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Cost and survival of video-assisted thoracoscopic lobectomy versus open lobectomy in lung cancer patients: a propensity score-matched study

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Key question

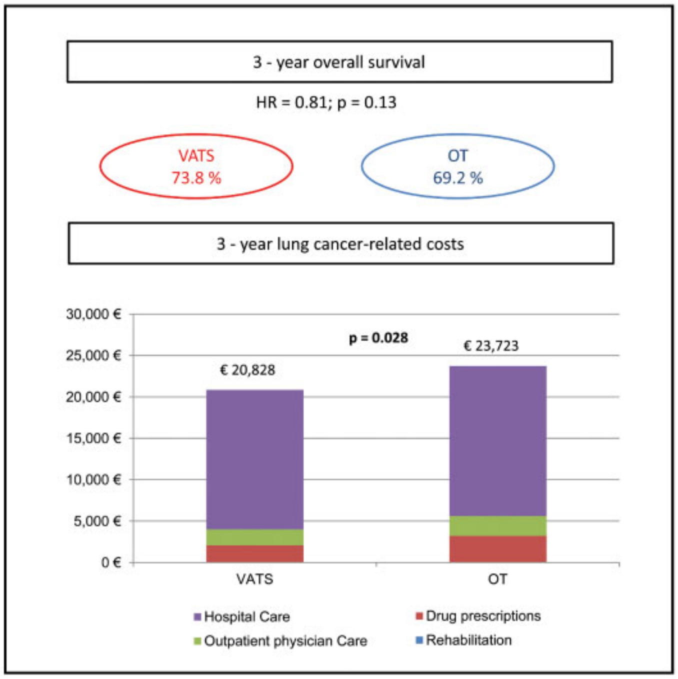
Is video-assisted thoracic surgery (VATS) superior or equal to open thoracotomy (OT) regarding survival, cost and length of hospital stay?

Key finding(s)

No difference in survival rates. Costs for hospital stay similar between methods, but lung cancer-related costs lower. Length of hospital stay shorter with VATS.

Take-home message

VATS shows advantages in length of hospital stay and is at least equal in costs and 3-year survival rate compared with OT.



Abstract

OBJECTIVES: A video-assisted thoracoscopic surgery (VATS) is an accepted alternative to open thoracotomy (OT) in lung cancer patients undergoing lobectomy, but evidence of the benefits of VATS remains inconsistent. The aim of this study was to compare VATS and OT regarding survival, costs and length of hospital stay (LOS).

METHODS: We identified lung cancer patients (incident 2013) undergoing VATS or OT from German insurance claims data and performed 1:2 propensity score matching. A 3-year survival was analysed using the Kaplan–Meier curves and a univariable Cox model. Group differences in the 3-year lung cancer-related costs and costs of hospital stay with lobectomy were compared via univariable generalized linear gamma models. LOS was compared using the Mann–Whitney–Wilcoxon test.

RESULTS: After propensity score matching, we compared 294 patients undergoing VATS and 588 receiving OT. We found no differences in the 3-year survival (VATS: 73.8%, OT: 69.2%, $P = 0.131$) or costs for hospital stay with lobectomy (VATS: €11 921, OT: €12 281, $P = 0.573$).

However, VATS patients had significantly lower lung cancer-related costs (VATS: €20 828, OT: €23 723, $P = 0.028$) and median postoperative LOS (VATS: 9 days, OT: 11 days, $P < 0.001$).

CONCLUSIONS: From a payer's perspective, extending the use of VATS is beneficial, as it shows economic benefits without affecting survival. However, for a more comprehensive assessment of the benefits of VATS from a society's point of view, further aspects such as patient-reported outcomes and provider-related standby costs need to be investigated further.

Keywords: Video-assisted thoracic surgery • Open thoracotomy • Lung cancer • Spending • Mortality • Length of stay

INTRODUCTION

Among all types of cancer, lung cancer has the highest incidence worldwide and is the most common cause of cancer death [1]. When curative treatment intent is possible, a lobectomy is the recommended procedure. The lobectomy can be performed as either an open thoracotomy (OT) or video-assisted thoracoscopic surgery (VATS), and there are no clear recommendations about the method that should be used. Owing to progress in the last 20 years, VATS has become an accepted alternative to OT and has been used increasingly [2].

Some studies have reported advantages in postoperative length of hospital stay (LOS), overall complications [3], quality of life and postoperative pain [4] for patients undergoing VATS, but evidence on survival benefits is inconsistent [5, 6]. This is also true for the economic implication of VATS compared with OT [7, 8]. Comprehensive comparison on the costs and effects of VATS and OT are still sparse, particularly for the time period beyond the hospital stay for lobectomy.

The objective of this study was to provide patient-level information comparing VATS and OT using data from a large health insurance company.

The primary aim is to compare survival up to 3-years between VATS and OT as well as 3-year lung cancer-related costs. The secondary aim is to investigate cost differences in the costs of hospital stay with lobectomy and differences in postoperative LOS after lobectomy.

MATERIALS AND METHODS

Study design

Data set. The primary data set contained 18 770 patients diagnosed with lung cancer in 2013 provided by the AOK Research Institute (WIdO). In Germany, health insurance is mandatory and, in 2013, the AOK Statutory Health Insurance Funds (SHI) covered around one-third of the resident German population [9].

The data set contained information on claims for hospitalizations, outpatient hospital visits, outpatient physician visits and drug prescriptions including OPS (German version of the International Classification of Procedures in Medicine), ATC (German Anatomical Therapeutic Chemical Classification) and ICD-10 (International Classification of Diseases, German Modification) codes. Available patient-level information was month and year of birth and death (where applicable), sex, nursing home residency, care level and residential area through postal codes. We had information about each individual patient over a 3-year follow-up period after diagnosis.

Sample selection. We identified patients with incident lung cancer according to a 3-step process. First, we selected all patients with a diagnosis of lung cancer (ICD-10 code C34) in 2013. Second, to avoid false positives, we only included patients with at least 1 inpatient principal diagnosis or at least 2 confirmed outpatient diagnoses in 2 distinct quarters in 2013. Third, we excluded all patients with a history of lung cancer or lung metastases in the 2 years prior to 2013, as well as patients without continuous insurance in these years.

We included all patients undergoing a lobectomy in the first 365 days after diagnosis based on the corresponding OPS codes (OPS 5.324). We excluded all patients with a code for VATS as well as OT on the same day, a larger resection than lobectomy, a robotic-assisted surgery, an aborted surgery or a code for lobectomy as a reoperation. The first lobectomy after diagnosis was used for assignment to the VATS or OT group, regardless of further procedures.

Group assignment

The main variable of interest in this study was whether lobectomy was performed as VATS or OT. We identified both groups by looking at the OPS codes (VATS 5324.7, 5324.8 | OT 5324.A, 5324.B) from the day of the lobectomy.

Outcome variables

Our primary outcomes were survival and costs of care over a 3-year time frame.

We calculated survival as the time between date of diagnosis up a maximum of 3 years. Patients with longer survival were censored at 3 years.

We calculated lung cancer-related costs as costs of hospitalizations with a primary diagnosis of lung cancer, costs of lung cancer-related drugs (chemotherapeutics, inhibitors, immunotherapeutics, antiemetics, antianaemics, bisphosphonates and granulocyte-colony stimulating factors) and outpatient physician visits with a confirmed diagnosis of lung cancer. (Outpatient ICD diagnoses in Germany have to be categorized as: 'Z' = condition after, 'A' = exclusion diagnosis, 'V' = suspected diagnosis and 'G' = confirmed diagnosis.)

Secondary outcomes were costs of the hospital stay with lobectomy and postoperative LOS after lobectomy. In order not to introduce bias, we added the postoperative LOS and costs of subsequent hospital stays if a patient was transferred to another hospital after lobectomy.

Costs of the hospital stay with lobectomy as well as lung cancer-related costs refer to costs for the health insurance company, without accounting for additional costs, e.g. material costs for the hospital, over-the-counter drugs or any other cost that was paid by the patient.

Variables used for propensity score matching

We used propensity score matching (PSM) to balance the distributions of potential confounders for patients treated by VATS or OT.

The variables used to estimate the PS were age, sex, metastasis status, Charlson Comorbidity Index, care level, nursing home residency, neoadjuvant chemotherapy, neoadjuvant radiotherapy, number of lobectomies per hospital, days from admission to surgery and residential area. We assessed metastasis status as ICD-10 codes, coded in the quarter before and after diagnosis and categorized them as no metastases, lymph node metastases (ICD-10 code C77) and other metastases (ICD-10 codes C78, C79). To calculate the Charlson comorbidity index at baseline, we included the ICD-10 codes for the 2 years prior to diagnosis. Lung cancer was excluded from this calculation to only account for additional primary tumours given the presence of lung cancer. Care level was defined as the need for long-term care and was coded as a binary variable. Nursing home residency was available as a binary variable, defining whether a patient lived in a nursing home. Neoadjuvant chemotherapy and neoadjuvant radiotherapy referred to chemotherapy and radiotherapy between the date of diagnosis and the date of lobectomy and were identified via OPS, ATC and GONR (German medical fee index) codes. We identified patients treated in the same hospital using an anonymized hospital reference number. From this, we calculated the number of lobectomies per hospital. The number of days between admission and surgery was defined as days from hospital admission to lobectomy. We classified residential area as major city, urban districts, rural districts and remote rural districts using the zip code-based definition of district types defined by the Federal Institute for Research on Building, Urban Affairs and Spatial Development [10].

Propensity score matching

We used nearest neighbour matching as the matching algorithm. Matching was done without replacement. A maximal possible difference, the caliper width, between matched subjects was prespecified at 0.2 SD of the logit of the PS, as suggested by Austin in 2011 [11]. The balance of the PS between the groups was assessed by the standardized mean difference, which was compared before and after matching. Differences of <0.1 were considered as to be well matched [12]. As the number of patients in the OT group was much higher, we matched 2 OT patients to 1 VATS patient. Two to one matching was found to perform better in the context of the bias-variance trade-off in comparison with choosing 3 or more controls [13]. When analysing the data, the whole groups were used and the matched pairs were treated as independent [14].

Statistical analysis/methods

When PSM is performed, a direct treatment effect can be estimated between the groups within the matched sample [12]. Therefore, no additional confounder adjustment is needed when analysing the matched sample.

The Kaplan–Meier curves were used to describe the survival over 3 years and compared using log-rank tests. We used a univariable Cox proportional hazard model to calculate the hazard ratio (HR) between VATS and OT and the 95% confidence intervals (CIs). To test the cost-specific group differences in total costs and for each cost category, univariable generalized linear gamma models [15, 16] with a log link were used.

To test the differences in postoperative LOS, the Mann–Whitney–Wilcoxon test was performed. For this analysis, patients who died during the hospital stay with lobectomy were excluded.

In a sensitivity analysis, we analysed costs for survivors only, as the costs for patients who died were much higher, which could lead to differences in costs caused by a small number of patients. Therefore, we examined an additional PSM. The procedure for this PSM was the same as described above.

All tests were 2-sided and were defined as significant at P-value ≤0.05. All analyses were done with R-Software 3.4.2.

RESULTS

Sample selection

Of the 18 770 lung cancer patients 1884 (10.3%) underwent lobectomy within 365 days after the initial diagnosis. From this sample, we excluded 125 patients in accordance with our eligibility criteria. The final sample consisted of 1759 patients, of whom 1465 (83.3%) had OT and 294 (16.7%) had VATS (Fig. 1).

Although a caliper width was included in the matching process, we were able to match every VATS patient to 2 OT patients. The matched sample consisted of 294 VATS and 588 OT patients. The characteristics with group differences before and after matching are shown in Table 1. Matching achieved a good balance with standardized mean differences <0.1 for all variables. All further results are reported for the matched sample.

Survival

About 69.2% of OT patients and 73.8% of VATS patients survived the 3-year observation period. This corresponds to 188 and 77 events, respectively. The risk of dying was 19% lower in the VATS group (HR 0.81, CI 0.62–1.06). Figure 2 shows differences in the Kaplan–Meier curves in both groups.

Costs

Over the 3-year observation period, lung cancer-related mean costs amounted to €20 828 for the VATS group and €23 723 for the OT group. The resulting difference of €2895 was statistically significant (P = 0.028). The cost differences are shown in Fig. 3. Costs for rehabilitation made up only a small part of the total costs, and we found no significant differences between the groups. Mean costs for hospitalizations were €1281 (P = 0.19) and mean costs for drug prescriptions were €1141 (P = 0.06) lower in VATS patients. Costs of outpatient physician care were significantly lower [−€464 (P = 0.01)] in VATS patients.

Costs of the hospital stay for lobectomy were similar in VATS (€11 921) and OT (€12 281) patients, with a difference of only €361 (P = 0.573).

The results of the univariable GLM gamma regression are presented in Table 2.

Length of stay

After exclusion of 24 patients who died during the hospital stay with lobectomy 570 OT patients (96.9%) and 288 VATS patients (98.0%) were included in the analysis of postoperative LOS. Postoperative LOS in VATS patients (11.7 days) was 2.1 days

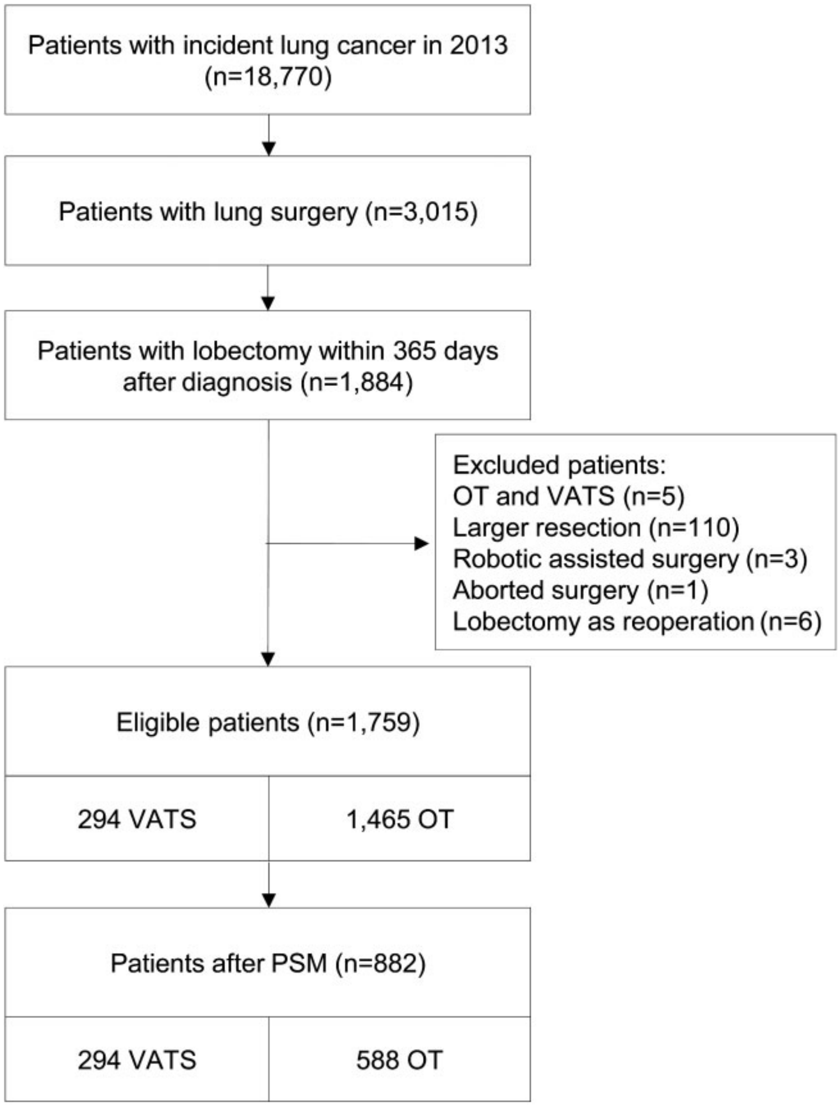


Figure 1: Participant flow of study population. OT: open thoracotomy; PSM: propensity score matching; VATS: video-assisted thoracoscopic surgery.

shorter than in OT patients (13.8 days). The median postoperative length of stay was 11 days for OT and 9 days for VATS patients ($P < 0.001$).

Sensitivity analysis

A total of 217 VATS patients survived the 3-year follow-up period and were matched with 434 OT patients. The variables used for PSM were well balanced after matching with all standardized mean differences <0.1. Lung cancer-related costs were significantly lower in the VATS group (-€2628, $P = 0.050$) and the costs of the hospital stay with lobectomy did not differ (-€204, $P = 0.614$).

DISCUSSION

The aim of this study was to evaluate possible differences between VATS and OT with regard to 3-year survival, costs of the hospital stay with lobectomy, 3-year lung cancer-related costs and LOS after lobectomy. To the best of our knowledge, this is the first study comparing claims data of patients undergoing VATS and OT in Germany.

In our study, we did not find a significant difference between VATS and OT regarding overall survival, even though the risk of dying was 19% lower in VATS patients. However, when interpreting this result one has to consider that information on tumour, node and metastasis (TNM) stage was not available in the dataset. Previous publications in this regard are inconsistent. Taioli *et al.* [17] performed a meta-analysis in 2013 including 20 studies from 1990 to 2011. They reported a long-term survival benefit for patients undergoing VATS lobectomy compared with OT. Cai *et al.* [18] reported similar results in their meta-analysis from 2013, where they included 9 studies focusing on stage I non-small-cell lung cancer (NSCLC). In contrast, a recent meta-analysis from Hamaji *et al.* [6] from 2017, including 11 studies, reported no significant differences in long-term survival between VATS and OT in patients with early-stage NSCLC. Additionally, Hamaji *et al.* discussed 7 other meta-analyses, including studies by Taioli *et al.* and Cai *et al.*, and concluded that all meta-analyses reported suboptimal effect measures and some of them included studies that should have been ineligible. After removing

Table 1: Patient characteristics of matched and unmatched population

		Matched		Unmatched	
	VATS (*n* = 294)	OT (*n* = 588)	SMD	OT (*n* = 1465)	SMD
Age (years), mean (SD)	66.8 (8.7)	67.18 (9.1)	0.040	67.01 (9.2)	0.020
Female gender, *n* (%)	119 (40.5)	241 (41.0)	0.010	450 (30.7)	0.205
Metastasis, *n* (%)			0.029		0.349
None	230 (78.2)	453 (77.0)		928 (63.3)	
Lymph nodes	29 (9.9)	61 (10.4)		299 (20.4)	
Other	35 (11.9)	74 (12.6)		238 (16.2)	
Median Charlson Index (Q1–Q3)	2.0 (1.0–4.8)	2.0 (1.0–4.0)	0.009	2.0 (1.0–4.0)	0.002
Care level, *n* (%)	16 (5.4)	38 (6.5)	0.043	123 (8.4)	0.117
Nursing home, *n* (%)	0 (0.0)	0 (0.0)	<0.001	11 (0.8)	0.123
Neoadjuvant chemotherapy, *n* (%)	16 (5.4)	32 (5.4)	<0.001	123 (8.4)	0.117
Neoadjuvant radiotherapy, *n* (%)	0 (0.0)	0 (0.0)	<0.001	22 (1.5)	0.175
Median number of lobectomies per hospital (Q1–Q3)	5.0 (2.0–13.0)	4.0 (2.0–12.0)	0.041	4.0 (2.0–12.0)	0.064
Median number of days between admission and lobectomy (Q1–Q3)	1.0 (1.0–5.0)	2.0 (1.0–4.0)	0.022	1.0 (1.0–4.0)	0.002
Residential area, *n* (%)			0.059		0.072
Unknown	2 (0.7)	6 (1.0)		10 (0.7)	
Major city	85 (28.9)	176 (29.9)		399 (27.2)	
Urban districts	110 (37.4)	207 (35.2)		526 (35.9)	
Rural districts	49 (16.7)	98 (16.7)		257 (17.5)	
Remote rural districts	48 (16.3)	101 (17.2)		273 (18.6)	

Q: quartile; SD: standard deviation; SMD: standardized mean difference; OT: open thoracotomy; VATS: video-assisted thoracoscopic surgery.

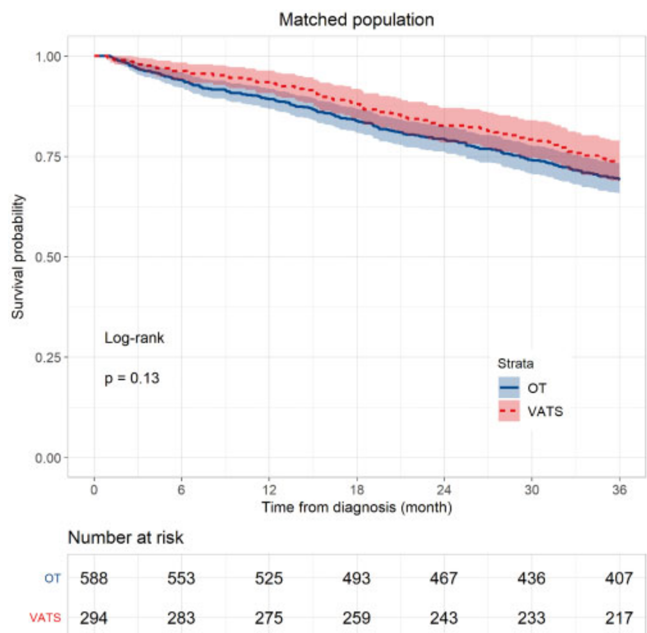


Figure 2: Kaplan–Meier survival curves for group comparison of VATS versus OT with 95% confidence bands. OT: open thoracotomy; VATS: video-assisted thoracoscopic surgery.

the ineligible studies, 16 of the 17 remaining original studies were not significant. However, one has to consider that, in our study, 850 events would have been required to detect a 4.5% difference (as observed within our study) with a power of 80% at an alpha-level of 5%. Therefore, most studies on survival—including ours—were apparently too small to detect statistically meaningful differences. Thus, clinical relevance might be a more helpful decision criterion. Our Kaplan–Meier plot suggests a survival benefit for VATS soon after surgery, which persisted over the whole observation period. Moreover, according to the German Institute for Quality and Efficiency in Health Care (IQWIG), interventions with a HR below 0.85 have an added value. Our study had a HR of 0.81.

When comparing VATS with OT regarding costs, our results show that the costs were lower for patients undergoing VATS. However, these differences were significant for lung cancer-related costs, but not for the costs of the hospital stay with lobectomy.

There are only a few studies investigating cost differences between VATS and OT beyond the hospital stay with lobectomy. Farjah *et al.* [19] analysed claims data in the United States comparing inpatient, outpatient and pharmacy costs up to 90 days after lobectomy with data from 2007 to 2011. Costs for VATS patients were reported to be significantly lower. A prolonged LOS after lobectomy was named as the main reason for the cost differences between the groups. In our study, we did not find significant differences in the costs of the hospital stay with lobectomy. Therefore, cost differences in lung cancer-related costs cannot be explained by prolonged LOS. In another claims data analysis from the United States with data from 2010, health care expenditures and drug expenditures were compared for 90 and 365 days after lobectomy [20]. No significant group differences were found in health care expenditures in the 90 and 365 days after lobectomy. Only 90-day drug expenditures were significantly different with lower costs for the VATS groups. To the best of our knowledge, there are no studies reporting 3-year cost differences between VATS and OT comparable with our results. The differences in cancer-related costs were mainly driven by higher costs for OT patients in inpatient care, drug prescriptions and outpatient physician care. An explanation for this could be that more patients in the OT group received adjuvant therapy after the resection, causing higher expenditures for chemotherapy and more hospitalizations. However, as we do not have information about the TNM stage of the patients, we cannot infer whether these differences in adjuvant therapy resulted from the resection

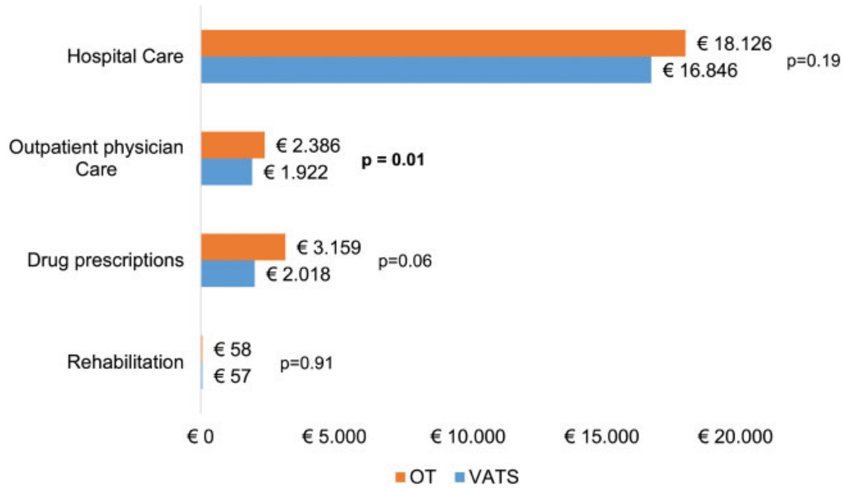


Figure 3: Lung cancer-related costs in cost categories and among resection groups. OT: open thoracotomy; VATS: video-assisted thoracoscopic surgery.

Table 2: Group differences in lung cancer-related costs and costs of the hospital stay with lobectomy in the matched population

	Matched population		
	VATS β	Difference 95% CI	*P*-value
Lung cancer-related costs (€)	-2895	-5219 to -237	0.028
Costs of the hospital stay with lobectomy (€)	-361	-1473 to 860	0.573

CI: confidence interval; VATS: video-assisted thoracoscopic surgery.

method or different tumour sizes. Therefore, the differences have to be interpreted carefully.

Most previous studies, investigating differences between VATS and OT regarding costs of hospital stay with lobectomy adapt the hospitals' point of view. These studies report varying results, with some studies showing that the costs of the hospital stay are significantly lower for VATS patients [21, 22], comparable [23] or even higher [24, 25]. These inconclusive findings might arise from study-driven and framework related differences, e.g. no confounder adjustment or small sample sizes. Additionally, it is not possible to draw a conclusion concerning the costs when comparing VATS and OT in an international context. Differences between countries, e.g. Taiwan, Turkey, Poland and Germany [24–26] are too big because of different costs for materials and hospital staff. In our study costs of the hospital stay did not differ significantly. The payer perspective of the study can probably explain the main reason for this. In Germany, VATS and OT are assigned to the same DRG; therefore, the amount of reimbursement paid by the health insurance company is the same for VATS and OT. So, the comparable costs for the hospital stay with lobectomy were not unexpected. Additionally, a supplementary payment to the DRG is only indicated if the patient has severe complications or the LOS is beyond 21 days after admission. Therefore, even if the mean LOS was 2.1 days shorter in patients undergoing VATS in our study, this has only a small impact on the costs of the hospital stay reimbursed by the health insurance fund. Here, adjustments in the current DRG system could change the preference for either procedure from a payer perspective in the long run.

However, up to now, it remains unclear as to which approach is more beneficial for the hospitals in Germany, as it is not clear whether a shorter postoperative LOS or other advantages that VATS possibly entails can compensate for the higher costs of materials, e.g. staplers.

Postoperative LOS is an outcome frequently studied when comparing VATS and OT. In our study, postoperative LOS was significantly shorter in patients undergoing VATS. Our results are in line with several studies comparing postoperative LOS between VATS and OT. Two published meta-analyses support these findings [3, 27] as well as a recently published randomized controlled trial [4]. Compared with other studies, postoperative LOS was longer in our analysis. This can be explained as an artefact of the German health care system which is characterized by extended hospital stays. According to the OECD, Germany was the country with the fourth highest average LOS for hospitalizations in 2013 [28]. For example, the average LOS was 2.3 days higher in Germany compared to the United States (7.7 vs 5.4 days). Another reason might be the source of the data. Whereas most studies are performed in single institutions, our data cover many hospitals throughout Germany. Single institution studies are mostly performed in specialized hospitals, which might perform more surgeries. In a claims data study in the United States, a lower LOS was reported in high-volume hospitals [29]. When comparing the median postoperative LOS with claims data studies, the difference between the reported postoperative LOS compared with our study becomes smaller. For instance, the median postoperative LOS in a study from the European Society of Thoracic Surgeons database reports a median LOS of 6 days for VATS and 8 days for OT patients [30].

Our sensitivity analysis, including only patients who survived for at least 3 years, resulted in a significant, but lower difference between the 2 groups concerning lung cancer-related costs. Even though the overall survival did not differ significantly between the groups, we observed a difference in survival rates (69.2% OT vs 73.8% VATS). However, this does not explain the higher lung cancer-related costs in the OT group. As in the main cost analysis, the missing information on TNM stage has to be taken into account and differences have to be interpreted carefully.

Limitations

When interpreting the results of this study, some caveats have to be considered. First, unmeasured confounding is possible, as PSM just balances for measured confounding. Possible confounders are behavioural risk factors, TNM stage, tumour histology and severity of comorbidities. However, by including metastasis status, neoadjuvant therapy and comorbidities at baseline, we tried to address this issue as much as possible. Nevertheless, this careful adaptation cannot fully reflect the missing clinical data. Another limitation is that we had no information about the conversion from VATS to OT. It may be possible that patients initially indicated for VATS received an OT. In the survival analysis, we only had information on all-cause mortality. It would be more appropriate to analyse survival for lung cancer-related death when comparing VATS and OT. Assessment of lung cancer-related costs might be vulnerable to distortions, e.g. if patients had multiple tumours we would overestimate the lung cancer-related costs.

Despite these drawbacks, our study has the advantage of providing insights into real world healthcare provision across a population-representative cohort of lung cancer patients in Germany. In addition, this is the first large multicentre study in Germany comparing VATS and OT across hospitals with different degrees of specialization and one of a few looking into follow-up care after lobectomy with a time horizon of several years. Unlike most other studies, we had complete patient-level information beyond the hospital stay for a 3-year follow-up period.

CONCLUSION

Our results suggest that, at least from a payer's perspective, the performance of VATS is beneficial, as VATS shows advantages in postoperative LOS and follow-up costs of care. Although we did not find significant differences in survival, we believe that differences displayed in the survival curves could indicate survival benefits. Furthermore, for a more comprehensive evaluation of the benefits of VATS from a society's point of view, further aspects such as patient-reported outcomes and provider-related standby costs are required. The limitations of our study have to be kept in mind, and higher levels of evidence are needed to determine causal relationships.

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