Journal of Physiotherapy 68 (2022) 130–135

Journal of PHYSIOTHERAPY

journal homepage: www.elsevier.com/locate/jphys

Research

The 6-minute stepper test and the sit-to-stand test predict complications after major pulmonary resection via minimally invasive surgery: a prospective inception cohort study

Fairuz Boujibar [a,b], André Gillibert [c], Tristan Bonnevie [b,d], Philippe Rinieri [e], François Montagne [f], Jean Selim [b,g], Antoine Cuvelier [b,h], Francis-Edouard Gravier [b,d], Jean-Marc Baste [a,b]

[a] *Department of Thoracic Surgery, Rouen University Hospital, Rouen, France;* [b] *Normandie University, UNIROUEN, INSERM U1096, Haute Normandie Research and Biomedical Innovation, Rouen, France;* [c] *Department of Biostatistics, Rouen University Hospital, Rouen, France;* [d] *ADIR Association, Rouen University Hospital, Rouen, France;* [e] *Department of Thoracic Surgery, Centre Médico-chirurgical du Cèdre, Bois-Guillaume, France;* [f] *Department of Thoracic Surgery, University Hospital of Lille, Lille, France;* [g] *Department of Anaesthesiology and Critical Care, Rouen University Hospital, Rouen, France;* [h] *Pulmonary, Thoracic Oncology and Respiratory Intensive Care Department, Rouen University Hospital, Rouen, France*

KEY WORDS

Lung resection
6-minute stepper test
Sit-to-stand test
Prognostic cohort studies
Physical therapy

ABSTRACT

Questions: How well do the 6-minute stepper test (6MST) and sit-to-stand test (STST) predict complications after minimally invasive lung cancer resection? Do the 6MST and STST provide supplementary information on the risk of postoperative complications in addition to the prognostic variables that are currently used, such as age and the American Society of Anesthesiology (ASA) score? **Design**: Prospective inception cohort study with follow-up for 90 days. **Participants**: Consecutive sample of adults undergoing major lung resection with video-assisted thoracic surgery (VATS) or robot-assisted thoracic surgery (RATS). **Outcome measures**: Patients had a preoperative functional evaluation with the 6MST and STST. The number of steps, heart rate change, saturation and dyspnoea during the 6MST and the number of lifts during the STST were recorded. Complications graded ≥ 2 on the Clavien-Dindo classification were recorded for 90 days after surgery. **Results**: Between November 2018 and November 2019, 118 patients with a mean age of 65 years (SD 9) were included and analysed. Their surgeries were via VATS in 88 (75%) and via RATS in 30 (25%). For predicting a postoperative complication graded ≥ 2 on the Clavien-Dindo classification, the area under the Receiver Operating Characteristic curve was: 0.82 (95% CI 0.75 to 0.90) for the number of steps during the 6MST, with an optimum cut-off of 140 steps; and 0.85 (95% CI 0.77 to 0.93) for the number of lifts during the STST, with an optimum cut-off of 20 lifts. **Conclusion**: The 6MST and STST predicted morbidity and mortality after lung cancer resection via minimally invasive surgery. The preoperative use of these exercise tests in clinical practice may be useful for risk stratification. **Registration**: NCT03824977. **[Boujibar F, Gillibert A, Bonnevie T, Rinieri P, Montagne F, Selim J, Cuvelier A, Gravier F-E, Baste J-M (2022) The 6-minute stepper test and the sit-to-stand test predict complications after major pulmonary resection via minimally invasive surgery: a prospective inception cohort study. *Journal of Physiotherapy* 68:130–135]**

Introduction

Lung cancer is currently the leading cause of cancer mortality, with more than 1.7 million deaths each year worldwide.[1] For patients with non-small cell lung cancer, pulmonary resection remains the optimal therapeutic approach to treat stage I and II tumours.[2] Surgery leads to significant morbidity,[3] especially in patients with impaired cardiorespiratory function. It is in this context that numerous preoperative assessments are carried out in order to determine the surgical options and estimate the operative risk.[4] The reference standard for stratification of surgical risk (perioperative and postoperative complications) is currently the cardiopulmonary exercise test (CPET),[5] which not only allows for the assessment of respiratory function, but also of cardiovascular and muscular function during exercise.

Low technology exercise tests such as the 6-minute stepper test (6MST) and the sit-to-stand test (STST) allow for functional assessment, reproducing movements of daily life. Several studies have investigated how well postoperative complications can be predicted by the 6-minute walking test,[6] the incremental shuttle walking test[7] and the stair-climbing test[8] before surgery. The first test requires a long corridor (of at least 30 m), the second one requires cones and a soundtrack with the recording of the test protocol, while the third requires stairs that are high enough.

https://doi.org/10.1016/j.jphys.2022.03.001

The STST and 6MST are usually used in people with other pathologies such as chronic obstructive pulmonary disease[9] or cystic fibrosis.[10] To date, no study has evaluated STST and 6MST in preoperative thoracic surgery in the modern era of minimally invasive surgery. In practice, these tests measure the concentric and eccentric muscular force of the knees and hips; in doing so, they give an indication of the physical profile of the patient, their degree of autonomy and possible functional limitations.[11]

Therefore, the research questions for this prospective inception cohort study were:

1. How well do the 6MST and the STST predict complications after minimally invasive lung cancer resection?
2. Do the 6MST and STST provide supplementary information on the risk of postoperative complications in addition to the prognostic variables that are currently used, such as age and the American Society of Anesthesiology (ASA) score?

Methods

Design

This prospective inception cohort study was conducted in the Department of Thoracic Surgery, Rouen University Hospital, France. Consecutive adults scheduled for major lung resection via minimally invasive surgery were recruited between November 2018 and November 2019. Patients had a preoperative functional evaluation with the 6MST and STST. Complications graded ≥ 2 on the Clavien-Dindo classification were recorded for 90 days after surgery. The participants' results on the two preoperative exercise tests were analysed for their ability to predict postoperative complications. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed to report this study.[12] Privacy and confidentiality as well as the anonymity of the participants were ensured at all stages of data collection.

Participants

Eligible patients were those aged > 18 years and requiring major lung resection with video-assisted thoracic surgery (VATS) or robotic-assisted thoracic surgery (RATS) for clinically confirmed non-small cell lung cancer with clinical Tumor Node Metastatis status of stage I or II according to the American Joint Committee on Cancer classification. Exclusion criteria were: partial or total amputation of the lower limb; weight > 100 kg because it is the upper limit of the stepper device; orthopaedic, vascular or neurological disorders precluding performance of the exercise tests; patient under guardianship; and pregnancy.

Baseline measures

After a period of rest of 20 minutes, participants performed one 6MST and one STST during their preoperative consultation, supervised by an experienced physiotherapist, in a quiet room to avoid any disturbance or external stimulation. Participants first performed the 6MST, followed by the STST when their heart rate and pulse oxyhaemoglobin saturation (SpO_2) had returned to the resting values and 20 minutes had elapsed. For participants who underwent prehabilitation, the 6MST and STST were conducted one day before surgery rather than before prehabilitation. The physiotherapist first demonstrated the tests; participants were then asked to reproduce them under the physiotherapist's supervision, to familiarise themselves with the apparatus. The tests were carried out in ambient air or with supplemental oxygen if it was usually used during routine physical activity.

6-minute stepper test: The 6MST was performed on a stepper[a] with a walking height of 20 cm, placed in front of a wall or parallel bars, so the patients could hold on if they lost balance. Patients were instructed to make the maximum number of steps possible in 6 minutes, and were given a time check at 1-minute intervals. This stepper contains metallic springs, with no warm-up effect on the resistance, contrary to hydraulic jacks. The instructions were standardised and comparable with those of the 6-minute walk test.[13] Heart rate and SpO_2 were measured at 1-minute intervals. Dyspnoea was assessed using the Borg scale before and after the 6MST.[14] After 6 minutes, the number of steps was recorded, even if the patient stopped the test prematurely or paused during the test.

Sit-to-stand test: The STST was performed using a chair measuring 47 cm in height. The patient was instructed to sit in the chair and then perform the maximum number of lifts possible from the chair in 1 minute with arms folded and without leaning against the chair.[15] Dyspnoea was evaluated at the beginning and end of the STST using the Borg scale. SpO_2, heart rate and dyspnoea were recorded at the beginning and end of the STST. The number of complete lifts was recorded.

Surgical procedures

VATS resection was performed using an anterior approach with three ports[16] and RATS resection was performed using a complete three-port[17] or four-port technique.[18] All participants were informed about the risk of conversion to open surgery and of postoperative complications.

Follow-up and outcome measures

Data on postoperative complications and their treatments were collected prospectively on day 30 during the postoperative consultation and on day 90 by analysis of hospital medical records, telephone contact with the patient and the attending physician if the patient suggested that there was a complication; the assessor (physiotherapist) was not always blind to the patient's performance on the baseline tests. All Clavien-Dindo grading from the complication description was performed by one independent physician who was blind to the patient's performance on the baseline tests. The primary outcome was the presence of at least one complication graded ≥ 2 on the Clavien-Dindo classification[19] occurring postoperatively up to day 90.

Data analysis

The primary statistical analysis was the estimation, by De Long's 95% CI, of the area under the Receiver Operating Characteristic (ROC) curve (AUC) of the number of steps on the 6MST for the prediction of a postoperative complication of Clavien-Dindo grade ≥ 2 by day 90 after surgery. A complete case analysis was planned if $< 10\%$ of 6MST data were missing; otherwise imputation was planned. The descriptions of the sensitivity, specificity, and positive and negative predictive values at thresholds defined by the deciles of the empirical distributions of the 6MST were planned. The positive (LR+) and negative (LR–) likelihood ratio statistics were added post hoc. A definition of optimal thresholds was performed by accepting two false positives to avoid one false negative (Appendix 1 on the eAddenda). The optimal thresholds were computed on smoothed ROC curves. Prognostic performances at the optimal thresholds were corrected for overfitting by leave-one-out cross-validation. In a sensitivity analysis, the overfitting was estimated by bootstrap, then corrected on estimates and confidence intervals of the prognostic performances.

ROC curves of STST and 6MST with adjustment on age, ASA score, forced expiratory volume in one second (FEV_1), the diffusion capacity of the lung for carbon monoxide (DLCO) and surgery type (segmentectomy, lobectomy, pneumonectomy) were constructed by weighting the ROC curve on a prognostic score constructed by a logistic regression explaining the risk of complications by the adjustment variables (post hoc analysis). Overlap weights rather than inverse probability weighting were used to avoid extreme weights.[20] The AUC

of adjusted ROC curves was estimated and compared by percentile bootstrap with multiple imputation for DLCO and FEV_1 with the Boot-MI strategy[21] (bootstrap, then multiple imputation). All analyses were performed with R software[b].

The sample size was computed to provide a two-sided 95% De Long's CI for the AUC, with a total width (upper boundary minus lower boundary) of 0.20, assuming that the complication rate was 32%,[22] the AUC was 0.75 and the distribution of the number of steps on the 6MST can be expressed, after monotone normalising transformation, as two shifted distributions with the same variance in the group with and the group without complications. Simulations showed that major deviations from that hypothesis had a minor impact on the sample size. The required sample size was estimated at 106.

Results

Compliance with the study protocol

There were no missing data regarding postoperative complications, the number of steps during the 6MST or the number of lifts during the STST. No imputation or exclusion was needed.

Flow of participants through the study

Between November 2018 and November 2019, 132 patients were screened for inclusion. After the exclusion of ineligible patients, 118 patients were available for the primary analysis (Figure 1). The characteristics of the study participants are summarised in Table 1. Although all patients had stage I or II cTNM, a few patients were upstaged to stage III or IV pathological Tumor Node Metastatis status (pTNM) and seven (6%) patients had a histological invalidation of the cancer diagnosis. None of these patients were excluded. Twelve (10%) patients who had minimally invasive surgery had a conversion to thoracotomy, but were not excluded because it was unknown whether there would be a conversion or not at the time of the prognosis.

Incidence of postoperative complications

Postoperative complications graded $\geq$ 2 on the Clavien-Dindo classification occurred in 32 (27%) patients: 24 (75%) during their hospital stay, six (19%) between discharge and postoperative day 30, and two (6%) between postoperative days 30 and 90 (Table 2). One patient died before postoperative day 90.

Prediction of postoperative complications

The median number of steps during the 6MST was 156 (IQR 117 to 203) and the median number of lifts during the STST was 23 (IQR 18 to 27). Other variables measured during the 6MST and STST are described in Table 3. The crude AUC of the ROC curves for the prediction of a postoperative complication of Clavien-Dindo grade $\geq$ 2 was 0.82 (95% CI 0.75 to 0.90) for the number of steps during the 6MST (primary analysis) and 0.85 (95% CI 0.77 to 0.93) for the number of lifts during the STST (Figure 2) without significant difference between both AUCs (0.031, 95% CI −0.033 to 0.094, post hoc analysis). The AUC of the ROC curves with adjustment (post hoc analyses) for age, ASA, FEV_1, DLCO, surgery type (segmentectomy, lobectomy, pneumonectomy) were estimated at 0.77 (95% CI 0.66 to 0.87) for the number of steps during the 6MST and 0.82 (95% CI 0.70 to 0.92) for the number of lifts during the STST.

Predictive performances of the STST and 6MST at all decile thresholds are presented in Table 4 on the eAddenda. The optimal thresholds for the number of steps during the 6MST and number of lifts during the STST were 141 steps and 19 lifts, respectively, rounded to 140 and 20 for simplicity. Table 5 shows the prognostic performance (sensitivity, specificity, predictive values and likelihood ratios)

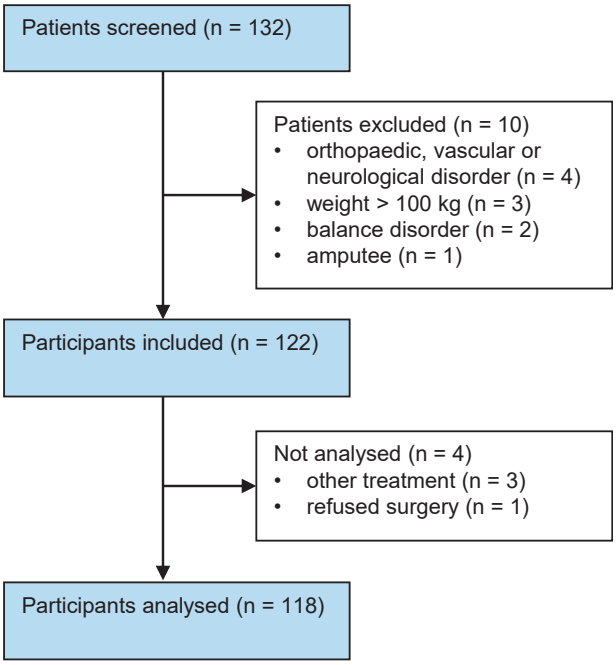

Figure 1. Flow of participants through the study.

of the 6MST and STST at these rounded optimal thresholds with correction for overfitting. Severe complications requiring a reintervention with general anaesthesia or with a risk of death due to organ failure (Clavien-Dindo grade $\geq$ 3B) were found in 0 of 70 (0%, 95% CI 0.0 to 5.1) patients having performed $\geq$ 140 steps during the 6MST and in 2 of 78 (2.6%, 95% CI 0.3 to 9.0) patients having performed $\geq$ 20 steps during the STST: one pleural effusion and one infectious pleurisy.

The sensitivity analysis for the overfitting correction showed no major difference, as presented in Table 6 on the eAddenda.

Multivariable model

In a post hoc multivariable analysis (described in Appendix 2 on the eAddenda), a prognostic score based on baseline variables and 6MST results was created for the prediction of complications. The score formula was:

1.1×(age in years) + 200×ASA + 98×(Borg effort dyspnoea) – 5.7×(number of steps) + 21×(resting SpO_2 in %) + 230×(decrease in SpO_2 in %) + 14×(resting heart rate in beats/minute) – 0.91×(increase in heart rate in beats/minute).

The overfitting-corrected AUC of the score was estimated at 0.84 (95% CI 0.77 to 0.92) without significant improvement compared with the crude number of steps at 6MST (0.02, 95% CI −0.05 to 0.10). The crude AUC of individual variables of the multivariable analysis are shown in Table 7 on the eAddenda.

Supplementary results are presented in Appendix 3 on the eAddenda.

Discussion

It is believed that this is the first prospective study assessing the ability of the 6MST and STST to predict postoperative complications. Other low-technology tests, such as the stair climbing test[23] or the ISWT,[7] have been shown to predict postoperative complications. This study found that the number of steps during the 6MST and the number of lifts during the STST were strongly predictive of postoperative morbidity, both having an AUC > 0.74 including the lower boundary of the confidence intervals. At the optimal threshold, both tests seemed to have acceptable positive predictive values (> 35% according to the confidence intervals).

Table 1
General characteristics of the analysed participants.

Characteristic	Participants (n = 118)
Age *(y)*, mean (SD)	65 (9)
Sex, n (%)	
female	50 (42)
male	68 (58)
ASA score, n (%)	
1	23 (19)
2	68 (58)
3	27 (23)
Body mass index *(kg/m²)*, n (%)	
< 18.5	5 (4)
18.5 to 24.9	60 (51)
25.0 to 29.9	31 (26)
≥ 30	22 (19)
FEV_1 *(%)*, mean (SD)[a]	90 (21)
DLCO *(%)*, mean (SD)[b]	73 (17)
VO_{2peak} *(ml/min/kg)*, mean (SD)[c]	16.0 (3.7)
pTNM staging, n (%)	
non-cancer[d]	7 (6)
IA	53 (45)
IB	21 (18)
IIA	10 (8)
IIB	17 (14)
IIIA	7 (6)
IIIB	2 (2)
IV	1 (1)
Histology, n (%)	
adenocarcinoma	73 (62)
squamous cell carcinoma	24 (20)
typical carcinoid	5 (4)
neuroendocrine carcinoma	1 (1)
other	8 (7)
non-cancer[d]	7 (6)
Tobacco use, n (%)	
current smoker	34 (29)
former smoker	64 (54)
never smoker	20 (17)
Prehabilitation program, n (%)	43 (36)
Postoperative length of stay *(d)*, median (IQR)	4 (2 to 6)
Resection, n (%)	
segmentectomy	26 (22)
lobectomy	86 (73)
bilobectomy	3 (3)
pneumonectomy	3 (3)
Surgical approach, n (%)	
VATS	88 (75)
RATS	30 (25)

Some percentages do not sum to 100 due to the effects of rounding.
ASA = American Society of Anesthesiologists physical status classification score, DLCO = diffusion capacity of the lung for carbon monoxide, FEV_1 = forced expiratory volume in 1 second, RATS = robotic-assisted thoracic surgery, VATS = video-assisted thoracic surgery, VO_{2peak} = oxygen uptake at peak exercise, pTNM = pathological Tumor Node Metastatis status.
[a] n = 109.
[b] n = 92.
[c] n = 20.
[d] Patients with a malignant diagnosis invalidated at final histology.

The 6MST and STST are cheap, widely reproducible and require minimal personnel and equipment; they are easily achievable during the preoperative consultation at a time when the surgeon needs to determine operability (ie, whether the surgery is indicated or contraindicated). These tests can be carried out in the consultation room, without having to go to the corridors or the staircase, thus ensuring optimal safety. They are accessible to most patients: 7% of the cohort that was initially assessed could not perform these tests for functional reasons, which would also have prevented the completion of the other currently recommended field tests. Although no incident was noted during their performance, there are rare but severe risks related to high-intensity exercise testing.

Although both the 6MST and STST are feasible in clinical practice, there are several reasons to prefer the STST. First, the equipment is more readily available for the STST than for the 6MST. Second, it is faster to complete (1 minute versus 6 minutes). Third, counting the number of lifts is easier to perform without error, while steps can be hard to count precisely if they are fast. Fourth, not all steppers have the same resistance and patient's performance may depend on the stepper model and its maintenance. Not all chairs have the same height, but the variance is small and 47 cm is the most standard height. Fifth, the stepper requires the patient to balance on a moving surface above floor level, often necessitating a support structure for the balance to be maintained. The risk of injurious fall may be higher than the risk in the STST, although larger studies are required to assess the actual risk. According to the confidence interval of the difference of AUCs, the prognostic performances of the STST may be lower than that of the 6MST by 0.033, which is a small difference that would not outweigh the practical advantages of the STST. The prognostic performance of the STST may be equivalent or superior to that of the 6MST.

The negative predictive values of STST and 6MST are not large enough to preclude complications. Even severe complications are possible in patients with good performances on the 6MST and STST, albeit less probable than in patients with poor 6MST and STST performances. Absolute contraindications to surgery are rare because the benefit of the oncological resection far outweighs the risk of complications in most patients, but preoperative risk stratification helps to adapt the perioperative management; for instance, sedentary patients with a high risk of complications might benefit from prehabilitation. The STST induces similar cardiorespiratory stress to that of the CPET,[24] and it is a stronger predictor of 2-year mortality (AUC 0.78) than FEV_1 (AUC 0.61) for patients with chronic obstructive pulmonary disease.[25] The STST and 6MST have two main advantages: they are dynamic exercises and are global functional tests. Consequently, rather than assessing a very specific physiologic function, they assess frailty; cardiac, pulmonary, neurologic, orthopaedic and rheumatologic disorders may alter these tests. This is the main strength but also the main weakness of the STST and 6MST. They provide an assessment of the frailty but do not provide information on which physiological function is impaired. That is why CPET and pulmonary function testing provide complementary information for preoperative assessment and management. Due to the complexity and poor availability of CPET, the STST could potentially be used to select patients for CPET. Patients having very good performances on the STST would most probably have a normal CPET and low risk of postoperative complication, so CPET prescription may be avoided for these patients. A recent publication found that a performance of ≥ 49 chair rises during the 3-minute sit-to-stand test could indicate a VO_{2peak} ≥ 15 ml/kg/minute. Azzi et al found that the test is a useful screening tool to determine the necessity for a comprehensive cardiopulmonary exercise test.[26] However, the current guidelines[27] recommend the use of the FEV_1 to choose whether to prescribe CPET or not. These guidelines are based on patients who undergo thoracotomy and do not take in account the major shift towards minimally invasive surgery in the last two decades. The FEV_1 is limited to one physiologic parameter and could potentially be less relevant to select patients for the prescription of CPET rather than the STST. However, the current study was not designed to answer this question. Further studies are needed to assess the optimal preoperative assessment strategy.

The main strength of this study was the carefully developed prospective protocol that was successfully implemented, as illustrated by the completeness of data collection and no dropouts. It directly studied the relationship between these low-technology tests and the risk of complications. These complications were collected over a long period (90 days) and graded according to Clavien-Dindo scale[19] for more precision. The Clavien-Dindo scale has been refined by Ivanovic et al,[28] but the current study used the base classification that is well known and widely accepted. In contrast to a retrospective cohort study, this design guarantees that all patients had STST and 6MST assessments at baseline with a standardised procedure, thereby avoiding measurement bias and selection bias. Attrition bias was also avoided by systematically calling patients and family doctors.

Table 2
Description of complications of all Clavien-Dindo grades occurring in the 90 days after surgery. The most severe complications occurred in participants who had more than one complication.

Complications, n participants	Clavien-Dindo grade							Total
	1	2	3A	3B	4A	4B	5	
Infectious complications								
pneumonia	0	4	1	0	0	0	0	5
pleurisy	0	0	1	0	1	0	0	2
parietal abscess	0	1	0	0	0	0	0	1
other infection	0	1	0	0	0	0	0	1
Pleuro-pulmonary complications								
air leak	10	1	0	0	0	0	0	11
atelectasis	1	1	2	0	0	0	0	4
respiratory distress	0	2	0	0	1	1	0	4
pneumothorax	0	0	3	1	0	0	0	4
subcutaneous emphysema	0	0	2	1	0	0	0	3
pleural effusion	1	0	1	1	0	0	0	3
pulmonary embolism	0	0	0	1	0	1	0	2
Other complications								
cardiac rhythm disorder	1	2	1	0	0	0	0	4
nerve paralysis[a]	3	0	0	0	0	0	0	3
death	0	0	0	0	0	0	1	1
Total	16 14%	12 10%	11 9%	4 3%	2 2%	2 2%	1 1%	48 41%

[a] Recurrent laryngeal nerve or phrenic nerve.

This study also had some limitations. Exercise testing showed random fluctuations according to the day it was performed. Repeating tests to average these fluctuations might have improved their performance. The study was designed to assess the predictive performance of the 6MST and STST but not to compare their performances to VO_{2peak} (current reference standard).

This prospective study was conducted in a single centre, which limits its external validity. Although postoperative complications were defined by the Clavien-Dindo classification, they were highly heterogeneous, and it is hard to know which complications were predicted by these tests. The assessor of complications (physiotherapist) was not blind to each patient's baseline results on the 6MST and STST; that could have led to some measurement bias. However, the Clavien-Dindo grading was performed by an independent physician. The sample size was not large enough to define a multidimensional postoperative complication predictor, taking into account all examinations and clinical variables available preoperatively. The sample size was large enough to analyse overall complications with the Clavien-Dindo scale but not each complication separately; therefore the primary outcome was highly heterogeneous. Moreover, the Clavien-Dindo scale is based on the actual treatment given to the patient; therefore, it depends on the prescription habits of the physician following the patient. This study did not randomise the order of the 6MST and STST tests. Even though the heart rate returned to normal and it was ensured that the rest time between the tests was 10 to 20 minutes, there may have been some residual fatigue, leading to an underestimation of: number of lifts during the STST; the optimal threshold; and maybe the AUC, due to the variance of fatigue adding noise to the measurements. Future multicentre evaluation and comparison of the 6MST and STST with VO_{2peak} would strengthen these results.

Supplementary discussion is presented in Appendix 3 on the eAddenda.

In conclusion, the 6MST and STST are useful tools to assess candidates for lung surgery. These tests could help to stratify the risk of postoperative morbidity. The STST is easier to use than the 6MST in practice and has a similar prognostic value. A patient achieving < 20 lifts during the STST or < 140 steps during the 6MST is a patient at risk of postoperative complications. Further studies are needed to evaluate the use of these low-technology tests in combination with

Table 3
Results of the 6-minute stepper test (6MST) and the sit-to-stand test (STST) and physiological measures during the tests.

Measure	6MST (n = 118)	STST (n = 118)
Number of repetitions, median (IQR)[a]	156 (117 to 203)	23 (18 to 27)
Resting cardiac frequency *(cycles/min)*, mean (SD)	78 (11)	79 (10)
Effort cardiac frequency *(cycles/min)*, mean (SD)	103 (15)	101 (14)
Change in cardiac frequency *(cycles/min)*, mean (SD)	25 (11)	22 (10)
Resting SpO_2 *(%)*, mean (SD)	97 (2)	97 (2)
Effort SpO_2 *(%)*, mean (SD)	95 (3)	96 (3)
Change in SpO_2 *(%)*, mean (SD)	−2.1 (1.8)	−1.7 (1.9)
Resting Borg dyspnoea *(0 to 10)*, mean (SD)	0.04 (0.20)	0.03 (0.18)
Effort Borg dyspnoea *(0 to 10)*, mean (SD)	5.92 (1.87)	4.91 (1.82)

SpO_2 = pulse oxyhaemoglobin saturation.
[a] Repetitions were the number of steps in the 6MST and the number of lifts in the STST.

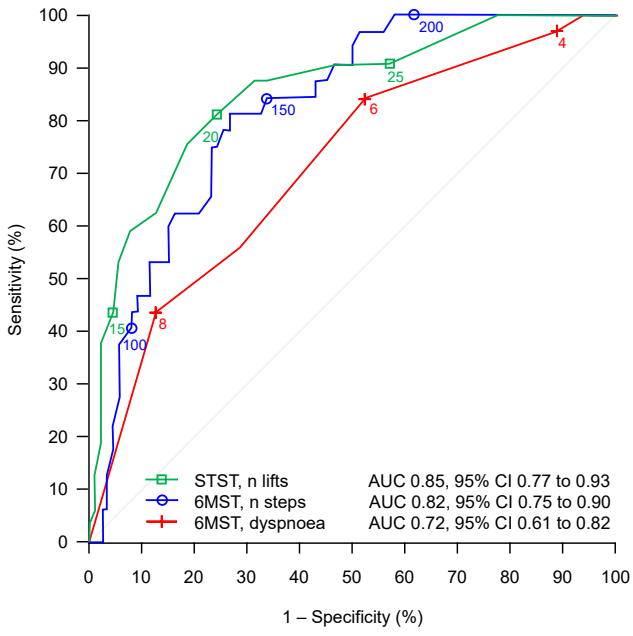

Figure 2. Crude ROC curves of the number of steps at 6-minute stepper test (6MST), Borg dyspnoea scale at the end of 6MST, number of lifts at sit-to-stand test (STST) to predict a postoperative complication of grade ≥ 2 of the Clavien-Dindo scale with presentation of the thresholds (sensitivity, specificity).

Table 5
Prognostic performances of the 6-minute stepper test (6MST) and the sit-to-stand test (STST) at the optimal thresholds for the prediction of postoperative complications graded ≥ 2 on the Clavien-Dindo classification, with overfitting correction by cross-validation.

	6MST	STST
Threshold	< 140 steps	< 20 lifts
PPV	25/48 (52.1%, 95% CI 37.2 to 66.7)	24/40 (60.0%, 95% CI 43.3 to 75.1)
NPV	63/70 (90%, 95% CI 80.5 to 95.9)	70/78 (89.7%, 95% CI 80.8 to 95.5)
Sensitivity	25/32 (78.1%, 95% CI 60.0 to 90.7)	24/32 (75.0%, 95% CI 56.6 to 88.5)
Specificity	63/86 (73.3%, 95% CI 62.6 to 82.2)	70/86 (81.4%, 95% CI 71.6 to 89.0)
LR+	2.92 (95% CI 1.99 to 4.44)	4.03 (95% CI 2.54 to 6.81)
LR–	0.30 (95% CI 0.14 to 0.53)	0.31 (95% CI 0.15 to 0.52)

LR+ = positive likelihood ratio, LR– = negative likelihood ratio, NPV = negative predictive value, PPV = positive predictive value.

other assessments such as pulmonary function testing and CPET in the preoperative assessment.

What was already known on this topic: In patients with non-small cell lung cancer, preoperative assessments are carried out in order to determine the surgical options and to estimate the the risk of postoperative complications.
What this study adds: In patients undergoing lung cancer resection via minimally invasive surgery, < 20 lifts during the sit-to-stand test or < 140 steps during the 6-minute stepper test predict postoperative pulmonary complications. Given that their prognostic ability is similar, the sit-to-stand test might be preferred due to simpler administration.

Footnotes: [a] Stepper essential, Decathlon™, France.
[b] R software, V3.6, R Foundation for Statistical computing, Vienna, Austria.

eAddenda: Tables 4, 6 and 7 can be found online at https://doi.org/10.1016/j.jphys.2022.03.001.

Ethics approval: The French research ethics committee CPP Ile de France X approved this study (ID RCB: 2018-A02694-51). All participants gave written informed consent before data collection began.

Competing interests: Nil.

Source(s) of support: This work was supported by Rouen University Hospital.

Acknowledgements: The authors are grateful to Nikki Sabourin-Gibbs, Rouen University Hospital, for her help in editing the manuscript.

Provenance: Not invited. Peer reviewed.

Correspondence: Fairuz Boujibar, Department of General and Thoracic Surgery, CHU Rouen, Rouen, France. Email: F.boujibar@gmail.com

References

1. Cancer today [Internet]. http://gco.iarc.fr/today/home. Accessed April 23, 2020.
2. Howington JA, Blum MG, Chang AC, Balekian AA, Murthy SC. Treatment of stage I and II non-small cell lung cancer: Diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest*. 2013;143(5 Suppl):e278S–e313S.
3. Bernard A, Falcoz P-E, Thomas PA, Rivera C, Brouchet L, Baste JM, et al. Comparison of Epithor clinical national database and medico-administrative database to identify the influence of case-mix on the estimation of hospital outliers. *PLoS ONE*. 2019;14:e0219672.
4. Charloux A, Brunelli A, Bolliger C. Lung function evaluation before surgery in lung cancer patients: how are recent advances put into practice? A survey among members of the European Society of Thoracic Surgeons (ESTS) and of the Thoracic Oncology Section of the European Respiratory Society (ERS). *Interact Cardiovasc Thorac Surg*. 2009;9:925–931.
5. Brunelli A, Charloux A, Bolliger CT, Rocco G, Sculier J-P, Varela G, et al. The European Respiratory Society and European Society of Thoracic Surgeons clinical guidelines for evaluating fitness for radical treatment (surgery and chemoradiotherapy) in patients with lung cancer. *Eur J Cardiothorac Surg*. 2009;36:181–184.
6. Sathyaprasad SL, Thomas M, Philip FA, Krishna KJ. Performance in 6-min walk test in prediction of post-operative pulmonary complication in major oncosurgeries: A prospective observational study. *Indian J Anaesth*. 2020;64:55–61.
7. Fennelly J, Potter L, Pompili C, Brunelli A. Performance in the shuttle walk test is associated with cardiopulmonary complications after lung resections. *J Thorac Dis*. 2017;9:789–795.
8. Boujibar F, Gillibert A, Gravier FE, Gillot T, Bonnevie T, Cuvelier A, et al. Performance at stair-climbing test is associated with postoperative complications after lung resection: a systematic review and meta-analysis. Thorax [Internet]; 2020. https://thorax.bmj.com/content/early/2020/07/09/thoraxjnl-2019-214019. Accessed August 5, 2020.
9. Gephine S, Bergeron S, Tremblay-Labrecque P-F, Mucci P, Saey D, Maltais F. Cardiorespiratory Response during the 1-min Sit-to-Stand Test in Chronic Obstructive Pulmonary Disease. *Med Sci Sports Exerc*. 2020;52:1441–1448.
10. Radtke T, Puhan MA, Hebestreit H, Kriemler S. The 1-min sit-to-stand test–A simple functional capacity test in cystic fibrosis? *J Cyst Fibros*. 2016;15:223–236.
11. Bohannon RW, Crouch R. 1-Minute Sit-to-Stand Test: systematic review of procedures, performance, and clinimetric properties. *J Cardiopulm Rehabil Prev*. 2019;39:2–8.
12. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bull World Health Organ*. 2007;85:867–872.
13. Grosbois JM, Riquier C, Chehere B, Coquart J, Béhal H, Bart F, et al. Six-minute stepper test: a valid clinical exercise tolerance test for COPD patients. *Int J Chron Obstruct Pulmon Dis*. 2016;11:657–663.
14. Mador MJ, Rodis A, Magalang UJ. Reproducibility of Borg scale measurements of dyspnea during exercise in patients with COPD. *Chest*. 1995;107:1590–1597.
15. Crook S, Puhan MA, Frei A. STAND-UP and RIMTCORE study groups. The validation of the sit-to-stand test for COPD patients. *Eur Respir J*. 2017;50.
16. Hansen HJ, Petersen RH, Christensen M. Video-assisted thoracoscopic surgery (VATS) lobectomy using a standardized anterior approach. *Surg Endosc*. 2011;25:1263–1269.
17. Ninan M, Dylewski MR. Total port-access robot-assisted pulmonary lobectomy without utility thoracotomy. *Eur J Cardiothorac Surg*. 2010;38:231–232.
18. Cerfolio RJ, Watson C, Minnich DJ, Calloway S, Wei B. One Hundred Planned Robotic Segmentectomies: Early Results, Technical Details, and Preferred Port Placement. *Ann Thorac Surg*. 2016;101:1089–1095.
19. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240:205–213.
20. Li F, Thomas LE, Li F. Addressing Extreme Propensity Scores via the Overlap Weights. *Am J Epidemiol*. 2019;188:250–257.
21. Schomaker M, Heumann C. Bootstrap inference when using multiple imputation. *Stat Med*. 2018;37(14):2252–2266.
22. Boujibar F, Bonnevie T, Debeaumont D, Bubenheim M, Cuvellier A, Peillon C, et al. Impact of prehabilitation on morbidity and mortality after pulmonary lobectomy by minimally invasive surgery: a cohort study. *J Thorac Dis*. 2018;10:2240–2248.
23. Olsen GN, Bolton JW, Weiman DS, Hornung CA. Stair climbing as an exercise test to predict the postoperative complications of lung resection. Two years' experience. *Chest*. 1991;99:587–590.
24. Géphine S, Bergeron S, Saey D, Mucci P, Maltais F. Évaluation des capacités fonctionnelles dans la BPCO : le test de lever de chaise d'une minute un exercice maximal ? *Revue des Maladies Respiratoires*. 2019;36:A9.
25. Puhan MA, Siebeling L, Zoller M, Muggensturm P, ter Riet G. Simple functional performance tests and mortality in COPD. *Eur Respir J*. 2013;42:956–963.
26. Azzi M, Debeaumont D, Bonnevie T, Aguilaniu B, Cerasuolo D, Boujibar F, et al. Evaluation of the 3-minute chair rise test as part of preoperative evaluation for patients with non-small cell lung cancer. *Thorac Cancer*. 2020;11:2431–2439.
27. Brunelli A, Kim AW, Berger KI, Addrizzo-Harris DJ. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: Diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest*. 2013;143(5 Suppl):e166S–e190S.
28. Ivanovic J, Al-Hussaini A, Al-Shehab D, Threader J, Villeneuve PJ, Ramsay T, et al. Evaluating the reliability and reproducibility of the Ottawa Thoracic Morbidity and Mortality classification system. *Ann Thorac Surg*. 2011;91:387–393.