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Causes, predictors and consequences of conversion from VATS to open lung lobectomy

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Abstract
Background To analyze causes, predictors and consequences of conversions from intended VATS lobectomy to open surgery.
Methods This is a retrospective analysis of a prospectively maintained database.
Results From 2009 until December 2012, 232 patients were scheduled for anatomical VATS resection. Conversion to open surgery was necessary in 15 (6.5 %) patients. Reasons for conversion were bleeding in six, oncologic in five and technical in four patients (adhesions after pleuritis or radiotherapy for other tumors: 3; limited space: 1). In a univariable exact logistic regression analysis, conversion rate was significantly higher in patients after induction therapy ($p = 0.019$). There was also a statistical trend to a higher conversion rate in patients with larger tumor size (<3 vs. $\geq$3 cm, $p = 0.117$) and during the first half of our series ($p = 0.107$). Conversion rate was not influenced by patient age, nodal stage (pN0 vs. pN+), body mass index, the presence of chronic obstructive pulmonary disease, lung function (FEV1) or benign disease. In a multivariable exact logistic regression, induction treatment ($p = 0.013$) and tumor size ($p = 0.04$) were independent significant risk factors for conversion. Conversion did not translate into higher overall postoperative complication rate (33.3 vs. 29.5 %), longer chest drain duration (median, 5 vs. 5 days) or in-hospital mortality (0 vs. 1 %). However, length of hospital stay was significantly longer in the conversion group (median 11 vs. 9 days, $p = 0.028$).
Conclusions Induction therapy was an independent risk factor for conversion to thoracotomy in this VATS lobectomy series. Following induction therapy, patients should be carefully selected for a VATS approach. Conversion to thoracotomy did not increase the postoperative rate of complications or mortality, but significantly increased length of hospital stay.

Keywords VATS · Conversion · Thoracotomy · Risk factor

Video-assisted thoracoscopic surgery (VATS) was introduced more than 20 years ago [1]. Although no well-designed prospective randomized trial of sufficient statistical power exists, propensity-matched studies and metaanalysis have demonstrated equivalent oncologic outcomes, shorter length of stay, and fewer postoperative complications with a VATS approach than with open lobectomy [2–4]. For these reasons VATS was advocated as the gold-standard resection approach for early-stage non-small-cell lung cancer (NSCLC) [5]. General acceptance led to broader application of the technique with extended indications, including larger and centrally located tumors, nodal-positive patients and patients receiving induction treatment, on the one hand, and an increasing number of centers starting a VATS program at different levels of training, on the other [6, 7]. However, this broader application might increase the risk of intraoperative complications and for conversion to thoracotomy [8]. Conversion to thoracotomy during a minimally invasive approach becomes necessary for

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various reasons ranging from failure to proceed to emergency conversion to cope with disastrous intraoperative events. Conversions are reported to occur in 2–23 % of intended VATS lobectomies [9, 10]. Although the feasibility of a VATS approach for advanced tumors has been reported and training programs for VATS lobectomy have been safely introduced, there is a lack of literature on the reasons and risk factors for conversion to thoracotomy and the impact of conversion on postoperative outcome [11]. This study was performed to analyze causes and consequences of conversions from a VATS approach to an open technique and to identify possible predictors of conversion.

Materials and methods

Patients

The institutional database was searched for intended VATS anatomical resections between February 2009 and December 2012. Demographics, comorbidities, operative data and postoperative outcomes were obtained by reviewing the surgical notes and patients' charts. All patients with conversion from VATS to thoracotomy for any cause were identified and included in this analysis.

During the same period, 128 patients were scheduled for primary open surgery: 76 patients for open lobectomy, 14 for open bronchial sleeve resection and 38 for primary open pneumonectomy.

Staging for all our patients consisted of PET-CT scan. Endobronchial ultrasound and mediastinoscopy were used in all patients with suspected N2 disease (PET-positive or enlarged mediastinal lymph nodes >10 mm). Induction treatment was indicated in all patients with proven N2 disease and in general consisted of two to three cycles of a platinum-based regimen without concomitant radiotherapy.

The study was approved by the local ethics committee.

Surgical technique

For all patients in the VATS group, we used an anterior approach with three incisions for VATS: The patient was placed in a lateral position. The first incision for the camera trocar was placed in the 7th intercostal space at the anterior axillary line. The second incision was placed in the 4th to 5th intercostal space starting at the anterior edge of the latissimus dorsi muscle. This incision was extended to 4–5 cm and a wound protector (Alexis® Wound Protector, Applied Medical, CA, USA) was used to facilitate the insertion of instruments. A third incision was placed in the 7th to 8th intercostal space and posterior axillary line. All procedures in the VATS group were performed solely by means of endoscopy and were followed on a monitor. No rib spreader was used. Hilar structures were divided using an endoscopic stapling device and hilar and mediastinal lymph node dissection was performed in every lung cancer patient according to the definition of the Cancer and Lymphoma Group B [12, 13]. Intercostal nerve blocks were performed using 25 ml of bupivacaine 0.25 % at the end of the procedure. Finally, one to two chest tubes were inserted.

Conversion to thoracotomy was performed at the discretion of the surgeon. In all conversions, the utility incision was extended and rib spreaders were used to assure access to the thoracic cavity.

Statistical analysis

Statistical analysis was performed using SPSS 22.0 and STATA/MP 11.2. Patient demographics and surgical outcomes in the conversion group and the VATS group were compared using Chi-square tests, or Student's t test, as appropriate. To define predictors for conversion from VATS to thoracotomy, a univariable exact logistic regression analysis was applied for variables that may influence conversion including patient demographics, pulmonary function measured by preoperative FEV1, body mass index, tumor size, nodal involvement confirmed by pathology, experience at time of surgery (1st vs. 2nd half of our series) and induction treatment. All patients with benign disease were considered small tumors, as none of these patients had a benign mass larger than 3 cm and because difficulty in handling the mass is the main factor assumed to prompt conversion. Also, benign disease was considered nodal-negative in this series. Variables that were associated with a p value <0.25 were selected for the multivariable exact logistic regression analysis. Exact rather than conventional logistic regression analyses were used because of the relatively low conversion frequency ($n = 15$). Overall survival was calculated using Kaplan–Meier estimates. Differences between survival curves were tested for significance using the log-rank test. Two-tailed p values of <0.05 were considered significant.

Results

Between February 2009 and December 2012, 232 patients were scheduled for anatomical VATS resection at our institution. A total of 217 (93.5 %) patients had a complete VATS lobectomy, and 15 (6.5 %) patients underwent conversion to open thoracotomy. Patient characteristics of the completed VATS group and the conversion group are shown in Table 1. Injury of the pulmonary artery occurred in six patients. Only one patient needed emergency conversion due to massive intraoperative bleeding. All other

Table 1 Patient demographics

	VATS group, $n = 217$	Conversion group, $n = 15$	p value
Age, median (range)	63 (18–83) years	61 (47–79) years	0.922
Gender, male/female	124/93	8/7	0.793
BMI, median (range)	24.2 (13.3–38.5) kg/m^2	26.5 (17.9–37) kg/m^2	0.187
Tumor size <3 cm	152	7	0.082
Nodal stage			0.834
pN0	169	11	
pN1	29	2	
pN2	19	2	
Histology			0.533
Adenocarcinoma	133	13	
Squamous cell carcinoma	35	1	
Carcinoid tumor	29	1	
Small cell lung cancer	2	0	
Metastasis	6	0	
Benign disease	12	0	
Location of tumor			0.578
Right upper lobe	63	3	
Middle lobe	18	0	
Right lower lobe	45	3	
Left upper lobe	45	5	
Left lower lobe	46	4	
FEV1, median (range)	80 % (43.5–130)	76 % (47–109)	0.735
Induction treatment	18	6	0.002

FEV1 forced expiratory volume in 1 s

patients were safely converted while the injury was controlled by compression with a swab. Oncologic reasons for conversion were given in five patients with a positive mediastinal lymph node in one and unexpected tumor extension into the mediastinum, the thoracic wall and the adjacent lobe in the other four patients, requiring pneumonectomy in three patients. Technical reasons for conversion included dense adhesions in three patients and the inability to proceed due to space restrictions in one morbidly obese patient. Reasons for conversion are summarized in Table 2.

The results of univariable exact logistic regression analysis for predictors of conversion are shown in Table 3. In univariable exact logistic regression, the conversion rate was not influenced by patient age at the time of surgery, nodal involvement (pN0 vs. pN+), body mass index, preoperative FEV1 or benign disease as indication for surgery. There was a statistical trend to a higher conversion rate in patients during the first half of the series ($p = 0.107$) and to larger tumor size (<3 vs. $\geq$3 cm, $p = 0.117$). The only significant factor predicting conversion in univariable exact logistic regression analysis was induction therapy ($p = 0.019$).

In a multivariable exact logistic regression model, induction therapy (OR 6.689; 95 % CI 1.471–29.073) and tumor size (OR 3.825; 95 % CI 1.055–15.184) were independent predictors of conversion. No other preoperative patient-related variable predicted the likelihood of conversion (Table 4).

Perioperative outcome of patients after VATS lobectomy and conversion to thoracotomy is displayed in Table 5. No increase was seen in chest tube duration (median, 5 vs. 5 days), postoperative mortality or minor and major postoperative complications (VATS 64/217 = 29.5 % vs. conversion 5/15 = 33.3 %, $p = 0.7666$) resulting from conversion. The only significant difference found in this analysis was a longer postoperative hospital stay following conversion, namely 11 vs. 9 days ($p = 0.028$).

For patients with NSCLC, conversion did not affect overall survival (log-rank, $p = 0.638$). However, there were more disease recurrences in patients after conversion (9/15 patients) than in patients who were completed with VATS (60 vs. 30.5 %, $p = 0.024$).

Discussion

A minimally invasive approach to anatomical lung resection has consistently been shown to be equivalent or even superior to conventional open lobectomy for objective

Table 2 Reason for Conversion

Patient no.	Reason for conversion	Description of intraoperative finding
# 13	Emergency	Bleeding from pulmonary artery (A1), stapler misfire
# 24	Oncologic	Tumor infiltration of thoracic wall
# 35	Technical	Mediastinal adhesions
# 42	Technical	Limited space due to adipositas
# 45	Emergency	Bleeding from pulmonary artery (A2)
# 52	Emergency	Bleeding from PA (truncus anterior A1, 3), adhesions following radiotherapy
# 56	Emergency	Bleeding from pulmonary artery (interlobar artery)
# 64	Oncologic	Tumor extension into upper and lower lobe
# 88	Emergency	Bleeding from pulmonary artery (central pulmonary artery)
# 96	Technical	Adhesions, s/p pleuritis
# 106	Oncologic	Positive mediastinal lymph node
# 150	Oncologic	Tumor extension into mediastinum
# 193	Emergency	Bleeding from pulmonary artery (A1)
# 207	Emergency	Bleeding from pulmonary artery (truncus anterior A1,3)
# 231	Oncologic	Tumor extension

Arterial branch is indicated in parentheses

Table 3 Univariable exact logistic regression for predictors of conversion

	Odds ratio	95 % confidence interval		p value
		Lower	Upper	
Induction therapy	5.459	1.319	20.002	0.019
Experience, 1st versus 2nd half	0.342	0.077	1.201	0.107
Tumor size, <3 versus ≥3 cm	2.66	0.806	9.01	0.117
Body mass index, per kg/m^2	0.95	0.860	1.049	0.312
Benign disease	0.536	0	3.404	0.572
COPD	1.554	0.465	5.997	0.61
Nodal involvement	1.279	0.284	4.568	0.889
FEV1, per %	0.998	0.969	1.028	0.895
Age, per year	0.998	0.959	1.042	0.907

COPD chronic obstructive pulmonary disease, *FEV1* forced expiratory volume in 1 s

Table 4 Multivariable exact logistic regression for predictors of conversion

	Odds ratio	95 % confidence interval		p value
		Lower	Upper	
Induction therapy	6.689	1.471	29.073	0.013
Tumor size, <3 versus ≥3 cm	3.825	1.055	15.184	0.04
Experience, 1st versus 2nd half	0.362	0.079	1.325	0.148

COPD chronic obstructive pulmonary disease, *FEV1* forced expiratory volume in 1 s

Table 5 Consequences of conversion from VATS to open lung resection

	VATS group, $n = 217$	Conversion group, $n = 15$	p value
Chest tube duration, median (range)	5 (1–28) days	5 (3–30) days	0.31
Postoperative complication	64 (29.5 %)	5 (33.3 %)	0.767
In-hospital mortality	2	0	1.0000
Length of hospital stay, median (range)	9 (3–87) days	11 (9–70) days	0.028

perioperative outcome [2–4]. With increasing acceptance of the VATS approach, more and more centers are starting a minimally invasive lobectomy program. One of the key points in safely introducing this technique to daily routine is a prudent patient selection. The learning curve for VATS lobectomy is considered to be 50 cases [14, 15]. As part of the learning curve, conversions to thoracotomy are done for technical reasons or because of intraoperative complications. The overall rate of conversion varies in the literature from 2 to 23 % [9, 10]. However, the rate of catastrophic intraoperative events is around 1 %, as recently published [16].

In our series, the overall conversion rate was 6.5 %. Bleeding as result of injury to the pulmonary artery occurred in six patients. Massive intraoperative bleeding with a blood loss of more than 2 l was seen in only one of these patients. No intraoperative death or 90-day mortality occurred in patients converted because of intraoperative complications, indicating that conversion does not increase postoperative complications or associated mortality.

In this series, three surgeons performed all cases and thus completed their learning curve. All surgeons had extensive training in minimally invasive general surgery and minor thoracoscopic procedures prior to starting the program. When comparing the first and second half of the consecutive cases, a statistical trend was seen to a higher conversion rate in the first half of the series, indicating the impact of the learning curve on conversion. When splitting the series into consecutive groups of 25 patients each, we found the highest conversion rate in the second and third groups (patients #26–#75) (Fig. 1). There are several explanations for this finding. The most obvious one is the selection of patients: while the first 25 patients were selected as a case for beginners, i.e., small peripheral tumor, no clinical evidence of nodal disease and low patient age, the indication for a VATS approach was extended once the surgeons felt more confident with the technique. Therefore, the conversion rate rose from 8 % in the first group of 25 consecutive patients to 12 % in the second and third groups. After 100 patients, the conversion rate remained stable at around 4 %. This stable conversion

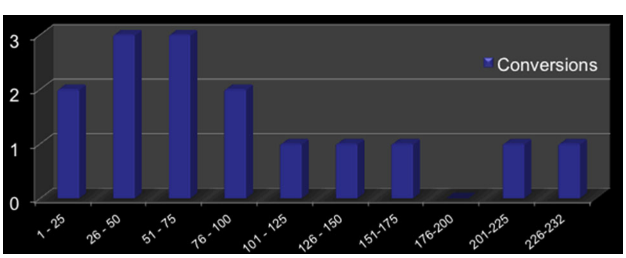

Fig. 1 Rate of conversion from VATS to open surgery for groups of 25 consecutive patients

rate also marks the end of the learning curve of two surgeons, who did 85 of these 100 cases jointly. It must be stressed that assisting at an operation is another crucial factor in obtaining high exposure and thus experience in a minimally invasive approach. The third surgeon, who started rather late, benefited from the team's expertise and had a shorter learning curve [15].

When looking at risk factors, induction treatment was the most significant risk factor for conversion in this series. There was no difference in the rate of intraoperative complications or technical conversions when comparing the induction group and the primary surgery group (data not shown). Induction treatment is probably a surrogate for other influencing factors, such as larger tumors, more advanced disease, or more fragile tissue. This hypothesis is supported by the fact that larger tumor size also increased the risk of conversion. Still, after induction treatment 75 % of patients were completed with a VATS approach.

Adhesions were the reason for conversion in three cases. It deserves mentioning that these were dense and broad adhesions, especially after mediastinal radiation and empyema in one patient each. In the first patient, the surgeon felt unsafe continuing dissection at the hilum, while in the second case it was not possible to perform adhesiolysis in the correct plain without destroying the visceral pleura. In all other cases involving minimal adhesions, the use of a VATS approach simplified removal of adhesions, as stated previously, due to better visualization [17].

Oncological reasons for conversion included unexpected findings such as tumor invasion into the mediastinum or thoracic wall. We strongly encourage using a minimally invasive approach for exploring thoracic cavities to diagnose advanced oncologic conditions like pleural carcinosis and thus avoiding thoracotomy where it is not indicated. Moreover, as the VATS technique evolves, reports have been published on minimally invasive thoracic wall resection and other complex procedures [18, 19].

Regarding the consequences of conversion, we found such patients to have a longer postoperative hospital stay. No difference in postoperative morbidity, drainage duration, or postoperative mortality was observed between the VATS and the conversion group. This study confirms previous findings showing that conversion during VATS lobectomy does not negatively affect short-term outcome and therefore should not be considered a failure [20, 21]. Patient safety must remain the primary focus during surgery, along with a complete resection. Conversion should be considered at any time when patient safety is not guaranteed. Surgeons must be aware that delayed conversion and an unsuccessful attempt to manage complications, especially bleeding, with minimally invasive techniques increase the risk of disastrous intraoperative events. As stated previously, conversion is a step toward patient safety rather than a sign of failure [22].

With regard to oncologic follow-up, the rate of tumor recurrence is higher after conversion. This is explained by the larger tumor size, the higher tumor stages and the number of advanced tumors in the conversion group, also characterized by the larger number of patients who underwent induction treatment. Whether changes in immunology due to increased blood loss and tissue trauma contribute to this higher rate of recurrence remains to be studied in larger series. Survival between the groups did not differ. However, survival analyses have to be interpreted with care, as the sample size of the conversion group was rather small, on the one hand, and, on the other hand, tumor stages are heterogeneous.

Whether or not this study supports the concept of primary surgery for single station N2 disease is a matter of debate [23]. Conversion rates might decrease if no induction treatment is administered. However, as already stated, induction treatment is a surrogate parameter and a larger tumor by itself would cause a greater risk of conversion. We feel that especially this subgroup of patients should be discussed on an individual basis in a multidisciplinary team. A minimally invasive approach must not compromise oncological principles. In the case of single-zone N2 disease proven by invasive mediastinal staging primary surgery might be justified. However, treating these patients in randomized controlled trials to gain further insight into this specific question of thoracic surgery should be considered.

In conclusion, we were able to identify risk factors for conversion from VATS to open anatomical lung resection. Induction treatment significantly increased the likelihood of conversion. Also, larger tumor size ($\geq$3 cm) was associated with conversion. However, as anatomical lung resection can be accomplished with a minimally invasive approach in 75 % of patients after induction treatment, surgeons should not use the results of this study to exclude such patients from VATS lobectomies. Instead, this study should help raise awareness among surgeons and patients for the likelihood of conversion. This study will also help surgeons select patients when starting a VATS lobectomy program and introduce the program into daily clinical routine without discouragingly high conversion rates.

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Compliance with ethical standards

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