Original Article

Perioperative morbidity and 3-year survival in non-intubated thoracoscopic surgery: a propensity matched analysis

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Background: Non-intubated thoracoscopic surgery with spontaneous breathing is rarely utilized, but may have several advantages over standard intubation, especially in those with significant cardiopulmonary comorbidities. In this study we evaluate the safety, feasibility, and 3-year survival of thoracoscopic surgery without endotracheal intubation for oncologic and non-oncologic indications.

Methods: All consecutive patients [2018–2022] selected for lung resection or other pleural space intervention under local anesthesia and sedation were compared to a cohort undergoing elective thoracoscopic procedures with endotracheal intubation. A propensity-score matched cohort was used to compare perioperative outcomes and 3-year overall survival.

Results: A total of 72 patients underwent thoracoscopic surgery without intubation compared to 1,741 who were intubated. Non-intubated procedures included 19 lobectomies (26.4%), 9 segmentectomies (12.5%), 25 wedge resections (34.7%), and 19 pleural or mediastinal resections (26.4%). Non-intubated patients had a lower average body mass index (BMI; 24.6 *vs.* 27.1 kg/m^2, P<0.001) and a higher comorbidity burden. Primary lung cancer was the indication in 30 (41.7%) non-intubated patients. The non-intubated cohort had no operative or 30-day mortality. After propensity-score matching, there was no significant difference in pre-operative factors. In propensity-score matched analysis, non-intubated patients had shorter median total operating room time (109 *vs.* 159 min, P<0.001) and procedure time (69 *vs.* 119 min, P<0.001). Peri-operative morbidity was rare and did not differ between intubated and non-intubated patients. There was no significant difference in 3-year survival associated with non-intubation in the propensity-score matched cohorts (95% *vs.* 89%, P=0.10) or in a Cox proportional hazard model [hazard ratio (HR), 1.15; 95% confidence interval (CI): 0.36–3.67; P=0.81].

Conclusions: Non-intubated thoracoscopic surgery is safe and feasible in carefully selected patients for both benign and oncologic indications.

Keywords: Non-intubated thoracoscopic surgery; video-assisted thoracoscopic surgery (VATS); safety and quality

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Introduction

While advantageous to the surgeon, general anesthesia and endotracheal intubation have well-established deleterious effects on the patient, especially in those with significant cardiopulmonary comorbidities (1-3). Several recent reports have revisited thoracic surgery in the non-intubated patients both in limited pleural operations without hilar dissection and in anatomic lung resection (4-10). However, these studies have lacked significant follow-up which is critical in patients undergoing resection for oncologic indications.

Herein, we report on the feasibility, safety, and 3-year survival of non-intubated thoracoscopic surgery on a highly selected group of patients. Perioperative outcomes and 3-year survival were compared to a propensity-score matched cohort of patients undergoing elective thoracoscopic surgery. We hypothesized that non-intubated surgery could be performed on carefully selected patients without a significant increase in perioperative morbidity or 3-year mortality. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-591/rc).

Methods

Patients

All consecutive patients (January 2018–July 2022) selected for lung resection or other pleural space intervention under local anesthesia and sedation were included. All non-intubated procedures were performed by two independent attending surgeons. The decision to perform a procedure without endotracheal intubation was made at the discretion of the attending thoracic surgeon and attending anesthesiologist following a standardized set of guidelines (Appendix 1). Influencing patient factors included cardiopulmonary comorbidities, body mass index (BMI), and underlying disease process. Operations were performed at both a major quaternary care center as well as an affiliated community hospital. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The protocol for this study was approved by the Mass General-Brigham Institutional Review Board (No. 2022P000958, 25 April 2022) and patient consent was waived given the retrospective nature of this work.

The control cohort included all consecutive patients undergoing elective minimally invasive video-assisted thoracoscopic surgery (VATS) or robotic-assisted thoracoscopic surgery (RATS). In both the intubated and non-intubated patients, procedures were performed thoracoscopically using a standard multiport approach. Patients were excluded if they were missing documentation of cardiopulmonary comorbidities and American Society of Anesthesiologists (ASA) physical status score within the institutional database.

Surgical and anesthetic methods

Patients were selected for non-intubated operations primarily by their BMI (less than 25 kg/m^2 for most) as it affects diaphragmatic excursion and ventilatory compensation. Additional considerations included a lack of prior ipsilateral pleural intervention and early disease in lung cancer. Patients in the control arm were intubated with a double lumen endotracheal tube or rarely single lumen endotracheal tube with a bronchial blocker. Non-intubated patients were brought to the operating room and monitored sedation was provided through administration of propofol, midazolam, and fentanyl. Rarely, a laryngeal mask airway (LMA) was placed at the discretion of the attending anesthesiologist. None of the non-intubated patients had a bronchial blocker or similar device inserted in the airway. Pain was managed with either a preoperative paravertebral block performed by anesthesia or intraoperative intercostal blocks using 0.25% or 0.5% bupivacaine with epinephrine. An open pneumothorax was created. The region of the Vagus nerve was infiltrated with several milliliters of local anesthetic—on the right adjacent to the trachea and on the left below the aortic arch—to suppress coughing in a manner similar to that described by Hung *et al.* (9).

Highlight box

Key findings

- Non-intubated thoracoscopic surgery was associated with similar 3-year mortality and reduced operative time.

What is known and what is new?

- Non-intubated thoracoscopic surgery has been explored in multiple settings.
- This study uniquely examines 3-year survival in propensity-score matched patients with oncologic and non-oncologic indications for resection.

What is the implication, and what should change now?

- Non-intubated thoracoscopic surgery is safe, feasible, and associated with similar 3-year survival in carefully selected patients.

Patients maintained spontaneous breathing throughout the procedure and oxygen was delivered through a face mask or LMA. During the operation appropriate resources were available should the patient decompensate and require urgent intubation.

Covariates and outcomes

Covariates utilized in this study included age, sex, BMI, ASA score, and common comorbidities [hypertension, congestive heart failure (CHF), coronary artery disease (CAD), diabetes mellitus (DM), cerebrovascular disease (CVD), and chronic kidney disease (CKD)]. Smoking status and predicted 1 second forced expiratory volume (pFEV1) were included. Diffusing capacity of the lung for carbon monoxide was excluded due to absence in up to 30% of cases. Additional variables included prior cardiothoracic surgery, the type of procedure, and indication for the procedure (oncologic *vs.* non-oncologic).

Perioperative outcomes included total time in the operating room, total procedure time, and conversion from thoracoscopy to thoracotomy. Definitions for complications consistent with those collected by the Society of Thoracic Surgeons (STS) were utilized: atelectasis requiring bronchoscopy, post-operative pleural effusion requiring additional drainage procedure, pneumonia, respiratory failure, new atrial arrhythmia requiring treatment, bleeding requiring reoperation, air leak greater than 5 days. We also included post-operative intensive care unit (ICU) disposition, transfer to the ICU, length of hospitalization, and discharge location. Both 30-day and 3-year mortality were analyzed.

Statistical analysis

Bivariate analysis of patient characteristics was performed using the chi-squared test or Fisher exact test for categorical variables, and the *t*-test or Mann-Whitney *U* test for continuous variables. Survival was measured as days from date of surgery to death. Survival curves were created using the Kaplan-Meier method. Survival differences were assessed using the log-rank test. Two strategies were used to adjust for independent variables: Cox proportional hazards and propensity-score matching. Data elements considered patient sex, age, BMI, comorbidities, type of procedure (lobectomy, segmentectomy, wedge, other), and diagnosis of pulmonary malignancy. Proportional hazards assumptions were assessed through inspections of log-log plots of the survival function and results reported as a hazard ratio (HR) with a 95% confidence interval (CI). The number of non-intubated cases was based on the institutional data set which included cases performed over a 5-year study period. We believe this timeline provided enough perioperative and follow-up data to allow for a meaningful comparison with intubated patients. In *post-hoc* analysis with α of 0.05, we were powered to detect a 5% difference between the two groups.

The propensity-score score matching was performed using the same independent variables using 2:1 greedy (nearest-neighbor) approach for controls to cases with a caliper of 0.25, resulting in two well-matched groups (all variables had a standard mean difference of less than 0.1). A subgroup analysis included only patients with oncologic indication. In this analysis, a separate independent propensity-score match was performed with a caliper of 0.25, again resulting in two well-matched groups (all variables had a standard mean difference of less than 0.1). Significance was set at a two-sided $P<0.05$. There was no missing data among the included patient cohorts. Stata software, version 15.1 (StataCorp, College Station, TX, USA) was used for computations, while propensity-score matching was performed with SAS statistical software version 9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 72 patients underwent a thoracoscopic procedure without intubation, of whom five underwent urgent procedures for empyema. The remainder underwent non-urgent elective procedures. A preemptive LMA was placed in 7 (9.7%) of patients, although spontaneous ventilation was maintained in all. Conversion to intubation occurred in one patient who experienced myoclonus during propofol infusion. The infusion was stopped prior to any surgical incision, and the operation was canceled before any incision. The eventual operation was performed using a standard double lumen endotracheal tube. No patients required intubation mid-procedure.

Primary lung cancer was the indication for the procedure in 30 patients (41.7%) and anatomic resection (lobectomy or segmentectomy) was performed in 28 (38.9%) (*Table 1*). In patients without primary lung cancer non-pulmonary procedures included mediastinal biopsy (36.8%), decortication for empyema (26.3%), pleurodesis (15.8%), pericardial window (10.5%), and pleural biopsy (10.5%) (Table S1).

In comparison, 1,741 patients who underwent an elective

Table 1 Bivariate analysis of unmatched and propensity matched intubated and non-intubated cohorts

Patient and operative variables	Unmatched			Propensity matched		
	Intubated (n=1,741)	Non-intubated (n=72)	P value	Intubated (n=134)	Non-intubated (n=67)	P value
Male	698 (40.1)	25 (34.7)	0.36	44 (32.8)	22 (32.8)	>0.99
Age (years)	66.4 (11.3)	68.4 (11.0)	0.13	67.9 (12.0)	68.2 (11.1)	0.85
BMI (kg/m^2)	27.1 (5.6)	24.6 (3.9)	<0.001*	24.9 (3.9)	24.6 (4.0)	0.64
ASA classification			0.002*			0.51
I	14 (0.8)	1 (1.4)		0 (0.0)	1 (1.5)	
II	597 (34.3)	22 (30.6)		49 (36.6)	22 (32.8)	
III	1,099 (63.1)	43 (59.7)		82 (61.2)	42 (62.7)	
IV	31 (1.8)	6 (8.3)		3 (2.2)	2 (3.0)	
Hypertension	926 (53.2)	40 (55.6)	0.69	69 (51.5)	36 (53.7)	0.76
CHF	9 (0.5)	2 (2.8)	0.015*	0 (0.0)	0 (0.0)	>0.99
CAD	207 (11.9)	10 (13.9)	0.61	15 (11.2)	8 (11.9)	0.88
DM	234 (13.4)	9 (12.5)	0.82	12 (9.0)	7 (10.4)	0.73
CVD	85 (4.9)	2 (2.8)	0.41	5 (3.7)	2 (3.0)	0.79
CKD	75 (4.3)	4 (5.6)	0.61	7 (5.2)	4 (6.0)	0.83
pFEV1	91.0 (76.0, 105.0)	90.0 (76.0, 103.0)	0.69	97.5 (77.5, 111.5)	90.0 (76.0, 103.0)	0.30
Smoking status			0.088			0.90
Current	277 (15.9)	5 (6.9)		8 (6.0)	5 (7.5)	
Former	974 (55.9)	46 (63.9)		87 (64.9)	42 (62.7)	
Never	413 (23.7)	21 (29.2)		38 (28.4)	20 (29.9)	
Unknown	77 (4.4)	0 (0.0)		1 (0.7)	0 (0.0)	
Prior cardiothoracic surgery	478 (27.5)	16 (22.2)	0.33	24 (17.9)	14 (20.9)	0.61
Procedure			<0.001*			0.99
Lobectomy	711 (40.8)	19 (26.4)		39 (29.1)	19 (28.8)	
Other†	56 (3.2)	19 (26.4)		24 (17.9)	14 (20.9)	
Segmentectomy	254 (14.6)	9 (12.5)		18 (13.4)	9 (13.4)	
Wedge	720 (41.4)	25 (34.7)		53 (39.6)	25 (37.3)	
Robotic assisted	457 (26.2)	0 (0.0)	NA	29 (21.6)	NA	NA
Indication primary lung cancer	1,245 (71.5)	30 (41.7)	<0.001*	60 (44.8)	30 (44.8)	>0.99

Data are presented as n (%), mean (SD), or median (IQR). *, P<0.05. †, other procedures included decortication, mediastinal biopsy, and pleural biopsy. Further information is included in Table S1. BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; CAD, coronary artery disease; DM, diabetes mellitus; CVD, cerebrovascular disease; CKD, chronic kidney disease; pFEV1, predicted 1 second forced expiratory volume; NA, not available; SD, standard deviation; IQR, interquartile range.

VATS or RATS procedure with standard endotracheal intubation were included in analysis, while 282 where excluded due to missing ASA score or comorbidities (Figure S1). The included patients had complete documentation without missing pre-operative, peri-operative, or post-operative variables. Patients who underwent a VATS or RATS with

Table 2 Perioperative morbidity and mortality in propensity matched cohorts

Morbidity and mortality	Intubated (n=134)	Non-intubated (n=67)	P value
Intraoperative mortality	0 (0.0)	0 (0.0)	>0.99
Total time in operating room† (min)	159 [117, 193]	109 [84, 128]	<0.001
Procedure time‡ (min)	119 [77, 156]	69 [44, 99]	<0.001
Convert to open	0 (0.0)	1 (1.5)	0.16
Post-operative ICU	3 (2.2)	3 (4.5)	0.38
Peri-operative morbidity	15 (11.2)	4 (6.0)	0.23
Atelectasis requiring bronchoscopy	0 (0.0)	1 (1.5)	0.16
Postop pleural effusion requiring additional drainage procedure	5 (3.7)	1 (1.5)	0.38
Pneumonia	1 (0.7)	0 (0.0)	0.48
Respiratory failure	0 (0.0)	1 (1.5)	0.15
New atrial arrhythmia requiring treatment	5 (3.7)	3 (4.5)	0.80
Bleeding requiring reoperation	0 (0.0)	1 (1.5)	0.21
Air leak greater than 5 days	5 (3.7)	0 (0.0)	0.11
Pneumothorax requiring replacement of chest tube	1 (0.7)	0 (0.0)	0.48
Unexpected admission to ICU	1 (0.7)	1 (1.5)	0.62
Length of stay (days)	2.0 [2.0, 3.0]	2.0 [1.0, 3.0]	0.12
Discharge to home	130 (97.0)	61 (91.0)	0.066
30-day mortality	0 (0.0)	0 (0.0)	>0.99

Data are presented as n (%) or median [IQR]. †, time from entry to operating room to exit from operating room; ‡, time from start of procedure to end of procedure. ICU, intensive care unit; IQR, interquartile range.

standard intubation had a higher BMI (27.1 *vs.* 24.6 kg/m^2, P<0.001) and were less likely to have CHF (0.5% *vs.* 2.8%, P=0.015). Correspondingly, there were fewer patients with ASA IV score in the intubated group (1.8% *vs.* 8.3%, P=0.002). Oncologic indication (71.5% *vs.* 41.7%, P<0.001) and an anatomic resection (lobectomy or segmentectomy) were more common in intubated patients. Propensity-score 2:1 matching resulted in 134 intubated and 67 non-intubated patients without significant group differences (excluding five non-elective non-intubated patients undergoing urgent operations).

Perioperative morbidity and mortality

In propensity-score matched analysis there was no intraoperative or 30-day mortality (*Table 2*). Total time in the operating room (entrance to exit) was 1.5 times longer in the intubated patients compared to the non-intubated patients (159 *vs.* 109 min, P<0.001). Similarly, total procedure time (start to end of operative procedure) was 1.7 times longer in the intubated cohort (119 *vs.* 69 min, P<0.001). There was no difference in peri-operative morbidity or ICU admission. One non-intubated patient underwent resection of ribs 6, 7, and 8 for unexpected chest wall involvement. Hospital length of stay and discharge-to-home rate did not differ significantly between the study cohorts.

Survival analysis and Cox proportional hazard model

Median follow-up time was 30.6 months in the intubated cohort and 36.0 months in the non-intubated cohort. Unadjusted 3-year survival, which included non-oncologic indications, was 97% in the intubated cohort and 86% in the non-intubated cohort (P<0.001). Propensity-score matched 3-year survival was 95% in the intubated and 89%

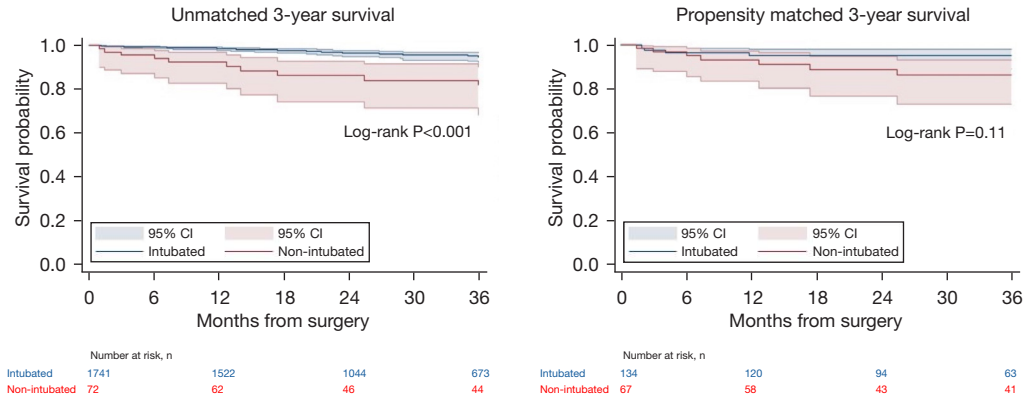

Figure 1 Unadjusted and propensity-score matched overall survival in intubated and non-intubated patients undergoing thoracoscopic procedures. CI, confidence interval.

in the non-intubated cohort (P=0.11) (*Figure 1*). These results were supported in a Cox proportional hazard model in which intubation was not associated with a significant survival benefit (HR, 1.15; 95% CI: 0.36–3.67; P=0.81) (*Table 3*). Conversely, increasing ASA classification and pFEV1 <80% were associated with decreased survival. Compared to lobectomy, wedge resection was associated with lower survival (HR, 0.29; 95% CI: 0.11–0.74; P=0.01).

Subgroup analysis among patients with a primary lung cancer

In a subgroup analysis of 30 non-intubated patients with primary lung cancer, 19 (63.3%) underwent lobectomy, 9 (30.0%) underwent segmentectomy, and 2 (6.67%) underwent wedge resection. The unadjusted 3-year survival in the intubated cohort was 90% compared to 89% in the non-intubated cohort (P=0.31). Propensity-score matched overall survival was 92% in the intubated cohort and 89% in the non-intubated cohort (P=0.61) (*Figure 2*). No statistically significant difference was found in clinical or pathologic stage between the propensity-score matched groups (*Table 4*). The dominant histologic subtype was adenocarcinoma. The average number of harvested nodes and nodal stations did not significantly differ between cohorts.

Discussion

In this study of 72 patients undergoing non-intubated VATS procedures for benign and malignant disease, we found no difference in perioperative morbidity or 3-year survival compared to a control cohort undergoing elective procedures using standard endotracheal intubation. Subgroup analysis did not demonstrate any significant difference between the groups when the indication for the procedure was primary non-small cell lung cancer (NSCLC). This work is important because it demonstrates that non-intubated thoracoscopy may be performed safely and with similar 3-year survival in patients with benign and malignant disease at both large quaternary centers and affiliated community centers.

The Hungarian surgeon Guyla Sebestény performed more than 500 lobectomies, pneumonectomies, and segmental resections between 1938 and 1953 on conscious patients, using intercostal nerve blocks and local anesthesia. His experience, never published, was recounted much later in the memoirs of an East German surgeon who witnessed and assisted in 40 such operations during a 1953 visit to Budapest (11). Neither the operative mortality, quoted by his visitor as "12–15%" in lung cancer and "3–4%" in tuberculosis, nor his own passing in 1954 fully explain Sebestény's silence: this experience would have likely encountered intense controversy among the surgeons of his time.

More recent studies from Asia and Europe have explored the peri-operative outcomes of standard and uniportal VATS in non-intubated patients (12-15). Unlike these studies, we included a 3-year follow-up time in a North American center (tertiary and community). It is critical that innovations in surgical technique that improve perioperative outcomes do not compromise oncologic outcomes (16). We were encouraged that we found no difference in survival in our propensity-score matched cohorts or when performing

Table 3 Cox proportional hazards model for 3-year survival

Patient and operative variables	HR (95% CI)	P value
Non-intubated	1.15 (0.36–3.67)	0.81
Male	0.46 (0.21–1.00)	0.51
Age	1.1 (1.01–1.09)	0.04
BMI	1.03 (0.95–1.10)	0.49
ASA classification		
I	Ref.	
II	0.41 (0.21–0.64)	<0.001
III	0.09 (0.05–0.14)	<0.001
IV	0.01 (0.001–0.03)	<0.001
Hypertension	1.16 (0.65–2.39)	0.68
CHF	1.34 (0.13–12.9)	0.8
CAD	0.89 (0.33–2.33)	0.81
DM	1.30 (0.53–3.15)	0.56
CVD	1.48 (0.42–5.11)	0.54
CKD	0.85 (0.19–3.86)	0.83
pFEV1 <80%	0.41 (0.21–0.81)	0.011
Smoking status		
Never	Ref.	
Former	1.72 (0.47–6.34)	0.41
Current	2.09 (0.78–5.61)	0.14
Procedure		
Lobectomy	Ref.	
Segmentectomy	0.89 (0.34–2.25)	0.8
Wedge	0.29 (0.11–0.74)	0.01
Other	5.97 (1.10–32.4)	0.04
Indication primary lung cancer	2.48 (0.57–10.7)	0.22

HR, hazard ratio; CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; CAD, coronary artery disease; DM, diabetes mellitus; CVD, cerebrovascular disease; CKD, chronic kidney disease; pFEV1, predicted 1 second forced expiratory volume.

subgroup analysis for patients whose indication for resection was a primary lung cancer. We did note a relatively high overall survival in this population with 95% 3-year survival in the intubated cohort and 89% 3-year survival in the non-intubated cohort. While higher than some previous reports, the patients in this study tended to have early-stage disease and the reported survival is similar to that described in the recent JCOG0802 trial (17).

Total operating room time and procedure time were reduced by 69% and 58% in the non-intubated cohort. This resulted in a total time savings of nearly 1 hour and significant potential cost savings to the hospital system (18). There are several explanations for this finding. Intubation, bronchoscopic positioning of a double lumen endotracheal tube, and extubation are eliminated in the non-intubated cohort. In addition, the emergence from anesthesia is

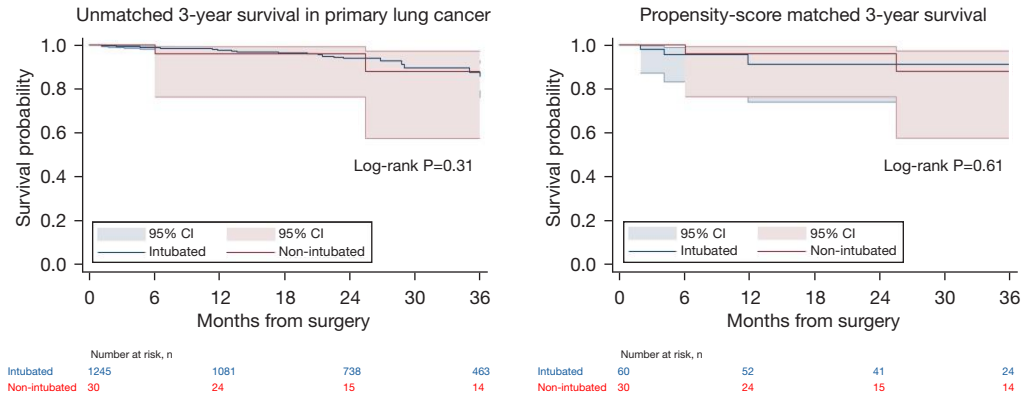

Figure 2 Unadjusted and propensity-score matched overall survival in intubated and non-intubated patients undergoing thoracoscopic procedures for primary lung cancer. CI, confidence interval.

Table 4 TNM status and short-term oncologic outcomes in propensity matched cohorts

Tumor staging	Intubated (n=60)	Non-intubated (n=30)	P value
Clinical T status			0.57
cT1	51 [85]	27 [90]	
cT2	8 [13]	2 [7]	
cT3	1 [2]	1 [3]	
Clinical N status			0.48
cN0	59 [98]	30 [100]	
cN1	1 [2]	0 [0]	
Pathologic T status			0.39
pT1	44 [73]	24 [80]	
pT2	12 [20]	4 [13]	
pT3	4 [7]	1 [3]	
pT4	0 [0]	1 [3]	
Pathologic N status			0.059
pN0	52 [87]	25 [83]	
pN1	5 [8]	0 [0]	
pN2	2 [3]	1 [3]	
pNX	1 [2]	4 [13]	
Nodal stations sampled	3.0 (2.0, 4.5)	3.0 (2.0, 6.0)	0.67
Total nodes sampled	6.0 (3.0, 11.0)	8.0 (3.0, 14.0)	0.72
Histology			0.52
Adenocarcinoma	51 [85]	28 [93]	
Other	5 [8]	1 [3]	
Squamous	4 [7]	1 [3]	

Data are presented as n [%] or median (IQR). TNM, tumor-node-metastasis; IQR, interquartile range.

shorter due to lack of neuromuscular blockade and lighter sedation (19). More surprisingly the length of procedure time was also reduced in the non-intubated cohort. We suspect that during non-intubated surgery there is more impetus to operate in an expedient manner and reduce any delays. We did not limit to simple cases but did use the criteria included in Appendix 1 in selecting patients for non-intubated surgery. This includes factors such as lower BMI and less advanced disease. While these factors were included in our propensity-score match not all patient and disease factors affecting the operation are accessible to balance, and it is possible there were uncaptured differences. As non-intubated thoracoscopic surgery becomes more widely adopted we may see a paradoxical increase in operative time as the surgical and anesthesiology teams become more comfortable with the procedure.

In subgroup analysis of patients undergoing elective procedures for primary NSCLC, we found no difference between the matched cohorts. A vast majority of lung cancers were early (T1a and T1b) clinical stage I, and pathologic upstaging was rare in both cohorts. The mean of sampled nodal stations and harvested nodes were similar for intubated and non-intubated patients. For part of the study time-period the recommended nodal harvest for anatomic resection was ≥10 nodes (20). In the intubated and non-intubated cohorts, the average nodal harvest was significantly less at 6. However, this may reflect limitations in this quality metric which has since been abandoned. Indeed, within the STS database this metric was frequently missed among participating centers (21). Unfortunately, sampling of three mediastinal stations and one hilar station as recently adopted by the American College of Surgeons Commission on Cancer and National Comprehensive Care Network was not reliable tracked, and rose not to a standard during the majority of the study interval (22,23). While access to mediastinal stations is potentially more difficult in the non-isolated lung (7), our study did not confirm this assumption, and was therefore consistent with the propensity-score matched analysis by Liu and coauthors (8).

There have been several recent reports on non-intubated VATS both for anatomic and non-anatomic lung resection with pain control augmented with epidural catheters (2,12). In both a general adult and geriatric population, Chen *et al.* and Wu *et al.* demonstrated the safety and short-term efficacy of anatomic resection for early-stage NSCLC (7,24). This work was replicated in a randomized clinical trial performed by Liu *et al.* involving 354 patients, again with the use of an epidural catheter (25). Perioperative outcomes were similar except for a slight reduction in hospital stay in the non-intubated cohort.

Conversely, we achieved adequate analgesia with instillation of local anesthetic, without use of an epidural catheter. While well-positioned epidural catheters may aid in analgesia, a variety of complications, including post-operative hypotension, has been observed in nearly 5% of patients (26). In a comparison of patients undergoing VATS procedures, patients receiving liposomal bupivacaine intercostal blocks performed favorably and at a lower overall cost compared to patients receiving thoracic epidural catheters (27). The epidural catheter remains the discretion of operating surgeon and anesthesiologist; however, our study shows that non-intubated VATS procedures may be performed safely and effectively with local anesthetic, selective use of intravenous analgesics and monitored sedation alone (28).

As with the adoption of any new procedure or technique there was significant apprehension associated with non-intubated surgery. However, prior to adoption meetings occurred between surgeons and anesthesiologists. A pre-defined selection criteria (Appendix 1) was agreed upon which included preference for patients of lower BMI, less advanced disease, and tumors involving the lower lobes. This helped ameliorate any anxiety associated with adoption. As the number of patients and clinicians involved with non-intubated surgery increased it became more routine and these sources of stress were reduced. By the end of the 5-year study period, there was significant accrued experience with 11 anesthesiologists being directly involved in patient care during the procedures.

Strengths of this study include its setting in both a quaternary care academic center and associated community hospital. It includes 3-year follow-up of patients operated on for both malignant and benign disease by two different surgeons. Perioperative outcomes were recorded using the same definitions as those reported by the STS. However, generalizability may be limited by the inclusion of only two affiliated centers. The greatest limitation of this work is the inherent selection bias in the patients who undergo non-intubated thoracoscopic surgery. Despite a 5-year accrual period, we were only able to include 72 patients who underwent non-intubated procedure. Moreover, this was a heterogenous study group with oncologic and non-oncologic indications for intervention. We attempted to control for this using propensity-score matching and subgroup analysis of patients with a primary pulmonary

malignancy, but it is possible that unaccounted variables effected the results of this study. In addition, we were unable to match five patients in the non-intubated cohort that underwent nonelective procedures. Missing DLCO and other variables may have influenced treatment decisions. Given the retrospective nature of this work, we did not assess postoperative delirium, of interest because general anesthesia, compared to its avoidance, is associated with increased delirium in older patient populations (29,30). Other limitations include the lack of disease-specific survival, recurrence-free survival, or distance to margin. These variables were not included in the institutional or STS database and were not available for this study. It is possible that despite similar overall 3-year survival, these variables differ significantly in patients receiving non-intubated thoracoscopic surgery and that differences in survival would become more apparent at 5- or 10-year follow-up.

Conclusions

Non-intubated thoracoscopic surgery is safe, feasible, and efficacious in carefully selected patients. Gradual relaxation of selection criteria may broaden the practice of pleural space operations, while avoiding muscle relaxation and tracheal intubation. Thoracic surgeons and anesthesiologists should be aware and familiar with non-intubated thoracoscopic approaches and their potential benefits.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-591/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-591/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The protocol for this study was approved by the Mass General-Brigham Institutional Review Board (No. 2022P000958, 25 April 2022) and patient consent was waived given the retrospective nature of this work.

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