Time in the stair-climbing test as a predictor of thoracotomy postoperative complications

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Objectives: The stair-climbing test as measured in meters or number of steps has been proposed to predict the risk of postoperative complications. The study objective was to determine whether the stair-climbing time can predict the risk of postoperative complications.

Methods: Patients aged more than 18 years with a recommendation of thoracotomy for lung resection were included in the study. Spirometry was performed according to the criteria by the American Thoracic Society. The stair-climbing test was performed on shaded stairs with a total of 12.16 m in height, and the stair-climbing time in seconds elapsed during the climb of the total height was measured. The accuracy test was applied to obtain stair-climbing time predictive values, and the receiver operating characteristic curve was calculated. Variables were tested for association with postoperative cardiopulmonary complications using the Student *t* test for independent populations, the Mann–Whitney test, and the chi-square or Fisher exact test. Logistic regression analysis was performed.

Results: Ninety-eight patients were evaluated. Of these, 27 showed postoperative complications. Differences were found between the groups for age and attributes obtained from the stair-climbing test. The cutoff point for stair-climbing time obtained from the receiver operating characteristic curve was 37.5 seconds. No differences were found between the groups for forced expiratory volume in 1 second. In the logistic regression, stair-climbing time was the only variable associated with postoperative complications, suggesting that the risk of postoperative complications increases with increased stair-climbing time.

Conclusions: The only variable showing association with complications, according to multivariate analysis, was stair-climbing time. (*J Thorac Cardiovasc Surg* 2013;145:1093-7)

Postoperative complications (POCs) occur in 6.8% to 30% of individuals who undergo noncardiac thoracic surgery.¹ Because POCs increase morbidity and mortality, and, secondarily, the duration and cost of hospitalization, it is important to identify patients who may have such complications to reduce their risk by means of preoperative preparation. However, to date, no agreement has been reached in regard to the best test to stratify surgical risk.²

The cardiopulmonary stress experienced by patients in the intraoperative and postoperative periods of thoracic surgery is responsible for POCs. Cardiopulmonary stress is complicated to measure and sometimes makes the decision to perform surgery difficult because of the uncertainty of whether the patient can withstand the procedure. However,

few studies suggest that cardiorespiratory exercise tests can be applied for this purpose.³

The exercise test has been used in the last few years in patients who are eligible for thoracotomy. Of the variables obtained in the ergospirometric test, maximal oxygen uptake (VO₂) is considered to be the gold standard in surgical risk and postoperative prognosis prediction.⁴ In the past, diffusing capacity of carbon monoxide also was considered the best predictor of postoperative pulmonary complications in lung resection,⁵ but its use in the preoperative evaluation of patients undergoing lung resection has not been routine.⁶

VO₂ assessment by means of ergospirometric tests is costly and depends on specific equipment, an appropriate site, and properly trained staff. Diffusing capacity of carbon monoxide assessment also depends on specific equipment. However, many hospitals do not have such equipment, and thus other tests are used to predict surgical risk, among which is the stair-climbing test (SCT).⁷

There is a correlation between the results of VO₂ obtained on the ergospirometric test and various parameters obtained from the SCT, such as the estimated VO₂, height achieved,^{8,9} testing speed,¹⁰ desaturation during its performance,¹¹ and time spent to climb the steps.^{12,13}

As described in the literature, height is the main variable in SCT, not taking into account the time spent to reach it. On

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Abbreviations and Acronyms

FEV ₁	= forced expiratory volume in 1 second
Paco ₂	= arterial pressure of carbon dioxide
POC	= postoperative complication
ROC	= receiver operating characteristic
SCT	= stair-climbing test
SCt	= stair-climbing time
VO ₂	= maximal oxygen uptake

the basis of the findings by Cataneo and Cataneo,¹² our study proposes the use of stair-climbing time (SCt) as a predictor of POCs. Therefore, the present study aimed to determine whether the time for climbing all the steps during the SCT can be a predictor of post-thoracotomy complications and whether other tests, such as forced expiratory volume in 1 second (FEV₁) of spirometry, are capable of predicting POCs.

MATERIALS AND METHODS**Studied Population**

Inpatients from the Thoracic Surgery Ward of the Botucatu School of Medicine University Hospital, São Paulo State University, UNESP, were studied from June 2006 to July 2009. This project was approved by the institution's research ethics committee (REB398/06).

Patients aged more than 18 years with a recommendation of thoracotomy for major lung resection were included in the study. Patients with a history of unstable angina, myocardial infarction less than 3 months before surgery, decompensated heart failure, decompensated obstructive pulmonary disease, difficulties in walking (muscle skeletal, neurologic, or vascular alterations), and resting pulse rate greater than 120 beats/min were excluded.⁹

Measurements

Spirometry was performed according to the criteria by the American Thoracic Society¹⁴ on a Medgraphics Pulmonary Function System 1070 spirometer (Medical Graphics Corp, St Paul, Minn). The FEV₁ value was obtained in liters and predicted percentage.

The SCT was performed on shaded stairs with a 30-degree incline, which consisted of 6 flights with 12 steps each, thus totaling 72 steps. Each step measured 16.9 cm, with a total of 12.16 m in height. The patient was advised to climb all the steps at the shortest possible time with verbal stimulation standardized at every flight. Between the stair flights, the patient needed to take 2 or 3 steps, where speed should be maintained. The test would be interrupted by fatigue, intense dyspnea, thoracic pain, or exhaustion. The time in seconds that elapsed during the climb of the total height was denominated as the SCt. Stair-climbing power (P) was calculated as $P = m \times g \times h / \text{SCt}$, where *m* is the patient's body mass in kilograms, *g* is the acceleration of gravity (9.8 m/s²), *h* is the total height of the stairs in meters (12.16 m), and SCt is the time spent to climb all the steps. The VO₂ was estimated from SCt ($\text{VO}_{2t} = 43.06 - 0.4 \times \text{SCt}$) and $P (\text{VO}_{2P} = 15.9 + 0.048 \times P)$.¹³ All intraoperative complications and surgical duration were recorded. In the postoperative period, patients were followed up daily, and cardiopulmonary complications were recorded. The following events unrelated to the surgical technique were considered to be complications¹¹: myocardial infarction, congestive heart failure, arrhythmia, reintubation, orotracheal intubation for more than 24 hours after surgery, pneumonia, atelectasis requiring bronchoscopic aspiration, pulmonary thromboembolism, arterial pressure of carbon dioxide (Paco₂) of

50 mm Hg or more in patients who had normal Paco₂ preoperatively, acute pulmonary edema, and death. Postoperative hospitalization time and the time of maintenance of a thoracic drainage also were recorded.

Statistical Analysis

Patients were divided into 2 groups according to the absence (no POC group) or presence (POC group) of POCs. To define the cutoff points that could stratify surgical risk, SCt was categorized according to time as follows: less than 30 seconds, 30 to 50 seconds, and more than 50 seconds. Through these accuracy tests, predictive values for different SCt cutoff points were estimated. Two times (30 and 50 seconds) were selected to optimize the selection criteria: Patients who were able to climb all the steps in less than 30 seconds would have a low probability to develop POCs, and patients who took more than 50 seconds to climb all the steps would have a higher probability to develop POCs. SCt categorization for statistical analyses was based on previous studies.^{9,12,13} The receiver operating characteristic (ROC) curve also was applied for SCt. Such a curve was constructed on the basis of the variable that classifies the individuals with and without complications, and then showed through the other variable (SCt) the cutoff point by sensitivity and specificity analyses. Independent variables were tested for association with POCs (dependent variable). These variables initially underwent univariate analysis and then multivariate analysis (logistic regression). The continuous variables with normal distribution were compared by the Student *t* test for independent populations, and those that did not show normal distribution were compared by the Mann-Whitney test. The categorical variables were compared by the chi-square or Fisher exact test.

To test the association of variables with the presence of complications, logistic regression (full model) was performed. The dependent variable was the presence of complications, and the independent continuous variables were age, FEV₁, and SCt. Statistical analyses were performed by using SAS version 9.2 (SAS Institute Inc, Cary, NC).

RESULTS

Ninety-eight patients (60 male) were evaluated. Seventy-one patients (72.4%) had no POCs (no POC group), and 27 patients (27.6%) had POCs (POC group). Of the several complications found in the POC group, 15 patients had only 1 complication and 12 patients had 2 or more complications. Eleven patients had atelectasis, 10 patients had pneumonia, 7 patients had prolonged orotracheal intubation, 5 patients had arrhythmia, 5 patients had Paco₂ greater than 50 mm Hg, 2 patients had congestive heart failure, 2 patients were reintubated, 2 patients died, 1 patient had acute myocardial infarction, 1 patient had pulmonary thromboembolism, and 1 patient had acute pulmonary edema. Patients' characteristics are shown in Table 1.

By stratifying the patients according to SCt, it is observed that the lower the SCt, the lower the percentage of patients with complications. Of the patients who took less than 30 seconds to climb the stairs, 14% had POCs, increasing to 26% for those who took 30 to 50 seconds and to 60% for those who took 50 seconds or more to climb the stairs (Table 2). The rate of complications for patients who took 50 seconds or more to climb the stairs is 4.3-fold that of those who took less than 30 seconds (9/15 vs 4/29).

By applying the accuracy test for different cutoff points, it is observed that a patient's probability to show

TABLE 1. Characteristics of the studied patients in mean ± standard deviation values

Variable	No POC group mean ± SD	POC group mean ± SD	Total mean ± SD	P value
Age (y)	50.5 ± 17.4	58.4 ± 15.3	52.7 ± 17.2	.04
BMI (kg/m ²)	25.0 ± 5.0	25.5 ± 4.9	25.1 ± 5.0	.62
FEV ₁ (L)	2.4 ± 0.8	2.1 ± 0.6	2.3 ± 0.8	.08
FEV ₁ (%)	85.3 ± 26.1	72.0 ± 24.6	84.3 ± 25.6	.55
SCt (s)	35.8 ± 12.8	46.6 ± 17.4	38.7 ± 14.9	.005
P (w)	250.8 ± 94.8	193.4 ± 72.7	235.0 ± 92.5	.005
VO ₂ t (mL/kg/min)	28.8 ± 5.1	24.4 ± 7.0	27.6 ± 6.0	.005
VO ₂ P (mL/kg/min)	27.9 ± 4.5	25.2 ± 3.5	27.2 ± 4.4	.005
Smoking (pack-y)	21.7 ± 25.9	25.4 ± 26.4	22.8 ± 25.9	.53

POC, Postoperative complication; SD, standard deviation; BMI, body mass index; FEV₁, forced expiratory volume in 1 second; SCt, stair-climbing time; P (w), power expressed in watts; VO₂t, oxygen consumption estimated from SCt; VO₂P, oxygen consumption estimated from P.

complications if he/she climbs the stairs in less than 50 seconds is 60%, but if he/she climbs the stairs in less than 30 seconds, the probability decreases to 33.3% (Table 3). The cutoff point obtained by the ROC curve for SCt in this group of patients was 37.5 seconds (Figure 1).

There was no difference between the groups in occasional intraoperative complications or surgery duration (no POC group: 4.6 ± 1.9 hours; POC group: 5.0 ± 2.1 hours, *P* = .49). No statistically significant association was found between the presence of complications and the surgery type (lobectomy or pneumonectomy) (*P* = .52).

Patients in the POC group remained drained for 6.6 ± 3.8 days, and patients in the no POC group remained drained for 4.3 ± 1.9 days (*P* = .005). Postoperative hospitalization time was 5.6 ± 2.5 days in the no POC group and 13.7 ± 12.7 days in the POC group (*P* = .003).

By multivariate analysis, the only significant variable showing an association with POCs was SCt (odds ratio, 1.041; 95% confidence interval, 1.005-1.079) (Table 4). The risk of POCs increases 4% per second to climb the stairs.

DISCUSSION

The spirometric variables did not differ between groups, probably because both had capacities and volumes within or close to normality, and perhaps for that reason FEV₁ was not able to stratify the risk group. In other studies^{15,16} on patients undergoing thoracic surgery, there was no difference in spirometric variables when comparing the groups with and without POCs. In a previous study, when

TABLE 2. Cardiopulmonary complications stratified by time in stair-climbing test

SCt	<30 s (n = 29)	30-50 s (n = 54)	>50 s (n = 15)
Cardiopulmonary complications n (%)	4 (14)	14 (26)	9 (60)

SCt, Stair-climbing time. *P* = .0047.

TABLE 3. Predictive positive and negative values for different stair-climbing time cutoff points

SCt (s)	PPV (%)	NPV (%)
30	33.3	86.2
50	60.0	78.3

SCt, Stair-climbing time; PPV, positive predictive value; NPV, negative predictive value.

our group measured the accuracy of predictive tests for surgical risk using VO₂ as a gold standard,^{12,13} it was observed that FEV₁ both in liters and in predicted percentage showed low sensitivity and specificity to predict VO₂ values by not stratifying compromised patients, but only excluding those without clinical conditions for extensive resections.

Spirometry variables were close to normality in this population, showing that patients' pulmonary conditions were good despite their respiratory comorbidities and smoking. The American College of Chest Physicians establishes, as one of the guidelines for use of spirometry in the pulmonary resection postoperative period, that patients with an FEV₁ greater than 1.5 L can undergo lobectomy, and those with an FEV₁ greater than 2 L can undergo pneumonectomy, without the need of other tests, with level of evidence 1C.¹⁷ In the studied population of 59 patients with FEV₁ greater than 2 L, 14 had POCs, thus showing that spirometry alone is not capable of predicting risk and that other evaluations are required, because even patients with good pulmonary function and small resections had POCs. Likewise, another study¹⁸ found a complication rate after thoracotomy as high as the one presented in this study in patients who had normal FEV₁ (83.8% on average). When just elderly patients were included, even if they had Charlson Comorbidity index zero, the POCs were greater than 50%.¹⁹ Since the mid-20th century, studies have shown that mortality is

FIGURE 1. ROC curve for stair-climbing time sensitivity (true positive) and 1 - specificity (false positive). Cutoff point = 37.5 seconds (sensitivity = 67%, specificity = 69%), area = 0.725, standard deviation = 0.058, and *P* = .001. ROC, Receiver operating characteristic.

TABLE 4. Logistic regression

Variable	Estimation	SE	P value	OR (95% CI)
Constant	-2.254	1.475	.127	0.105
Age (y)	0.006	0.018	.727	1.006 (0.971-1.043)
FEV ₁ (L)	-0.304	0.352	.388	0.738 (0.370-1.472)
SCt (s)	0.040	0.018	.027	1.041 (1.005-1.079)

Dependent variable: POCs. Independent variables: age, FEV₁, and SCt. SE, Standard error; OR, odds ratio; CI, confidence interval; FEV₁, forced expiratory volume in 1 second; SCt, stair-climbing time.

correlated to the number of steps that the patient is able to climb during the SCT.^{20,21} Therefore, SCT can be complementary to spirometry.²² Although the SCT is extensively used, its performance has not been standardized; most literature data show the correlation between the height reached and POCs. Nevertheless, tests are performed on stairs of different sizes, where patients are advised to take their time during climbing and to climb as far as they can without stimulation, which always hinders comparisons.

Because the SCT has not been standardized, there is no agreement in the literature in regard to the minimum height to be reached by patients with complications, and it may range from 6.42 m¹⁶ to 16.23 m.²² However, a recent study showed that patients who reached a height less than 12 m during the SCT had higher mortality and POCs.¹¹ Nevertheless, height as an isolated variable is not significant, because an individual who takes 40 seconds to reach 12 m is different from one who takes 120 seconds.

A minimum height and the performance of verbal stimulation are still objects of investigation, although we believe that such variables will contribute to SCT standardization. The use of stair height alone may be a limitation in some hospitals, for example, in the Botucatu School of Medicine Hospital, which is mostly a horizontal hospital. However, according to the literature, high heights are not necessary, because 12 m was enough to identify complication risk. In a previous study performed by the current authors,¹² the use of stairs with a fixed height of 12.16 m was standardized in the hospital. On those stairs, all the steps should be climbed at the shortest time possible with verbal stimulation at each flight and using the time as the only variable. With this test, it was possible to accurately measure the power and the work performed during the climb, which would be proportional to the individual's functional capacity. Such standardization also allows for reproducing the test on any stairs with a minimum height of 12 m, which also can be compared with procedures in studies using speed,¹⁰ as shown by Cataneo and colleagues.¹³

The inclusion of the SCt as a variable is also important because it showed high correlation with the VO₂ obtained in ergospirometry,^{12,13} thus allowing the estimated VO₂ to be obtained.

The SCt in the POC group was longer than in the no POC group, and as SCt decreased, so did the number of

complications; in addition, the complication rate in those taking less than 30 seconds to climb all the steps was 4.3-fold less frequent than in those taking 50 seconds. A similar result was found by Brunelli and colleagues¹¹ for the height reached in the SCT, and not time, thus showing that the patients who climbed less than 12 m had twice as many complications as those who climbed more than 22 m.

The cutoff point for SCt to separate the groups found through the ROC curve was rather reduced, because the curve separates patients with and without complications in a population believed to have good physical performance. By using accuracy tests, previous studies^{12,13} observed that patients taking less than 40 seconds to climb all the steps were highly likely to show VO₂ greater than 25 mL/kg/min, which confirmed their good physical performance.

CONCLUSIONS

Although the evaluated patients were in good physical condition and the studied groups were similar, the SCT could stratify them, indicating that it would be useful and necessary to invest in prospective multicenter studies to standardize and validate the SCT for application in the preoperative period, because this is an inexpensive test that can be performed in most hospitals, as opposed to ergospirometry. In addition, such a test can identify alterations even in individuals with good physical performance, in whom FEV₁ in liters and predicted percentage could not.

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