A successful shift from thoracotomy to video-assisted thoracoscopic lobectomy for non-small cell lung cancer in a low-volume center

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Abstract

Objectives: Although video-assisted thoracoscopic (VATS)-lobectomy has become the gold standard for pulmonary resections of NSCLC, lobectomy is still performed via thoracotomy in many European and North American centers. VATS-lobectomy was implemented overnight from thoracotomy in our low-volume center in early 2019, after one senior surgeon undertook observership VATS-training overseas, and immediately became the mainstay of surgical treatment for non-small cell lung cancer (NSCLC) in Iceland. We aimed to investigate our short-term outcomes of VATS-lobectomy.

Methods: This was a retrospective study on all pulmonary resections for NSCLC in Iceland 2019-2022, especially focusing on VATS-lobectomies, all at cTNM stage I or II. Data were retrieved from hospital charts, including information on perioperative complications, mortality, length of stay and operation time.

Results: Out of 204 pulmonary resections, mostly performed by a single senior cardiothoracic surgeon, 169 were lobectomies (82.9%) with 147 out of 169 (87.0%) being VATS-lobectomies. Anterolateral thoracotomy was used in 34 cases (16.7%), including 22 lobectomies (64.7%), and 5 (3.4%) conversions from VATS-lobectomy. The median postoperative stay for VATS-lobectomy was 4 days and the average operating time decreased from 155 to 124 minutes between the first and last year of the study ($p<0.001$). The rate of major and minor complications was 2.7% and 15.6% respectively. One year survival was 95.6% and all patients survived 30-days postoperatively.

Conclusions: The implementation of VATS-lobectomy has been successful in our small geographically isolated center, serving a population of 390.000. Although technically challenging, VATS-lobectomy was implemented fast for most NSCLC-cases, with short-term outcomes that are comparable to larger high-volume centers.

Introduction

The mainstay of curative treatment for non-small cell lung cancer (NSCLC) is lobectomy, and is used for around 80% of the surgically treated patients [1, 2]. Traditionally lobectomies were performed via thoracotomy. However, for the last three decades, VATS-lobectomy has gained increasing popularity for showing advantages over thoracotomy regarding hospital stay, fewer complications, faster recovery times and non-inferior survival rates both for early-stage and locally advanced disease [3-6]. Despite these clinical benefits approximately 30-40% of centers in North America and Europe still perform lobectomy via thoracotomy [7, 8]. Globally the implementation of VATS is challenged both by being a more expensive option and more technically challenging, reflected in a learning curve ranging of 35-50 procedures [6, 8-11].

In Iceland, a geographically isolated island in the North Atlantic with around 390.000 inhabitants, lung cancer has for decades been the second most common cancer for both genders [12]. Today, approximately 170 individuals are diagnosed annually with NSCLC, with every third patient undergoing pulmonary resection at Landspitali University Hospital, the only center offering pulmonary surgery in Iceland [13]. Traditionally, these procedures were performed by muscle-sparing anterolateral thoracotomy by senior cardiothoracic surgeons not having previous experience with VATS-lobectomy, with a 30-day mortality under 1%. [2, 14]. In early 2019, VATS was introduced as the mainstay treatment for both lobectomies and sublobar resections in our center, after one of the senior surgeons (surgeon 1) undertook a two month VATS-training program, mostly consisting of observership, at high-volume centers in Sweden and Denmark. His time overseas was mostly spent observing, however, also performing several VATS-lobectomies under the supervision of another senior surgeon (surgeon 2) that a year later moved to Iceland to work partime.

The aim of this study was to investigate short-term outcomes of our initial four-year experience with VATS-lobectomies, focusing on the learning curve, postoperative complications, and 30-day mortality.

Materials and methods

Ethics statement

The study was approved by the Icelandic National Bioethics Committee (Ref.: 98-060-V5-S1). As individual patients were not identified, the need for individual consent was waived.

Study design

This was a retrospective cohort study including all patients that underwent lobectomy with VATS for primary NSCLC with curative intent in Iceland from January 1, 2019 until December 31, 2022. The inclusion criteria for VATS-lobectomy were histologically verified NSCLC, clinical TNM-stages I or II, all tumors being <7 cm in maximal diameter and without signs of mediastinal lymph node metastasis (N0) on imaging studies. Endobronchial ultrasound (EBUS) was performed if mediastinal lymph nodes were positive on positron emission tomography (PET) or enlarged. Otherwise a lobectomy was performed on resectable patients via an anterolateral thoracotomy. This study focused on the 147 patients operated on with VATS-lobectomy, including those that were converted to thoracotomy, but excluding patients that underwent lobectomy via anterolateral thoracotomy incision, wedge resections, segmentectomy, and pneumonectomy. Patients with a postoperative pathological diagnosis of carcinoma *in situ*, adenoid cystic carcinoma, mucoepidermoid carcinoma, carcinoid, or sarcoma were excluded.

All procedures were performed at Landspitali University Hospital, the only hospital in Iceland performing cardiothoracic surgery. Two senior surgeons conducted all procedures, both being senior cardiothoracic surgeons performing pulmonary and cardiac procedures: One of them (Surgeon 1) had no prior experience with VATS-lobectomy, and performed 78% of the cases, including all cases performed in the first year of the study, but the other (Surgeon 2) had 7 years experience with VATS-lobectomy when starting working part-time in Iceland in 2020.

Data curation and demographics

Cases were identified from three databases: the operation registry at Landspitali University Hospital, the diagnosis registry at Landspitali University Hospital and the Icelandic Cancer Registry.

Clinical data were retrieved from medical records and surgical reports. Over sixty variables were collected for each patient, including: age, gender, smoking history, comorbidity (chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD) and arrhythmias), pulmonary function tests (FEV1 and FVC), type of surgery performed, postoperative length of stay, postoperative complications, adjuvant therapy, American society of anesthesiology (ASA)-score and date of death.

The seventh edition of the TNM staging system was used to stage all the tumors postoperatively (pTNM). Previous smokers were defined as patients who stopped smoking 5 years before surgery. Complications following surgery were defined as major and minor complications. Major complications included bronchopleural fistula (BPF), myocardial infarction (MI), acute respiratory distress syndrome (ARDS) and reoperation for postoperative bleeding. Minor complications were congestive heart failure (CHF), empyema, new-onset atrial fibrillation, postoperative pneumonia, recurrent nerve paralysis, wound infection, air leakage over 7 days, and intraoperative bleeding of >1 L (without reoperation). Operation mortality was defined as death within 30 days of surgery. Patients were assigned a date of death or identified as living on June 14, 2023, using data from the Icelandic National Population Registry. The mean follow-up time was 795 days (26.1 months, range: 65-1609 days).

Surgical procedure

VATS-lobectomy was performed in general anesthesia using double-lumen intubation for single lung ventilation, with the patient placed in the lateral decubitus position. The standard three port anterior approach was used. A 3-5 cm utility incision was performed in the mid-axillary line between the 4th and 5th rib, without using a rib retractor. A 0,5 cm or 1 cm camera port was placed at the level of the

diaphragm in the anterior axillary line, with an additional 1.5 cm in the posterior axillary line, at the same level as the camera port. The utility incision allowed for direct access to the lung hilum and for dissection of vessels and bronchi. In case of conversion, the utility incision was extended to an anterolateral thoracotomy. Lobectomy was always performed with an anatomical dissection of the hilum and systematic mediastinal lymph node dissection was performed, including stations 4R, often 2R, 7, 10, 11 and 9 on the right side and stations 4L, 5, 10, 11, 7 and 9 on the left side. The pulmonary veins, arteries and bronchi were dissected and stapled using an endoscopic stapler, and an endoscopic bag was used to remove the specimens through the utility incision. Before closing the incision, an intercostal local anesthesia from the thoracic cavity was performed using ropivacaine.

Statistical analysis

Microsoft Excel was used to store the dataset and statistical analyses were carried out using R (Vienna, Austria), version 4.2.2., via R Studio (RStudio, PBC, USA), version 2022.12.0+353. Chi-squared test was used to compare categorical variables and ANOVA was used to compare continuous variables. Differences were considered significant if the p-value was less than 0.05. The Kaplan-Meier method was used to estimate the overall survival of the group.

Results

A flowchart showing the inclusions of the patients is shown in **Figure 1**. Out of 621 patients that were diagnosed with NSCLC during the four-year study period, 197 (31.7%) of them underwent 204 pulmonary resections. Lobectomy was performed in 169 cases (82.9%), with 147 out of 169 (87.0%) being VATS-lobectomies and 22 via anterolateral thoracotomy incision (13.0%). Other pulmonary resections consisted of 28 sublobar resections (wedge or segmentectomy, 13.7%), 23 performed with the VATS technique, and 7 pneumonectomies all performed via a thoracotomy incision (3.4%).

Patient demographics, comorbidities and risk factors are shown in **Table 1**. The average age was 70 (SD = 8) years and 54.4% were female. Altogether, 92.5% of the patients had a history of smoking with 36 (SD = 24) pack-years on average and 53.7% smoked within 5 years prior to the diagnosis. For TNM staging, the majority exhibited stage I (71.4%) disease, predominantly stage IA (46.9%). Stage II disease was seen in 22.4% of cases, with stage IIA and IIB rates being 8.8% and 13.6% respectively. Additionally, 6.2% of patients had surgically resectable locally advanced disease (stage IIIA). During the study period 10 patients had N1 lymph node disease after pathology analysis and 5 patients N2 disease. The most common histology types were adenocarcinoma (76.2%) and squamous cell carcinoma (20.4%), but large cell and adenosquamous carcinoma were less common (1.4% and 2.0% respectively). Cancer-free surgical margins were observed in 146 cases (99.3%) and microscopic disease at the resection margins (positive margins) was detected in one patient (0.7%). The mean size of the surgically resected tumors measured 2.8 (SD = 1.6) cm, with a range spanning from 0.9 to 9.8 cm.

Both minor and major complications are listed in **Table 1**. Four patients (2.7%) had one or more major complications. No patient developed a bronchopleural fistula (BPF). Altogether, 23 patients (15.6%) had one or more minor complications, air leakage for more than seven days being the most common one (13 patients, 8.8%), with 19 patients (12.9%) having air leakage for more than five days. Atrial fibrillation occurred in 4.1% of patients and other minor complications were less common, which

included intraoperative bleeding over 1000 mL (2.0%), pneumonia (1.4%), and empyema (0.7%). The median postoperative stay was 4 days overall. Adjuvant therapy was administered postoperatively to 25 patients (17.0%) and the median days until the start of adjuvant therapy was 41 days.

The annual proportions of lobectomies performed with the VATS technique from 2019 to 2022, were 80.5% (n=33), 82.5% (n=33), 89.2% (n=33) and 94.1% (n=48) respectively, but did not change significantly (p=0.125). In 5 patients (3.4%) VATS was converted to thoracotomy because of intraoperative bleeding (n=2) or adhesions (n=3), all of them occurring in the first two years of the study.

The average operative time for each year and for surgeons 1 and 2 that performed all of the operations are shown in **Figure 2**. The mean operative time was 142 minutes (range: 47-280 min) decreasing significantly over the four-year period, reaching 124 minutes in 2022 (p=0.031). Surgeon 1, performing his first VATS-lobectomy in 2019, had an average operative time of 152 minutes, decreasing from 168 minutes to 132 minutes during the study-period (p=0.029). Surgeon B, who had been performing VATS-lobectomies for 7 years in Sweden, had an average operative time of 107 minutes, and his operating time did not change during the study period.

Overall survival is shown in **Figure 3**, with a Kaplan-Meier graph. All patients survived the operation with a 0% 30 day and hospital mortality. 90 day mortality was 0.68% and one year survival was 95.6%.

Discussions

In this nationwide retrospective cohort study on 147 consecutive NSCLC patients treated for curative resection, we investigated the implementation of VATS-lobectomy in our low-volume single center. Although the introduction of this technically challenging procedure happened overnight, we experienced low complication rates, all patients survived 30 days, short postoperative stay and low 1-year mortality. Furthermore, the mean operative time decreased significantly during the period, reaching around two hours in 2022. We believe that our findings support that VATS-lobectomy can be implemented safely in a low-volume center without compromising patient safety and quality of care.

All patients survived 30 days postoperatively, in line with prior studies on VATS-lobectomy [15], but similarly our own long experience with anterolateral thoracotomy, where mortality has been below 1% [2]. Due to insufficient follow-up time, we are unable to draw conclusions on longer-term outcomes, however, our 95.6% one-year mortality is comparable to previous reports from high-volume centers [6, 16, 17].

Our overall rate of complications was relatively low, usually ranging between 6-34% in prior studies. However, this fluctuation may be dependent on varying definitions for complications [18-20]. Importantly, most of the complications observed were minor and only 2.7% of the patients (n=4) sustained a major complication, most often myocardial infarction (1.4%) and reoperation for bleeding (1.4%). For comparison, other studies have reported major complication rates of around 8% [18, 20, 21]. Persistent air leakage extending 7 days was the most common minor complication (8.8% and 12.1% after 5 days) and is the most common cause of prolonged hospital stay after lung cancer surgery [22]. The median postoperative stay in the current study was 4 days, which is in line with many other studies [6, 17, 23], although shorter times (2-3 days) have been reported [24, 25]. Notably, 31.3% and 12.2% of our patients were discharged on post-op day 2 and 3, respectively. For comparison, an Icelandic study on 493 lobectomies performed with anterolateral thoracotomy between 1991 and

2014 reported 17.2% air leakage over 7 days and the median postoperative length of stay was 9 days [2]. Although the time periods of these two studies differ, the median postoperative stay has shortened substantially since VATS-lobectomy was introduced, presumably driven by the much lower rates of air leakage associated with VATS.

Our findings are comparable to an Italian study that reported short-term outcomes of VATS-lobectomy, all performed by a single surgeon with previous training and work experience in a high-volume center. Although the operative time was longer in the small thoracic unit in the study, median postoperative stay was 4.5 days, compared to 4.1 days in the high-volume center, but short-term outcomes were otherwise very similar, including intraoperative and 30-day mortality [23].

The mean operative time for the whole study period was 142 minutes, all of the operations being performed by two senior surgeons, regularly performing pulmonary and cardiac procedures. Surgeon 1 had no prior experience in VATS-lobectomy when the study started, except for two months of VATS-lobectomy training in high-volume centers in Sweden and Denmark, and performed all of the 33 cases during the first year of the study. Surgeon 2 started working part-time in Iceland in early 2020 and performed 33 of the 147 cases (22%), but he had seven years of prior experience with VATS-lobectomies in a high-volume center in Sweden. The median operative time for surgeon 1 decreased significantly after the first year, or from 168 minutes to 152 and 132 minutes in the last two years, respectively (p=0.029). The learning curve for surgeon 1 therefore seems to be in line with the 35-50 operations frequently reported in the literature for VATS-lobectomy, although these numbers usually originate from high-volume centers [8, 10, 11].

Today, VATS training is widely incorporated in thoracic surgery training, and therefore a growing number of centers in the future will have surgeons equipped with VATS-lobectomy experience [26]. Importantly, starting a VATS-lobectomy program does not only require experienced surgeons, but also

equipment, such as a thoracoscopy-module with high-definition imaging and special endoscopic surgical instruments. This investment in tools, especially endoscopic staplers, is costly and one of the main reasons that the implementation of VATS has been delayed, especially in low-volume centers. Furthermore, training of other personnel, such as operating nurses and anesthetists is also of vital importance, as is training of nurses on the wards, if ERAS fast-track principles are to be followed [27]. Although the initial cost of VATS is higher when compared to thoracotomy, VATS-lobectomy has been shown to be cost-effective in numerous studies, as postoperative hospital stay is shortened, and readmissions are fewer [28-30].

One of the main limitations of this study is the retrospective design, as well as potential lack of documentation on the patients history and postoperative care. The strength of the study is that the cohort consists of patients from a whole population, all of whom were operated on in a single center by two surgeons, reducing the risk of institutional bias. Importantly, during the study period all NSCLC cases were discussed on a Tumor Board, before and after surgery, and all patients were operated on in Iceland and no patients were operated on overseas.

Conclusions

This nationwide cohort study supports that the implementation of VATS-lobectomy in small low-volume centers without prior experience in advanced anatomical VATS-resections is possible within a short time frame, importantly not impacting on patient safety and with favorable short-term outcomes that are comparable to larger high-volume centers. We hope our experience will pave the way for more low-volume centers to introduce VATS-lobectomy.

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Disclosure statement

Conflict of interest: none declared.

All authors have contributed to the study and final manuscript.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Figure legends and tables

Central image:
The mean operative time (*dashed line*) for each year and for the two surgeons that performed the first 147 VATS-lobectomies in Iceland over the four year study period. Red line shows the learning curve for surgeon 1. Surgeon 2, who had several years experience with VATS-lobectomy, started working in Iceland 2020.

Figure 1:
Study inclusion flowchart. NSCLC: Non-small cell lung cancer, VATS: Video-assisted thoracoscopic surgery.

Figure 2:
The mean operative time (*dashed line*) for each year and for the two surgeons that performed the first 147 VATS-lobectomies in Iceland over the four year study period. Surgeon 2, who had several years experience with VATS-lobectomy, started working in Iceland 2020.

Figure 3:
The overall survival for all 147 VATS-lobectomy patients in Iceland, 2019-2022.

Table 1. Patient demographics, preoperative risk factors and comorbidities, TNM-staging, histology, post-operative complications and adjuvant therapy administered for the first 147 VATS-lobectomies in Iceland, 2019-2022.

	n (%)
Descriptive factors	
- Female	80 (54.4)
- Age (years)	70 (SD = 8)
Risk factors	
- Smoking history	136 (92.5)
- Smoker within 5 years	79 (53.7)
- COPD	56 (38.1)
- IHD	37 (25.2)
- Arrhythmias	31 (21.1)
- FEV1 < 75%	37 (25.2)
pTNM stage	
- IA	69 (46.9)
- IB	36 (24.5)
- IIA	13 (8.8)
- IIB	20 (13.6)
- IIIA	9 (6.2)
Tumor factors	
- Adenocarcinoma	112 (76.2)
- Squamous cell carcinoma	30 (20.4)
- Adenosquamous carcinoma	3 (2.0)
- Large cell carcinoma	2 (1.4)
- Diameter of tumor (mean, cm)	2.8 (0.9-9.8)
- Free surgical margins	146 (99.3)
Major complications	4 (2.7)
- BPF	0
- MI	2 (1.4)
- ARDS	1 (0.7)
- Reoperation for bleeding	2 (1.4)
Minor complications	23 (15.6)
- CHF	1 (0.7)
- Empyema	1 (0.7)
- AF	6 (4.1)
- Pneumonia	2 (1.4)
- RNP	0
- Wound infection	0
- Air leakage >7 days	13 (8.8)
- Intraoperative bleeding >1L	3 (2.0)
Adjuvant therapy	25 (17.0)
- Median days until administration	41 [35-48]
Total postoperative stay	
- Mean	5.9 (SD = 5.3)
- Median	4 [2-7]

COPD: chronic obstructive pulmonary disease; IHD: ischemic heart disease; FEV1: forced expiratory volume in 1 second; BPF: bronchopleural fistula; MI: myocardial infarction; ARDS: acute respiratory distress syndrome; CHF: congestive heart failure; AF: atrial fibrillation; RNP: recurrent nerve paralysis.

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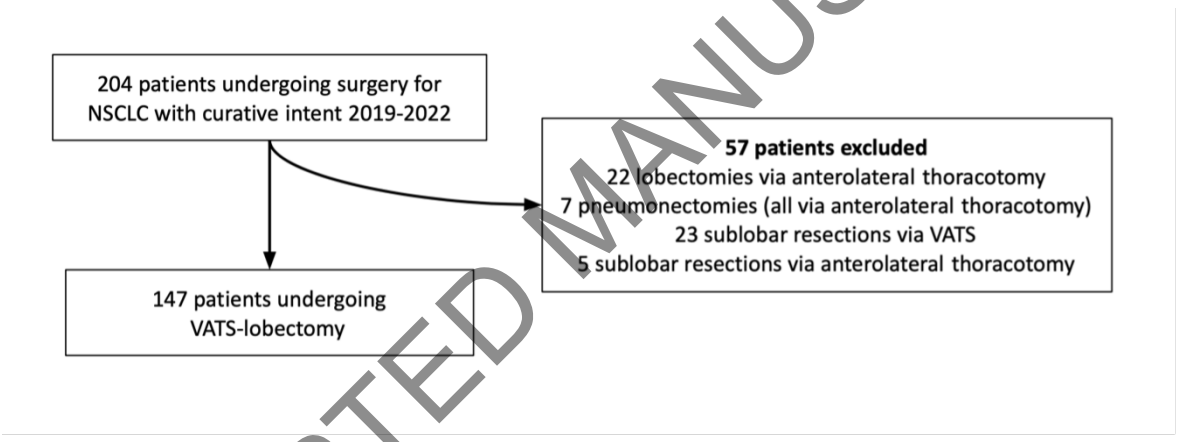


Figure 2

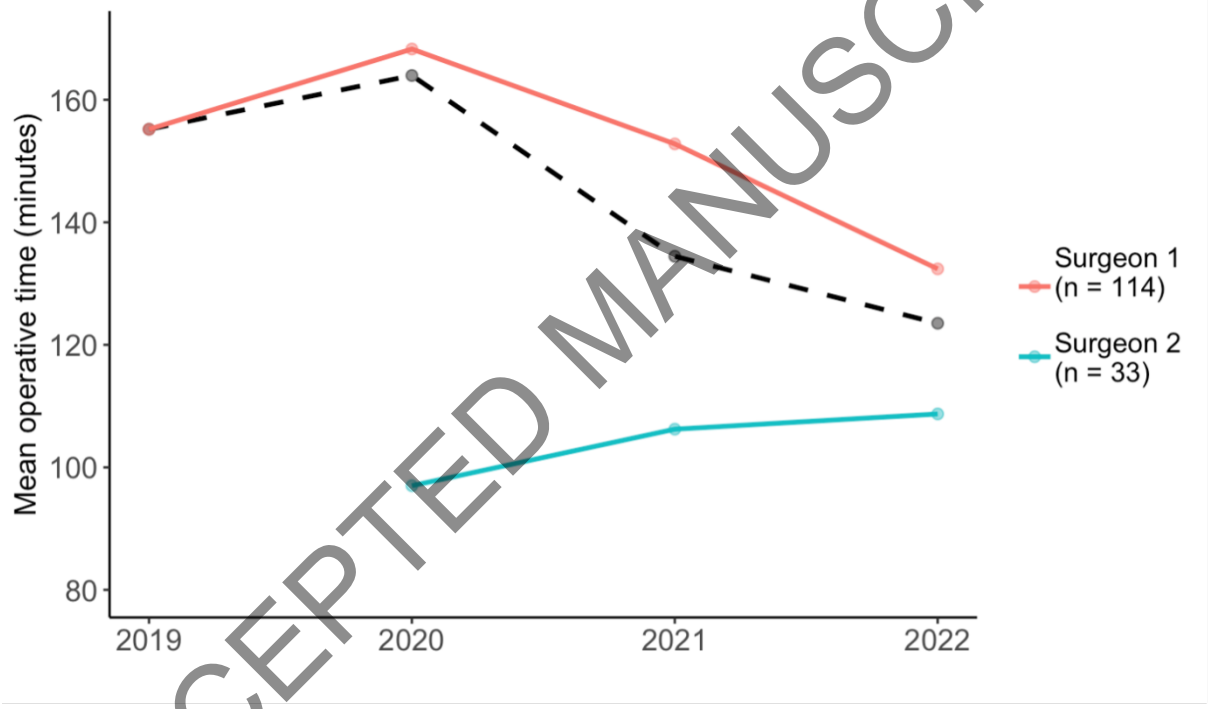
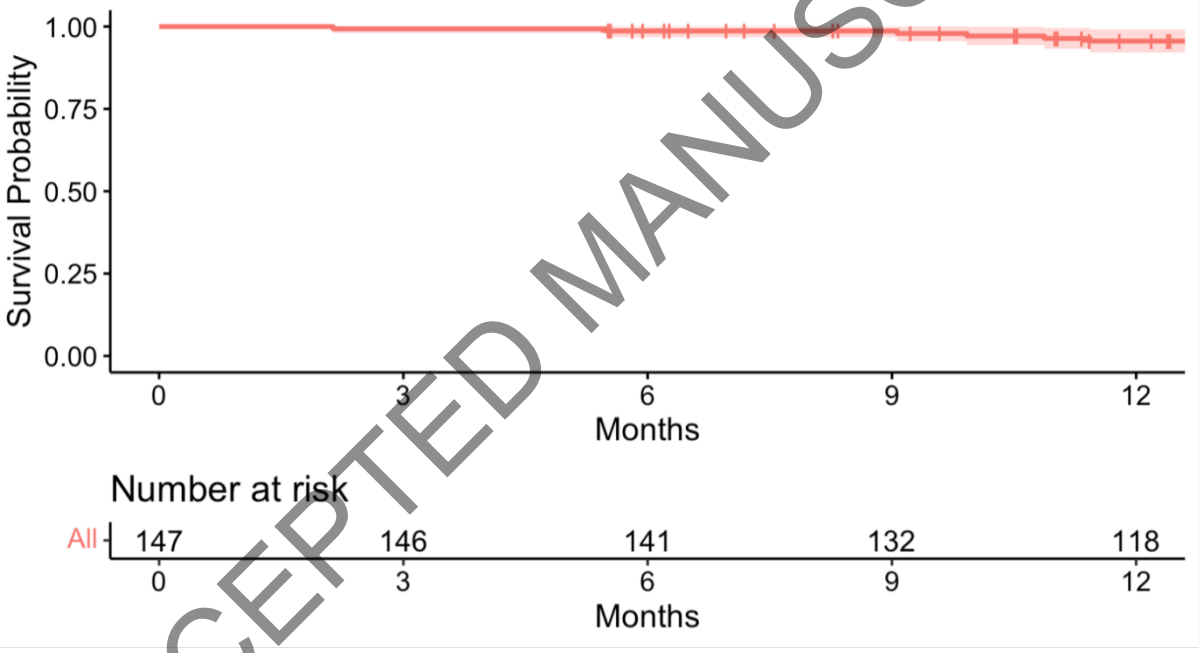


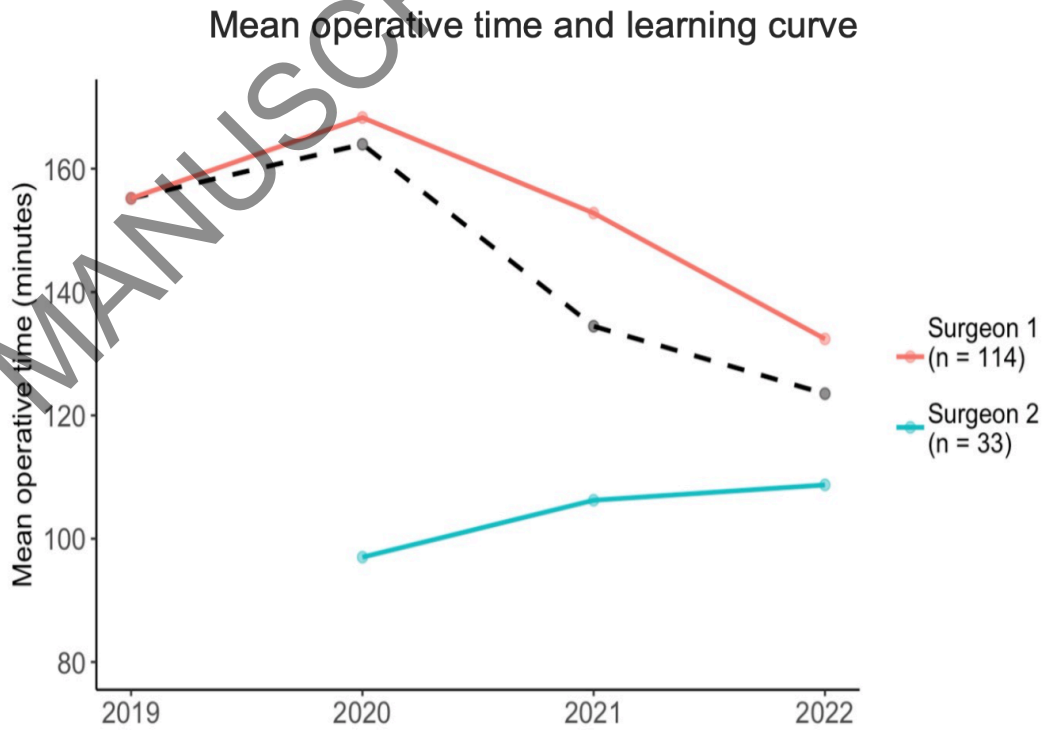
Figure 3



A successful shift from thoracotomy to VATS-lobectomy for NSCLC in a low-volume center

Summary

In a retrospective study of 147 patients who underwent VATS-lobectomy for NSCLC in a small geographically isolated center, we examined the learning curve and short-term outcomes during the initial four years. We found that VATS-lobectomy can be implemented, overnight, in a low-volume center without compromising patient safety and quality of care.



VATS: video-assisted thoracoscopic surgery, NSCLC: non-small cell lung cancer