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Thoracic enhanced recovery with ambulation after surgery: a 6-year experience

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Abstract

OBJECTIVES: Our institution implemented a protocol known as thoracic enhanced recovery with ambulation after surgery (T-ERAS) in thoracic operations. The objective was early ambulation starting in the postoperative ambulatory care unit.

METHODS: Video-assisted thoracoscopic surgery lobectomy patients are placed on a chair in the preoperative area and then walked to the operating room. Postoperatively, patients are placed on a chair as soon as possible. Our target ambulation goal was 250 feet within 1 h of extubation. Patients then walk to their hospital room. T-ERAS adoption and outcomes were compared to a pre-T-ERAS period, in addition to the comparing early and late T-ERAS cohorts.

RESULTS: Over 6 years, 304 patients on T-ERAS underwent a planned video-assisted thoracoscopic surgery lobectomy. Median age was 67 years (range 41–87 years). The target goal was achieved in 187 of 304 (61.5%) patients and 277 of 304 (91.1%) patients ambulated 250 feet at any time in the postoperative ambulatory care unit. The T-ERAS period had a median length of stay of 1 day vs 2 days in the pre-T-ERAS period ($P < 0.001$). There were low rates of pneumonia (2/304, 0.7%), atrial fibrillation (12/304, 4.0%) and no postoperative mortalities for T-ERAS. The target goal was achieved at a greater rate in the late (92/132, 72.0%) versus early (28/75, 37%) T-ERAS cohort. The mean time to ambulation was reduced in the late cohort (46–81 min).

CONCLUSIONS: Early postoperative ambulation was feasible and considered key in achieving low morbidity after video-assisted thoracoscopic surgery lobectomy. Adoption of T-ERAS improved over time. Further studies will help define adoptability at other sites and validate impact on improving outcomes.

Keywords: Early ambulation • Video-assisted thoracoscopic surgery lobectomy • Enhanced recovery after surgery

INTRODUCTION

Over the past 25 years, there has been tremendous development and adoption of video-assisted thoracoscopic surgery (VATS) lobectomy by centres around the world [1, 2]. Although minimally invasive approaches can decrease morbidity and enhance recovery compared to thoracotomy, there is potential to further improve clinical outcomes. Institutions utilizing enhanced recovery after surgery or enhanced recovery with ambulation after surgery (ERAS) protocols offer an opportunity to accentuate the efficacy of minimally invasive procedures [3]. A key component of most ERAS programmes is early postoperative ambulation [4]. In July 2010, our institution implemented an early ambulation protocol known as 'thoracic enhanced recovery with ambulation after surgery (T-ERAS)'. This fast-track recovery programme originated as a quality improvement initiative which aimed to optimize the benefits of minimally invasive approaches on our thoracic surgery service.

Over the last 6 years, 1172 thoracic surgery patients have entered the T-ERAS protocol. The current report focuses on patients undergoing video-assisted thoracoscopic surgery (VATS) lobectomies. The T-ERAS protocol involves ambulation instituted within 1 h of extubation after a VATS resection. The successful implementation of this programme has required strong interdisciplinary partnerships with nursing, anaesthesia and administration. Details of the T-ERAS protocol and results after planned VATS lobectomy are presented below.

MATERIALS AND METHODS

This is an institutional review board-approved, single-centre, retrospective analysis of a quality improvement protocol. This report includes 2 cohorts of patients who were scheduled for a VATS lobectomy. The T-ERAS cohort consists of patients from July 2010 to July 2016 and recovered in a dedicated, cardiothoracic, postoperative ambulatory care unit (PACU). The pre-T-ERAS cohort consists of patients from June 2007 to June 2010, which was analysed as a historical comparison cohort. Fig. 1 shows the study flowchart of inclusion and exclusion criteria. The T-ERAS protocol consists of 4 phases of care: preoperative, intraoperative, PACU and step-down unit (Fig. 2).

Preoperative phase

Prior to surgery, patients are counselled about the ambulation protocol. All key members of the patient's social support network, (the 'family') are invited for this discussion. The patient and their family are encouraged to take a brisk walk (or an equivalent or more vigorous activity) for 20 min, 3 times per day, prior to surgery. Smoking cessation is required, with a 3-week period of complete smoking cessation prior to the date of operation. Members of the patient's household and family are all encouraged to quit smoking. Our pain management philosophy revolves around setting appropriate patient-centred expectations. This includes a discussion of the use of a minimally invasive approach, local anaesthetic techniques to minimize opioid use and the health benefits of early postoperative ambulation. Reasonable expectations for pain tolerance are set. The family, friends and healthcare team are charged with the responsibility of successful execution of this philosophy.

On the day of surgery and arrival to the preoperative area, the patient is placed in a chair rather than a bed. Expectations for postoperative ambulation are reiterated by all members of the care team. The patient walks from the preoperative area to the operating room and is assisted onto the operating room table. Phase 1 is designed to support full patient autonomy and is vital in addressing the aim to decrease preoperative 'medical' intervention and priming the patient and their family for success after surgery.

Intraoperative phase

To minimize barriers to an early ambulation, the use of central or arterial lines are employed in only necessary cases. Urinary and epidural catheters are avoided when possible. To prevent hypothermia, the operating room temperature is kept at 24°C and warming blankets are used. Intravenous fluids are minimized (goal <100 cc/h) throughout surgery. If intraoperative hypotension occurs, it is treated with phenylephrine. Anaesthetic management is focused on reducing the need for postoperative

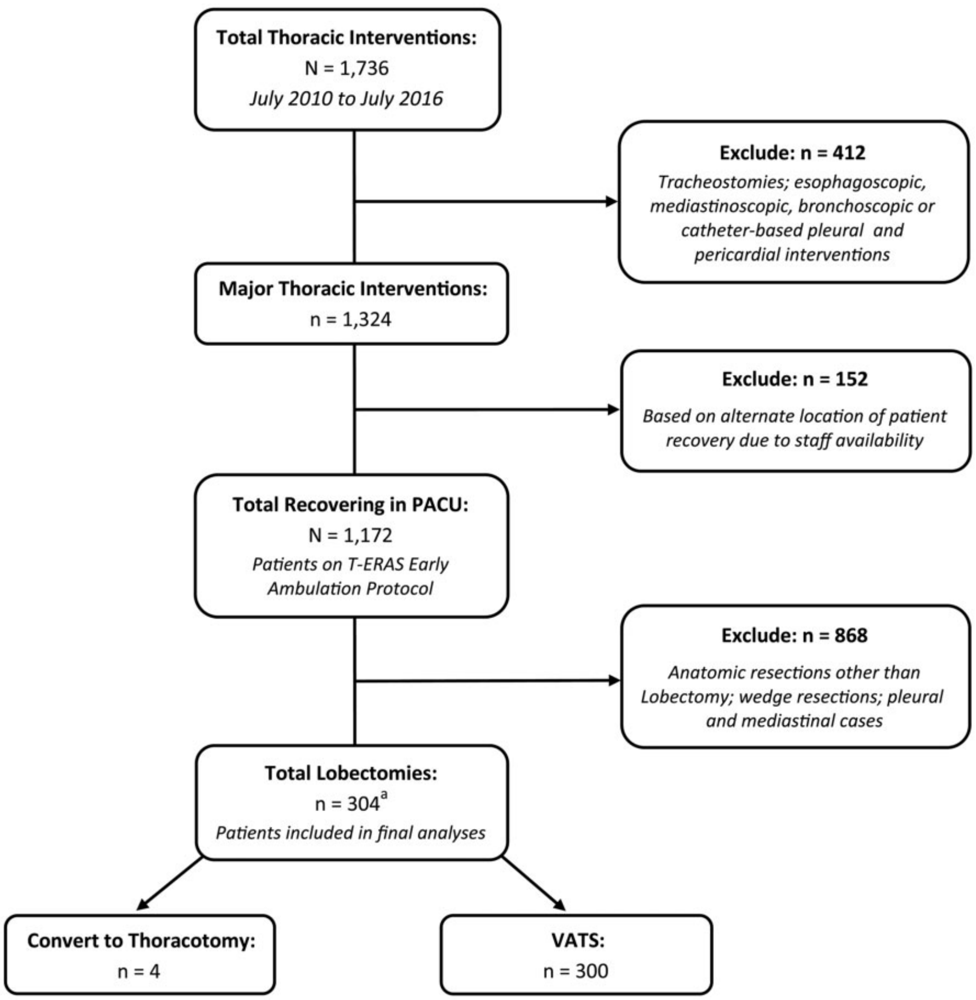

Figure 1: Study flowchart for T-ERAS patients from July 2010 to July 2016. [a]All VATS lobectomies ($n = 100$) from the pre-T-ERAS period (2007–2010) are not represented in chart but used as the historical cohort for Tables 1 and 2. PACU: postoperative ambulatory care unit; T-ERAS: thoracic enhanced recovery with ambulation after surgery; VATS: video-assisted thoracoscopic surgery.

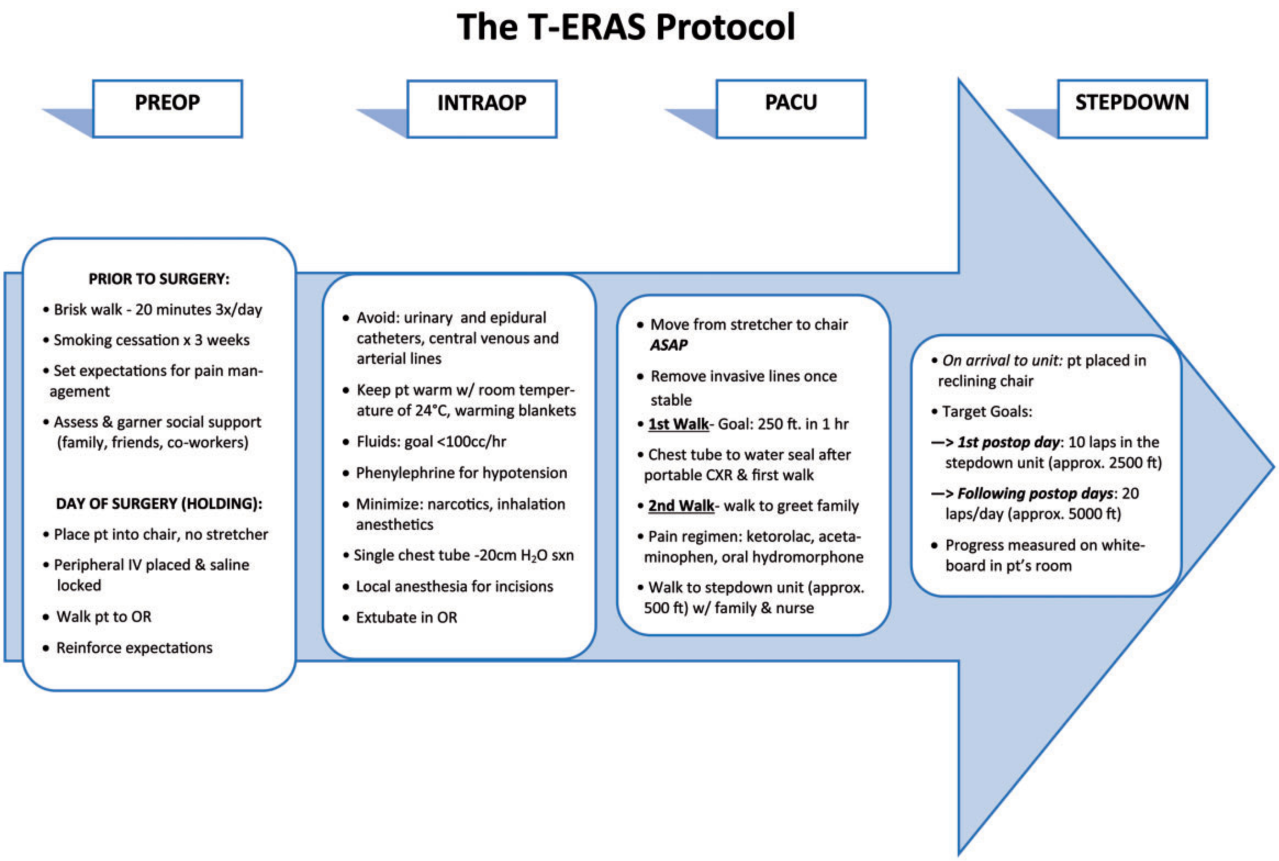

Figure 2: Key components of the T-ERAS protocol by operative stage. ASAP: as soon as possible; CXR: chest X-ray; INTRAOP: intraoperative; IV: intravenous; OR: operating room; PACU: postoperative ambulatory care unit; postop: postoperative; PREOP: preoperative; pt: patient; sxn: suction w/: with; T-ERAS: thoracic enhanced recovery with ambulation after surgery; w/: with.

opioid use and inhalation agents. A minimally invasive approach with no rib spreading is employed. A single chest tube is placed to -20 mmHg suction. A subcutaneous incision site injection with 10–20 ml of 0.25% bupivacaine is placed at the end of the VATS procedure. Epidural catheters are not used after VATS lobectomy, and if thoracotomy is undertaken, an On-Q® system is placed. The patient is routinely extubated in the operating room. During the 6-year period, the thoracic surgery service conducted a randomized controlled trial using the On-Q (catheter-based pump delivery) system and a single-blinded randomized controlled trial study on the benefits of Exparel® (liposomal bupivacaine), which is currently in the data analysis phase [5].

Postoperative ambulatory care unit phase

Upon arrival to the PACU, the patient is carefully placed on a chair as soon as safely possible. If the patient is clinically stable, all invasive monitoring lines, if present, are removed. Within 1 h of extubation, the patient is assisted in ambulation by the nursing staff. An initial target goal for walking distance is set to 250 feet. If the target time and distance goals are not met upon the initial attempt, a comment is recorded by the PACU nurse, and repeat attempts are made until the target distance is met, and this time is then recorded. The patient will greet the family during the 2nd walk in the PACU. Pain medications in the PACU include ketorolac, acetaminophen and oral hydromorphone. Intravenous opioids are avoided. The chest tube is placed to water seal after review of the chest radiograph. When cleared by the PACU nurses, the patient will walk to the step-down unit (~500 feet from the PACU) with the family and PACU nurse in attendance.

Step-down unit phase

On arrival to the step-down unit, the patient is placed in a reclining chair rather than a hospital bed. Upright positioning facilitates pulmonary toilet and encourages a sense of well-being, not only for the patient but is also helpful for the family members to see the patient in this state shortly after an operation. The target ambulation goal on the operative day is 10 laps around the step-down unit (~2500 feet). On the following postoperative days, the target goal is at least 20 laps. A checkbox is placed on a whiteboard in the patient's room, and each lap walked is checked off when completed (Fig. 3). The chest tube is removed on the day of discharge, typically postoperative Day 1 or 2. If an air leak persists but the patient is otherwise stable and prepared for discharge, i.e. ambulating well, good pulmonary toilet, a well-expanded lung on chest radiograph and tolerable pain, then the patient is discharged with the chest tube connected to a portable chest drainage canister.

Data collection and analysis

The primary ambulation target goal was the ability to walk 250 feet within 1 h after extubation. Early ambulation data in the

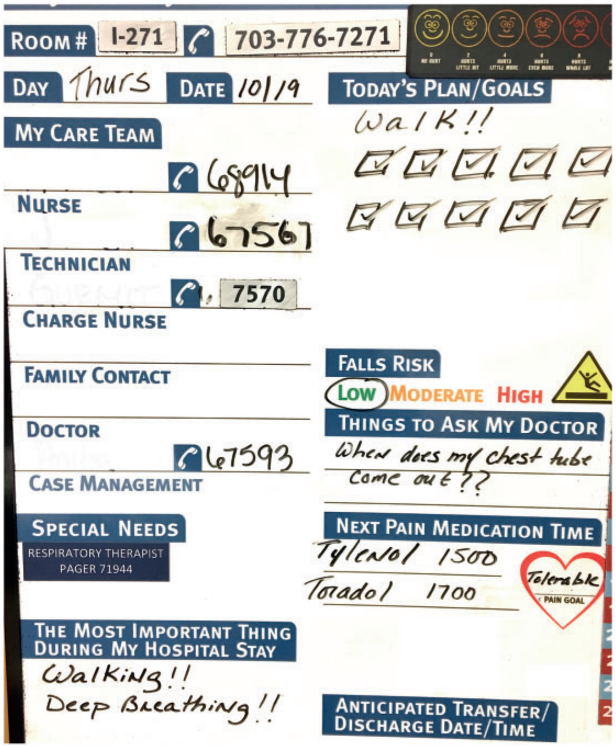

Figure 3: Whiteboard in patient room with the number of laps completed.

PACU was prospectively collected on all patients as part of this quality improvement project. The following data points were included: time of extubation, time to ambulation, distance ambulated and a comment if the target goal was not met. Data collection was kept active for the duration of time spent in the PACU.

Retrospective chart review for 30-day complications was undertaken and descriptive statistics are presented. The learning curve for the adoption of the T-ERAS protocol was analysed by comparing the early cohort (July 2010–July 2012) and the late cohort (July 2014–July 2016). In order to assess the benefits of T-ERAS, and whether more experience with ambulation translated into better outcomes, length of stay (LOS) and 30-day complication rates were evaluated for the pre-T-ERAS and T-ERAS periods. Additionally, LOS and 30-day complication rates were analysed for the early and late T-ERAS cohorts. Statistical tests of the Pearson's χ^2 test or Fisher's exact test for dichotomous outcome variables and Mann–Whitney–Wilcoxon rank-sum test for continuous variables were used to evaluate differences among the subsets. *P*-values of $<$ 0.05 were considered statistically significant. All statistical analysis was performed in R (R Core Team, Vienna, Austria) [6].

RESULTS

From July 2010 to July 2016, 304 patients scheduled for VATS lobectomy were analysed with respect to postoperative ambulation, complications and clinical outcomes. There were 4 cases converted to thoracotomy (4/304, 1.3%), 3 due to the tumour size and location favouring an open approach and 1 for bleeding that could not be controlled thoracoscopically. The median age was 67 (range 41–87) years and included 126 men and 178 women. Patient characteristics are summarized in Table 1.

The ambulation target goal distance of 250 feet within 1 h of extubation was achieved in 187 of 304 (61.5%) patients. Additionally, 208 of 304 (68.4%) patients were able to ambulate any distance within the 1st h and 288 of 304 (94.7%) patients ambulated any distance within 2 h. Only 3 (1.0%) patients were unable to ambulate at all in the PACU. The reasons for failure to ambulate included 2 cases of hypotension requiring vasopressors and 1 case of orthostatic hypotension with severe nausea. The 2 patients requiring vasopressors were transferred to the intensive care unit from the PACU and not to the step-down unit. These were the only patients in the cohort requiring intensive care unit monitoring. Comparison of patient outcomes and ambulation measures from our early and late cohorts are summarized in Tables 2 and 3, respectively. The target goal of 250 feet within 1 h of extubation was achieved in only 28 of 75 (37%) of the early cohort compared to 92 of 132 (72.0%) in the late cohort ($P < 0.001$). Several outcomes related to the timing of ambulation were significantly improved in the late cohort.

For the total VATS lobectomy sample population during the T-ERAS period, the median LOS was 1 day (interquartile range 1–1.25 days) postoperatively. Outcomes were then compared to all patients undergoing VATS lobectomy ($n = 100$) in the pre-T-ERAS period (June 2007–June 2010). The median LOS was 2 days (interquartile range 1–4 days), where a strong statistical significance was observed between the pre-T-ERAS and T-ERAS periods ($P < 0.001$). Furthermore, the 1st postoperative day discharge was achieved in 228 of 304 (75.0%) patients in the T-ERAS period vs only 25 of 100 (25.8%) patients in the pre-T-ERAS period ($P < 0.001$). Complications within 30 days of surgery are demonstrated in Table 2.

Thirty-day postoperative pneumonia was defined according to the Society of Thoracic Surgeons (STS) as meeting 2 of the 5 characteristics: fever, leucocytosis, chest X-ray with infiltrate, positive culture from sputum and/or treatment with antibiotics [7]. The pre-T-ERAS pneumonia incidence was observed in 6 of 100 (6.0%) patients and the T-ERAS period was observed in 2 of 304 (0.7%) patients ($P = 0.004$). There were no 30-day mortalities in the T-ERAS period, and a 30-day readmission rate is reported in 15 of 304 (4.9%) patients and related to the following: pulmonary/pleural (11/304, 3.6%), cardiac (2/304, 0.7%), renal (1/304, 0.3%) and gastrointestinal (1/304, 0.3%). There were no falls or injuries related to the implementation of the T-ERAS protocol in VATS lobectomy cases. When comparing clinical outcomes in the early and late cohorts of the T-ERAS period, there were no statistically significant differences except the duration of air leak (Table 2).

DISCUSSION

ERAS programme development and acceptance has grown with the increasing use of minimally invasive approaches for different surgical procedures. In a recent randomized trial, the application of an ERAS pathway resulted in shorter hospital stay after colorectal surgery [8]. Reduced hospital stay is one of the goals of ERAS for thoracic surgery patients as demonstrated by Scarci *et al.* [9–11] in the UK, and other groups have evaluated chest physiotherapy and ambulation measured by a pedometer to decrease postoperative pulmonary complications.

A systematic review of ERAS after elective lung resection was recently conducted and identified 1 randomized and 5 non-randomized studies [3]. The 5 non-randomized studies reported

Table 1: VATS lobectomy patient demographics

Patient characteristics	Early cohort (*n* = 75)	Late cohort (*n* = 132)	*P*-value	Pre-T-ERAS (*n* = 100)	T-ERAS (*n* = 304)	*P*-value
Age, mean ± SD	65.0 ± 10.7	65.9 ± 10.3	0.56[a]	66.2 ± 10.0	66.2 ± 10.5	0.98
Gender, *n* (%)						
Male	27 (36)	58 (43.9)	0.33[b]	53 (53.0)	178 (58.6)	0.39
Female	48 (64)	74 (56.1)		47 (47.0)	126 (41.5)	
Race, *n* (%)						
White	63 (89)	97 (75.2)	0.12[b]	73 (73.7)	236 (81.1)	0.46
Black	2 (3)	10 (7.8)		8 (8.1)	19 (6.5)	
Asian	4 (6)	18 (14.0)		14 (14.1)	28 (9.6)	
Hispanic	2 (3)	4 (3.1)		4 (4.0)	8 (2.8)	
FEV_1, mean ± SD	88.0 ± 22.2	85.6 ± 18.0	0.26[a]	86.6 ± 19.9[c]	87.5 ± 19.6[d]	0.70
DLCO (%), mean ± SD	71.8 ± 20.7	74.3 ± 18.4	0.20[a]	72.7 ± 22.7[e]	75.7 ± 27.0[f]	0.29

Statistical tests compare proportions of demographic data for the following time periods: the early T-ERAS cohort (July 2010–July 2012) to the late T-ERAS cohort (July 2014–July 2016), and the pre-T-ERAS cohort (June 2007–June 2010) to the whole T-ERAS cohort (July 2010–July 2016) are also compared. There are 4 missing data records, 1 in race and 3 in LOS for pre-T-ERAS, so the numbers do not sum 100.

[a]The Mann–Whitney–Wilcoxon test for difference of continuous distributions.

[b]The χ^2 test or the Fisher's exact test for difference in proportions.

[c]Seven missing data records.

[d]One missing data record.

[e]Ten missing data records.

[f]Eight missing data records.

DLCO: diffusing capacity of the lungs for carbon monoxide; FEV_1: forced expiratory volume in 1 s; LOS: length of stay; SD: standard deviation; T-ERAS: thoracic enhanced recovery with ambulation after surgery; VATS: video-assisted thoracoscopic surgery.

Table 2: Comparison of clinical patient outcomes and 30-day complications in both VATS lobectomy patients prior (*n*=100) to and after (*n*=304) the T-ERAS protocol implementation (July 2010) and in the early T-ERAS cohort versus the late T-ERAS cohort

Clinical outcomes and 30-day complications	Early T-ERAS cohort (*n* = 75), *n* (%)	Late T-ERAS cohort (*n* = 132), *n* (%)	*P*-value	Pre-T-ERAS (*n* = 100), *n* (%)	T-ERAS (*n* = 304), *n* (%)	*P*-value
LOS (days)						
1[a]	47 (63)	96 (72.7)	0.28	25 (26)[b]	228 (75.0)	<0.001
2	17 (23)	24 (18.2)		24 (25)[b]	46 (15.1)	
≥3	11 (15)	12 (9.1)		48 (50)[b]	30 (9.9)	
Discharged with chest tube	14 (19)	6 (4.6)	0.002	17 (17)[b]	33 (10.9)	0.11
Atrial arrhythmia	3 (4)	6 (4.6)	>0.99	8 (8.0)	12 (4.0)	0.12
Pneumonia	1 (1)	1 (0.8)	>0.99	6 (6.0)	2 (0.7)	0.004
Air leak >5 days	11 (15)	4 (3.0)	0.004	3 (3.0)	22 (7.2)	0.16
Deep vein thrombosis	2 (3)	0 (0)	0.13	0 (0)	2 (0.7)	>0.99
Pulmonary embolus	1 (1)	1 (0.8)	>0.99	1 (1.0)	2 (0.7)	0.58
Acute renal failure	1 (1)	0 (0)	0.36	0 (0)	1 (0.3)	>0.99
30-day readmissions	6 (8)	6 (4.6)	0.36	6 (6.0)	15 (4.9)	0.61
Transfusions	0 (0)	3 (2.3)	0.55	3 (3.0)	3 (1.0)	0.16
30-day mortality[c]	0 (0)	0 (0)	>0.99	2 (2.0)	0 (0)	0.06

[a]One patient included in this category was discharged on POD 0.

[b]Three patients in the pre T-ERAS period were mortalities that were never discharged; therefore, the percentages were out of 97, not 100 for LOS and home with chest tube variables.

[c]Deaths related to stroke, myocardial infarction or cardiac complications.

LOS: length of stay; POD: postoperative day; T-ERAS: thoracic enhanced recovery with ambulation after surgery; VATS: video-assisted thoracoscopic surgery.

shorter LOS when ERAS was applied, while the 1 randomized study in this systemic review did not. The median LOS in that randomized study was 11 days after lobectomy in both groups, which is longer than what is typically reported [12]. Although there were no differences in the overall complication rate, in the randomized study, the fast-track group demonstrated a statistically significant lower rate of pulmonary complications at 6.6% vs 35.0%, supporting the role of ERAS ($P = 0.0009$) [12]. Fewer pulmonary adverse events are an important goal of a fast-track approach. The T-ERAS pneumonia rate of 2 of 304 (0.7%) compares favourably with

Table 3: Postoperative ambulation outcomes

Ambulation outcomes	All 6 years (n = 304)	Early cohort (n = 75)	Late cohort (n = 132)	P-value[a]
Met target goal (250 feet in 1 h), n (%)	187 (61.5)	28 (37)	95 (72.0)	<0.001
Cannot walk at all, n (%)	3 (1.0)	3 (4)	0 (0)	0.09
Any distance in 1 h, n (%)	208 (68.4)	29 (39)	108 (81.8)	<0.001
Any distance in 2 h, n (%)	288 (94.7)	64 (85)	128 (97.0)	0.005
250 feet in any time, n (%)	277 (91.1)	59 (79)	113 (85.6)	0.28
Attempted walking in first 30 min of extubation, n (%)	47 (15.5)	0 (0)	37 (28.0)	<0.001
Time from extubation to attempt of ambulation, mean ± SD (median)	57.3 ± 33.2 (51 min)	80.5 ± 43.5 (65 min)	46.2 ± 25.6 (38.5 min)	<0.001[b]

Proportions of the targeted ambulation outcomes of time and distance for the early (July 2010–July 2012) and the late (July 2014–July 2016) T-ERAS cohorts are compared.

[a]The χ^2 or Fisher's exact test for difference in proportions.

[b]The Mann–Whitney–Wilcoxon test for difference in continuous distributions.

SD: standard deviation; T-ERAS: thoracic enhanced recovery with ambulation after surgery.

reported pneumonia rates from other studies and is a statistically significant improvement when compared to the pre-T-ERAS era (P = 0.004) [2, 13].

The major focus of our protocol was early ambulation. The concept of early ambulation is not new. In 1949, Leithauser [14] put forward a rationale for early ambulation, at a time when many surgeons routinely placed patients on bed rest after surgery. In 2014, 1 centre reported a 12-week protocol consisting of brisk walking exercises that started the day after transfer to a regular ward [15]. Thirty-three patients received the walking intervention, and a later group of 33 patients received standard of care. The intervention group had significantly better pulmonary function at 3 and 6 months. Another centre reported their 5-year experience with a fast-track programme, which included 109 patients who underwent lobectomy where early ambulation was encouraged within 1–2 h, but no target distances were defined in the report [4]. Early ambulation was achieved in 90.8% of their patients, and the median hospital stay was 2 days [4].

Since the inception of our institution's protocol, and throughout its implementation, safety was a prime consideration. We have previously presented safety results for the T-ERAS protocol at the World Conference on Lung Cancer [16]. During the time period of the quality improvement initiative using the T-ERAS protocol, a total of 1172 thoracic surgical patients (excluding endoscopy, bronchoscopy, tracheostomy and catheter-based pleural procedures) were recovered in our PACU with no falls and no injuries.

This report focuses on VATS lobectomy patients to provide a homogeneous subset that is readily comparable across programmes. Over the course of 6 years, a majority of patients (61.5%) achieved the set target ambulation goal of 250 feet in 1 h of extubation. Of the 304 patients, 94.7% were able to ambulate any degree within 2 h and only 3 of 304 (1.0%) patients could not walk at all in the PACU. The impact of the learning curve and protocol adoption over time is demonstrated with the target ambulation being achieved in 72.0% (95/132) of patients in the late T-ERAS cohort compared to only 37% (28/75) of patients in the first 2 years of implementing the T-ERAS protocol.

Family engagement and the setting of rigorous expectations are key to a successful implementation of the protocol. The consistent family participation throughout the whole process is vital to patient success. Family support begins at the initial consult visit, followed by preoperative goal reinforcement, greeting the patient during the 2nd walk in the PACU and family members help monitor ambulation by tracking walks (times and distance) on the inpatient room whiteboard. These supporting activities provide a goal-orientated approach in which the patient and family can participate in tandem with the clinical staff.

Another important factor to the success of our protocol has been the collaboration from nursing, anaesthesia staff and administration. Intraoperative strategies such as fluid restriction, avoidance of opioids and the employment of a minimally invasive technique are used to limit pulmonary oedema, early postoperative sedation and facilitate early mobilization. Nursing commitment and buy-in is a cornerstone for implementation, as these clinical staff interact with the patient and family the most frequently and provide the necessary reinforcement of expectations.

Our facility is a 900-bed hospital with a dedicated cardiothoracic operating suite on the same floor as our cardiothoracic step-down unit. The advantage of a smaller, focused group of individuals and administrative recognition of appropriate staffing levels should be emphasized as a significant benefit to the success of implementation. There were no increased costs associated with the implementation of the T-ERAS protocol and the results have inspired the growth of similar initiatives in other specialties at our institution. The ability to ambulate from the recovery room to a patient's room may not be achievable in many centres, but other aspects of this protocol may lend themselves to adoption.

LOS and clinical outcomes were improved when comparing the pre-T-ERAS to the T-ERAS periods. Of interest, when the early versus late T-ERAS periods were compared, there is no clear difference in clinical outcomes, despite a notable improvement in the ambulation speed and performance in the late T-ERAS cohort. This suggests that having a focus on ambulation results in a positive culture shift, which has resulted in improved patient outcomes. Simply having a mandate for ambulation in the early postoperative period requires commitment and engagement from every member of the care team.

CONCLUSION

In summary, we report the successful adoption of the T-ERAS protocol after VATS lobectomy. T-ERAS is a major and positive contribution to our institution's thoracic patient population and should be implemented across other institutions. This protocol will not only help shorten hospital LOS but, most importantly, decrease morbidity in patients. It is hoped that other sites will adopt T-ERAS and that these results can be validated in future studies. Our institution will continue to expand the ERAS protocol in our patient population and conduct further analyses to support the efficacy and success of the protocol.

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Conflict of interest: Sandeep J. Khandhar is a consultant for Medtronic. Amit K. Mahajan is a consultant for Aurus, Medtronic and Boston Scientific. Hiran C. Fernando is a consultant for Galil Medical and Medtronic. None of these relationships are relevant to this manuscript.

REFERENCES

[1] Swanson SJ, Herndon JE, D'Amico TA, Demmy TL, McKenna RJ, Green MR *et al*. Video-assisted thoracic surgery lobectomy: report of CALGB 39802—a prospective, multi-institution feasibility study. J Clin Oncol 2007;25:4993–7.
[2] Paul S, Altorki NK, Sheng S, Lee PC, Harpole DH, Onaitis MW *et al*. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity-matched analysis from the STS database. J Thorac Cardiovasc Surg 2010;139:366–78.
[3] Fiore JF, Bejjani J, Conrad K, Niculiseanu P, Landry T, Lee L *et al*. Systemic review of the influence of enhanced recovery pathways in elective lung resection. J Thorac Cardovasc Surg 2016;151:708–15.
[4] Das-Neves-Pereira J-C, Bagan P, Coimbra-Israel A-P, Grimaillof-Junior A, Cesar-Lopez G, Milanez-de-Campos J-R *et al*. Fast-track rehabilitation for lung cancer lobectomy: a five-year experience. Eur J Cardiothorac Surg 2009;36:383–92.
[5] Ghee CD, Fortes DL, Liu C, Khandhar SJ. A randomized controlled trial of continuous subpleural Bupivacaine after thoracoscopic surgery. Semin Thorac Cardiovasc Surg 2017; doi:10.1053/j.semtcvs.2017.09.012.
[6] R (R Core Team). Vienna, Austria; 2017. https://www.r-project.org Inc.
[7] The Society of Thoracic Surgeons. General Thoracic Surgery Database v.2.3 Training Manual September 2017. 2017. The Society of Thoracic Surgeons. http://www.sts.org/sites/default/files/documents/GTSDTrainingManual_Sept2017.pdf (22 October 2017, date last accessed).
[8] Forsomo HM, Pfeffer F, Rasdal A, Ostgaard G, Mohn AC, Komer H *et al*. Compliance with enhanced recovery after surgery criteria and preoperative and post-operative counselling reduces length of hospital stay in colorectal surgery: results of a randomized controlled trial. Colorectal Dis 2016;18:603–11.
[9] Scarci M, Solli P, Bedetti B. Enhanced recovery pathway for thoracic surgery in the UK. J Thorac Dis 2016;8(Suppl 1):S78–83.
[10] Novoa N, Ballesteros E, Jiménez MF, Aranda JL, Varela G. Chest physiotherapy revisited: evaluation of its influence on the pulmonary morbidity after pulmonary resection. Eur J Cardiothorac Surg 2011;40:130–4.
[11] Novoa N, Varela G, Jiménez MF, Ramos J. Value of the average basal daily walked distance measured using a pedometer to predict maximum oxygen consumption per minute in patients undergoing lung resection. Eur J Cardiothorac Surg 2011;39:756–62.
[12] Muehling BM, Halter GL, Schelzig H, Meierhenrich R, Steffen P, Sunder-Plassmann L *et al*. Reduction of post-operative pulmonary complications after lung surgery using a fast-track clinical pathway. Eur J of Cardiothorac Surg 2008;34:174–80.
[13] Villamizar NR, Darrabie MD, Burfeind WR, Petersen RP, Onaitis MW, Toloza E *et al*. Thoracoscopic lobectomy is associated with lower morbidity compared thoracotomy. J Thorac Cardiovasc Surg 2009;138: 419–25.
[14] Leithauser DJ. Rational principals of early ambulation. J Int Coll Surg 1949;12:368–74.
[15] Chang N-W, Lin K-C, Lee S-C, Chan JY-H, Lee Y-H, Wang K-Y. Effects of an early postoperative walking exercise programme on health status in lung cancer patients recovering from lung lobectomy. J Clin Nurs 2014; 23:3391–402.
[16] Khandhar SJ, Powers C, Schatz C, Rosner C, Kiernan P. OA01.06 Early post-operative ambulation after thoracic surgery—the WAVE experience. J Thorac Oncol 2017;12:S244–5.