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ORIGINAL ARTICLE

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The longitudinal impact of division-wide implementation of an enhanced recovery after thoracic surgery programme

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Key question

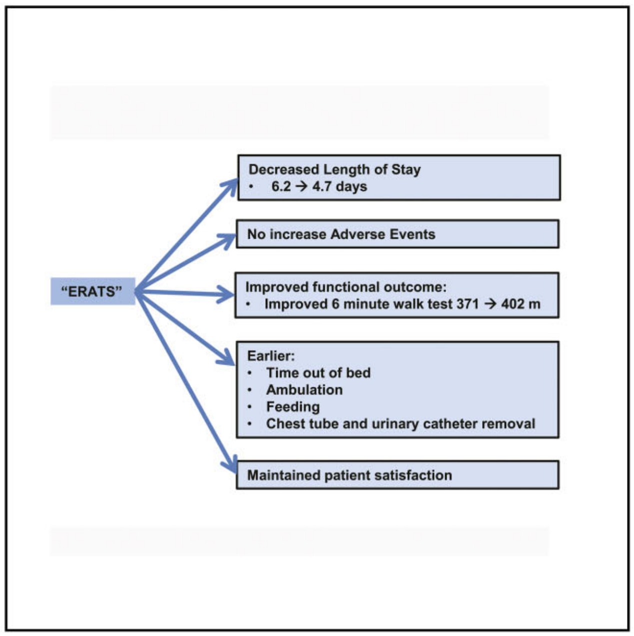
Can an Enhanced Recovery After Thoracic Surgery (ERATS) programme be effectively and safely implemented, and what are the effects on patient satisfaction and functional outcome?

Key finding(s)

Decreased length of stay; Expedited feeding and ambulation without increasing adverse events or readmissions.

Take-home message

ERATS is safe and effective for reducing length of stay and improving functional outcomes.



Abstract

OBJECTIVES: Data regarding enhanced recovery after thoracic surgery (ERATS) are sparse and inconsistent. This study aims to evaluate the effects of implementing an enhanced ERATS programme on postoperative outcomes, patient experience and quality of life (QOL).

METHODS: We conducted a prospective, longitudinal study evaluating 9 months before (pre-ERATS) and 9 months after (post-ERATS) a 3-month implementation of an ERATS programme in a single academic tertiary care centre. All patients undergoing major thoracic surgeries were included. The primary outcomes included length of stay (LOS), adverse events (AEs), 6-min walk test scores at 4 weeks, 30-day emergency room visits (without admission) and 30-day readmissions. The process-of-care outcomes included time to 'out-of-bed', independent ambulation, successful fluid intake, last chest tube removal and removal of urinary catheter. Perioperative anaesthesia-related outcomes were examined as well as patient experience and QOL scores.

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RESULTS: The pre-ERATS group ($n = 352$ patients) and post-ERATS group ($n = 352$) demonstrated no differences in demographics. Post-ERATS patients had improved LOS (4.7 vs 6.2 days, $P < 0.02$), 6-min walk test scores (402 vs 371 m, $P < 0.05$) and 30-day emergency room visits (13.7% vs 21.6%, $P = 0.03$) with no differences in AEs and 30-day readmissions. Patients experienced shorter mean time to 'out-of-bed', independent ambulation, successful fluid intake, last chest tube removal and urinary catheter removal. There were no differences in postoperative analgesia administration, patient satisfaction and QOL scores.

CONCLUSIONS: ERATS implementation was associated with improved LOS, expedited feeding, ambulation and chest tube removal, without increasing AEs or readmissions, while maintaining a high level of patient satisfaction and QOL.

Keywords: Thoracic surgery • Enhanced recovery • Implementation • Length of stay • Adverse events

ABBREVIATIONS

AEs	Adverse events
ER	Emergency room
ERAS	Enhanced recovery after surgery
ERATS	Enhanced recovery after thoracic surgery
LOS	Length of stay
QOL	Quality of life
TOH	The Ottawa Hospital

INTRODUCTION

Surgical interventions for thoracic cancer are among the most challenging procedures, particularly for patients with limited physiological reserve [1, 2]. Despite improvements in perioperative care, there remain a significant proportion of patients who experience major adverse events (AEs) following these procedures [3]. Major complications include pneumonia, acute respiratory distress syndrome, empyema, anastomotic leak, acute renal impairment, pulmonary embolism and cardiovascular instability [3–5]. Postoperative AEs prolong hospitalization resulting in higher hospital costs [5, 6]. Efforts to reduce AEs are essential to reduce hospital length of stay (LOS), improve flow of care and maximize the utilization of available resources.

Enhanced recovery after surgery (ERAS) programmes represent a shift in perioperative care that is multidisciplinary and supported by evidence-based medicine that aims to optimize patient recovery following surgical intervention [2, 3]. Multiple surgical specialties have developed and implemented ERAS in daily practice [7]. Generally, these perioperative pathways are designed to achieve rapid recovery through maintenance of preoperative organ function, early ambulation and oral intake, reduction of the stress response following surgery and increased adoption of minimally invasive surgical techniques [7]. ERAS entails a patient-centred, multidisciplinary, multiphasic and multimodal approach that can result improvement in clinical outcomes and cost savings [8]. Key elements to ensure successful implementation include preoperative counselling and prehabilitation, optimized nutrition, standardized multimodal analgesic and anaesthetic regimens, early mobilization, removal of tubes and oral intake. Evaluation of individual care elements may provide modest benefit to the patient's recovery. Optimization of all care elements simultaneously may provide a synergistic effect that attenuates surgical stress and promotes rapid recovery [9].

Implementation of an enhanced recovery after thoracic surgery (ERATS) programme is a novel initiative with limited studies [10–14]. A systematic review of ERAS in lung resection concluded that more rigorous trials are required to suggest benefit [15]. None of these studies have evaluated the simultaneous impact on LOS, hospital readmissions, AEs, patient satisfaction and quality of life (QOL). A critical component in ERAS is the focus on patient education, as positive outcomes following surgery are dependent on patient compliance, ownership and responsibility for the active role they take in their own recovery [16]. Improvements in the recovery of thoracic surgery patients should decrease LOS by minimizing complications such as acute lung injury, persistent air leak and chronic pain [3, 17, 18].

The purpose of this study is to comprehensively evaluate the impact of a division-wide implementation of an ERATS programme at a single academic, tertiary care hospital on postoperative outcomes, processes of care, patient satisfaction and QOL.

MATERIALS AND METHODS

Study design and eligibility criteria

The ERATS protocol was approved by the Ottawa Health Science Network Research Ethics Board (# 20170687). Recruitment began on 1 September 2017 and was completed over 2 years. This is a prospective, longitudinal study between September 2017 and May 2019. It included a 9-month pre-ERATS implementation period (September 2017–May 2018), followed by a 3-month implementation period (June–August 2018) and a 9-month post-ERATS implementation period (September 2018–May 2019). All patient and process outcome data were collected prospectively. Consent was deemed unnecessarily by Research Ethics Board because all patients received same standard of care with the implementation of ERATS pathways. Patients were consented to complete patient satisfaction and QOL questionnaires, as well as 6-min walk test. Records are kept in a locked cabinet in the Division of Thoracic Surgery for 10 years following enrollment of the last patient. Access will be restricted to study investigators and research assistants. Data will be stored on a secure, password-protected, computer within the Division of Thoracic Surgery and kept strictly confidential.

Clinical care pathways. The Division of Thoracic Surgery at The Ottawa Hospital (TOH) updated care pathways and patient education booklets under the ERATS programme for the purpose of standardizing care. The process of care for inpatient procedures, including lung resection, oesophageal resection and hernia repair, was reviewed by a multidisciplinary team (physicians, nurses, physiotherapists, occupational therapists, pharmacists, social workers, dieticians). We also solicited feedback from patients on the educational material. Following a literature search of various ERAS initiatives, thoracic ERAS elements were targeted for inclusion into ERATS clinical care pathways. Once the ERATS team reached consensus regarding elements for inclusion, they were incorporated into the established TOH clinical pathways over an implementation period of 3 months.

All adults aged ≥18 years underwent major elective thoracic surgical procedures: lung resection (wedge resection, segmental resection, lobectomy and pneumonectomy), oesophagectomy, gastrectomy and paraesophageal hernia repair. Laparoscopic, thoracoscopic and open procedures were included.

The following patients were excluded from the study: day surgery procedures (i.e. no hospital admission), procedures not listed in the inclusion criteria or emergency surgery. Patients were excluded from the postoperative outcomes analysis if their procedure was aborted or incomplete.

ERATS implementation

Patient education. ERATS patient education material was created to engage patients more actively in the recovery process. This material included a clear review of expectations for LOS, patient diary, smoking cessation, exercise prior to surgery, education on the benefits of early mobilization and enteral feeding, along with expected discharge time and day, and directions to follow upon discharge. This information was provided via preoperative information sessions by nurses, following surgical consultation. The patient education documents (https://www.ottawaerats.org/) were evaluated and modified by the TOH Patient, Family and Caregiver Education Documents Project to meet healthy literacy criteria, which included: patient feedback, plain language format (grades 6–8), clear design, adult education principles and accessibility compliance.

The introduction and maintenance of the ERATS programme in the preoperative anaesthesia unit, postoperative anaesthesia care unit and ward was facilitated through the education of nursing and allied staff. Presentations (given by Andrew J.E. Seely, Calvin Thompson, Donna E. Maziak and Amanda M.S. Mattice) throughout the ERATS implementation phase outlined the aspects of care, which had the greatest potential of improving patient recovery determined through team consensus. Education sessions were provided to nursing staff, physiotherapists, social workers, dieticians, pharmacists, occupational therapists, research and the administrative teams.

A standardized plan of anaesthesia was developed and added changes to ensure optimized perioperative multimodal analgesia, intraoperative ventilation, reversal of muscle relaxation and control of postoperative nausea and vomiting (https://www.ottawaerats.org/).

Postoperative ERATS elements included: standard order sets, multimodal analgesia, early ambulation, early chest tube removal, early removal of urinary catheter, early introduction of oral feeds after surgery and early discontinuation of intravenous fluids. All patients received physiotherapy ensuring early ambulation, breathing exercises and chest physiotherapy. For lung resection, the use of digital chest drainage systems enabled accurate and uniform assessment of air leaks and outputs.

Outcomes

Primary outcomes. The primary outcomes were LOS, postoperative AEs, 6-min walk test scores, 30-day emergency room (ER) visits and 30-day readmissions. AEs are documented by the Thoracic Morbidity and Mortality system [19], which utilizes the Clavien-Dindo classification schema [20]. The highest AE was recorded per patient. Accordingly, AEs were further divided into minor (Clavien-Dindo classes I and II) and major (Clavien-Dindo classes III–V). The 6-min walk test was conducted for each patient at 4 weeks (± 1 week) after discharge from hospital as per the guidelines described by the American Thoracic Society [21]. Absolute contraindications for the test included unstable angina or myocardial infarction during the previous month.

Patient satisfaction and quality of life scores. Patient satisfaction was evaluated with EORTC IN-PATSAT-32 questionnaire [22]. QOL was assessed through patient-reported EORTC QLQ-C30 questionnaire [23] at 4 weeks (± 1 week) and 6 months after surgery.

Process-of-care outcomes. Process-of-care outcomes included: first time to sitting on bed, out-of-bed, independent ambulation, successful fluid intake, diet as tolerated, removal of first and last chest tube and removal of urinary catheter. These outcomes were assessed directly by nursing staff and were measured at hours postoperatively. These measurements monitored compliance of the ERATS programme elements.

Anaesthesia-related outcomes. Compliance with preoperative administration of multimodal analgesia (celecoxib and pregabalin) was assessed. Assessment of intraoperative compliance with the standardized anaesthetic management included: one-lung ventilation protective strategy (tidal volume of 4–5 ml/kg ideal body weight), administration of dexamethasone (8 mg intravenous) and confirmation of reversal of muscle relaxation. The postoperative use of epidural and patient-controlled analgesia was assessed.

Sample size and analysis methods. Estimates of LOS were based on the average number of days patients spent at TOH from 2008 to 2016: wedge lung resection (4.9 days), segmental resection (4.7 days), lobectomy (6.9 days), pneumonectomy (10.1 days), oesophagectomy (14.9 days) and gastrectomy (11.7 days). The reported AE rate for the same time period was: wedge lung resection (18%), segmental resection (28%), lobectomy (39%), pneumonectomy (51%), oesophagectomy (53%), gastrectomy (40%) and paraesophageal hernia repair (26%). Sample size calculations were based on expected overall average LOS of 7 ± 8 days, with an effect size of 25% LOS reduction; a sample size of 329 patients per group provides 80% power to detect a difference in the means. Based on the average monthly case volume of 35 operations, we elected to enrol for 9 months to ensure sufficient power, prior to and post the 3-month implantation period. The differences in continuous variables, such as LOS, and categorical variables, such as AEs, were calculated using *t*-test and chi-square, respectively. A *P*-value of <0.05 was considered to be statistically significant. SPSS software was used for statistical analysis.

RESULTS

Baseline characteristics. Our final analysis included 352 patients in the pre- and post-ERATS implementation groups,

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respectively. The mean age and gender distribution were similar (Table 1). There was no significant difference in the comorbidities between the 2 groups (Table 1). The most common procedures were minimally invasive lobectomy and sublobar resections, constituting around two-third of the total number of procedures in each group. There were more gastrectomies and open lobectomies in the pre-implementation group (3.4% vs 0.9% $P = 0.024$ and 9.9% vs 2.6%, $P = 0.045$, respectively, Table 2).

Primary outcomes. The mean overall LOS was shorter in the post-implementation group (4.7 vs 6.2 days, $P = 0.011$, Table 3).

Table 1: Baseline characteristics

Variable	Pre-ERATS	Post-ERATS	*P*-value
Total count, *n*	352	352	–
Age (years), mean (± SD)	65.1 (13.2)	64.4 (11.7)	0.09
Male (%)	47.5	46.0	0.15
Comorbidities, *n* (%)			
COPD	32 (9.1)	36 (10.2)	0.72
Asthma	22 (6.3)	26 (7.4)	0.91
CAD	10 (2.8)	7 (2.0)	0.25
Renal disease	4 (1.1)	6 (1.7)	0.74
Diabetes	29 (8.2)	27 (7.7)	0.28
Hypertension	77 (21.9)	99 (28.1)	0.64

CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; SD: standard deviation; ERATS: Enhanced Recovery After Thoracic Surgery.

This was mainly due to the statistically significant reduction of LOS in the patient population that specifically underwent open oesophagectomy, open lobectomy and sublobar resection. Other procedures such as bullectomy/pleurectomy and gastrectomy had reduced LOS post-implementation by 50.5% and 41.3%, respectively, but this did not reach statistical significance (Supplementary Material, Table S1).

There were no statistically significant differences in the rates of major (13.6% vs 10.8%, $P = 0.25$) and minor (18.2% vs 21.3%, $P = 0.31$) AEs in the pre- and post-implementation groups (Table 3).

There was a statistically significant drop the in the rate of 30-day ER visits from 21.6% to 13.7% ($P = 0.027$). There was a trend towards decreased rate of 30-day readmissions, but this did not reach statistical significance (9.5% in the pre-ERATS group vs 4.7% in the post-ERATS group, $P = 0.057$, Table 3).

The distance walked in the 6-min walk test was longer in the post-implementation group (402 vs 371 m, $P = 0.046$). There was no difference in the proportion of patients who had to stop before completing the test.

Process-of-care outcomes. Implementation of ERATS led to significant improvements in all process-of-care outcomes. The post-ERATS group showed less time to 'out-of-bed', independent ambulation, successful fluid intake, last chest tube removal and removal of urinary catheter (Table 4).

Following ERATS implementation, there was an increase in the preoperative use of pregabalin in appropriate patients

Table 2: Procedures

Procedures	Pre-ERATS (*n* = 352)	Post-ERATS (*n* = 352)	*P*-value
Bullectomy/pleurectomy, *n* (%)	7 (2.0)	11 (3.1)	0.91
Gastrectomy, *n* (%)	12 (3.4)	3 (0.9)	**0.024**
Hiatal hernia repair, *n* (%)	28 (8)	36 (10.2)	0.29
MIS oesophagectomy, *n* (%)	9 (2.6)	11 (3.1)	0.56
MIS lobectomy, *n* (%)	107 (30.4)	130 (36.9)	0.072
Open oesophagectomy, *n* (%)	12 (3.4)	11 (3.1)	0.57
Open lobectomy, *n* (%)	35 (9.9)	9 (2.6)	**0.045**
Pneumonectomy, *n* (%)	5 (1.4)	4 (1.1)	0.74
Sublobar resection, *n* (%)	118 (33.5)	105 (29.8)	0.29
Other procedures, *n* (%)	19 (5.4)	32 (9.1)	0.061

P-values in bold indicate statistical significance.
ERATS: enhanced recovery after thoracic surgery; MIS: minimally invasive surgery.

Table 3: Primary outcomes

Variable	Pre-ERATS (*n* = 352)	Post-ERATS (*n* = 352)	*P*-value
Length of stay, mean in days ± SD	6.2± 13.2	4.7± 8.7	**0.011**
AEs, *n* (%)			
Minor AE	64 (18.2)	75 (21.3)	0.31
Major AE	48 (13.6)	38 (10.8)	0.25
30-Day ER visits	41 (21.6)	32 (13.7)	**0.027**
30-Day readmissions	18 (9.5)	11 (4.7)	0.057
Distance walked in 6 min, mean ± SD	371±107	402±85	**0.046**
Stop prior to end of test, *n* (%)	20 (12.6)	17 (8.8)	0.25

P-values in bold indicate statistical significance.
AEs: adverse events; ER: emergency room; ERATS: enhanced recovery after thoracic surgery; SD: standard deviation.

Table 4: Process-of-care outcomes

Variable	Pre-ERATS (*n* = 352)	Post-ERATS (*n* = 352)	Difference (h)	*P*-value
Time to 'out-of-bed', h (SD)	18.2 (40.3)	11.6 (8.1)	-6.6	**0.002**
Time to independent ambulation, h (SD)	53.7 (67.7)	40.3 (39.0)	-13.4	**0.001**
Time to successful fluid intake, h (SD)	30.0 (101.9)	16.3 (41.1)	-13.7	**0.013**
Time to last chest tube removal, h (SD)	95.3 (88.4)	76.7 (66.6)	-18.6	**0.034**
Duration of urinary catheterization, h (SD)	50.9 (85.5)	31.6 (52.3)	-19.3	**0.001**

P-values in bold indicate statistical significance.
ERATS: enhanced recovery after thoracic surgery; SD: standard deviation.

Table 5: Anaesthesia-related outcomes

Variable	Pre-ERATS (*n* = 352)	Post-ERATS (*n* = 352)	*P*-value
Preoperative multimodal analgesia (%)			
Celecoxib	57.9	66.2	0.051
Pregabalin	45.8	60.9	**0.00017**
Intraoperative optimization (%)			
Dexamethasone use	73.4	84.2	**0.00024**
One-lung ventilation	89.7	87.1	0.28
Muscle relaxants reversed	88.3	96.2	**0.00004**
Postoperative pain management			
Duration of epidural analgesia (h)	95.4	64.6	0.11
Duration of PCA analgesia (h)	42.6	48.3	0.24

P-values in bold indicate statistical significance.
ERATS: enhanced recovery after thoracic surgery; PCA: patient-controlled analgesia.

(45.8–60.9%, $P = 0.00017$). The intraoperative use of dexamethasone increased during the study period from 73.4% to 84.2% ($P = 0.00024$), as well as the intraoperative use of muscle relaxant reversal (88.3–96.2%, $P = 0.00004$). There were no statistically significant differences with preoperative celecoxib use, protective one-lung ventilation strategy or postoperative pain modality (Table 5).

Patient satisfaction and quality of life scores. The 2 groups maintained a high level of postoperative satisfaction with no statistically significant differences (Supplementary Material, Table S2). Similarly, the QOL scores at 4 weeks and 6 months were not statistically different pre- and post-ERATS implementation (Supplementary Material, Tables S3 and S4).

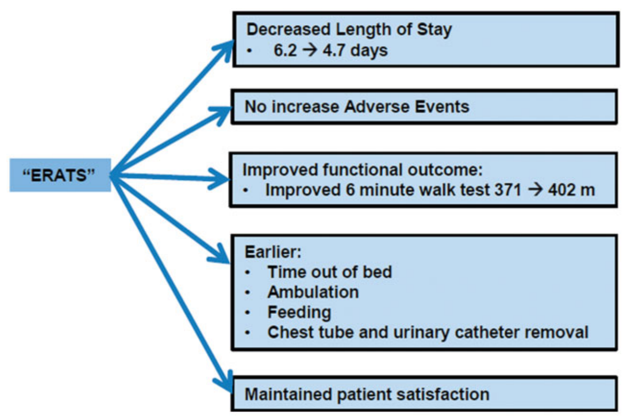

Figure 1: Benefits of enhanced recovery after thoracic surgery.

DISCUSSION

In this single-centre longitudinal evaluation, we found that systematic divisional (5 surgeons) implementation of an ERATS programme was associated with a reduction in time to accomplish key in-hospital process-of-care outcomes, a significant reduction in overall LOS from 6.2 to 4.7 days for thoracic pulmonary and oesophagogastric surgery, with no increase in AEs, and significantly decreased 30-day ER visits with a trend to decreased 30-day readmission rate. In addition, we found that ERATS implementation was associated with improved postoperative functional status, reflected by improved 6-min walk test scores. No change in patient satisfaction and/or QOL was demonstrated (Fig. 1). These results demonstrate the effectiveness and safety of a broad ERATS implementation.

A key element of success in this study was the patient-centred and holistic focus. This is an important cornerstone to the success of any healthcare system change initiative. Multidisciplinary engagement and clear patient expectations influence compliance and adherence to ERATS protocols. Achieving important milestones in terms of LOS at the expense of AEs, patient satisfaction or QOL is not of benefit to the patient. Our results show that implementation of an ERATS pathway does not increase the risk of minor or major AEs and maintains patient satisfaction and QOL. This study focused on all phases of care. The advantage of the holistic design utilized is to demonstrate the sum total of a multitude of factors, which collectively achieve a desired result. It is however impossible to identify which individual factors led to the observed results. It is our experience that patient and staff expectations were paramount to the success of the programme. The principal challenges in ERATS implementation surrounded establishing multidisciplinary consensus, finalizing all care pathways, education of all personnel and collection of process-of-care outcomes. Several studies have demonstrated the effectiveness of clinical pathways in the reduction of hospitalizations and costs across multiple surgical fields [2, 13, 24–26].

Reduction in the LOS remains the most common marker of ERAS success [27]. LOS was successfully reduced across multiple surgical procedures in our study. It is difficult to differentiate the impact of the various procedures on outcomes given the design of the study. We demonstrated a clinical but not statistical significant reduction in LOS across most thoracic procedures. Statistically significant reductions in LOS were found only with open oesophagectomies, open lobectomies and sublobar resections (Table 2).

ERAS initiatives generally result in reduction in hospital costs but may only be a surrogate marker of recovery and may not necessarily reflect the patient's true recovery at home [27]. Additional measurements to be considered include early mobilization, early independent ambulation and early oral intake of food. A recent editorial argued that a properly informed patient without pain, nausea, vomiting, drains and tubes and free from postoperative complications should be willing to eat and ambulate [28]. Earlier ambulation and oral intake could be a good marker for recovery similarly to LOS [28]. Patients who undergo more invasive procedures may refuse to ambulate early due to either the presence of pain or the fear of experiencing pain [16]. This reflects the importance of considering all aspects of care through a multidisciplinary team where pain control must be targeted to promote earlier ambulation. As demonstrated in this study, alternative markers for recovery, such as time to independent ambulation and successful oral intake, also decreased in the post-implementation phase. Such improvement in these recovery markers may have contributed to shorter LOS while preserving patient satisfaction.

The ERAS Society and ESTS published 45 perioperative elements in their enhanced recovery guidelines for lung surgery in 2019 [29], presenting consensus recommendations, 2 years after initiation of our study. While our implementation included all major thoracic surgery, not just pulmonary resection, a notable difference between our pathways and the ESTS ERAS guidelines was our lack of a formal prehabilitation programme; however, all patients were given preoperative exercise counselling and early postoperative physiotherapy. As we developed our ERATS programme based on best available evidence prior to these guidelines, we similarly reviewed individual care elements in our pathways and incorporated those which appeared to be missing or more influential than others from other specialties. Significant variation in practice and perceived difficulties with ERAS implementation has recently been described [30]. The main differences between our ERATS programme and our previous pathways were a focus on patient and staff education, and on those elements geared towards improving postoperative mobility, and removing barriers to early ambulation and po intake. The 2 most relevant challenges to implementation related to data collection and staff education. It was clear that collecting local relevant data on the many patient care elements was significant. Education of staff (physician, nursing, physiotherapy) on the ERAS pathways coupled with providing data on compliance with processes of care back to the staff was instrumental to promote changes in healthcare provider practice.

Limitations

The main limitation of this study is its non-randomized controlled trial design. Its longitudinal nature raises the possibility of a secular 'time' bias, where practices may have evolved with time regardless of the intervention. We observed a decrease in the number of open lobectomy surgeries during the study. Although the study included a high number of participants, we believe that the study period was not long enough to lead to such a profound change. Furthermore, the study involved implementation and measurement of specific interventions and metrics, which help mitigates the risk of longitudinal secular trend bias. Barriers identified during the study included the ongoing management of patient expectations, continuous training of involved healthcare workers and creating postoperative pathways. Despite the limitations, we have shown that it is possible to overcome such barriers through a systematic and inclusive approach.

CONCLUSION

Implementation of ERATS is a holistic and dynamic process, which leads to improved quality of care and clinical outcomes in thoracic surgery. We describe our experience at a Canadian academic centre with implementation of an ERATS programme. We found an association with improved LOS and process-of-care outcomes, while maintaining safety and a high level of patient satisfaction and QOL. It is also associated with trends towards improved functional outcomes as reflected by the superior 6-min walk test scores. Future work on the impact of individual elements as well as focused enhanced recovery programmes for specific types of surgeries may lead to greater improvements in outcomes.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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Author contributions

Calvin Thompson: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing; Co Principal Investigator. **Amanda M.S. Mattice:** Data curation; Formal analysis; Investigation; Methodology; Project administration; Validation; Writing—original draft;

Writing–review & editing. **Yaseen Al Lawati:** Data curation; Formal analysis; Investigation; Methodology; Project administration; Validation; Writing–original draft; Writing–review & editing. **Nazgol Seyednejad:** Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing–review & editing. Alex Lee: Formal analysis; Project administration; Writing–review & editing. **Donna E. Maziak:** Investigation; Methodology; Project administration; Writing–review& editing. **Sebastian Gilbert:** Investigation; Project administration; Writing–review & editing. **Sudhir Sundaresan:** Project administration; Writing–review & editing. **James Villeneuve:** Investigation; Project administration; Writing–review & editing. **Farid Shamji:** Project administration; Writing–review & editing. **Jamie Brehaut:** Data curation; Formal analysis; Writing–review & editing. **Tim Ramsay:** Formal analysis; Methodology; Project administration; Writing–original draft; Writing–review & editing. **Andrew J.E. Seely:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing–original draft; Writing–review & editing; Co Principal Investigator.

Reviewer information

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