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Risk factors and impact of conversion from VATS to open lobectomy: analysis from a national database

Stefano Bongiolatti[1] · Alessandro Gonfiotti[1] · Domenico Viggiano[1] · Sara Borgianni[1] · Leonardo Politi[1] · Roberto Crisci[2] · Carlo Curcio[3] · Luca Voltolini[1] · Italian VATS Group

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Abstract

Objective The objective of the study is to analyse the causes and impact of conversion from VATS to thoracotomy identifying any possible pre-operative risk factors and related consequences.

Methods Data from patient who underwent VATS lobectomy (VATS-L) for NSCLC at VATS Group participating centres were retrospectively analysed and divided in two groups: patients treated with VATS-L and patients who suffered from conversion. Predictors of conversion were assessed with univariate and multivariable exact logistic regression. Complications were evaluated as dependent variables of conversion in a Cox multivariable logistic regression model.

Results A total of 4629 patients underwent planned VATS-L for NSCLC and of these, 432 (9.3%) required conversion; the most frequent causes were bleeding (30.4%) and fibro-calcified hilar lymph nodes (23.9%). The independent risk factors at multivariable analysis model were sex male (OR 1.458, $p<0.01$), age older than 70 years (OR 1.248, $p=0.036$) and the clinically node-positive disease (OR 2.258, $p<0.01$). The mortality rate was similar, but the percentage of patients who suffered from any complication (41.7% vs 24.4%, $p<0.01$), the complication rate (65% vs 32.2%, $p<0.01$), chest tube duration ($p<0.01$) and the hospitalisation rate ($p<0.01$) were higher for patients converted. Atrial fibrillation (OR 1.471, $p=0.019$), prolonged air leak (OR 1.403, $p=0.043$), blood transfusions (OR 4.820, $p<0.01$), sputum retention (OR 1.80, $p=0.027$) and acute kidney failure (OR 2.758, $p=0.03$) were significantly associated with conversion at multivariable analysis.

Conclusions Conversion is associated with increased surgical morbidity, blood loss and hospital stay. Sex male, old age and the clinical involvement of lymph nodes were the strongest predictors of conversion.

Keywords Video-assisted thoracic surgery · Lobectomy · Lung cancer · Conversion · Complications

Since its introduction in 1991 [1], video-assisted thoracic surgery lobectomy (VATS-L) for non-small cell lung cancer (NSCLC) has evolved to become a safe and effective alternative to the conventional thoracotomic approach [2, 3]. VATS-L, compared with lobectomy by thoracotomy, is associated with a shorter length of stay, less postoperative pain, preserved pulmonary function, fewer postoperative complications and better compliance with adjuvant chemotherapy [4–7], while maintaining the oncological adequacy [8–11]. However, VATS-L is still considered a demanding procedure with a potential risk of major intraoperative complications which require emergent or urgent thoracotomy for management. The percentage of unexpected conversion to thoracotomy ranges between 2.5 and 23% [11–13], but the impact of conversion on postoperative outcomes remains controversial.

The objective of this retrospective study was to analyse the causes and consequences of conversion from VATS to standard thoracotomy and to identify possible pre-operative risk factors using a national multi-institutional database, the Italian VATS Group Database (http://www.vatsgroup.org).

✉ Stefano Bongiolatti
stefanobongiolatti@gmail.com

[1] Thoracic Surgery Unit, University Hospital Careggi, Largo Brambilla, 1, 50134 Florence, Italy

[2] Department of Thoracic Surgery, University of L'Aquila, L'Aquila, Italy

[3] Division of Thoracic Surgery, Monaldi Hospital, Naples, Italy

Materials and methods

Data source

The Italian VATS Group Database is a multicentre, web-based data system for collecting and reporting clinical characteristics, patterns of care and outcomes data on NSCLC patients treated with a VATS-L. The Italian VATS Group has maintained this prospective database since January 2014. At the time of the latest report, there were more than 40 participating centres (general thoracic surgery units or services, not individual surgeons) and about 5000 collected cases. Collected data are maintained by the VATS Group Board and inserted on a standardised data form that includes information about patient demographics, medical history, surgical procedures, cancer staging and outcome. Patients are reviewed and records are updated first time at 30 days after surgery, then at 180 days. Next update is recorded at 6 months from surgery and every 6 months for the first 2 years of follow-up, and annually thereafter. An Institutional Review Board at each centre has provided approval for the data collection, transmission and storage, as well as analyses of the data. The current analysis was reviewed and approved for scientific merit and feasibility by the VATS Group Scientific Committee and presented at the annual VATS Group meeting. The VATS Group Database implements rigorous quality assurance and safety procedures to maintain a high level of accuracy and security of data. These include real-time web-based edit checking, quality assurance reports that are provided by the data managers and on-site audits of a random sample of source documents against the submitted data performed by a Quality Committee. Security features include firewall security, web authentication password protected access and data encryption transmissions over the Internet. To be included in the database, patients must meet the criterion of a VATS-L using a standard approach as it has been defined by VATS Group policy: surgery performed by monitor vision, access incision smaller than 6 cm without rib spreading, one to three additional 1 cm ports, individual dissection of hilar structures with associated lymphadenectomy, use of an endo-bag for specimen extraction.

Patient population and study design

Study population consisted of patients who received intended VATS-L as the primary procedure for NSCLC at VATS Group participating centres and included in the VATS Group database between 1 January 2014 and 31 December 2017. We excluded all patients with incomplete clinical, intraoperative and postoperative data and also patients who underwent lobectomy for pathology different from NSCLC.

In order to analyse the causes of conversion and their impact on early postoperative outcomes, the study design provides a comparison between two groups of patients: the first group, identified as "VATS-L" (group A) comprising all operations completed by VATS while the second group, called "converted VATS-L" (group B) comprising all procedures converted to thoracotomy for any reason. The intraoperative and postoperative outcomes investigated were operative time, estimated blood loss, chest tube duration, length of stay, mortality, morbidity and the incidence of specific complications. We compared selected clinical variables to analyse the presence of pre-operative risk factors for conversion to thoracotomy and therefore we investigated the association between conversion with mortality and complication, identifying which postoperative variables were related and correlated with the conversion.

All patients underwent conventional pre-operative examinations, including cardio and pulmonary function tests (PFTs), contrast-enhanced thoracic and abdominal computed tomography scan (CT), brain CT scan and positron emission tomography-CT (PET-CT) scan. In case of mediastinal lymph node CT enlargement or PET-CT scan hyperactivity, endobronchial ultrasound transbronchial needle aspiration (EBUS-FNA) or mediastinoscopic biopsy was performed before surgery. Induction chemotherapy was administered when indicated in patient with proven N2 disease and in general consisted of cycles of a platinum-based therapy. Restaging was completed with thoracic and abdominal CT scan, PET-CT scan and/or EBUS-FNA or mediastinoscopy.

Statistical methods

Statistical analysis was performed using SPSS 24.0 (SPSS Inc., Chicago, IL). Standard descriptive statistics have been used to summarise data, with respect to demographic and oncological characteristics. Continuous variables, expressed as mean values ± SD, were compared by unpaired Student's *t* tests; categorical variables were analysed by means of Chi-square tests. p values below 0.05 were considered as statistically significant. To define predictors for conversion, an univariate exact logistic regression analysis was performed for clinical variables that may influence conversion including patient demographics (sex and age), PFTs (FEV1%, DLCO/VA%), clinical stage, nodal involvement and induction treatment. Variables associated with a p value < 0.10 were selected for the multivariable logistic regression analysis. The Spearman's rank correlation coefficient was used to demonstrate correlation between complications and

conversion. Specific and overall complications were evaluated as dependent variables of conversion in a Cox multivariable logistic regression model.

Results

During the study period, a total of 4629 patients underwent planned VATS-L for NSCLC and of these, 432 (9.3%) required conversion to thoracotomy (Fig. 1). Patients' demographics, clinical staging, pre-operative functional status and comorbidities of the two groups are resumed in Table 1.

Causes of conversion

The most frequent reasons of conversion were thoracoscopically uncontrollable bleeding ($n=131$) and severe fibro-calcified hilar lymph nodes ($n=110$) followed by dense pleural adhesion ($n=77$) and tumour extension ($n=65$) (Table 2). Resuming the causes using the VALT system [14], we observed 195 patients (45.1%) converted for anatomy reason (A), 131 (30.4%) for vascular injury (V) and 103 (23.9%) for lymph nodes. Technical failure or time limit were rare causes of conversion.

Pre-operative clinical data and clinical risk factors

In group B, there was a significant predominance of men (68.3% vs 59%, $p<0.01$) and also the clinical stage ($p<0.01$) and suspected nodal metastasis ($p<0.01$) were different compared to group A. In group B, the percentage of patients who underwent to induction treatment before VATS-L was higher (15.3% vs 12.2%, $p=0.055$). In group B, the PFTs demonstrated significant lower values of FEV1% ($p<0.01$) and DLCO/VA% ($p=0.045$), although the incidence of COPD was similar (group A 20% vs group B 20.9%, $p=0.7$).

The univariate analysis of some pre-operative variables, selected a priori, identified the following as significant risk factors: male gender, age older than 70 years and clinical nodal involvement.

Inserting the variables with $p<0.10$ at univariate analysis in a multivariable logistic regression analysis model, sex male (OR 1.458, CI 95% 1.178–1.803, $p<0.01$), age older than 70 years (OR 1.248, CI 95% 1.014–1.535, $p=0.036$) and the clinical suspect of lymph node metastasis (OR 2.258, CI 95% 1.538–3.317, $p<0.01$) were confirmed as independent risk factors for predicting conversion (Table 3).

Outcomes of patients underwent conversion

Conversion was more frequent for upper lobectomy on the left side (group A 38.1% vs group B 46.3%); conversely, the different surgical approaches and the centre experience were not associated with unplanned thoracotomy. Estimated blood loss and operative time differed significantly between the two groups (both $p<0.01$). Advanced stage ($p<0.01$), larger tumours at pathology ($p<0.01$) with metastatic lymph

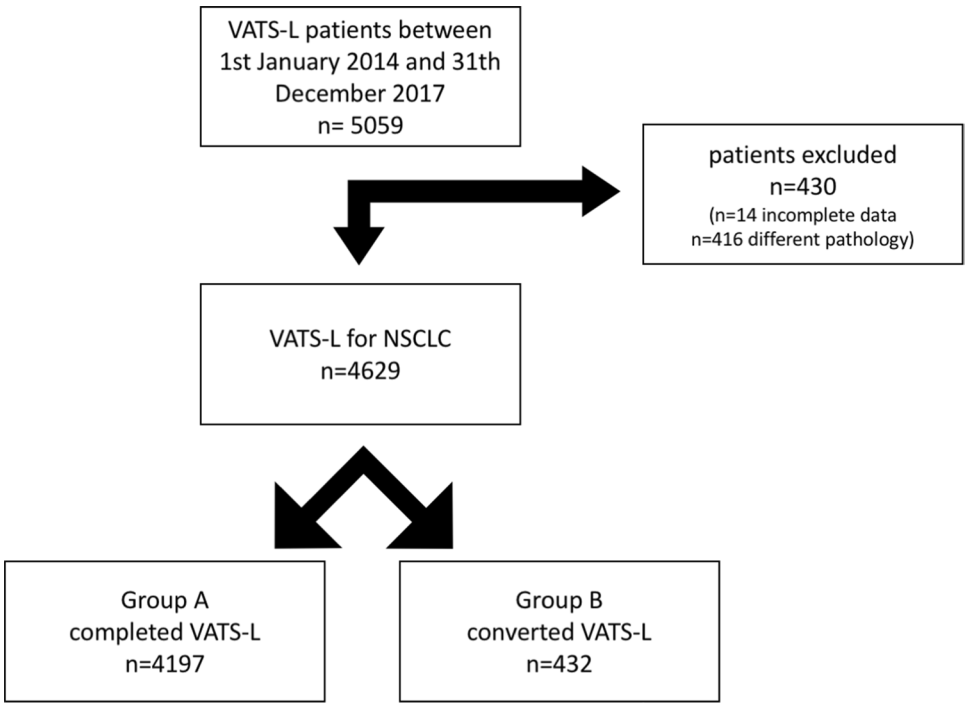

Fig. 1 Flow diagram of the patients' selection and study design

Table 1 Pre-operative clinical data in non-conversion and conversion group

Variables	Group A VATS group ($n=4197$) 90.7%	Group B Conversion group ($n=432$) 9.3%	p
Age	67.58 ± 9.56	68.22 ± 9.38	0.19
Male	2476 (59%)	295 (68.3%)	< 0.01
Coronary disease	426 (10.2%)	48 (11.1%)	0.506
Chronic heart failure	107 (2.5%)	15 (3.5%)	0.267
COPD	841 (20%)	90 (20.9%)	0.7
Connective disease	95 (2.3%)	12 (2.8%)	0.499
Diabetes	512 (12.2%)	66 (15.3%)	0.067
Renal failure	197 (2.5%)	13 (3%)	0.526
Pre-operative chemotherapy	506 (12.1%)	66 (15.3%)	0.055
FEV1 value (litres)	2.35 ± 0.67	2.28 ± 0.66	0.067
FEV1%	94.45 ± 21.2	90.16 ± 20.4	< 0.01
DLCO%	64.54 ± 38.3	61.5 ± 40	0.045
cStage			< 0.01
IA	2840 (69.7%)	249 (57.6%)	
IB	763 (18.2%)	88 (20.4%)	
IIA	243 (5.8%)	34 (7.9%)	
IIB	110 (2.6%)	12 (2.8%)	
III	198 (4.7%)	40 (9.3%)	
IV	43 (1%)	9 (2.1%)	
cN			< 0.01
0	3894 (92.8%)	364 (84.3%)	
1	118 (2.8%)	28 (6.5%)	
2	172 (4.1%)	37 (8.6%)	
3	13 (0.3%)	3 (0.7%)	

COPD chronic obstructive pulmonary disease, *FEV1* forced expiratory volume in 1 s, *DLCO* diffusing capacity of the Lung for Carbon Monoxide

Table 2 Causes of conversion to thoracotomy

Cause	No.	VALT classification	No.	%
Uncontrolled bleeding	131	Vascular	131	30.4
Severe fibro-calcified lymph nodes	110	Lymph nodes	103	23.9
Dense pleural adhesions	77	Anatomy	195	45.1
Tumour invasion or extension	65	Technical	3	0.6
Incomplete interlobar fissure	58			
Anatomic anomalies	51			
Tumour not found	23			
Time limit	9			
Wrong incisions	2			

The total number of conversion is higher than the total number of patients who underwent conversion because in some patients two causes determined the conversion (for example, fibro-calcified lymph nodes adhered to the pulmonary artery that caused an uncontrolled bleeding)

nodes ($p<0.01$), were frequent conditions associated with unplanned conversion as reported in Table 4.

Regarding the perioperative outcomes, the in-hospital mortality rate was similar, but the percentage of patients who suffered from any complication (41.7% vs 24.4%, $p<0.01$), the complication rate (65% vs 32.2%, $p<0.01$), chest tube duration ($p<0.01$) and the length of stay ($p<0.01$) were significantly higher in group B.

Complications developed in the two groups are summarised in Table 5. The only complication that minimally correlated with conversion using the Spearman correlation test (Table 6) was blood transfusion ($\rho=0.125$). Atrial fibrillation (OR 1.471, CI95% 1.066–2.031, $p=0.019$), prolonged air leak (OR 1.403, CI95% 1.011–1.947, $p=0.043$), blood transfusions (OR 4.820, CI95% 3.046–7.627, $p<0.01$), sputum retention (OR 1.807, CI 95% 1.070–3.051, $p=0.027$) and acute kidney failure (OR 2.758, CI95% 1.074–7.079, $p=0.03$) were significantly associated with conversion at multivariable analysis (Table 7).

Discussion

VATS-L has increased its popularity during the last years, since VATS, compared with lobectomy by thoracotomy, is associated with superior postoperative outcomes and fewer postoperative complications [5]. Furthermore, VATS-L is strongly recommended for early-stage NSCLC [15], becoming the standard of surgical care, but its application is increasing for locally advanced stage and after induction treatments [16–19].

Technical barriers, long and demanding learning curve [11, 20, 21], the fear of oncological inadequacy [8–10, 13] and the potential risk of intraoperative massive bleeding are important factors limiting the worldwide acceptance of VATS-L.

The incidence of intraoperative conversion to thoracotomy ranged between 2.5 and 23% [11–13]. In our series, the overall conversion rate was 9.3%, resulting consistent with other studies [11, 12, 21–24]. Resuming the reasons of conversion with the VALT classification system [14], we observed that the higher percentage of conversion was due to anatomical reasons (45.1%: adhesions, fused fissure, anatomical anomalies) and oncological findings (i.e. large tumour, tumour invading the chest wall). Actually, with the increased experience in minimally invasive surgery, surgeons expand their indications and this behaviour is reflected by the portion of patients that suffered from conversion due to pleural adhesion ($n=77$) and tumour extension ($n=65$). A greater cohort of patients with tumours larger than 5 cm (10.5% vs 5.1%) and consequently with an advanced pathological stage (33.3% with stage IIA or more vs 21.7%) were treated in group B. Our results are consistent with previous

Table 3 Analysis for clinical risk factors of conversion

Variable	Univariate analysis			Multivariable analysis[a]		
Variable	OR	CI9 5%	*p*	OR	CI 95%	*p*
Age ≥ 70	1.284	1.053–1.566	0.014	1.248	1.014–1.535	0.036
Gender male	1.497	1.222–1.850	< 0.01	1.458	1.178–1.803	< 0.01
Pre-operative chemotherapy	1.315	0.996–1.737	0.053	1.292	0.976–1.71	0.073
FEV1 < 60%	1.499	0.979–2.295	0.062	1.391	0.905–2.140	0.133
DLCO < 40%	1.210	0.957–1.531	0.112			
Clinical nodal involvement	2.401	1.807–3.190	< 0.01	2.258	1.538–3.317	< 0.01
Stage I	0.555	0.414–0.743	< 0.01	0.960	0.645–1.429	0.84

The threshold of age, FEV1 and DLCO/VA were established *a priori* based on clinical significance

FEV1 forced expiratory volume in 1 s, *DLCO* Diffusing Capacity of the Lung for Carbon Monoxide

[a]Forward stepwise regression model

published data demonstrating VATS-L as a feasible and effective approach also for advanced stage NSCLC, but the role of VATS-L in this setting must be still well defined [16–19]. Furthermore, the main objective of the surgical treatment is the completeness of resection and, if this topic is not amenable by VATS, the surgeon is forced to convert the procedure to assure an accurate resection.

The dreadful reason of unplanned thoracotomy is the uncontrollable bleeding that happened in about a third of cases in our series (30.4%). Bleedings during VATS-L are frequently due to a direct injury to the fragile pulmonary artery (PA), rarely to the pulmonary vein. Although catastrophic haemorrhage is described in a percentage under 1% of cases as published by Flores et al. [25], the PA injury deals a change in surgical strategy and sometimes causes an adjunctive procedure such as sleeve resection or pneumonectomy.

Some arterial bleedings and injury are not predictable, but various pre-operative radiological findings and patient' clinical history could be predictive of conversion: in particular, the presence of fibro-calcified hilar lymph nodes, the PET-CT-scan hilar positivity or a personal history of tuberculosis, pneumoconiosis, granulomatous disease and previous cardiothoracic surgery. Also in our series, the association between conversion and the presence of fibro-calcified hilar lymph nodes is strong, determining a quarter of all conversion to thoracotomy. Samson et al. [12] observed a 23% of conversions caused mostly to the presence of hilar calcifications (36%) in an endemic region of histoplasmosis. They introduced a calcification score that could be a useful tool to select more accurately the surgical approach. This topic is particularly true in the early phase of the learning curve when the surgeon has not reached the needed experience to safely dissect the pulmonary vessels from these adherent lymph nodes or to effectively control a massive bleeding by VATS.

Previous studies have identified as predictors of conversion older age, impaired lung function [23], sex male [22], fibro-calcified lymph nodes [12, 23], clinically node-positive disease [13], larger tumour size and induction therapy [22]. In our study, the univariate analysis showed a significant association with male gender, advanced clinical stage and presence of clinical involvement of hilar and/or mediastinal lymph nodes. Interestingly, the frequencies of induction treatment did not differ statistically between the two groups. However, the multivariable analysis confirmed as independent risk factors of conversion male gender, advanced age and clinical lymphatic involvement. Although the first variables had a relative impact on conversion, our multivariable analysis on this large multicentre database clearly demonstrated the strong impact of the clinically node-positive disease as previously reported by Villamizar et al. [13]. This association is also validated by the significant difference in the proportion of N1 (12.7% vs 7.1%) and N2 (10.2% vs 6.6%) disease between the two groups.

A decline of the conversion rate, parallel to the increasing surgical experience, is a well-known characteristic of the VATS-L learning curve [11, 20, 21] and Puri et al. [24] demonstrated a fall of conversion rate from 28% to 11% during years. Our study did not show this typical finding of the conversion rate during year (Fig. 2) nor significant difference between experienced centre and centre in learning curve (Table 4; Fig. 3), although the conversion rate was lower for experienced centre. Our study did not show this characteristic because we analysed data about patients who underwent VATS-L between 2014 and 2017 and therefore most of the centres have already overcome the learning curve.

The converted procedure implied a significant prolonged operative time, increased one-lung ventilation and surgical manipulation, higher blood loss, all of which could adversely affect the postoperative outcomes. Although the mortality rate was similar, the length of stay, the chest tube duration and the incidence of complications (65% vs 32.2%,

Table 4 Surgical characteristics and outcomes in non-conversion and conversion group

Variables	Group A VATS group ($n=4197$) 90.7%	Group B Conversion group ($n=432$) 9.3%	p
VATS approach			0.20
Anterior	3180 (75.8%)	327 (75.7%)	
D'Amico	538 (12.8%)	60 (13.9%)	
Uniportal	378 (9%)	29 (6.7%)	
Side			< 0.01
Right	2596 (61.9%)	232 (53.7%)	
Left	1601 (38.1%)	200 (46.3%)	
Centre experience > 75	3377 (90.9%)	337 (9.1%)	0.228
Centre experience < 75	820 (89.6%)	95 (10.4%)	
Histology			< 0.01
ADC	3013 (71.8%)	269 (62.3%)	
SCC	654 (15.6%)	97 (22.5%)	
Other	530 (12.6%)	66 (15.3%)	
Procedure			< 0.01
Upper lobectomy	2327 (55.4%)	232 (53.7%)	
Lower lobectomy	1492 (35.5%)	167 (38.7%)	
Middle lobectomy	323 (7.7%)	20 (4.6%)	
Lower bilobectomy	21 (0.5%)	11 (2.5%)	
Upper bilobectomy	34 (0.8%)	2 (0.5%)	
Lymphadenectomy			0.14
SND	2906 (69.2%)	284 (65.7%)	
Sampling	1291 (30.8%)	148 (34.3%)	
pStage			< 0.01
IA	2245 (53.4%)	191 (44.2%)	
IB	1041 (24.8%)	97 (22.5%)	
IIA	386 (9.2%)	68 (15.7%)	
IIB	164 (3.9%)	21 (4.9%)	
III	329 (7.8%)	48 (11.1%)	
IV	35 (0.8%)	7 (1.6%)	
Pathological diameter in cms			< 0.01
< 2	2067 (49.2%)	184 (42.6%)	
2–3	1045 (24.9%)	97 (22.5%)	
3–5	871 (20.8%)	106 (24.5%)	
5–7	170 (4.1%)	37 (8.6%)	
> 7	44 (1%)	8 (1.9%)	
pN			< 0.01
0	3622 (86.3%)	333 (77.1%)	
1	297 (7.1%)	55 (12.7%)	
2	278 (6.6%)	44 (10.2%)	
Total of lymph node resected	13.34 ± 7.9	13.13 ± 7.59	0.589
N1 resected lymph nodes	6.4 ± 4.57	6.47 ± 4.07	0.769
N2 resected lymph nodes	6.94 ± 5.18	6.65 ± 5.47	0.277
Operative time	180.68 ± 68.27	222.56 ± 74.96	< 0.01
Estimated blood loss	126.89 ± 112.66	347.11 ± 466.49	< 0.01
Chest tube duration	4.79 ± 3.12	5.62 ± 3.04	< 0.01
Length of stay	8.84 ± 7.76	10.8 ± 8.44	< 0.01
Patients with complications	1024 (24.4%)	180 (41.7%)	< 0.01
In-hospital mortality	48 (1.1%)	4 (0.9%)	1

ADC adenocarcinoma; *SCC* squamous cell carcinoma, *SND* systematic nodal dissection

$p < 0.01$) were higher in patient who underwent unplanned thoracotomy. Patients who suffered from conversion were more prone to develop surgical (prolonged air leak, blood transfusions, laryngeal nerve palsy) medical (supraventricular arrhythmias, renal failure) and respiratory complications (atelectasis, sputum retention) as identified at univariate and multivariable analysis. Other severe pulmonary complications, such as ARDS and pneumonia, were associated with conversions only at univariate analysis. Furthermore, the only complication correlated with conversion was blood transfusion (Table 6), while the incidence of pulmonary complications could be interpreted also with the lower respiratory reserve. From the analysis of the literature emerged that the overall mortality rate is not influenced by conversion, while the impact of unplanned thoracotomy on postoperative outcomes appears controversial: in some reports, the complication rate was not higher for converted patients [22, 23], while others described an increased significant incidence of adverse events [12, 13, 24]. Our experience is in line with the last report. The complication rate is quite higher than expected in both groups for two reasons: the first is the presence of several minor complications (grade I of the Clavien–Dindo scale [26]); the second is the presence of redundant information. The VATS group database is very detailed and some pulmonary complications, such as pneumonia, could be depicted individually, but were often resumed with more variables, increasing the number of complications for each patient. Actually, the rate of patient with complications is in line with previous published data; moreover, the analysis of single complication demonstrated percentages similar to other experience.

Our study has several limitations. First, it suffers from all of the inherent biases proper to retrospective analyses. Second, the absence of oncological outcomes

Table 5 Complications in detail between non-converted and converted patients

Variables	Group A VATS group ($n=4197$) 90.7%	Group B Conversion group ($n=432$) 9.3%	p
Atrial fibrillation	321 (7.6%)	54 (12.5%)	<0.01
Acute myocardial infarction	8 (0.2%)	3 (0.7%)	0.076
Cardiac arrest	5 (0.1%)	2 (0.5%)	0.133
PAL	334 (8%)	55 (12.7%)	<0.01
Pulmonary embolism	3 (0.1%)	1 (0.2)	0.324
ARDS	15 (0.4%)	6 (1.4%)	0.01
Persistent pleural space	100 (2.4%)	17 (3.9%)	0.074
Pneumonia	131 (3.1%)	26 (6%)	<0.01
Mechanical ventilation	16 (0.4%)	5 (1.2%)	0.04
Middle lobe torsion	4 (0.1%)	1 (0.2%)	0.387
Atelectasis	79 (1.9%)	17 (3.9%)	<0.01
Sputum retention	94 (2.2%)	23 (5.3%)	<0.01
Hemothorax	55 (1.3%)	6 (1.4%)	0.825
Bronchopleural fistula	11 (0.3%)	3 (0.7%)	0.136
Chylothorax	16 (0.4%)	1 (0.2%)	1
Phrenic nerve palsy	7 (0.2%)	1 (0.2%)	0.544
Recurrent laryngeal nerve palsy	16 (0.4%)	6 (1.4%)	0.013
Blood transfusions	71 (1.7%)	35 (8.1%)	<0.01
Renal failure	18 (0.4%)	7 (1.6%)	<0.01
Urinary tract infection	20 (0.5%)	1 (0.2%)	0.715
Dialysis	1 (0.0%)	1 (0.2%)	0.178
Prolonged mechanical ventilation	21 (0.5%)	4 (0.9%)	0.286

PAL prolonged air leak, *ARDS* adult respiratory distress syndrome

Table 6 Spearman correlation test between conversion and complications in detail

Variable	ρ	p
Atrial fibrillation	0.052	0.01
Acute myocardial infarction	0.03	0.04
Cardiac arrest	0.026	0.08
PAL	0.05	<0.01
Pulmonary embolism	0.016	0.281
ARDS	0.045	<0.01
Persistent pleural space	0.029	0.05
Pneumonia	0.047	<0.01
Re-intubation	0.034	0.022
Middle lobe torsion	0.012	0.412
Atelectasis	0.037	0.011
Sputum retention	0.057	<0.01
Hemothorax	0.002	0.892
Bronchopleural fistula	0.023	0.119
Chylothorax	-0.007	0.624
Phrenic nerve injury	0.005	0.758
Recurrent nerve palsy	0.043	<0.01
Blood transfusions	0.125	<0.01
Renal failure	0.049	<0.01
Mechanical ventilation	0.017	0.251

PAL prolonged air leak, *ARDS* adult respiratory distress syndrome

represents another limitation, although the long-term results were not the main topic of this study. Third, it was not possible to discern between emergent and elective conversions and also the intraoperative consequences of the injury or adjunctive procedure (i.e. pneumonectomy, sleeve resection) were not identifiable. Some well-known risk factors of conversion could be pre-operatively predicted by CT scan: hilar calcifications, pleural calcifications and obliterated interlobar fissure; however these data were not registered in the large multi-institutional database used for this retrospective study.

Concluding, unexpected conversion to thoracotomy during VATS-L for NSCLC increased surgical morbidity, blood loss and hospital stay. This study showed also the feasibility of VATS-L in patients with large tumours or after induction treatment without an increased risk of conversion. Consequently VATS-L should not be denied to patients with these clinical features. Sex male, advanced age and the clinical involvement of mediastinal or hilar lymph nodes were the pre-operative strongest predictors of conversion.

Table 7 Multivariable Cox logistic regression model of complications associated with unplanned thoracotomy

Variable	OR	CI 95%	*p*
Atrial fibrillation	1.471	1.066–2.031	0.019
Acute myocardial infarction	1.751	0.393–7.808	0.463
PAL	1.403	1.011–1.947	0.043
ARDS	2.999	0.986–9.125	0.053
Persistent pleural space	1.173	0.664–2.074	0.583
Pneumonia	1.394	0.866–2.246	0.171
Re-intubation	1.729	0.486–6.148	0.398
Atelectasis	1.347	0.729–2.488	0.341
Sputum retention	1.807	1.070–3.051	0.027
Recurrent nerve palsy	3.873	1.498–10.012	< 0.01
Blood transfusions	4.820	3.046–7.627	< 0.01
Acute kidney failure	2.758	1.074–7.079	0.035
Mechanical ventilation	0.473	0.105–2.122	0.328
Patient with complications	2.213	1.805–2.714	< 0.01

PAL prolonged air leak, *ARDS* adult respiratory distress syndrome

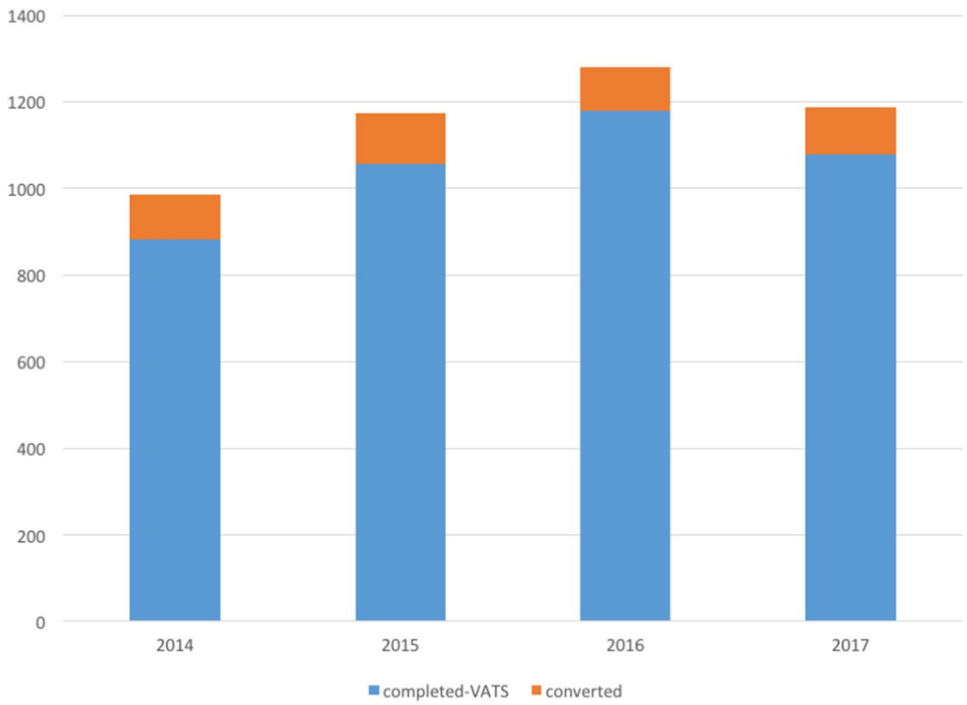

Fig. 2 Completed VATS-L and conversions per year

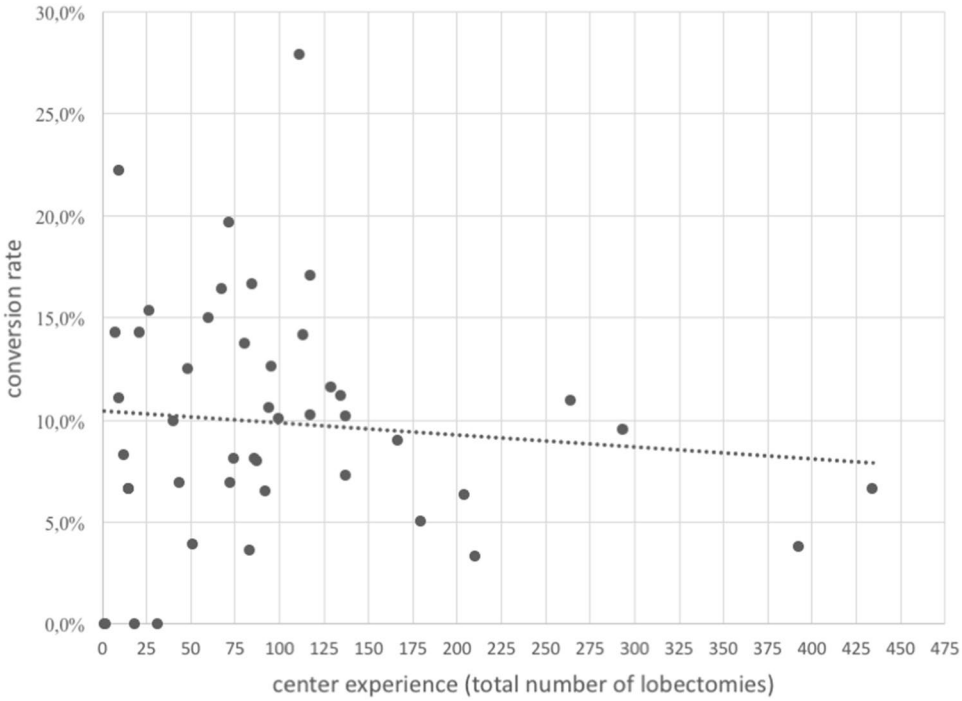

Fig. 3 Graphical proportion between completed VATS-L and conversion rate per centre

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Compliance with ethical standards

Disclosures Stefano Bongiolatti, Alessandro Gonfiotti, Domenico Viggiano, Sara Borgianni, Leonardo Politi, Roberto Crisci, Carlo Curcio and Luca Voltolini have no conflicts of interest or financial ties to disclose.

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