Butler K, Patel J, Hodson J, Weblin J. Can the one-minute sit-to-stand test predict the development of post-operative hospital-acquired pneumonia in patients undergoing oesophagectomy: a service evaluation. *ACPRC Journal*. 2025;57(2):44-52. doi:10.56792/ARXF8356

Surgery

Can the one-minute sit-to-stand test predict the development of post-operative hospital-acquired pneumonia in patients undergoing oesophagectomy: a service evaluation

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Keywords: one minute sit to stand, risk stratification, oesophagectomy, post-operative outcomes, pneumonia

https://doi.org/10.56792/ARXF8356

Journal of the Association of Chartered Physiotherapists in Respiratory Care

Vol. 57, Issue 2, 2025

Abstract

Introduction

Oesophagectomy remains the only potentially curative treatment strategy for patients with oesophageal cancer. However, it is associated with high rates of post-operative pulmonary complications, including hospital acquired pneumonia (HAP), negatively impacting patient recovery and survival. Poor pre-operative functional status has been linked with increased post-operative morbidity and mortality. Validated pre-operative risk stratification assessments (e.g. the incremental shuttle walk test) are available to assess pre-operative fitness. However, many of these need to be performed in-person, or require equipment or adequate space. Restrictions during the COVID-19 pandemic meant that alternative assessment strategies needed to be used, with our institution selecting the one-minute sit-to-stand test (STS).

Aim

To assess the predictive accuracy of the STS at our institution, with respect to the primary outcome of HAP and secondary outcomes including hospital length of stay (LOS).

Method

A retrospective service evaluation was performed for patients undergoing pre-operative STS assessment prior to elective oesophagectomy for oesophageal cancer. The evaluation covered two periods when the STS was being used at our institution: July - December 2020 and April 2022 - May 2023. Predictive accuracy was quantified by the area under the receiver operating characteristic curve (AUROC) for the outcome of HAP, and Spearman's rho for LOS.

Results

The 55 patients achieved a mean (± standard deviation) pre-operative STS of 27 ± 9, and 13 (24%) developed HAP. STS was not found to be significantly predictive of HAP (AUROC: 0.48, 95% CI: 0.31-0.64, p=0.796). However, a significant association between STS and LOS was observed (rho: -0.37, p=0.005), with LOS reducing by 16% (95% CI: 2-28%) per five-point increase in the STS score.

Conclusion

The STS did not have clinical utility in identifying patients at risk of HAP after elective oesophagectomy at our institution. However, it may be useful in identifying patients who are likely to have an extended post-operative LOS. Further investigation of the STS is warranted, to validate these findings at other institutions, and identify the effectiveness of the STS in predicting other outcomes, particularly patient-centred outcome measures such as functional recovery and quality of life.

INTRODUCTION

Oesophageal cancer is the fourteenth most common type of cancer in England and Wales, with around 9,400 people diagnosed annually, and 3,733 patients undergoing potentially-curative oesophagectomy between 2019 and 2022.[1] Despite the implementation of Enhanced Recovery After Surgery (ERAS) protocols and advancements in surgical techniques, patients undergoing oesophagectomy for oesophageal cancer still experience high rates of post-operative morbidity and mortality,[2] with 24-40% of patients experiencing pulmonary complications such as hospital-acquired pneumonia (HAP), respiratory failure, or acute respiratory distress syndrome.[3-6] Post-operative complications after oesophagectomy, including HAP, have been shown to have a significant detrimental impact on longer-term patient survival.[2] In an attempt to improve these outcomes, there is an increasing focus on the assessment of patients' pre-operative functional capacity. The pre-operative functional status of patients can be used to guide the consent process and shared decision making; avoid decisional regret having undergone surgery[7]; plan best and individualised post-operative care; and to understand outcomes allowing for risk adjustment. Pre-operative risk stratification has also been utilised to guide prehabilitation requirements.[8]

The incremental shuttle walk test (ISWT) is an objective measure of functional capacity and physiological reserve.[9] Studies have suggested that a pre-operative mobilisation of <350m is indicative of a higher-risk patient, and is associated with significantly higher rates of post-operative complications and 30-day and three-year mortality in patients undergoing oesophagectomy.[10-12] However, the ISWT requires a face-to-face clinician/patient appointment, and adequate space to be performed. This caused challenges during the COVID-19 pandemic, due to many hospitals repurposing physiotherapy and rehabilitation space, and the need to move to virtual pre-assessment clinic appointments to adhere to social distancing guidelines.[13] As a result, alternative field tests to assess functional capacity were utilised, including the one-minute sit-to-stand test (STS). This has the benefits of needing minimal space and no equipment, other than a chair; and that it can be explained, administered and witnessed over a videocall, allowing for the test to be used in virtual clinic appointments.[14] Despite restoration of normal services post-pandemic, the STS continues to be widely used by clinicians as a measure of an individual's functional capacity, with outcomes of the STS contributing to multidisciplinary team (MDT) decision making relating to fitness for surgery.[15] However, whilst the STS is widely used in cardiothoracic pre-assessment, there is currently a lack of published research assessing its utility in predicting the risk of pulmonary complications in patients undergoing oesophagectomy.[16]

AIM

This service evaluation aimed to assess the clinical utility of performing the STS at the pre-operative assessment at our institution. Specifically, the primary aim was to assess the ability of the STS to predict the development of HAP after oesophagectomy. The secondary aims were to compare the performance of the STS to other risk assessment tools, and to assess associations with secondary outcomes, including length of stay and 90-day mortality.

METHODS

DESIGN

This was a single-centre service evaluation conducted in a large tertiary-level acute care hospital. This service evaluation was registered as an audit on the Clinical Audit Registration and Management System (CARMS) at University Hospitals Birmingham NHS Foundation Trust (UHB; audit ID: CARMS-19300).

SETTING

The Queen Elizabeth Hospital Birmingham (QEHB), UK, covers a population of 1.7 million. As a major tertiary upper gastrointestinal unit, it treats local and regional patients undergoing curative treatment for oesophageal cancer. Prior to oesophagectomy surgery, all patients attended a pre-assessment clinic, during which they were reviewed by a physiotherapist. However, due to funding limitations, during periods of annual leave and sickness, a physiotherapist was unable to join pre-assessment clinics to perform this review. Prior to the COVID-19 pandemic, an ISWT was performed during the clinic to quantify functional capacity and physiological reserve. However, due to social distancing requirements, this was substituted for the STS between July 2020 and December 2020. Due to re-deployment of physiotherapy staff during the COVID-19 pandemic, there was a hiatus in physiotherapy attendance at pre-assessment clinic subsequently. When staff returned to their previous duties in May 2021, the STS was replaced with the ISWT. However, the STS then was reimplemented for a second period between April 2022 and May 2023, due to a repurposing of therapy space, which left insufficient room for the ISWT to be performed.

PARTICIPANTS

The service evaluation included a convenience sample of consecutive patients attending pre-assessment clinics between the two periods when STS was being used (July 2020 - December 2020 and April 2022 - May 2023). Patients were included if they had been listed for an elective oesophagectomy for oesophageal cancer, and completed the STS as part of pre-assessment within 90 days prior to surgery. Patients were excluded if they did not complete the STS or did not proceed to surgery.

PROCEDURE

Since the first period of the service evaluation commenced during the COVID-19 pandemic, patients either attended in-person clinics, or were assessed in virtual clinics using videocalls, depending on the prevailing social distancing guidelines. For patients reviewed by a physiotherapist during their pre-assessment clinic, the STS was completed according to a standardised protocol, which involved patients completing as many sit to stands from a chair as possible within one minute.[17] The STS was then repeated after a 15-minute break, with the second result recorded, to negate the learning effect.[18] After performing the STS, patients were asked to rate their perceived level of exertion on the Borg scale, giving a score in the range of 6-20.[19] Observations performed at the pre-operative assessment, along with the details of the planned operative approach were then used to calculate the ARISCAT score.[20] The ARISCAT is validated risk tool for prediction of perioperative pulmonary complications devised from a heterogeneous surgical cohort.[21] The clinician additionally recorded the Eastern Cooperative Oncology Group (ECOG) performance status for each patient.[22]

Post-operatively, all patients received standard care as normally provided in our institution. This consisted of an ERAS pathway, including daily reviews by a physiotherapist for the provision of respiratory care and progression of mobility. The level of mobility at each of these reviews was quantified using the Manchester Mobility Scale (MMS).[23]

OUTCOMES

The primary outcome was diagnosis of HAP from any cause, including ventilator-acquired pneumonia, as defined by the US Centres for Disease Control.[24(pp327-330)] Specifically, this included the presence of a chest radiograph (or two in patients with underlying pulmonary or cardiac disease), with at least one of the following:

1. New or progressive and persistent infiltrates;
2. Consolidation;
3. Cavitation ***AND*** symptoms of HAP

For the final point, symptoms of HAP were defined as the combination of at least one of the following:

Fever (>38ºC) with no other recognised cause; leucopoenia (white cell count $<4x10^9 litre^{-1}$); leucocytosis (white cell count $>12x10^9 litre^{-1}$); ***OR*** altered mental status with no other recognised cause (for adults >70 years old);

AND at least two of the following

1. New-onset of purulent sputum or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements;
2. New-onset or worsening cough, or dyspnoea, or tachypnoea;
3. Rales or bronchial breath sounds;
4. Worsening gas exchange (hypoxaemia, increased oxygen requirement, or increased ventilator demand).

HAP diagnoses were made by retrospective review of patient notes on the electronic health record (EHR) system by the study authors.

Secondary outcome measures included the number of days from surgery to achieving an MMS score of seven (MMS7; defined as mobilising ⩾30m), as well as the lengths of stay in the ICU and hospital, and 90-day mortality.

DATA COLLECTION

Clinically-relevant variables relating to patient characteristics, treatment and outcomes were chosen *a priori*, and retrospectively extracted from the EHR. Specifically, these comprised patient demographics, pre-operative assessments of functional capacity, use of neoadjuvant chemotherapy, surgical approach, post-operative analgesia modality, and post-operative MMS assessments. Dates of admission, discharge, and death were additionally extracted, and used to calculate lengths of stay and survival times.

STATISTICAL METHODS

Association between patient characteristics and HAP were performed using Mann-Whitney U tests for ordinal or continuous variables, or Fisher's exact tests for nominal variables. The predictive accuracy of the STS with respect to HAP at our institution was then assessed using a receiver operating characteristic (ROC) curve, which was quantified using the area under the ROC curve (AUROC). This analysis was also performed for the other risk stratification tools and assessments of functional capacity. The association between the STS and HAP rates was further assessed using a univariable binary logistic regression model, with the STS as a continuous covariate.

The relationships between the STS and other outcomes were then analysed, with the associations initially being quantified using Spearman's rank correlation coefficients (rho). Univariable regression models were then produced, with the STS a covariate, and the outcome of interest as the dependent variable. Outcomes were $\log_2$-transformed prior to analysis, to reduce the level of skew in the distribution and improve model fit. The coefficients from the resulting models were then anti-logged and converted into percentage changes per five-point increase in the STS, for ease of interpretation.

All analyses were performed using IBM SPSS v29 (IBM Corp. Armonk, NY), with $p<0.05$ deemed to be indicative of statistical significance throughout. Continuous variables are reported as *mean* ± *standard deviation*, where approximately normally distributed, or as *median (interquartile range; IQR)* otherwise. Cases with missing data were excluded from the analysis of the affected variable.

SAMPLE SIZE CALCULATION

Since the service evaluation was based on a retrospective convenience sample of patients, it was based on a fixed sample size. As such, rather than performing a sample size calculation *a priori* to determine the required sample size,

a *post hoc* power calculation was instead used, to assess the feasibility of performing the service evaluation with the available sample size. Based on the included sample size (N=55) and HAP prevalence (24%), a *post hoc* power calculation for the primary aim of assessing the ability of the STS to predict the development of HAP returned a minimal detectable AUROC of 0.75 at 80% power and 5% alpha. Whilst this represented a relatively large effect size, this was within the range of AUROC values deemed by Hosmer et al. to be indicative of "acceptable" discriminative accuracy (i.e. an AUROC of 0.70-0.79).[25] As such, it was concluded that, whilst the service evaluation would be underpowered to detect small-to-moderate effect sizes, such effects would likely represent insufficient predictive accuracy for the STS to be deemed to have clinical utility. As such, the sample size was deemed sufficient to achieve the primary aim of the service evaluation.

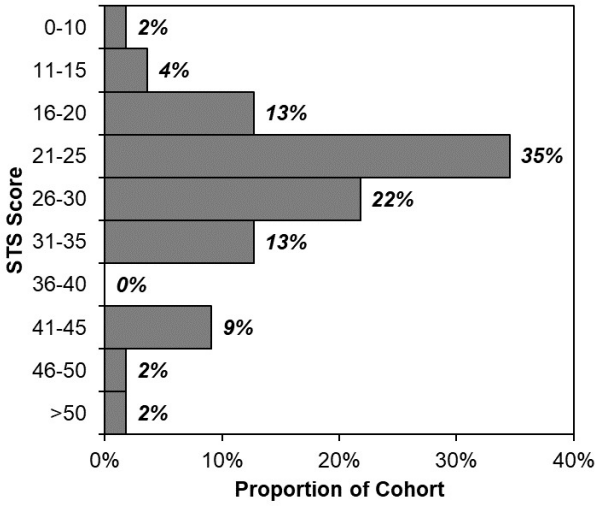

Figure 1. Distribution of pre-operative STS scores

STS: One-minute sit-to-stand test.

RESULTS

COHORT CHARACTERISTICS

In total, 87 patients underwent oesophagectomy surgery during the service evaluation periods, of whom 32 (37%) did not complete the STS at the pre-assessment, due to the absence of a physiotherapist at the clinic. This was largely a consequence of staffing limitations, either due to insufficient clinical capacity or redeployment due to the COVID-19 pandemic. The 55 who completed the STS and were included in the service evaluation had a mean age of 64±8 years and 71% were male. A total of 13 (24%) of these patients developed HAP; comparisons between these cases and the remainder of the cohort found no significant differences in demographic- or treatment-related factors (***Table 1***). Development of HAP was not found to be significantly associated with the MMS scores on post-operative day one (p=0.802). However, there was a non-significant tendency for patients developing HAP to have a lower MMS score on post-operative day two (p=0.053) and to take longer to achieve an MMS score of seven (median: 6 vs. 4 days p=0.057). HAP was associated with significantly longer lengths of stay in ITU (median: 7 vs. 3 days, p=0.022) and hospital (median: 20 vs. 13 days, p=0.022).

ASSOCIATION BETWEEN STS AND HAP

At the pre-operative assessment, a median of 11 days (IQR: 7-25; maximum: 87) prior to surgery, patients achieved a mean STS score of 27 ± 9, with scores ranging from 10 to 53 (***Figure 1***). The STS score was not found to be significantly predictive of HAP (p=0.796), with an AUROC of 0.48 (95% CI: 0.31-0.64; ***Table 2***, ***Figure 2***). The fact that this was <0.5 implies that the direction of the effect was the opposite to what was anticipated *a priori* (i.e. higher STS scores were associated with marginally higher risk of HAP).

ASSOCIATION BETWEEN OTHER ASSESSMENTS AND HAP

The other risk stratification tools or assessments of functional capacity considered had similarly poor performance to that of the STS, with none found to be significantly predictive of HAP (i.e. Borg score, ARISCAT score or ECOG performance status; **Table 2**). Again, all scores had AUROC values that were <0.5, implying that any trends for these scores were in the opposite direction to what was anticipated *a priori* (i.e. higher scores were associated with lower risk of HAP).

ASSOCIATIONS BETWEEN STS AND SECONDARY OUTCOMES

Significant negative correlations were observed between the STS and the time from surgery to achieving an MMS of seven (rho: -0.48, p<0.001), ICU length of stay (rho: -0.28, p=0.041) and hospital length of stay (rho: -0.37, p=0.005). Regression modelling estimated an increase of five points on the STS to be associated with a 23% (95% CI: 11-34%) reduction in the time from surgery to achieving an MMS of seven, a 16% (95% CI: 2-28%) reduction in the ICU length of stay, and an 11% (95% CI: 0-20%) reduction in the hospital length of stay (**Figure 3**). Analysis of 90-day mortality was not performed, due to the low event rate (4%; n=2).

DISCUSSION

This single-centre service evaluation found the STS to have no clinical utility for predicting the development of HAP in patients undergoing elective oesophagectomy at our institution. Other measures of functional capacity, such as the ISWT, have previously been shown to offer better predictive accuracy for post-operative outcomes in this patient cohort.[10-12] Unlike the ISWT, the STS is dependent on participant motivation, due to a lack of external pacing.[26] The STS also lacks specificity to assess cardiovascular fitness, with performance potentially limited by lower limb muscle weakness rather than aerobic capacity.[27] However, it was not possible to assess the ISWT in the present evaluation,

Table 1. Cohort characteristics

	Whole Cohort (N=55)	Hospital-Acquired Pneumonia		p-Value
		No (N=42)	*Yes (N=13)*	
Age (Years)	64 ± 8	64 ± 7	65 ± 11	0.481
Male Gender	39 (71%)	28 (67%)	11 (85%)	0.304
BMI (kg/m^2)	25.8 (23.2-30.0)	25.9 (23.9-30.1)	25.6 (23.0-28.3)	0.692
Smoking History				0.192
Never	16 (29%)	14 (33%)	2 (15%)	
Previous	21 (38%)	17 (40%)	4 (31%)	
Current	18 (33%)	11 (26%)	7 (54%)	
Neoadjuvant Chemotherapy	47 (85%)	34 (81%)	13 (100%)	0.176
Type of Procedure				0.423
Open	11 (20%)	7 (17%)	4 (31%)	
Hybrid	40 (73%)	31 (74%)	9 (69%)	
Minimally invasive	4 (7%)	4 (10%)	0 (0%)	
Post-operative Analgesia				0.110
Epidural	25 (45%)	22 (52%)	3 (23%)	
Block	30 (55%)	20 (48%)	10 (77%)	
MMS on Post-operative Day 1				0.802 [a]
1-3	18 (33%)	14 (33%)	4 (31%)	
4-5	31 (56%)	23 (55%)	8 (62%)	
6-7	6 (11%)	5 (12%)	1 (8%)	
MMS on Post-operative Day 2				0.053 [a]
1-3	16 (29%)	12 (29%)	4 (31%)	
4-5	28 (51%)	19 (45%)	9 (69%)	
6-7	11 (20%)	11 (26%)	0 (0%)	
Surgery to Achieving MMS 7 (Days) [b]	4 (3-8)	4 (2-8)	6 (5-19)	0.057
ITU Length of Stay (Days)	4 (2-8)	3 (2-6)	7 (5-15)	**0.022**
Hospital Length of Stay (Days) [c]	14 (11-28)	13 (10-21)	20 (13-62)	**0.022**
90-Day Mortality	2 (4%)	1 (2%)	1 (8%)	0.420

Continuous variables are reported as "mean ± standard deviation" or "median (interquartile range)", with p-values from Mann-Whitney U tests. Categorical variables are reported as "N (column %)", with p-values from Fisher's exact tests, unless stated otherwise. Bold p-values are significant at p<0.05. [a] p-Value from a Mann-Whitney U test on the ungrouped MMS data, as the factor is ordinal. [b] One patient was discharged on post-operative day 62 without achieving MMS7; a value of 99 days was assumed for analysis. [c] One patient died in hospital on post-operative day 109; hence, this was used as their length of stay. ITU: Intensive treatment unit, MMS: Manchester Mobility Score.

since the patients in this cohort did not undergo this assessment.

To our knowledge, this is the first published service evaluation to examine the use of the STS as a predictor of HAP in patients undergoing oesophagectomy. Notably, smaller studies within the thoracic surgery population, including those involving minimally invasive approaches, have indicated that completing ⩽20–22 repetitions in the STS test may be associated with a higher incidence of post-operative complications.[16] Direct comparison between patients undergoing thoracic surgery and those receiving oesophagectomies is inherently limited. Unlike standard thoracic procedures, oesophagectomies involve dual cavity access and significantly prolonged anaesthesia durations, both of which contribute to a heightened vulnerability to post-operative complications, including HAP.[3-6]

Analysis of the secondary outcomes found the STS to be significantly associated with the time taken to achieve MMS 7 (i.e., mobilising ⩾30m) post-operatively, as well as the ICU and hospital length of stay. Therefore, the STS may have some utility in targeting finite physiotherapy resources to patients who may see the greatest benefit, both with respect to prehabilitation and in the post-operative period. The STS may be particularly useful in situations where space or resources are limited, or where in-person clinic appointments are challenging or impossible for patients to attend, given that it can be performed during a virtual appointment and only requires a chair.[14]

Our service evaluation also highlights the likely frailty of the patients undergoing oesophagectomy at our institution. With a mean age of 65 years, the mean STS of 27 was considerably lower than the average age-matched healthy individual, which has been reported as 35 in males and 33 in females.[28] This could be contributing to the high rates of post-operative morbidity observed, specifically the HAP rate of 24%, although this is similar to other studies reporting pneumonia rates of ~22%.[29]

Table 2. Associations between pre-operative assessments of functional capacity and hospital-acquired pneumonia

		Hospital-Acquired Pneumonia			
	Whole Cohort (N=55)	***No (N=42)***	***Yes (N=13)***	**AUROC (95% CI)**	**p-Value**
Pre-op. Assessment to Surgery (Days)	11 (7-25)	11 (7-18)	16 (7-30)	-	0.585
STS	27 ± 9	27 ± 9	27 ± 7	0.48 (0.31-0.64)	0.796
Borg Score	13 ± 3	13 ± 3	12 ± 3	0.45 (0.27-0.63)	0.596
ARISCAT Score				0.44 (0.25-0.62)	0.302
47	4 (7%)	2 (5%)	2 (15%)		
50	45 (82%)	35 (83%)	10 (77%)		
58	3 (5%)	3 (7%)	0 (0%)		
61	3 (5%)	2 (5%)	1 (8%)		
ECOG Performance Status				0.41 (0.24-0.59)	0.310
0	24 (44%)	17 (40%)	7 (54%)		
1	21 (38%)	16 (38%)	5 (38%)		
2	7 (13%)	7 (17%)	0 (0%)		
3	3 (5%)	2 (5%)	1 (8%)		

Data are reported as "mean ± standard deviation", "median (interquartile range)", or "N (column %)", as appropriate, with p-values from Mann-Whitney U tests; bold p-values are significant at p<0.05. AUROCs are reported anticipating that a higher score would be associated with a higher risk of HAP for all assessments, except for STS, where lower scores were anticipated to be associated with a higher risk of HAP. As such, AUROCs <0.5 indicate that the association between the assessment is in the opposite direction to what was anticipated a priori. AUROC: area under the receiver operating characteristic curve, Pre-op.: Pre-operative, STS: One-minute sit-to-stand test.

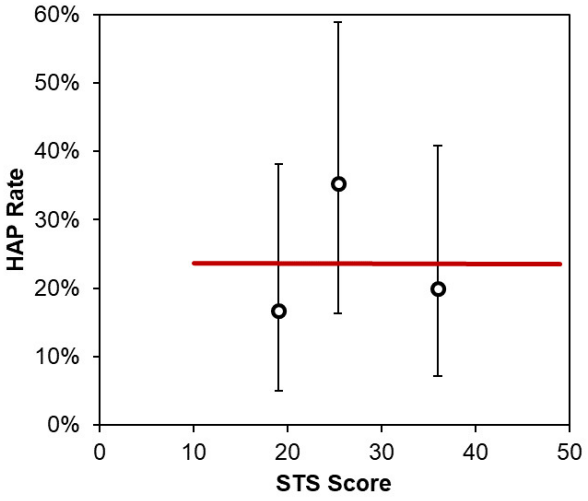

Figure 2. Association between pre-operative STS score and hospital-acquired pneumonia

Points represent the observed HAP rates within subgroups of patients defined by the tertiles of STS scores (<23, 23-28 and >28), and are plotted at the mean of the interval; whiskers represent 95% confidence intervals. The trend line is from a binary logistic regression model on the patient-level data, with the STS score as a continuous covariate. HAP: Hospital-acquired pneumonia, STS: One-minute sit-to-stand test.

LIMITATIONS

The primary limitation of this service evaluation was the small sample size, particularly in the HAP group, which will have resulted in low statistical power. The *post hoc* power calculation for the primary outcome of HAP returned a minimal detectable AUROC of 0.75 at 80% power and 5% alpha, which was within the range deemed by Hosmer et al.[25] to be indicative of "acceptable" accuracy (i.e. 0.70-0.79). As such, this service evaluation is likely underpowered to identify pre-operative assessments that had small-to-moderate accuracy in identifying patients at risk of developing HAP. Consequently, the findings need to be interpreted in the light of the increased risk of false-negatives. The second limitation was that this is a single-centre service evaluation; hence, the results are not necessarily generalisable to other centres. However, an evidenced-based ERAS pathway was used throughout the period of the evaluation to standardise post-operative care; hence, the findings should be consistent with other centres that use a similar approach. Finally, the pre-operative assessments included a mixture of virtual and face-to-face appointments, which may have introduced some heterogeneity when performing the physical assessments. However, a standardised methodology was used, regardless of the type of appointment, which should have minimised the level of such heterogeneity.

CONCLUSION

In the drive to identify novel, alternative and cost-effective pre-assessment tools to risk stratify oesophagectomy patients for post-operative HAP, our single-centre service evaluation has added to the void of evidence. The STS was a poor predictor of post-operative HAP at our institution; however, it was found to have some utility in identifying patients at risk of extended post-operative hospital stays. Further research is required to identify the clinical utility of the STS in oesophagectomy, ideally with a larger sample size, comparisons to other similar assessments of physical

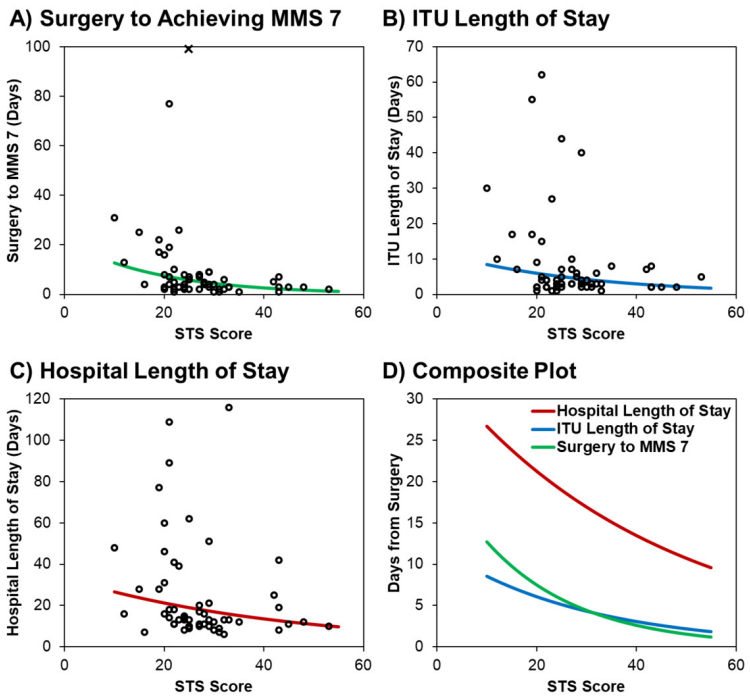

Figure 3. Associations between pre-operative STS score and other outcomes

Points represent individual patients, and plots are based on N=55. Trend lines are from regression models, with the STS score as a covariate, and the $\log_2$-transformed number of days as the dependent variable. All three models are then plotted together in Figure D, to illustrate the trends more clearly. In Figure A, the point indicated by crosses represents a patient who had not achieved MMS 7 at hospital discharge; this is plotted at 99 days, on the assumption that this patient would have the longest time to MMS 7 in the cohort. ITU: Intensive treatment unit, MMS: Manchester Mobility Scale, STS: One-minute sit-to-stand test.

function (e.g., the ISWT), and assessing a broader range of outcomes, particularly patient-centred outcome measures, such as functional recovery and quality of life.

Key Points

- The one-minute sit-to-stand test was not found to be predictive of the development of post-operative hospital acquired pneumonia in patients undergoing an oesophagectomy at out centre.
- However, it may have some utility in predicting time to mobilise, ICU and hospital length of stay.

CONFLICTS OF INTEREST/COMPETING INTERESTS

The authors have no conflicts of interest to declare

FUNDING

No additional funding was received to complete this project

Submitted: February 03, 2025 GMT. Accepted: September 18, 2025 GMT. Published: November 01, 2025 GMT.

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