexed with the head well forward over the knees. It is essential that the plinth be the same height as the wheelchair for transfer training, and, ideally, all surfaces should be at the correct height. Tetraplegic patients will achieve a transfer only under these conditions, but after training, most paraplegic patients will transfer to any surface without difficulty. The mechanics of transferring weight are covered in Chapter 9. To prevent damage through shear forces, a shield of a malleable synthetic substance can be made to fit over the upper quadrant of the wheel during transfers. This can be useful for patients, particularly those with cervical lesions, who find difficulty in learning to transfer.

The chair

In all cases, the chair must be in the position of maximum stability. It may slip during the transfer if the tyres are worn or the floor is slippery, or if the patient pushes horizontally instead of vertically. If possible, the footplates are removed but this will depend upon their design. This is not necessary for independent transfer to the plinth or bed. It is dangerous to pull up the footplates without swinging them out, since they may catch on the malleoli and cause bruising or damage to the skin.

TRANSFERS BY THE THERAPIST

When *one* therapist transfers a patient who can give little or no assistance, the therapist must take great care to position herself and the patient correctly in order to avoid undue strain.

To transfer from chair to plinth with the patient moving to his right

Position of the chair
The chair is angled at approximately 30° to the side of the bed.

Position of the patient
1. Bring the buttocks forward in the chair until the feet are on the floor.
2. Flex the trunk and hips until the patient is lying over the therapist's right shoulder (Fig. 12.1A). The therapist always has her head turned in the direction of the movement (Fig. 12.1B).

Action of the therapist
1. Brace the feet and knees against the outside of the patient's feet and knees.
2. Flex the hips, keep the back straight and hold the patient under the buttocks.
3. Rock the patient against the knees and move him across to the plinth (Fig. 12.1C, D).

If preferred, a transfer belt can be used instead of holding the patient under the buttocks. The belt is made of reinforced strong webbing. It has three or four loops or holding straps along its length. The belt is fastened securely round the patient's waist. The therapist grasps either one of the loops or the bottom of the belt on each side.

A sliding board can also be used to assist in the transfer. Boards are available in a variety of shapes, e.g. straight when the board has to be placed in front of the rear wheel, or horseshoe-shaped when the board fits around the wheel.
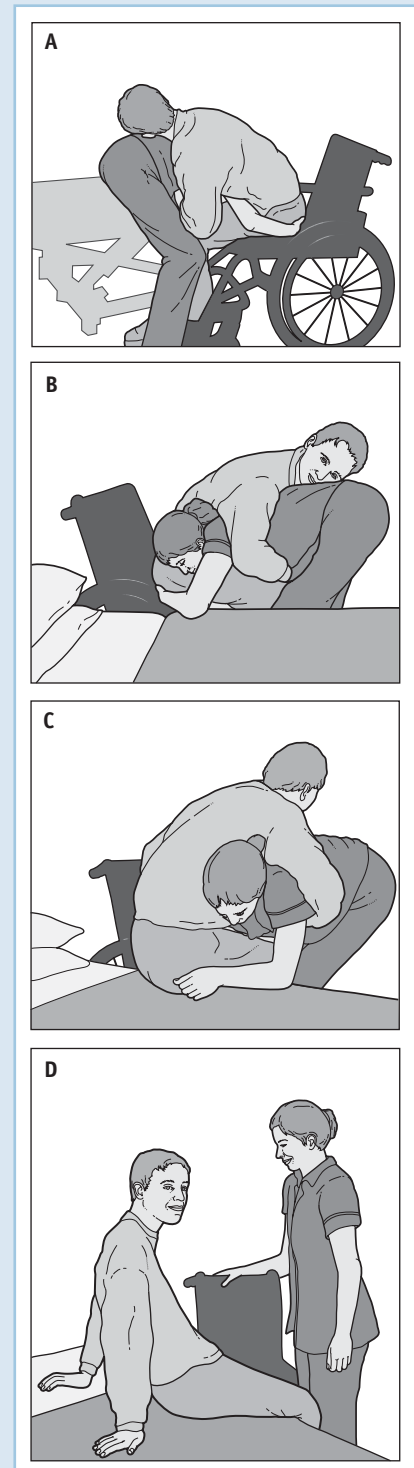
Figure 12.1 Transferring a patient with a lesion above C5.

The 'cervical lift' using two therapists

Where other methods of transferring the patient are not possible and mechanical equipment is not available, this method is considered the safest for both patient and therapists. The lift can be used to transfer a patient to and from the bed, a second chair or from the floor in an emergency.

Transfer from bed to chair

The chair is angled at approximately 30° to the side of the bed.

Position of the patient

The patient is in long-sitting with the head and trunk flexed and the arms folded across the lower ribs.

Position of the therapists to transfer the patient to the left

Operator 1 stands behind the patient with one leg on each side of the right rear wheel. She holds the patient around the thorax, grasping the patient's folded arms. The therapist must grip the lower thorax with her forearms to prevent the upper spine from elongating as the patient is lifted.

Operator 2 is in step-standing facing the bed. She grasps the legs with one arm high up under the thighs and the other under the lower legs. The heavier the patient, the higher up the legs the grasp needs to be (Fig. 12.2A).

On a prearranged signal, both operators lift together, operator 1 taking a step sideways and operator 2 a step backwards. The patient must be lifted high enough to avoid knocking the buttocks against the rear wheel or the spine against the chair handle or backrest support (Fig. 12.2B).
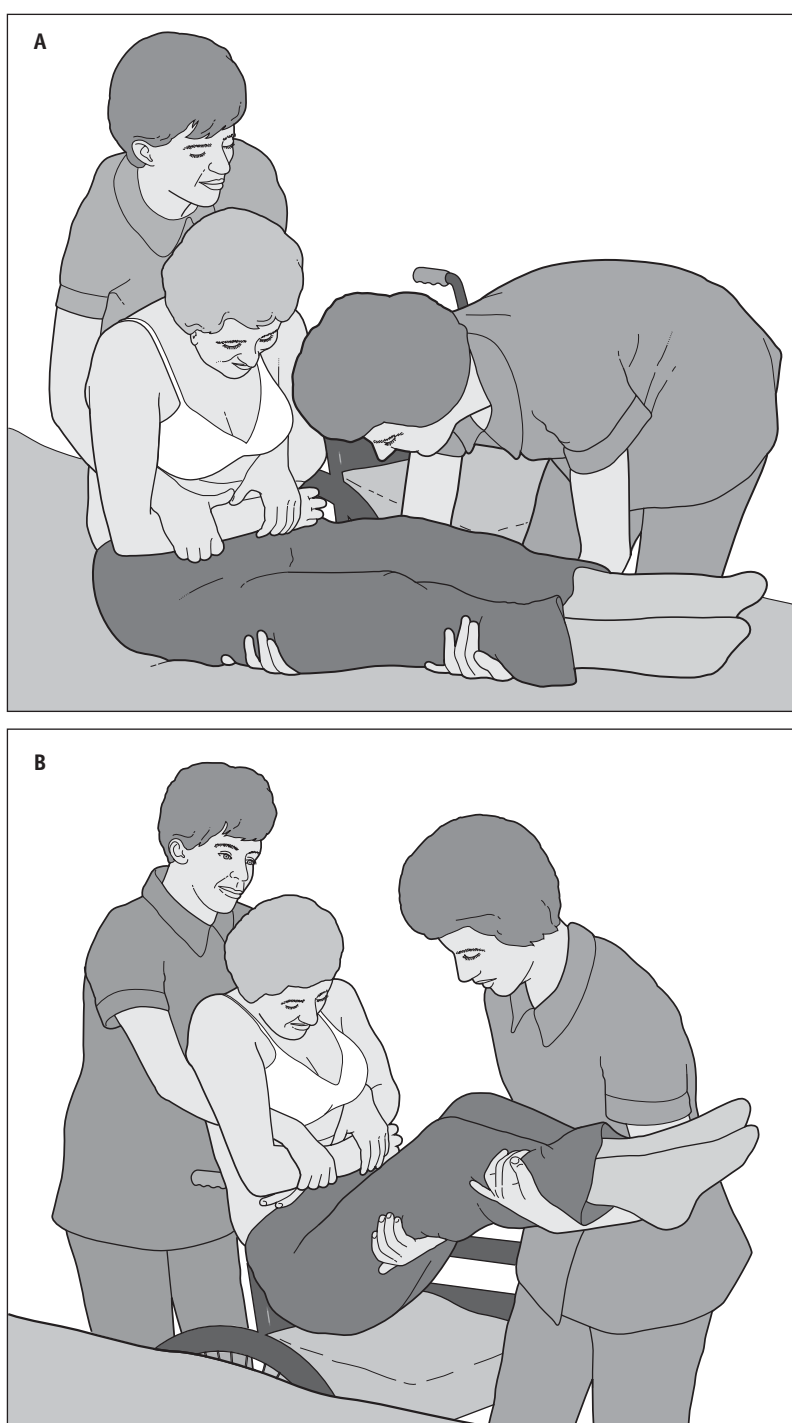
Figure 12.2 Transfer using two therapists.

INDEPENDENT TRANSFERS

Various methods of lifting the buttocks for patients with lesions at different levels are shown in Figure 12.3). The position of the hands and trunk and the use of the head will vary considerably in patients with cervical lesions.

The simplest lift is achieved by pushing down on the armrests or the top of the rear wheel, straightening the elbows and depressing the shoulders (Fig. 12.3A–D). Lifting and repositioning should be done slowly and carefully. Patients with cervical lesions may only be able to lift one side at a time (Fig. 12.3E, F), and those without triceps need to hyperextend the elbows.

To transfer to the plinth (moving to the right)

This transfer consists of three manoeuvres:

- to bring the buttocks forward in the chair
- to lift the legs onto the plinth
- to transfer the trunk onto the plinth.
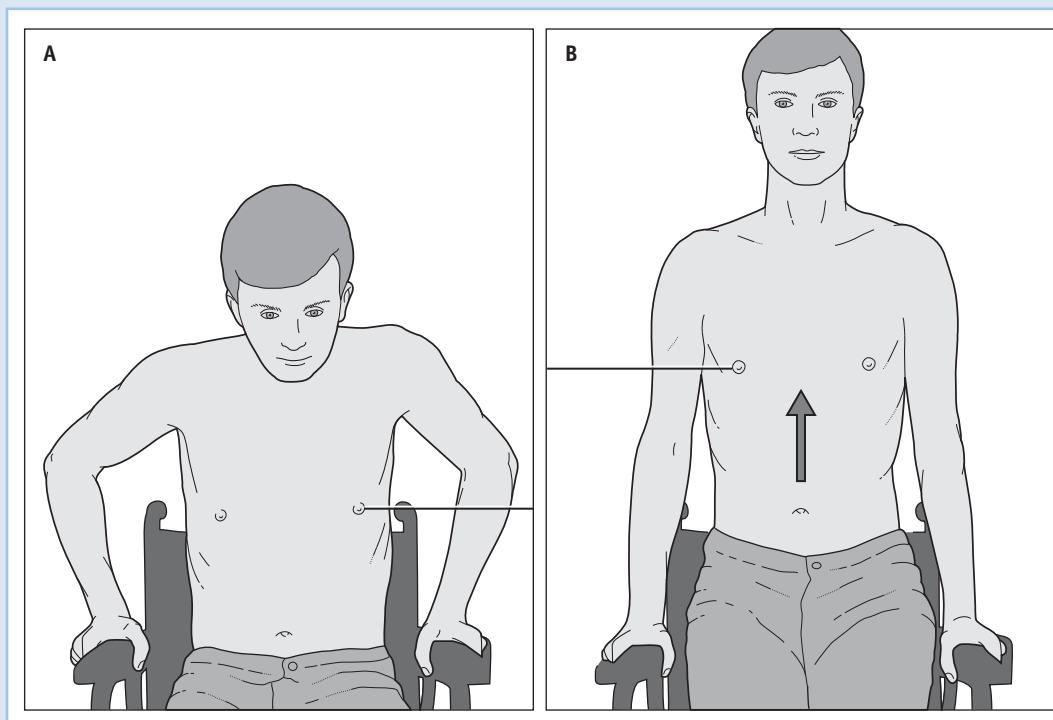
Figure 12.3 Various methods of lifting in the wheelchair.
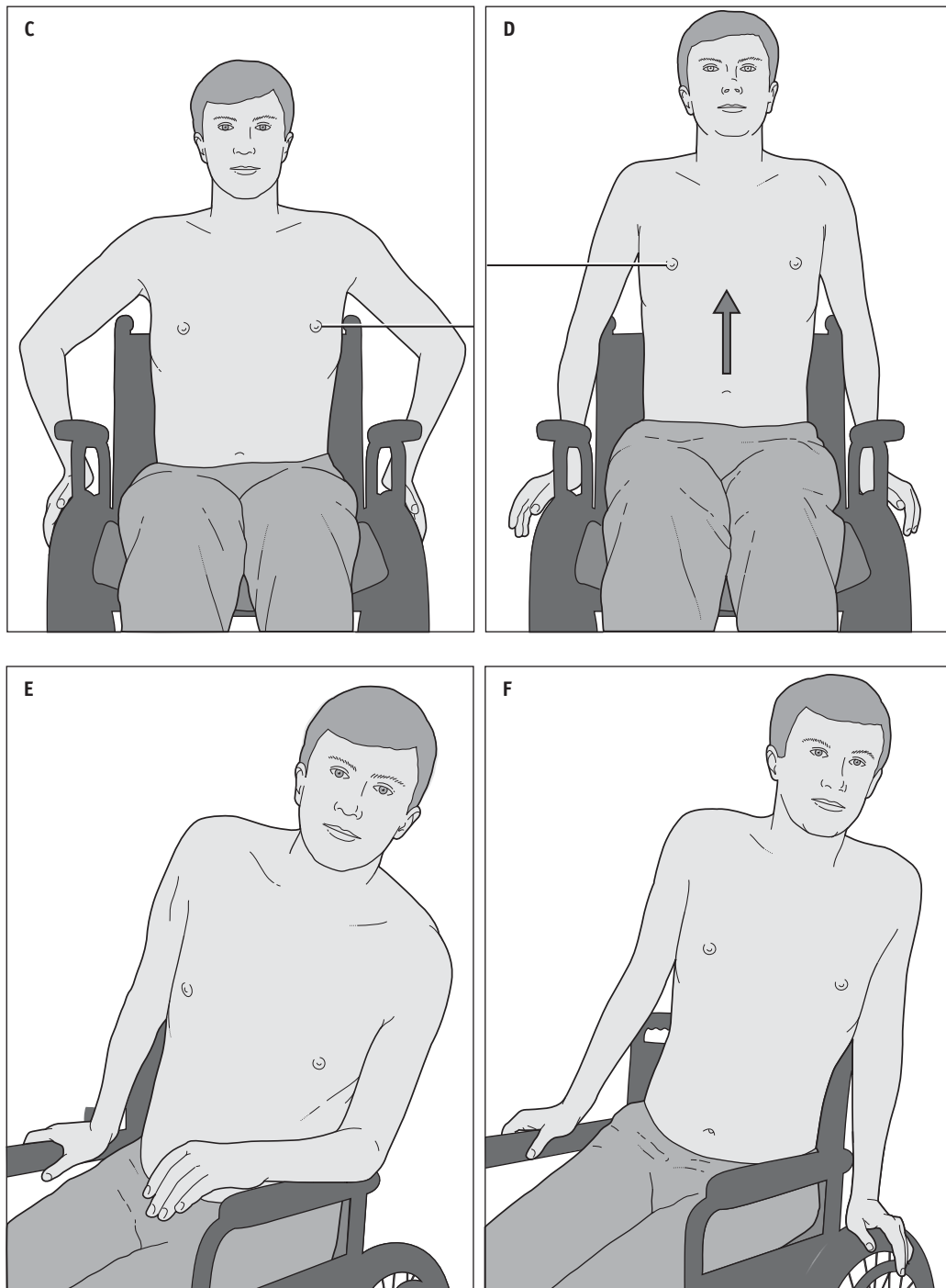
Figure 12.3 cont'd

Position of the chair

Line the chair up with the plinth at an approximate angle of 20°. With the buttocks forward in the chair, this small angle allows the transfer to occur in front of the rear wheel. A shield or a pillow is placed over the rear wheel to prevent injury should the buttocks knock against it during training.

The therapist. The therapist stands in front of the patient, ready to encourage flexion of the head and trunk and to assist or resist the individual movements as necessary.

Action of the patient
To bring the buttocks forward in the chair

1. Extend the right wrist and flex the forearm under the right armrest.
2. Using the right arm, pull the trunk a little to the right and insert the left wrist behind the left hip. If wrist extension is strong, the forearm is pronated; if it is weak, the forearm is supinated (Fig. 12.4A).
3. Push on the right elbow on the back of the armrest. Flex the left elbow and push the left hip forward and at the same time extend the head and lean backwards. The cushion will slide forward with the leg (Fig. 12.4B). Repeat to bring the right hip forward. Figure 12.4C shows an alternative method for bringing the hips forward by pushing with both hands behind the hips at the same time.

To lean forward over the legs, place both hands on the rear wheels and at the same time flex the head, protract the shoulders and thrust forward on the hands (Fig. 12.4D).

To lift the legs onto the plinth

1. To maintain balance, hook the right forearm round the right chair handle.
2. Put the left wrist under the right knee and lift the leg by flexing the elbow (Fig. 12.4E). Pull the knee up to the chest by pulling the trunk upright with the right arm and leaning back in the chair.
3. Rest the left wrist on the right armrest and bring the right arm forward onto the plinth (Fig. 12.4F).
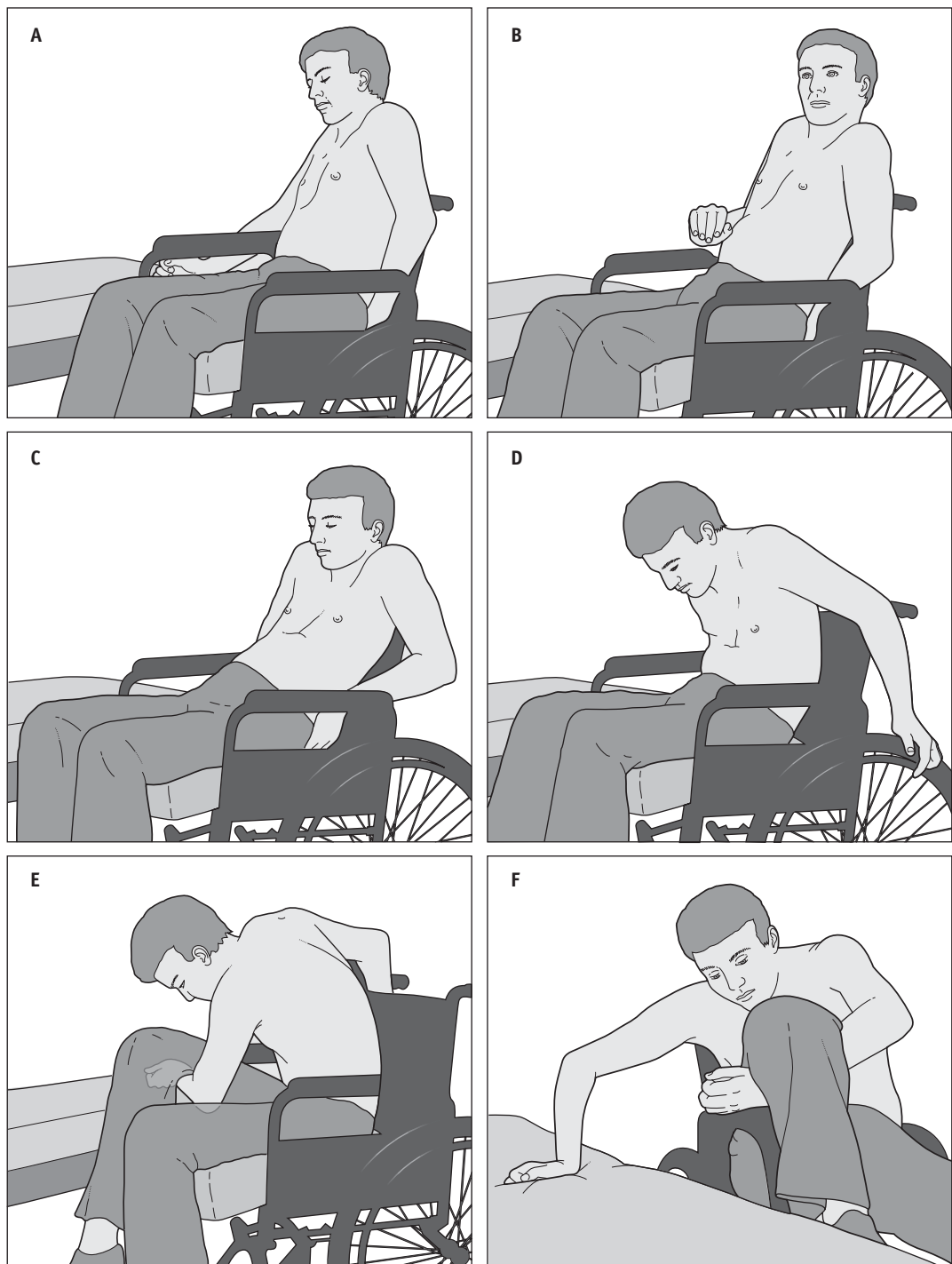
Figure 12.4 Transferring to a plinth. Patient with a complete lesion below C6 without triceps.

4. Change the position of the arms so that the right wrist holds the knee, with the forearm supported on the armrest. The supinated left forearm moves down to support the lower leg (Fig. 12.4G).
5. Push the heel onto the plinth. Remove the right armrest.
6. Lift the left knee as for the right and hold the hip and knee in as much flexion as possible.
7. Maintaining balance on the left elbow, lift the lower leg with the right wrist (Fig. 12.4H).
8. Lean over to the right and cross the left leg over the right (Fig. 12.4I).

To transfer the trunk onto the plinth

The basic technique for this activity is the same as for lifting sideways on the mat:

1. Place the right hand on the plinth level with the upper thigh and the left hand on the cushion (Fig. 12.4J), or on the armrest where possible.
2. With the head and trunk flexed, lift upwards and then to the right (Fig. 12.4K).
3. Several lifts will be necessary to complete the transfer (Fig. 12.4L).

Removal of the footplates

Depending on the type of chair the footplates may need to be removed.
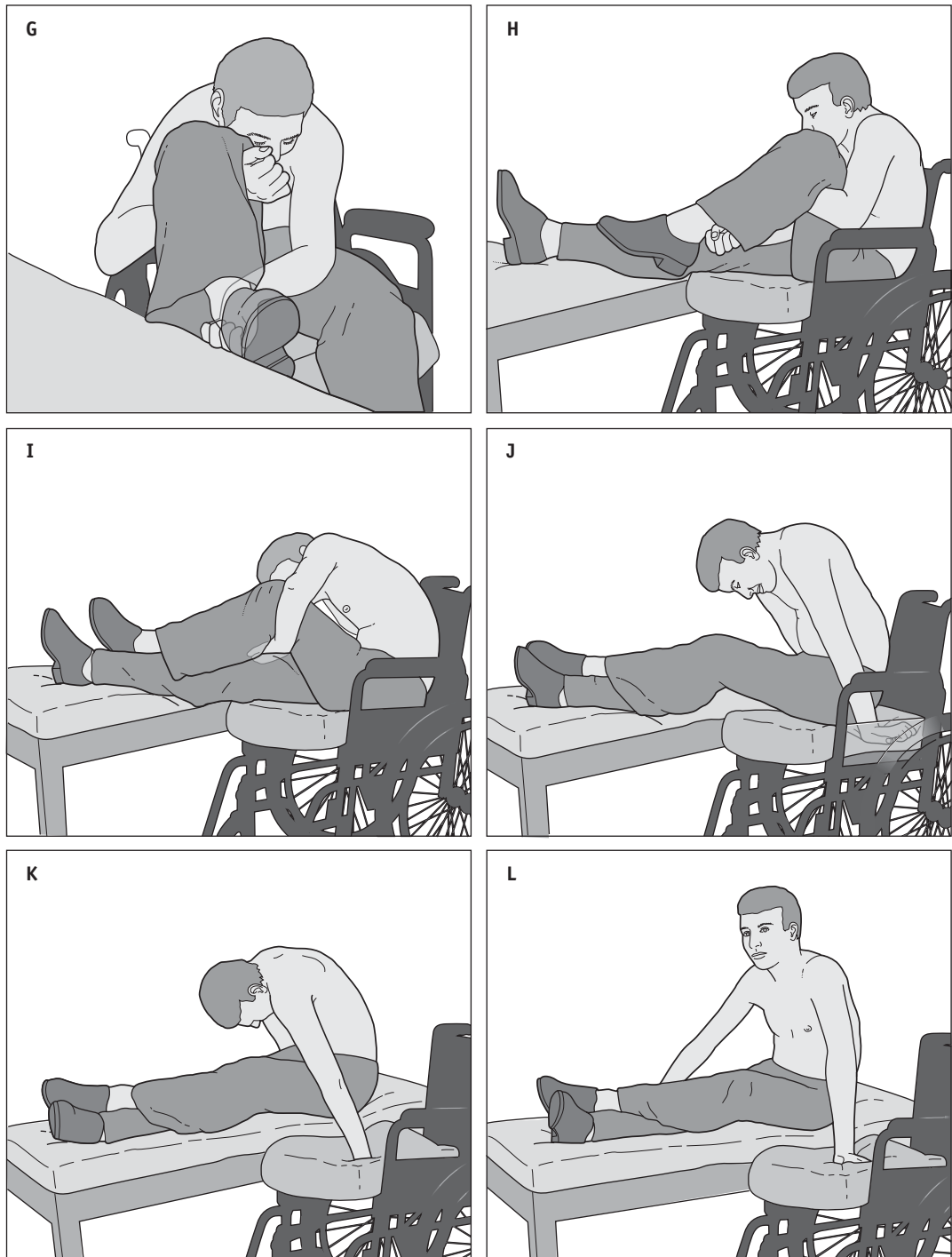
Figure 12.4 cont'd

To remove the right footplate

Action of the patient
Transfer the right foot to the left footplate or to the floor

1. Balance is maintained with the left hand on the armrest if the patient has a lesion at C7, or with the left elbow or wrist hooked around the left chair handle if triceps is paralysed.
2. With the right wrist extended under the lower leg (Fig. 12.5A), flex the elbow and lift the foot over to the left footplate (Fig. 12.5B).

Remove the footplate (Fig. 12.5C–F)

1. With the wrist extended, release the lever by pushing it forward with the dorsum of the hand (Fig. 12.5D).
2. Swing back the footplate using extension of the wrist (Fig. 12.5E).
3. Lift the footplate off the bracket using the dorsum of the hand and wrist extension (Fig. 12.5F).
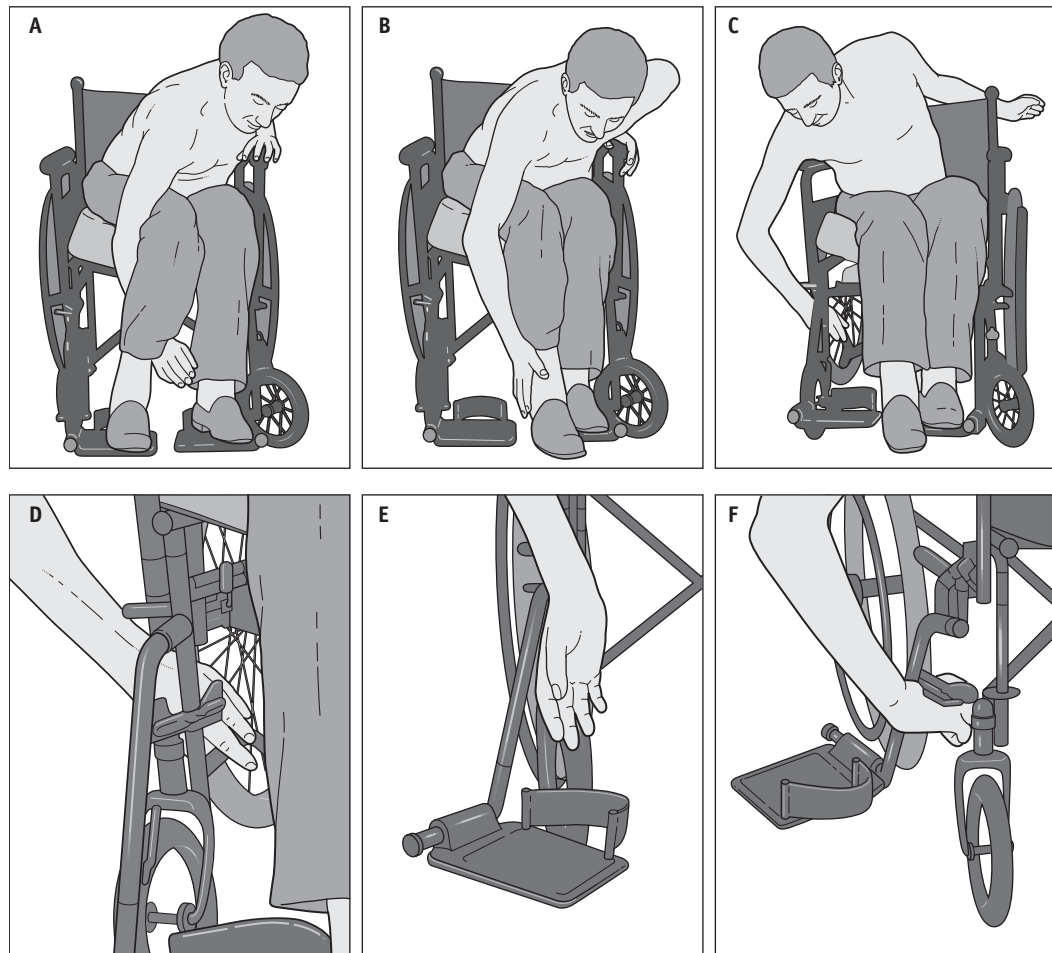
Figure 12.5 Tetraplegic patient removing the footplate.

To transfer to the car (moving to the left)

Some patients with lesions at C6 without triceps, and those at C7 with no hand function, may find that a sliding board facilitates this transfer. The most useful dimensions of the sliding board have proved to be 60 cm × 20 cm × 1.5 cm tapered at both ends. A notch at the end facilitates the handling of the board, and a loop may be necessary for some patients to enable them to remove the board after transfer.

Position of the chair

The chair is angled at approximately 30° to the side of the car. Remove both footplates or, if preferred, only one (the left in the case of Fig. 12.6).

Action of the patient
1. Lift the feet into the car as for transferring to the plinth. Remove the armrest.
2. Place a sliding board under the left thigh.
3. Lift using the left half of the sliding board and the right armrest or chair seat (Fig. 12.6A), keeping the head and trunk well flexed.
4. Repeat the lift as often as necessary, moving the hands a little to the left each time (Fig. 12.6B). The head and trunk must remain flexed with the nose almost touching the steering wheel during the later lifts (Fig. 12.6C).
5. Remove the sliding board from the right and adjust the legs in the sitting position (Fig. 12.6D).
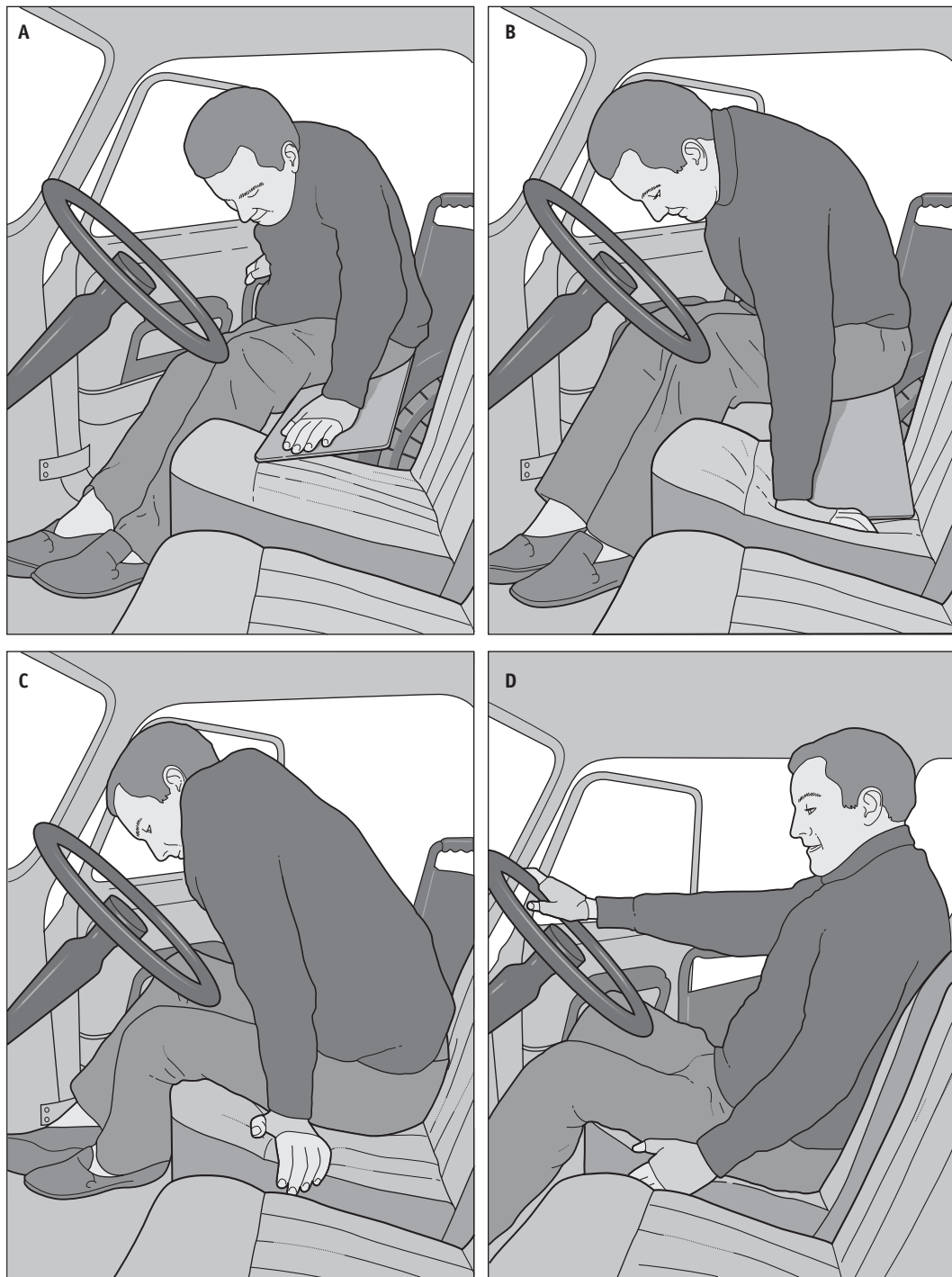
Figure 12.6 Transferring to a car. Patient with a complete lesion below C7 with wrist control only.

To transfer to the toilet (moving to the right)

Position of the chair

Place the chair at an angle of between 50° and 90° to the toilet seat. Many patients find the lift easier with the chair at right angles, because this position brings the armrest furthest from the toilet closer to the handrail. Remove the footplates if necessary.

The therapist
The therapist stands in front of the patient, bracing the patient's knees and feet and holding under the buttocks or in the trouser band. As the patient's proficiency increases, the therapist gradually withdraws her support.

Action of the patient
1. Check the position of the feet to see that they are flat on the floor and vertically beneath the knees so that the weight is over them. Remove the right armrest.
2. Keep the head and shoulders flexed throughout the transfer.
3. With the left hand on the armrest and the right on the rail, lift to the right (Fig. 12.7A, B).
4. With the left hand on the wheel and the right hand on the rail, lift further back onto the toilet (Fig. 12.7C).

To transfer back to the chair reverse the procedure.

In the absence of a wall rail, the experienced paraplegic patient can lift with his right hand on the toilet seat.
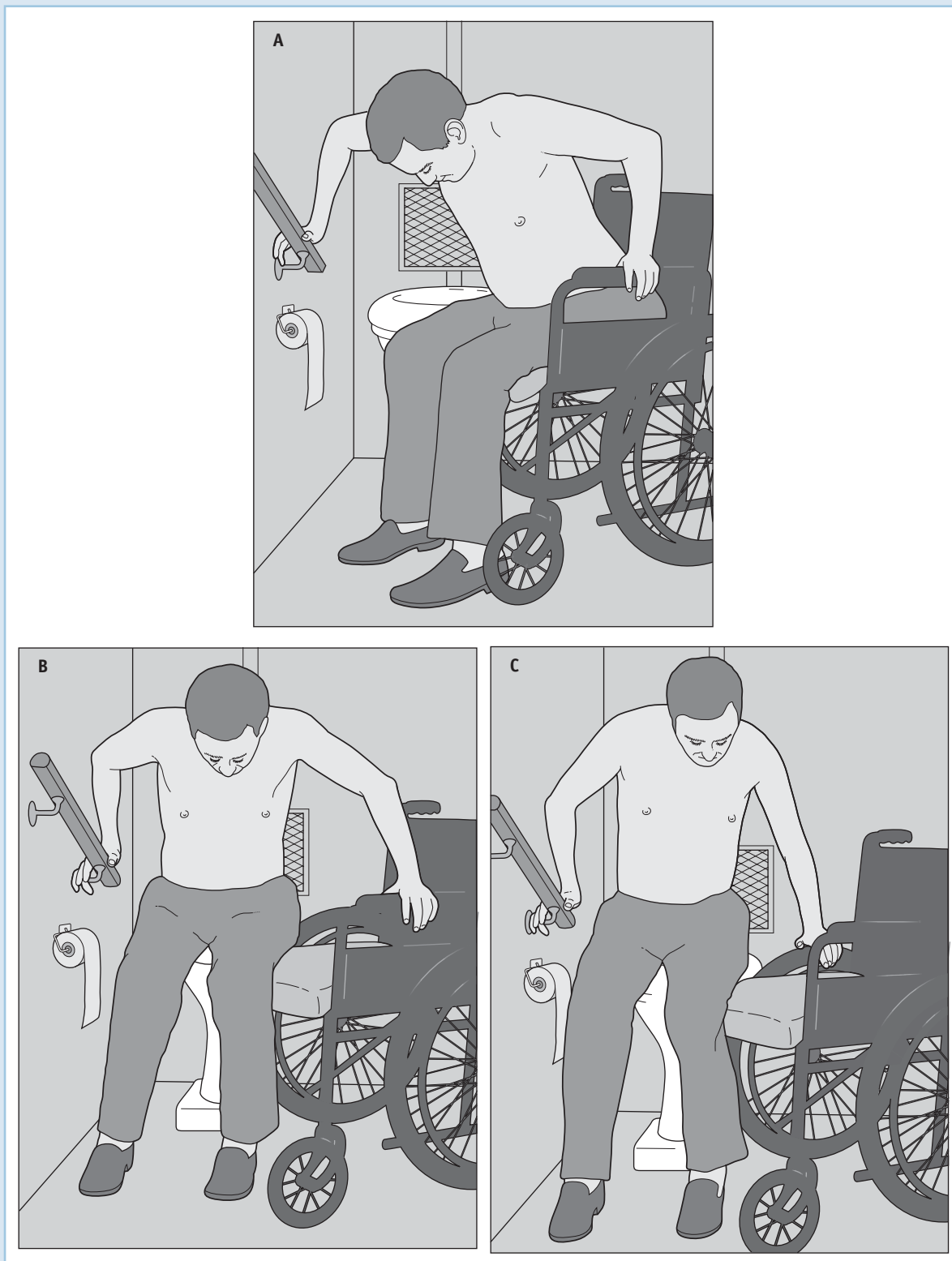
Figure 12.7 Transferring to a toilet. Patient with a complete lesion below C7 with wrist control only. (Note back support on toilet.)

To transfer to the toilet through the back of the chair

This method can be used when spasticity is severe. For example, the patient may be at risk transferring sideways when there is a combination of hip extension and knee flexion spasticity.

The normal backrest can be replaced by one which opens throughout its length by means of a zipper. The patient lifts backwards as shown in Figure 12.8, with one hand on the rail and the other on the toilet seat. Relaxation of the extensor spasticity may be obtained by flexing one or both legs before lifting backwards.

To transfer into an easy chair

This transfer is basically the same as the sideways transfer to the toilet, the arm of the easy chair being used instead of the wall rail. The wheelchair is positioned at right angles to the easy chair, with the front edge of the seat approximately halfway along the seat of the easy chair. This position brings the two lifting points closer together.

To transfer to the bath

The bath is filled with water before entering and drained before leaving. Bath transfer can be accomplished by patients with lesions at C7 and below.

Figure 12.8 Backwards transfer.

To transfer over the bath end

Action of the patient

1. Position the chair so that the feet almost touch the bath.
2. Lift both legs onto the edge of the bath (Fig. 12.9A).
3. Swing away the footplates (Fig. 12.9B).
4. Wheel forward until the chair is adjacent to the bath (Fig. 12.9C).
5. Lift the buttocks forward in the chair.
6. Continue lifting forward with the right arm on the bath edge and the left arm on the armrest (Fig. 12.9D).
7. Transfer the left hand to the bath and lift onto the edge of the bath with the trunk almost fully flexed (Fig. 12.9E).
8. Maintaining the flexion, move the hands along the bath sides and lift, lowering the body into the bath as gently as possible (Fig. 12.9F, G).

To get out of the bath, reverse the procedure, flexing the legs before commencing to lift. Those patients who are unable to lift the whole depth of the bath can use a low wooden bath seat as an interim step. The edge of the seat must be padded and care taken to ensure that the skin is not damaged during the lift.
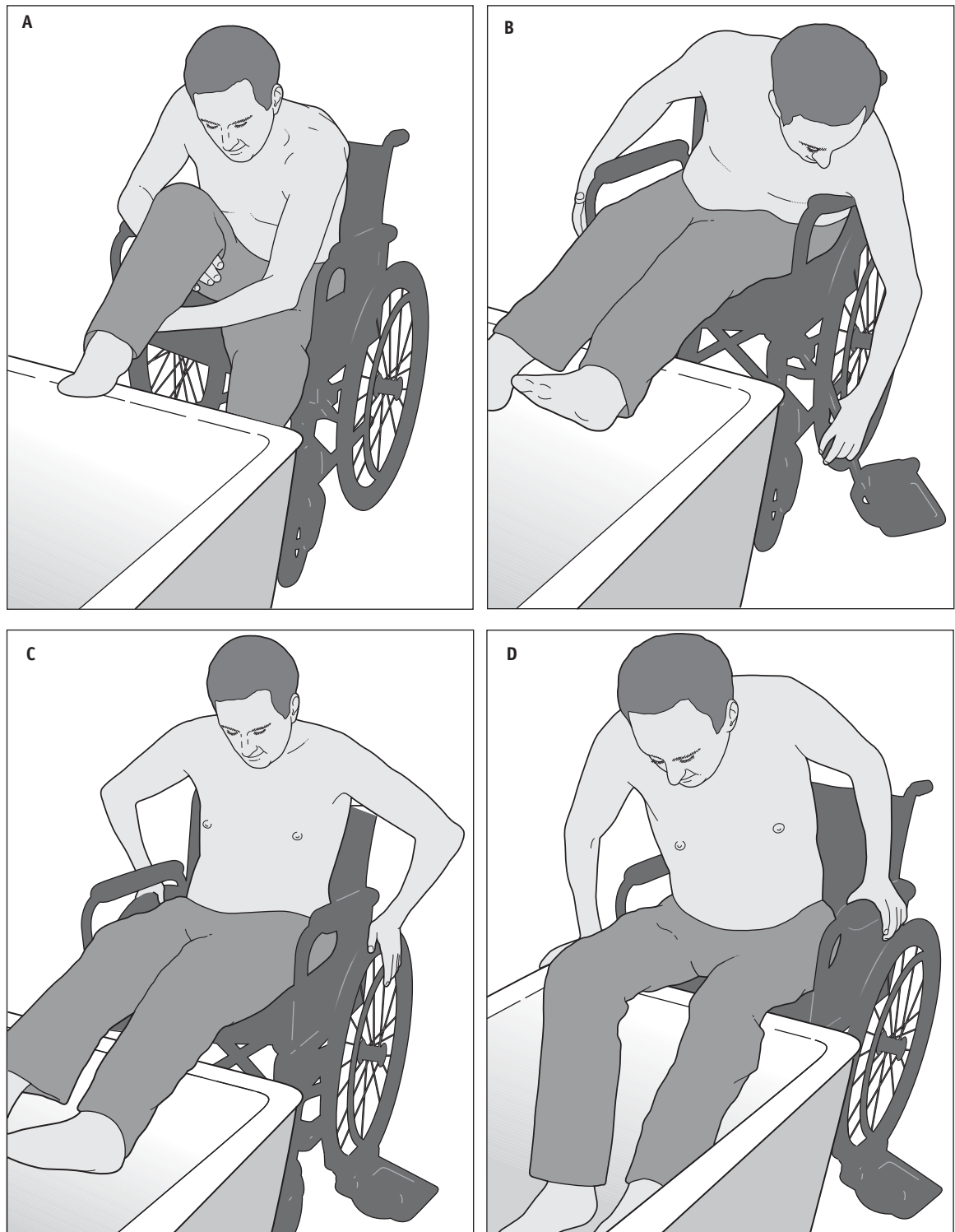
Figure 12.9 Transfer over the bath end. Patient with a complete lesion below C7 with wrist control only.
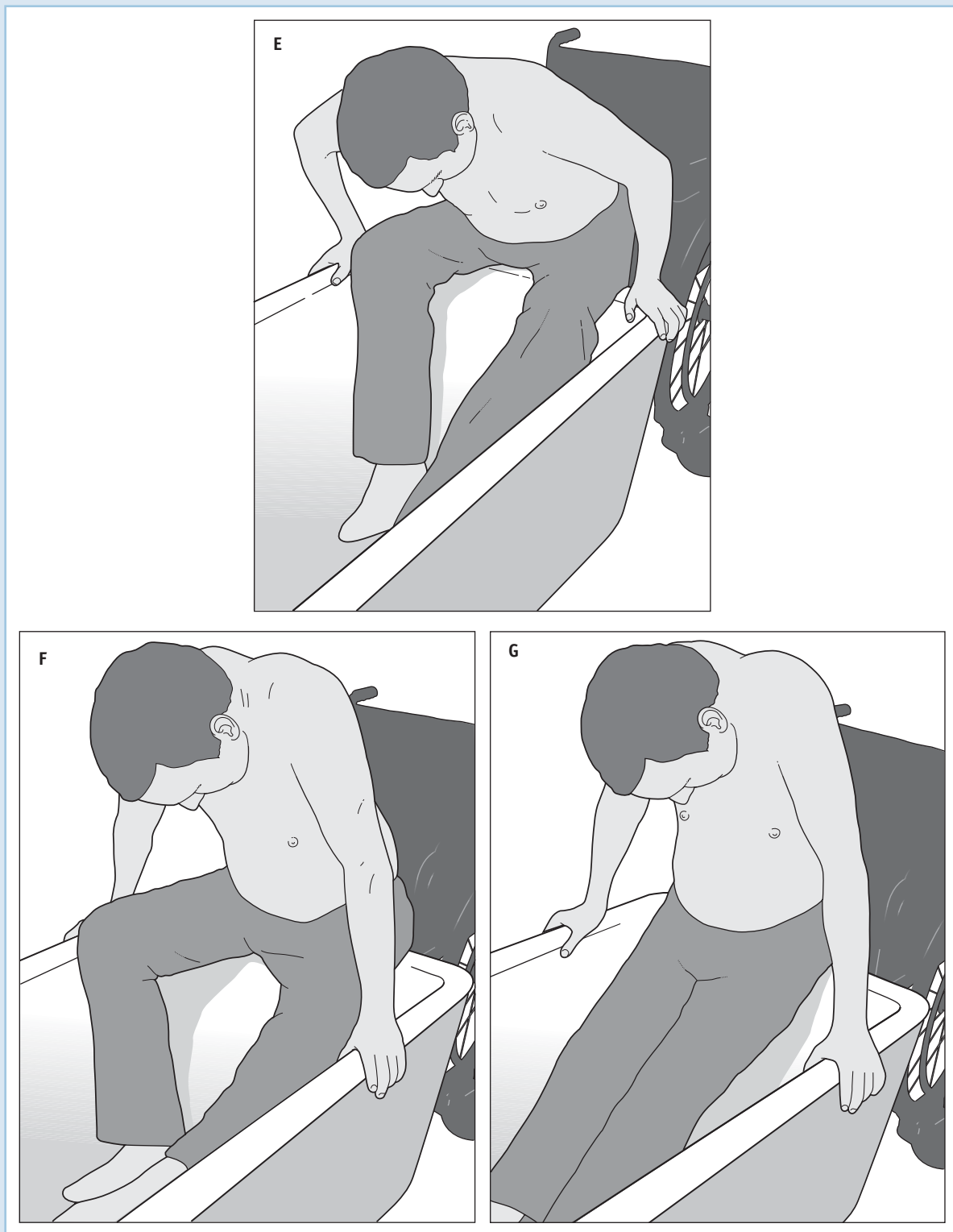
Figure 12.9 cont'd

To transfer over the bath side

Position the chair either sideways at an angle of 30° to the bath or facing the bath:

1. Lift the legs into the bath.
2. Lift onto the bath edge.
3. With one hand on each side of the bath, turn to face the bath (Fig. 12.10).
4. Lift and lower gently into the bath.

Where there is a ledge behind the bath, a combination of these two methods can be used. First, transfer over the side onto the ledge, where the patient is more stable, and from there into the bath, as in Figure 12.9.

Figure 12.10 Transfer over the bath side. Patient with a complete lesion below C8.

To transfer to the floor

The therapist
The therapist stands in front of the patient, correcting his position and assisting him to maintain balance as necessary.

Action of the patient
1. Remove the armrests.
2. Lift with the left elbow on the backrest and the right hand on the wheel, and pull the cushion out with the left hand (Fig. 12.11A).
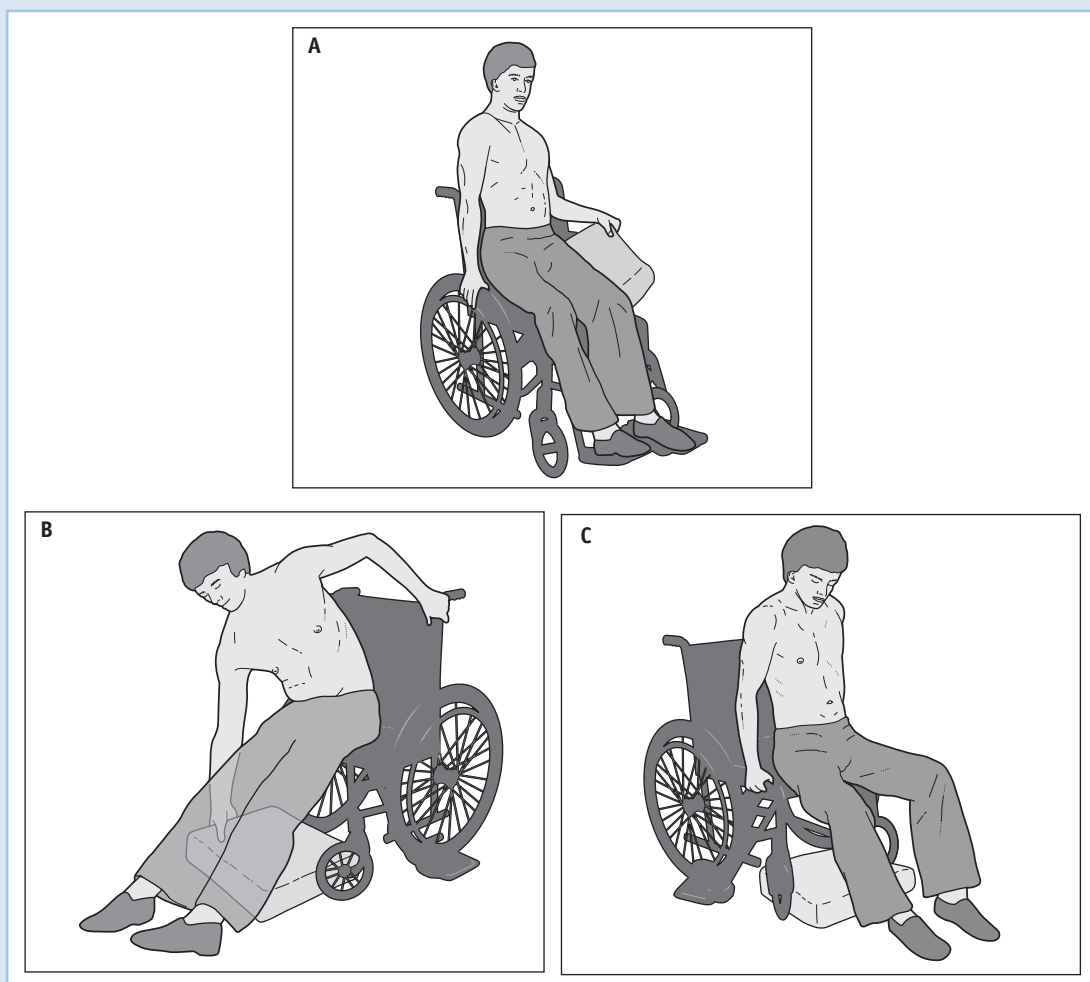
Figure 12.11 A–E: Transfer to the floor. F–I: Transfer back into the chair. Patient with a complete lesion below T11.
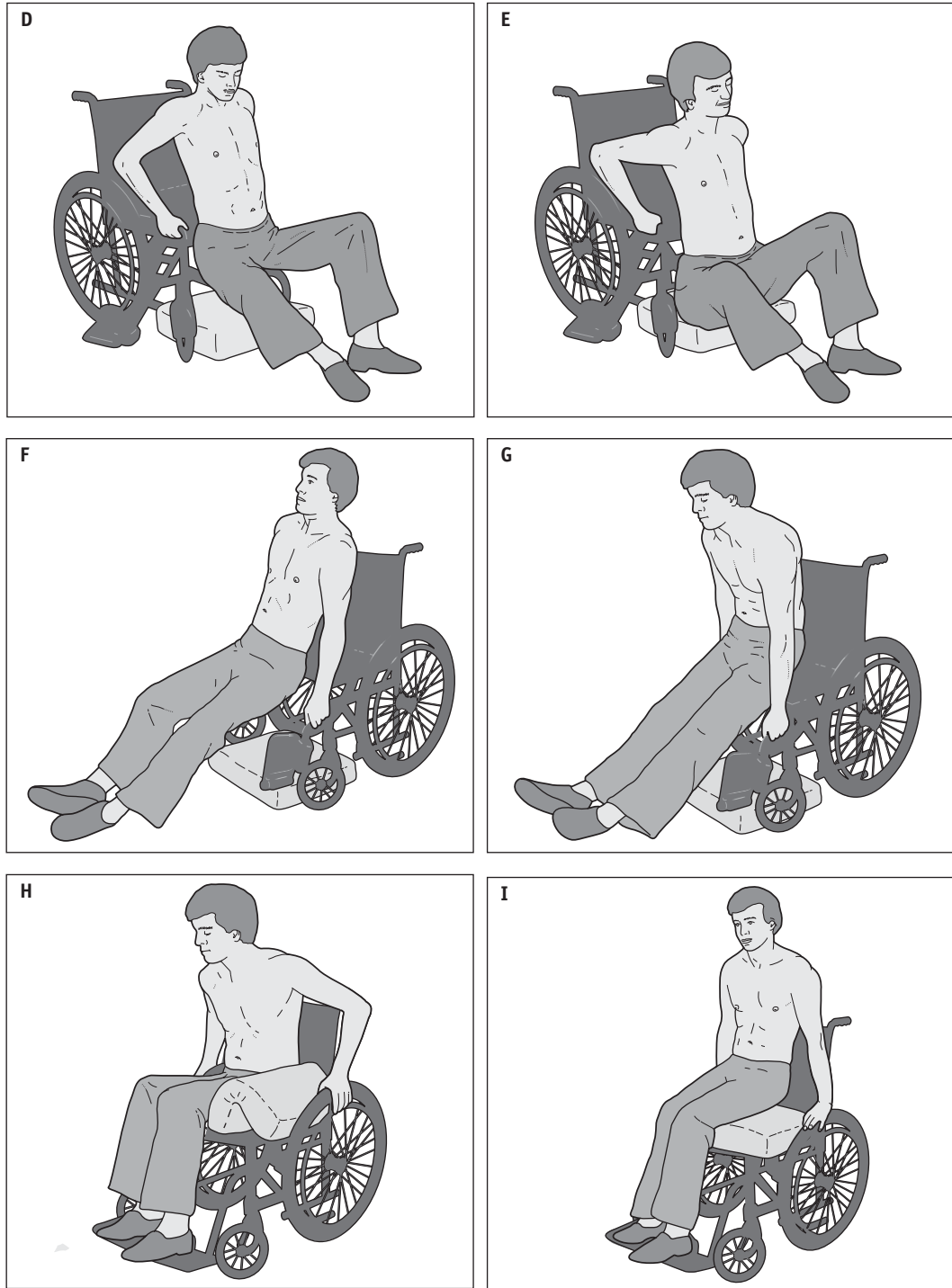
Figure 12.11 cont'd

3. Remove the footplates and place the cushion between the front wheels for protection when sitting on the floor (Fig. 12.11B).
4. Gripping the front of the seat supports, lift the trunk (Fig. 12.11C) and allow the buttocks to slip forward over the edge of the chair (Fig. 12.11D).
5. Gradually lower the weight to the floor (Fig. 12.11E).

Patients without abdominal muscles will need to extend the head and shoulders to tip the buttocks forward off the chair at step 4. The extension is maintained to prevent the patient pitching forward whilst lowering the trunk.

To lift back into the chair

Action of the patient
Sitting with the back to the chair:

1. Either place both hands on the front of the seat supports or replace one footplate and place one hand on the top of the footplate fitting.
2. Lift strongly, extending the head and neck (Fig. 12.11F).
3. Contract the abdominals, if present, and depress the shoulders to pull the pelvis back onto the seat (Fig. 12.11G).
4. Lift the feet onto the footplates.

To replace the cushion
If the cushion is soft enough double the cushion and place it between the wheel and the hip (Fig. 12.11H). Lift on both wheels and the cushion 'springs' into place under the buttocks (Fig. 12.11I).

Alternative method for patients without abdominals

Replace the armrests. Double the cushion and place it low down between the back and the backrest. Lift on both armrests and the cushion 'springs' into position.

In both methods, the position of the cushion may need final adjustment.

If the cushion is heavy and/or solid and the above method cannot be used, the patient will need to first transfer into his wheelchair, then to another surface, replace the cushion and transfer back into his wheelchair.

To transfer forward onto the bed

The forward transfer may be useful for the very young or for those who are overweight or severely spastic.

Action of the patient
1. Lift the feet onto the bed.
2. Wheel the chair forward until it is touching the bed.
3. Keeping the head and trunk flexed, lift forward in the chair. Small children who cannot lift on the armrests may lift by pushing down on the cushion (Fig. 12.12A). Repeated lifts may be necessary (Fig. 12.12B).
4. With the left hand on the bed and the right hand on the cushion, lift the buttocks sideways onto the bed (Fig. 12.12C, D). Repeated lifts will be necessary.
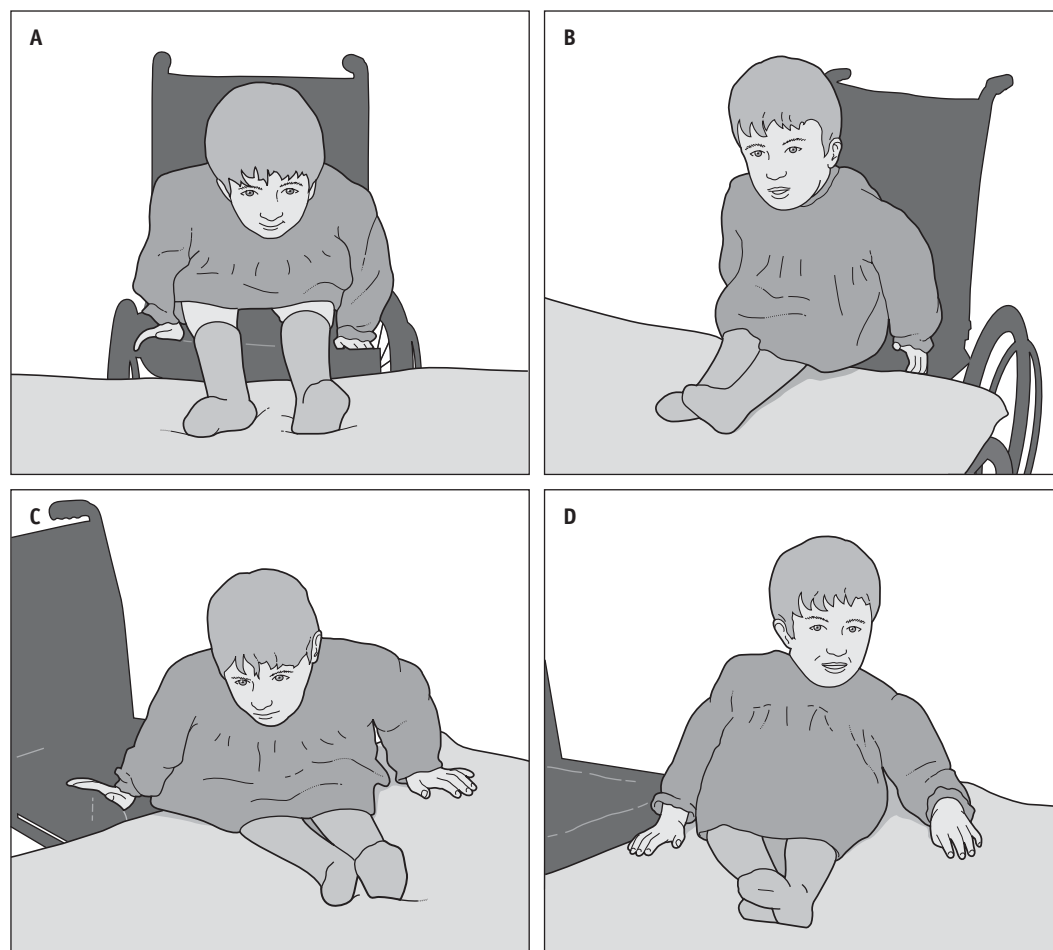
Figure 12.12 Forward transfer to the bed. Child with a complete lesion below T10.

TRANSFERS FROM A HIGH PERFORMANCE WHEELCHAIR

Some adjustment in technique is required when transferring from the high performance wheelchair, which may have rigid footplates and a more forward position of the rear wheels than on the standard chair. When transferring sideways to, for example, the toilet or bath, the angle between the chair and the toilet may have to be altered and, with non-detachable footrests, forward transfer to the bed or over the bath end may not be possible.

Transfers to and from the floor are achievable by patients with complete lesions below C7 using the high performance wheelchair.

To transfer to the floor

Action of the patient
1. Bring the hips forward in the chair as described on page 192.
2. Remove the armrests.
3. Lift the feet onto the floor in front of the footplates.
4. Holding the top of the left footrest support with the left hand, lean forward and to the right until the right hand can take weight on the floor (Fig. 12.13A).
5. Lift towards the right hand, keeping the head and trunk well flexed (Fig. 12.13B) and lower the body onto the floor (Fig. 12.13C).

The high performance wheelchair will move during this manoeuvre, but this should not affect the patient's control of the movement.

To transfer from the floor to the chair

Action of the patient
1. Sit close to the right side of the footplates.
2. Hold the top of the left footrest support with the left hand and place the right hand on the floor beside the right hip (supported on the knuckles to give extra height if necessary, as in Fig. 12.14A).
3. Flex head and trunk as far as possible.
4. Push on the right hand and pull with the left hand (Fig. 12.14B).
5. Swing the buttocks into the chair. To ensure minimum effort, the lift needs to be performed as quickly as possible commensurate with safety, avoiding knocking the hips or buttocks on the chair (Fig. 12.14C).
6. As the buttocks reach the chair, hold firmly with the left hand and pull the trunk to the left to regain balance (Fig. 12.14D).

The chair will move during the lift but this should not affect the patient's control of the movement.

The transfer using a hoist is described in Chapter 14.
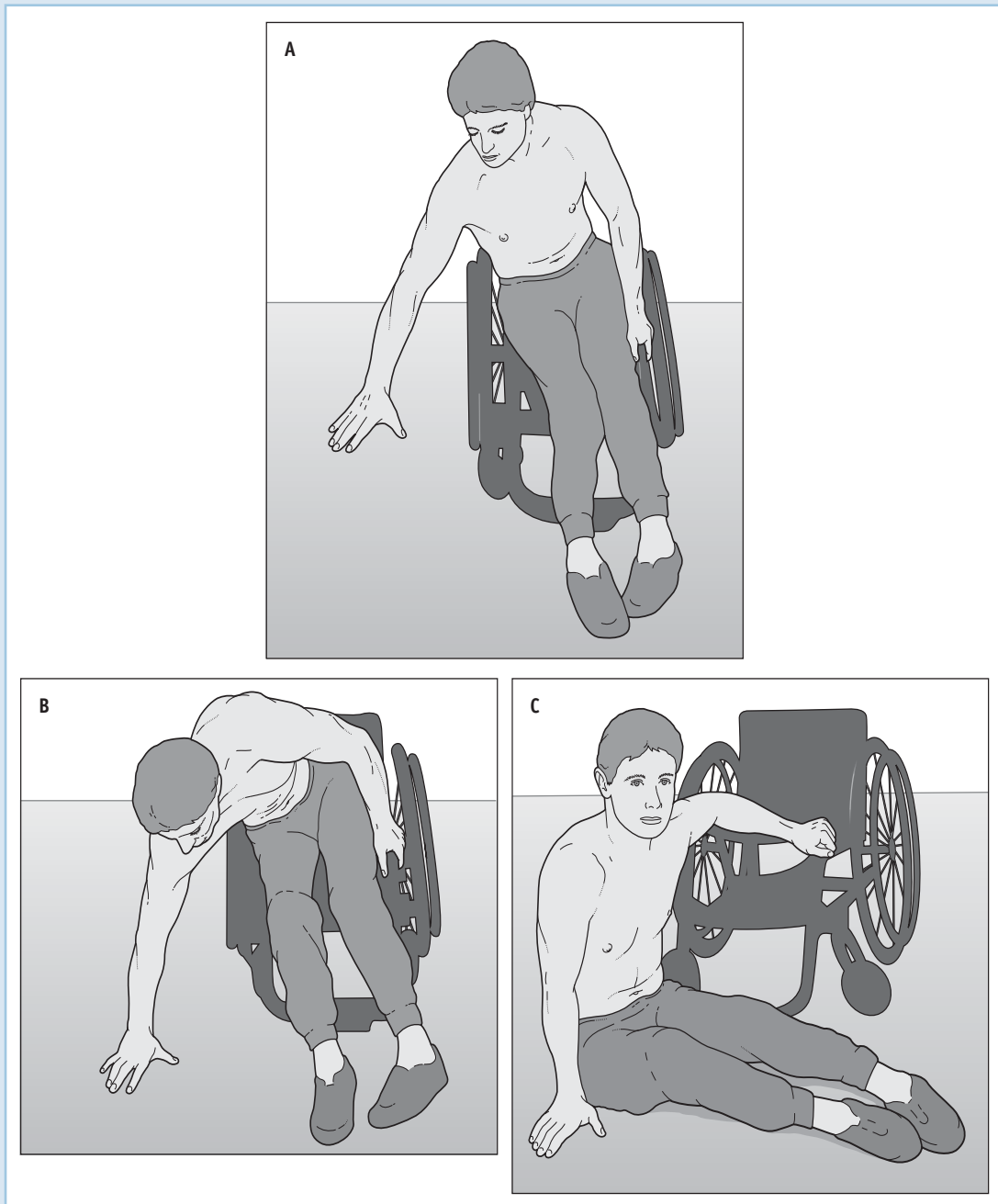
Figure 12.13 Transfer to the floor from a high performance wheelchair. Patient with a complete lesion below T12.
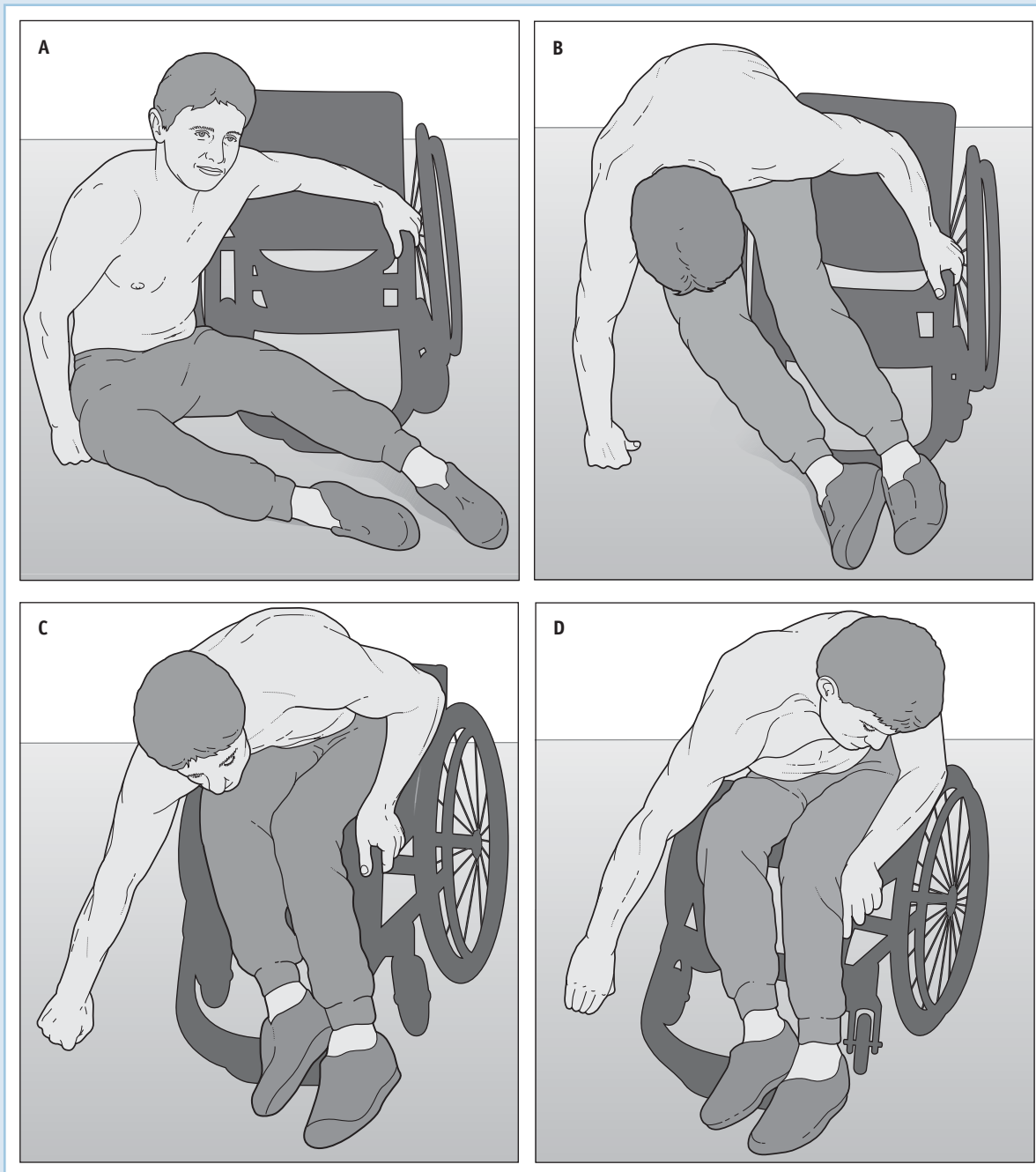
Figure 12.14 Transfer from the floor to a high performance wheelchair. Patient with a complete lesion below T12.

Gait training

It is important to put walking into perspective in terms of function in everyday life amongst able-bodied people outside hospital. Although most patients want to learn to walk, the energy cost of walking on crutches is high even for patients with low lesions, and in general only those with lesions at T10 and below, who are not overweight and who demonstrate some athletic ability, are successful and use their walking for functional purposes. Orthoses are expensive. Research has shown that the majority of paraplegic patients use their wheelchairs as their main means of locomotion. Not more than 10% of patients with complete lesions use orthoses for functional activities and a little less than one-third never use them at all (Haln 1970, Hong et al 1990). In view of this and the constantly increasing cost of medical services, fewer patients are being taught to walk. To be proficient enough to walk in the environment an extended period of hospitalization is required. In some units a patient keen to walk returns to hospital maybe one year post-injury when strength and balance have improved. In some countries to be able to walk is almost essential if the patient is to function outside his living accommodation.

As in all rehabilitation, much depends upon the physical proportions, age, sex and previous medical history of the patient, and even more upon his motivation. Further research on predictive factors is required to identify those patients with complete lesions who will become and remain functional walkers.

All patients are encouraged to stand, as the upright posture is believed to have a positive influence on:

- contractures in the lower limbs
- osteoporosis of the long bones with the danger of recurrent fractures
- the circulation
- spasticity
- renal function.

In a study on children with myelomeningocele, the non-walkers had five times the number of pressure sores and twice the number of fractures as the walking group (Mazur et al 1989).

Most patients with lesions between T1 and T9 are able to walk between parallel bars using a swing-to gait and may progress to

walking with crutches or a rollator for exercise only. Some may prefer to use a hip–knee–ankle–foot orthosis and use a four-point gait. Where the terrain is difficult for wheelchair use and motivation is high, some patients with lesions from T6 to T9 may learn swing-through gait on crutches and use it functionally at home, though these are rare exceptions.

Patients with lesions from C5 to C8 use a standing frame (Fig. 13.1) or stand between parallel bars, and those with higher lesions use a tilt table. The physiotherapist needs to bear in mind that posture has an effect on respiration (see Ch. 5). As the arterial pressure falls when the patient is tilted head up into standing, the tilt table should be raised gradually and remain at 45°, or below if more comfortable for the patient, for the first session (Houtman et al 2000;). The degree of tilt is increased as the patient becomes more accustomed to the position. Standing unassisted between bars aids the retraining of postural sensibility even for those with low cervical lesions, for the patient utilizes all innervated arm and trunk

Figure 13.1 Oswestry standing frame.

muscles to maintain balance. It is therefore an excellent exercise even for those who will not be able to walk.

Functional gait

The aim is to teach the use of both wheelchair and crutches so that the patient is equipped to use either, as the occasion demands. A widely increased sphere of independence is gained through crutch walking. Independent entrance can be obtained, for example, to buildings with small doorways, hotel accommodation, aircraft and trains. For the active patients, the benefits gained in everyday life far outweigh the patience and effort involved in training.

Concern is sometimes expressed about the effect that weight-bearing has on the shoulder joint. Research to determine the effect of the swing-through crutch walking gait on shoulder degeneration showed that no degenerative changes occurred, and there was an increase in the forearm bone density (Wing & Tedwell 1983). More recent studies have shown that, as most of the activities undertaken by active paralysed people involve the shoulder joints in weight-bearing, in older age problems in the shoulders occur at an earlier age than in the rest of the population (see Ch. 17).

Appliances

The basic requirements are to fix the knee joints and to hold the feet in dorsiflexion. The overdevelopment of the trunk muscles, together with the creation of a new postural sense, may render any additional bracing unnecessary. Patients with low cervical or high thoracic lesions may walk with a hip–knee–ankle–foot orthosis (HKAFO), which supports the hips and trunk. Research continues to try to improve the function and appearance of these orthoses, and the hybrid system of orthosis plus functional electrical stimulation (FES) or using FES alone. Important advances have been made, but apart from the KAFO it is difficult to use these orthoses functionally.

Knee–ankle–foot orthosis (KAFO) (calipers)

Knee–ankle–foot orthoses (KAFOs), which allow the legs to bear the weight, are the only essential appliance for many patients. If standing is to minimize the formation of osteoporosis, it is vital that the weight should go through the long bones. Ischial weight-bearing is to be avoided because of the danger of causing pressure ulcers. A bucket-type thigh corset is used. The knee supports need to be wide. They encircle the knee to prevent lateral movement and give adequate support to the paralysed joint (Fig. 13.2). Round sockets are used in the shoe with backstops. In a small number of cases with extreme plantarflexion spasticity, toe-raising springs may be needed in addition to the backstops.

These orthoses are made of duralumin as they need to be as light as possible although if necessary they can be made of steel. For selected patients, usually those with flaccid lesions or who have minimum spasticity, ortholon cosmetic calipers may be prescribed. The lower section is moulded around the calf and heel and under the foot to just below the metatarsophalangeal joints, and the upper section is moulded around the back of the thigh. They are cosmetically more acceptable, but care must be taken to ensure that they do not cause pressure ulcers, particularly around the ankle.

Caution

Ortholon calipers are unsuitable for patients with severe spasticity or oedema of the feet and lower legs.

KAFOs are available which have adjustable locked ankle joints (Scott 1971). The correct angle to gain maximum stability is found with the patient standing in the balanced position between the parallel bars, with hips hyperextended and feet dorsiflexed beyond 90° (see p. 221). The ankle joint is locked with the patient standing in this position. The shoe is flat to take a steel plate and is permanently fixed to the orthosis, which is made of steel and is heavier than if made from duralumin. Greater stability is provided and they may be particularly useful for patients with lesions between T6 and T9 (Duffus & Wood 1983).

Modular KAFOs and plaster of Paris leg splints

Modular KAFOs can be kept in stock to fit on a temporary basis until the made-to-measure orthosis is available. In the absence of modular calipers, posterior shells of plaster of Paris are made for each patient and used to stabilize the knees. The shells extend from 5 cm (2 inches) below the ischial tuberosities to 5 cm above the malleoli. It may be necessary to reinforce the plasters with a strip of steel or wire for patients who are overweight or who have severe spasticity. Temporary toe-raising springs are used with these splints to hold the foot in dorsiflexion. They consist of a webbing band round the leg, with adjustable straps, a short spring and a narrow webbing band under the shoe (Fig. 13.3).

Shoes

Shoes for use with any type of orthosis should provide good support for the feet and be made of soft leather without toe caps. To prevent pressure ulcers, all the inside seams, particularly around the heel, must be smooth. Leather soles stitched to the uppers provide the most suitable support for the sockets, back stops, or T-straps if necessary. To accommodate for slight oedema and avoid damage when putting them on, the shoe fitting should be at least half a size larger than the size previously worn.
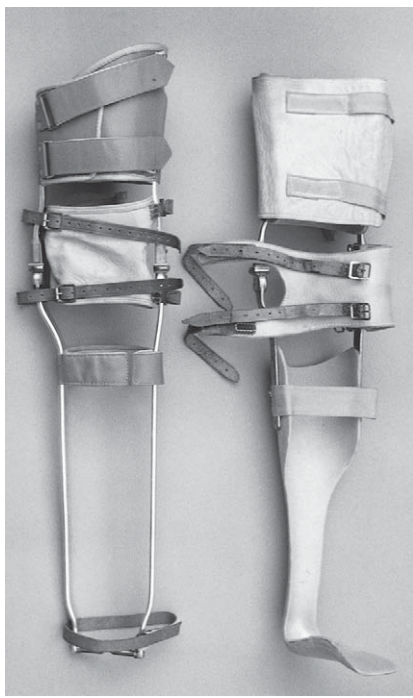
Figure 13.2 Calipers.
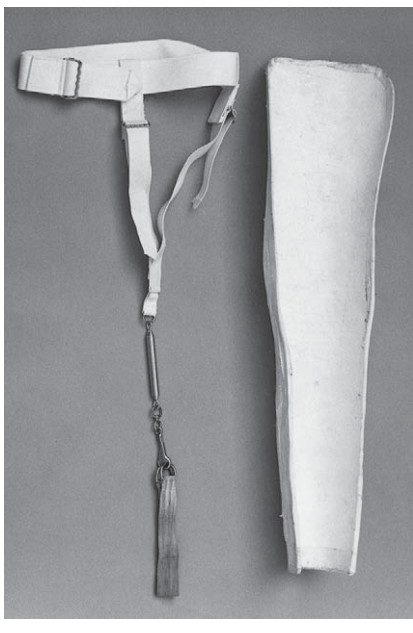
Figure 13.3 Temporary toe-raising spring and plaster of Paris splint.

STANDING A PATIENT WITH A KNEE–ANKLE–FOOT ORTHOSIS

Standing between parallel bars

Because of the loss of all postural and equilibrium reactions below the level of the lesion, a new postural sense must be developed in the erect position. Compensation by sight for the loss of sensation is essential, and a long mirror is used at the end of the bars and another to the side of the patient. Patients without muscle control at the hips lift their legs by the action of latissimus dorsi and the associated action of trapezius and shoulder girdle muscles. Postural sense in standing is developed largely through the action of these 'bridge' muscles. Occasionally, vasomotor disturbances occur on standing patients with higher lesions. If necessary, an abdominal binder can be worn temporarily to assist in preventing pooling of the blood in the splanchnic vessels. Fainting is more likely to occur when the patient is tall and thin (Figoni 1984).

Position of the wheelchair

The chair is positioned with the supporting crossbar of the bars behind the front wheels, if possible. This will prevent the chair from slipping backwards.

Height of the bars

For the efficient use of latissimus dorsi and triceps, the bars must be at the correct height. With the hand on the bar and the shoulders relaxed, the elbow should be slightly flexed. This usually brings the wrist approximately level with the greater trochanter, but this depends upon individual physical proportions. For the initial stand, the height of the bars is determined by guesswork. After seeing the patient on his feet, the therapist must make the necessary adjustments. It is a common error to have the bars too high. In this case, elevation of the shoulder renders depression almost impossible and the patient cannot lift the leg effectively. With the bars too low, stability can be gained only when the patient leans forward with his weight on his hands.

To stand a patient

Action of the therapist
Stand facing the patient, with the feet either side of the patient's legs, ready to grip with the knees to prevent the feet from sliding forward. Step-standing may be preferred, as in Figure 13.4A. Hold the patient under the buttocks and pull the hips forward as the patient lifts.
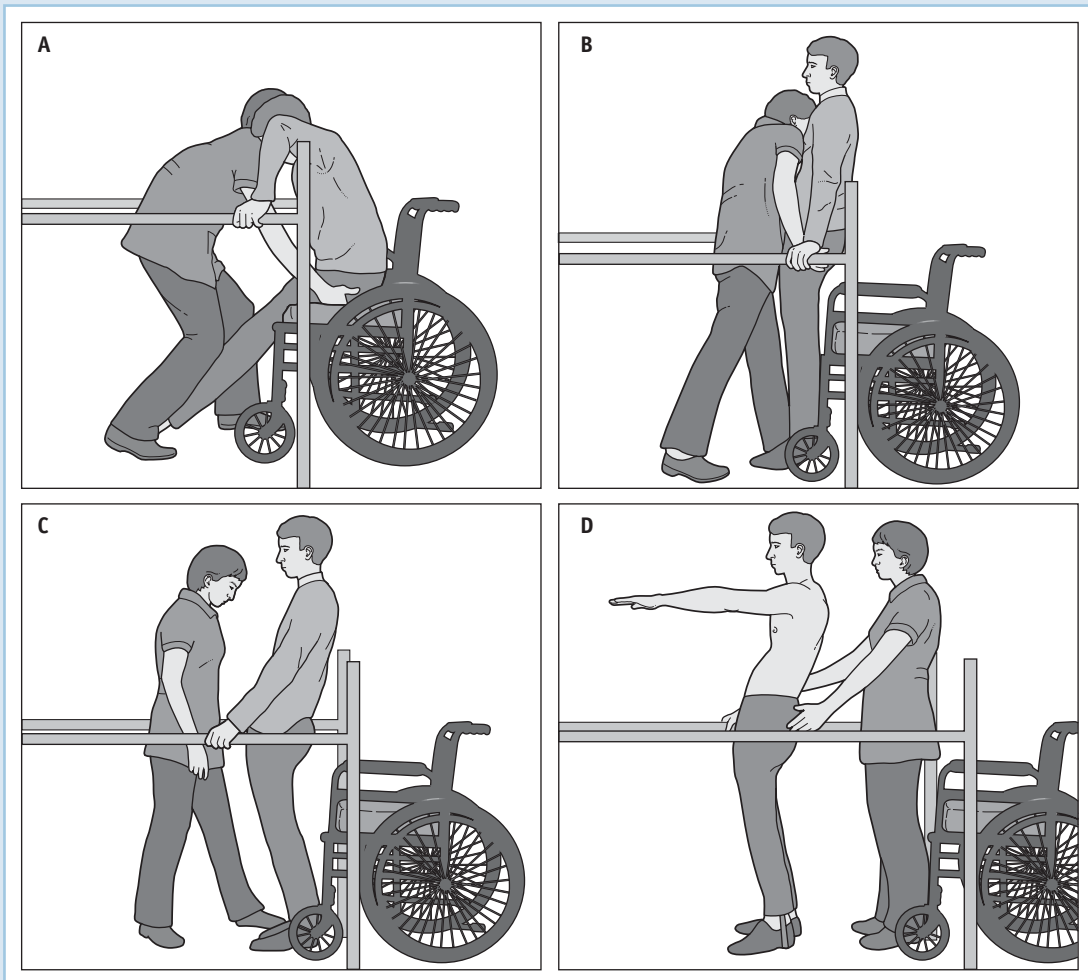
Figure 13.4 A–C: Standing a paraplegic patient. D: Balance exercise in the bars. Patient with a complete lesion below T5.

Action of the patient

1. Sitting well back in the chair, lean forward and place the hands at the end of the bars with the elbows vertically above the wrists (Fig. 13.4A). This position allows the patient to stand by pushing down on the bars. The tendency to reach along the bars and pull up must be avoided.

2. Push down on the hands and stretch upwards, not forward (Fig. 13.4B).

3. As the weight comes over the feet, hyperextend the hips and at the same time extend the head and retract the shoulders.

4. Move the hands a short distance forward along the bars (Fig. 13.4C). If the patient is tall or overweight, a second therapist

may be needed to push the feet back as the patient lifts. This will reduce the effort required by the patient.

To get behind the patient and establish the balanced position

Action of the therapist

Keeping the hips in extension with the left hand, and the upper trunk extended with the right arm, move behind the patient by passing under his right arm. At the same time, slide the arms around the patient's trunk to maintain his position (Fig. 13.5).

Brace one hip against the patient's sacrum to maintain hyperextension of his hips. Prevent forward or lateral movement of the trunk with the right hand on the upper thorax and the left hand on the pelvis (Fig. 13.4D). Watching in the mirrors, the therapist helps the patient to find his point of balance and encourages him to hold it without her support.

When this has been achieved, resisted exercises can be given to improve balance and coordination.

Suitable patients with lesions at C6/7 should be able to stand in this way, but will need the assistance of a second therapist to push the buttocks and hips forward and the shoulders back.

If a young and active patient with a lesion at C7 or C8 is anxious to walk, swing-to gait can be taught as for the paraplegic patient.

Posture correction

The standing posture is corrected so that:

1. weight goes through the heels
2. legs are inclined only a few degrees forward of 90° at the ankle
3. hips are slightly extended so that the line of gravity lies behind the hip joints, through the knee joints and slightly in front of the ankle joints to prevent the 'jack-knife' fall forward
4. spine is as upright as possible. Some adjustment must be made in the upper thoracic spine to compensate for the hyperextended hips. Overcorrection must be avoided
5. bars are held with the hands approximately level with the toes
6. shoulders are relaxed.

The posture of the patient with useful abdominal muscles should be almost erect except for the slight hyperextension necessary at the hip joints. As the level of the lesion rises, a greater degree of compensation will be necessary at the hip joints. In all cases, overcorrection should be avoided. If the patient is allowed to lean forward with the weight over the toes and with the spine and shoulders extended, he will be unable to lift the weight off his feet. The second mirror placed at the side of the patient may assist him to correct his posture by showing the anteroposterior deviations from the vertical.

Figure 13.5 Moving behind the patient (note abdominal belt).

There is a fine point between over- and undercorrection. This position provides the basic balance point from which all gait training proceeds.

Duration of the stand

Depending upon the height of the lesion the patient may remain on his feet for only 2 minutes or up to 5 or 10 minutes on the first day. A gradual increase in the duration of the stand is most important in order to allow the circulation to adapt with the minimum ill effect on the patient.

Initially it is more beneficial to stand two or three times for a few moments only than to stand once for a longer period. The constant change in posture stimulates the vascular system and promotes a more rapid establishment of vasomotor adjustment.

To sit down

The therapist, holding the patient under the buttocks and controlling his legs with her knees and feet, allows him to sit down gradually.

Action of the patient
With the feet approximately a foot's length from the chair:

1. Hyperextend the hips and place the hands in their original position on the bars.
2. Take the weight on the arms.
3. Flex the head and trunk, and lower the weight gently until the buttocks reach the chair.

Caution

Care must be taken to ensure that the patient does not knock his hips against the sides of the chair, or drop his weight suddenly onto the buttocks. Bruising, both superficial and in the deeper tissues, can easily occur.

When resting in the chair, with splints or calipers on the legs, the heels must be supported on a stool; otherwise the weight of the leg is taken on the upper end of the femur. If preferred, calipers can be unlocked at the knee joints.

Exercises in standing

As control is gained over the upper thorax, the therapist can place both hands around the hips to support only the pelvis. The hands are placed along the iliac crest, with the fingers over the anterior superior iliac spine. With the hands in this position, the therapist

can pull the pelvis back with her fingers (Fig. 13.6A), push it forward with the heel of her hand (Fig. 13.6B), give pressure downwards (Fig. 13.6c) or lift upwards. In this way, the therapist has complete control of the patient and can assist or resist movement in any direction.

Balance exercises

Watching his position in the mirror, the patient is taught to:

- hold, move out of and regain the correct posture
- maintain balance whilst lifting one hand off the bar (Fig. 13.4D). Progression is made by moving the arm in all directions, and later by repeating this with the eyes closed
- move both hands forwards and backwards along the bars.

Exercises for strength and control

Before commencing gait training, the patient must learn to tilt his pelvis by using latissimus dorsi, and to become aware of the degree of control he can achieve with this compensatory mechanism.

Pelvic side tilting

To 'hitch' the left leg, place the left hand on the bar only slightly in front of the left hip, and the right hand about half a foot length further forward. Keeping the elbow straight, press firmly down on the left hand and *depress the shoulder.*

The leg must be lifted upwards and not forwards.

To lift both feet off the ground and control the pelvis

Place both hands on the bars slightly in front of the hip joints. Push down on the bars, with the elbows straight, and depress the shoulders. To gain control of the pelvis, the patient should practise holding himself at both full and partial lift, rotating the trunk and tilting the pelvis with the feet lifted off the ground.

Resisted trunk exercises

For greater efficiency in balance, strength and control, resisted trunk exercises in the standing and 'lifting' positions and resisted 'hitching' are also given.

Passive stretch in standing

Where strong spasm in the hip flexors and abdominal muscles prevents the patient from assuming the erect posture, a passive stretch can be given. The therapist gives firm pressure forwards with her hip

against the patient's sacrum, and with her hands pulls backwards over the front of the shoulder joints.

If the position is maintained for a few moments the spasticity usually relaxes and the patient is able to maintain his balance.

Cautions

1. Stretching must always be performed with extreme care. Unskilled passive stretching has resulted in fracture of the neck of the femur. The top of the caliper becomes the fulcrum and the strain is transferred to the femoral neck.
2. Until the spasm relaxes, the patient may experience some difficulty in breathing. The spasticity is initially increased by the stretch, and the tightness of the abdominal muscles may prevent adequate movement of the diaphragm.
3. The therapist must make sure that she has no hard objects in her pocket which could cause pressure.

Standing frames

Where walking is impractical, a standing frame may be used (Fig. 13.1). Some standing frames have additional supports at each side so that a strap can be used to control the trunk of the tetraplegic patient, if required.

Standing frames are being produced which allow the patient to stand and move on flat indoor surfaces. The Dynamic Parapodium and the Grandstand are two such devices. Hand wheels drive the front wheels of the latter and it is adjustable, which enables it to continue to fit a child as he grows. The Dynamic Parapodium, which has to be carefully adjusted to each user, enables each foot to move forward a few inches at a time by rocking from side to side (see Appendix 8).

GAIT

There are three types of gait used:

- swing-to gait
- four-point gait
- swing-through gait.

Controlled walking is achieved only through perseverance, perfect timing, rhythm and coordination. The patient is taught always:

1. to move the hands first
2. to walk slowly and place his feet accurately
3. to take the weight through the feet and so ensure that the hands can relax between each step
4. to lift the body upwards and not to drag the legs forwards.

An accurate technique must be achieved in bars if crutch walking is to be successful.

Where it is anticipated that the patient will become an accomplished walker, it is usual to commence training with the four-point gait. It is easier to learn to use the latissimus dorsi muscles at first separately and then together than vice versa.

GAIT TRAINING IN THE BARS

Swing-to gait

This is the universal gait because it is both the simplest and the safest. All patients with lesions above T10 are normally taught this gait first.

The therapist
The therapist stands behind the patient with her hands over the iliac crests. Assistance is given to lift, to control the tilt of the pelvis and to transfer weight as necessary (Fig. 13.6A–C).

Action of the patient
1. Balance in the hyperextended position.
2. Move the hands, either separately or together, forward along the bars approximately half a foot length in front of the toes.
3. Lean forward, with the head and shoulders over the hands (Fig. 13.6D), and lift the legs, which will swing forward to follow the position of the head and shoulders. The step is short and the feet must drop just behind the level of the hands (Fig. 13.6E). To achieve this, the lift must be released quickly, otherwise the feet will travel too far and land between or in front of the hands. When on crutches, it is unstable and therefore dangerous to have the feet and hands in line. It must therefore be avoided in the bars. The swing-to gait is a 'staccato' gait with no follow through: 'lift and drop'.

The patient should also be taught to swing backwards along the bars.
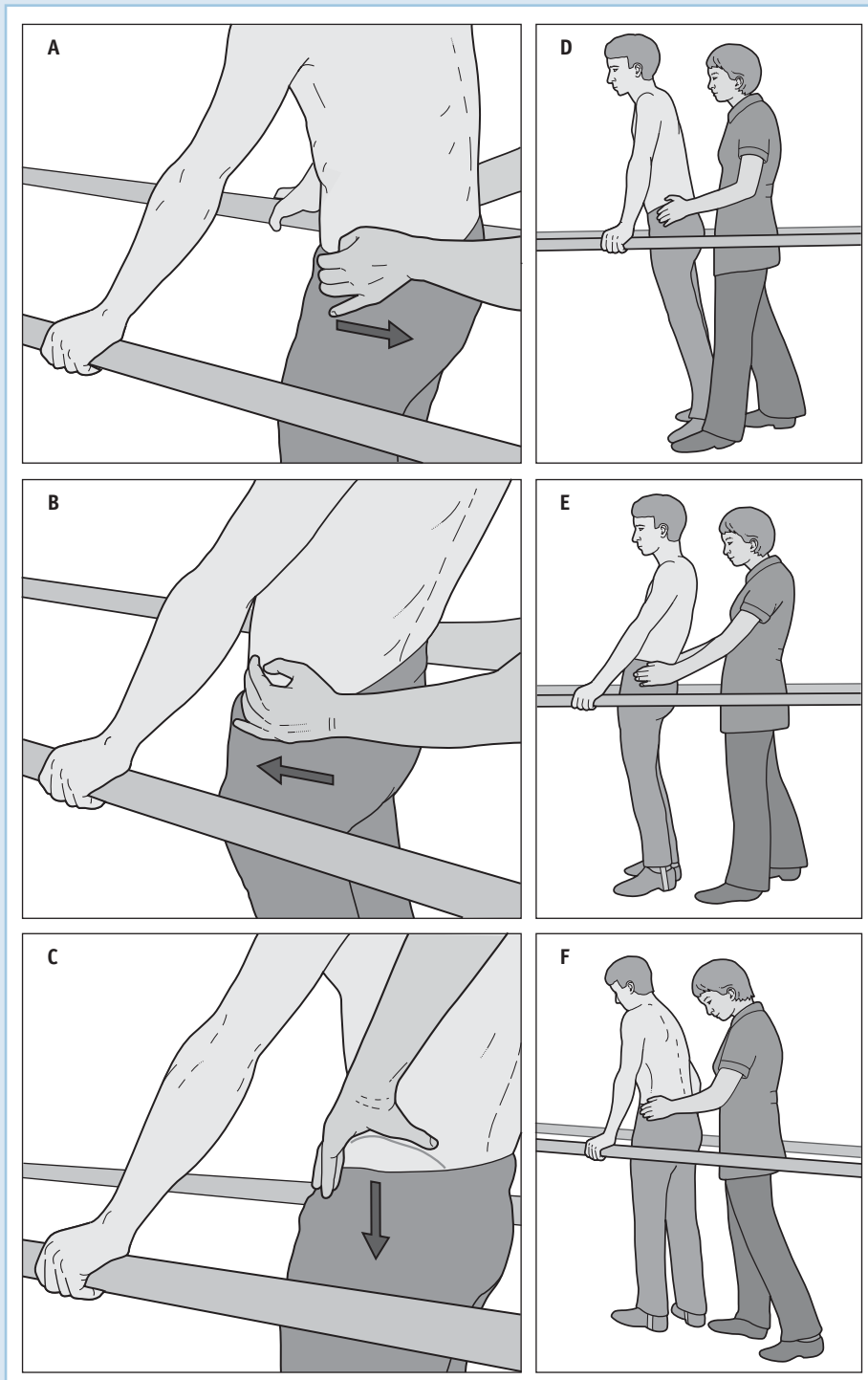
Figure 13.6 A–C: Position of the therapist's hands. D, E: Swing-to gait. F: Four-point gait.

To turn in the bars

The turn is achieved in two movements by turning through 90° each time.

   To turn to the right:

1. Place the left hand forward about a foot length along the bars and the right hand either level with or a little behind the trunk.
2. Lift and twist the shoulders and upper trunk to the right. The feet land facing the bar to the right (Fig. 13.7A).
3. Balance in this position and move the left hand across to the right bar (Fig. 13.7B).
4. Twisting the upper trunk to the right, place the right hand on the opposite bar.
5. Lift the feet round to a central position between the bars (Fig. 13.7C).
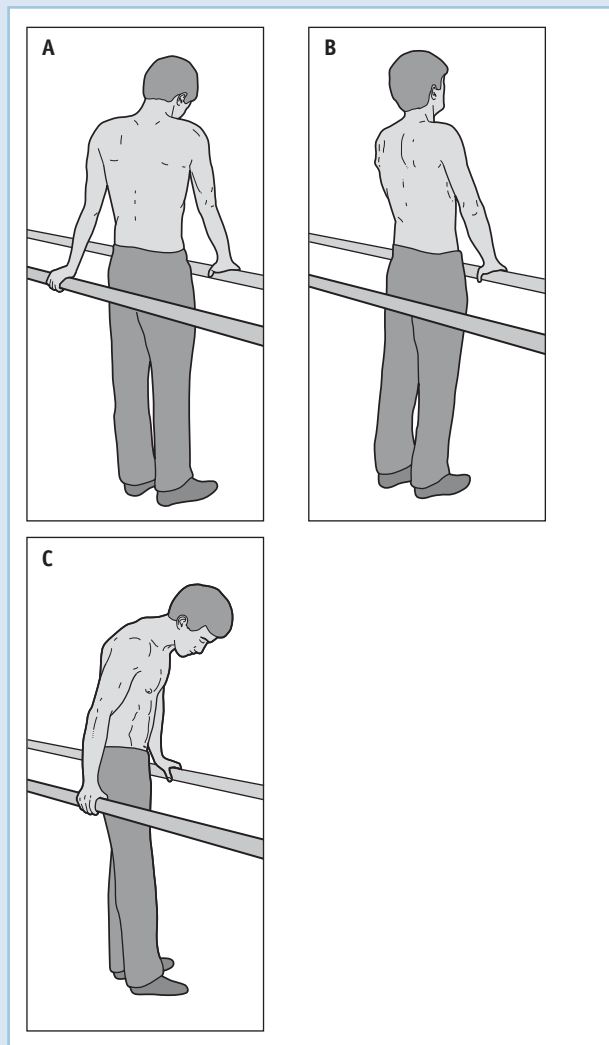
Figure 13.7 Turning in the bars. Patient with a complete lesion below T11.

Four-point gait

This gait is the slowest and most difficult of all and is only achieved on crutches by accomplished walkers. It facilitates turning and manoeuvring in confined spaces. It also provides an excellent training exercise in strength, balance and control.

The therapist. The therapist holds the pelvis in the usual way. Both by instruction and by correction with her hands, the therapist emphasizes each move, ensuring that the patient achieves it correctly. Only when the patient consistently makes a single movement correctly does the therapist stop correcting that component. The patient needs to see and 'feel' the correct posture at each move, and therefore constant repetition is necessary.

Action of the patient
To take a step forward with the left leg

1. Place the right hand forward about half a foot length along the bar and the left one just in front of the hip joint.
2. Take the weight on the right leg, so that the hip is over the right foot and the knee and ankle in a vertical line.
3. With the left shoulder slightly protracted, push on the left hand and depress the shoulder (Fig. 13.6F, p. 227). The effort is to 'lift' the leg upwards.
4. As the left leg is lifted, it swings forward to follow the shoulder. The 'lift' is released when a large enough step has been made. (Small steps should be taken initially, but the foot must always land *in front* of the hand.)
5. Take the weight over the left leg.
6. Move the left hand forward along the bar in preparation for moving the right leg. Pelvic rotation must be avoided.

The following are possible reasons for an inadequate lift:

- some weight remains on the moving leg
- the hands are too far forward
- the weight may be over the toes and not back over the heels, in which case the trunk may be hyperextended and the legs consequently inclined too far forward
- insufficient depression of the shoulder girdle on the side of the moving leg
- the bars are too high or too low
- the lift is not held for sufficient time to allow the leg to swing forward.

To take a step backward with the left leg

1. Place the left hand slightly behind the hip joint.
2. Lift the leg and at the same time lean forward on that side.
3. Bend the elbow and 'flip' the leg backwards.

Swing-through gait

This gait requires skilled balance, but it is the fastest and most useful.

The therapist
The therapist gives assistance where necessary with her hands controlling the pelvis until the patient can accurately and slowly perform the movements. The forward thrust of the pelvis to push the weight over the feet usually needs to be emphasized.

Action of the patient
1. Place the hands forward along the bars as for the swing-to gait.
2. Lean forward and take the weight on the hands.
3. Push down on the bars, depress the shoulder girdle and lift both legs. The lift must be sustained until the legs have swung forward to land the same distance in front of the hands as they were originally behind. Considerably more effort is required than for the swing-to gait.
4. As the weight is lifted and the legs swing forward, hyperextend the hips, extend the head and retract the shoulders.
5. To move the trunk forward over the feet, push on the hands, extending the elbows and adducting the shoulders. When the weight is firmly on the feet, move the hands along the bars for the next step.

GAIT TRAINING ON CRUTCHES

Progression is made to crutch walking only when the technique between the bars is good. The height of the elbow crutches is checked as for the bars.

The change from walking in bars to crutch walking is considerable, and all patients are initially unstable and fearful. A high degree of balance skill is essential and this is only achieved with perseverance and much practice.

Balance exercises

Balance on crutches is trained in the same way as when balancing in the bars (Fig. 13.8A). Resisted work is also given to enable the patient to gain adequate control over the trunk and pelvis.

Walking on crutches

Swing-to and four-point gaits are taught first and progression is made to swing-through (Fig. 13.8B, C). Until the new postural sense is established training is again carried out in front of a mirror.

Progression in the four-point gait may be made by using one bar and one crutch if preferred. Otherwise, progression is directly onto two crutches, as there is less tendency to trunk and pelvic rotation.

The technique for each gait is the same as already described for walking in bars. Much greater skill is required and several weeks of practice will be needed to acquire the necessary balance and coordination.
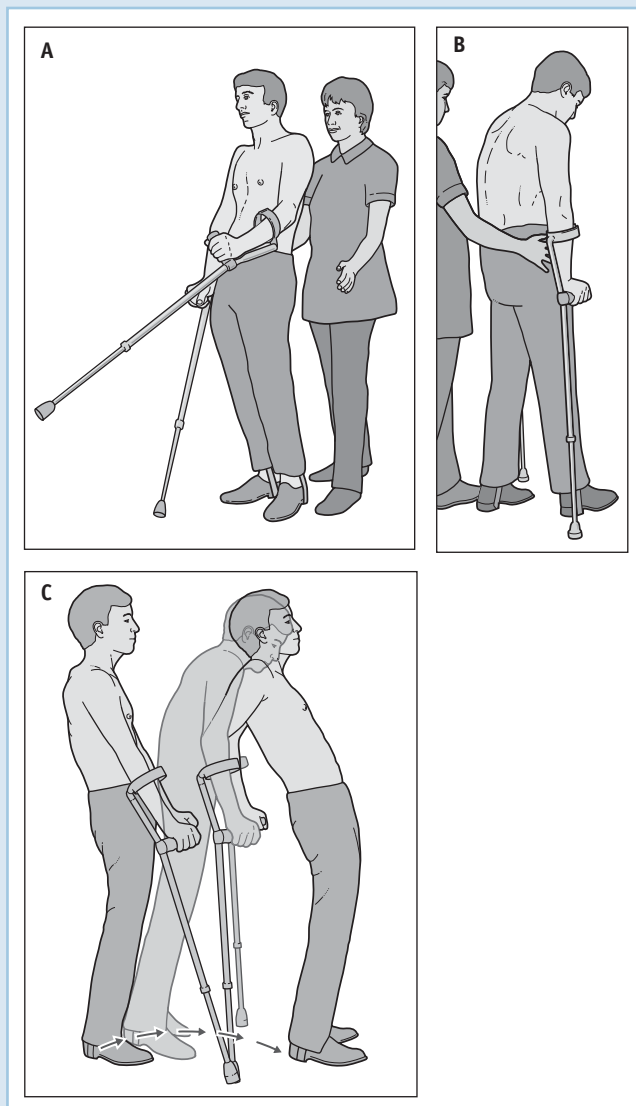
Figure 13.8 A: Balance exercise on crutches. Patient with a complete lesion below T5. B: Four-point gait. C: Swing-through gait. Patient with a complete lesion below T12 (B and C).

To transfer from chair to crutches

An unaided exit from a chair is essential if crutch walking is to be functional. There are three techniques used to get into and out of the chair with crutches:

- forwards technique
- sideways technique
- backwards technique.

All three methods are taught where possible, and the patient chooses that which he finds easiest.

Forwards technique

Severe abdominal and/or flexor spasticity which prohibits the necessary hyperextension at the hips, or excessive height, may prevent a patient accomplishing this technique. When the patient is well over average height with the extra length primarily in the legs, the elbows are higher than the shoulders with the crutches in position for the lift. Latissimus dorsi and triceps are thus at a mechanical disadvantage and a balanced lift is impossible.

The therapist
The therapist stands in front of the patient astride the legs and ready to give support with her hands around the scapula region (Fig. 13.9A–D).
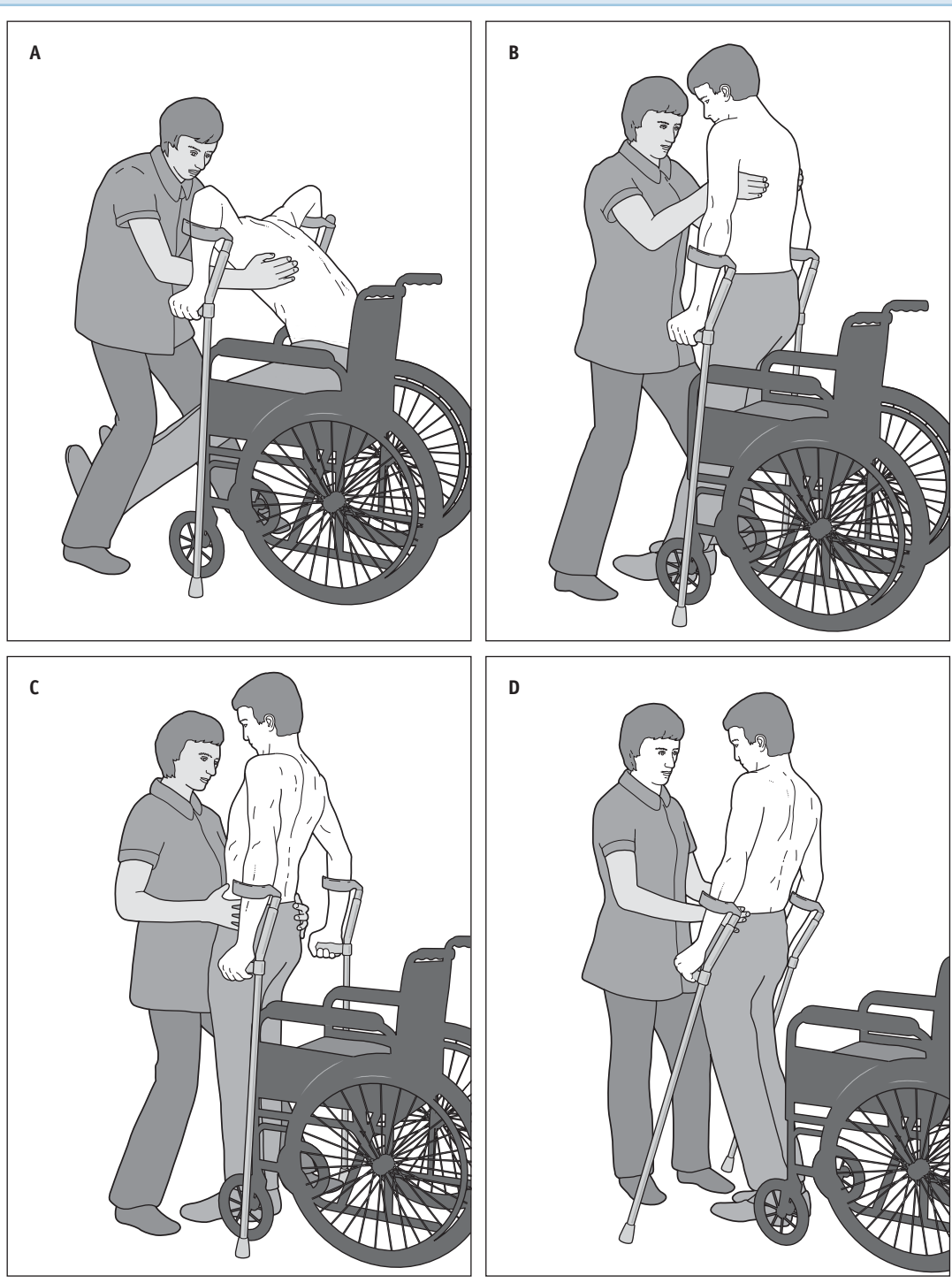
Figure 13.9 Chair to crutches – forwards technique. Patient with a complete lesion below T6.

Action of the patient

1. Check the position of the chair and swing away or remove the footplates. During early training, when the weight distribution may be incorrect, a feeling of stability is given if the chair is backed against a wall.
2. Sit well back in the chair (Fig. 13.10A).
3. Place the crutches midway between the front and rear wheels, level with each other and equidistant from the sides of the chair (Fig. 13.10B). To avoid rotation during the lift, the position of the crutches must be accurate.
4. Lean forward over the crutches and balance.
5. Lift on the crutches, adducting and extending the shoulders.
6. The feet are lifted backwards, and as the weight goes onto them, hyperextend the hips and retract the shoulders (Fig. 13.10C).
7. When balanced, move the crutches forward and assume the correct standing position (Fig. 13.10D).

To sit down, reverse the procedure, as in Figures 13.10D–A.

If the physical proportions of the patient are suitable, an alternative method is shown in Figure 13.10E. The short patient reaches back with his hands, releases the crutch handles and grasps the armrests. Such patients may be able to stand up in the same way. To prevent trauma, which could result in haemorrhage and bursa formation, sitting down should be done slowly without bumping on the chair.

Sideways technique

Some patients of below average height are able to get out of the chair using one crutch and an armrest:

Figure 13.10 A–D: Chair to crutches – forwards technique. Patient with a complete lesion below T9. E: Short patient sitting down.

1. Put the left arm through the forearm support, position the left crutch and grasp the armrest.
2. Turn through 45° towards the left armrest.
3. Place the right crutch in front and to the left of the midline of the chair.
4. Lift on both arms (Fig. 13.11A, B).
5. With the weight on the feet, balance on the right crutch and grasp the left crutch handgrip.

Reverse the procedure to sit down.
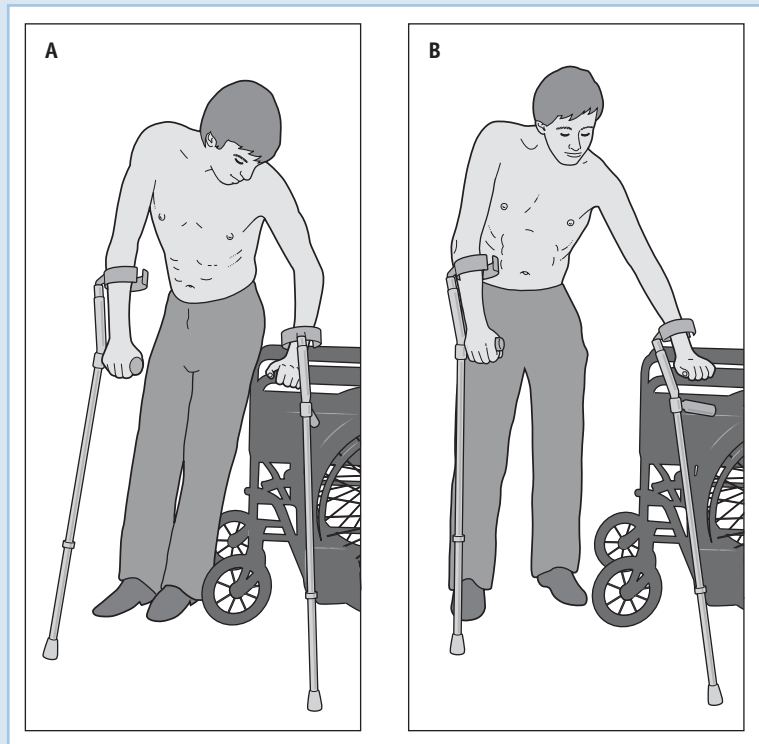
Figure 13.11 Chair to crutches – sideways technique.

Backwards technique

The therapist stands in front of the patient ready to control the pelvis or legs as necessary.

To turn to the left:

1. Cross the right leg over the left (Fig. 13.12A).
2. Lift the buttocks to the right side of the chair (Fig. 13.12B).
3. Turn the trunk to the left, moving the left hand to the right armrest and the right hand to the left armrest (Fig. 13.12C).
4. Push on both armrests to stand (Fig. 13.12D) facing the chair.
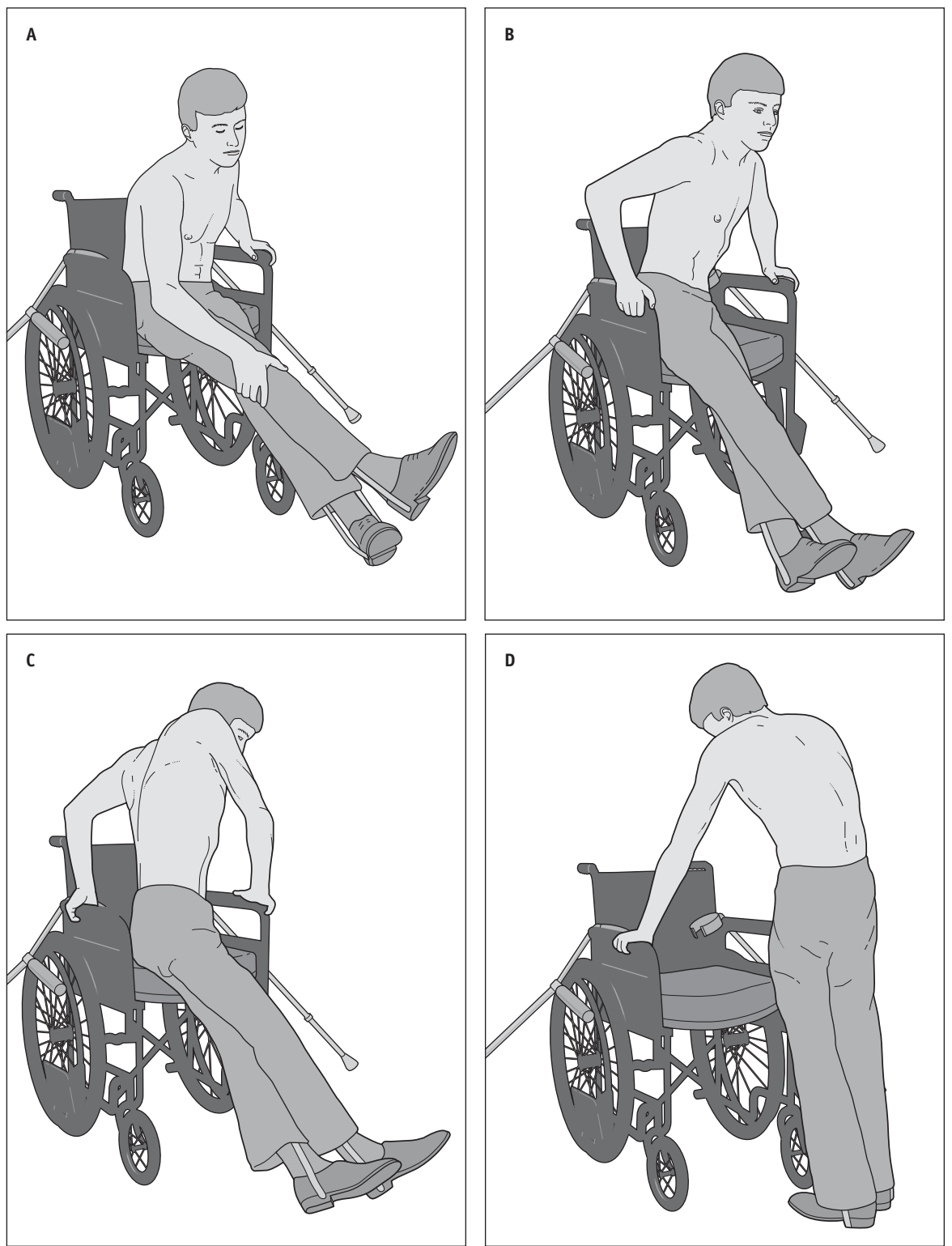
Figure 13.12 Chair to crutches – backwards technique. Patient with a complete lesion below T12.
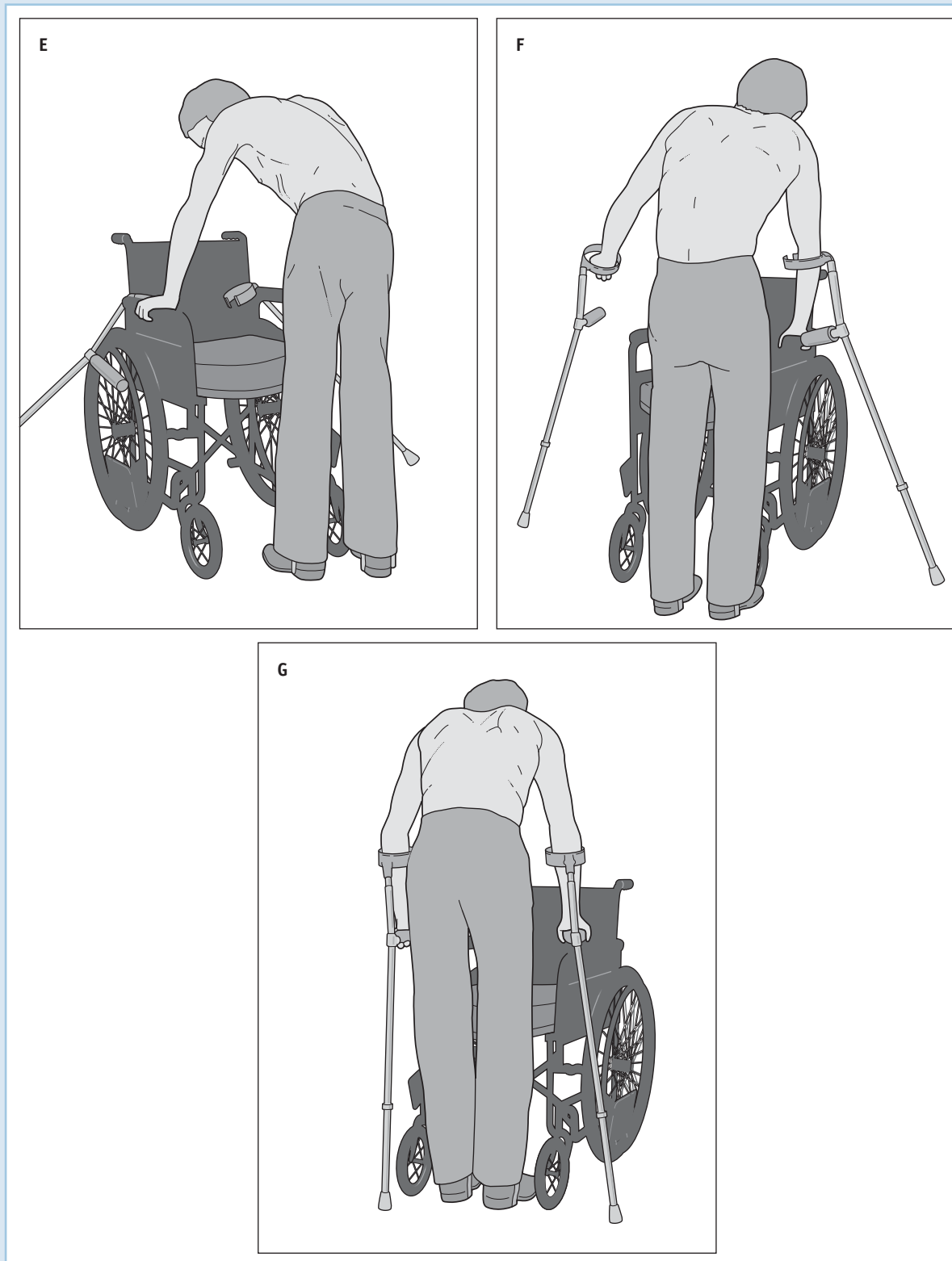
Figure 13.12 cont'd

5. Hitch the feet to the left (Fig. 13.12E).
6. Put each hand through the crutch forearm supports and return to holding the armrests (Fig. 13.12F).
7. Grasp the handgrips in turn.
8. Walk backwards away from the chair (Fig. 13.12G).

Reverse the procedure to sit down.

Stairs

Climbing stairs is normally functional for patients with good abdominal muscles. Some young and active patients with lesions between T6 and T10, with or without a spinal brace, may also become efficient and independent.

Patients can climb the stairs either forwards or backwards. The forwards technique is usually taught first because it has the advantage that the patient can see where he is going. Most agile patients with good abdominal muscles will learn both methods and make their own choice. Where there is severe abdominal and/or hip flexor spasticity, the degree of hyperextension easily obtainable at the hip joints may be too limited for the forwards technique.

Two rails are used initially, progression being made to one rail and one crutch. Finally, the second crutch must be carried, usually in the crutch hand, as illustrated in Figure 13.13.

The therapist. The therapist always stands behind the patient. She holds the trouser band or a therapeutic belt with one hand and grasps the patient round the waist with the other. After the initial attempts, both hands should be placed around the pelvis in the usual position for greater control. Assistance is given, as necessary, until the technique is mastered.

Forwards technique using one rail and one crutch

To walk upstairs

1. Standing close to the rail, grasp it approximately half a foot length in front of the toes.
2. Place the right crutch on the stair above, level with the hand on the rail (Fig. 13.13A). The hands must be level to avoid trunk rotation when lifting. The tendency to grasp the rail too far forward and 'pull' must be avoided.
3. Lean over the hands and lift as high as possible, keeping the trunk and pelvis in the horizontal plane (Fig. 13.13B).
4. As soon as the feet land on the stair above, hyperextend the hips to find the balance point (Fig. 13.13C).

To walk downstairs

1. Standing close to the rail and keeping the body in the horizontal plane, place the right crutch close to the edge of the same stair.
2. Place the left hand down the rail on a level with the crutch (Fig. 13.13D).
3. Lift and swing the feet down to the stair below (Fig. 13.13E).
4. Hyperextend the hips and retract the shoulders as soon as the feet touch the ground (Fig. 13.13F).

Very short patients may need to put the crutch on the stair below the feet and lift down to the crutch.

Backwards technique using one rail and one crutch

To walk upstairs

1. Balance in hyperextension whilst placing the left hand higher up the rail and the crutch on the stair above, keeping the hands level (Fig. 13.13F).
2. Lift backwards (Fig. 13.13E).
3. Regain the balance (Fig. 13.13D).

To walk downstairs

1. Place the crutch on the edge of the same stair as the feet, with the hands level (Fig. 13.13C).
2. Lift the feet backwards to the edge of the stair.
3. Lean forward on the hands, lift and 'flick' the pelvis backwards (Fig. 13.13B).
4. Drop the feet onto the stair below (Fig. 13.13A).
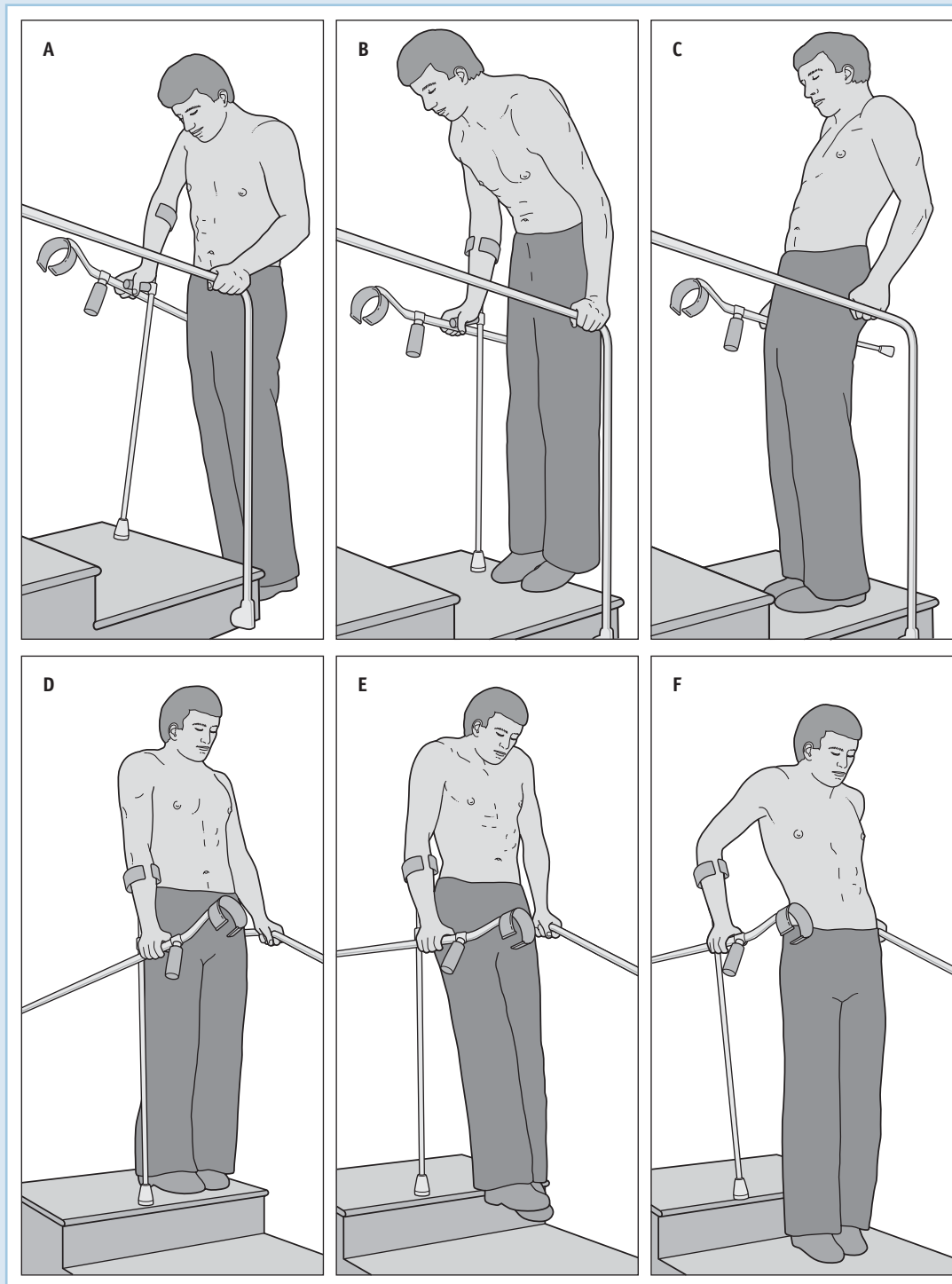
Figure 13.13 Climbing and descending stairs. Patient with a complete lesion below T11.

Kerbs

Kerbs are negotiated by putting the crutches on the kerb first and then taking a swing-through step onto the pavement. The same technique is used to descend a kerb. A long shallow step can be mounted in the same way.

Patients are not taught to ascend flights of narrow steps on two crutches.

To get down and up from the floor onto crutches

Crutches to floor

The therapist stands behind the patient and controls the pelvis, feet and legs, as necessary:

1. From the standing position on the mat (Fig. 13.14A), 'walk' the crutches forward one by one (Fig. 13.14B) until the hips and trunk are sufficiently flexed for the outstretched hand to reach the floor.
2. Balance on the right crutch, release the left crutch and put the left hand on the floor (Fig. 13.14C).
3. Balance on the left hand, release the right crutch and put the right hand on the floor (Fig. 13.14D).
4. 'Walk' forward on the hands until lying prone (Fig. 13.14E).
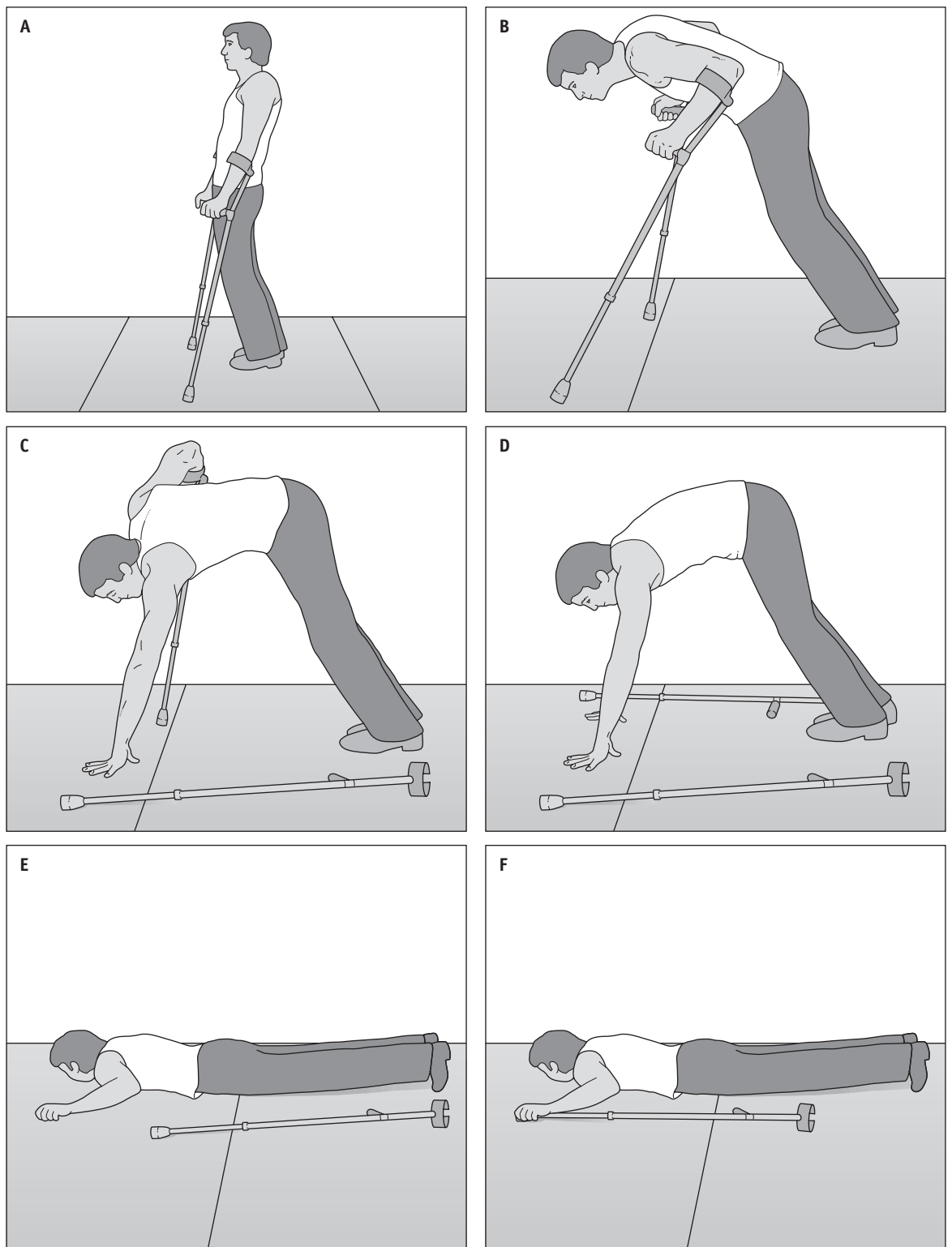
Figure 13.14 A–E: Crutches to floor. F–K: Floor to crutches. Patient with a complete lesion below T11.

Floor to crutches

The therapist may need to assist the patient to get the weight over his feet initially:

1. Lying prone, make sure the ankles and toes are dorsiflexed so that the feet are vertical (Fig. 13.14F).
2. Position the crutches, tips forward, well in front of the body and put both forearms through the forearm supports.
3. Press up on the hands, and at the same time use the abdominal muscles to pull the pelvis towards the hands and so prevent the legs being pushed backwards.
4. Maintaining the action of the abdominal muscles, 'walk' the hands towards the feet, trailing the crutches (Fig. 13.14G) until the weight is over the feet (Fig. 13.14H).
5. Balance on the left hand, grasp the right crutch handgrip and place the crutch on the floor (Fig. 13.14I).
6. Balance on the right crutch and take hold of the left crutch in a similar manner. Balance on both crutches (Fig. 13.14J).
7. 'Walk' the crutches towards the feet until standing erect (Fig. 13.14K).

To get out of a car onto crutches

1. Turn to face the open door and lift the legs out of the car.
2. Lock the knee joints.
3. With the window open, use the window ledge and the back of the seat, or the seat and a crutch, to lift into standing.
4. Balance with the hips hyperextended and take hold of each crutch in turn.

Final functional activities on crutches

The patient is taught to walk on slopes and over uneven ground such as grass and shale. He must also learn to open and close a door, to sit in and rise from an easy chair, and to sit down at and rise from a table by pushing down on the table with one hand and using the crutch in the other.

The Walking Index for Spinal Cord Injury (WISCI) is a complex scale developed to measure walking ability and to be used particularly in clinical trials (Marshall & Nance 2000). It is a more precise scale for documenting change in levels of walking than the Functional Independence Measure, where the main emphasis is on the physical assistance needed for daily living. WISCI was constructed by international experts from spinal cord injury units in eight countries. The inter-rater reliability was shown to be 100% by Ditunno et al (2000) and the Index is being tested through retrospective and prospective studies in the clinical field (Box 13.1).
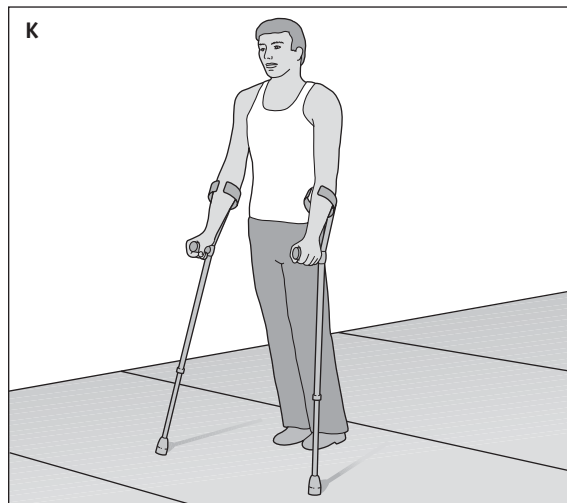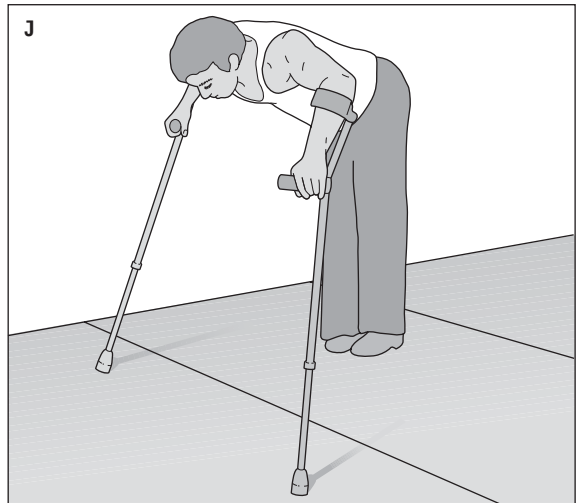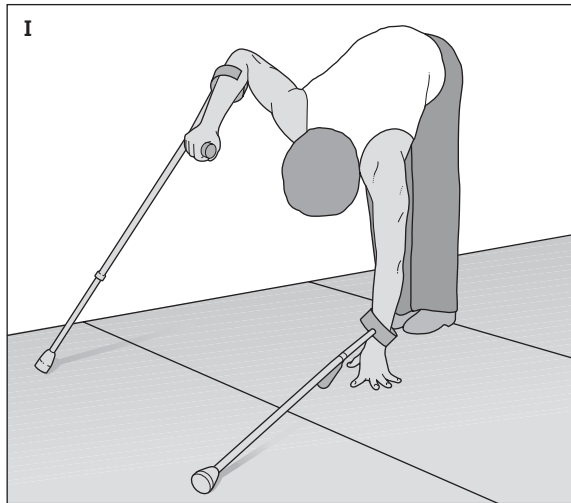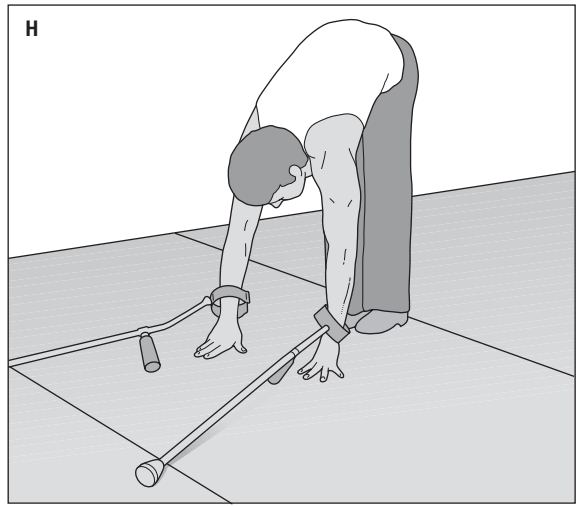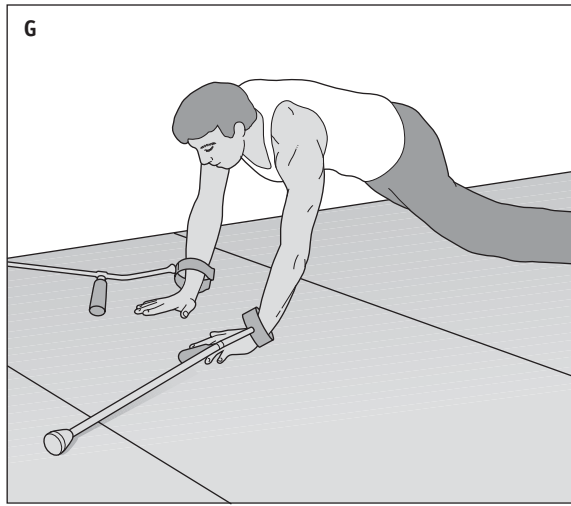
Figure 13.14 cont'd

Box 13.1 Walking Index for Spinal Cord Injury (WISCI) From Ditunno et al (2000), with permission

Physical limitation for walking secondary to impairment is defined at the person level and indicates the ability of person to walk after spinal cord injury. The development of this assessment index required a rank ordering along dimension of impairment, from the level of most severe impairment (1) to least severe impairment (19) based on the use of devices, braces and physical assistance of one or more persons. The order of the levels suggests each successive level is a less impaired level than the former. The ranking of severity is based on the severity of the impairment and not on functional independence in the environment. The following definitions standardize the terms used in each item:

Physical assistance:	'Physical assistance of two persons' is moderate to maximum assistance 'Physical assistance of one person' is minimal assistance.
Braces:	'Braces' means one or two braces, either short or long leg 'No braces' means no braces on either leg.
Walker:	'Walker' is a conventional rigid walker without wheels.
Crutches:	'Crutches' can be Lofstrand (Canadian) or axillary
Cane:	'Cane' is a conventional straight cane.

Level	Description
1	Ambulates in parallel bars, with braces and physical assistance of two persons, less than 10 meters.
2	Ambulates in parallel bars, with braces and physical assistance of two persons, 10 meters.
3	Ambulates in parallel bars, with braces and physical assistance of one person, 10 meters.
4	Ambulates in parallel bars, no braces and physical assistance of one person, 10 meters.
5	Ambulates in parallel bars, with braces and no physical assistance, 10 meters.
6	Ambulates with walker, with braces and physical assistance of one person, 10 meters.
7	Ambulates with two crutches, with braces and physical assistance of one person, 10 meters.
8	Ambulates with walker, no braces and physical assistance of one person, 10 meters.
9	Ambulates with walker, with braces and no physical assistance, 10 meters.
10	Ambulates with one cane/crutch, with braces and physical assistance of one person, 10 meters.
11	Ambulates with two crutches, no braces and physical assistance of one person, 10 meters.
12	Ambulates with two crutches, with braces and no physical assistance, 10 meters.
13	Ambulates with walker, no braces and no physical assistance, 10 meters.
14	Ambulates with one cane/crutch, no braces and physical assistance of one person, 10 meters.
15	Ambulates with one cane/crutch, with braces and no physical assistance, 10 meters.
16	Ambulates with two crutches, no braces and no physical assistance, 10 meters.
17	Ambulates with no devices, no braces and physical assistance of one person, 10 meters.
18	Ambulates with one cane/crutch, no braces and no physical assistance, 10 meters.
19	Ambulates with no devices, no braces and no physical assistance, 10 meters.

WISCI Scoring Sheet

Patient Name _____
Date _____

Check descriptors which apply to current walking performance, then assign the highest level of walking performance

In scoring a level, one should choose the level at which the patient is safe as judged by the therapist, with patient's comfort level described. If devices other than stated in the standard definitions are used, they should be documented as descriptors. If there is a discrepancy between two observers, the higher level should be chosen.

Descriptors			
Devices	**Braces**	**Assistance**	**Patient reported comfort level**
// bars <10 ft	Long leg braces – Uses 2 / Uses 1	Max assist × 2 people	Very comfortable
// bars 10 ft	Short leg braces – Uses 2 / Uses 1	Min/mod assist × 2 people	Slightly comfortable
Walker – Standard Rolling platform		Min/mod assist × 1 person	Neither comfortable nor uncomfortable
Crutches – Uses 2 / Uses 1			Slightly uncomfortable
Canes – Quad / Uses 2 / Uses 1			Very uncomfortable
No devices	**No braces**	**No assistance**	

WISCI levels				
Level	**Devices**	**Braces**	**Assistance**	**Distance**
1	Parallal bars	Braces	2 persons	Less than 10 meters
2	Parallal bars	Braces	2 persons	10 meters
3	Parallal bars	Braces	1 person	10 meters
4	Parallal bars	No braces	1 person	10 meters
5	Parallal bars	Braces	No assistance	10 meters
6	Walker	Braces	1 person	10 meters
7	Two crutches	Braces	1 person	10 meters
8	Walker	No braces	1 person	10 meters
9	Walker	Braces	No assistance	10 meters
10	One cane/crutch	Braces	1 person	10 meters
11	Two crutches	No braces	1 person	10 meters
12	Two crutches	Braces	No assistance	10 meters
13	Walker	No braces	No assistance	10 meters
14	One cane/crutch	No braces	1 person	10 meters
15	One cane/crutch	Braces	No assistance	10 meters
16	Two crutches	No braces	No assistance	10 meters
17	No devices	No braces	1 person	10 meters
18	One cane/crutch	No braces	No assistance	10 meters
19	No devices	No braces	No assistance	10 meters

Level assigned _____

Figure 13.15 Parawalker.

Figure 13.16
Reciprocating gait
orthosis.

GAIT USING HIP–KNEE–ANKLE–FOOT ORTHOSES (HKAFOs)

Over the past few years some of the mechanical problems of the early reciprocating *walking* orthoses (this is a generic term for all the following orthoses) have been eliminated and their popularity has increased. These orthoses enable patients with lesions from C6/7 (with triceps) to T12 to walk with more stability and greater freedom than with knee–ankle–foot orthoses (KAFOs) because they offer support to the trunk, pelvis and hips as well as to the knees and feet.

Work in the late 1960s produced HKAFOs that linked the hips together to allow reciprocal movement of both hips. In the UK, Scrutton (1971) used Bowden cables in an HKAFO for children with spina bifida and Motlock in Canada developed a mechanism based on the use of gears. A refinement on the original design by Scrutton produced the reciprocating gait orthosis at the Louisiana State University (Scott 1971).

At the present time, four main types of reciprocating *walking* orthoses are available internationally.

The *ORLAU* (Orthotic Research and Locomotor Assessment Unit) or *Parawalker* (Hip Guidance Orthosis) was produced in Oswestry, UK, initially for children with spina bifida but more recently for adults with spinal cord lesions (Butler & Major 1971, Stallard 1986). The Parawalker is a rigid structure with good lateral stiffness, which prevents adduction of either hip. The control of adduction is important as the swing leg has less ground clearance if the stance leg adducts (Stallard & Major 1995). The hip joints are free to move between 18° of flexion and 6° of extension when locked for walking. The swing phase is achieved by a pendulum action using gravity and a low-friction orthotic hip joint. The shoes fit onto metal footplates with rocker soles, which adds to the rigidity of the brace but prevents the orthosis being worn under everyday clothing (Fig. 13.15). When the gluteal muscles were stimulated to support hip extension and abduction in an FES hybrid walking project, energy consumption was reduced (Nene & Patrick 1990).

The *Reciprocating Gait Orthosis* (RGO) uses two Bowden cables to link the two sides of the brace (Douglas et al 1983). The front cable assists flexion of the hip and the rear one maintains extension of the brace, effectively acting as the absent hip extensor. This orthosis is more flexible and lighter than the Parawalker. The foot support is plastic and fits inside the shoe, allowing the orthosis to be worn under normal clothing (Fig. 13.16).

Although patients can don and doff the orthosis, it is difficult to stand up or sit down in it without assistance.

Modifications to the RGO were made by Hugh Steeper Ltd to produce the *Advanced Reciprocating Gait Orthosis* (ARGO). The piston mechanism of this orthosis assists the action of standing and sitting by enabling the knees to extend and flex. The two Bowden

cables are reduced to one, which is encased in a tube, in an effort to prevent the cables breaking and to improve cosmesis.

Motlock suggested a modification to the RGO which is known as the *Isocentric Reciprocating Gait Orthosis* (IRGO). As the cables in the RGO are the least dependable part of the orthosis and are cosmetically unacceptable, they are replaced by a centrally pivoting bar attached around a pelvic jacket (Motlock 1992). Whereas hip extension in the RGO is adjusted by tightening the Bowden cables, in the IRGO it is achieved by turning the screw threads inside a barrel at each hip joint.

Although continued exercise is linked in many research articles to improvement in psychological well-being, rejection of the ARGO is common. Scivoletto et al (2000) found it to be 47%. This is an expensive device which still does not provide autonomy and its use is limited. RGOs that are adjustable may be the way forward as the patient could try out the system before a specific orthosis is made for him. This might reduce the number of orthoses that are subsequently rejected (Scivoletto et al 2003).

Walkabout

This orthosis was designed in Australia. It is available in the UK and elsewhere, although it is not as extensively used as the Parawalker and RGO in the UK, where it is mainly prescribed for patients with low thoracic lesions.

Plastic shells support the upper and lower legs and pass under the soles of the feet, and the knee joints are hinged. In an attempt to avoid the problems that arise at the hip joints, the KAFOs in this orthosis are joined at the top inside edge by a small bar. This contains the mechanism that allows the swing leg to move forward when the weight on it is released. There are no hip joints, but a flexible thoracic band attached to the calipers by loops can provide some trunk support if required. The Walkabout is more easily concealed beneath normal clothing than either the Parawalker or the RGO.

Similarities and differences in HKAFOs

Most braces have a weight tolerance limit. The recommended weight for the Parawalker is 75 kg (165 lb). Above 76.4 kg, the Bowden cables tend to snap on the RGO, and over 80.9 kg (177.9 lb) it becomes a physical struggle for the user to walk.

In the two main types of orthoses, Parawalker and RGO, the aim is similar although the orthoses are different in design and appearance. The body is braced from mid-trunk to the feet with knees and ankles immobilized in both orthoses. Flexion and extension are allowed at the hips but adduction is prevented when the leg is lifted off the ground. Both braces work to bring about flexion of the swing leg after weight transference (Whittle et al 1991).

The Parawalker was designed to be used with crutches and the RGO with a specially designed rollator with the restrictive front bar removed to allow for a more normal stride length. In practice, patients using either orthosis can walk with crutches or rollator.

After 4 months' use, Whittle et al (1991) found no significant difference between the Parawalker and the RGO in the general gait parameters of cadence, stride length and velocity, and effort expenditure was similar. Banta et al (1991) and Bowker et al (1992) found energy cost less with the Parawalker. Whittle & Cochrane (1989) found that the effort expended through the crutches was less with the Parawalker. The RGO was lighter and therefore easier to transport and its cosmesis was preferred (Whittle & Cochrane 1989). The functional results did not differ between subjects or centres as greatly as expected in a multicentre trial of the Parawalker, RGO and ARGO orthoses in Italy (Lotta et al 1994). The main difference in outcome seemed to depend on the device adopted. For example, patients in the Parawalker cannot climb stairs, but the orthosis never needed repairs, it took the shortest time to don and doff and less time for the patients to learn to use it. Using the IRGO as opposed to the ARGO, energy cost was slightly less and mean velocity slightly greater, although neither was statistically significant (Winchester 1993).

Assessment

If the patient is to be successful in using a reciprocating *walking* orthosis, it is essential that an accurate assessment is undertaken before it is prescribed. More important perhaps than the usual physical factors, such as spasticity or flexion contracture which might mitigate against continued use of the orthosis, is the patient's perception of its functional use and his expectations of the degree of independence it might allow (Sykes et al 1995). Walking with any of these orthoses has many limitations. The gait is slow and the patient can only cover short distances with great physical effort (Whittle et al 1991). Disappointment can only be avoided if the patient appreciates that walking with one of these orthoses is a useful form of exercise. It is not an alternative to wheelchair locomotion (Stallard et al 1989).

As well as the physical and psychological assessment, the home and work situation must also be discussed. Stallard et al (1989) suggest that all the following factors should be considered:

- independence – as well as walking in the orthosis, the patient should be able to don and doff it and be able to get into and out of the wheelchair
- energy cost
- cosmesis
- reliability of the orthosis
- cost.

The problem is to identify those patients who will continue to use the orthoses so that optimal benefit can be achieved with minimal wastage (Sykes et al 1995). The usual practice in spinal cord injury units in the UK is to reassess the patient who shows an interest in using a reciprocating *walking* orthosis approximately 1 year after discharge from the initial period of rehabilitation. The orthosis most suited to the needs of the individual patient can then be selected.

Team

An experienced team consisting of an orthotist, doctor, physiotherapist and orthotic technician must be involved in the assessment, prescription and construction of the orthosis. A tailored fit is crucial and the team approach is essential if the patient is to succeed. When the patient starts to use the orthosis and is learning to walk, the team continues to monitor progress and adjust the fit as necessary.

Training

Before learning to use a reciprocating *walking* orthosis, the patient completes a training programme to increase muscle strength, aerobic power and cardiovascular efficiency.

Gait

To achieve reciprocating gait, three actions must occur:

- the swing leg has to clear the ground
- the swing leg has to move from extension to flexion
- the trunk has to move forward over the stance leg, i.e. the hip has to extend.

Parawalker

The patient transfers to the plinth and the Parawalker is placed in the wheelchair. The patient lifts into it and fastens the straps. The chair is positioned in the bars as described earlier.

Action of the patient
1. Lock the knee joints.
2. With the heels on the ground, lie back in the chair and lock the hip joints. (If low in the chair, lift up until the body is at an approximate angle of 45°.)
3. Hold onto the bars and pull up into standing.

Two therapists usually assist the patient to stand for the first time, one on each side of the bars. As the patient has been at home for at least a year and has undertaken a strengthening programme before

being fitted with the orthosis, his arms should be strong and little effort should be required of the therapists.

To walk moving the right leg first

1. Push *sideways* with right hand using latissimus dorsi to transfer weight to left leg.
2. The right leg swings forward.
3. Take the weight on the right leg and continue to push with right hand to extend right hip.

Repeat on left side.
　　Crutch walking is commenced in 2 or 3 days.

To stand up with crutches

1. Lock the knee and hip joints in the wheelchair.
2. Place the tip of the crutches alongside the back of the rear wheels on each side of the chair.
3. Push into standing.
4. Edge crutches forward, one at a time to the balance position with the crutches in front.

Walk as described above.
　　To sit down reverse the procedure.

RGO

The chair is positioned between the bars as already described.

To stand up

1. Engage the clips at the hip joints.
2. Push down on the bars and stand up.
3. Extend the hips to complete the locking action at the hips.

To sit down

Disengage the clips and lower gently into the chair.
　　The Bowden cables can be tightened to adjust the degree of extension at the hips or, if the hip flexors are tight, the degree of flexion. One of the most vital adjustments to the brace is the control of extension of the trunk to enable the patient to maintain his balance. The two upper straps at the front and back of the brace can be adjusted to control the position of the trunk within the brace. Extension is controlled by slackening the Velcro fastening on the back strap and then tightening the front strap. The upper body weight is moved backwards over the heels, achieving the balance position and correct posture for a patient with spinal cord injury. If the back strap is too tight, the patient is pushed forward off balance.

IRGO

The IRGO has largely replaced the RGO as it is less cumbersome and the pre-selection function of the hip joints of the IRGO enables the patient to stand up and sit down safely.

To stand up

1. In sitting, place the clips at the hip joints (called 'pre-selection' hip joints) in the 'up' position.
2. Push down on the bars and stand up.
3. Forcibly extend the hips; the joints will lock automatically in their pre-selected setting.

To sit down

1. Place the clips at the hip joints in the pre-selected 'down' position.
2. Forcibly extend the hips; the hip joints will unlock.
3. Lower gently into the chair.

To walk moving the right leg

1. Transfer weight onto the left leg.
2. Using latissimus dorsi, lift the right (swing) leg by pushing down on the right hand.
3. The right leg swings forward.
4. Transfer weight onto the right leg.
5. Continue to push with the right arm to extend the right hip.

This movement into full extension on the supporting leg is called the 'tuck phase'.

Repeat to move the left leg.

The patient learns to walk in parallel bars and progresses to rollator or crutches.

To create a relatively normal stride using the rollator, the patient pushes the rollator forward between each step. Crutch walking is described on page 231.

Follow-up studies on the number of patients who continue to use these orthoses when the training period is over are remarkably similar. Sixty-four per cent continued to use the Parawalker (Moore & Stallard 1991) and 62% continued to use the RGO (Ellis 1995).

The effort of walking is the main reason why most patients do not continue to walk after discharge from hospital (Coghlan et al 1980). Using the IRGO as opposed to the ARGO, the energy cost was slightly less and the mean velocity slightly greater, although neither was statistically significant (Winchester 1993).

Although construction problems still exist and the energy required to walk in these orthoses is high, they enable patients with high lesions, including those with low cervical lesions, to stand and walk, and as long as patients are interested progress will continue to be made.

GAIT USING FUNCTIONAL ELECTRICAL STIMULATION (FES) STANDING SYSTEMS

For the past 30 years, experiments have been undertaken to enable patients to walk using electrical stimulation of the relevant muscles. Surface, nerve cuff and deep muscle electrodes have been used. FES is applied to the intact lower motoneurone pathways and is therefore only suitable for upper motoneurone paralysis, as with stimulation of the phrenic nerve (Ch. 5). Initially, FES is used to improve the condition and bulk of the paralysed muscles. When the state of the muscles has improved, electronic implants can be used to activate muscles in functional sequence. Interestingly, 50 years ago Sir Ludwig Guttmann showed that muscle bulk could be improved in rabbits (Guttmann & Guttman 1942) and later in humans using galvanic stimulation (Guttmann & Guttman 1944).

Surface stimulation

Root stimulation gives access to the whole motor output, whilst surface stimulation reaches only part of it. Usually the gluteal and hamstring muscles are stimulated for standing, and quadriceps and the flexor withdrawal response for walking. To stimulate more muscles is impractical as it is too time-consuming. Surface stimulation is wasteful of current and requires assiduous attention to skin care, and the stimulation varies with movement of the limbs (Rushton et al 1995).

As surface stimulation methods are essentially limited to experimental work and for assessment, the electrode system must be implanted to obtain consistent and selective results.

Implanted electrodes

Three types of implanted electrodes are used:

- Percutaneous wires are inserted through the skin and focused on a motor point. Any number of wires may be used. Formal surgery is not required and the wires are inserted easily by a practised operator. This procedure has a high risk of electrode failure and a high incidence of infection. Cosmesis is unacceptable (Barr et al 1995).
- The nerve cuff electrode is placed around peripheral nerves in a formal surgical procedure.

- The epimysial electrode (disc type of electrode) is placed near the motor point of large muscles. Less dissection is required than for the cuff type but multichannel lower limb systems still require extensive surgery and the cabling also has to be implanted in the limb. As cable connectors tend to fracture, further surgery is often required.

A *sacral anterior root stimulator implant* (SARSI) has been widely used to restore bladder control in male and female patients and erectile function in male patients (Brindley & Rushton 1990). A *lumbar anterior root stimulator implant* (LARSI) has been used to stimulate lumbar and sacral roots (L2–S2) to restore lower limb function in two patients. These systems are now commercially available, as are some surface and upper limb motor locomotor systems.

Stringent criteria are necessary for the selection of patients for any FES system, which will include psychological as well as physical assessments. For example, joints must have full range of movement and be free of osteoporosis and the patient must be physically fit, as energy consumption is high. Patients gain the usual benefits from standing and walking with these systems, and Jaeger et al (1990) found psychological benefits also, in that the patients' self-esteem and confidence appeared to increase. To use a surface system long term is impractical, but surface stimulation as a non-invasive means of assessment and training is necessary for an implant system (Barr et al 1995). Both systems are useful and in many ways complementary (Rushton 1996).

FES does not restore functional gait. It is a form of exercise and remains experimental. Whatever the technique used, walking speed is slow and, together with energy consumption, is a limiting factor. Major technical problems continue to be encountered, for example in the selection and control of stimulation, failure of equipment and muscle fatigue.

To replace the intricate mechanism of normal gait is an enormous task. It is not surprising that progress is slow. Research continues in many centres worldwide.

In a study to examine the safety of FES, Ashley et al (1993) found evidence to suggest that there was a danger of autonomic dysreflexia during treatment in patients with lesions above the splanchnic outflow, i.e. above T6. Extra caution should therefore be employed with these patients.

GAIT USING HYBRID SYSTEMS – RGO WITH FES

The difficulties of mimicking the voluntary activity of walking by computer-controlled electrical stimulation, and its potential use to restore function, are well documented by Peckham (1987). With such a large number of sophisticated component parts, computer-controlled gait is open to malfunction and this has given rise to the use of functional electrical stimulation with an orthosis, producing an integrated or hybrid system.

Interest has developed since 1984 when, in the United States, the Louisiana State University reciprocating gait orthosis was combined with FES to quadriceps and the gluteal muscles (Petrofsky et al 1985). The reciprocating gait orthosis supported the patient as only a few of the muscles used in walking were stimulated and greater use of the trunk and arms was required to maintain balance. In addition, if the electrical system failed, the patient was still supported.

Research continues in many countries, but a functional system has not yet been developed. In most studies, the quadriceps and hamstring muscles are stimulated but the user still has to lift his body weight with his arms to swing the stride leg forward. The energy cost of paraplegic walking is intrinsically high (Nene et al 1996).

Few patients continue to use the systems after the training programmes are completed (Merati et al 2000). Hip and knee adjustments are required, the electrical connections are fragile and break easily, and other problems occur. This means that the patient needs to be frequently in contact with the rehabilitation team and this is not always practical because of distance.

Patients will only use a system if it allows them to walk without too much effort and perform other functions when wearing it. Energy consumption, transportability and the gait pattern all need improving if patients are to continue to use these systems (Nene et al 1996).

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Ultra-high lesions

Injuries to the upper cervical spine (C1–C3) paralyse the diaphragm as well as the other muscles of respiration and prove fatal at the scene of the accident unless the condition is recognized and artificial respiration given immediately.

Due to the knowledge and expertise of the emergency services in the UK, many patients with fractures at this level now reach hospital. The most common injury is at C2 when the cranial nerves are intact and there is partial supply to the accessory nerve but the diaphragm is paralysed and the patient will need ventilation.

Where the injury occurs at C4, the patient usually manages to reach hospital on a partially functioning diaphragm. Most lesions then ascend a segment when a ventilator becomes necessary. The lesion descends in the majority of cases and the patient finally manages to breathe unaided. The major muscles remaining innervated in the patient with a lesion at C4 are the upper portion of the trapezius and sternomastoid supplied by the accessory nerve, and platysma supplied by the facial nerve.

In the United States 52% of spinal cord injuries are in the cervical region. Of these 20% will require mechanical ventilation initially and approximately 5% will always require it (Di Marco 2001).

Not only are these patients totally paralysed apart from the head, but if ventilated they have no means of communication and therefore no way of expressing emotions and physical needs. A rudimentary system of communication needs to be established with the patient as soon as possible (Chawla 1993). Eye movements or blinking can be used to indicate 'yes' and 'no'. Later a scanning system can be used, such as selecting alphabet letters, items or words from a chart. The speech and language therapist needs to be involved from the day of admission. All staff need to remember that the patient has no means of initiating conversation.

When the patient on a ventilator becomes used to it he will learn to speak on inspiration, when the air flows both towards the lungs and through the larynx. During expiration almost all the air flows towards the ventilator as the impedance of the ventilator pathway is much lower than that of the laryngeal pathway. The speech produced during inspiration is not very satisfactory, the speech phase is short, so speech comes in bursts and there are long pauses which often come

when in the middle of a sentence. Hoit et al (2003) suggest that speech can be improved by simple changes in the ventilator setting, that is by lengthening inspiratory time, applying end-expiratory pressure and combining these two. The changes give longer time for speech and reduce the length of the pauses by reducing expiration. Each of these interventions improved speech but the most successful was the combination of the two. Although caution should always be used when applying positive end-expiratory pressure to individuals with compromised cardiac function or those with autonomic dysfunction, these interventions were found to be safe and comfortable on a short-term basis.

Verbal independence

Even with so little ability to communicate, the patient's wishes should be taken into account. An early priority is to assist the patient to begin to take control of himself and his environment; for example, as soon as possible, the patient is encouraged to know where his belongings are to be found in the locker and when he needs replenishments.

The ability to describe all aspects of the care he needs is vital for the patient with an ultra-high cervical lesion.

During his rehabilitation the patient must learn, for example:

- the settings for the ventilator
- suction and hyperinflationary techniques
- correct positioning in bed and in the wheelchair
- turning procedures
- bladder and bowel care
- the management of all equipment
- how to avoid pressure ulcers
- how to recognize indicators of impending problems.

Not only must he master the details of the care taught to him by the various professionals, he must also show that, in turn, he can teach his carers.

Plasticity of the human motor cortex may explain the increase in acuity of sight and hearing which those who treat patients with lesions at C2 observe. Hallett et al (1993) suggested that the relationship between the motor cortex and the muscles supplied may be modified in patients with disability. They used transcranial magnetic stimulation and muscle responses (motor-evoked potentials) to demonstrate the change in cortical mapping which occurs in patients with complete spinal cord lesions. It would appear that cortical representation of intact muscles spreads onto the area previously controlling the now paralysed muscles. Previous studies (Levy et al 1990, Topka et al 1991) support Hallet et al's findings. However, Brouwer & Hopkins-Russeel's (1997) study does not and they suggest 'there is a need for further investigation to determine the association of

pathology and specific rehabilitation intervention strategies with the occurrence or extent of motor cortical expansion'.

Patients with lesions between C1 and C4 have no motor power in the arms, trunk or legs. There is complete loss of sensation, bladder, bowel and sexual function, and vasomotor control. As a result of the paralysis of the vasoconstrictors, there is a marked vasodilatation initially. This causes blockage of the nasal air passages which adds to the difficulties of respiration without a tracheostomy. This phenomenon, known as Guttmann's sign, is often present in patients with lower cervical lesions also (Guttmann 1976).

When the stage of spinal areflexia is over, spasticity and rigidity of muscle develop, the limbs becoming predominantly spastic in extension.

Physical rehabilitation is limited to training the vasomotor system to enable the patient to lead a wheelchair life and to teaching him control of the power-drive chair and his environment. Special equipment is needed for those patients who return home, and the relatives require expert training.

Due to their respiratory problems and limited conversation patients with high lesions need a level of trust in staff and carers beyond that of other patients. Patterson et al (2005) suggest that peer support volunteers, who have had some training in understanding the issues involved, may assist in building trust with a newly injured patient and bridging the gap between patient and staff.

PHYSIOTHERAPY DURING THE ACUTE STAGE

Chest therapy is vital and is described in Chapter 5, including the treatment of a patient on a ventilator.

Treatment will be needed every 2 hours if not every hour for the first 24–48 hours. For patients without a tracheostomy, it is advisable to continue daily postural drainage for several months as a prophylactic measure once the acute stage is over. For patients with a tendency to chest infection, this should be continued throughout life. If a patient with a lesion at this level develops a head cold, he should remain in bed for a day or two to prevent secretions dripping down into the chest when the patient is vertical.

The ventilated patient will need to gain confidence in the physiotherapist and others involved in his care in order to be as relaxed as possible when the respirator is removed for suction or other purposes. Whilst giving the patient encouragement and reassurance, and with his permission, the physiotherapist needs to disconnect the ventilator for very brief periods to acclimatize the patient. If possible, ventilated patients should be taught to breathe using the accessory muscles. Glossopharyngeal breathing is also useful if the staff know how to teach it and if the patient can learn it, but it does prove a difficult task (Pool & Weerden 1973). Later these patients may be assessed for diaphragmatic pacing.

To minimize the effect of the extensor spasticity, the position of the arms is important. From the first day, the correct position is adduction of the shoulder, 45° flexion or mid-position of the elbow, extension of the wrist and flexion of the fingers.

When the fracture is healed, training for the vasomotor system must be taken very slowly. An abdominal binder is often a help for the first few weeks to minimize pooling of the blood in the splanchnic vessels. Some patients may continue to wear them.

Taylor et al (2002) employed functional electrical stimulation to the abdominal muscles to control blood pressure and augment cough in a patient with a C2/4 lesion. The patient used a chin-controlled joystick to activate the electrodes placed on either side of his abdomen. After eating, when his blood pressure fell to a low level, stimulation was self-administered every 3 to 5 minutes, gradually increasing the time between groups of bursts to once every hour after 90 minutes. This increased expiratory flow. The user became independent in coughing, has no need of suction and the maintenance of blood pressure has improved the quality of his life (see Ch. 5).

Caution

Functional electrical stimulation is mentioned by Karlsson (1999) as a potential trigger for autonomic dysreflexia if applied to the legs or visceral organs. Blood pressure needs to be monitored.

PHYSICAL REHABILITATION

The power-drive chair

These patients will require a power-drive chair. The chair will be controlled by pushing a small sensitive lever in the appropriate direction, using the chin, head, mouth or breath. As the power-drive chair is heavy to dismantle and put in a car, the patient will also need a transit chair.

The patient on a ventilator will need to carry on his chair the ventilator unit with back-up system, suction equipment and manual hyperinflation bag. The non-ventilated patient may need to carry a portable ventilator and the patient with a paced diaphragm will have to fix the pacer to his chair, usually attached to the armrest (Fig. 14.1).

Particular care needs to be taken in choosing a chair and cushion to fit the individual requirements of the user (Chs 6 and 11).

Position of the patient in the wheelchair

The patient has no muscles with which to save himself, and therefore his position in the chair must be carefully checked for safety and
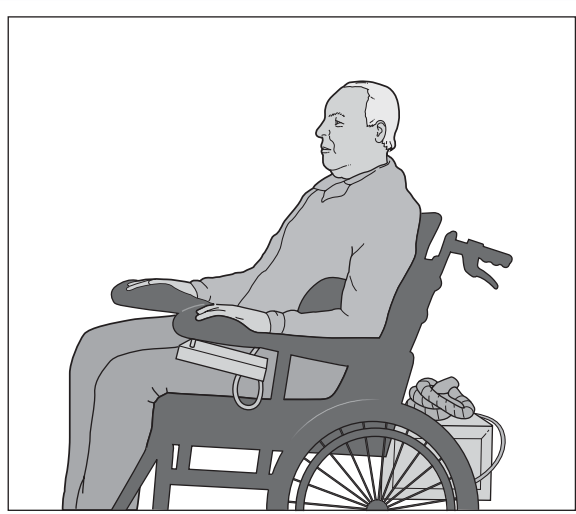
Figure 14.1 A patient with a pacer on the armrest and a ventilator between the rear wheels.

stability and to ensure that there are no factors likely to irritate his spasticity.

A semi-reclining backrest assists both stability and respiration, particularly if the patient is ventilated or the diaphragm remains partially paralysed. The arms need to be adequately supported to reduce spasticity and to minimize the strain on the shoulder joints. The forearms and hands can be positioned on a wheelchair tray, cushion on the lap or specific support made for some models of wheelchair (Fig. 14.2).

It is suggested by Corfman et al (2003) that patients using electric powered wheelchairs should always use a seatbelt and footrests when driving as falls from the chair only occurred when seatbelts and footrests were not being used. Driving speed was not a factor.

Physiotherapy

Once the patient is up, treatment is directed towards:

- hypertrophy of the innervated muscles
- control of the power-drive chair
- reducing spasticity
- educating the patient and relatives/carers in all relevant aspects of care
- maintaining balance in the chair, for the patient with a lesion at C4.
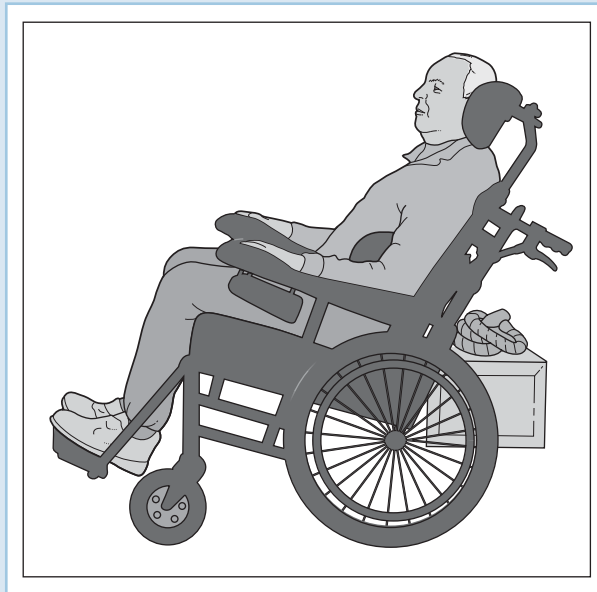
Figure 14.2 Position in the wheelchair of a patient with a lesion at C2.

Patient with a lesion at C1–C3

The patient will not be able to move within his wheelchair. The main priority is to mobilize and strengthen the neck muscles to enable the patient to look around, take his head off the head rest, use a computer, drive the power-drive wheelchair and control his environment by electronic means.

Hypertrophy of the few remaining muscles can be achieved with surprising results.

Free movement and manual resistance are used to mobilize and strengthen. As the neck gets stronger, the head rest is removed for short periods. Passive movements to the arms are continued and, if necessary, to the legs also.

Patient with a lesion at C4

In addition to the above, balance exercises in the chair are carried out in front of the mirror to help the patient (1) become aware of his position in space, and (2) use his head and shoulders to maintain his equilibrium, especially when moving over uneven ground.

1. The therapist sits the patient away from the back of the chair and if necessary reclines the backrest to a greater angle to give more room for the exercise. The therapist finds the balance point and the patient tries to hold the position by moving his head and using trapezius.

2. The patient sits back in the chair, leaning against the backrest and facing the mirror. By flexing the head quickly and then lifting it quickly, the patient can learn to 'bounce' his shoulders away from the backrest. Having bounced the upper trunk away from the chair, the patient side-flexes his head, and his upper trunk moves a few inches to one side. Once learnt, this manoeuvre is invaluable as it aids stability when the chair is being moved. This may require a great deal of practice but repays the effort involved.

Reduction of spasticity

Spasticity may be reduced by passive movements, by reflex-inhibiting postures on the plinth or bed, by careful positioning in bed at night and by standing. Drugs may be given to control severe spasticity.

Standing

A tilt table is used to stand patients with ultra-high lesions as they have insufficient motor power to assist in maintaining their own standing position. A tilting bed may be used at home.

The patient stands for only 2 or 3 minutes on the first day. This is increased to two periods of the same duration on the second day. Subsequently, the time is increased a few minutes only per day until the patient can stand for about 20 minutes.

In time, some patients, even those with lesions at C2, can stand and want to stand for long periods, i.e. 2 hours or more, as they say they enjoy it.

It is helpful for the patient to stand daily whilst training the vaso-motor response, but afterwards the patient stands two or three times a week. If possible, a relative is taught the technique so that the patient can continue to stand at home.

Abilities

The patient with a lesion at C1–C3 can learn to operate a computer using the voice, chin, head, mouth or another muscle with a suitably adapted interface (see Ch. 8).

The patient with a lesion at C4 can learn to use various mouth sticks to operate a computer, type, turn pages, paint and play certain games. A platform can be fitted at a convenient height so that the patient can pick out and replace the mouth sticks required. Innovative schemes enable some enthusiastic people with lesions at this level to take part in certain sports, for example target shooting. The rifle is manipulated by means of a microswitch triggered by the tongue and a weighted lever and pivot allow the gun to be aimed (Owen-Jones 2004).

Several environmental control systems are available which enable the completely paralysed patient to operate a selection of appliances in his environment. This is done by means of a switch, activated by the lightest touch, for example, of the chin, head or breath, or by the voice. The patient can, for example, control lights, doors, power points, curtains, entertainment systems and use a telephone.

Patients with these high lesions may need to employ carers, and if so, will need to be able to advertise, interview, train and arrange for payment for them.

HANDLING THE PATIENT

To relieve pressure

This is discussed in Chapter 6.

To turn the patient

1. Cross one ankle over the other in the direction of the turn.
2. Turn the shoulders by putting one arm, e.g. the right, across the chest to hang down on the left side and pull the left shoulder back.
3. The therapist thrusts her arms underneath the buttocks until she can grip the anterior superior iliac spine, if possible. The arms are kept close together – the heavier the patient, the closer the arms need to be.
4. Turn the buttocks and at the same time pull them back into the middle of the bed. The 'bounce' of the mattress can be utilized to flip the patient over.

When a turn onto the side is not necessary but pressure over the sacrum and buttocks needs to be relieved, steps 3 and 4 alone can be used to turn the buttocks through 30°. A pillow should be used to support the buttocks.

To transfer a patient with a lesion at C1–C3 from bed to chair using a hoist

Before moving the patient, ensure that the ventilator is appropriately positioned.

1. Sit the patient up and put the sling behind him as low down as possible.
2. Lie the patient down.
3. Lift one leg at a time, to bring the sling under the thighs. Or,
   a. roll the sling lengthwise
   b. roll the patient onto one side

      c. place the sling as far as possible under the back
      d. roll onto the other side and pull the sling through.
4. Attach the sling to the hoist (Fig. 14.3A), which may be free-standing or on a permanent rail in the patient's own home, for example.
5. Use the hoist to lift, move and lower the patient into the chair (Fig. 14.3B, C).
6. Lift the thigh to remove the sling on each side.
7. Lean the patient forward and remove the sling from behind his back.
8. Lift buttocks back in the chair (Fig. 14.3D) and correct his sitting position.

Reverse the procedure to move from chair to bed.

    Occasions will occur when the patient needs to be transferred but the hoist is not available, e.g. when travelling. In this case, manual lifts will be required; these are described in Chapter 12.
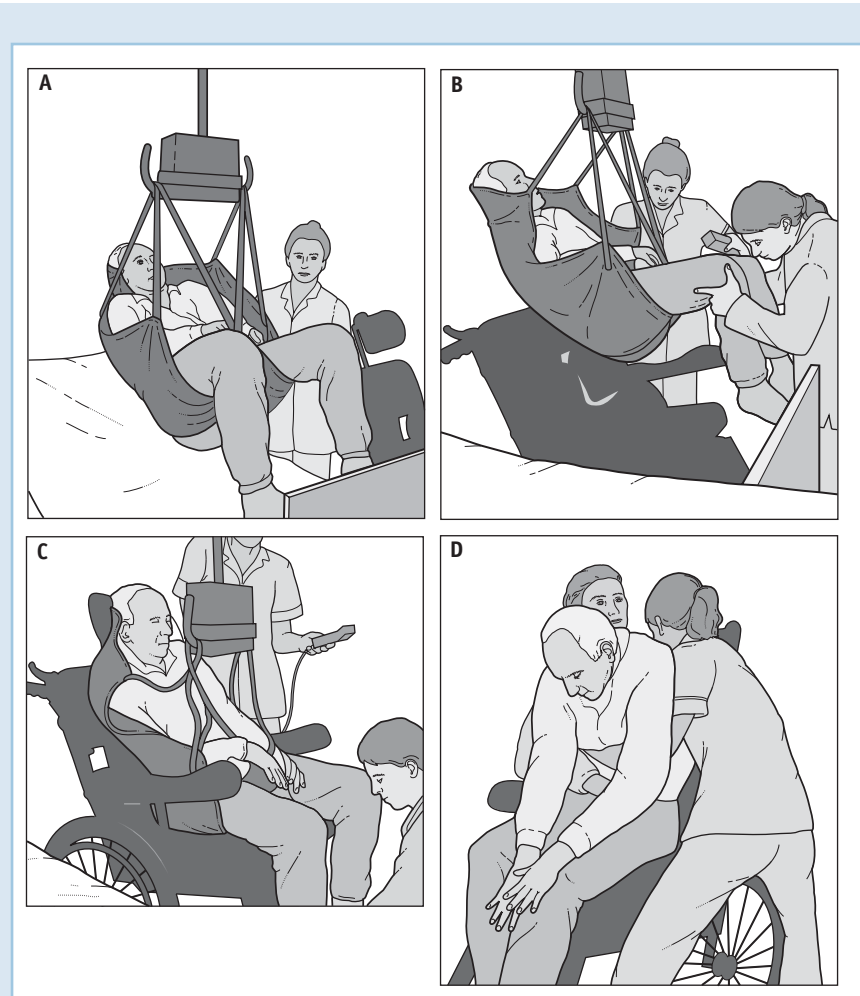
Figure 14.3 Transfer using a hoist.

HANDLING THE WHEELCHAIR

To push up a kerb

1. Tip the chair onto its rear wheels by pressing down on the chair handles and one of the tipping levers.
2. Push the chair on the rear wheels until the front wheels are over the kerb.
3. Lower the chair onto the front wheels and push the rear wheels up the kerb.

To push down a kerb

Tilt the chair onto its rear wheels and push down the kerb on the rear wheels only. If the patient is large and heavy, or excessively nervous, turn the chair around and allow the rear wheels to descend first.

To put the chair in the boot of the car

Take out the cushion, remove the wheels if applicable, fold the chair and remove the footplates if necessary. Check that the brakes are on. With the side of the chair facing the operator, hold onto the crossbars or the wheels. Tip the chair up onto the thighs and pivot it into the boot. Lightweight wheelchairs are more easily handled.

If the wheels are not removable, they are usually placed to the back of the boot. Deep boots entail lifting the chair the depth of the boot before it can be taken out. Therefore, unless two chairs need to be carried, a boot in which the floor is level with the door is more convenient.

STAFF EDUCATION

An increasing number of patients require ventilation during re-habilitation and on a permanent basis. All the staff of a spinal unit need to have the knowledge and confidence to manage a ventilator-dependent patient, so that he can move safely around the unit and take advantage of all the hospital has to offer. Coggrave (2001) suggests that multidisciplinary study sessions can be a useful way of educating staff. Porters, administrative staff and managers as well as doctors, nurses and therapists can all be included. People who are mobile in hospital are more likely to participate in community activities after discharge (Kennedy et al 1991).

PERMANENT CARE

It is a tribute to the medical social workers, to the social services and particularly to the relatives that so many of the patients with ultra-high lesions return to their own homes. Some patients have large families where the strain of caring for the disabled person is spread between several members. In other cases, there is only one relative available. Some depend on maximum social support, while others accept only a little help.

Patients with additional problems may need permanent hospital care. Others may have no suitable relative young and fit enough to cope with the full-time care needed. Some of these patients may be able to pay for the necessary assistance, while others will need to go into long-term care in homes with heavy nursing wards. Many questions are still to be answered regarding long-term planning for people with high spinal cord lesions (Mathson-Prince 1997).

The person who is to care for the patient with a very high lesion at home needs special training which should start as soon as possible. If willing and able, carers are encouraged to assist the staff in suctioning techniques from an early stage. There are many tasks for them to learn and the carer should spend a minimum of a week at the hospital before the patient is discharged. The carer will need to learn how to handle the patient and the wheelchair, how to dress the patient and attend to the bladder and bowels. It is also important for the carer to see what the patient can do for himself and how best to help him achieve even minimum independence.

The staff need to assist the patient and carer to find the most appropriate way of dealing with all the tasks so that in time they will occupy a less prominent role in home life. The presence of a ventilator-dependent person in the home obviously has a profound effect on family life. The most important factors in successful adaptation appear to be the level of communication with the family and the degree of commitment between all family members (Glass 1993).

Due to improvements in medical care and rehabilitation, as well as in technology, people with high tetraplegia are living longer. A longitudinal study of people with lesions from C1 to C4, 14 to 24 years post-injury was undertaken by Bushnik & Charlifue (2005). They found that the 63 subjects reported living 'rich and fulfilled lives'.

Equipment

Beds

An electronically manipulated bed and/or special mattress is usually required for home use. These aids do not negate the necessity to turn the patient but either lengthen the period between turns or facilitate the turn itself. Beds are available which raise the patient from supine

to the sitting position and there are also beds that turn the patient. Some relatives may prefer to turn the patient manually. In some cases and with suitable adaptations, the patient may be able to operate the bed himself, thus achieving a small measure of independence.

These patients, with or without a pacer, will also require ventilators, suction equipment with all disposable supplies, a manual chair and a power chair at home.

Hoists

The hammock sling supports the head and is completely safe for patients with high cervical lesions. As the support for the lower body is under the thighs, not under the buttocks, it can easily be removed during the day so that the patient does not have to sit on it.

Hoists are available to get in and out of the car but are often cumbersome and bulky to use.

The patient with a C1–C3 lesion will need to travel in a car in his wheelchair. Mechanisms are available which enable the patient in a wheelchair to be lifted either into the area of the passenger's seat or into the rear of a hatchback car or van.

Safety procedures for patients with a lesion at C1–C3 are vital. When at home, someone who knows how to suction the patient and who can cope with any other possible problem should always be able to see, and be seen by, the patient. All equipment needs to be taken with the patient when he travels by car and someone should travel with the patient in addition to the driver.

Technology for the future

Studies on the use of robotics technology in the development of manipulative aids for personal care and control of the environment continue. Further work in this interesting field is required in order to simplify the devices and make them effective but less expensive, and to establish the rehabilitation potential and acceptability to the user of this approach.

Recent advances in the technology of functional electrical stimulation and new systems for the patient to control equipment may allow the control of multiple functions. Research continues on functional electrical stimulation systems which could enable the patient with high tetraplegia to have some arm and even hand function (Bryden et al 2005).

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The incomplete spinal lesion

Susan Edwards

INTRODUCTION

The term 'incomplete lesion' encompasses all patients with some sparing of neural activity below the level of the lesion. The number of patients with incomplete lesions as opposed to complete lesions is increasing and is now reported to be 55% of the total spinal cord injury population (Sekhon & Fehlings 2001) although Paddison & Middleton (2004) put the figure as high as 65%. The reasons for this changing trend towards more incomplete lesions include greater awareness of the importance of immobilization after injury, the use of restraints and airbags in motor vehicles and treatment once in hospital to limit secondary damage (Sekhon & Fehlings 2001).

The percentage of incomplete lesions may in fact be even higher as data relating to spinal cord demographics and treatment outcome are usually reported in the spinal cord injury literature and yet many patients with spinal cord lesions are never admitted to a spinal injuries unit. Non-traumatic incomplete spinal cord lesions account for at least 1.2% of all neurology outpatient consultations (Stevenson et al 1996).

The outcome for patients with complete lesions, for example a C6 or T12, is more predictable than for those with incomplete lesions. As with all lesions, the pre-morbid status of the patient is of paramount importance in influencing outcome but, according to a review carried out by Burns & Ditunno (2001), it is now possible to predict with reasonable accuracy the long-term outcome within a week of the initial injury. However, patients with incomplete lesions include not only those who sustain their injury as a result of trauma, but also those with more diverse pathologies, many of which are progressive. Prognosis for patients with progressive pathology is inevitably more difficult to predict.

Patients with incomplete spinal cord damage as a result of pathological causes include those with:

- vascular accidents or disease
- tumours
- cervical myelopathy
- inflammatory disease.

CLASSIFICATIONS

No two lesions will be identical. The pathology will always be different because of the complex nature of the spinal cord. However, certain types of lesions are referred to as syndromes. These include:

- central cord syndrome
- anterior cord syndrome
- Brown–Séquard syndrome.

Central cord syndrome

The central cord syndrome (CCS) was initially described by Schneider et al (1954) and it is reported to be the most common type of incomplete spinal cord injury (Bosch et al 1971, Chen et al 1997, Tow & Kong 1998). The American Spinal Injury Association (ASIA) define this syndrome as: 'a lesion, occurring almost exclusively in the cervical region that produces sacral sparing and greater weakness in the upper limbs than in the lower limbs' (ASIA 2000).

Cause

This type of lesion usually affects older people with pre-existing cervical spondylosis. The mechanism of injury is that of hyperextension with inward bulging of the ligamentum flavum squeezing or pinching of the spinal cord (Tow & Kong 1998, Newey et al 2000). Falls or motor vehicle accidents are reported to be the main cause of CCS although men over the age of 40, with predisposing narrow cervical canals and osteoarthritis of the cervical spine, have also been identified to be at risk following body surfing accidents (Scher 1995).

Although more common in the middle-aged and elderly population, CCS may occur in people of any age and be associated with other aetiologies, injury mechanisms or predisposing factors (Fig. 15.1) (Roth et al 1990). In older age groups, fracture of the cervical spine is less common than in younger subjects (Penrod et al 1990) and in the absence of a fracture, this lesion may be difficult to diagnose. Magnetic resonance imaging will provide confirmation and additional information.

The acute CCS is considered to arise from an injury which affects primarily the central part of the spinal cord and is frequently haemorrhagic (Fig. 15.2) (Morse 1982, Maroon et al 1991). However, Quencer et al (1992) found no evidence of haemorrhage into the substance of the cord and concluded that CCS was not primarily a grey matter lesion but that the neurological disability, at least in part, was due to damage to the white matter tracts. They suggested that the most common mechanism of injury may be direct compression
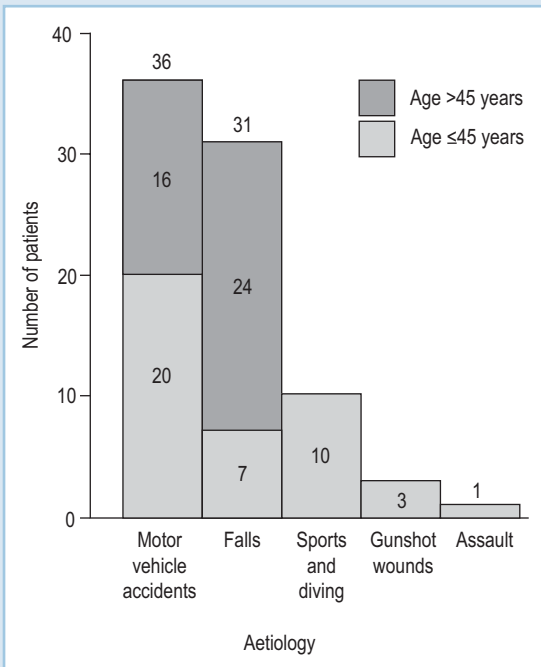
Figure 15.1 Aetiology distribution of central cord syndrome patients. (From Roth et al 1990, with permission from American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation.)
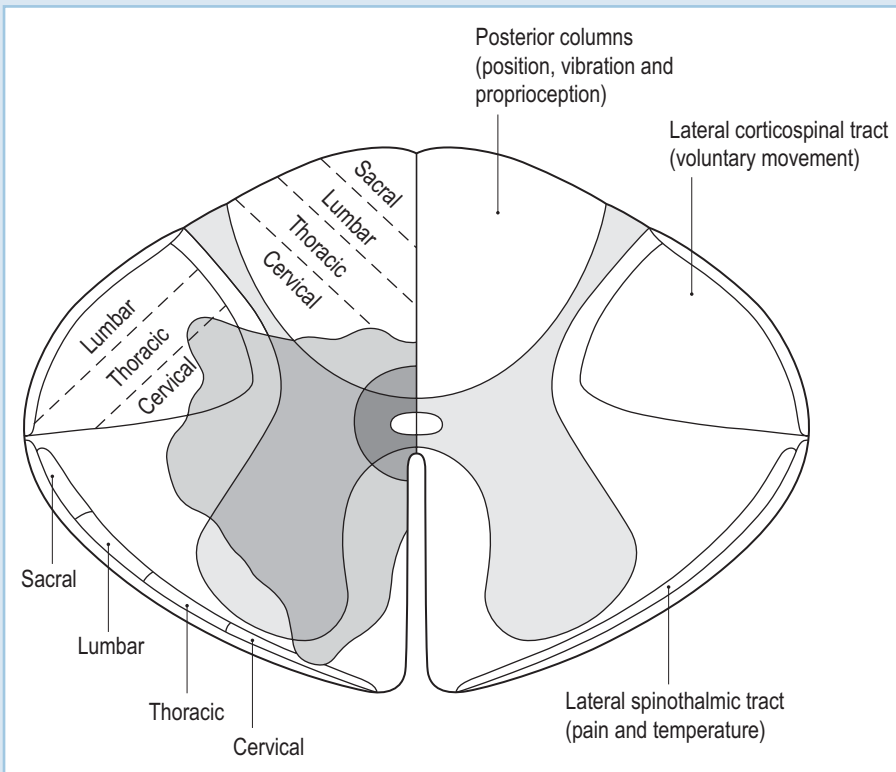
Figure 15.2 Cross-section of cervical spinal cord. Hatched areas represent a zone of central haemorrhage (▨) and surrounding oedema (▫). The impingement on pathways, especially central cervical fibres, in part subserving upper extremity function, is readily apparent. (After Morse 1982, with permission from American College of Emergency Physicians.)

of the cord in an already narrowed spinal canal. This would explain the predominance of axonal injury in the white matter of the lateral columns. These findings were supported by Collignon et al (2002), who concluded that acute traumatic CCS may be due to the impairment of the corticospinal tract; the results of their study confirming the absence of intramedullary haemorrhage.

Roth et al (1990), in a study of 81 traumatic CCS patients, found that more than 90% of patients had neurological recovery of both upper and lower limbs, neurological recovery being defined as an increase in strength of one muscle grade. This recovery generally occurred in the order of lower limbs, bladder function, upper limbs and finally the hands. The extent of recovery is greatest in younger patients, who have a better prognosis for recovery of activities of daily living and in becoming functional walkers (Penrod et al 1990, Roth et al 1990), although Newey et al (2000) noted that the poorer outcome identified in patients over 50 is heavily weighted by a particularly bad outcome in those over 70 years of age. The tendency for older people to have a higher incidence of comorbid medical problems may also contribute to this poor functional outcome (Tow & Kong 1998) and it is possible that arteriosclerosis may compromise blood supply to the cord in older subjects and that the initial damage may be more severe due to cervical spondylosis (Scher 1995).

Clinical picture

The general clinical picture is of:

- disproportionately more motor impairment of the upper than lower extremities
- bladder dysfunction, often with urinary retention
- varying degrees of sensory loss.

Spasticity, shoulder pain, hand oedema and dysaesthetic pain are noted complications (Roth et al 1990, Maroon et al 1991) and the development of contractures and/or painful joints of the upper limbs remains a very real danger throughout all stages of treatment and management and may progress over time. Roth et al (1990) found the number of patients with shoulder pain and dysaesthetic pain increased, to be greater at discharge than during rehabilitation.

Progressive neurological deterioration, characterized by spasticity, has been identified in older patients with CCS, whereby patients who were initially functionally ambulant became wheelchair-dependent (Maroon et al 1991). However, in contrast, Newey et al (2000) found that, although most patients had brisk reflexes and some continued to experience spasms, spasticity did not cause significant functional problems and motor power continued to improve after the patient was discharged from rehabilitation. Tow & Kong (1998) had similar findings in that, whilst 20% of patients in their study (n = 73) required antispastic medication for lower limb spasticity, neurologi-

cal recovery, as assessed by the discharge motor score, was not significantly different between these patients and those without spasticity.

Motor deficit

At the level of the lesion, there will be damage to the motoneuronal pool resulting in a flaccid paralysis of those muscles supplied from this level (Scher 1995). For example, a lesion occurring at the C5 level will give rise to flaccidity, most notably of deltoid and biceps. The wasting of these muscles gives rise to the fairly typical upper limb picture associated with the central cord lesion.

Hand dysfunction is an outstanding feature of cervical myelopathies (Nakajima & Hirayama 1995) but this is variable in CCS. The hands may be relatively uninvolved, but without the background of proximal stability, selective upper limb function will be impaired. In other cases, the hands may be paralysed. The predominant loss of muscle function in distal muscles may be explained by axonal damage. Disruption of axons, particularly in the lateral columns in the region occupied by the corticospinal tracts, reflects their importance for hand and finger function (Quencer et al 1992, Collignon et al 2002). Paralysis of the hands may lead to the development of stiff and painful joints or cervical hand syndrome (p. 45) and swelling may occur that is compounded by the effect of gravity.

Many patients with CCS will achieve an independent gait with or without the use of walking aids and all too often they walk independently before they have significant recovery of the upper limbs. In a sense, these patients differ from virtually all other patients with neurological disability, in that use of the arms in gait re-education is recommended. Whilst it cannot be extrapolated that increased use of the upper limbs for balance and support in gait re-education will transfer to more selective functional use of the hands, this might go some way to facilitating neuronal adaptation and cortical reorganization (Puri et al 1998, Smith et al 2000). Once the patient is able to walk independently, there may be little if any opportunity for the arms to be involved in function (Fig. 15.3).

Depending on the severity of the lesion, the patient will demonstrate some degree of motor deficit in the trunk and lower limbs which is invariably characterized by the presence of hypertonicity.

Sensory deficit

This is extremely variable, ranging from severe sensory loss to virtually no impairment.

The disability of these patients is often underestimated. Those who are ambulant may appear less disabled and yet, without the use of their upper limbs, they are invariably more impaired than the chairbound paraplegic person.

Figure 15.3 Standing posture of people with central cord syndrome. The use of the arms for support on a frame or crutches is encouraged.

Anterior spinal cord syndrome

Cause

Traumatic

This syndrome may result from a forced flexion, compression injury which may occur in diving or road traffic accidents (Foo et al 1981). The trauma is often associated with anterior spinal artery compression giving rise to ischaemia which may contribute to the clinical presentation (Grundy & Swain 2002).

Non-traumatic

The anterior cord syndrome may result from infarction secondary to anterior spinal artery thrombosis, spinal cord angioma or rupture of aortic aneurysm. Significant neurological recovery following spinal cord infarct is unusual unless there is improvement within the first 24 hours (Geldermacher & Nager 1989, cited in Stevenson et al 1996).

Clinical picture

This syndrome results from damage to the anterior part of the spinal cord. The clinical signs and symptoms are those of:

- motor loss
- loss of pain and temperature sensation
- preservation of tactile and joint position sense.

The severity of impairment will depend upon the extent and exact site of the damage but continuous pain has been identified as a key feature following spinal cord infarction (Pelser & van Gijn 1993).

Patients presenting with motor loss and sensory sparing are classified as Frankel B, or B on the ASIA impairment scale. However, these scales make no distinction between the types of sensory sparing, for example, tactile joint position sense and pain and temperature.

A clear distinction has been made between the different types of sensory sparing with those with preserved pin prick being shown to have an excellent prognosis to regain a functional gait. Crozier et al (1991) found that 66% of Frankel B patients with preservation of pin perception recovered to become functional walkers, whereas only 14% with light touch were able to walk ($n = 33$).

Vibration sense, tactile and joint position sense are served by the dorsal columns, whereas pain and temperature sensation are dependent upon the spinothalamic tracts. Preservation of pin prick indicates some integrity of the spinothalamic tracts in the anterolateral aspect of the spinal cord and therefore the possibility of some sparing of the adjacent corticospinal tracts (Foo et al 1981).

Body awareness enables patients with anterior cord lesions to respond more quickly to the rehabilitation process, often achieving their treatment goals in a shorter time, but management of these patients is the same as that for Frankel A patients. Although sensory sparing clearly indicates that the lesion is incomplete, a significant difference in outcome is only possible where there is some motor recovery.

Brown–Séquard syndrome

This syndrome results from a transverse hemi-section of the spinal cord, whereby half of the spinal cord is damaged laterally (Grundy & Swain 2002, Sullivan 1989).

Cause

Lateral damage to one side of the cord may be caused by penetration injuries such as stab wounds but may also result from other aetiologies and injury mechanisms such as road traffic accidents and rugby football injuries. Fracture dislocation of a unilateral articular process and acute ruptured intervertebral disc have also been reported to give rise to this syndrome (Sullivan 1989).

Although knife injuries may result in the classical picture of Brown–Séquard syndrome, their incidence is variable. In over 1600 cases of spinal cord injury in the United States, only 1.1% were due to penetrating injuries other than gunshot wounds (Waters et al 1995). However, of 1600 patients in South Africa admitted to a spinal injuries unit, a quarter were the result of stab wounds. Of these, 50% had Brown–Séquard syndrome (Peacock et al 1977).

Clinical picture

Motor deficit

Paralysis or weakness occurs on the same side as the lesion due to destruction of the motor tracts. In addition, there will be a lower motoneurone lesion at the level of spinal cord damage resulting from damage to the motoneuronal pool which is particularly significant at the cervical or lumbar enlargements.

Sensory deficit

Destruction of the posterior column results in loss of position sense, vibration and tactile discrimination below the level of the lesion on the affected side.

Destruction of the lateral spinothalamic tract causes loss of sensation of pain and temperature on the side opposite to the lesion. As the fibres entering this tract do not cross for several segments, the upper level of this sensory loss is likely to be a few segments below the level of the lesion. Fibres entering the cord at the level of the lesion may be involved before they cross, causing a narrow zone of similar pain and temperature loss on the same side.

Typical cases of Brown–Séquard syndrome are rare. Many patients with incomplete lesions will present with some asymmetry whilst not fulfilling the exact criteria of this syndrome. Patients with a total severance of the lateral half of their spinal cord will have little if any recovery, whereas those with contusions or contra-coup injuries are likely to show significant functional improvement.

The majority of these patients will walk independently, with a reciprocal gait, as only one leg has lost or reduced motor power. An orthosis and/or walking aids may be required.

Even among these syndromes described above, there is considerable variability in the severity of neurological damage and thus in the

functional outcome. Incomplete spinal cord damage resulting from other pathologies, such as tumours, inflammatory disease, cervical myelopathy and vascular disease, is often more diverse and the outcome even more unpredictable.

Psychological factors

Obviously, with both complete and incomplete lesions, the psychological factors resulting from such a devastating injury have to be taken into account throughout all stages of rehabilitation. The patient with an incomplete lesion may have a particular problem in coming to terms with his disability. Being incomplete, prognosis is ill-defined and it is particularly difficult, even for those with a substantial functional recovery, to accept less than 100% normality (Sullivan 1989).

If surrounded by patients with complete lesions, it is easy to consider the patient with an incomplete lesion fortunate because he has some sparing. Although this is true, even those patients making a good recovery may still be unable to return to their normal lifestyle.

Understanding the patient's psychological response to his condition is crucial for effective rehabilitation. The physiotherapist, because of her close contact with the patient, may be the one chosen as 'confidante' by both the patient and his relatives. It is important that she allows him to express his fears and/or frustrations while offering constructive advice. Where more professional counselling is thought to be required, the patient and/or relatives should be encouraged to talk to a clinical psychologist.

TREATMENT

General comments

The therapeutic management of a patient with an incomplete lesion may differ significantly from that of a patient with a complete lesion. Therapists working in spinal injury units develop great skill in maximizing the potential of patients with complete lesions and may be tempted to treat the patient with an incomplete lesion along similar lines. Clearly, it is essential for all persons involved in the rehabilitation of the patient with an incomplete spinal cord injury to assess the activity limitation and participation restriction of each patient as it relates to that individual and not to compare him with other patients, especially those with complete lesions.

It has been suggested that patients with incomplete spinal cord lesions, particularly those caused by slowly progressive pathologies, are best managed in a neurological rehabilitation unit as opposed to a spinal injury unit (Stevenson et al 1996) and, given that over 50%

of all spinal injured patients have incomplete lesions, this statement is of enormous significance to the future management of this client group. However, a key consideration relates to bladder and bowel management in that the patient with an incomplete spinal cord lesion may have severe disruption of bladder and bowel function, which requires the specific expertise of a spinal injury unit. Greater liaison and transference of skills should be made between therapists and other staff working in spinal injury units and neurological rehabilitation centres.

Patients with incomplete spinal cord lesions demonstrate many diverse disabilities depending on the level and extent of the pathology. It is important that both the patient and therapist have realistic expectations in terms of outcome and that appropriate short-term goals are selected to demonstrate progress. Accurate initial and ongoing assessment is essential to set and monitor these mutually agreed goals with appropriate, objective outcome measures to determine the efficacy of treatment.

Whilst 'normal movement' is often cited as the ultimate goal of rehabilitation, all too often this is not achievable for patients with extensive neurological damage and compensatory strategies are necessary in order for the patients to overcome their physical limitations. The therapeutic skill lies in determining that compensation which is necessary and even essential for function and that which is unnecessary and potentially detrimental to the patient.

Analysis of movement and implications for treatment following incomplete spinal cord damage

Many authors describe the analysis of movement as the basis for the development of treatment techniques for patients with neurological damage (Bobath 1990, Carr et al 1995, Shumway-Cook & Woollacott 2001, Edwards 2002). However, the emphasis differs with regard to treatment approaches. For example, Bobath (1990) advocated the control of abnormal reflex activity and the underlying tone to improve coordination of movement, whereas Carr et al (1995) direct movement training towards improving performance of everyday actions, thereby enabling the patient to learn control of muscle activity and develop strength and endurance during functional motor performance. Over recent years, the emphasis of the Bobath approach has changed significantly in that the musculoskeletal consequences of neurological damage are now recognized to be of equal importance to the tonal problems. Unfortunately, although this more holistic approach is now widely taught on Bobath adult hemiplegia courses in the UK, there is no current literature to describe this change of emphasis.

Normal movement is dependent upon an intact central nervous system (CNS) which can receive, integrate and respond to stimuli. The complexity of this processing is illustrated by Harris-Warwick

& Sparks (1995), where they refer to 'motor plans being implemented through networks that determine the order, timing and strength of movement around each joint, which is translated into a choreography of motoneurone activity that drives the individual muscles at the right moment and with the right force'. Spinal cord damage will affect this processing; the extent to which it is damaged being determined by the site and severity of the lesion.

Key features that influence movement include:

- muscle tone and positioning
- speed of movement and degree of support
- sensory feedback and feedforward
- postural control and balance reactions
- musculoskeletal viability.

Muscle tone and the influence of positioning

Normal muscle tone is dependent upon an intact CNS, which enables an individual to maintain an upright posture and adapt to a varying and often changing base of support and which allows selective movement for function.

Tone is the resistance offered by muscles to continuous passive stretch (Brooks 1986) and this definition clearly has implications for both the neural and non-neural components of the movement disorder. Following spinal cord damage, tone may be impaired as a result of overactivity of affected muscle groups and/or the musculoskeletal consequences of impaired mobility.

The management of patients with incomplete spinal cord lesions will be determined to a large extent by the alterations in muscle tone. Positioning in bed, particularly during the early stages, passive/active movements, facilitation of transfers, posture in the wheelchair and standing will all be influenced by the underlying tone. Equally, the manner in which these activities are carried out will in turn influence the prevailing muscle tone.

Facilitation of active movement on a background of impaired tone, particularly low tone, is often more difficult when the patient is fully supported. Bedrest is often essential in the immediate aftermath of traumatic spinal cord injury and therefore alternative positioning is not possible. However, as soon as the medical condition allows, positioning against gravity with appropriate support is recommended to stimulate a more active response (Edwards 2002).

Speed of movement and degree of support

This is of particular relevance to the postural adjustments that precede and accompany movement. Horak et al (1984) examined the activation times for trunk and leg movement while lifting the arm. Activity in these postural muscles preceded the arm displacement, presumably to provide stability for the ensuing movement. The

sequencing of these postural adjustments was found to be more variable during slower movements. As less stabilization is required during slower movement, the preparatory muscle activity is not programmed as rigidly as with more rapid movement. These early changes in postural muscles were significantly decreased if the subject was supported at the shoulder or even touched a rail with a single finger (Cordo & Nashner 1982).

These two factors, the speed at which the movement is performed and the support provided during movement, are of particular significance for patients with neurological damage such as may result from spinal cord injury. Many patients will be unable to move as quickly as normal subjects and changes in the postural adjustments may be related to the speed of the movement as much as the pathology. The order and timing of postural adjustments will be influenced when providing assistance for a patient to stand and walk. Clearly it is important to facilitate a more normal posture or movement, but it may be of equal value to allow the patient to correct his own posture. If the therapist constantly supports the patient, the postural adjustments will always be dependent upon this support.

Sensory feedback and feedforward

Postures and movements are guided by a mixture of motor programmes and sensory feedback because calculations made ahead of time in the CNS are always corrected after central and peripheral reports about reality (Brooks 1986).

Rothwell (1994) describes the production of voluntary movement as being sequential in terms of the idea or reason to move, the motor plan which is constantly updated to fit the requirements of the muscles involved in the movement and the execution of the movement. This interaction between central and peripheral systems may be considered a cyclical event whereby movement skills are constantly reinforced and refined by repetition. If the patient is unable to move due to significant paralysis, he will be unable to reinforce his movement skills.

Hallett et al (1993) demonstrated the change in cortical mapping of a patient with a complete cervical spinal cord lesion using transcranial magnetic stimulation (TMS). The cortical representation of deltoid expanded to encroach on the territory previously subserving the paralysed muscles innervated below the neurological level of the lesion.

Patients who develop abnormal tone and movement may create new motor programmes that are dictated by the stereotyped activity. Movements attempted on a background of increased neural activity will involve effort and produce an abnormal sensory input to the CNS. The aim of physiotherapy is to modify this often stereotypical response by facilitation of more normal movement patterns. Prolonged use of a limited repertoire of pathological movement patterns creates a dominant abnormal response which becomes increasingly difficult to reverse. Once established, re-education of more purpose-

ful movement can sometimes only be achieved with outside intervention such as localized injections of botulinum toxin to weaken the overactive muscles (p. 309).

The direct effect of sensory loss is more difficult to quantify. Patients who have full muscle power but who have no appreciation of movement can be as disabled as those without motor control. Clearly any specific sensory loss will have implications for the initiation, guidance and control of movement.

Postural control and balance reactions

Postural control, which provides stability and orientation, requires:

- the integration of sensory information to assess the position and motion of the body in space
- the ability to generate forces for controlling body position (Shumway-Cook & Woollacott 2001).

Postural adjustments occur throughout the body and are effective only on a background of normal muscle tone. They occur during any movement and any alteration in the position of the body's centre of gravity requires modification of tone throughout the body musculature. For example, during quiet stance, the muscles of the feet and lower limbs are constantly making minute adjustments to maintain equilibrium with the body's centre of gravity over the base of support. Shumway-Cook & Woollacott (2001) refer to this response as the ankle strategy, in that the body is maintained or restored to a position of stability through movement centred primarily about the ankle joints. If this proves to be inadequate, movements to regain balance or maintain equilibrium over a compliant or small surface area may then occur at the hip, this being referred to as the hip strategy; and if this fails, the natural response is to take a step, the stepping strategy.

For patients with incomplete spinal cord lesions, the hip strategy will be called into play if there is inadequate control at the ankles, which may result from weakness and/or muscle imbalance. A typical example of this is in patients with a positive support reaction whereby the foot is unable to adapt to and accept the base of the support. The patient is unable to transfer weight over the full surface of the foot and the ankle remains in a degree of plantarflexion. The compensatory response is flexion at the hip to maintain the body weight over the base of support (Bobath 1990, Edwards 2002).

Postural adjustments also refer to the alignment of body segments, the head, trunk and limbs, with each other and with the environment. They are observed in virtually all sequences of movement, such as rolling, sitting up and lying down, and are dependent upon the interaction between flexion and extension which allows for rotation. Any traumatic injury to the spine will interfere with these responses in that there is invariably a reduced range of movement following any acute injury.

This is particularly noticeable following immobilization of the cervical spine using a halo jacket. It has been observed in clinical practice that even those patients who have full neurological function have severe difficulties in attaining correct body alignment following prolonged immobilization in this type of support. Although a valuable means of stabilization, it would appear that the rigidity of the device virtually negates muscle activity between the points of contact. It is therefore not unusual to see an anterior tilt of the pelvis and poking chin, with little if any neck and trunk rotation, on removal of the support.

Patients with impaired movement control are often apprehensive, realizing that their response to sudden and unexpected perturbations may be inadequate to maintain balance. Movements are consequently slower and the background postural tone higher, particularly when standing and walking, in anticipation of potential falls.

Musculoskeletal viability

The different types of skeletal muscle are referred to as slow oxidative (SO), fast glycolytic (FG) and fast oxidative glycolytic (FOG). Their characteristics are summarized in Table 15.1 (Rothwell 1994).

The SO muscles are those which participate in long-lasting but relatively weak contractions, such as in the control of posture, whereas the FG muscles generate large forces but are readily fatigued. The recruitment order of a motor unit is dependent upon the size of its motoneurone (Henneman et al 1956, cited in Rothwell 1994) and is in the order of SO, FOG, FG. From a functional perspective, the SO muscles provide postural control to allow for the FG to perform the more selective movements.

Muscles alter their characteristics in response to function, that is to say it is the activity of the muscle which determines the muscle fibre type (Pette & Staron 1997). Following spinal cord injury, the disturbance of spinal cord circuitry leads to disordered muscular activation patterns which will alter the muscle characteristics (Fung et al 1990).

Damage to motoneuronal cells at the level of the lesion gives rise to flaccid paralysis or weakness of the affected muscle groups. This is well illustrated in patients with central cord syndrome at the level

Table 15.1 The characteristics of different types of skeletal muscles (from Rothwell 1994, Table 3.1, with permission)

Fibre type	I SO	IIA FOG	IIB FG
Motor unit type	Slow (S)	Fast fatigue resistant (FR)	Fast fatiguable (FF)
Fibre diameter	Small	Medium–small	Large

of C5 where the shoulder muscles are often significantly wasted, exhibiting rapid and extensive atrophy in response to the deprivation of normal activity patterns (Goldspink & Williams 1990, Given et al 1995).

Pathological movement patterns may emerge due to damage to the descending tracts and these will impose different activity patterns on muscle due to the stereotyped movements. Phenotype expression is dependent upon both neural activity and mechanical factors and all muscles stay fast unless they are subjected to stretch and force generation (Goldspink 1999). Therefore, in the absence of dynamic muscular activity against gravity, the SO muscles atrophy more readily than the FG (Given et al 1995). However, a relative increase in both SO and FG fibre types has been reported in the literature. Dattola et al (1993) and Edstrom (1970) found an increase in SO fibre type in patients following stroke and Goldspink et al (1992) and Vrbova et al 1995 reported a change in fibre type from slow to fast in patients with neurological disability that interfered with their ability to maintain postural control against gravity.

From a therapy perspective, people who, following spinal cord injury, are unable to sustain muscle activity against gravity will be unable to maintain the SO muscle characteristics associated with postural control. Re-education of postural control may then be dependent upon the activity of FG muscle fibres, which are not suited to this task as they are unable to sustain force (Edwards 2002).

In both scenarios, atrophy will be a notable feature due to denervation as a result of damage to the motoneuronal cells and/or disuse as a result of disruption to the descending tracts as occurs in upper motoneurone lesions (Gordon & Mao 1994).

The mechanical properties of muscle, particularly the length and stiffness, are also key determinants for normal functional use. The length-associated changes of muscle will affect patients with paralysis and/or hypertonus in that, in both instances, full-range active movement is impaired and normal motor function is not possible (Ada & Canning 1990, Goldspink & Williams 1990, Edwards 2002). Muscle imbalance occurs when relative changes in muscle length and recruitment patterns take place between agonist/antagonist and synergic muscle groups (Fitzgerald & Stokes 2004).

Imposed length changes have been shown to alter the mechanical properties and structure of muscle. Immobilization in a shortened position produces short, stiff muscles with fewer sarcomeres and an increase in connective tissue. These length changes and sarcomere loss are accelerated when the muscle shortening is induced by electrical stimulation or tetanus toxin and it is suggested that these results provide a model for the rapid length changes seen in spastic muscle (Herbert 1988).

The main remit of the physiotherapist is to maintain the range of movement in all affected muscle groups. This is of particular significance for patients with incomplete spinal cord lesions in that the majority of patients will have some degree of neurological recovery.

As recovery occurs in a specific muscle, if the antagonist muscle has become shortened, it will be more difficult, if not impossible, to maximize this recovery.

An understanding of these key features of movement is essential for the development of treatment techniques for the patient with incomplete spinal cord injury. Of all patients with neurological damage, the patient with an incomplete spinal cord injury often presents with the most diverse functional problems, which will depend upon the site and extent of the lesion. In order to develop appropriate treatment strategies, it is important to distinguish between the primary deficit and the secondary compensation. Analysis of positions and movement sequences in normal subjects is useful to draw comparison with the postural and movement deficits which may result from incomplete spinal cord damage. In this way, the distinction between the primary cause and secondary compensation can be more readily made.

Analysis of specific positions

Although few individuals demonstrate identical characteristics when assuming any one position, certain features are remarkably similar. A detailed description of the normal characteristics of supine-lying, prone-lying, side-lying, sitting and standing is to be found in Edwards (2002).

Table 15.2 provides a summary of the identified features when assuming each of these positions. This table is by no means conclusive. Its purpose is to allow comparisons to be drawn between normal subjects and patients with movement disorders. Analysis of these positions in this way provides a structure for the assessment of patients with physical disability and for the selection of the most appropriate position in which to treat the patient. For example, patients with flaccidity should be stimulated by treatment in positions requiring anti-gravity activity. Those with hypertonus should be mobilized in an appropriate position to inhibit the hypertonia in order to prepare them to accept the base of support.

Key points of control

Key points of control are described as areas of the body from which movement can be most effectively controlled and from where movement may be centralized. The proximal key points are the trunk, shoulder girdles and pelvis, and the distal key points are the hands and feet (Bobath 1990).

Trunk mobilization is recognized as an important treatment modality and in the majority of cases is a prerequisite for the facilitation of movement of the limbs (Davies 1990, Edwards 2002). If the trunk is unable to make the required postural adjustments to movement of the limbs, then these distal movements will inevitably be abnormal.

Table 15.2 Characteristics of supported positions and positions requiring anti-gravity activity

| | Supported positions | | | Positions requiring anti-gravity activity | |
	Prone	Supine	Supported sitting	Sitting	Standing
Head	To side	Midline	Midline	Midline	Midline
Shoulders	Forwards of CKP	Backwards of CKP	Forwards of CKP	Forwards of CKP	Forwards of CKP
Pelvis	Forwards of CKP (anterior tilt)	Backwards of CKP (posterior tilt)	Forwards of CKP (posterior tilt)	Backwards of CKP (anterior tilt)	Backwards of CKP (posterior tilt)
Upper limbs	Flexion, adduction, medial rotation	Extension, abduction, lateral rotation	Flexion, adduction, medial rotation	Flexion, adduction, medial rotation	Flexion, adduction, medial rotation
Lower limbs	Adduction, medial rotation	Extension, abduction, lateral rotation	Flexion, adduction, medial rotation	Flexion, abduction, lateral rotation	Extension, lateral rotation
Overall	Flexion	Extension	Flexion	Flexion	Extension influence

CKP = central key point.

Posture and movement within the trunk may be effectively controlled by manual guidance from a central point between the xiphisternum and the T8 vertebra. This is called the central key point. The relationship of the central key point with the proximal key points provides a basis for the analysis of abnormal patterns of posture and movement. In the normal subject, although asymmetrical postures may be adopted, the relationship between the central key point, the head and the proximal key points is generally symmetrical. Although asymmetry may be seen, as in cross-legged sitting, it is in no way comparable to that of a patient with neurological dysfunction.

As a basis for the analysis of neurological damage and the resultant impaired movement, it is helpful to assess the patient in terms of the midline deviation. This may be considered in three planes of movement:

- the sagittal plane
- the coronal plane
- the horizontal plane.

The relationship of the key points to the midline will vary in different positions depending upon the ability of the individual to:

- support himself in anti-gravity situations
- accept the base of support in supported positions.

A key point from which to influence movement is determined by the ability of the individual to respond to facilitation of movement. For example, care must be taken when facilitating from a distal key point, such as the hand, to ensure that there is appropriate activity within the trunk and at the shoulder. If the patient is unable to make the required adjustments, the shoulder may be traumatized.

This analysis demonstrates that there can be no stereotyped picture of what is 'normal'. Individuals have different levels of postural tone in accepting the base of support and reacting to the effects of gravity. Similarly, movements from one position to another will show similarities but may vary quite considerably whilst still being accepted as being within a normal range.

Pathophysiology

The movement dysfunction of patients with incomplete spinal cord lesions may originate from:

- impairment of supraspinal control through damage to descending tracts (Dimitrijevic et al 1983)
- disturbance of spinal cord circuitry which leads to disordered muscular activation patterns and abnormal reflex activity (Fung et al 1990)
- weakness/atrophy due to damage to the motoneuronal pool at the level of the lesion and/or as a consequence of damage to the descending tracts (Gordon & Mao 1994)

- change in the mechanical properties of muscle (Given et al 1995)
- muscle imbalance, as a result of changes in muscle length and recruitment patterns taking place between agonist/antagonist and synergic muscle groups (Fitzgerald & Stokes 2004).

The activity limitation and participation restriction following incomplete spinal cord injury therefore arises primarily as a result of hypertonia and/or weakness, through both neural and mechanical mechanisms.

Neural components of hypertonia

Spasticity is a common consequence of spinal cord injury and is often more severe in patients with incomplete lesions, particularly those classified as Frankel B and C (Maynard et al 1990, Heckman 1994). However, there is some controversy with regard to terminology and the definition of spasticity (Sheean 2001).

The classical definition of spasticity is that it is 'a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks resulting from hyperexcitability of the stretch reflex as one component of the upper motoneuron (UMN) syndrome' (Lance 1980). However, whilst patients with incomplete spinal cord injury may demonstrate spasticity, this is rarely the primary disabling feature.

The upper motoneurone (UMN) syndrome is a more general term used to describe patients with abnormal motor function following cerebral or spinal cord lesions (Katz & Rymer 1989). The clinical features are broadly divided into negative and positive phenomena. The negative features include weakness and loss of dexterity whereas the positive features are characterized by excessive or inappropriate motor activity. Spasticity, as defined by Lance (1980), is but one component of this syndrome.

Whereas spasticity is velocity dependent and is therefore afferent mediated, many patients present with continuous muscle contraction that continues in the absence of movement. This is referred to as spastic dystonia, which is thought to arise as a result of continuous supraspinal drive to the spinal motoneurones and is therefore efferent mediated (Burke 1988, Young 1994, Sheean 2001).

The supraspinal control of muscle tone is primarily dependent upon the balanced interaction between parapyramidal tracts which arise in the brainstem. The key tracts are the dorsal reticulospinal tract, which has an inhibitory influence, and the medial reticulospinal and vestibular-spinal tracts, which have a facilitatory effect on extensor tone. All three systems are thought to inhibit flexor reflex afferents (Brown 1994, Sheean 2001). The main clinical difference between complete and incomplete spinal cord lesions is that incomplete lesions often have more dominant extensor tone as opposed to the complete lesion, which is strongly flexor (Brown 1994). Where the facilitatory tracts in the ventral part of the cord are spared, this incomplete lesion will give rise to paraplegia in extension; with a

complete lesion, the flexor reflex afferents are disinhibited resulting in paraplegia in flexion (Sheean 2001).

A characteristic feature of spasticity is impaired reciprocal inhibition (Boorman et al 1996), frequently termed reciprocal innervation by physiotherapists (Edwards 2002). This is associated with an increase in the degree of antagonist muscle contraction seen during alternating muscle actions. It has been suggested that muscle relaxation is accomplished, not simply by inhibition of the active motoneurone pool, but also by active, possibly presynaptic, processes which speed 'de-recruitment' of the motoneurones. These active processes are impaired in patients with incomplete spinal cord lesions with spasticity (Boorman et al 1996). Dietz et al (1995) proposed that reduced modulation of electromyographic (EMG) patterns observed during locomotion – a longer lasting tonic gastrocnemius EMG activity and co-activation of antagonist leg muscles – may be due to impaired function of polysynaptic spinal reflexes.

Neural hypertonia may be considered as a dynamic phenomenon and reflects the age, site and size of the lesion responsible for its genesis. The reorganization of neural pathways following spinal cord injury occurs as a result of the sprouting of new neuronal connections and through unmasking of existing but functionally inactive pathways. Whereas sprouting occurs over time, unmasking is evident within hours (Topka et al 1991).

In the uninjured spinal cord, the efficiency of synaptic function and the pattern of synaptic connections within the neural circuitry responsible for learning have been shown to be activity-dependent. This dispels the concept that the spinal cord is relatively non-plastic and serves simply to relay supraspinal commands. There is evidence supporting both activity-dependent and injury-induced plasticity after spinal cord trauma (Muir & Steeves 1997).

Non-neural components of hypertonia

Neural hypertonia will invariably give rise to muscle imbalance with one muscle group being dominant over the antagonist group. This in turn will lead to changes in the biomechanical properties of muscle and reduced tendon compliance (Dietz 1992).

The increased mechanical resistance of the musculoskeletal system including reduced tendon compliance and physiological and histochemical changes in muscle fibres is an inevitable consequence of paralysis and/or stereotyped pathological movement patterns. It is these mechanical factors that are considered by many to be the major cause of residual disability (Dietz 1992, Given et al 1995, O'Dwyer et al 1996).

However, in spite of the importance of mechanical factors to the genesis of hypertonia, the mechanical contribution to hypertonia would not arise without the damage to the CNS producing the reduced activity and/or stereotypical postures associated with spinal cord injury (Edwards 2002).

Pathological activity associated with hypertonia

Positive support reaction

This term is used primarily by physiotherapists to describe a pathological extensor response in the lower limb evoked by a stimulus of pressure on the ball of the foot (Bobath 1990, Sheean 2001, Edwards 2002). This reaction, which is considered to be of distal origin, prevents transference of weight over the full surface of the foot. The patient, with increased extensor tone of the lower limb and plantarflexion and inversion of the foot, is unable to accommodate to the supporting surface. This extensor response prevents hip extension during stance phase of gait, the patient having to flex forward at the hip to maintain balance.

Although the knee is held in extension, this position is not maintained with normal quadriceps activity and it is not uncommon to observe wasting of this muscle group. The knee becomes hyperextended due to the inability to attain normal alignment of the pelvis over the foot, impaired interaction between the hamstrings and quadriceps muscle groups and shortening of gastrocnemius (Edwards 2002).

Patients with a positive support reaction are in danger of developing contractures of all muscle groups held in a shortened position. Those most notably affected are:

- soleus and gastrocnemius
- tibialis posterior
- intrinsic foot musculature and plantar fascia
- iliopsoas
- rectus femoris
- hip adductors.

The clinical picture of the positive support reaction is most apparent during gait. The increased extensor tone prevents release of the knee and the patient has to hitch the leg forward during the swing phase of gait. It may also affect the patient's ability to stand up or sit down, the extensor tone preventing mobility at the knee.

Inhibition of this pathological response must incorporate desensitization by mobilization of the foot itself. Physiotherapists are often advised to avoid contact with the ball of the foot. However, in this instance, mobilization of the foot, the posterior crural muscle group and the Achilles tendon is recommended to desensitize against both the intrinsic and extrinsic stimuli (Edwards 2002). This distal intervention should be used in conjunction with facilitation of more normal alignment of the pelvis over the weight-bearing foot.

Botulinum toxin is increasingly being used to weaken the dominant muscle groups responsible for the positive support reaction (Dunne et al 1995, Richardson et al 2000). Used in conjunction with physiotherapy and in some cases splinting, this has shown promising results (Edwards 2002) .

Flexor withdrawal response

This response occurs as a protective mechanism in normal subjects and may be observed as an individual withdraws the hand from a hot stove, or the foot when stepping on a nail. It is determined by the direction of the noxious stimulus and therefore may not necessarily be into flexion (Rothwell 1994). Patients with incomplete spinal cord lesions may demonstrate this response, but in a more stereotyped and consistent pattern and in response to a fairly innocuous stimulus such as removal of the bedclothes. The withdrawal response in the lower limbs is that of flexion and lateral rotation at the hip, flexion at the knee and dorsiflexion or plantarflexion at the ankle. The foot may be everted or inverted, often being everted with dorsiflexion or inverted with plantarflexion at the ankle.

Noxious stimulus on a background of abnormal tone may give rise to this response. For example, a pressure ulcer, pain or an ingrowing toenail may cause an increase in hypertonia with flexion of the limb (Schomburg 1990, Thompson 2002). It is essential to determine if there is an external cause and to treat this prior to undertaking more radical intervention. The short-term influence of such a stimulus may be readily reversible, but prolonged exposure may have more residual effects such as the development of contractures (Edwards 2002).

The clinical picture of the flexor withdrawal response is most apparent during the swing phase of gait where there is exaggerated flexor activity. Weight-bearing through the affected limb(s) was previously recommended but this should be carried out with caution. Attempts to stand the patient on a leg which is contracted into flexion may further aggravate the situation, not least by imposing an additional painful stimulus (Edwards 2002).

Paralysis/weakness

Weakness may result from damage to the motoneuronal pool producing peripheral denervation or as a consequence of damage to the corticospinal tract.

With a complete spinal cord lesion, there is total ablation of the anterior horn cells at the level of the lesion and therefore no 'final common pathway' to the muscle. This produces a flaccid paralysis of muscles innervated from that level of the spinal cord.

In incomplete lesions, the extent of this destruction will be variable depending on the site and severity of the lesion. The lesion may affect virtually all efferent and afferent neurons at a certain level but not causing complete interruption of their function. Alternatively, there may be lesions where there are distinct parts of the spinal cord which are completely damaged but others that are preserved intact (Bajd et al 1989).

In many instances, the strength of the muscle will be reduced, but some control may remain, producing weakness as opposed to a complete paralysis. EMG investigations have revealed that the active units could be divided into those under normal control, spontaneous active units which could not be activated by the subject, and units which could only be slowly and weakly activated (Stein et al 1990).

The acute lesion in bed

One of the main aims of physiotherapy is to minimize the effects of hypertonia and to prevent length-associated changes in the musculoskeletal system to enable more appropriate function.

Changes in cortical representation of body parts due to loss of function have been shown to occur within minutes (Hallet et al 1993) and therefore early treatment is essential to minimize these adverse effects.

The spinal cord damage gives rise to the presenting signs and symptoms with regard to impaired muscle tone, but it is how the patient copes with this pathological movement that will determine the outcome in terms of muscle, neural and soft tissue changes.

Although this section relates to the early management of these patients, it is of relevance throughout all stages of rehabilitation.

Positioning

In the early stages of traumatic spinal cord injury, the positioning of the patient is determined by the management of the fracture site. The position of the incomplete lesion is, therefore, the same as that for the complete lesion.

Where severe hypertonia is a complicating factor, it may be necessary to avoid the supine position and to use pillows and sandbags to support the fracture site and keep the patient in side-lying. If the extensor aspect of the patient's body is in contact with the bed, as is the case even when on his 'side' on the Egerton–Stoke Mandeville electric turning bed, a stimulus is provided for him to push against which may exacerbate his hypertonus and might therefore be contraindicated.

The 'frog position', where the hips are abducted, laterally rotated and flexed to approximately 40°, can be used to break up severe extensor hypertonus (Fig. 15.4). Patients positioned in this way to control extensor tone should be closely monitored for any increase in flexor tone, as it is possible to reverse the pattern of hypertonus completely.

Alternate positioning of the arms is also recommended in certain spinal injury units. The crucifix position and positioning of the arms in lateral rotation (Fig. 15.5A, B) should be used with caution as they are at the extreme end of range. Any shortening of, for example, the pectoral muscles or medial rotators of the shoulder may place undue stress on an already vulnerable joint. The neural structures may also become shortened and specific tension tests are recommended to maintain or restore adaptive lengthening of the nervous system (Davies 1994, Panturin 2004).
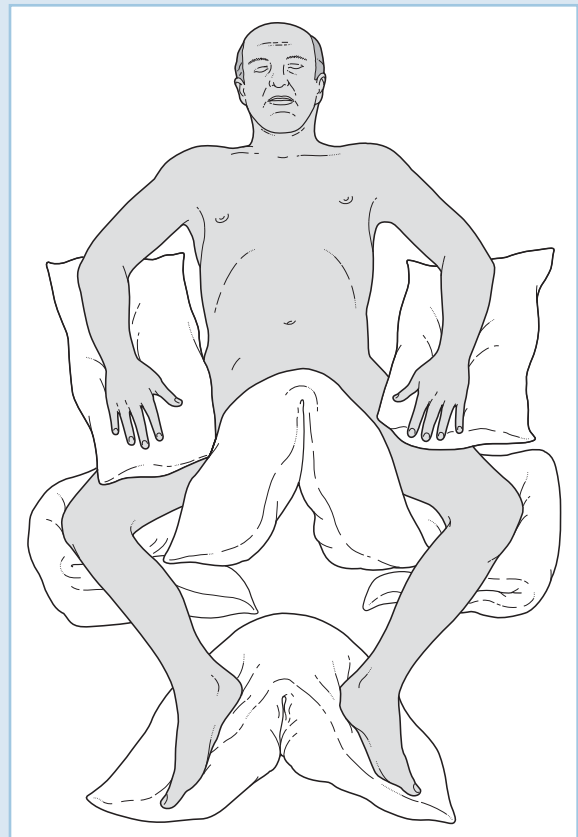
Figure 15.4 Frog position.
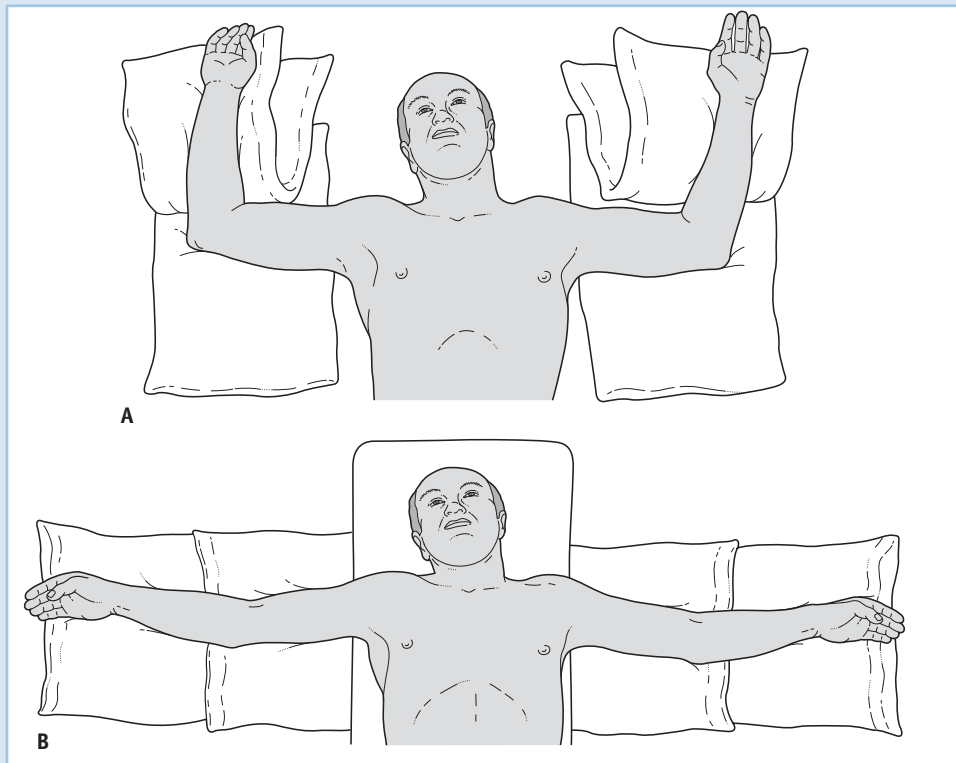
Figure 15.5 Positioning of arms. A: The arms in lateral rotation. B: Crucifix.

Clearly the aim is to prevent this shortening occurring in the first place, but even with the most rigorous intervention with regard to positioning and movement in the early stages, it is very difficult to replicate the full repertoire of normal movement. Any normal subject lying in the crucifix position will appreciate the discomfort felt over a relatively short period of time.

Passive/active movement

Assisted movements should be carried out with the patient's full awareness and participation. Regenerating axons in the adult CNS are capable of forming synapses with both appropriate and inappropriate target neurons. Facilitation of appropriate patterns of activity will assist in establishing functional connections between regenerating supraspinal axons and spinal neurons (Muir & Steeves 1997).

Motor learning is an active process and can only occur as a result of relatively permanent changes in the capability for skilled movement (Schmidt 1991). Passive movement, while of value in maintaining muscle and joint range, does little to effect functional change unless there is some participation on the part of the patient. As such, the term 'passive' is inappropriate in that the patient should always be involved in the activity. In the early stages following spinal cord injury, no active movement may be possible. However, given that there is often significant anatomical continuity across the injury site, even in patients with minimal function below the lesion (Dimitrijevic et al 1983), it is imperative to ensure that the patient is aware of, and contributes to, the desired movement.

The physiotherapist must appreciate changes in tone and, by her handling, modify this tone before taking the limb through normal joint range. If movements are performed in this way, with close communication between patient and therapist, there will be less danger of trauma and of the joints becoming painful and contracted.

Effort during movement should be avoided where hypertonus is present. The physiotherapist gives sufficient guidance and assistance to the patient to reduce to a minimum the effort required to perform the movement. This is particularly important where pathological movements may jeopardize stability at the fracture site. Some patients may be particularly sensitive to any stimulus, even removal of the bedclothes prior to doing the movements and, with cervical lesions it may be necessary for another person to support the shoulders to eliminate excessive movement around the fracture site.

In the majority of patients, extensor hypertonus is the dominant pattern in the lower limbs (Bajd et al 1989) and this posturing may also be in evidence in the arms and trunk of a patient with a high cervical lesion. A combination of both flexor and extensor hypertonus frequently occurs and movement initially may be from one total pattern to the other.

In those cases where there is severe extensor hypertonus, it may be necessary initially to move the limbs into the total flexor pattern in order to have any effect on the predominant extension. After breaking up the total extensor synergy, it is important to work recovering muscles out of any stereotyped pattern. For example, with the leg flexed, the patient is encouraged to use any active hip flexion with adduction and medial rotation and, when moving into extension, this should incorporate abduction and lateral rotation, always maintaining control to avoid an extensor thrust.

Partial preservation of brain influences contribute to the central excitatory state of segmental reflexes and hypertonia and, as control of movement improves, there is often a notable reduction in the level of hypertonicity (Maynard et al 1990).

Compensatory movements

Teaching compensatory movement patterns may be considered to be inappropriate in the early stages, but this is dependent upon the

functional outcome. For example, for patients with a complete C6 lesion, in the absence of triceps, extension of the elbow can only be accomplished by means of lateral rotation at the shoulder with distal support at the hand. Although the resultant movement is compensatory, it in no way precludes recovery of triceps. Clinical experience suggests that the reverse is true, in that with extension of the elbow and using this movement in functional activities, activity in triceps is stimulated.

It has been shown that the cortical representation of extensor carpi radialis varies according to the function. Some parts of its cortical representation are concerned with this muscle as a 'prime mover', for example when used in the tenodesis grip, while others are concerned with its role as a stabilizer of the wrist during movements of the hand (Turton et al 1993). The early use of the tenodesis grip is therefore more difficult to substantiate. Patients with no finger movement but with wrist extension will readily use a tenodesis grip to maximize function. However, if finger movements then recover at a later date, it is often difficult for the patient to cease to rely on this grip, thereby impeding functional use of the fingers.

Compensatory movement must therefore be viewed on merit in the light of the presenting signs and symptoms and the expected prognosis, always assuming a positive outcome.

The shoulder

Patients with cervical cord damage, particularly those with central cord lesions, will invariably have abnormal movement at the shoulder due to the imbalance of muscle activity (Roth et al 1990). The shoulder joint is the most mobile joint of the body, sacrificing stability for this mobility. With paralysis or weakness of the muscles around the shoulder, functional activities are severely compromised.

It is essential to understand the components of normal activity at the shoulder in order to prevent trauma and possible contracture through inappropriate handling and movement. The shoulder joint cannot be viewed in isolation. Movements of the shoulder joint are dependent upon the integrity and responsiveness of the shoulder girdle, trunk, pelvis and lower limbs. For example, full elevation of the arms is dependent upon adequate extension within the thoracic spine (Crawford & Jull 1993).

The normal shoulder mechanism is dependent upon the structure and relationship of seven articulations (Fig. 15.6). The scapula lies in a slightly laterally rotated position, there being a ratio of approximately 2:3 in the distance between the medial edge of the spine of the scapula and the vertebral column, and the inferior angle and the vertebral column (Fig. 15.7A).

The glenoid fossa faces anteriorly, laterally and superiorly in its articulation with the head of the humerus. This relationship between the head of the humerus and the glenoid fossa provides a degree of stability described as the locking mechanism of the shoulder (Basmajian 1978).
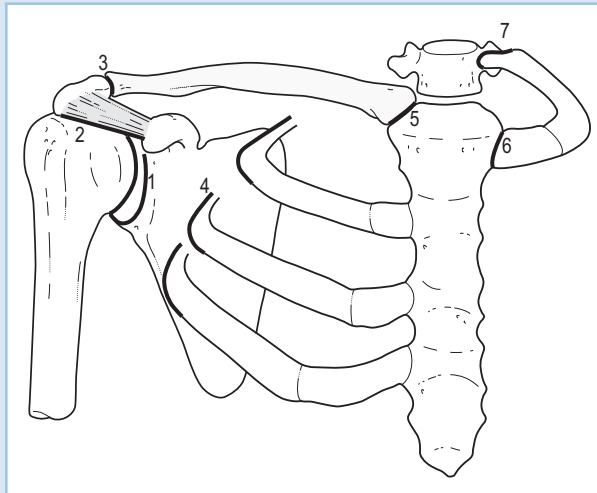
Figure 15.6 Composite drawing of the shoulder girdle. 1, Glenohumoral; 2, suprahumeral; 3, acromioclavicular; 4, scapulocostal; 5, sternoclavicular; 6, costosternal; 7, costovertebral. (From Cailliet 1987.)
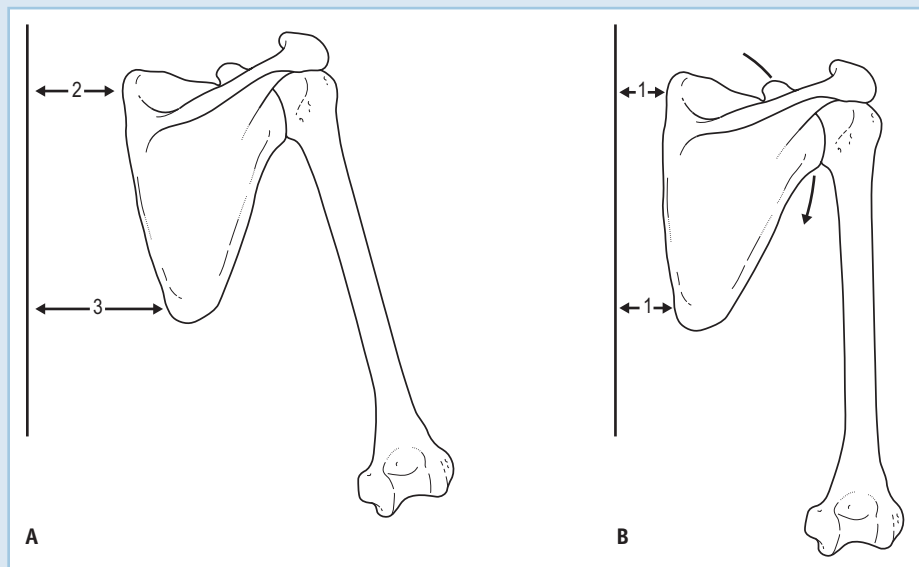
Figure 15.7 Relationship of the shoulder girdle and vertebral column. A: Normal relationship. B: Abnormal relationship.

Functional movement of the upper limb requires coordination of movement between the glenohumeral joint and the scapula on a background of dynamic co-contraction and stability in the trunk. This interaction is dependent upon normal muscle activity. In patients with cervical cord damage, this muscle activity will be impaired.

The patient with flaccidity/low tone, on assessment in the sitting position, demonstrates the following:

- The scapula adopts a more vertical position (Fig. 15.7B), the inferior angle lying the same distance from the vertebral column as the spine of the scapula. Winging of the scapula is apparent.
- The glenoid fossa lies vertically in its articulation with the head of humerus, thereby creating a position of abduction at the glenohumeral joint. This nullifies the locking mechanism and the support of the arm now depends primarily on the capsule and the coracohumeral ligament. Subluxation frequently occurs.
- The upper fibres of trapezius become hyperactive in an attempt to counteract the weight of the upper limb.

The patient with neural hypertonia presents with similar malalignment, but the situation is exacerbated by the increased tone:

- The scapula will be pulled medially towards the vertebral column under the influence of the rhomboids. In extreme cases, the position of the inferior angle of the scapula will be closer to the vertebral column than that of the medial aspect of the spine of the scapula. Winging of the scapula is often pronounced.
- The degree of abduction at the glenohumeral joint may be increased.
- Hypertonia of the medial rotators of the upper limb will cause further malalignment of the glenohumeral joint and may give rise to anterior subluxation.
- In some cases, the medial rotators of the upper limb may become shortened.

Movements of the arm away from the body will, in this situation, create a hypermobile scapula. The inferior angle will rotate laterally around the chest wall and there will be little or no isolated movement at the glenohumeral joint.

Because of the variability in injuries sustained, it is not possible to describe in detail the particular problems that any one patient with cervical cord damage will have. It is important to recognize that although contractures are more likely to occur in the presence of hypertonia (Yarkony & Sahgal 1987), profound disability has been reported as a result of reduced joint mobility in patients with Guillain–Barré syndrome, a peripheral CNS disorder (Soryal et al 1992).

This analysis describes a basic concept of normal movement, to enable the therapist to identify the patient's individual problem(s) and select appropriate treatment techniques. In every case, treatment must attempt to restore a more correct alignment of the upper limb, shoulder girdle and trunk. Movements of the upper limb, be they passive or active, must be performed with a full understanding of the normal shoulder mechanism and an accurate analysis of the patient's problem.

The pelvis and gait

Extensive work has been carried out in the field of gait analysis taking into consideration:

- kinematics – monitoring the gait pattern
- electromyography – monitoring muscle activity
- kinetics – monitoring forces that produce change/motion
- efficiency of gait – measuring energy expenditure, speed and endurance.

An understanding of these aspects of normal gait is invaluable when assessing patients with incomplete spinal cord damage. This detailed analysis using highly sophisticated equipment allows the primary errors in walking to be distinguished from compensatory changes, which is essential in planning effective treatment (Sutherland 1992).

The different problems that may arise as a result of incomplete spinal cord damage are too numerous and diverse to enable a standardized treatment approach. However, there are certain aspects of gait which must be considered with observational analysis and in planning treatment:

- the quality of postural tone, both the neural and mechanical components
- the speed and efficiency of gait
- the midline orientation of the central key point and the proximal key points of the shoulder girdles and the pelvis in terms of the sagittal, coronal and transverse planes
- the ability of the feet to accept the base of support.

In addition, each patient must have a full neurological assessment to determine the motor and sensory deficit. Special attention must be paid to aspects such as skeletal deformity or surgical intervention in the form of vertebral fusion or the insertion of, for example, a Harrington rod.

Normal walking is dependent upon a continual interchange between mobility and stability, which requires free passive mobility and appropriate muscle action (Perry 1992). Box 15.1 provides a summary of normal muscle activity and function during gait. This box illustrates the complexity of gait. The muscles identified do not have one single action but may work concentrically, eccentrically or isometrically at different stages of the gait cycle.

This is of particular relevance when considering the use of muscle or nerve blocks. For example, the role of the plantarflexors during gait is to contribute to knee stability, provide ankle stability, restrain the forward movement of the tibia on the talus during stance phase, and minimize the vertical oscillation of the whole-body centre of mass (Sutherland et al 1980). Therefore, whilst muscle or nerve blocks will reduce undesirable hyperactivity such as may occur with hypertonia, they may also lead to knee and ankle instability and increased energy expenditure.

Box 15.1 A summary of normal muscle activity and function during gait (after adaptation by Gage 1991, after Perry 1989, with permission from Cambridge University Press)

Terminal swing

Muscle function. Ends swing and prepares limb for stance.

- Hip flexors – these muscles are usually not active at this time
- Hamstrings – eccentric action decelerates the forward swing of the thigh and leg
- Quadriceps – concentric action to extend knee for stance
- Tibialis anterior – ankle dorsiflexion supports the ankle at neutral to prevent foot drop

Initial contact

Muscle function. Acts to allow smooth progression and stabilizes joints while simultaneously decelerating the body's inertia.

- Gluteus maximus – controls flexor moment produced by ground reaction forces (GRFs)
- Hamstrings – inhibit knee hyperextension and assist in controlling flexion moment at hip
- Tibialis anterior – initiates the heel rocker

Loading response

Muscle function. Acts to allow smooth progression and stabilizes joints while simultaneously decelerating the body's inertia.

- Hamstrings – concentric action unlocks the knee
- Tibialis anterior – decelerates foot fall by eccentric contraction and pulls the tibia anterior to the body's

weight line which results in knee flexion
- Quadriceps – eccentric contraction to decelerate knee flexion and absorb shock of floor contact
- Gluteus maximus – concentric action to extend hip and accelerate trunk over femur. Its action through the iliotibial band contributes to knee extension
- Adductor magnus – concentric action to advance and internally rotate pelvis on stance limb
- Gluteus medius – eccentric action to abduct hip and stabilize pelvis to minimize contralateral pelvic drop

Midstance

Muscle function. Acts to allow smooth progression over a stationary foot while controlling position of the GRF referable to hip and knee.

- Soleus – eccentric action to decelerate ankle dorsiflexion over the planted foot during the period of the second rocker
- Quadriceps – stabilizes flexed knee. Action ceases when GRF vector passes in front of knee
- Gluteus maximus – ceases action when GRF becomes posterior to hip

Terminal stance

Muscle function. Acts to provide acceleration and adequate step length.

- Soleus – intensity of action increases to limit dorsiflexion. Also acts as invertor of subtalar joint to provide stability
- Gastrocnemius – concentric action to stop forward motion of tibia and begin plantarflexion of ankle
- Tibialis posterior – stabilizes the foot against eversion forces

- Peroneals – stabilize the foot against inversion forces
- Long toe flexors – stabilizes metatarsophalangeal (MTP) joints to augment forefoot support

Pre-swing

Muscle function. Muscle control ends stance and prepares limb for swing.

- Gastrocnemius – may unlock the knee so that it may resume flexion
- Adductor longus – concentric action advances the thigh
- Rectus femoris – eccentric action at knee to decelerate the inertia of the shank. Concentric action at hip to augment hip flexion

Initial swing

Muscle function. Provides ability to vary cadence and maintain foot clearance.

- Hip flexor group (iliacus, adductor longus, sartorius, gracilis) – concentric action to advance thigh and works in conjunction with shank inertia to create knee flexion
- Biceps femoris (short head) – augments knee flexion during slow gait when inertial forces are inadequate
- Tibialis anterior – concentric action to dorsiflex foot
- Long toe extensors – concentric action with tibialis anterior to dorsiflex foot

Midswing

Muscle function. Little muscle action necessary because inertial forces are propelling the limb.

- Tibialis anterior – concentric action to prevent foot drop

Normal gait has four major attributes which are frequently lost in abnormal gait. These are:

- stability in stance
- sufficient foot clearance during swing
- appropriate swing-phase pre-positioning of the foot
- an adequate step length (Gage 1992).

For example, with predominant extensor tone, both legs are used for weight-bearing, preventing adequate flexion of the moving leg.

The most obvious features are:

- extensor hypertonus of the lower limbs with adduction and medial rotation at the hips and plantarflexion and inversion at the ankle and foot
- a posterior tilt of the pelvis
- compensation of the trunk and upper limbs, which is dependent upon whether or not the arms are used for support or balance.

The compensatory mechanisms often used to overcome this pathological activity include the following:

- The patient rises higher on his toes, throwing his trunk backwards to propel the moving leg forward with a minimum of flexion at the hips and knees. The patient walks with a 'scissor gait' with gross overactivity of the upper limbs to preserve balance.
- With the increased extensor activity in the trunk, the tilt of the pelvis may be altered, the resulting anterior tilt reversing the pattern of hypertonia in the legs to one of flexion.
- Use of crutches or a frame may result in overuse and fixation into flexion of the upper limbs and trunk.

The positive support reaction is invariably present. Treatment must therefore combine desensitization of the feet with appropriate re-education and facilitation of more normal standing balance and gait. Treatment will be determined by the compensatory mechanism used by the patient. It is important to realize that in many patients it is possible to completely reverse the pattern of hypertonia. There is inadequate normal extensor activity in the supporting limb, and facilitation of flexion of the moving limb may produce a reciprocal inhibitory effect in the supporting limb, causing the patient to collapse.

It must be appreciated that some patients depend upon their extensor hypertonus to allow them to walk. Whilst it is important to inhibit this pathological synergy in order to facilitate more normal extensor activity, over-inhibition may prevent the patient maintaining himself upright against gravity. There is a very fine line between a functional gait, albeit abnormal, and the wheelchair-bound patient.

The essential requirement for normal walking is a comprehensive feedback system affording balance, stability and selective movement. This can only exist on a background of normal postural tone and full range of movement of muscles and joints. Although the lower limbs provide the dynamic movement component of gait, postural stability within the trunk and contralateral arm swing are equally important.

The importance of the pelvis in providing dynamic stability throughout the gait cycle cannot be overemphasized. It provides the

integration of all phases of the gait cycle, allowing for movement at the swing phase and stability during the weight-bearing stance phase, with reciprocal interchange of action. For example, flexor hypertonia of the lower limbs is associated with an anterior pelvic tilt with compensatory hyperextension of the lumbar spine and overuse of the upper limbs for balance. Treatment in this instance would initially be in standing, to encourage normal extensor activity in the legs (Brown 1994) while mobilizing the pelvis to prevent the often unnecessary degree of compensation (Edwards 2002).

Basic principles of treatment which should be observed in all cases include:

- Standing balanced with the body in correct alignment and with the weight taken throughout the entire surface of the feet.
- Standing without using the arms. If this is impossible the patient is encouraged to use his arms for balance only, rather than for weight-bearing. If the patient learns to push down with the hands in front, the weight is brought forward over the ball of the foot. This will tend to elicit the positive support reaction in those patients with hypertonia and predisposes to flexor contractures of the hips.
- Pelvic control. Pelvic alignment and stability are essential to ensure dynamic control of the lower limbs. Weakness or paralysis of the hip abductors and extensors, producing instability at the pelvis, may well give rise to hyperextension of the knee. Treatment must be directed at improving control at the pelvis rather than correction of the more apparent problem at the knee (Edwards 2002).
- Weight transference in both the sagittal and coronal planes with appropriate release of the non-weight-bearing leg.
- Selective movement of the lower limb without excessive use of the trunk.

The use of splints or orthoses must be carefully assessed. In normal gait, foot clearance is only 0.87 cm (third of an inch) in midswing, leaving very little room for error (Gage 1992). Weakness of the dorsiflexors or excessive tone or shortening of plantarflexors will compromise a normal gait pattern and lead to compensatory mechanisms such as a high stepping gait or 'hip hitching'. The therapist must determine the benefits or otherwise of ankle–foot orthoses, or indeed knee–ankle–foot orthoses (KAFOs), depending on the degree of paralysis, abnormal tone and changes in muscle length. For detailed information regarding the use of splints and orthoses see Edwards & Charlton (2002).

Functional electrical stimulation (FES) has been reported to be effective in the treatment of incomplete spinal cord injured patients (Biss & Fox 1988, Granat et al 1993, Stein et al 1993) and has been recommended as an orthotic approach in the management of patients with incomplete spinal cord injury (Bajd et al 1989). Stimulation of the common peroneal nerve stimulates the flexor withdrawal

response, thereby aiding the swing-through phase of gait (Granat et al 1993). It has been suggested that FES may be of assistance in the prevention of pressure ulcers, contractures, muscle atrophy and bone demineralization (Bajd et al 1989).

More recent advances in gait training for these patients include the use of a treadmill with the body weight supported (Fung et al 1990, Dobkin et al 2003, Dietz et al 1995, Muir & Steeves 1997). Barbeau (2003) highlighted the importance of task specificity with regard to the use of treadmill training with supported body weight for patients with incomplete spinal cord injury. Rehabilitation approaches that focus on reducing hypertonia or are non-specific, such as passive stretching or general home exercises, are unlikely to have any beneficial effect on functional locomotion.

It is suggested that by supporting the body weight with treadmill training, the activation of hypertonia and some of the functional consequences of disordered motor control may be reduced (Dobkin 1994). The spinal cord has the capacity not only to generate a loco-motor pattern, but also to 'learn' (Dietz 2003). This method of enhancing lower limb movement may prove useful in guiding and strengthening functional synapses of regenerating axons to maximize their contribution towards restoring function (Muir & Steeves 1997, Dietz 2003).

Walking aids

Although it has been suggested that the use of assistive devices such as parallel bars may lead to overcompensation (Barbeau 2003), in many instances some form of walking aid is necessary to enable patients with incomplete spinal cord injury to attain an independent gait. Where possible, the aid should be used to assist balance rather than as a means of support but inevitably this will depend on the degree of impairment.

Crutches, a rollator or the patient's own wheelchair are preferred to a frame, as they enable the patient to obtain a greater degree of hip and trunk extension and in consequence a more normal walking pattern. With the frame in the forward position, prior to the patient taking a step, flexion and retraction occur at the hips, thereby increasing the danger of hyperextension of the knees.

If either one or two sticks are required, they should be slightly higher than is usually prescribed (to the height of the greater trochanter). This prevents the patient using them for excessive support and initiating walking by means of trunk flexion and trunk side-flexion.

Orthoses and splints

The choice of orthosis will depend upon the degree of paralysis and the severity of hypertonia. Not only the rehabilitation staff but also the patient must be involved in this choice. Unless the patient believes that the orthosis will benefit him and is prepared to use it, there is no value in supplying one.

There has been considerable improvement in the orthoses available, with particular emphasis on their cosmetic appearance. The lightweight, moulded orthoses or the 'toe-off' orthoses are often appropriate for patients with flaccid paralysis and may also be used for some patients with hypertonus (Edwards & Charlton 2002).

To assess the benefit of a below-knee orthosis, a bandage can be used to maintain the foot in dorsiflexion. Where hypertonus is present, the bandage must hold the foot in eversion as well as dorsiflexion to inhibit the overactivity in the invertors (Fig. 15.8). Not only does this allow the physiotherapist to assess the patient's gait with the appropriate correction, but it also indicates if the patient is likely to develop proximal hypertonia in response to the corrective device on his foot. The main disadvantage of this bandage is that it may restrict the blood flow to the lower leg and can therefore only be used for short periods of time.

Splinting materials may also be used as an adjunct to treatment and/or as a means of evaluating the effect of a more permanent orthosis. A combination of 'Softcast' and 'Scotchcast' splinting materials is increasingly being used in clinical practice to support or maintain range of movement of a limb. Softcast is impregnated with a polyurethane resin, which sets on exposure to water or the air (Schuren 1994). Once 'set', this material has a rubberized texture which provides only semi-rigid immobilization. Reinforcement with Scotchcast enables specific control across a joint as the clinical presentation dictates. Details of the use of these materials are to be found in Edwards & Charlton (2002).

Patients with incomplete spinal cord injury show varied problems necessitating different orthoses or casts which can range from KAFOs or back slabs to a single below-knee splint. Splints may also be required to maintain range of movement in the upper limb or to provide stability at one joint to facilitate movement at another. They are frequently used as an adjunct to treatment following treatment with botulinum toxin.

Great care is taken with selection and the patient must be assessed at regular intervals following discharge from hospital to ensure that the orthosis remains appropriate to his needs.

Gymnastic ball

Treatment using the gymnastic ball was originally devised by Klein-Vogelbach (1980) and was adapted for use in neurological conditions
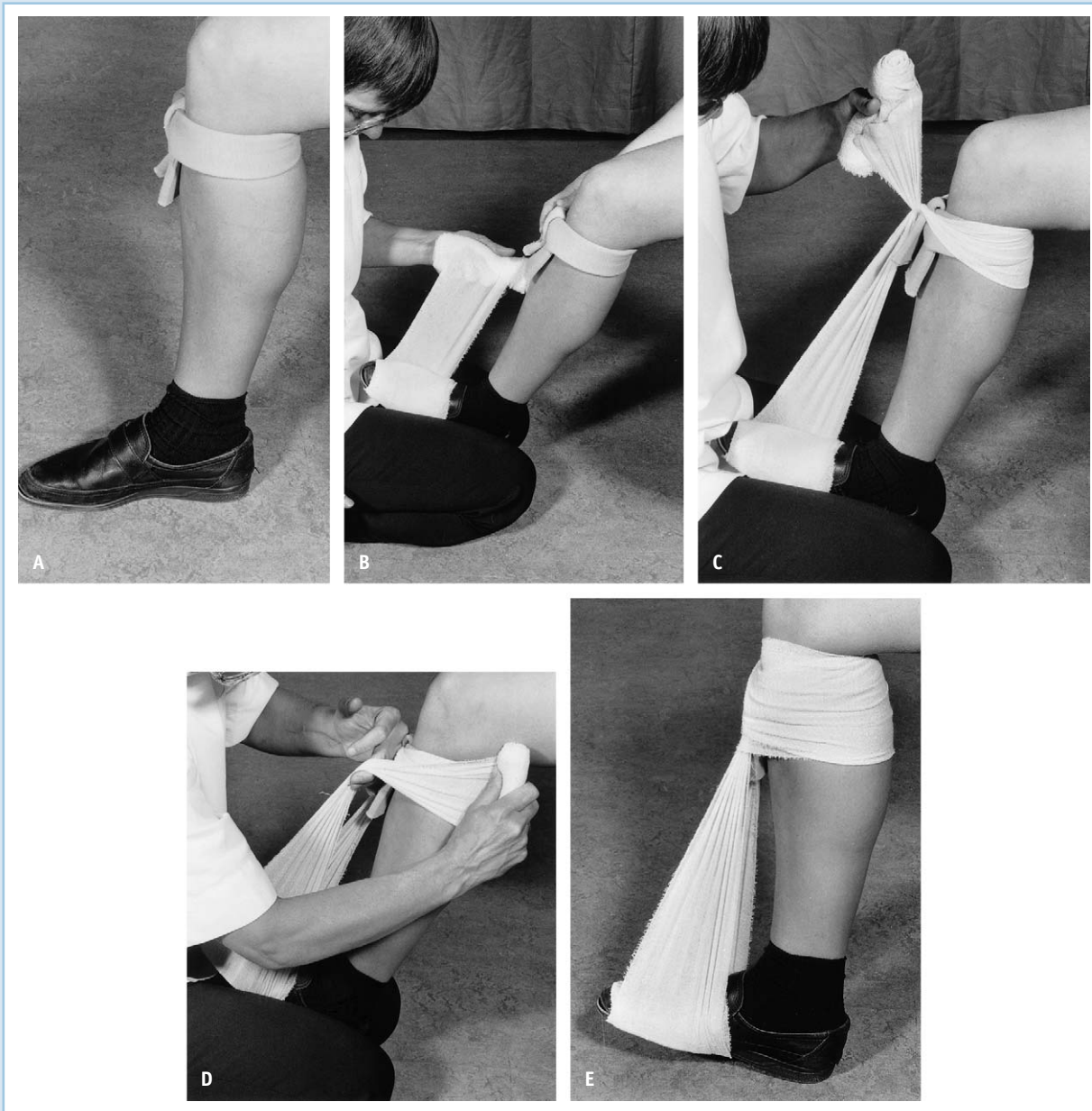
Figure 15.8 Application of bandage to hold the foot in dorsiflexion and eversion. Note the small band of foam (A) to protect the skin from the pressure of the bandage.

by Hasler (1981); a comprehensive description of the use of the ball is to be found in Carriere (1999).

The ball, which is made of resilient hard plastic, comes in various sizes and may be used with good effect in the treatment of some patients with incomplete spinal cord injuries (Silva & Luginbuhl 1981). The choice of size depends upon the reason for which the ball is being used and the physical proportions of the patient.

The ball is useful:

- as a means of inhibition and proximal mobilization where there is excessive hypertonia
- in retraining balance reactions and coordination, thereby improving body awareness
- in giving controlled strengthening exercises where weakness of specific muscle groups is apparent.

It is essential that the patient is totally confident and unafraid. If the patient is frightened, not only will the treatment be ineffective, but it may cause a significant increase in hypertonicity and therefore prove to be detrimental (Lewis 1989). It is also important to appreciate that, although the ball is widely used in many areas of neurological rehabilitation, there is no evidence to date to support the effectiveness of this intervention (Jackson 2004).

More recent advances in the medical management of increased tone

Botulinum toxin for the management of focal hypertonia and intrathecal baclofen for the treatment of more global hypertonia are increasingly being used in the management of patients with neurological disability.

Botulinum toxin

Botulinum toxin is a potent neurotoxin which produces temporary muscle weakness by presynaptic inhibition of acetylcholine release at the neuromuscular junction (Hambleton & Moore 1995). This weakness does not occur immediately but usually takes between 10 and 14 days, depending on the size of the muscle injected and the dosage. Recovery occurs over a period of approximately 10 to 12 weeks through terminal sprouting.

Botulinum toxin is widely accepted as an effective treatment for focal dystonias and it is licensed for use in the treatment of blepharospasm, hemifacial spasm, cervical dystonia, the upper limb following stroke and the lower limb in children with cerebral palsy. It is only more recently that the use of botulinum toxin in the treatment of hypertonia has become more established, although there is still considerable variation between studies (Thompson 2002).

Where specific localized muscles are considered to be a major influence in the production and maintenance of hypertonia, botulinum toxin may be a useful adjunct to rehabilitation. The main reasons for its use in the treatment of spasticity are to:

- redress problems created by muscle imbalance
- enable improved hygiene
- evaluate the effects of surgery, primarily for children with cerebral palsy (Cosgrove et al 1984).

The purpose of intervention with botulinum toxin is to weaken the dominant overactive muscle or muscles to enable clearly identified treatment goals to be accomplished. For example, patients with a positive support reaction are unable to transfer their weight over the full surface of the foot during stance phase of gait due to hypertonia of the posterior crural muscles. The compensatory strategies which may be adopted by the patient in response to this reaction are described above (p. 293). Treatment of the overactive muscles with botulinum toxin weakens the calf muscles, enabling an improved gait pattern for the duration of the toxin's effect. It is hypothesized that during this period, the improved gait pattern will become established as a more normal motor programme, thereby enabling carryover in the longer term (Scrutton et al 1996, Richardson et al 2000). However, the adverse effects that this weakness may have on gait have been discussed (p. 302) and the toxin should be used with caution.

Patients with incomplete spinal cord lesions may also have muscle imbalance which is due to dominant muscle activity precluding recovery of the weaker antagonists. Botulinum toxin has been used successfully in the treatment of a patient with an incomplete C6 lesion. Recovery of the finger extensors was impeded by the dominance of finger and thumb flexion and reliance on a tenodesis grip. Using a combination of botulinum toxin to weaken the dominant flexor muscles and a removable cast to control the position of the wrist in a neutral position, this prevented the use of the tenodesis grip. Over the course of 12 weeks the patient developed sufficient control to enable functional use of his finger extensors (Richardson et al 1997).

The use of botulinum toxin in the treatment of hypertonia differs from that in the treatment of focal dystonia. Patients with focal dystonia usually attend at 3-monthly intervals for reinjection. For patients with hypertonia, the treatment may be only a single event which should always be used in conjunction with therapy.

Splinting is often of value to supplement the effects of the toxin. If splinting is to be incorporated as part of the therapy programme, application of the cast should be delayed until the effects of the toxin are apparent, 5 to 7 days after injection.

It is essential to determine that the cause of the movement impairment is due to overactivity and not to mechanical changes of muscle and soft tissue. Botulinum toxin weakens muscle and it is therefore of no use whatsoever for patients who no longer demon-

strate increased muscle activity, characteristic of neural hypertonia. Assessment with electromyography (EMG) is therefore recommended (Thompson 2002). It is possible to identify the more superficial muscles with surface EMG electrodes, but the more deeply sited muscles require needle EMG to ensure accurate administration of the toxin.

Criteria for effective use of what is an expensive treatment are:

- identification of the clinical problem
- the use of EMG to confirm increased muscle activity as the cause of the movement disorder
- an ongoing therapy programme to re-educate movement for the duration of the toxin's effect.

Botulinum toxin is suitable only for more focal hypertonia, as the dose that can be administered is limited. Patients with more widespread stereotyped pathological patterns of the lower limbs may be more effectively managed with intrathecal baclofen.

Intrathecal baclofen

Baclofen is a gamma-aminobutyric acid (GABA) receptor agonist. GABA is the major inhibitory neurotransmitter of the central nervous system. Baclofen binds to GABA receptors and has a presynaptic effect on the release of excitatory neurotransmitters. It also acts postsynaptically, directly decreasing the firing of motor units (Losseff & Thompson 1995).

Oral baclofen does not readily cross the blood–brain barrier but is equally distributed to the brain and spinal cord. This may lead to centrally mediated effects such as drowsiness, dizziness and confusion without adequate relief of spasticity. Intrathecal administration permits direct access of the drug to the receptor sites in the dorsal horn of the spinal cord, thereby minimizing these central effects (Porter 1997). Doses of less than one-hundredth of those required orally have been shown to be effective in the management of hypertonia (Thompson 2002).

Indications for usage

Uncontrolled hypertonus may be so severe as to cause pain, interrupt sleep and interfere with function. Although more widely used in the treatment of patients with complete spinal lesions and multiple sclerosis with severe flexor hypertonia, intrathecal baclofen is also effective in regulating increased tone in patients with incomplete cord lesions. Severe hypertonus may mask underlying active movement and reduction of this may enable the patient to utilize this potential function.

In spite of the potential side effects of oral baclofen, this would always be the method of choice. It is only those patients who are refractory to oral administration, or who have intolerable side effects, who may be considered suitable for intrathecal baclofen.

The patient must be free of noxious stimuli such as pressure ulcers, infection or constipation as these may prevent an accurate assessment of the patient (Porter 1997).

Delivery system

The delivery system consists of a pump which lies subcutaneously in the abdomen with a reservoir of baclofen which is connected to the intrathecal space by means of a catheter. The dose can be titrated to the individual's need, delivering bolus or continuous infusion at a predetermined rate (Losseff & Thompson 1995). The pump needs to be refilled every 4–12 weeks and the dose adjusted as required (Gianino 1993).

The patient's response to intrathecal administration of baclofen is assessed by means of a bolus injection given via a lumbar puncture before proceeding to permanent infusion (Thompson 2002). Potential complications include respiratory distress and infection, and technical problems such as pump malfunction or problems with the catheter have been reported (Losseff & Thompson 1995).

It is recommended that this procedure is carried out in a specialist centre where there are standardized protocols and patients are regularly monitored. Depending on the severity and possible functional use of the spasticity, the dose may be a simple continuous cycle or less during the day to enable function and more at night to allow sleep (Gianino 1993).

Intrathecal baclofen may be contraindicated in patients who depend on their hypertonus for function. For example, patients who are ambulant, albeit with a grossly pathological gait pattern, may no longer be able to walk following this intervention. The majority of patients in this situation will opt to keep mobile for as long as possible unless the purpose of the intervention is management of pain.

SUMMARY

Patients with incomplete spinal cord lesions demonstrate many different and diverse movement disorders necessitating thorough assessment and individualized treatment programmes. The prognosis is less predictable than for patients with complete lesions and the therapeutic management must reflect the variability of the presenting signs and symptoms.

This chapter provides a basis for a problem-solving approach to treatment. Improved understanding and awareness of movement enable the therapist to identify how a posture or movement differs from the normal and thereby to select appropriate treatment strategies.

For those patients with non-progressive pathology, throughout all stages of rehabilitation, treatment is aimed at improving functional abilities without the use of unnecessary compensation. However, patients with progressive pathology, for example those with carci-

noma, may benefit from the use of early compensation to allow them to return home as soon as possible to give them the maximum time in their familiar environment.

The restoration of function is the ultimate goal of rehabilitation, but all too often this is not achievable for patients with extensive neurological damage. There must be a balance between re-education of more normal movement patterns and acceptance and indeed promotion of necessary and desirable compensation (Edwards 2002). As previously stated, the therapeutic skill lies in determining that compensation which is necessary, and even essential, for function and that which is unnecessary and potentially detrimental to the patient.

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Spinal cord injury in children

Ebba Bergström

INTRODUCTION

Children with spinal cord injury (SCI) who are under the age of 16, and particularly before they have reached maturity, have special rehabilitation needs because of the ongoing physical, intellectual, psychological and social development (Vogel & Betz 1996). Although the rehabilitation is largely the same as for adults with SCI, there are many aspects that are specific to young children. This chapter will principally deal with those aspects of management specific to children with SCI.

Growth and maturity influences all aspects of the care and management. The development of the skeleton is affected by a neurological injury such as SCI. It predisposes the child to joint contractures and spinal deformity. Spinal deformity in particular is then in turn exacerbated by growth. It is the most common and severe complication for a child following SCI. The rehabilitation process should continue until skeletal development is completed and the child is sufficiently mature to care for him/herself. Close links with parents, carers, school and local healthcare agencies must be established. Teaching, of all those involved with the child, in the consequences and complications of childhood SCI is also an important part of the rehabilitation.

The incidence of SCI in children under 13 years is much less than in teenagers and adults (5–10% of the adult incidence) (Vogel & De Vivo 1996).

The cause of accidents is similar to the adult population and always reflects the surrounding society. In the industrialized world, road traffic accidents are the most common cause of injury (including a larger proportion of pedestrian injuries among children), followed by falls from heights, sporting injuries and assault. In some urban areas, gunshot wounds are reported to equal the number of road accidents (Haffner & Hoffer 1993, Montes 1996) and in some reports they are higher.

The immature spine has anatomical and structural characteristics. The head is proportionally larger, the cervical spine proportionally longer and the facet joints are more horizontal. Children are therefore vulnerable to certain traumas. They have a higher frequency of upper cervical cord injuries than teenagers and adults. Spinal cord injury

without radiographic abnormalities (SCIWORA) (Osenbach & Menezes 1989, Pang & Pollack 1989) is common among the young. It has been suggested that, through its elasticity and cartilaginous properties, the spine of a young child can withstand gross distortion, especially in flexion and rotation, without fracturing bones. The spinal cord cannot stand the same degree of stretch; consequently, traction results in cord damage. However, with modern radiological diagnostic tools, such as magnetic resonance imaging, it is now possible to detect changes to the spinal cord and the term SCIWORA should therefore be used with care.

An approximately equal number of spinal cord lesions in children as in adults result from non-traumatic lesions caused by transverse myelitis, vascular accidents and cysts or tumours.

The aim of rehabilitation is the same for the child with SCI as for the adult, namely to:

- maximize potential in order to reach as high a degree of independence as possible
- teach the individual and their carer how to prevent and manage complications.

A child's rehabilitation potential depends on age (developmental stage) and size as well as on the extent of the neurological damage. The child's normal chronological development will have an influence on the timing and progression of rehabilitation. Some skills may have to be postponed until the child is mature enough to tackle them. For example, it is inappropriate to teach a 2-year-old to dress or a 5-year-old to catheterize himself. The size of the child may also mean that some transfer techniques need to be modified. All these factors need to be taken into account when planning rehabilitation and management of the spinal cord injured child.

Rehabilitation is a continuous process throughout childhood and adolescence till physical, psychological and general maturity is reached. Regular assessments are essential to identify the need for and timing of rehabilitation periods. Specific aspects of the management during these rehabilitation periods will be addressed (e.g. transfers, dressing, bladder and bowel management).

During the acute phase, physiotherapy for the child is the same as for the adult patient. Some modification to therapy is required in certain aspects of rehabilitation (as will be discussed later) but the major difference in the treatment of children is in the approach to the management and monitoring of contractures and the development of the spine in the presence of neurological deficit.

SPINAL DEFORMITY

The most serious and common complication following paediatric SCI is spinal deformity and contractures (Lancourt et al 1981, Mayfield et al 1981), which are strongly correlated to age at onset of

paralysis and level of lesion (Bergström et al 1999). Those injured in early childhood and those with paraplegia develop more severe curves but virtually all children are likely to develop some degree of deformity.

The sequence of events and the reasons for the development of spinal deformity are not completely understood but many factors play a part in this development.

Continual growth and an immature skeleton are obviously what sets children apart from adults and exaggerate the development and speed of the processes below:

- the posture collapses due to paralysis under the influence of gravity
- asymmetrical neurological lesions causes asymmetrical pull on the skeleton
- contracted joints will pull the spine out of its normal alignment
- muscles lengthen on the convex side of the curve and shorten on the concave side
- bones that are not supported by a normal neuromuscular system change shape.

Other important factors are spasticity and sleeping postures.

Growth

Growth is mainly determined by genetic factors and growth hormones. The functional use and loading of the skeleton are other factors influencing growth. The use of the skeleton is severely altered after a spinal cord injury.

Any bone tissue in the body that has an excessive repetitive force applied to it will form itself accordingly. The immature skeleton is particularly susceptible to such stress and reshaping. The growth will also exacerbate this process by laying down the bone growth according to the stresses exerted upon it.

For children with SCI it is therefore very important that a correctly aligned posture is maintained at all times, except when engaged in sport, play or other specific tasks that are part of a normal movement pattern.

Spinal column

Collapsing spine

The collapsed posture, so commonly seen following SCI, is caused by the paralysis itself. The muscles that kept the body upright before paralysis can no longer do this; therefore gravity will pull the body down. The spinal column, with its multitude of bones and joints, is particularly susceptible to this lack of support and will collapse (Figs 16.1, 16.2, 16.3). The definitive shape that the spine adopts will

Figure 16.1 *(left)* Forward flexion. Patient aged 9 years (injured at 2 years) with a complete lesion below T5.

Figure 16.2 *(right)* Side flexion. Patient aged 11 years (injured at 5 years) with a complete lesion below T6.

vary and develop individually with each child, depending on the particular distribution of paralysis and spasticity as well as their habits of moving, sitting and sleeping.

The spine may collapse into flexion, giving rise to a long kyphotic 'C' curve which results in weight-bearing on the sacrum and total obliteration of the lumbar lordosis (Fig. 16.1). In most cases, this posture will be accompanied by external rotation of the femur and, in time, extension contracture of the hip which makes correction of the posture difficult.

The spine may collapse into side flexion with rotation of the vertebral bodies, causing a long C-shaped scoliosis with an oblique pelvis or a lumbar scoliosis with a compensatory curve above it (Fig. 16.2). The collapsing spine is readily correctable with traction (or, as in Fig. 16.4, self traction by lifting) but in time develops severe structural change.

Figure 16.3 *(left)* Correction of spinal deformity with traction. Patient aged 10 years (injured at 4 years) with a complete lesion below C7.

Figure 16.4 *(right)* As Figure 16.3.

Scoliosis (due to uneven muscle activity)

Unilateral muscle pull due to asymmetrical neurological deficit or spasticity of the thoracic and lumbar spine induces side flexion or rotation of the trunk. This often means that the individual has to position himself further into the asymmetry in order to balance during two-handed activity, thus further increasing the risk of spinal deformity.

Unilateral innervation of hip flexors will pull the pelvis out of normal alignment and influence the alignment of the spinal column.

Reversal of the lumbar lordosis and thoracic kyphosis

Flattening of the lumbar lordosis, usually caused by poor sitting posture or extensor spasticity, will lead to compensatory extension of the spine higher up and flattening of the thoracic kyphosis (Fig. 16.5). In severe cases, these curves are reversed to lumbar kyphosis and thoracic lordosis.

Hyperlordosis of the lumbar spine

This is associated with hip flexion contractures that if allowed to develop, will make it difficult to stand and to fit any standing orthosis (Fig. 16.6). This may be caused by active hip flexor muscles, which

Figure 16.5 *(left)* Flattening of lumbar lordosis. Patient aged 11 years (injured at 8 years) with a complete lesion below C8.

Figure 16.6 *(right)* Hyperlordosis of the lumbar spine. Patient aged 18 years (injured at 8 years) with a complete lesion below C7.

tilt the pelvis forwards, or it may be secondary to an accentuated thoracic kyphosis due to a displaced fracture as well as postural collapse.

Secondary deformity of the ribcage

All scolioses will give rise to rotation of the spinal column. The rotation will cause a posterior rib hump on the convex side of the scoliosis (see Fig. 16.3). The ribs on the convex side will be more horizontal than normal, whilst those on the concave side will be more vertical (Fig. 16.7).

Summary

Any spinal deformity will add to the problems of paraplegia and tetraplegia. It will diminish the chest cavity and further decrease lung function. Pelvic obliquity causing uneven pressure will heighten the risk of pressure sores. Poor posture will influence balance and general function. All spinal deformities will alter the position of the neck and may in future years cause musculoskeletal changes and give rise to
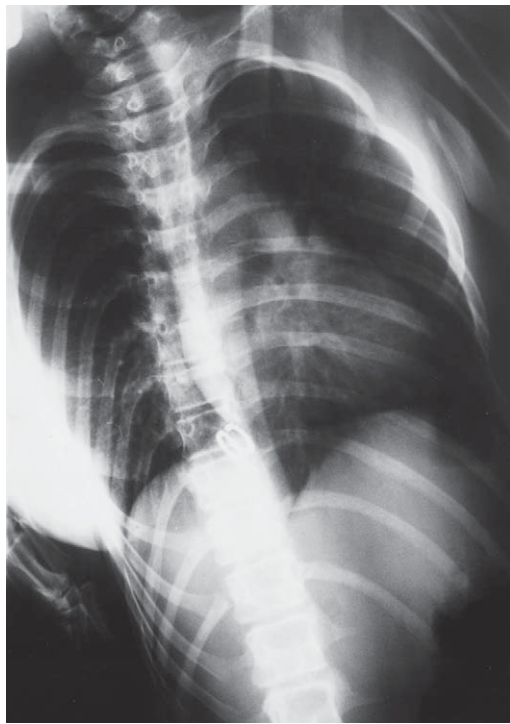
Figure 16.7 Postero-anterior X-ray of ribcage. The ribs on the convex side are more horizontal than normal, while those on the concave side are more vertical. The left lung volume is decreased.

pain and impaired movement of the neck, shoulders and arms. A severe spinal deformity is also aesthetically unacceptable to most people and gives a negative self-image and reduces self-esteem.

Contractures

All joint contractures influence the position of the adjoining joints. Limb contractures, particularly the hip joints, will determine the position of the pelvic and thus the spinal column. In many cases this is what initiates the development of the spinal deformity.

Hip joint

The angle between the neck of femur and the shaft is 150° in the newborn and reduces to 125° in the adult. The more erect angle of the femur contributes to poor development of the hip joint in those paralysed in early childhood. For the acetabulum and the head of the femur to form a stable joint with well-rounded surfaces, the hip joint has to be held and loaded in normal alignment (extension, neutral rotation and slight, 5°, abduction).

Internal rotation and adduction of the femur (whether by the femur flexing on the pelvis or through pelvic obliquity and rotation on the femur) will give little or no surface contact in the joint. Poor development of the joint (Fig. 16.8) and a predisposition to subluxation or dislocation will follow.

Figure 16.8 Antero-posterior X-ray of pelvis. The left acetabulum is relatively flat and the head of the left femur is grossly abnormal. (The apparent pelvic deformity is mainly projectional.)

Contracture of the hip flexor and shortening of the iliotibial tract and tensor facia lata mean that full extension of the hip joint may only be obtained in abduction – it cannot be obtained with the limb in midline. In truth this masks a hip flexion contracture; therefore, when passive movements are performed, correct alignment of the limb must always be maintained.

Knee joint

The knee joint of the toddler is in a varus position and develops into valgus after 4 years of age and continues to develop into a straight adult knee. During this time the head and neck of femur changes alignment. The anterior torsion of the neck of femur reduces from 40° in the newborn to 12° in the adult and the angle between the neck of femur and the shaft reduces from 150° to 125°. This explains the change in alignment of the knee joint. However, the change is also dependent on normal neuromuscular development.

Valgus deformity of the knee joint (Fig. 16.9) is commonly seen in children with SCI and is caused by a combination of the anterior

Figure 16.9 Valgus deformity of knee joints.

torsion of the neck of femur and contracture of tensor facia lata and the iliotibial tract. It will be exacerbated by collapse of the medial arch of the foot when standing (Fig. 16.10A). The knee appears to have full extension and increased valgus deformity, but in reality it is primarily a knee flexion contracture. This is demonstrated by extending the leg while ensuring correct alignment at hip, knee and ankle, allowing no internal rotation of femur or tibia/fibula. This valgus deformity should not be compensated for in the fitting of a knee–ankle–foot orthosis (KAFO) as this will exacerbate the problem. The caliper should be made as straight as possible (seen in the sagittal plane), allowing the knee to remain in the degree of flexion necessary for the limb to be in correct alignment.

Weight-bearing with the knee in the valgus position may result in an altered angle between the tibial plateau and the shaft of the tibia.
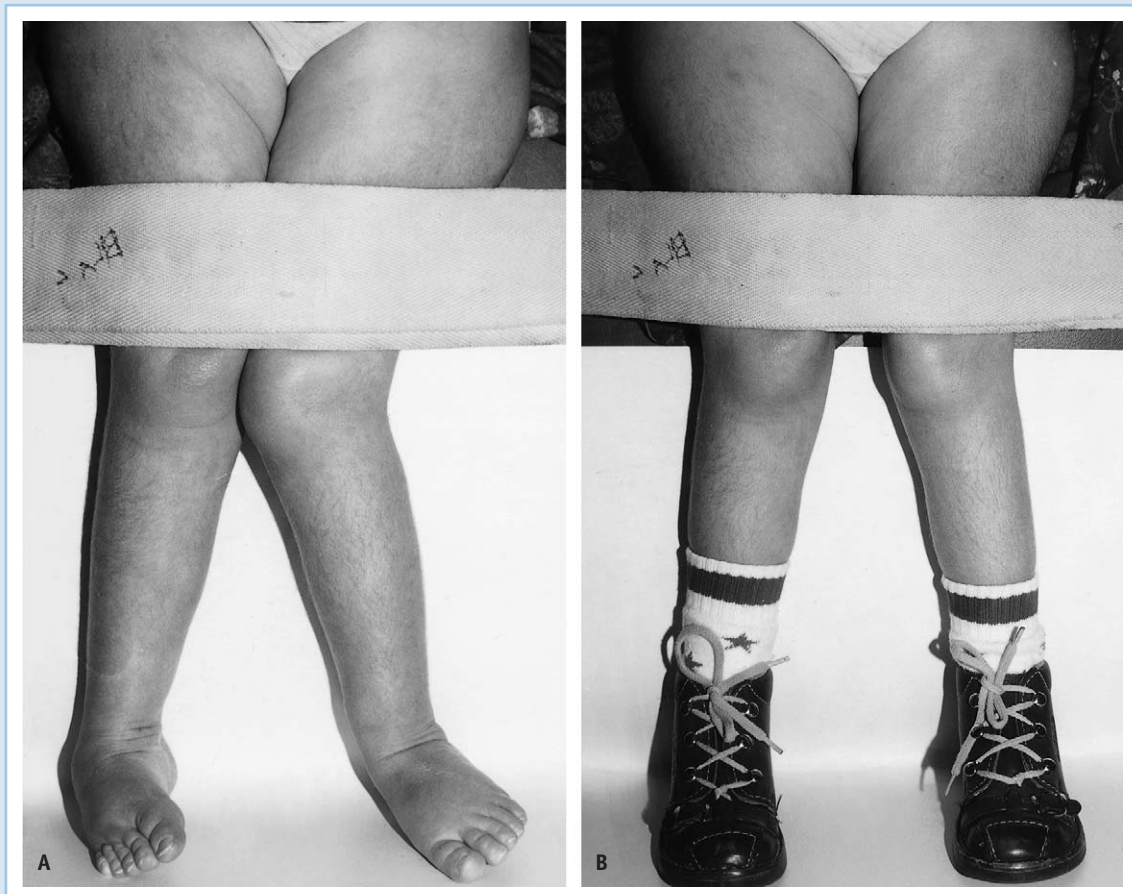
Figure 16.10 A: Valgus deformity of the left knee with collapse of the medial longitudinal arch of the foot. Patient aged 5 years (injured at 1 year) with a complete lesion below T12/L1. B: Medial longitudinal arch supported.

This in turn may cause torsion of the tibia, pulling the foot into external rotation. If this deformity is corrected in the caliper by positioning the foot in neutral, it increases the internal rotation of the leg. The foot should be allowed to remain in external rotation in the caliper. However, the degree of rotation of the tibia varies in normal children so that sometimes the foot is naturally externally rotated. In this case also, where no other deformity is present, the design of the caliper should allow the foot to remain in its natural position. The action of the KAFO should be augmented by passive stretching of the knee into extension, maintaining the limb in midline.

Foot

Collapse of the medial arch will cause eversion of the foot, and if the foot is allowed to remain in this position, the tendo Achillis will shorten on the lateral side. When passively stretching the tendo Achillis, first the heel must be pulled towards midline and only then should the foot be dorsiflexed. Footwear must be fitted with a medial longitudinal arch support (Fig. 16.10B), which will also help to reduce valgus deformity of the knee.

Tone

Increased tone and spasticity usually develop in a specific pattern for each individual. It acts as an unopposed muscle pull and will repetitively pull the affected part of the body in the same direction. When there is no counter-pull it will contribute to the development of contractures and deformity of both spine and limbs.

Sleeping postures

The postures and positions that are adopted during sleep are also very important in the general management of the body. After all, a considerable proportion of time is spent sleeping. It is therefore important to ensure that positions of optimum correction are encouraged. (The correct position is identified for each individual according to his or her posture and tone.)

All the factors described here will influence one another and become part of a perpetual cycle.

Management

As virtually all children with SCI will develop some degree of spinal deformity it is important to implement management strategies to

avoid this and to try to incorporate them into the daily routines of the child, family and school.

Spinal posture

Lack of sensation following SCI causes a reduced postural awareness. This can easily lead to poor posture (see Ch. 6). Observation in front of a mirror, with minimal clothing, is useful to help establish a well-aligned posture. Constant vigilance is needed to ensure a good posture in the future; it is a useful routine to continue to check the posture in the mirror from time to time.

The posture is also corrected and maintained by wearing a made-to-measure external spinal support.

As soon as possible after the acute bed phase, a cast is made for a body jacket. Very young or anxious children need to become familiar with the procedure and the people involved in the making of the orthosis to ensure cooperation during the casting of the brace.

The brace should be as near to normal in alignment as possible, with special care taken to maintain a lordosis so that the child remains upright with minimal force applied at the top and bottom of the brace. For maximum support of the spinal column and stabilization of the pelvis, the brace needs to be as long as possible whilst allowing for shoulder depression in order that the child can lift during functional activities.

It is important that a brace is worn as early as possible, while the spine is still straight or at least correctable. This is to ensure that as much growth as possible takes place under the most favourable conditions. The thoracic support is either a moulded leather or plastic jacket or in some cases a corset. The material chosen will depend on the need of the individual child. Moulded leather and plastic will give good support; however, leather will allow itself to yield slightly to the wearer and therefore offers better protection against skin breakdown. This becomes more apparent the heavier the person is and the more deformed the spine. For the high tetraplegic person it is important to be aware of respiratory function. A firm plastic back shell with a fabric or elastic front may be a suitable compromise. Fabric corsets may provide enough support and reminder for those with a clinically straight back and who have a thoracolumbar lesion. The spinal support should be worn at all times when the child is up and about. Children with a very low or incomplete lesion, with no neurological deficit of the trunk, may not need a brace. In these cases, the development of the spine will still need to be closely monitored as hip contractures may develop and pull the spine out of alignment.

Standing for the complete lesion

Normal bone growth and development is influenced by weight-bearing as well as the forces of compression and traction produced

in normal walking, running and playing. Standing is the only position where the spine adopts all its normal curves: cervical and lumbar lordosis and thoracic kyphosis. It also maintains the hip joints in their anatomical position and assists them to develop correctly. This is particularly important for those injured at an early age before the joint is fully developed. Standing also stretches the knees and ankles. Walking is a physical stimulation for the skeleton, which if done regularly may decrease the risk of osteoporosis and fractures. To avoid malalignment of the skeleton it is important that this is done with the legs and spine fully supported by the spinal brace and calipers for the legs, to avoid malalignment of the skeleton.

Well-aligned standing is best maintained by the use of a thoraco-lumbar sacral hip–knee–ankle–foot orthosis (TLSHKAFO) (Fig. 16.11A) These are made from the age of 18 months (i.e. when standing would normally start). The KAFO part is made with overlapping steels above and below the knee to allow for growth. Knee joints will be included as soon as practical, i.e. as soon as the child's leg is long
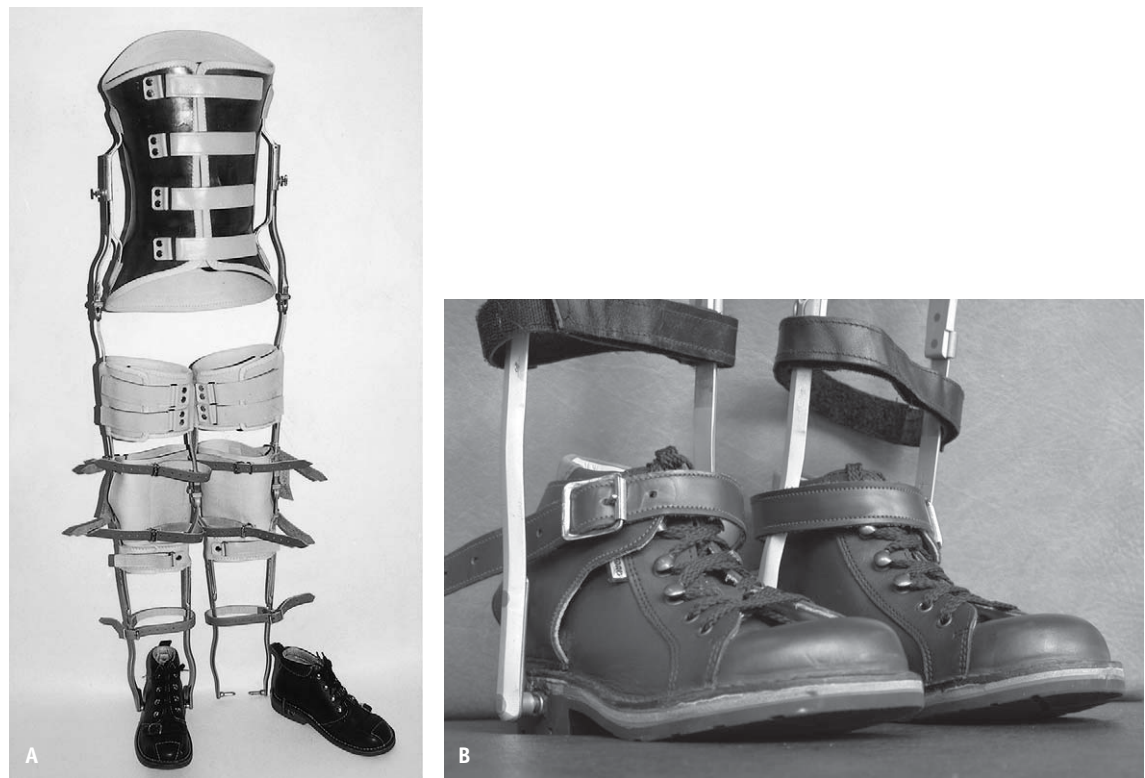
Figure 16.11 A: Hip–knee–ankle–foot orthosis. B: T-straps.

enough to allow the joints to be incorporated in the length of the orthosis. For stability of the knee in the median plane and for some control of rotation of the leg (either from the hip or from the foot), a wrap-around knee extension strap is used (see Fig. 16.11A). This can be reversed to offer a different directional pull on the leg. In most cases, the KAFOs will be attachable to the brace to achieve stability of the hips and make ambulation easier (Fig. 16.11A). If the thoraco-lumbar support from the TLSHKAFO is to be worn on its own, the hip joints must be part of the KAFOs and not the brace. Alternatively a separate brace for sitting only can be provided. Footwear should provide a stable support and include the ankle and an extensive opening to provide easy access to check size and the position of the toes. T-straps (Fig. 16.11B) may be added to give extra support to the ankle joint in the sagittal plane.

In order to stand for several hours it may be necessary to use a standing frame or a mobile stander (see Fig. 16.13). Standing frames on their own do not give sufficient support when the skeleton is still growing as they do not support each joint specifically as a bespoke set of caliper and brace does. The rotational forces in particular are very difficult to control and they will produce subtle changes in the alignment that are easily missed until a contracture has been established.

Ambulating for the complete lesion

Back slabs made from plaster of Paris, Soft/Scotchcast or thermo-plastic materials may be used initially to achieve the upright position while waiting for the completion of the orthosis.

Gait training with crutches or rollator is commenced at the age when able-bodied children would start to walk or slightly later, i.e. 18–24 months old. Where possible, all three gaits are taught. When the child is wearing the TLSHKAFO, it is only possible to teach swing-to and swing-through gaits (see Ch. 13). Crutches are the most versatile walking aid, allowing faster walking and greatest access. Slightly longer crutches will be necessary since trunk flexion is not possible when lifting, due to the restriction of the brace. A rollator may be preferred to crutches, especially in crowded environments such as school where the risk of being inadvertently knocked over is high. Walking with a rollator is slower than with crutches and some adjustment to techniques for getting from the wheelchair to standing may be required depending on the height of the child and the size of the wheelchair.

To enable the child to stand and move around throughout the day, it may be necessary to use the TLSHKAFO together with a swivel walker (Fig. 16.12), mobile stander (Fig. 16.13) or standing frame. The swivel walker allows the child mobility without using his hands for support, thus freeing them for other activities, and a child with a very high lesion (C3–C4) can use it. If used without the orthosis, donning and doffing is easier, which is appreciated by busy school staff. However, it does not provide such a good support for the limbs
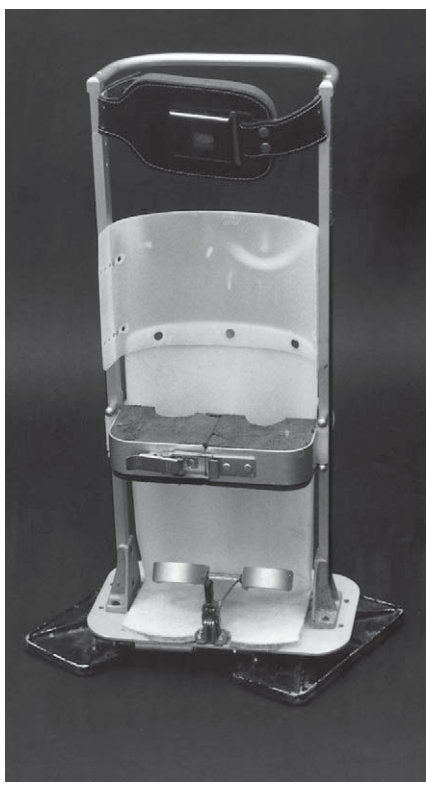
Figure 16.12 Swivel walker.

(as discussed under 'Standing for the complete lesion') and walking is slow. The mobile stander (see Fig. 16.13) is a self-propelling device that the child stands in, preferably wearing the orthosis. This offers independent mobility for the child with a higher lesion (from C6 to the upper thoracic lesions) and freedom to use the hands when stationary.

Contractures

Apart from standing and ambulating, another way to ensure good movement of all the joints is regular passive movements of all or particular joints that may be influenced by spasticity or other unopposed muscle activity. For some children, the joints will have to continue to be stretched daily and for others it may be enough to do it three to four times a week.

Established contractures will always require specific stretches. Overall stretches, such as standing and prone-lying, will only stretch the most mobile segments, usually the spinal column.

Some children will require an ankle–foot orthosis (AFO) to maintain the ankles at neutral (90°), either as night splints or for use during the day or both. Corrective devices such as below knee (BK) irons with corrective T-straps are sometimes used.

Elbow and hand splints as well as leg gaiters are also used.

Sleeping habits

A large part of our lives is spent in bed sleeping. It is important that this period is recognized as a potential force for influencing posture.

The lying position should be assessed carefully to ensure that the sleeping positions used will enhance the posture and that habits (typically one-handed habits dictated by the position of the bed in the room) are not allowed to become the driving force behind the development of deformity. If it becomes more comfortable to sleep on one side rather than the other, it may be an early indicator that the structures adjacent to the spine are becoming more mobile and stretched on one side and shortened on the other. Changing the position or correcting it with wedges or pillows could counter this.

This time can also be used for gentle stretches. Sleeping prone is a useful way to stretch hips, knees and the back. It also gives the skin, which during the day time is the weight-bearing area, a prolonged rest, without taking up extra time. This routine should be instigated before any contractures have developed, as those with shortened hip flexors may overstretch the lumbar lordosis instead of stretching the hips.

For those with high lesions, a special 'sleep system' that allows careful positioning will be of great help. This consists of foam wedges and blocks that are designed to be easily positioned and secured, to keep limbs and/or torso in optimum position.

Figure 16.13 Mobile stander.

Spasticity

The management of increased muscle tone (as a result of spasm) is usually the same as for contractures. Passive movements, orthoses and standing may help some people considerably. If this is not sufficient it may be necessary to resort to drug treatment (see Ch. 18).

At times the management has to be a compromise in order to fit in with the life of the child, family, school and educational commitments. Therefore it is particularly important to reassess the situation frequently.

MODIFICATIONS NECESSARY TO ADULT REHABILITATION PROGRAMME

Most treatment and techniques to move, transfer, dress and perform general self-care tasks are the same as those for the adult. Some general adjustments will have to be made when treating children.

Children, depending on their age, have a short attention span and require shorter treatment sessions. Games and play are useful ways to get children to work for general balance, coordination, strength and fitness as well as specific tasks.

Most activities will be taught at the age-appropriate time, but as well as being too young the child may simply be too small for some transfers. Therefore, if the child with SCI is very young, short periods of rehabilitation related to specific tasks will be required over many years.

Wearing a rigid trunk support will change the biomechanical basis for rehabilitation and some alteration in the methods may be required.

Postural sensibility

Children aged 3 years and over are given short periods of training, sitting on the plinth in front of the mirror in the usual way. This is augmented for small children by play therapy on the mat. Games and activities involving the use of first one and then both hands are encouraged whilst the unassisted sitting position is maintained. Children under 3 years are usually treated daily on the mat only, but where possible a mirror is used to give the child the necessary visual feedback.

Mat work

The ability of the young child to sit up from lying down is very important, as it releases the mother from going to the child early in the morning to sit him up in his cot to play. Where this activity has

not been taught, the mother may continue to lift the child even when he is 5, 6 or 7 years of age.

To sit up from lying down on the mat:

1. Turn the upper trunk and left arm to the right (Fig. 16.14A).
2. Push up onto both elbows and then hands (Fig. 16.14B).
3. 'Walk' on the hands to the sitting position (Fig. 16.14C, D).

The child is also taught to turn over, to roll into the prone position and to move himself and his legs around on the mat.
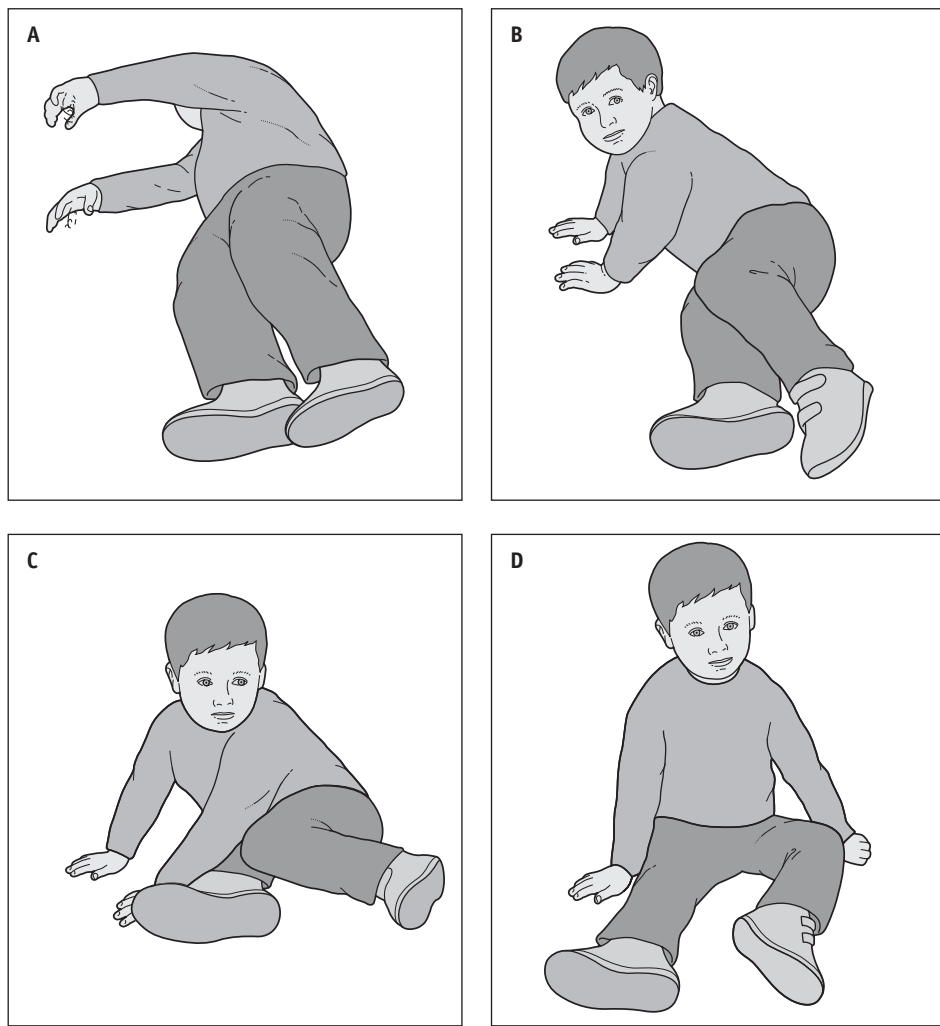
Figure 16.14 Sitting up. Child with a complete lesion below T10.

Muscle strength

In order to prevent spinal deformity, particularly if the child is wearing a brace, it is important to hypertrophy the back muscles and latissimus dorsi and to continue these exercises throughout growth.

Dressing and self-care

The child with SCI is taught to dress and wash at the same age as the able-bodied child. He is also taught as early as possible to look at his own legs for pressure marks, to put pillows between the legs when turning in bed, and to lift and move with care. If the child plays on the floor, crawling and turning, he needs to be made aware of positions that the lower limbs may adopt. When dragging legs that have no sensation, they may become trapped in awkward positions, which in some cases can cause them to fracture.

Transfers

Some of the techniques of transferring may have to be altered due to the size of the child. The brace will also influence the transfer technique. For example, it gives stability to a collapsing spine and in this case becomes a helpful aid. It is important that the transfers are taught wearing the brace since different postures will alter the bio-mechanical relationships of the body and thereby necessitate a different technique. (It can be difficult to motivate a child to learn the same task twice, with and without the brace.)

It is easier and safer for the young child to get onto the bed forwards (see Fig. 12.12).

When transferring onto the toilet, the child will need to keep his feet on the footplates or have them propped on a solid stool of suitable height until the feet reach the floor.

The lifts involved are usually too great for a child to transfer onto the floor or into the bath without assistance. Stools of varying height can be used as stepping stones for the child to get from his chair to the floor and back. A bath seat may be used in a similar way.

To transfer into a car, a sliding board may be necessary if the gap is too wide for the small child.

Wheelchair

The chair should offer the child a good posture and mobility with minimum energy expenditure. Since children are not scaled down adults, it is not sufficient to have a scaled down adult chair. A child's wheelchair should be adjustable to allow for growth.

Seat height from the floor needs to be considered. Small children mainly play on the floor and have their environment, such as school

and infant school, furnished to their size. In this environment the paralysed child needs a chair that will bring him into contact with his peer group. The adult carer needs push handles that are extended above and are situated away from the backrest, in order not to impede the child's mobility (see Ch. 11). To give maximum ergonomic advantage for the carer, the push handles need to be angled away from the backrest. Various sizes of wheels, castors and supports for the castors are available. These allow the seat to be raised to accommodate the growing child. The backrest can be adjusted in height and, on some models, the seat and back canvasses are provided in several sizes (see Ch. 11).

INVOLVEMENT OF PARENTS

The responsibility for any child's physical well-being and care falls to the parent, as does the responsibility for the majority of decisions regarding his life. The parents should therefore be involved in all aspects of rehabilitation and great care needs to be taken to make sure that they have a clear understanding of all the special tasks and techniques as well as the reasoning behind them. It is essential that parents learn in detail the care of the bladder, bowels and skin, and see how the child walks and how to give any necessary assistance. It is also important for parents to see what the child can accomplish by himself, e.g. in dressing and transfers, and be taught how important it is that the child should continue his independence when home, even if he is slow at first. Parents should also be made aware that, as the child grows and becomes heavier they (the parents) are at increased risk of damaging their own back if they continue to give physical help in the same manner as when the child is toddler age. The parents must have enough knowledge to feel confident to encourage the child to further independence, and be made to feel welcome to come back for further advice, and help.

The treatment outlined in this chapter is very demanding for the child, but perhaps more so for the parents. It can be very difficult to allow the child maximum independence when it means very slow progress through the day's tasks. To motivate a child to stand and walk – in the knowledge that he is quicker, gets less tired and can participate in more social activities if he uses a wheelchair – is hard for any parent, and even more so if it causes conflict with the child and threatens to undermine their relationship. Therapists and medical staff must face these realities, take their share of responsibility and assist the parents and child to arrive at a working compromise.

INVOLVEMENT OF THE SCHOOL

The education of the physically disabled child is of paramount importance. He must be encouraged and assisted to make the best use of his intellectual resources since so many manual occupations will be

inaccessible to him. The Education Act 1981 has introduced in Britain the principles of the integration of children with special educational needs with able-bodied children and the development of facilities to meet the special needs of disabled children. It is desirable that, after spinal cord injury, children should return to mainstream schools and playgroups when their initial period of rehabilitation is concluded. They will then integrate at an early age with able-bodied children and will also have the same chance to achieve the necessary qualifications for higher education. It is encouraging that more schools are welcoming the child back to school after becoming disabled, and are making the necessary alterations to school buildings.

As a large part of the child's day is spent at school, it will be necessary for the school to be involved in the special routines incorporated in the child's care. Special provision for standing may be necessary, such as a standing frame or a high table in the classroom. The child may have to don and doff the orthosis for toileting or rest, and the skills needed have to be passed to the appropriate person(s) at the school. Access to the school will have to be considered as for the home or the workplace for an adult, and any necessary adaptations undertaken.

FOLLOW-UP

Due to the child's continued physical and general maturity, a regular and frequent follow-up system is necessary, usually taking place every 6–9 months. The most important aspect of the follow-up for the therapist is to monitor the development of the spine and contractures and to check the fit of orthoses and other equipment. This needs to be done as objectively as possible. A simple method to record the development of the spine is to photograph the children in a standardized manner. With the spinal column and the posterior superior iliac spine marked, posterior and lateral views are taken with the convex side of the spine furthermost when the child is seated unsupported (to see the maximum deformity) and suspended either by lifting himself or by being lifted under the axilla, to see the spontaneous correction. A skyline (contour) view at the angle of maximum deformity is also taken. When the camera is kept at a constant distance from the child and at a constant height in relation to the seat, some comparison between the pictures can be made and a trend in development can be seen. However, it needs to be augmented with radiographs every 2 years, and yearly if deformity is evident, as this is more revealing than inspection only (Fig. 16.15A, B). This will enable a more realistic assessment of the development of the spinal deformity to be made and intervention of a more vigorous form such as internal fixation to be considered if and when necessary.

Children with SCI will succumb to the complications of spinal deformity and contractures much more readily than adult patients.
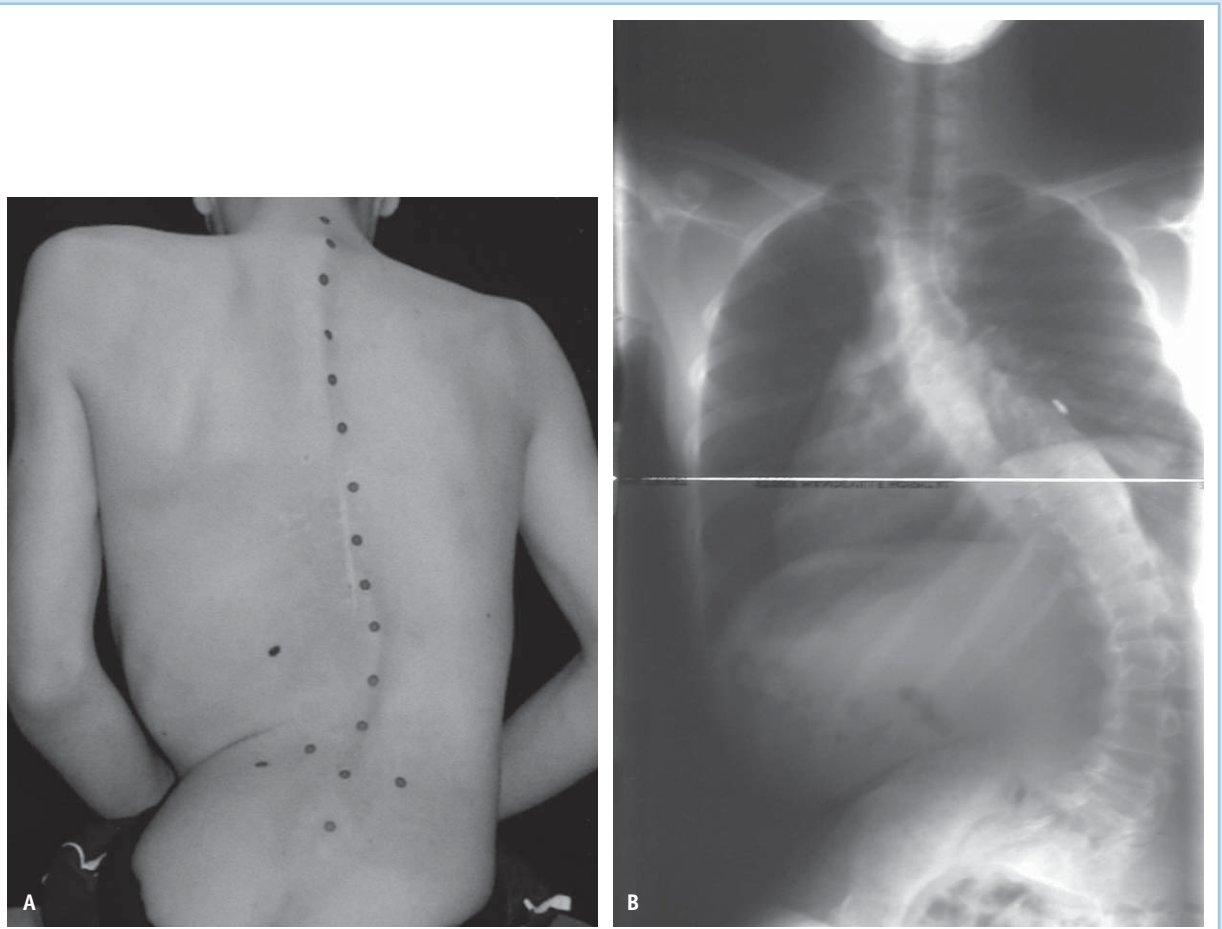
Figure 16.15 A: Photograph of back (neurological level T9) seated. Spinous processes and posterior superior iliac spines are marked. B: Radiograph taken seated of the same back as in part A.

All concerned should work to reduce and minimize this process so that the child reaches adulthood with as near normal a posture as possible. The spine needs to be kept mobile, not only to prevent deformity and possible consequent damage to internal organs, but also to ensure maximum success should surgical stabilization of the spine be considered when the child gets older.

As the children mature intellectually, they need to take on more of their own care and further intensive periods of rehabilitation may be required. The children should be given every opportunity to achieve their potential so that they can gain their maximal social and intellectual as well as physical independence.

RESEARCH FINDINGS

A study was undertaken at the National Spinal Injuries Centre (NSIC), Stoke Mandeville Hospital (Bergström 1994), to assess the impact of childhood SCI on spinal deformity and growth in the now adult individual. The 80 subjects taking part in the study came from 189 patients who had an acute onset SCI before their 16th birthday and were treated at the NSIC from within 1 year of onset.

Seventy-six of the subjects had radiographs of their whole thoracic and lumbar spine taken in their habitual upright position (56 seated and 20 standing) in a standardized manner. The statistical analysis was primarily based on two-way subdivisions of the subjects (due to the small sample) as follows:

- level of lesion – tetraplegic/paraplegic
- severity of lesion – complete/incomplete lesion
- age at injury – <11 years, >11 years.

Scoliosis, lordosis and kyphosis were measured from the radiographs according to Cobb (1948). For the purpose of cross-tabulation, these three parameters were divided into three groups:

- scoliosis – mild (<20°), moderate (20–59°), severe (>59°)
- lordosis – hypolordosis (<35°), normal (35–64°), hyperlordosis (>64°)
- kyphosis – hypokyphosis (<25°), normal (25–49°), hyperkyphosis (>49°).

Of the 76 subjects analysed, 78% had a scoliosis of more than 10° and 53% had one of moderate to severe magnitude; 42% had a hyperlordosis and 41% a lordosis that was too flat; 45% were hyperkyphotic, while 14% had a thoracic spine that was too flat. Only one subject had a 'normal' spine.

Both level and severity of paralysis as well as age at onset have a strong influence on the magnitude of the scoliosis, as illustrated in Table 16.1.

The level of lesion, expressed simply as tetraplegia and paraplegia, has a clear inverse relationship with the degree of scoliosis. The paraplegic subjects have a greater scoliosis than the tetraplegic subjects and also appear in proportionally larger numbers in the increasingly more severe scoliosis group.

The severity of lesion, when only divided two ways into complete and incomplete lesions, shows a positive relationship with the magnitude of scoliosis. The complete lesions have more severe scoliosis than the incomplete lesions. The proportion of complete lesions also increases as the magnitude of the scoliosis increases.

Age at onset is closely related to the occurrence and magnitude of scoliosis. The very young at onset have a more severe scoliosis and are proportionally more numerous in the increasingly more severe scoliosis group.

Table 16.1 The distribution of scoliosis (Cobb angle) by level of injury, severity of injury, age at onset, duration of injury and range of hip movement in 76 childhood SCI subjects

	Level of injury		Severity of injury		Onset age (years)		Duration (years)		Flexion contracture	
	Tet	Par	Comp	Incomp	<11	>11	<20	>20	<15°	≥15°
Number	26	50	42	34	17	59	38	38	42	32
Mean Cobb angle	17°	33°	36°	18°	38°	24°	22°	33°	21°	37°
Level of significance	**		***		*				**	
Scoliosis										
0–19°	18	18	12	24	4	32	20	16	25	9
20–59°	8	23	23	8	8	23	16	15	15	16
≥60°	0	9	7	2	5	4	2	7	2	7
Level of significance	**		**		*				*	
Missing cases									2	

Tet = tetraplegia; Par = paraplegia; Comp = complete lesion; Incomp = incomplete lesion.
*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

When analysing the lordosis angle separately for the seated and standing subjects, those seated show a significantly greater lordosis in the paraplegic subsection than in the tetraplegic (50° and 28°, respectively) and also among those with severe (15°) hip flexion contracture compared with those with no or mild (<15°) hip flexion contracture (56° and 27°, respectively) (Table 16.2).

Among the 20 standing subjects, there was a significant difference of lordosis angle when subdivided according to level of lesion only. The lordosis was significantly larger in the paraplegic group (78° compared to 62° in the tetraplegic group). Of the 20 individuals the majority (15) had hyperlordosis, and 13 of those had no or mild contracture of the hips (Table 16.3).

These subjects illustrate the connection between hyperlordosis and hip flexion contractures when constantly seated. However, this is not the case for those who predominantly walk.

Measurements of body segments were carried out in accordance with Weiner & Laurie (1969).

In order to examine the effect of SCI on growth, the length of the humerus and the tibia were compared. The humerus was chosen as the single bone least likely to be affected by the paralysis and the tibia as the bone most likely to be affected. Table 16.4 shows the mean tibial length to be longer than the mean humeral

Table 16.2 The distribution of lordosis angle in 56 seated childhood SCI subjects by level of injury, severity of injury, age at onset, duration of injury and range of hip movement

	Level of injury		Severity of injury		Onset age (years)		Duration (years)		Flexion contracture	
	Tet	Par	Comp	Incomp	<11	>11	<20	>20	<15°	≥15°
Number	17	39	42	14	14	42	27	29	25	30
Mean lordosis angle	28°	50°	40°	51°	51°	41°	38°	48°	27°	56°
Level of significance	*								**	
Lordosis										
0–34°	12	18	24	6	6	24	15	15	20	10
35–64°	3	6	7	2	2	7	5	4	3	6
≥65°	2	15	11	6	6	11	7	10	2	14
Level of significance									**	
Missing cases									1	

Tet = tetraplegia; Par = paraplegia; Comp = complete lesion; Incomp = incomplete lesion.
*, $P < 0.05$; **, $P < 0.01$.

Table 16.3 The distribution of lordosis angle in 20 standing childhood SCI subjects by level of injury, severity of injury, age at onset, duration of injury and range of hip movement

	Level of injury		Severity of injury		Onset age (years)		Duration (years)		Flexion contracture	
	Tet	Par	Comp	Incomp	<11	>11	<20	>20	<15°	≥15°
Number	9	11	–	20	3	17	11	9	17	2
Mean lordosis angle	62°	78°	–	71°	69°	71°	66°	78°	71°	71°
Level of significance	*									
Lordosis										
0–34°	1	0	–	1	0	1	1	0	1	0
35–64°	2	2	–	4	2	2	3	1	3	1
≥65°	6	9	–	15	1	14	7	8	13	1
Level of significance										
Missing cases									1	

Tet = tetraplegia; Par = paraplegia; Comp = complete lesion; Incomp = incomplete lesion.
*, $P < 0.05$.

Table 16.4 Mean humeral length and tibial length for female and male subjects by level and severity of lesion and age at onset

	Female			Male		
	Humerus (mm)	Tibia (mm)	n	Humerus (mm)	Tibia (mm)	n
All	338	350	34	363	366	41
Level of injury						
Tetraplegic	347	369	12	358	379	14
Paraplegic	333	340	22	366	359	27
Severity of injury						
Complete	340	345	17	363	359	25
Incomplete	336	355	17	364	376	16
Onset age						
<11 years	334	331	6	370	357	13
>11 years	339	354	28	360	370	28

Table 16.5 Mean humeral length and tibial length for female and male subjects with neurological damage at and below L1 by severity of lesion and age at onset

	Female			Male		
	Humerus (mm)	Tibia (mm)	n	Humerus (mm)	Tibia (mm)	n
All	333	345	9	338	342	3
Severity of injury						
Complete	342	335	4	360	351	1
Incomplete	327	351	5	327	338	2
Onset age						
<11 years	326	305	1	360	351	1
>11 years	334	349	8	327	338	2

length among both female and male subjects. In the female subjects, the mean tibial length is shorter in those injured before age 11. The male subjects show a shorter tibia in the paraplegic, incomplete and 'injured before 11 years' groups than their respective counterparts.

In order to examine the effect of a lower motoneurone injury on growth, the humeral/tibial relationship was re-examined in the same manner, separately for those nine subjects with neurological damage at L1 and below (Table 16.5). The lower motoneurone lesion is thought to have greater retarding influence on growth than upper motoneurone lesions, as the upper motoneurone lesion has an intact

neural arc. This allows involuntary motor function below the lesion level which ensures better circulation and some muscular stresses on the bones. Both are important factors in stimulating growth. The relationship between the two bones now shows a similar picture for females and males. The mean length of the tibia is longer for both sexes, but when subdivided as previously, the complete lesions and those injured before the age of 11 have a shorter mean tibial length than mean humeral length.

These results indicate that SCI does affect the growth of a child, but the many factors potentially influencing growth are confounding one another in this small sample.

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Ageing with spinal cord injury

Ebba Bergström

INTRODUCTION

Over the last few decades, it has been acknowledged that spinal cord injury is not a static unchanging state, and studies have been undertaken on the problems associated with ageing in patients with longstanding spinal cord injury. Survival following spinal cord injury was relatively rare prior to World War II. Medical advances since 1945 have greatly enhanced both the initial and long-term survival of this group of people with permanent disability. Efforts have inevitably concentrated on improving initial care, emergency medical services, rehabilitation and social integration through the establishment of spinal cord injury centres but increased awareness of long-term outcomes has influenced the way initial rehabilitation is currently carried out.

LONG-TERM SURVIVAL

Mortality, morbidity, health, function and psychosocial outcomes were examined in an extensive study with 834 individuals who had their spinal cord injury at least 20 years previously (Whiteneck et al 1992). The study was carried out on patients treated at two spinal cord injury centres in the UK. As expected, morbidity was influenced by the decade in which the injury occurred and therefore the initial care given. The mean survival rate for those injured in the 1940s was 26 years, whilst the rate for those injured in the 1960s was 33 years. Patients with incomplete lesions and those with lower lesions lived longer.

Recent studies show survival times based on standard mortality ratio (SMR) (De Vivo & Stover 1995). This is used to calculate the life expectancy at different ages of injury. According to Yeo et al (1998) the life expectancy was 92% compared to the general population for those with incomplete lesions (Frankel D regardless of level), 84% for those with complete paraplegia and 70% for those with complete tetraplegia. These figures are similar to those presented by Frankel et al (1998) and De Vivo et al (1999). In addition to level of injury and completeness, survival time is also

dependent on age at injury, gender, ventilator status and aetiology of injury.

CAUSES OF DEATH

The study by Whiteneck et al (1992) showed that renal failure is no longer the primary cause of death in patients with spinal cord injury and, as death from renal failure decreased, the causes of death more closely resembled those of the general population.

Frankel et al (1998) reviewed the medical notes of 3179 individuals including the 834 reported by Whiteneck et al (1992) in a long-term survival study of spinal cord injury. The study spanned nearly 50 years (1943 to 1990) and confirms the changes in ranking of causes of death that has occurred. The urinary system is no longer the primary cause of death in patients with spinal cord injury as it was in the early decades of this study. Respiratory diseases are the main cause of death in the latter decades. It should, however, be noted that pneumonia is often cited as cause of death when no autopsy had been carried out or there was no definitive cause of death. Heart disease was the second and injuries and suicide the third most common cause of death in the last two decades of the study. These findings are also confirmed in US studies (De Vivo et al 1999, Soden et al 2000).

CHANGES IN FUNCTIONAL ABILITY WITH AGE

The 282 survivors in the study carried out by Whiteneck et al (1992) were medically examined, revealing significant changes in functional abilities associated with the ageing process. Problems were related to pressure ulcers, kyphosis or scoliosis, restricted neck flexion, loss of range of movement at the shoulders and hip flexion contractures.

Changes in functional ability, in the same study involving 279 individuals with long term spinal cord injury, were examined by Gerhart et al (1993). Almost one-quarter reported that their need for physical assistance had increased over the years. The majority reported general good health and rated their quality of life as either good or excellent. Quality of life increased with length of time post-injury, apart from those who needed more assistance and felt their quality of life had declined. Ages at which physical decline appeared, late 40s for those with tetraplegia and early 50s for those with para-plegia, are considerably younger than would be expected in non-disabled individuals.

Factors identified as contributing to the need for more assistance were fatigue/weakness, specific medical problems, pain and stiffness, weight gain and postural changes. Pain in the shoulder was signifi-cantly more frequent in the group that needed more assistance.

These findings are corroborated by others and illustrate that individuals with spinal cord injury have much narrower margins of

fitness, strength and function than the general public. For many functional tasks, such as lifting a leg, transferring and pushing the wheelchair, maximal strength and fitness and optimal mobility, tone and weight are required. Minimal changes in only one of these variables can totally jeopardize the ability to function independently.

Pain in the shoulders

The shoulders are key weight-bearing joints for individuals who use a wheelchair or ambulation device (Bagley et al 1987). When a patient transfers, the intra-articular pressure in the shoulder joint rises dramatically and the bones, joints and soft tissues of the upper body are subjected to considerable stress while supporting the body weight (Jansen et al 1994). The same study showed that the level of physical strain is not uniform for patients with the same level of lesion performing the same activities of daily living.

A Wheelchair Users' Shoulder Pain Index (WUSPI) has been developed by physiotherapists in the United States to measure shoulder pain causing limitation of function in individuals who use wheelchairs (Curtis et al 1995a,b). It can be used as a tool for research purposes and for clinicians to document baseline dysfunction. Subjects in this study experienced most pain when performing activities requiring extreme range of shoulder movement or high level of upper limb strength, or when performing movements with the arm above the head. Activities such as wheeling up an incline or on outdoor surfaces, lifting an object from an overhead shelf, transferring from bath to wheelchair or washing the back caused most pain. An Australian study (Pentland &Twomey 1994) identified the same tasks as being most painful and also included driving.

Individuals who have joint pain induced by activity will eventually limit the activities to minimize the pain. The reduced activity level will then lead to reduced strength that in turn will exacerbate the pain as the biomechanics of the joint is further altered. Exercise regimens are necessary, to restore the muscle balance around the joint. Curtis et al (1999) demonstrated the effects of such an exercise protocol on shoulder pain, which interferes with functional activities in wheelchair users. Individuals who underwent the treatment showed an improvement compared to the control group. An assessment of the daily activities will identify areas where reduction in activities, without reducing independence or level of socialization, should be undertaken and discussed with the spinal cord injured person and the caregiver. The caregiver is particularly important if he or she is a spouse who is also experiencing the ageing process. The use of a sliding board and/or a sliding sheet will reduce the level of strain and muscle activity of the shoulder joints. A shower unit will reduce or cut out the split-level bath transfers that require maximal strength to perform. A shower wheelchair may also reduce the number of

toilet transfers considerably. Russell & Shamley (2003) showed a reduction of electromyographic (EMG) activity, in the pectoralis major and infraspinatus muscles, in both leading and trailing arm during transfers using a sliding board compared with no sliding board.

Advice should be given to patients about warming up before stressing limbs, checking the environment and avoiding over-reaching and sudden unusual stresses, e.g. long distance pushes or transfers to toilets where access is difficult. Although not every individual with spinal cord injury will experience upper limb joint pain, it has now been comprehensively demonstrated that it is a common occurrence and with severe consequences for those affected. Therefore these changes of daily activities should be discussed as soon as upper limb pain/weakness is experienced. If some of these changes can be accepted sooner, rather than later, maybe the level of pain and discomfort can be reduced. Those who underwent their rehabilitation in the 1960s and 1970s or earlier were often made to feel that the level of independence and skill they had achieved was expected to remain for all but their last few years of life. Anything less is often experienced as a failure.

Postural changes

Postural changes through development of spinal deformity, either kyphosis/lordosis or scoliosis and the position of the neck need careful assessment. Other common but more peripheral postural changes are limb contractures. The hip joint is commonly affected by contractures or poor alignment. These changes often lead to pain and discomfort that gets worse with prolonged sitting. In other words it is the posture itself that causes the pain. Long-term misalignment develops into fixed deformity as in contractures of joint capsules, ligaments and muscles. Some improvement can possibly be had with intensive stretching. For long-term correction of position, specialized seating systems and lower limb orthoses can be used. Increased thoracic kyphosis, which leads to excessive forward flexion, increases the amount of neck extension required to maintain horizontal vision (see Ch. 6). This often leads to unacceptable neck pain towards the end of the day. With the range of backrests on the market now, it is possible to accommodate such posture or have a chair that can vary the posture during the day. In some instances a corset or a firmer brace may alleviate the discomfort by the support it gives. Some cushions will not only improve the pelvic alignment when seated but will also enhance the position of the lower limbs with wedges and centre pommels. Sidepieces can help to align the femur. Good supportive footwear and ankle foot orthoses will also correct the position of the lower limb. These are often used when the position of the feet causes all the pressure to be distributed to one point on the foot instead of evenly over the whole sole of the foot.

Tissue viability

The ageing skin becomes more vulnerable and after a few decades with spinal cord injury even those who have never experienced problems with pressure ulcers may find that they are more prone to develop red marks and even ulcers. Liem et al (2004) found that pressure ulcers were the second most common reason for the need to increase help with activities of daily living. For those who learned to relieve pressure in the old way, by lifting and holding for 10–15 seconds, the lift may no longer be efficient for those with painful upper limbs. Pressure-relieving techniques have changed since research has shown that considerably longer periods of pressure relief are needed for oxygen levels to recover (Coggrave & Rose 2003). Different techniques, such as leaning forward or sideways are now advocated. After the treatment of a pressure ulcer, careful assessment of cushion and pressure distribution, wheelchair, posture and transfer techniques is imperative to identify the most suitable equipment and technique, thus minimizing the risk of it reoccurring. The skin covering the area of a healed pressure ulcer is not as viable as undamaged skin, so extra vigilance is necessary. The pressure mapping is particularly effective as a feedback tool to assess pressure relief. For further reading refer to Chapter 6.

Weight

Weight gain is normal in the later years of life in the general population. For the spinal cord injured it decreases functional skills, particularly for those who are functioning at the margin of their ability in terms of strength and mobility. It reduces the ability to transfer and do many activities of daily living that require good or optimal mobility, such as reaching the feet, picking up and moving the legs. Weight has been associated with median nerve injury in this group (Boninger et al 1999). The opportunity to keep a check on the weight is limited for most wheelchair users as access to suitable scales is scarce. It is also more difficult to lose weight when paralysed as the general ability to exercise has been restricted. Weight should be part of the general health check to ensure intervention as soon as possible.

THE ROLE OF THE PATIENT IN ACCEPTING CHANGE IN FUNCTION

Individuals with spinal cord injury need to realize the importance of respecting and protecting their upper limbs, to expect that their equipment needs will change and acknowledge that accepting assistance or using equipment does not signify failure (Whiteneck et al 1993). The professional who recommends the change of equipment

considers this as an easier and labour-saving way of achieving the goal. Although this is true in theory all new techniques and equipment need considerable training and familiarization just as they did during the original rehabilitation. This must be allowed for, to ensure that the patient is able to make full use of the new equipment and skill.

There is often a psychological barrier having to learn the same task in several ways even in the early stages of rehabilitation. Having overcome all difficulties and lived independently for several decades, it is difficult to accept that the process has to be repeated with a less independent goal to aim for. It is vital for the professional to give the spinal cord injured the time to accept this fact.

THE ROLE OF THE CAREGIVER IN ASSISTING CHANGE IN FUNCTION

Many caregivers of the older generation of the spinal cord injured are members of the family who are contemporaries with the person, such as spouses, or an older generation as in the case of parents, and are themselves experiencing the ageing process. Spouses of long-term spinal cord injured survivors who fulfil a caregiving role report more symptoms of stress and depression than their partners with disabilities and other spouses who are not caregivers (Weitzenkamp et al 1997). When assessing the changing needs of the patient, the need and capabilities of the caregiver have to be carefully considered. The caregivers may feel that they are letting the spinal cord injured person down if they are no longer able to help as before. They may no longer be able to assist with a lift or keep going all day to fulfil two persons' needs. Some changes in need may indeed be on account of the carer as opposed to the spinal cord injured individual. When a spouse or close relative is the main caregiver, the systems funding the care and equipment need to be flexible enough to take into account the combined needs of the spinal cord injured individual and the relative.

The professional should be aware of the fact that the person with spinal cord injury and his family sometimes find it difficult to discuss these issues openly, particularly in front of relative strangers. Sometimes each fails to appreciate the other's needs. The spinal cord injured person often has very poor insight into the stress experienced by the able-bodied spouse.

THE ROLE OF THE PROFESSIONAL IN FACILITATING CHANGE IN FUNCTION

If problems with posture or in other areas are to be identified early and avoided or delayed, professionals who understand the ageing process and know the patients over a long period need to be involved in their regular check-up. It is also important to have an understand-

ing of the state of the rehabilitation services at the particular era when the patient was first injured and the changes and developments that have happened since then. The choices are greater now compared with 20 years earlier and the patient may not have kept up with developments. It is possible to address problems related to strength, pain and posture by using adaptive equipment, lightweight or power-drive wheelchairs, cars that you can wheel into, customized seating systems and specialized cushions (Gerhart et al 1993). Change in bladder or bowel care may be indicated at this stage. Constipation has been cited as a common cause for increased need of assistance.

Changes in equipment, techniques and the amount of assistance needed have a severe effect on the life of the individual with spinal cord injury and his family. Some equipment, such as hoists and special beds for easier access when administering care, are bulky. Bathrooms may need redesigning to create room for a wheel-in shower. This may necessitate architectural changes in the home. A professional carer who comes at set times is an intrusion into the personal space of all family members. These changes often mean an altered life style. For the first generation of the ageing spinal cord injured this was often not fully appreciated.

Technical developments and changing attitudes in society in general, combined with the growing knowledge of the ageing effect on people with spinal cord injury, have led to changes in rehabilitation. In the 1960s and 1970s and before, the alternative to functional independence was dependence on family or living in a care home. With new legislation and attitudes, regardless of level of disability, everybody can live independently and have a choice in how to live their lives. Personal independence in self-care is often willingly sacrificed for the opportunity to go out to work. Further research into the functional changes associated with ageing and the need for further assistive devices and assistance will lead to more appropriate and timely educational programmes for this growing population of people with spinal cord injury.

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Complications

CONTRACTURES

Contractures cause delay in achieving or even prevent the achievement of maximum independence. It is the direct responsibility of the therapy and nursing staff to prevent their occurrence.

Causes

The causes of contractures are:

- incorrect positioning in bed or incorrect posture in the wheelchair
- inadequate physiotherapy
- spasticity.

It is difficult to separate these three closely linked factors in relation to the formation of a contracture.

Conservative treatment of established contractures

- Passive movements, including to the accessory joints
- Prolonged passive stretching
- Active exercises
- Splinting
- Passive and active exercises in a heated pool
- Ice therapy and ultrasound.

Passive movements

Passive movements are always given at every treatment in addition to any other methods employed. In conjunction with the passive movements, a passive stretch is also given in the position of maximum correction.

Prolonged passive stretching

Prolonged optimal passive stretching for both the prevention and correction of contractures is an effective means of treatment (Harvey

& Herbert 2002). A prolonged passive stretch can be given for flexion contractures of the hips and knees and adduction contractures of the hips by strapping the limbs in the corrected position. In bed, the corrective position is maintained by using pillows and padded straps. For example, for flexor contractures of the knee, the legs are kept in extension with a strap over the knees. To avoid pressure, pillows are placed (1) under the lower legs to keep the heels off the bed, (2) between the knees to prevent the apposition of skin surfaces, and (3) over the knees, underneath the strap.

Flexion contracture of the hips

The patient lies prone on the plinth. Two or three pillows are placed under the knees and similarly under the trunk, with a gap at the level of the hip joints. To avoid pressure, a pillow is placed between the knees, and the toes must be over the end of the plinth (Fig. 18.1). Correction is obtained by strapping the hips down to the plinth. The strap placed over a pillow on the sacrum is tightened gradually. Care must be taken to arrange the two groups of pillows so that the stretch is given to the hip flexors. If the space between the pillows is too wide, the stretch merely increases the lumbar lordosis. The ankles can also be tied down with a padded strap if there are flexion contractures of the knees. The stretch is normally maintained for 20–30 minutes at a time.

Active exercises

Hold–relax techniques are used to obtain relaxation where the muscle groups are innervated and resisted work is always given to the antagonists.
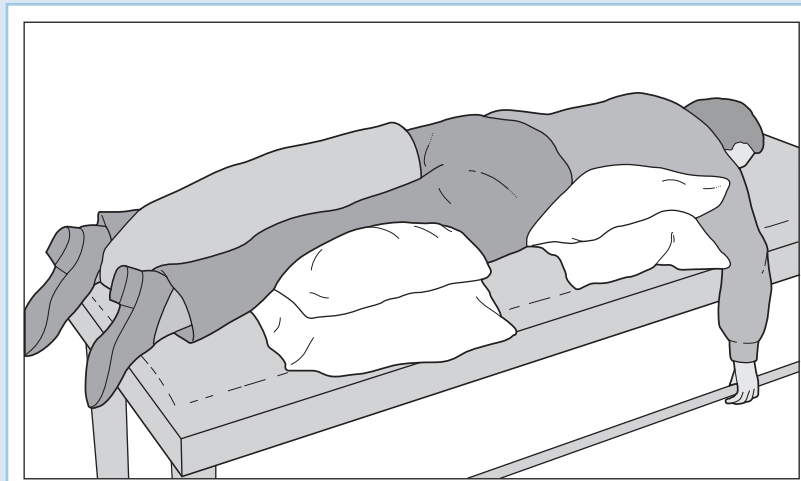
Figure 18.1 Passive stretch for the hip flexor muscles.

Splinting

To avoid excessive pressure, it is advisable to make serial splints and not try to obtain maximum correction initially. The contracture may involve more than one joint. In this case, maximum correction is obtained firstly at the joint principally controlled by the major muscle involved. For example, where the elbow, wrist and fingers are flexed, biceps is the major muscle and maximum correction is given at the elbow joint. Air-filled plastic splints are commercially available and can be useful in some cases.

Passive and active exercises in a heated pool

The hot water aids relaxation, and is especially beneficial if there is severe spasticity.

Ice therapy and ultrasound

Ice therapy and ultrasound are used as and where suitable.

'Constant attack' is the motto for dealing with contractures. Treatment needs to be carried out several times a day using a variety of methods. For example, contracted biceps tendons have been successfully treated by giving daily passive movements, active exercises, ice therapy, ultrasound and splinting; and hip and knee flexion contractures by giving passive movements, passive stretching on the plinth, ice therapy and exercises in a heated pool.

Surgical treatment

When no improvement has occurred for approximately 6 weeks in spite of intensive therapy, surgery may be considered.

Release of the iliopsoas by iliopsoas myotomy (Michaelis 1964), elongation of the tendo Achillis, and obturator neurectomy to release the adductor muscles are useful surgical procedures in cases of severe contractures which have not responded to conservative methods (Eltorai & Montroy 1990). If the patient has strong spasticity as well as contractures, other surgical procedures may be recommended (see p. 368).

HETEROTOPIC OSSIFICATION (HO) OR PARA-ARTICULAR CALCIFICATION

A special form of heterotopic ossification, exclusively of non-infectious or traumatic aetiology, has been repeatedly observed in both complete and incomplete paraplegic and tetraplegic patients below the level of the lesion. The condition is also found in patients

with non-traumatic lesions (Taly et al 1999). There are numerous publications from many parts of the world on this subject, but the aetiology and pathology of the disease remain obscure. An extensive clinical review of heterotopic ossification has been undertaken by van Kuijk et al (2002) which includes the incidence, clinical signs. risk factors and various therapies. Clinically significant heterotopic ossification was shown to be present in between 20% and 30% of patients.

The development of bone in the connective tissue always occurs below the level of the lesion and rarely after the first 6 months post-injury. The areas most commonly affected are the hips, knees and elbows, and the medial aspect of the femur. The joints themselves are not affected but the ossification can become massive enough to cause an extra-articular ankylosis. The therapist is often the first member of the team to notice the onset of the disease. When moving the limb, she becomes aware that the joint involved does not feel quite normal. Although there is no real resistance to movement, the joint does not 'feel' clear and free. It is as though the movement were taking place through sponge. At this very early stage, there will be no radiological evidence and there may not be any visible evidence, just the awareness of a vague abnormality on moving the limb. Swelling, and possibly some erythema, may occur within a few days.

Early X-ray evidence shows cloudy patches in the muscles involved but this may not show up for a further 2–3 weeks, and by this time there will be some joint stiffness. As the disease progresses, X-rays show calcareous deposits in the para-articular tissues and finally dense ossification of the ligaments, fasciae and muscles surrounding the joints. The degree of ossification which occurs before the disease burns itself out varies considerably. Some patients have very little residual loss of joint range, whilst others have severe loss of function and independence.

Early diagnosis is of crucial importance. Waiting for late clinical or radiographic symptoms may allow a significant amount of ectopic bone to be deposited before treatment is initiated.

Banovac & Gonzalez (1997) suggest that bone scintigraphy in asymptomatic patients is a sensitive test for early diagnosis of HO. The study showed that epidronate (the most common drug used for HO) therapy, given in higher doses and started in asymptomatic patients, may prevent the development of HO. Various types of medication have been used prophylactically. Banovac et al (2001) suggest that indometacin used prophylactically has an influence on the development of HO and Banovac et al (2004) suggest COX-2, a selective inhibitor (rofecoxib). Low field irradiation has been given to minimize or prevent HO and after surgery to prevent recurrence (Van Kuijk et al 2002).

Ultrasonography used by an experienced person can detect HO prior to seeing it on X-ray and it is being increasingly used to docu-

ment clinically suspected HO (Pullicino et al 1993). The sonographic appearance of early HO suggests that it might be due to a partial muscle tear with massive haemorrhage (Snoecx et al 1995). Passive movements on the seven patients in the Snoecx et al (1995) study were started a week after injury. Silver (1996) suggests that contractures could have been already forming in the limbs, tears occurred when passive movements were commenced and HO was the result. If the direction of tear could be determined (longitudinal or transverse), it could be related to the movements performed and the possibility of a link investigated (Silver 1996).

Most treatments appear to inhibit the development of HO but as yet there is no satisfactory way of preventing the condition. Its prophylaxis is mainly based on the early identification and adequate treatment of risk factors such as pressure ulcers, urinary tract infections and spasticity (Van Kuijk et al 2002).

Current physiotherapy

In the initial stage when the joint feels 'spongy' and the area may be red and swollen, passive movements to that joint are discontinued until the inflammation has subsided. This will take approximately a week; passive movements are then recommenced. The limb is moved slowly and carefully two or three times only, through as full a range as possible. No forced movements are given, but every effort is made to maintain the range. When the disease becomes less active, after approximately 4–8 weeks, the passive movements and general activity are increased and careful effort is made to increase the joint range. As it is possible that vigorous passive movements causing a small tear in a muscle may lead to HO, all passive movements must be given with extreme care.

Surgery

Gross heterotopic ossification limits joint range and, as a result, independence. It may even interfere with a comfortable sitting position in the wheelchair.

To restore some independence, operations are performed to remove the bone, but surgery is only considered after the disease has completely burnt itself out, which is usually 18 months to 2 years after onset. Recurrence of ossification is not uncommon even after this time lapse.

In ankylotic heterotopic ossification of the hip where there are mobility, social and hygiene problems, Becker et al (2003) suggest that total hip replacement surgery can be a satisfactory method of treatment. This may supersede the Girdlestone operation which has been used in these circumstances.

OEDEMA

Feet and legs

Due to the poor vasomotor control and loss of muscle tone in the legs, some patients get oedema of the feet, ankles and lower legs when they first start sitting out of bed. This is, of course, severely aggravated if the patient has had a deep venous thrombosis.

Every effort must be made to correct this condition in the early stages so that it does not become chronic.

To stimulate the vasomotor system, the legs are elevated several times during the day, and if necessary the bed is elevated at night. Besides being elevated in the physiotherapy department, the patient should be responsible for putting his feet up on a chair at appropriate times during the day, e.g. at meal times, in the occupational therapy department and while watching television. The patient and therapist should work out a suitable programme.

Only if this procedure fails to reduce the swelling after 3–4 weeks are elastic stockings supplied. These are more frequently necessary for patients who have had a deep venous thrombosis. Full-length stockings are given. The patient may need to spend 24–48 hours in bed with the foot of the bed elevated to disperse the oedema before measurements for the stockings can be taken.

Hands

Patients with high lesions sometimes develop oedema in the hands. This is again due to impairment of the vasomotor control with consequent loss of vasoconstriction in the blood vessels and poor venous return. This always occurs below the level of the lesion. If the oedema is not dispersed, the collagen deposit is changed into fibrous tissue and contractures develop (see p. 45).

Elevation

To reduce the oedema, the hands are kept in elevation day and night except during occupational therapy and physiotherapy sessions.

Passive movements

Forced passive movements to oedematous joints can only cause trauma and encourage the formation of contractures. Therefore, movements are given to affected joints with extreme care and full range is obtained only when the swelling is reduced, which may take half an hour or several days. Treatment is given several times a day, taking care to maintain full range of all the non-affected joints. After an initial period of elevation, boxing glove splints or other forms of adequate splinting may be used if desired to keep the swelling down.

In tetraplegic patients, usually over the age of 30, oedema followed by contractures of the metacarpophalangeal and interphalangeal joints sometimes occurs in spite of regular and intensive treatment. In these cases, the joints often resemble rheumatoid arthritic joints. They are red and shiny as well as swollen. When the disease has ceased to be active, treatment can be given as described for contractures. The aetiology of this complication is still obscure.

OSTEOPOROSIS

Research into the physiology of bone formation and absorption has shown that the mineral metabolism associated with atrophy of the muscular and skeletal systems changes as a result of prolonged bedrest. These changes are emphasized when the bedrest is combined with immobilization. Considering the inevitable immobility of the paralysed limbs, it is not surprising that osteoporosis is present to some degree, below the level of the lesion, in all tetraplegic and paraplegic patients (Frey-Rindova et al 2000). The degree of osteoporosis is considerably increased by chronic infection from any cause.

The natural history of the development of the atrophy of the skeleton below the level of the lesion is not well understood (Szollar et al 1997). The change in bone mass in patients with spinal cord lesions is different from that due to other causes, e.g. the menopause or age. Unlike vertebral collapse, in these other forms of osteoporosis there is mineral loss in the hips, no loss in the lumbar spine and, as far as can be detected by densitometry, the most dramatic loss in the femoral region (Szollar et al 1997). Belanger et al (2000) found that after treatment with functional electrical stimulation the bone mineral density of the distal femur and proximal tibia gained 30% of the bone lost in their study of 14 patients. No change occurred in the mid tibia. Treatment was given 5 days a week for 24 weeks. The benefit was not sustained after treatment ceased.

With the advent of sensitive, non-invasive techniques to measure bone mineral density (Szollar 1998) and sensitive biochemical markers now available, screening for osteoporosis may be advocated. Further research might then be facilitated, and therapeutic strategies identified to reduce the loss of bone density in these patients.

Spontaneous fractures

Osteoporotic bone is rarefied and therefore easily fractured (Lazlo et al 2001). Freehafer (1995) reported that fractures of the distal femur and proximal tibia account for 33% of all fractures in spinal cord injured patients and these are related to bone density loss. Fractures can occur as a result of exceptionally minor injuries and are referred to as 'spontaneous' fractures. For example, a patient who has had paraplegia for some time may fracture his femur whilst

dressing or turning over in bed, or a child may receive a simple knock in school.

The therapist can easily fracture an osteoporotic limb through careless handling when giving strong and extensive passive movements, particularly if contractures are present.

Due to the lack of sensation, the patient may be unaware that a fracture has occurred until the area becomes swollen, or until he feels unwell or has a fever. The therapy and nursing staff should inspect the legs regularly for any swelling and report abnormal findings immediately.

The fractures are generally treated conservatively using well-padded splints. The splint is removed daily and the limb inspected for any areas of excessive pressure or skin damage. The padding is renewed before reapplying the splint. Where possible, passive movements are continued to maintain joint range.

PAIN

Pain causes emotional distress in addition to that caused by the spinal cord injury and is a significant problem for paraplegic and tetraplegic people (Anke et al 1995). Large variations occur in the reported incidence of pain ranging from 18% to 96% in 29 classification systems over the past 50 years (Richards et al 2002). Siddall & Loeser (2001) report the incidence as variable but the average as 60% with a third of these rating the pain as severe. They also suggest that structural plastic changes in the central nervous system may cause changes in receptor function and normal inhibition and produce increased neuronal excitability resulting in pain.

There appears to be little consensus on the nature, terminology and definition of the various types of pain.

Classification systems

Classification systems usually describe the site and quality of pain and its bearing on the activities of daily life. In each system scales are used to describe the type of pain, the site of the pain and, for each site identified, the 'feel' of the pain to the patient. Words such as nerve, visceral, mechanical, overuse, psychogenic are used to describe the type of pain. Scales differ between researchers in descriptive words used and the number included. Donovan et al (1982) use five, Tunks (1986) nine, and Cardinas et al (2002) seven. Some systems may include other factors about the type of pain, for example its duration or whether there are aggravating or mitigating factors, such as rest or activity.

Words such as throbbing, stabbing, cramping, burning, tingling, aching are used to describe the 'feel' of the pain and again the lists of words vary in the different systems. Verbal descriptions are inevi-

tably used in these classifications but the validity of verbal descriptions alone to distinguish between pain types has yet to be established (Putzke et al 2002).

All researchers agree the need for some uniformity in classification in order to facilitate research and the comparison of results, so that progress can be made in the search for treatments for this distressing problem (Cardinas et al 2002).

Reviews of this subject have been undertaken by Hicken et al (2001) and Siddall & Loeser (2001).

Pain syndromes

The therapist should be familiar with:

- pain due to periarticular and muscular contractures
- central cord pain
- referred pain.
- neck pain in association with orthostatic or postural hypotension (Cariga et al 2002). This pain, described as aching or tiring, is present in the neck and across the shoulders in a 'coat-hanger' pattern. It occurs when getting up or late in the day, is increased by exercise and relieved by lying flat.

Pain due to periarticular and muscular problems

This pain is always found above the level of the lesion, most frequently in complete lesions of the cervical cord. Trauma to the cervical roots may cause some root irritation initially, but continuing pain appears to be due to contractures around the shoulder and shoulder girdle due to faulty positioning and lack of movement.

The number of patients with shoulder pain appears to vary between spinal units (Salisbury et al 2003). In this study the range of movement was limited in flexion, extension, and external rotation and abduction and may have been lost during the first weeks post-injury, possibly before admission to a spinal unit.

Further research is needed in relation to risk factors, especially positioning, surgery and physiotherapy. General mobilization is given as for any contracted joint where sensation is unimpaired. It must be borne in mind that the patient's general condition and morale at this time are often poor and pain tolerance low. Rough handling or indiscriminate stretching of a joint sets up involuntary protective spasm, and the patient loses confidence.

Independence is a major goal in rehabilitation but the wheelchair user puts an unnatural load on the muscles and joints of the upper trunk and limbs in almost every daily living task. Not surprisingly musculoskeletal pain is a common complication (Ballinger et al 2000). The posture in the wheelchair, if not carefully controlled, may also play a part. In order to balance and push the wheelchair many

patients sit in a kyphotic posture when the scapula changes its vertical alignment. 'The scapula will then rotate in the sagittal plane forward and downward, depressing the acromial process and changing the face of the glenoid fossa' (Samuelsson et al 2004). A correct and comfortable sitting position is all important (see Ch. 6).

The shoulder is a key weight-bearing joint for individuals who use wheelchairs or devices to aid ambulation (Bagley et al 1987). After the initial period of rehabilitation shoulder pain in paraplegic patients is most frequently associated with wheelchair activities, the most difficult and painful being loading the wheelchair into the car, followed by pushing up inclines (Samuelsson et al 2004).

Patients continue their daily life and perform their activities in spite of the pain and Ballinger et al (2000) found that the level of activity did not decrease. In contrast Widerstrom-Noga et al (2002) report decreased activity due to pain. In older patients or those who have had their paralysis for many years, shoulder pain can severely affect their activity (see Ch. 17).

Physiotherapists find the Wheelchair Users Shoulder Pain Index a useful tool. It measures shoulder pain that is limiting daily activities such as transfers and self-care tasks, and could be used to monitor the effects of interventions to prevent shoulder pain and loss of function (Curtis et al 1995).

Central cord pain (neuropathic pain)

Central cord pain remains a problem for patients with spinal cord injury. All who have this pain also have autonomic instability (Bowsher 1996, Bennett 1991) The sensations such as burning, scalding, stabbing are 'felt' at or below the level of the lesion and are more prevalent in patients injured when they are older. No correlation with gender was found (Werhagen et al 2004). The acute pain usually lasts a few seconds and is often followed by paroxysms of another type of pain which can be cramping in character. The number of attacks per day varies considerably from patient to patient and even from day to day in the same patient. There is no association between the severity of pain and level or completeness of injury (Anke et al 1995).

Management of this type of pain is the most difficult. Only mild analgesics are prescribed, as drugs are quickly habit-forming in these cases and they are not usually successful in relieving the pain. To et al (2002) report some initial success with gabapentin. Controlled trials are now required. Anticonvulsant drug therapy (Balazy 1992), antidepressants and transcutaneous nerve stimulation (Hachen 1978) have all been tried. Widerstrom-Noga & Turk (2003) confirm the inadequacy of available modalities to manage chronic pain related to spinal cord injury.

Occasionally, due to the severity of the pain, destructive procedures may be undertaken. Although the effect is limited to the pain at the level of the lesion Lammertse & Falci (2001) have shown improvement in the success rate of the dorsal root entry zone procedure.

Dorsal column stimulation and deep brain stimulation may be tried. Although these procedures have their advocates, no long-term benefits have as yet been documented.

Intensive physiotherapy may be useful, including some form of sport. The condition may show some spontaneous improvement as the patient learns to tolerate his pain by diversional activities.

Patients with complete lesions of the mid-thoracic and thoraco-lumbar cord sometimes develop a band of hyperpathia around the level of the lesion. The patient complains that there is a tight band around his chest, and occasionally is so hypersensitive that he cannot bear anything to touch his skin.

Referred pain

Patients with cervical and high thoracic lesions can experience pain in the shoulder region when any abnormal visceral activity occurs. Impulses are carried from the paralysed to the non-paralysed area via the phrenic nerve. For example, a patient with a C4 lesion had a hae-matemesis due to a perforated ulcer. On looking back at the therapist's notes, it was seen that the patient had complained of nausea and pain across the upper part of the shoulders for at least 2 weeks previously.

Patients with cervical lesions can suddenly develop severe frontal headache. This may be due to overdistension of the bladder and should be investigated without delay.

PRESSURE ULCERS

The effects of pressure and its prevention are described in Chapter 6. Patients admitted early to a spinal unit have a significantly lower risk of developing pressure sores (Aung & El Masry 1997). In their study of 60 patients, Rodriguez & Garber (1994) found that the pressure ulcers developed within 2 years post-injury and were more frequent in those with lesions above T6. Of those who smoked, 36% got pressure ulcers, as compared with 26% of the non-smokers.

The treatment of established pressure ulcers

Conservative treatment

Relieve pressure

The first essential step in treating a pressure ulcer is to relieve the pressure on the ulcer totally and continuously. This means complete bedrest for patients who are already ambulant or wheelchair bound.

The patient must be turned every 3 hours, day and night, to prevent further ulcers from developing on unaffected areas, and positioned in such a way that no weight is thrown on the ulcer(s). Rings around the heels to relieve localized pressure are contraindi-

cated. The area of skin under the ring may receive sufficient pressure to cut off the blood supply to the area in the centre, which is the area most at risk.

A low air loss bed facilitates positioning a patient with multiple ulcers, or a sorbo pack bed or pillow packs spaced as for sorbo packs can be used on top of an ordinary mattress.

If pressure is not relieved over the ulcer, any other measures taken will prove unsuccessful.

General treatment

Blood transfusions may be required to keep the haemoglobin level in the upper range of normal.

Local treatment

All slough and necrotic tissue is radically excised. This prevents the toxic effects which result from the absorption of dead tissue into the bloodstream. A wide range of lotions is used. The use of topical antibiotics is controversial. The dressing is completely sealed off with a wide porous dressing.

Surgical treatment

Various surgical procedures may be considered in selected cases.

Physiotherapy

Passive movements

Passive movements are given to the paralysed limbs to prevent contractures and are recommenced after surgery when the surgeon considers it advisable. As a general rule, the patients can be divided into those with severe spasticity and those with flaccid lesions.

If the patient has severe spasticity or if any one movement causes violent spasm, all movements are avoided until the ulcer is healed. If the lesion is flaccid or the patient has minimum spasticity, and the pressure ulcers are around the hips or back, it may be possible to commence moving the knees and feet after a week to 10 days.

Initially very gentle movements only are given. Whilst moving the joints involved, the therapist watches the scar to avoid excessive tension. The range of any movement which looks potentially dangerous is increased with extreme caution to avoid breakdown of the wound.

Grease massage

The pliability of the skin is an important factor when excision of the ulcer is considered. The more pliable the surrounding tissues, the

easier is the approximation of the skin following the excision. When necessary, daily massage with lanolin is given to a wide area surrounding the ulcer. Deep finger kneading increases the circulation and improves the elasticity and mobility of the skin and subcutaneous tissue.

Exercise

The patient is encouraged to pull a chest expander or lift weights of suitable strength several times every hour to maintain strength in the arms and upper trunk.

Chest therapy

Pre- and postoperative therapy is given if a general anaesthetic is used for any surgical procedures.

Pressure consciousness

The patient must be educated, or re-educated, in 'pressure consciousness' and have his posture, cushion and wheelchair checked by the therapist expert in the field.

Transfers

In spite of any previous rehabilitation, once the patient is mobile all transfers are checked to see that due care is taken when lifting and moving the limbs.

SHOULDER–HAND SYNDROME (SHS)

The clinical features of the SHS are shoulder pain, wrist/hand pain, oedema, vasomotor changes, trophic changes and osteoporosis on X-ray. Aisen & Aisen (1994) found that almost one-third of the patients in their study had three or more of these symptoms. Shoulder pain was more common in patients with lesions between C3 and C5 (23/23) whilst hand/wrist pain (15/23) occurred with the same frequency in patients with upper and lower cervical lesions (Aisen & Aisen 1994). Almost all were satisfactorily resolved with conservative treatment after about 4 months.

The pathophysiology of this condition is unclear, although sympathetic hyperactivity appears to be important The few studies reported are on SHS after stroke, where it is sometimes treated with corticosteroids and also by stellate block with good effect (Braus & Strobel 1991).

Treatment by physiotherapy is conservative, continuing movements without force and elevating the limb to reduce swelling.

SPASTICITY

During the period of spinal areflexia following complete transverse section of the cord, there is flaccid paralysis of all muscles below the level of the lesion. Subsequently, the isolated cord resumes some autonomous function and the motor paralysis becomes spastic.

The heightened reflex activity of the isolated cord is demonstrated by increased tone in the muscles and brisk tendon reflexes. The ensuing degree of spasticity varies. In some cases it may remain mild, while in others the afferent stimuli, uninhibited by higher centres, cause a mass response in the isolated cord, and a mass response of muscle action ensues. This can produce any combination of muscle spasm, e.g. total flexor or extensor patterns, or alternating flexor and extensor spasticity, or flexion of the knees with extension of the hips.

The increased muscular tension leads to an uneven distribution of pressure on joint cartilage. This may result in the destruction of cartilage, capsular contractures or partial dislocations of varying degrees. Spasticity is dealt with more extensively in Chapter 15.

Treatment of established spasticity

A combination of the following methods may be used:

- physiotherapy
- chemotherapy
- surgery.

Certain factors stimulate spasticity and these are excluded before deciding on a course of treatment:

- distension of internal organs below the level of the lesion, i.e. bladder and bowels
- septic conditions, such as urinary tract infections, or infected pressure ulcers
- contracted tendons and joints, which reduce the threshold of irritability of the stretch reflex
- local skin lesions, ingrowing toe nails, etc.

When considering treatment, the following facts are borne in mind:

- fatigue has a depressant effect on spasticity
- muscle accommodates to prolonged stretch
- posture influences reflexes
- spasticity is influenced by emotional factors.

Physiotherapy

Passive movements. These are always given to maintain mobility in all structures.

COMPLICATIONS ### Prolonged passive stretching

The stretch may be given manually, or by utilizing one of the stretch positions as for contractures, or in the standing position.

Hydrotherapy

Passive movements and swimming exercises in a heated pool may provide temporary relief for some patients.

Reflex inhibiting postures

These may be useful to reduce spasticity or maintain relaxation during treatment. The position adopted when sleeping can be used to reduce spasticity. For example, sleeping prone for 3 or 4 hours reduces flexor spasticity in the lower limbs.

Standing and walking

Weight-bearing reduces spasticity. However, in some severely spastic cases, the standing position may be impossible without first reducing the spasticity by some other means, e.g. passive movements, a passive stretch or hydrotherapy.

Ice therapy

Ice towels may reduce spasticity when it is associated with contracture, but they have not proved valuable in treating the large muscle groups for spasticity alone.

Chemotherapy

Chemotherapy is used in the following ways.

Drug therapy

Antispasmodic drugs can be used with some effect on certain patients, although their effectiveness in reducing severe spasticity is extremely limited. They are usually prescribed with caution only after a period of physiotherapy has proved insufficient, as the side effects, notably that of sedation, can affect the patient's rehabilitation.

Intrathecal injections and local temporary nerve block

(See also Ch. 15.) Intrathecal injections of baclofen have been used with good effect for some years in the treatment of severe spasticity (Penn &Kroin 1987, Azouvi et al 1996). Intrathecal morphine may be useful if the patient is intolerant to baclofen (Soni et al 2003).

Local temporary nerve blocks using botulinum toxin are also used to relieve spasticity in specific muscle(s) (see p. 309).

Surgery

Surgical procedures on peripheral structures may be required if chemotherapy and nerve blocks fail are preferred to those performed on the cord or roots. Methods used to reduce spasticity include diminishing the contraction potential of the muscle by elongating the tendon, or by severing the nerve supplying a large muscle group, and by tenotomy or capsulotomy (Eltorai & Montroy 1990).

In certain patients with complete or incomplete lesions, it appears that one muscle 'triggers' off the spastic pattern. In these cases, a surgical procedure may be performed to block conduction to the 'trigger' muscle. In most instances the result is an overall reduction in spasticity.

SPINAL DEFORMITY

Any patient confined to bed for some time is in danger of developing contractures and may also develop a scoliosis. Children and adolescents are in particular danger because of continuing growth and extreme joint mobility (see Ch. 16).

When a patient spends a high proportion of time in an abnormal, incorrect posture for functional activities, convenience or comfort, whether in bed or in a wheelchair, deformities develop. Gross scoliosis or pelvic distortion will severely hamper the patient's rehabilitation and may prevent him from attaining complete independence or from functional weight-bearing.

In assessing the deformity, the exact nature of the problem needs to be identified, especially whether the posture is correctable or has become fixed.

Prevention and treatment

Every effort must be made to prevent such deformities by correct positioning in bed and when seated in the wheelchair, re-education of posture and muscle development. The correct choice of cushion, and the posture and fit of the patient in his wheelchair are dealt with in Chapter 6.

The following methods of treatment can be useful:

- strengthening the weaker or less used muscle groups, including the use of functional electrical stimulation.
- stretching those muscles tending to shorten and maintaining a passive stretch in the overcorrected position.
- re-education of posture and regular reassessment of efficacy of the wheelchair cushion

- corrective sleeping postures
- bracing.

Corrective sleeping postures

Pillows can be used to support the spine in a corrected position at night. For example, a patient with a long 'C' curve to the left should have sufficient pillows under the thorax when lying on his left side to give maximum correction of the deformity.

Bracing

A spinal brace may be necessary to support the child or adolescent with a bad posture in sitting or standing. Occasionally an adult may also need a brace for this purpose.

Surgery

Surgical procedures may be indicated in selected cases.

SYRINGOMYELIA

The major symptoms of this complication are pain, which may be localized centrally or which may radiate into the arm or trunk, sensory impairment and increasing weakness. It appears to be more common in tetraplegic than in paraplegic patients (Rossier et al 1985).

The results of conservative treatment have proved unsatisfactory. With magnetic resonance imaging and the possibility of non-traumatic investigation, it is possible to detect syringomyelia earlier and to drain those cysts producing significant symptoms or signs. Human embryonic spinal cord tissue has been implanted into humans with post-traumatic progressive syringomyelia with some success. The procedure proved to be safe and to obliterate the cyst (Johnston 2001). Physiotherapy is directed towards re-education after surgery.

This is a distressing condition where increasing weakness can rob the patient of his independence.

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Sport in rehabilitation

THE THERAPEUTIC VALUE OF SPORT

Clinical sport has an important contribution to make in the rehabilitation of patients with spinal cord injury. It assists in restoring the patient's strength, balance, coordination and endurance. It stimulates activity of mind and encourages self-confidence and interaction with others. Some patients were enthusiastic sportsmen before becoming disabled and, once introduced to sport in a wheelchair, will continue when they leave hospital. Neill & Maguire (2004) found that most patients emphasized the importance of sport in rehabilitation. It is suggested by Ditor et al (2003) that participation in sporting activities increases quality of life and decreases stress and pain. Sports clubs provide a useful opportunity for mixing with the local community.

Swimming, archery and table tennis are particularly valuable during rehabilitation. Dartchery, snooker and basketball or volleyball are also useful (Guttmann 1976).

SWIMMING

The pool

To enable patients to swim, the pool must be a reasonable length, if possible a minimum of 8 metres. If different depths are required, a sloped floor is preferable to steps. Skin damage can easily occur against the hard edges of steps as the paralysed legs trail in the water. As it is generally found that cold water increases spasticity, the water temperature is kept high: 32–36°C (90–96°F). At this temperature, spasticity is reduced in the majority of patients.

Hygiene

The pool should have some form of continuous flow system through a filter plant. The chlorine content is maintained and checked twice

a day. Samples of the water are cultured regularly. The patient expresses his bladder prior to entering the pool and should have had a satisfactory bowel evacuation.

Entry into the water

Some type of hydraulic lift provides the safest method of entry for all tetraplegic patients and for those patients with lower lesions who are incapable of independent transfer. Active paraplegic patients enter over the side of the pool using a sorbo rubber pad placed over the edge to protect the skin from the hard surface.

Therapeutic uses

Swimming increases exercise tolerance, vital capacity and cardiovascular efficiency. Swimming prone increases the activity of the diaphragm and consequently lung volume in patients with cervical cord lesions because of the need to hold the breath in this position.

Increase of muscle strength

Swimming increases the strength of all innervated muscles. Motor power in patients with incomplete lesions can be increased by normal hydrotherapy techniques, using water to eliminate gravity or to assist or resist movement. In addition to swimming, exercises to increase muscle strength in patients with complete lesions can be given using the water to assist or resist movement as required.

Improved coordination

Coordination can be improved by all the strokes used in swimming, in particular the unilateral strokes.

Reduction of spasticity

This is achieved *passively* through the heated water, passive movements and passive stretching, and *actively* through swimming.

Reduction of contractures

Passive stretching of contractures is often facilitated by the heated water.

Psychological and social aspects

Mobility in the water is often the only experience of unaided body movement within the environment that most paralysed patients enjoy. Consequently, a new enthusiasm is often noted when pool activities

are commenced. It also provides a further opportunity to mix with able-bodied people. Many patients enjoy swimming with family and friends.

Swimming instruction

The Halliwick method of teaching independence in the water is largely used in the UK as a recreational activity, but it also has great value in the therapeutic field (Martin 1981). The objective of this method is water safety leading to independent freedom of movement in water, which is achieved with no help other than a close instructor–swimmer relationship. The method suggests that the swimmer should first adjust to the water and then learn to change his position in the water so that he can always move himself into a position in which he is able to breathe.

Rolling

To roll in the water, the swimmer turns his head to one side, e.g. the left, and moves one arm, e.g. the right, across his body causing him to tip over until he is face down in the water. The same procedure is repeated to continue the roll to bring the swimmer face upwards again. The 360° roll needs to be practised until it can be done with ease.

Independence in the water is first achieved on the back, the prone position being more difficult to maintain without muscle power at the hip joints. Symmetrical strokes are taught initially, as asymmetrical activity causes the paralysed limbs to roll and the patient finds difficulty in maintaining a straight course.

Instruction for patients with thoracic or lumbar lesions

When supine in the water, the paralysed portion of the body lies at an angle of 45° from the site of the fracture. To compensate for the paralysed limbs, the head needs to be well extended.

Backstroke

The therapist supports the patient under the neck; the patient, maintaining his head in extension, moves his arms simultaneously away from the sides with the elbows flexed. He then extends the elbows and brings the arms back to *midline*, with the thumbs just breaking the surface of the water. Because the hips are lower in the water, the body will be pushed upwards if the arms are brought back to the *sides*. Similarly, when the patient relaxes the stroke, his body will sink again. In this way, a vertical as well as a horizontal component

to the movement is produced with consequent wasted effort. Once the patient has become accustomed to his position in the water, the 'sculling' stroke is expanded, and the arms are brought out of the water close to the head, as in the Old English backstroke. To prevent his head submerging when the arms are in full elevation, the patient must relax his extended head for a second or two.

Breaststroke

The position of the body when the patient is prone in the water resembles an inverted U, with the head submerged and the buttocks floating to the surface. To counteract this tendency, the patient is initially taught to do the breaststroke with his head constantly out of the water, as strong extension of the head and upper trunk is needed to keep the buttocks submerged.

The therapist assists the patient with one hand under his chin and the other pressing down on his buttocks. As the patient becomes aware of his position in the water, the chin support is withdrawn. Later the pressure on the buttocks is gently released and the patient must work hard to maintain the necessary extension. When this is achieved, the patient begins to swim with his head under water for several strokes in the usual way. He must, however, *start* to extend his head much sooner than the able-bodied breaststroke swimmer. The head of the paraplegic swimmer will be forced under water just before his hands are level with his shoulders.

Unilateral strokes (crawl)

Without the necessary leg movement to prevent it, the lower half of the body will roll during a unilateral stroke. The roll can be prevented during back crawl by making small paddling movements with the non-stroke arm as the stroke arm pulls down.

Butterfly stroke

Patients with lesions at C6 and below who have been proficient in this stroke prior to their accident can relearn it.

Instruction for patients with cervical lesions

Patients with functional use of latissimus dorsi and triceps swim in the same way as patients with lower lesions. Patients with lesions at C6 can occasionally become independent swimmers, but the majority, although capable of swimming alone, need an attendant in case difficulties arise.

Rolling

This is described on page 375.

Backstroke

To gain extension at the elbow without triceps, the arm must be kept in lateral rotation and it can be lifted only a few degrees above shoulder level. As the arm returns to the water and pulls down, water pressure will keep the elbow straight.

Swimming prone

Without triceps, the true movements of the breaststroke are impossible. The patient with a lesion at C5–C6 *pulls* his arms through the water towards his body using biceps, deltoid and the clavicular head of pectoralis major. While the patient is swimming face down, it is important that the therapist keeps one hand on the patient's shoulder where he has sensation. Initially, most patients will only be able to swim two or three strokes, but within six or seven sessions this can be increased up to an average of 8–10 metres.

Leaving and returning to the side of the pool

To leave the side, the patient lies parallel with the side of the pool with the head extended and pushes off gently, with the arm just on the surface of the water. To return to the side, the patient swims in parallel with, and as close as possible to, the side of the pool, keeping the nearside arm under the surface of the water. He then rapidly flings the arm into the overflow trough and strongly flexes his neck. To maintain this position, paddling movements are performed with the free arm by pulling the water towards the body, as in the breaststroke movement.

Incomplete lesions

Patients with incomplete lesions with weak, scattered muscles and patchy sensation can gain strength and coordination from using all the available swimming strokes.

ARCHERY

From both the medical and recreational aspects, archery has proved to be an ideal sport for patients with spinal cord injury.

Therapeutic value

Increase of muscle strength

Archery develops and strengthens the essential muscles of the paraplegic patient, i.e. erector spinae, deltoid, pectorals, rhomboids, trapezius and latissimus dorsi (Fig. 19.1A).
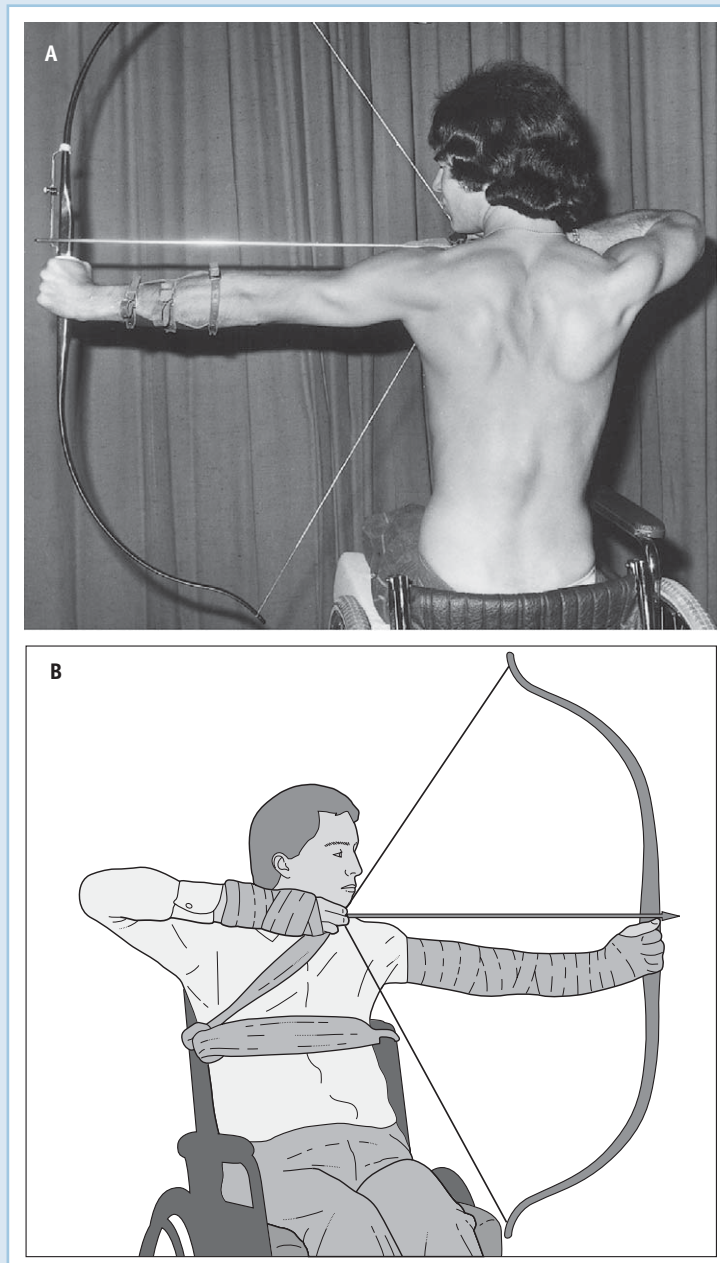
Figure 19.1 Archery. A: Patient with a complete lesion below T10.
B: Patient with a complete lesion below C6.

Balance, control and coordination

When the bow arm is lifted and the centre of gravity consequently
altered, skilled balance is required to maintain the erect posture.

Initially patients with high thoracic lesions may need to bring the buttocks slightly forward in the chair and lean heavily against the backrest to achieve sufficient stability. As the balance improves, the upright posture is resumed.

Accurate marksmanship requires control, dexterity and judgement, and demands fine coordination of the eye, hand and arm.

Social value

Whether the archer stands or is in a wheelchair, they meet on equal terms. The wheelchair archer can join a club for able-bodied sportsmen, which provides a further opportunity for integration with the local community.

Archery for patients with cervical cord lesions

Special equipment is necessary to enable the tetraplegic patient to shoot.

The release

To release the arrow without finger flexion or extension, a hook device is used. A small hook at the end of a metal splint is strapped to the palmar surface of the middle finger extending across the wrist of the drawing hand (Fig. 19.2). To release the string the archer slightly *pronates* his forearm. Pronation gives greater accuracy, as supination allows gravity to act on the unstable forearm. This causes the elbow to drop and results in inaccurate shooting. With the appropriate training, archers of ability who use the hook release can reach the longest international distance of 90 metres.

The bow arm

The patient without triceps needs a splint to maintain the elbow in extension. If the wrist extensors are weak, a wrist splint is frequently necessary to prevent the wrist being forced into flexion by the tension of the bow. The bow needs bandaging into the hand. To gain the necessary stability, all patients with cervical cord lesions need to be tied into the chair. The tie is usually placed around the upper thorax and tied to the chair handle on the side of the drawing arm (Fig. 19.1B).

DARTCHERY

This game, played in pairs, was developed for paraplegic patients. Bow and arrows are used to shoot at a target face which is a replica of a dartboard. The target is set at a distance of 15 metres from the
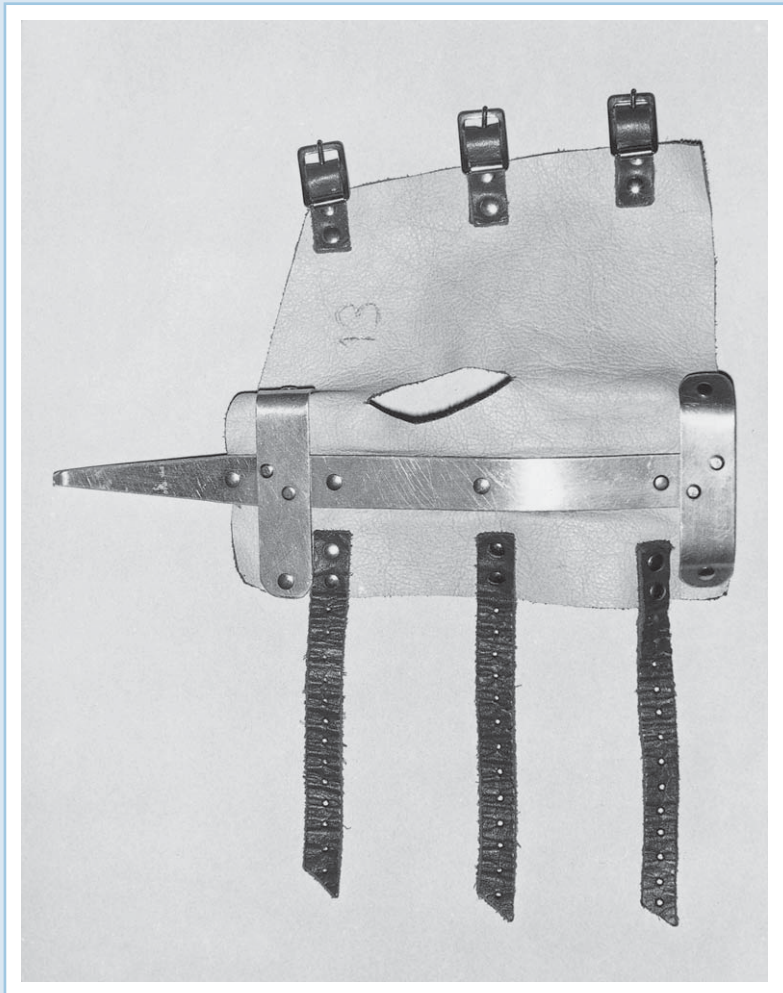
Figure 19.2 Archery hook.

players and the rules are basically the same as those governing dart play.

DARTS

The dart board must be at an appropriate height for wheelchair users. If the player cannot hold conventional darts, blow darts can be used. The rules are the same as for able-bodied players.

TABLE TENNIS

Therapeutic value

The therapeutic value of table tennis includes:

- improved coordination, especially that of eye and hand
- improved agility in the wheelchair.

The loss of sensation and lack of balance make the patient fearful of falling during his early days in a wheelchair. Consequently, the patient is often rigid, unwilling to move any part of his body except his head. In his desire to hit the ball, this fear is gradually forgotten and the patient comes to realize that he can move about within the chair without either tipping it or falling out. The patient is taught to play with the chair stationary in the centre of the backline. The rules of play are the same as for the able-bodied, with the exception of the 'alternate shot rule' for doubles. This rule is amended so that either partner can return any shot except when receiving service. Patients with cervical cord lesions also enjoy table tennis. Those without finger movement need the bat bandaged or strapped into the hand. To play backhand shots, those without triceps use outward rotation of the shoulder. An adjustable table tennis bat has been developed for tetraplegic sportsmen where the angle of the head of the bat can be changed in relation to the grip. The bat is held firmly in the hand by an elasticated glove. This allows a greater range of shots (Taktak 1997).

BASKETBALL

Wheelchair basketball is a fast and exciting game which calls for teamwork and accurate control of the body, chair and ball. Mobility, strength, endurance and dexterity in wheelchair management are developed. It is a game for those patients with a good functional grip, as accurate and immediate control of the chair is essential. A less active form of this game, volleyball, can be played by patients in their first period of rehabilitation.

BOWLS

Bowls are played from the wheelchair with the same rules as for able-bodied players. This game can also be played on a carpet with 5 cm bowls for tetraplegic and 10 cm bowls for paraplegic players during their rehabilitation. It can also be played on a snooker table when the 3 cm bowls are bowled down a wooden slide.

FENCING

The weapon used for novices is the foil. No wheelchair skills are required as the chair remains static and tactics are all-important.

SNOOKER

This game provides excellent practice in coordination skills, particularly for patients with cervical cord lesions.

TENNIS

The rules are the same as for able-bodied tennis except that the ball is allowed to bounce twice before it must be hit.

WHEELCHAIR RUGBY

This game is for people with tetraplegia. It is similar to basketball, except that the goals are scored by having two wheels over the back line of the key area whilst being in possession of the ball.

Some of these games, if not all, are usually available in spinal units as the skills required to play contribute to the rehabilitation of patients with spinal cord injury.

RULES

All sports are conducted, as far as possible, under the rules of the game for the able-bodied; for example, archery under the rules of the Grand National Archery Association and swimming under those of the Amateur Swimming Association. Each sport has its own rulebook with changes for disabled sportsmen where they are required.

THE BENEFIT OF COMPETITIVE SPORT

In one sense, all sport is competitive. The sportsman always competes with his past performance. He also competes, consciously or unconsciously, with others taking part in the same swimming or archery session. A profitable physical and psychological stimulus is provided by competitive sport. These activities create a sense of comradeship and help to eliminate any self-consciousness suffered by patients in relation to their disability. They can give a sense of physical adequacy

and increase self-esteem (Bedbrook 1981). Competitive sport is also of great value in integrating disabled people with the able-bodied community and the facilities of some sports centres are available for both groups. Some spinal units have a staff member, often a physiotherapist, who liaises with local fitness clubs and sports facilities to advise on equipment and access which may then enable people in wheelchairs to participate.

Inter-spinal unit games offer a taste of competitive sport to patients still in hospital. They provide the opportunity to mix with people from other units, some of whom will be paralysed and some able-bodied, in a relaxed atmosphere where the social as well as the athletic skills of the recently paralysed patient will be required. Some patients become proficient and enter international sporting events.

Some wheelchair users are not interested in competitive sport but want to participate in sporting activities with family and friends (Kennedy & Smith 1990).

Due to the initiative, enterprise and enthusiasm of disabled individuals, the list of sports open to the paralysed person is continually being extended. One person is now experimenting with aikido from a wheelchair, but he was a keen and able martial/artist prior to his accident (Booton 2003). Wheelchair users can enjoy angling, athletics, badminton, cricket, sailing, canoeing, scuba diving, snorkelling, waterpolo, karting and flying light aircraft with hand controls, parachuting in tandem, basketball, fencing, field events, swimming, track racing and weight lifting and many winter sports such as mono- and bi-skiing.

The majority of sports are unsuitable for open competition with able-bodied people, archery, angling, green bowling, snooker and table tennis being exceptions.

Competitive sport for patients with spinal cord injury is organized on a national and international level through the International Wheelchair and Amputee Sports Federation.

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ASIA scale (a): Standard neurological classification of spinal cord injury

Standard neurological classification of spinal cord injury

Motor

R L

Key Muscles

Level		
C2		
C3		
C4		
C5		Elbow flexors
C6		Wrist flexors
C7		Elbow extensors
C8		Finger flexors (distal phalanx of middle finger)
T1		Finger abductors (little finger)

0 = total paralysis
1 = palpable or visible contraction
2 = active movement,
    gravity eliminated
3 = active movement,
    against gravity
4 = active movement,
    against some resistance
5 = active movement,
    against full resistance
NT = not testable

Level		
T2		
T3		
T4		
T5		
T6		
T7		
T8		
T9		
T10		
T11		
T12		
L1		
L2		Hip flexors
L3		Knee extensors
L4		Ankle dorsiflexors
L5		Long toe extensors
S1		Ankle plantar flexors
S2		
S3		
S4-5		

Voluntary anal contraction (Yes/No)

Totals ☐ + ☐ = ☐   Motor score

(Maximum) (50) (50) (100)

Neurological level

The most caudal segment
with normal function

	R	L
Sensory		
Motor		

Maynard F M et al 1997 Figure 4 in *International Standards for Neurological and Functional Classification of Spinal Cord Injury.* Spinal Cord 35(5): 272 (with permission from American Spinal Injury Association).

Sensory
Key Sensory Points

Light touch: R L
Pin prick: R L

Sensory levels: C2, C3, C4, C5, C6, C7, C8, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1, L2, L3, L4, L5, S1, S2, S3, S4–5

0 = absent
1 = impaired
2 = normal
NT = not testable

Any anal sensation (Yes/No)

= Pin prick score (max: 112)

Totals + = Light touch score (max: 112)

(Maximum) (56) (56) (56) (56)

Complete or incomplete?
Incomplete = Any sensory or motor function in S4–55
ASIA Impairment Scale

Zone of partial preservation
Caudal extent of partially innervated segments

	R	L
Sensory		
Motor		

Key Sensory Points

ASIA Scale (b): Functional Independence Measure and impairment scale

Functional Independence Measure (FIM)

L E V E L S	7 Complete Independence (Timely, Safely) 6 Modified Independence (Device)	No Helper
	Modified Dependence 5 Supervision 4 Minimal Assist (Subject = 75%+) 3 Moderate Assist (Subject = 50%+) **Complete Dependence** 2 Maximal Assist (Subject = 25%+) 1 Total Assist (Subject = 0%+)	Helper

	ADMIT	DISCH
Self Care		
A. Eating		
B. Grooming		
C. Bathing		
D. Dressing-Upper Body		
E. Dressing-Lower Body		
F. Toileting		
Sphincter Control		
G. Bladder Management		
H. Bowel Management		
Mobility		
Transfer:		
I. Bed, Chair, Wheelchair		
J. Toilet		
K. Tub, Shower		
Locomotion		
L. Walk/Wheelchair	W C	W C
M. Stairs		
Communication		
N. Comprehension	A V N	A V N
O. Expression		
Social Cognition		
P. Social Interaction		
Q. Problem Solving		
R. Memory		
Total FIM		

NOTE: Leave no blanks; enter 1 if patient not testable due to risk.

ASIA IMPAIRMENT SCALE

☐ **A = Complete:** No motor or sensory function is preserved in the sacral segments S4–S5.

☐ **B = Incomplete:** Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4–S5.

☐ **C = Incomplete:** Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.

☐ **D = Incomplete:** Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.

☐ **E = Normal:** motor and sensory function is normal

CLINICAL SYNDROMES

☐ Central Cord
☐ Brown–Séquard
☐ Anterior Cord
☐ Conus Medullaris
☐ Cauda Equina

Maynard F M et al 1997 Figure 5 in *International Standards for Neurological and Functional Classification of Spinal Cord Injury* 35(5): 273 (with permission from American Spinal Injury Association).

SCIM – Spinal Cord Independence Measure

Loewenstein Rehabilitation Hospital, Department IV
(Version 1, May 1996, Raanana, Israel)
Patient Name: ID: Examiner Name:
(The score attached to the relevant description of each function
should be placed in the adjacent square below the relevant data)

Self-Care   DATE

1. Feeding (cutting, opening containers, bringing food to mouth, holding cup with fluid)
   0. Needs parenteral, gastrostomy or fully assisted oral feeding
   1. Eats cut food using several adaptive devices for hand and dishes
   2. Eats cut food using only one adaptive device for hand; unable to hold cup
   3. Eats cut food with one adaptive device; holds cup
   4. Eats cut food without adaptive devices; needs a little assistance (e.g., to open containers)
   5. Independent in all tasks without any adaptive device

2. Bathing (soaping, manipulating water tap, washing)
   0. Requires total assistance
   1. Soaps only small part of body with or without adaptive devices
   2. Soaps with adaptive devices; cannot reach distant parts of the body or cannot operate a tap
   3. Soaps without adaptive devices; needs a little assistance to reach distant parts of body
   4. Washes independently with adaptive devices or in specific environmental setting
   5. Washes independently without adaptive devices

3. Dressing (preparing clothes, dressing upper and lower body, undressing)
   0. Requires total assistance
   1. Dresses upper body partially (e.g., without buttoning) in special setting (e.g., back support)
   2. Independent in dressing and undressing upper body. Needs much assistance for lower body
   3. Requires little assistance in dressing upper or lower body
   4. Dresses and undresses independently, but requires adaptive devices and/or special setting
   5. Dresses and undresses independently, without adaptive devices

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DATE

4. Grooming (washing hands and face, brushing teeth, combing hair, shaving, applying makeup)
   0. Requires total assistance
   1. Performs only one task (e.g., washing hands and face)
   2. Performs some tasks using adaptive devices; needs help to put on/take off devices
   3. Performs some tasks using adaptive devices; puts on/takes off devices independently
   4. Performs all tasks with adaptive devices or most tasks without devices
   5. Independent in all tasks without adaptive devices

Respiration and Sphincter Management

5. Respiration
   0. Requires assisted ventilation
   2. Requires tracheal tube and partially assisted ventilation
   4. Breathes independently but requires much assistance in tracheal tube management
   6. Breathes independently and requires little assistance in tracheal tube management
   8. Breathes without tracheal tube, but sometimes requires mechanical assistance for breathing
   10. Breathes independently without any device

6. Sphincter management – Bladder
   0. Indwelling catheter
   5. Assisted intermittent catheterization or no catheterization, residual urine volume >100 cc
   10. Intermittent self-catheterization
   15. No catheterization required, residual urine volume <100 cc

7. Sphincter management – Bowel
   0. Irregularity, improper timing or very low frequency (less than once in 3 days) of bowel movements
   5. Regular bowel movements, with proper timing, but with assistance (e.g., for applying suppository)
   10. Regular bowel movements, with proper timing, without assistance

8. Use of toilet (perineal hygiene, clothes adjustment before/after, use of napkins or diapers)
   0. Requires total assistance
   1. Undresses lower body, needs assistance in all the remaining tasks
   2. Undresses lower body and partially cleans self (after); needs assistance in adjusting clothes and/or diapers
   3. Undresses and cleans self (after); needs assistance in adjusting clothes and/or diapers
   4. Independent in all tasks but needs adaptive devices or special setting (e.g., grab-bars)
   5. Independent without adaptive devices or special setting

Mobility (room and toilet)

9. Mobility in bed and action to prevent pressure sores

    0. Requires total assistance

    1. Partial mobility (turns in bed to one side only)

    2. Turns to both sides in bed but does not fully release pressure

    3. Releases pressure when lying only

    4. Turns in bed and sits up without assistance

    5. Independent in bed mobility; performs push-ups in sitting position without full body elevation

    6. Performs push-ups in sitting position

10. Transfers: bed–wheelchair (locking wheelchair, lifting footrests, removing and adjusting arm rests, transferring, lifting feet)

    0. Requires total assistance

    1. Needs partial assistance and/or supervision

    2. Independent

11. Transfers: wheelchair–toilet–tub (if uses toilet wheelchair – transfers to and from; if uses regular wheelchair – locking wheelchair, lifting footrests, removing and adjusting arm rests, transferring, lifting feet)

    0. Requires total assistance

    1. Needs partial assistance and/or supervision, or adaptive device (e.g., grab-bars)

    2. Independent

Mobility (indoors and outdoors)

12. Mobility indoors (short distances)

    0. Requires total assistance

    1. Needs electric wheelchair or partial assistance to operate manual wheelchair

    2. Moves independently in manual wheelchair

    3. Walks with a walking frame

    4. Walks with crutches

    5. Walks with two canes

    6. Walks with one cane

    7. Needs leg orthosis only

    8. Walks without aids

13. Mobility for moderate distances (10–100 meters)

    0. Requires total assistance

    1. Needs electric wheelchair or partial assistance to operate manual wheelchair

    2. Moves independently in manual wheelchair

    3. Walks with a walking frame

    4. Walks with crutches

    5. Walks with two canes

    6. Walks with one cane

    7. Needs leg orthosis only

    8. Walks without aids

14. Mobility outdoors (more than 100 meters)
    0. Requires total assistance
    1. Needs electric wheelchair or partial assistance to operate manual wheelchair
    2. Moves independently in manual wheelchair
    3. Walks with a walking frame
    4. Walks with crutches
    5. Walks with two canes
    6. Walks with one cane
    7. Needs leg orthosis only
    8. Walks without aids

15. Stair management
    0. Unable to climb or descend stairs
    1. Climbs 1 or 2 steps only, in a training setup
    2. Climbs and descends at least 3 steps with support or supervision of another person
    3. Climbs and descends at least 3 steps with support of handrail and/or crutch and/or cane
    4. Climbs and descends at least 3 steps without any support or supervision

16. Transfers: wheelchair–car (approaching car, locking wheelchair, removing arm and foot rests, transferring to and from car, bringing wheelchair into and out of car)
    0. Requires total assistance
    1. Needs partial assistance and/or supervision, and/or adaptive devices
    2. Independent without adaptive devices

Major segmental innervation of the muscles of the upper limb

C2
    +C3   Sternomastoid

C3
    +C4   Trapezius
        +C5   Levator scapulae

C4   Diaphragm

C5   Rhomboids
    Deltoid
    Teres minor
    Supraspinatus
    Infraspinatus
    Subclavius

    +C6   Biceps

C6   Brachialis
    Supinator
    Brachioradialis
    Subscapularis
    Teres major
    Coracobrachialis

    +C7   Serratus anterior
             Latissimus dorsi
             Extensor carpi radialis longus

        +C8   Pectoralis major

C7   Pronator teres
    Pectoralis minor
    Extensor digitorum
    Extensor digiti minimi
    Flexor carpi radialis

    +C8   Triceps
             Extensor carpi radialis brevis
             Palmaris longus

C8   Extensor carpi ulnaris
    Flexor carpi ulnaris
    Extensor indicis
    Flexor digitorum profundus
    Flexor digitorum sublimis
    Abductor pollicis longus
    Abductor pollicis brevis
    Opponens pollicis
    Flexor pollicis longus
    Extensor pollicis longus
    Extensor pollicis brevis
    +T1   Adductor pollicis

T1   Flexor pollicis brevis
    Abductor digiti minimi
    Flexor digiti minimi
    Opponens digiti minimi
    Lumbricales
    Interossei

Major segmental innervation of the muscles of the lower limb

L1	Psoas minor		
	+L2	Psoas major	

L2	Iliacus		
	+L3	Sartorius	
		+L4	Adductors

L3		
	+L4	Quadriceps

L4 Obturator externus

+L5 Tensor fascia lata
Tibialis posterior

+S1 Tibialis anterior
Extensor hallucis
Extensor digitorum longus
Peroneus tertius
Popliteus

L5 Gluteus medius
Gluteus minimus

+S1 Quadratus femoris
Semimembranosus
Semitendinosus
Biceps femoris
Peroneus longus
Peroneus brevis

S1 Obturator internus
Gastrocnemius

+S2 Gluteus maximus

S2 Flexor hallucis longus
Flexor digitorum longus
Soleus

+S3 Interossei

S3 Abductor hallucis
Adductor hallucis
Lumbricales
Abductor digiti minimi

Functional independence

Segmental level	Personal independence	Wheelchair management	Transfers	Gait
C4	Type, turn pages, use telephone and computer with mouthstick			
C5	Type Feed	Manipulate brake Push on the flat		
C6	Drink Wash, shave, brush hair Dress upper half Sit up/lie down in bed Write	Remove armrests/footplates Push on sloping ground Turn chair	Chair ↔ bed Chair ↔ car ?with sliding board	
C7	Turn in bed Dress lower half Skin care	Pick up objects from floor Wheel over uneven ground 'Bounce' over small elevations	Chair ↔ toilet Chair ↔ chair ?Chair ↔ bath	Stand in frame
C8	Bladder and bowel care	Negotiate kerbs	Chair↔ bath	Stand in frame
T1–T5		Balance on rear wheels Pull wheelchair into car	Chair ↔ floor	Stand in frame Swing-to in bars
T6–T9			Chair ↔ crutches	Swing-to on crutches or rollator ?Stairs
T10–L1				All three gaits on crutches Stairs Car ↔ crutches Floor ↔ crutches

Segmental innervation of the skin
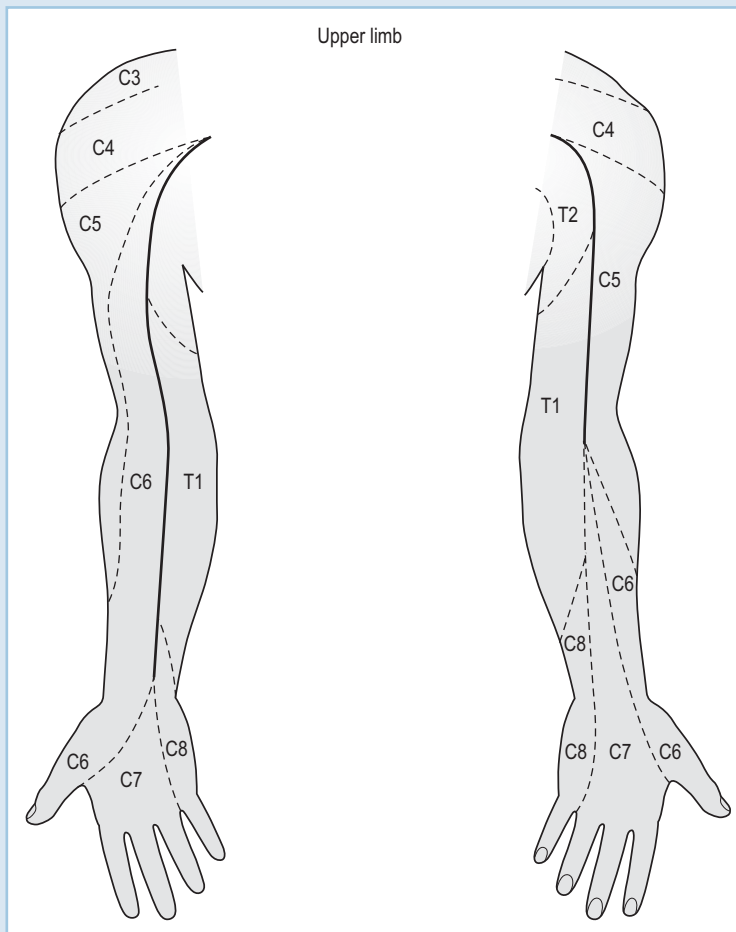
Figure A7.1 Upper limb. Reproduced from *Gray's Anatomy*, 35th edn, with permission.

Arrangement of dermatomes on the anterior aspect of the upper limb. The solid black line represents the *ventral axial line*, and the overlap across it is *minimal*. Across the interrupted lines, overlap is considerable.

Arrangement of dermatomes on the posterior aspect of the upper limb. The solid black line represents the *dorsal axial line*, and the overlap across it is *minimal*. Across the interrupted lines, the overlap may be and often is considerable.
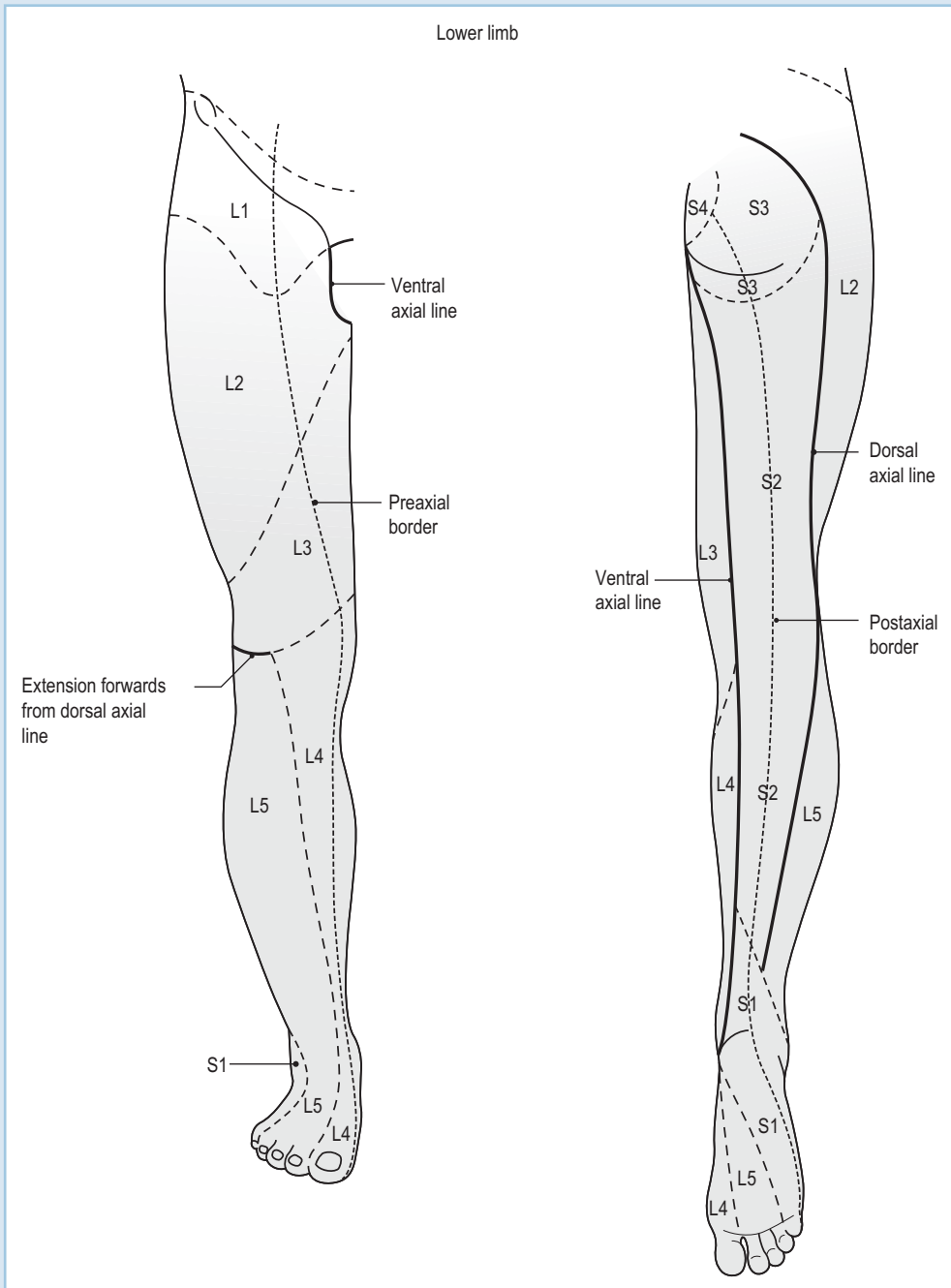
Figure A7.2 Lower limb. Reproduced from *Gray's Anatomy*, 35th edn with permission.

Segmental distribution of nerves of the lumbar and sacral plexuses to the skin of the anterior aspect of the lower limb.

Segmental distribution of nerves of the lumbar and sacral plexuses to the skin of the posterior aspect of the lower limb.

Useful addresses and equipment suppliers

LIST OF USEFUL ADDRESSES

*Access Travel (Lancs) Ltd
Holidays for Disabled Persons*
6 The Hillock
Astley
Lancashire M29 7GW
www.access-travel.co.uk

The Back-up Trust
The Business Village
Broomhill Road
London SW18 4JQ
www.backup.org.uk

*The British Wheelchair Sports
Federation* and *The International
Wheelchair and Amputees
Sports Federation*
Olympic Village
Guttmann Road
Aylesbury
Bucks HP21 9PP
www.wsw.org.uk

*Canine Partners – Opening
doors to independence*
(Canine partners for
independence)
Mill Lane
Heyshott
Midhurst
West Sussex GU29 0ED
www.caninepartners.co.uk

*Centre for Accessible
Environments*
Nutmeg House
60 Gainsford Street
London SE1 2NY

Disability Law Service
39 Cavell Street
London E1 2BP

Disability Sport England
Solecast House
13–27 Brunswick Place
London N1 6DX

*The Disabled Drivers'
Association*
Ashwell Park
East Harling
Norwich
NR16 1EX

Disabled Living Foundation
(Equipment for Disabled People)
380–384 Harrow Road
London W9 2HU

Equipment for the Disabled
(Equipment for Severely Disabled
People)
Mary Marlborough Lodge
Nuffield Orthopaedic Centre
Oxford OX3 7LD

*International Medical Society of
Paraplegia (IMSOP)*
National Spinal Injuries Unit
Stoke Mandeville Hospital
Aylesbury
Bucks HP21 8AL

*International Spine Research
Trust (ISRT)*
Nicholas House
River Front
Enfield
Middlesex EN1 3TR

Mobility Advice Charity
National Headquarters
Ashwellthorpe
Norwich NR16 1EX

Motability
(Provides Simple Wheelchairs
Overseas)
Brockley Academy
Brockley Lane
Backwell
Bristol BS48 4AQ
www.motivation.org.uk

The Pain Relief Foundation
University Hospital
Aintree
Liverpool L9 7AL

Society for Tissue Viability
Wessex Rehabilitation
Association
Odstock Hospital
Salisbury
Wiltshire SP2 8BJ

Spinal Injuries Association
Suite J, 3rd Floor
Acorn House
387–391 Midsummer Boulevard
Milton Keynes MK9 3HP
www.spinal.co.uk

EQUIPMENT SUPPLIERS

Automatic transmissions

Reselco Engineering Ltd
72 Black Lion Lane
Hammersmith
London W6

Chariot

Lomax Thomson Ltd
Kingsway East
Dundee
Scotland DD4 8ED

Countryside buggy suppliers

Able Buggies Ltd
Lane End Farm
Bare Heath
Wareham
Dorset BH20 7NS

Cushion suppliers (international)

Sunrise Home Healthcare Group
(Jay Cushions and backrests)
Mobility Products Division
7477 East Dry Creek Parkway
Longmont
CO 80503
USA
www.sunrisemedical.com

RoHo International Inc.
(RoHo Cushions and mattresses)
100 N Florida Avenue
Belleville
IL 62221–5429
USA
www.roho.com

Cascade Designs Inc.
(Varilite cushions and backrests)
4000 First Avenue South
Seattle
WA 98134
USA
www.varilite.com

Vicair BV
(Vicair cushions and backrests)
Koetserstraat 14
1531 NX Worner
The Netherlands
www.vicair.com

Electrical turning and tilting bed

Huntleigh Healthcare Ltd
310–312 Dallow Road
Luton LU1 1TD

Pegasus Limited
Pegasus House
Waterberry Drive
Waterlooville PO7 7XX

Environment control systems

The Gemini System
Scientific and Technical
Developments
Melbourne Road
Wallington
Surrey SM6 8SD

Possum Ltd
Middleton Green Road
Langley
Slough
Berkshire SL3 6DF

Gymnastic ball

Central Medical Equipment Ltd
7 Ascot Park Estate
Lenton Street
Sandiacre
Nottingham NG10 5DL

Highlite Portable Gantry

(Portable hoist)
Huntleigh Healthcare
Woden Road West
Wednesbury
West Midlands WS10 7BL UK
www.huntleigh-healthcare.com

Keytools

(Computer accessories for
severely disabled people)
For the Computer Enabled
PO Box 700
Southampton SO17 1LQ
www.keytools.com

Incontinence products

Condom urinals

GU Manufacturing Co Ltd
28a Devonshire Street
London W1

Conveen penile sheaths

Colloplast Ltd
Peterborough Business Park
Peterborough PE2 0FX

Rear and other access vehicles

Team Traction
130 Sturry Road
Canterbury
Kent CT1 1DP

Sorbo packs

Vitafoam Ltd
Don Mill
Middleton
Manchester M24 2DB

Standing frames

Grandstand

Prime Engineering (a Division of AXION industries Inc.)
UK Agent: Enhancement (Agencies) Ltd
IPER Division
23 Kingsland Road
Hemel Hempstead
Herts HP1 1QD

Dynamic parapodium

Doktor Perner Company Ltd
Tymienckiego 22/24 Street
90 349 Lodz
Poland
www.parapodium.pl

Oswestry standing frames

Theo Davies
Berwyn Mill
Glyn Ceiriog
Llangollen
Wrexham
South Wales LL20 7HN

Wheelchairs

Gerald Simmonds Healthcare Ltd
Gerald Simmonds Wheelchairs
Stoke Mandeville
9 March Place
Gatehouse Way
Aylesbury
Buckinghamshire HP19 3UG

Mobility 2000
Telford Industrial Centre
Stafford Park 4
Telford
Shropshire TF3 3BA

Hybrid power/manual chairs

E-Fix and E-Motion
Ulrich Alber GmbH
Vor dem Weissen Stein 21
D-72461 Albstadt-Tailfingen
Germany
Email: info@ulrich-alber.de
www.ulrich-alber.de

iGlide
Independence Technology
PO Box 7338
Endicott, NY 13760
USA
www.independencenow.com/iglide/

F16
Sunrise Medical Ltd
Sunrise Business Park
High Street
Wollaston
Stourbridge DY8 4PS
www.sunrisemedical.com

Sports and other wheelchairs

Cyclone
(Sports wheelchairs and 'off road/rough terrain' wheelchairs)
Ellesmere Port
South Wirral L66 1BR
www.chasswheel.com

EPC
(Equipment for the physically challenged – handbikes, scooters etc.)
43 Alexandra Road
Farnborough
Hants GU14 6BS
www.epc-wheelchairs.co.uk

International wheelchair suppliers

Sunrise Home Healthcare Group
(Quickie Wheelchairs)
Mobility Products Division
7477 East Dry Creek Parkway
Longmont
CO 80503
USA
www.sunrisemedical.com

Etac AB
(Etac wheelchairs – 'Swede')
PO Box 203
SE – 334 24 Anderstorp
Sweden
www.etac.com <http://www.etac.com>

Otto Bock Reha
(Wheelchairs)
Max-Nader Strasse 15
D-37115 Duderstadt
Germany
www.ottobock.com <http://
www.ottobock.com>

Invacare/Küschall – UK
(Wheelchairs)
Invacare UK Ltd
South Road
Bridgend Industrial Estate
Bridgend CF31 3PY
www.kuschall.com

Levo stand-up wheelchair
Valutec Ltd
Steigstrasse 2
Ch-8610 Uster 3/Zurich
Switzerland

Further reading

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Shumway-Cook A, Woollacott M 2001 Motor control – theory and practical applications. Lippincott Williams & Williams, Baltimore, MD

Wade D 2003 Measurement in neurological rehabilitation. Oxford University Press, Oxford

Whalley Hammell K 1995 Spinal cord injury rehabilitation (Therapy in Practice series). Chapman & Hall, London

Whiteneck G G, Charlifue S W, Gerhart K A et al 1993 Ageing with spinal cord injury. Demos Publications, New York

Video

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Subject Index