DANISH MEDICAL JOURNAL

Original Article

The experience of video-assisted thoracoscopic lobectomies

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Dan Med J 2025;72(4):A09240649. doi: 10.61409/A09240649

ABSTRACT

INTRODUCTION. Video-assisted thoracoscopic surgery (VATS) lobectomy is increasingly replacing open thoracotomy as the standard surgical treatment for early-stage non-small cell lung cancer owing to its greater efficacy, as demonstrated in RCTs. This study aimed to examine the effectiveness and evolution of lung cancer treatment by VATS lobectomy in a single centre.

METHODS. This retrospective single-centre cohort study at the Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, Denmark, examined operative reports for all VATS lobectomies performed in-house from 3 March 2008 to 6 July 2023, as well as medical records at one-year follow-up for 10% of the patients.

RESULTS. VATS lobectomies were identified (N = 1,705). A steady annual increase in performed procedures and the number of performing surgeons was observed, and more frail patients underwent the procedure. Operation time, mean chest tube drainage time, length of hospitalisation and rate of annual conversions declined along with the amount and severity of post-operative complications, cancer recurrence and mortality at the one-year follow-up.

CONCLUSIONS. Treatment effectiveness, measured by peri- and post-operative outcomes, aligned with the efficiency presented in RCTs, with significant benefits of VATS compared to traditional anterolateral thoracotomy. Furthermore, treatment effectiveness evolved during the study period, and the introduction and training of new surgeons improved, enhancing the quality and availability of VATS throughout the period.

FUNDING. None.

TRIAL REGISTRATION. Not relevant.

Following advancements in video-assisted thoracoscopic surgery (VATS), improved outcomes in post-operative pain, morbidity, complications and hospitalisation time have been reported compared to open surgery [1, 2]. As a result, VATS is increasingly replacing thoracotomy as the standard surgical treatment for a wide range of thoracic diseases, including early-stage non-small cell lung cancer [3].

The national resection rate of Danish lung cancer patients has increased from 12.9% (n = 507) in 2008 to 28.6% (n = 1,256) in 2021, with VATS accounting for 27.8% and 81.2% of all procedures performed, respectively [4]. As recommended by Danish guidelines [5], lobectomies dominate are the predominant surgical for lung cancer patients in clinical stages I and II without medical contraindications, accounting for 83% of cases nationwide [4]. Danish guidelines have not changed substantially from 2008 to 2023, but with increased experience, the rate of VATS increased accordingly.

Although RCTs [1, 2] have shown that VATS is more effective than thoracotomy, its effectiveness in lung cancer treatment may, in practice, be compromised by, e.g., the complexity of a more generalised population, resulting in care of uncertain benefit.

Danish VATS lobectomy rates are among the highest worldwide [6]. Denmark's tax-funded healthcare system provides equal access to healthcare for all citizens and stores all information on all in- and outpatient hospital contacts in a national registry. The standard Danish oncological regimen for lung cancer patients includes as a minimum post-operative clinical and computed tomographic follow-up every three months for two years [7]. These conditions allow for substantial, unbiased retrospective research on modern VATS treatment for lung cancer.

This study examined the evolution and effectiveness of lung cancer treatment by VATS lobectomy at Aarhus University Hospital (AUH), Denmark, focusing on peri- and post-operative outcomes, efficiency and availability through objective and subjective measures.

Methods

Design and screening

This retrospective single-centre cohort study was conducted at the Department of Cardiothoracic and Vascular Surgery, AUH, Denmark.

All lung cancer patients undergoing VATS lobectomy between 3 March 2008 and 6 July 2023 were identified and included from in-house patient files using national procedure codes (Thoracoscopic lobectomy of lung, KGDC01 and Thoracoscopic bilobectomy of lung KGDC11). Patients who were misclassified were excluded. Screening was performed by K. Steen and M. Bendixen.

Patient data were analysed, including age at surgery, sex, date of operation, length of operation, resected lobe(s), primary attending surgeon, perioperative death and conversion status. Information regarding intraoperative complications was extracted for all surgeries when converting from VATS to an open procedure.

Assessment of complications

Complications were assessed using 10% of the patients from the total cohort. The dataset was divided into three periods with groups of equal size: the first ("G1"), middle ("G2") and last cases ("G3") sorted by date of surgery. The patients included in the analysis were randomly picked from each cohort. All medical records of the subgroups were reviewed to assess pre-, peri- and post-operative patient status. The following information was extracted: preoperative patient comorbidities, BMI, pathological tumour-node-metastasis (pTNM) status, tumour size, forced expiratory volume in the first second (FEV1), diffusing capacity for carbon monoxide, intra- and post-operative complications (during and after hospitalisation), length of hospitalisation, post-operative chest drainage duration, cancer recurrence and post-operative survival time.

Patient files were reviewed for 12 months from the surgery date until death, emigration or study end on 11 April 2024, whichever occurred first.

Comorbidities (including cancer) were measured according to the Charlson Comorbidity Index [8].

Complications were graded according to the Clavien-Dindo Scale of Surgical Complications (CDC) [9]. Each patient's accumulated score was calculated according to the Comprehensive Complication Index (CCI) [10].

Ethics

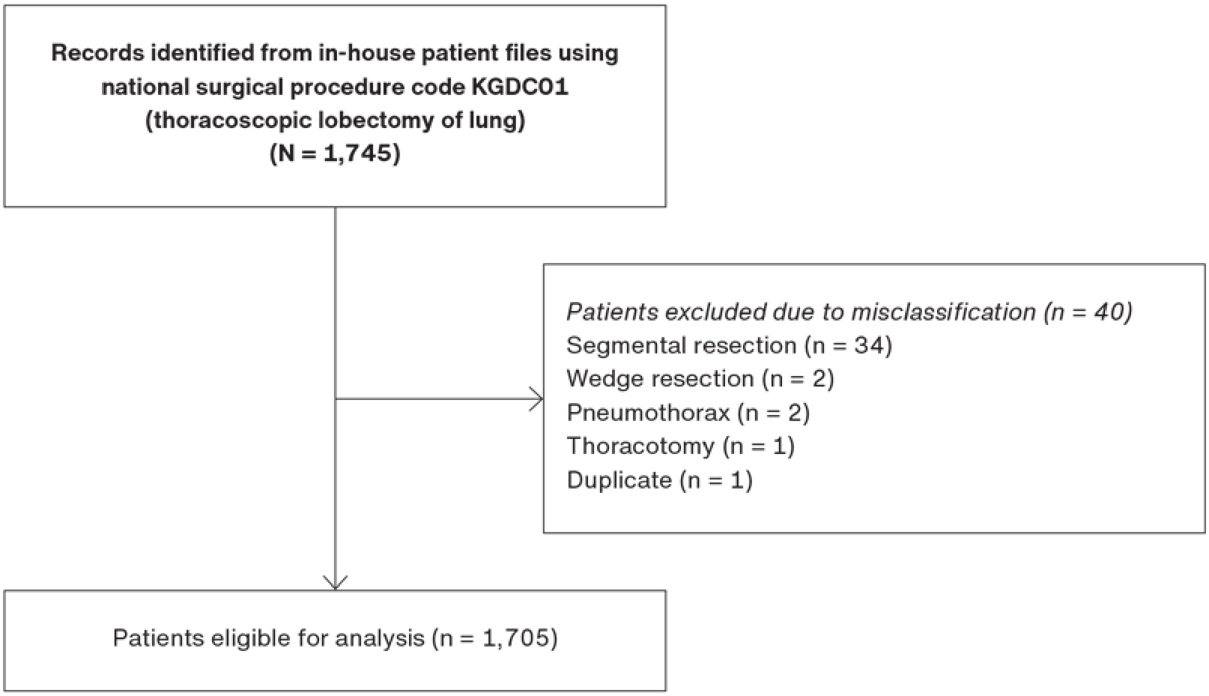
The Legal Department of Region Midtjylland (Central Jutland) approved this study through institutional registration (ref.: 789896). The Danish Health Data Authority provided the data.

Trial registration: not relevant.

Results

We identified 1,745 VATS lobectomies performed at AUH during the study period. After screening for misclassification, the final cohort consisted of 1,705 cases. See **Figure 1** for a flowchart presenting the screening process.

FIGURE 1 Flow chart presenting the screening process for study inclusion.



Cohort characteristics

Patient characteristics are presented in **Table 1**. Supplementary Table 1 includes annual baseline characteristics.

TABLE 1 Baseline characteristics of all lung cancer patients undergoing video-assisted thoracoscopic surgery lobectomy between 3 March 2008 and 6 July 2023 at the Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, Denmark.

Age at operation, mean (± SD), yrs	68.6 (± 8.14)
Male gender n/N (%)	786/1,705 (46.1)
Lobe resection n/N (%)	
Right upper lobe	565/1,705 (33.2)
Right middle lobe	125/1,705 (7.3)
Right lower lobe	355/1,705 (20.8)
Left upper lobe	389/1705 (22.8)
Left lower lobe	277/1,705 (16.3)
Bilobectomy	7/1,705 (0.4)
Secondary lobectomy[a]	8/1,705 (0.5)
Length of operation, mean (± SD), min.	141.2 (± 50.34)
Conversions, n/N (%)	74/1,705 (4.3)
Indication for conversion n/N (%)	
Bleeding	27/74 (36.5)
Adhesions	21/74 (28.4)
Anatomical difficulties	20/74 (27.0)
Tumour invasion	7/74 (10.8)
Other[b]	6/74 (8.1)
Perioperative death[c], n/N (%)	0/1,705 (0.0)

SD = standard deviation; VATS = video-assisted thoracoscopic surgery.
a) Patients undergoing two separate VATS lobectomies during the study period.
b) Remaining indications include bronchial rupture, intrathoracic infection and pulmonary hypertension.
c) All-cause mortality.

Subgroup characteristics

Medical journals were reviewed for 10% (n = 171) of the included patients. The journals were divided into three subgroups, each consisting of 57 patients: "G1" from 4 March 2008 to 26 October 2010, "G2" from 14 December 2018 to 27 May 2019 and "G3" from 17 April 2023 to 6 July 2023.

The subgroups reflected the overall patient characteristics regarding age, sex, and operation time.

One bilobectomy was performed in G1 (right upper and middle lobe). One G1-patient emigrated before the one-year follow-up. The baseline characteristics for each group are presented in **Table 2.**

TABLE 2 Subgroup baseline characteristics and post-operative hospitalisation, complications, cancer recurrence and death at one-year follow-up.

	Subgroup Date of operation		
	C1 **4 Mar 2008-26 Oct 2010**	**C2** **14 Dec 2018-27 May 2019**	**C3** **17 Apr 2023-6 Jul 2023**
Male gender, n/N (%)	31/57 (45.4)	27/57 (47.4)	28/57 (49.1)
Age at operation, mean (± SD), yrs	67.04 (± 1.25)	69.96 (± 1.0)	70.79 (± 1.1)
BMI at operation, mean (± SD), kg/m^2	24.96 (± 0.49)	26.92 (± 0.77)	26.56 (± 0.70)
Preoperative FEV1, mean (± SD), %	0.83 (± 0.19)	0.85 (± 0.19)	0.93 (± 0.21)
Preoperative DLCO, mean (± SD), %	0.76 (± 0.18)	0.74 (± 0.16)	0.77 (± 0.17)
Lung cancer type[a], n/N (%)			
Primary	57/57 (100.0)	55/57 (96.5)	56/57 (98.2)
Secondary	0/57 (0.0)	2/57 (3.5)	1/57 (1.8)
pTNM stage[b], n/N (%)			
T ≥ 3	3/57 (5.3)	3/57 (5.3)	5/57 (8.8)
N ≥ 1	7/57 (12.3)	4/57 (7.0)	4/57 (7.0)
M ≥ 1	1/57 (1.8)	3/57 (5.2)	1/57 (1.8)
Tumour size, mean (± SD), mm	26.59 (± 1.92)	23.96 (± 1.57)	19.7 (± 1.36)
Charlson Index score, mean (± SD)	4.55 (± 0.16)	5.02 (± 0.16)	4.89 (± 0.14)
Conversions, n/N (%)	7/57 (12.3)	3/57 (5.3)	3/57 (5.3)
Post-operation LOS, mean (± SD), days	8.16 (± 1.22)	5.4 (± 0.52)	4.89 (± 0.51)
Post-operation chest tube time, mean (± SD), days	6.29 (± 1.03)	4.39 (± 0.54)	3.55 (± 0.52)
CCI, mean (± SD)	17.59 (± 2.48)	11.33 (± 1.87)	10.63 (± 1.69)
Cancer recurrence, n/N (%)	10/57 (17.5)	9/57 (15.8)	2/57 (3.5)
Death[c], n/N (%)	6/57 (10.5)	1/57 (1.8)	0/57 (0.0)

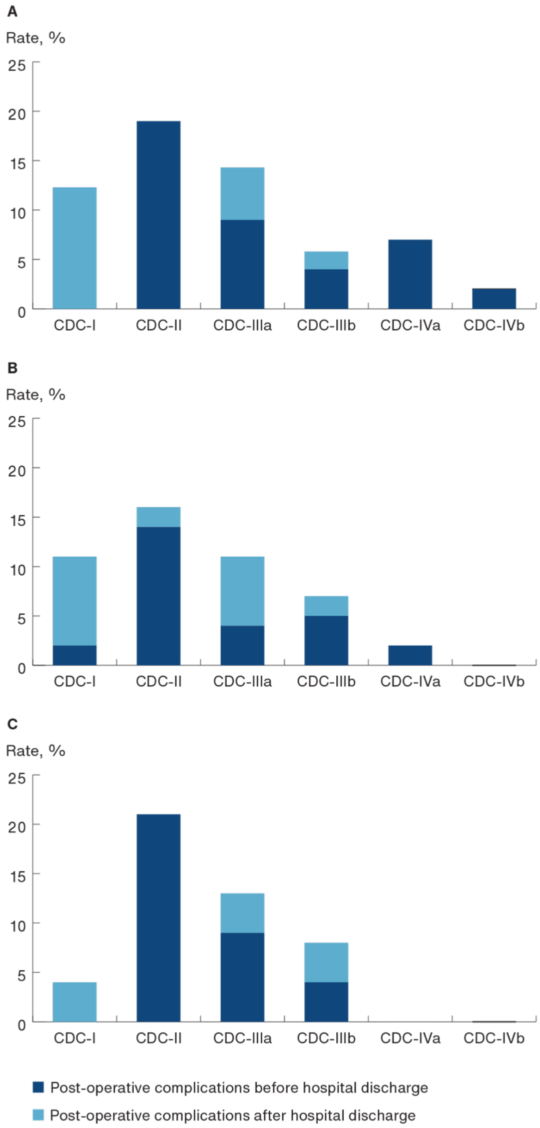
CCI = Comprehensive Complication Index; DLCO = diffusing capacity for CO; FEV1 = forced expiratory volume in 1st sec.; LOS = length of hospital stay; pTNM = pathological tumour-node-metastasis stage; SD = standard deviation.
a) All primary cancers were non-small cell lung cancers; all secondary were colorectal metastases.
b) All metastases were isolated to the brain.
c) Patient death within 1 yr of completed surgery (all-cause mortality).

The type of surgery was decided during multidisciplinary team meetings. Surgeons followed regional guidelines [5] using a standardised three-port anterior approach [11]; minor alterations (e.g., insertion of an extra port) were not recorded.

Complication rates

Table 2 presents the length of stay, complications, cancer recurrence and survival at one-year follow-up. **Figure 2** shows the accumulated post-operative complications before and after hospital discharge for each subgroup classified according to the CDC. Supplementary Table 2 provides a detailed description of conversions and post-operative complications.

FIGURE 2 Accumulated post-operative complications after video-assisted thoracoscopic surgery lobectomy for each subcohort. Complications are classified according to the Clavien-Dindo Scale of Surgical Complications (CDC). Thus, only the most severe complication for each patient is included. **A**. Accumulated post-operative complication rate (%) for subgroup C1 as a function of CDC stages (I-IV). **B**. Accumulated post-operative complication rate (%) for subgroup C2 as a function of CDC stages (I-IV). **C**. Accumulated post-operative complication rate (%) for subgroup C3 as a function of CDC stages (I-IV).



Using linear regression analysis, no statistically significant correlation was found between CCI score and BMI, length of stay, operation time, post-operative survival, pTNM, resected lobe, age, and comorbidity score or hospitalisation and operation time in any subgroup.

Discussion

When comparing data from the Danish Lung Cancer Registry (DLCR) [4] to those of our study, we found the same annual average increase (15.4%) in VATS lobectomies at the AUH in the 2008-2022 period. Simultaneously, the DLCR reported an increase in lobectomies performed at the AUH from 139 to 254. VATS lobectomies increased from 39.6% of total lobectomies in 2013 to 80% in 2022.

The percentage of VATS lobectomies performed at AUH was consistent with nationwide rates. However, in 2022, Denmark's largest centre of thoracic surgery at Rigshospitalet, Copenhagen, performed a significantly higher percentage of lobectomies by VATS (93.5%) than the remaining departments: 81.6% at Odense, 80.0% at Aarhus and 68.5% at Aalborg University Hospitals [4].

The baseline characteristics (age, sex, FEV1 and pTNM) were equivalent to those reported by current RCTs [1, 2]. Hospitalisation time was primarily related to chest tube drainage time, which aligns with other reports for groups G2 and G3 [2].

As persistent air leakage is the most common cause of prolonged hospital stay after lung cancer surgery [12], the observed shift suggests improved technique and management of chest tube drainage during the study period. Reduced hospitalisation time will likely impact post-operative morbidity and mortality, e.g., as the risk of nosocomial infections decreases. Furthermore, increased operative time has been identified as a risk factor for prolonged length of stay and post- and perioperative complications [13], likely affecting the rates of adverse effects throughout the study. The mean operating time was in line with those reported by other studies [1, 2].

Enhanced surgeon and staff experience combined with technological advancements introduced during the 15-year study period have improved VATS treatment, and this trend was underpinned by improvements in the introduction and training of new surgeons [14]. Conversions due to bleeding were less common, further indicating improved VATS management of acute perioperative complications. Bleeding and adhesions are reported as the most common reasons for conversion to thoracotomy [2], although the conversion rate was slightly higher than reported by RCTs [1, 2].

The complication rate was high compared to other reports [15]. This might be owed to the large data availability in our follow-up period, thanks to the Danish National Patient Registry, as well as the prolonged follow-up time (one year) compared to most other studies (30-90 days). However, RCTs with one-year follow-up also present lower rates [1, 2]. As the follow-up time increases, direct causation regarding post-operative sequelae becomes more challenging to distinguish from other causes, especially in multimorbid patients. An overrepresentation is likely in a heterogeneous population compared to less complex patients included in RCTs. Lastly, while the referenced studies have used different complication classification systems, our model employs a standardised approach. Our data aligned with those of other studies regarding complications before hospital discharge.

The different types of adverse effects and their proportional distribution are consistent with those reported in other studies [2, 4], with pulmonary, infectious and cardiac complications being the most frequent. Surprisingly, both short- and long-term pulmonary complications, of which air leak requiring additional chest tube insertion was the most common, did not decrease significantly during the study period. Conversely, reports of post-operative pain requiring analgesics decreased during the study period, possibly owing to improved surgical technique and post-operative care. Thus, although the data pointed to improved chest tube management as a cause, fitness for hospital discharge was also influenced by enhanced pain management, resulting in faster patient mobilisation and possibly lower wound and intrathoracic infection rates [2].

Perioperative and in-hospital mortality was nonexistent, whereas other studies reported VATS mortality rates up to 1.8% [16]. Mortality at the one-year follow-up was significantly higher in G1 than the 2.9-5.4% presented in RCTs [1, 2] but decreased significantly in the following years, with lower death rates in G2 and G3 than in the RCTs.

Strengths and limitations

The strengths of this study include a relatively large population compared to most RCTs, pre- and post-operative data on all inpatient and outpatient hospital contacts from a diverse population with access to free and unblinded healthcare, and the use of standardised classification systems for assessing complications and comorbidity, reducing selection biases.

The study also has some major limitations. Although differences in peri- and post-operative data were attributed to improved surgical management, a performance bias might exist, as inter-surgeon variations were not examined. A recent study found variations in post-operative length of stay to be more closely related to post-operative management and discharge practices than to surgical quality [17]. As over 63% of all surgeries were performed by three primary surgeons, examination of inter-surgeon variations regarding complications could potentially be relevant. A confounder could be deviations from standard operating procedures, as these were not assessed.

We did not record differences in oncological and anaesthesiologic treatment, and with improvements being achieved in both during the past 15 years, a substantial risk exists of performance and chronology bias regarding patient morbidity, mortality and cancer recurrence.

All comorbidities and post-operative complications were classified using standardised systems to avoid detection bias. However, due to a retrospective study design, reporting bias cannot be excluded. Not all patients in the last subgroup (G3) were observed 12 months after surgery as the study ended earlier, possibly underreporting post-operative complications and survival in the group. Finally, a major limitation of our study is that only 10% of the population was examined, which may not be representative of the entire cohort.

Perspectives

During the past 15 years of VATS lobectomy at the AUH, all procedures were performed using a standardised three-port anterior approach. Technological developments in endoscopic surgery have allowed the implementation of two- and uniport VATS approaches, as well as robot-assisted thoracoscopic surgery (RATS), for numerous indications, including lobectomy [18].

Evidence supporting RATS, along with two- and uniport VATS, over the standardised approach is sparse [19]. More high-quality studies (i.e. RCTs) with longer follow-ups are needed to determine whether they represent a valid alternative to three-port VATS (Copenhagen approach). Furthermore, implementing new techniques is costly, requiring investment in equipment and training of all surgical personnel before potential benefits can be reaped.

As the rates of VATS lobectomies for lung cancer patients at the AUH are among the highest, with steadily increasing availability and effectiveness in peri- and post-operative outcomes, an immediate change in technique could result in costly and potentially harmful care of uncertain benefit.

Conclusions

This retrospective single-centre cohort study supports using VATS for lobectomies in early-stage non-small cell lung cancer patients. Treatment effectiveness regarding peri- and post-operative outcomes is in line with data from RCTs, showing significant benefits compared to traditional open surgery. Furthermore, treatment effectiveness evolved, and the introduction and training of new surgeons improved, yielding more available VATS throughout the period and improved peri- and post-operative outcomes.

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Accepted 15 January 2025

Published 10 March 2025

Conflicts of interest Potential conflicts of interest have been declared. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

References can be found with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2025;72(4):A09240649

doi 10.61409/A09240649

Supplementary material: https://content.ugeskriftet.dk/sites/default/files/2025-01/a09240649-supplementary.pdf

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