European Journal of Cardio-Thoracic Surgery 00 (2018) 1–8
doi:10.1093/ejcts/ezy245

ORIGINAL ARTICLE

Cite this article as: Lutz JA, Seguin-Givelet A, Grigoroiu M, Brian E, Girard P, Gossot D. Oncological results of full thoracoscopic major pulmonary resections for clinical Stage I non-small-cell lung cancer. Eur J Cardiothorac Surg 2018; doi:10.1093/ejcts/ezy245.

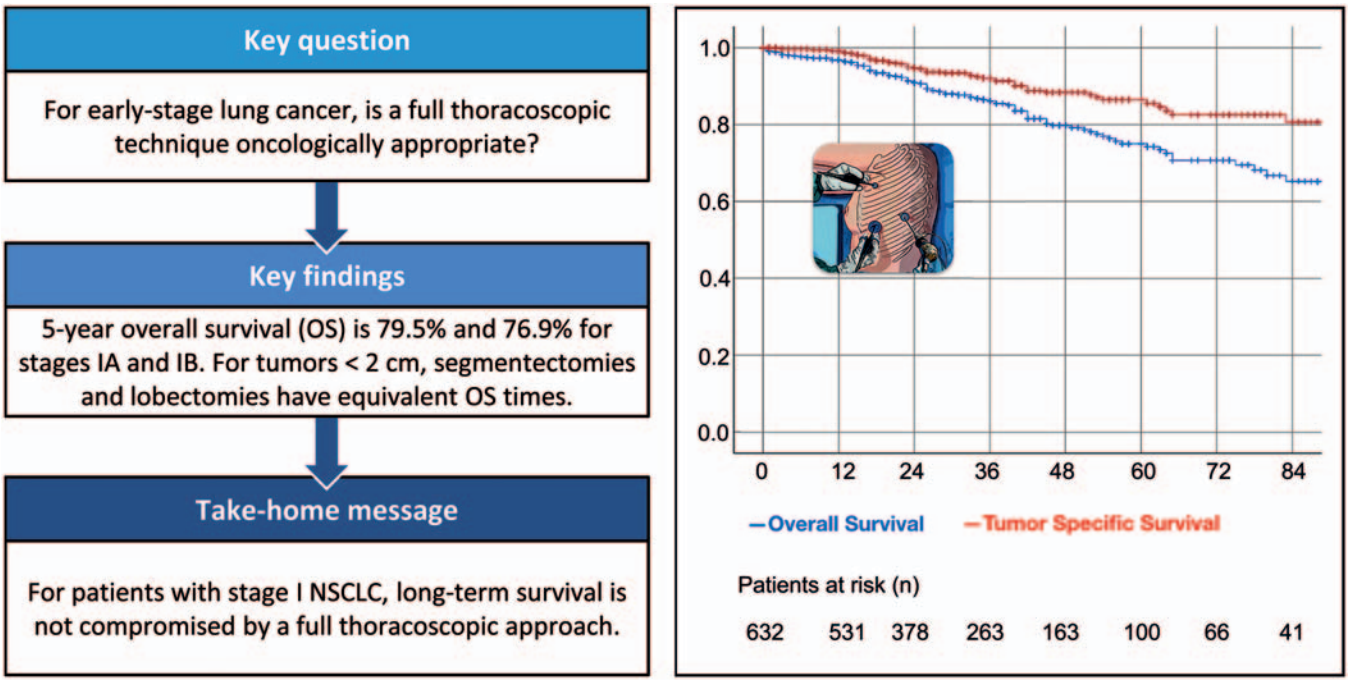
Oncological results of full thoracoscopic major pulmonary resections for clinical Stage I non-small-cell lung cancer

Jon A. Lutz[a,b], Agathe Seguin-Givelet[a,c], Madalina Grigoroiu[a], Emmanuel Brian[a], Philippe Girard[a] and Dominique Gossot[a,*]

[a] Thoracic Department, Institut du Thorax Curie-Montsouris, Institut Mutualiste Montsouris, Paris, France
[b] Division of General Thoracic Surgery, Inselspital, Bern University Hospital, University of Bern, Switzerland
[c] Paris 13 University, Sorbonne Paris Cité, Faculty of Medicine SMBH, Bobigny, France

* Corresponding author. Thoracic Department, Institut du Thorax Curie-Montsouris, Institut Mutualiste Montsouris, 42 Bd Jourdan, 75014 Paris, France. Tel: 33 1 56 61 62 14; e-mail: dominique.gossot@imm.fr (D. Gossot).

Received 22 February 2018; received in revised form 4 June 2018; accepted 7 June 2018



Abstract

OBJECTIVES: The full thoracoscopic approach to major pulmonary resections is considered challenging and controversial as it might compromise oncological outcomes. The aim of this work was to analyse the results of a full thoracoscopic technique in terms of nodal upstaging and survival in patients with non-small-cell lung carcinoma (NSCLC).

METHODS: All patients who underwent a full thoracoscopic major pulmonary resection for NSCLC between 2007 and August 2016 were analysed from an 'intent-to-treat' prospective database. Overall survival and disease-free survival were estimated using the Kaplan–Meier curves and comparisons in survival using the log-rank test.

RESULTS: A total of 648 patients met the inclusion criteria, of whom 621 patients had clinical Stage I and 27 had higher stages (16 oligo-metastatic patients were excluded from the analysis, 11 cT3 or cT4). The mean follow-up was 34.5 months. There were 40 conversions to thoracotomy (6.3%). Thirty-day or in-hospital mortality was 0.95%. Complications occurred in 29.3% of patients. On pathological

examination, 22.5% of clinical Stage I patients were upstaged. Nodal upstaging to N1 or N2 was observed in 15.8% of clinical Stage I patients. Five-year overall survival of the whole cohort was 75% and was significantly different between clinical Stages IA (76%) and IB (70.9%). For tumours <2 cm, no significant difference in overall survival was found for the segmentectomy group compared to the lobectomy group: 74% versus 78.9% ($P = 0.634$).

CONCLUSIONS: Long-term survival is not compromised by a full thoracoscopic approach. Our results compared favourably with those of video-assisted techniques.

Keywords: Lobectomy • Segmentectomy • Lung cancer • Survival

INTRODUCTION

Over the past 10 years, the rise in video-assisted thoracic surgery (VATS) for treating early-stage non-small-cell lung carcinoma (NSCLC) has been tremendous. After more than a decade of skepticism, VATS anatomical resections have been mentioned in 2009 as an acceptable alternative to thoracotomy [1, 2] and eventually recommended as the preferable approach for early-stage NSCLC by the American College of Chest Physicians (ACCP) guidelines in 2013 [3]. It is now known that VATS result in decreased postoperative pain, improved immune tolerance measured by cytokine release, reduced pulmonary complications, shorter hospital stay and better compliance to adjuvant chemotherapy [4]. However, many points still require investigation. It is not clear whether the better results of VATS lobectomies are related to the approach itself or to the concomitant changes in patient profiles at high-volume VATS centres [5]. Indeed, biases in the selection of patients do most likely exist, as VATS lobectomies are performed in patients with lower stage tumours and, generally, when a non-complex resection is foreseen [6]. In addition, even though most publications based on clinical or administrative databases suggest a lower postoperative morbidity rate, the question of intraoperative complications remains open, with some studies reporting a significant and worrying rate of major intraoperative complications that do not seem related to the surgical experience but might be inherent to the thoracoscopic approach itself [7, 8]. Finally, the most important question is the effectiveness of this technique in treating lung cancer, which is best evaluated by an analysis of long-term survival.

A meta-analysis of 20 observational studies comparing thoracoscopy to thoracotomy reported the advantage of long-term survival in patients who underwent thoracoscopy [9]. In addition to the selection bias due to their retrospective nature, these studies have 2 weaknesses: the heterogeneity of patients and the lack of details on the technique used (pure thoracoscopic, video assisted or hybrid) and on the type of lymph node (LN) dissection. The results are difficult to analyse as there are different surgical techniques, with some comprising a minithoracotomy—so-called hybrid—or an access incision, or no access incision with a full endoscopic approach. The latter has been considered a challenging or even unreasonable access because, as written several years ago by some authors, it might compromise the oncological results [10].

Since 2007, we have been using a standardized full thoracoscopic approach lobectomy or segmentectomy for clinical Stage I NSCLC [11]. We have reported our results in terms of perioperative outcome, morbidity [8] and quality of LN dissection [12], but long-term survival data were missing. The aim of this work was to analyse the results of the fully-closed chest technique in terms of nodal upstaging and long-term survival.

MATERIALS AND METHODS

Patients

All patients who were operated on in our institution for NSCLC between January 2007 and August 2016 by a full thoracoscopic technique (FT) were included. Patients operated on after this date were excluded to allow for a minimum follow-up time of 1 year. The analysis was done retrospectively from our database. This database (declared on CNIL1682873v0) is an 'intent to treat' prospective database of all thoracoscopic procedures for major pulmonary resections, including all converted patients. The study was approved by the ethics committee for clinical research of the French Society for Thoracic and Cardiovascular Surgery (CERC-SFCTCV-2015-12-7-51-14-Lujo).

The database included clinical and pathological variables, type of resection, intraoperative and postoperative data, complications, recurrence and survival. The preoperative staging was based on a routine computed tomography (CT) scan, brain magnetic resonance imaging or a cerebral CT scan and a fluorodeoxyglucose positron emission tomography scan (PET scan). For patients with abnormal mediastinal and/or hilar LNs at CT and/or PET, endobronchial ultrasound (EBUS) was performed for mediastinal and hilar staging. In case of negative EBUS and a highly suspicious malignant LN, mediastinoscopy was performed. Postoperative staging was done using the 7th edition of the tumour, nodes and metastasis (TNM) classification. Overall survival (OS) was defined as the time between surgery and death—whatever the cause—or date of the last follow-up. Disease-free survival (DFS) corresponded to the time from surgery to tumour recurrence (local, metastatic or metachronous NSCLC) or death. Tumour-specific survival (TSS) corresponded to the time from surgery to lung-cancer-related death. In-hospital mortality was defined as death within 30 days after the operation or in-hospital death without discharge.

Operative technique

Lobectomies and segmentectomies were performed by all 4 surgeons of our department using the same standardized technique with pure monitor display, high-definition imaging system and a 10-mm deflectable endoscope hold on a scope positioner, 3–4 ports without utility incision (an incision was made at the completion of the resection, its length being suited to the size of the specimen) and specifically designed small-diameter instruments. Compared to the so-called 'anterior' approach that comprises a dissection of the hilum with a fissure last division, our technique can be compared to the 'posterior' approach described by Walker *et al.* [13], which should rather be named 'fissure-based' or 'fissure-first' with dissection of the pulmonary artery branches in the fissure. The lobectomy or segmentectomy was completed

Table 1: Demographics

Characteristics	N = 632
Age (years), median (25th and 75th percentiles)	65 (59–71)
Gender, female/male (%)	321 (50.8)/311 (49.2)
Body mass index (kg/m^2), median (25th and 75th percentiles)	24 (21–28)
FEV_1 (% of predicted), mean ± SD	89 ± 9.8
Clinical stage, *n* (%)	
IA	465 (73.6)
IB	156 (24.7)
IIA–B	10 (1.6)
IIIA	1 (0.2)

Data are presented as absolute numbers or in median (lower and upper quartiles).

FEV_1: forced expiratory volume in 1 s; SD: standard deviation.

Table 2: Surgical and postoperative data

Resection type	*n*	Percentage
Left upper lobe	98	15.5
Left lower lobe	68	10.8
Right upper lobe	184	29.1
Middle lobe	40	6.3
Right lower lobe	79	12.5
Bilobectomy	3	0.5
Segmentectomy	160	25.3
Operating time (min)	160 (125–200)	
Estimated blood loss (ml)	100 (50–150)	
Conversions	40	6.3
30 Days or in-hospital mortality	6	0.95
Chest tube duration (days)	3 (2–5)	
Length of hospital stay (days)	6 (5–8)	

Data are presented as absolute numbers or in median (lower and upper quartiles).

Table 3: Pathological data

Pathological stage	*n*	Percentage
IA	281	44.5
IB	201	31.8
IIA	54	8.5
IIB	39	6.2
IIIA	57	9
Tumour size (cm)		
Median	2.2 (1.6–3)	
≤2 cm	285	46.5
>2 cm ≤ 5 cm	307	50.1
>5 cm	21	3.4
Histology		
Adenocarcinoma	498	78.8
Squamous-cell carcinoma	102	16.1
Large-cell carcinoma	32	5.1

Data are presented as absolute numbers or in median (lower and upper quartiles).

with a radical hilar and mediastinal LN dissection, according to a previously reported technique [12]. In summary, Stations 2, 4 and 7–10 on the right side and Stations 5–10 on the left side were totally removed. All peribronchial (Station 11) and interlobar and intersegmental (Stations 12 and 13) were cleared. During segmentectomies, intersegmental LNs and safety margins were examined by a frozen section. The procedure was converted to lobectomy in case of invaded LN or insufficient safety margin. Although LN dissection was radical in most patients, it was only partial or even not performed in patients older than 80 years when adjuvant chemotherapy would have been unfeasible, regardless of the postoperative stage.

Anatomical sublobar resections (SLRs), i.e. segmentectomies, were performed in cT1a and in some cT1b tumours for patients who had undergone a previous major pulmonary resection and/or whose pulmonary function was poor and/or who presented with 2 synchronous or metachronous tumours. The chest tube was removed if daily output was inferior to 400 ml with no air leakage.

Statistical analysis

Statistical analysis was performed using the IBM SPSS software version 25 for windows. Variables are expressed as median with lower and upper quartiles and categorical variables as absolute and relative frequencies. Analysis of follow-up data was done using the Kaplan–Meier method, and groups were compared with the log-rank test. Primary outcome was survival expressed as mean and 95% confidence interval. We also performed univariable and multivariable Cox regression analyses on OS and TSS. Univariable models were fitted to all potential predictors, and those with a *P*-value <0.2 were included in a multivariable model. The proportional hazard assumption was checked with log–log plots.

RESULTS

Demographics

At the time of writing this article, 1217 FT major pulmonary resections—regardless of the indication—were performed in our department (Table 1). The present study is based on a total of 648 patients presenting with proven or suspected NSCLC who were operated on by an FT between January 2007 and August 2016. Sixteen oligometastatic Stage IV patients (13 brains, 2 adrenals and 1 pleural metastasis) were excluded. Among the remaining 632 patients, 465 had clinical Stage IA and 156 clinical Stage IB tumours. Eleven patients had a higher staging because of separate nodule in the same lobe ($n = 6$), separate nodule in an ipsilateral lobe ($n = 1$) or tumour size >5 cm ($n = 4$). FT was, however, decided in these patients because there was no nodal involvement on a PET scan.

Perioperative results

The median operating time was 160 min (125–200 min), and the median estimated blood loss was 100 ml (50–150 ml) (Table 2). There were 40 conversions to thoracotomy (6.33%) for vascular tears ($n = 15$), oncological ($n = 2$) or technical issues such as dense adherences, or a totally fused fissure ($n = 23$). Thirty-day or in-hospital mortality was 0.95%: 1 intraoperative death due to cardiac injury already reported [8], 3 acute respiratory distress syndromes, 1 secondary rupture of the spleen and 1 massive pulmonary embolism. Complications occurred in 185 patients (29.3%). Most frequent complications were prolonged air leak ($n = 59$), atrial fibrillation ($n = 23$) and pneumonia ($n = 22$). Chest

Table 4: Reasons for tumour upstaging of clinical Stage I patients

	Pathological stage					Reasons of upstaging		
	IA/IB	IIA	IIB	IIIA	Total of patients with higher stages than IA/IB	≥T3	N1	N2
Clinical IA (*n* = 465)	383	25	18	39	82	23	28	34
Clinical IB (*n* = 156)	98	28	14	16	58	11	21	15

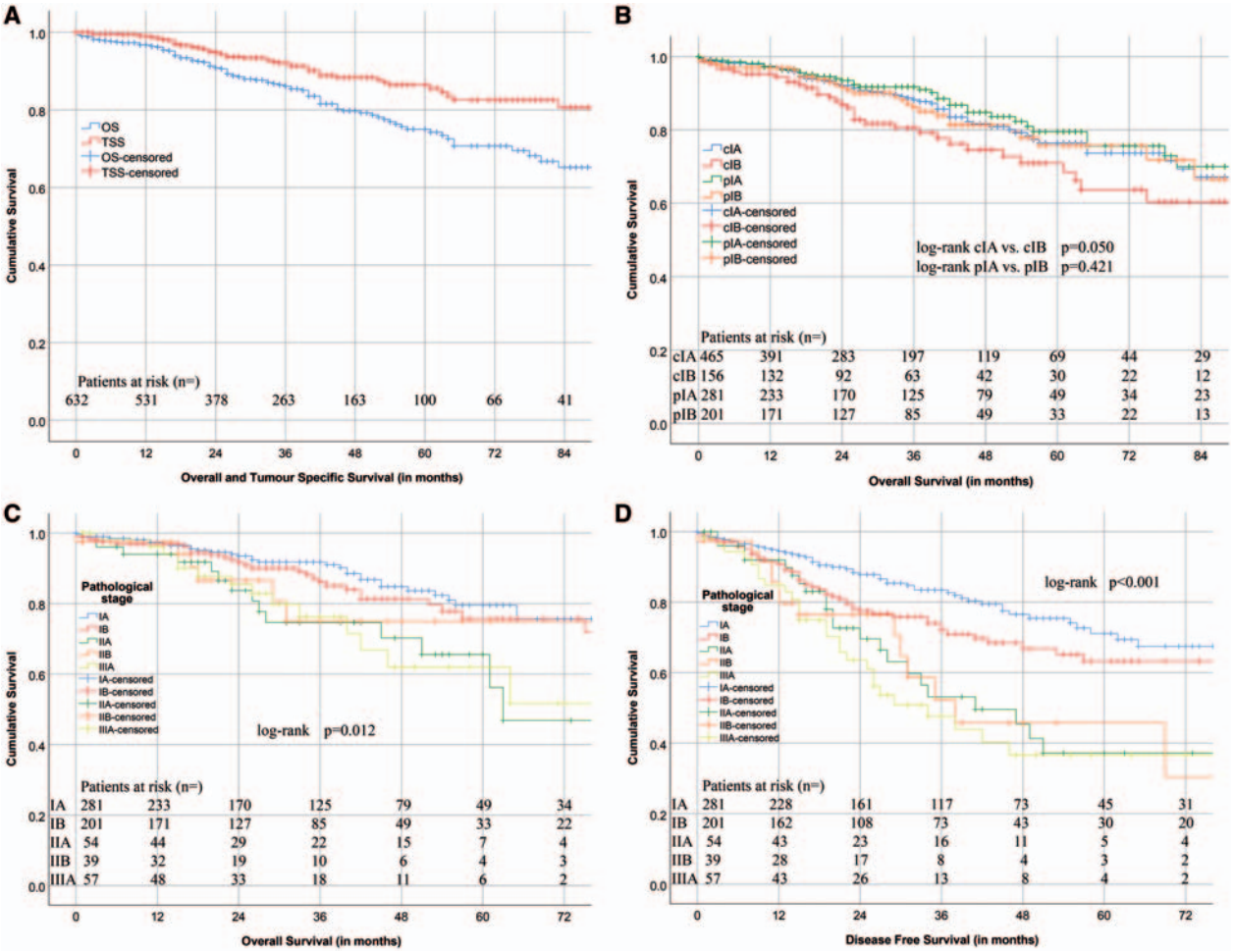


Figure 1: (**A–D**) OS, TSS and disease-free survival. (**A**) OS and TSS of all patients (*n* = 632). (**B**) OS by clinical Stages IA and IB (*n* = 621) and pathological Stages IA and IB (*n* = 482). (**C**) OS stratified by pathological stage (*n* = 569). (**D**) Disease-free survival stratified by pathological stage (*n* = 632). OS: overall survival; TSS: tumour-specific survival.

tube duration was 3 days (2–5 days), and length of stay was 6 days (5–8 days).

Pathological analysis

Adenocarcinoma was the most frequent histological type (*n* = 498, 78.8%) (Table 3). Four hundred and eighty-one patients (77.8%) were in Stage I on pathological examination, whereas 140 patients (22.5%) were upstaged (Table 4). The reasons for T-upstaging (*n* = 51) were the discovery of a second tumour in the same lobe or in an ipsilateral lobe, invasion of the parietal pleura and underestimation of tumour size on a preoperative CT scan. The rate of pT3 upstaging is likely to be overestimated as some of the patients had a doubtful additional small nodule in the same lobe on a preoperative CT scan. Nodal upstaging to N1 (*n* = 49) or N2 (*n* = 49) was observed in 98 (15.8%) of clinical Stage I patients. Sixty-two (63.3%) of these patients received adjuvant chemotherapy. The main reason for not administrating adjuvant treatment was age > 80 years. Nine patients had combined T and N upstaging.

Survival

The mean follow-up was 34.5 months. Five-year OS of the whole cohort was 75% (95% confidence interval 69.9–80.1%) and TSS

Table 5: Cox regression analysis for OS and TSS

	Univariable		Multivariable	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
OS				
Age <75 years	0.577 (0.363–0.915)	0.020*	0.612 (0.383–0.979)	0.041*
Female gender	0.564 (0.377–0.846)	0.006*	0.621 (0.409–0.944)	0.026*
Lobar resection	0.897 (0.510–1.269)	0.348		
Blood loss per decilitre	1.061 (1.006–1.118)	0.030*	1.050 (0.991–1.113)	0.101
Pathological stage		0.016*		0.035*
IA	0.423 (0.226–0.789)		0.420 (0.223–0.792)	
IB	0.515 (0.272–0.975)		0.489 (0.256–0.932)	
IIA	0.999 (0.476–2.096)		0.858 (0.403–1.823)	
IIB	0.694 (0.267–1.808)		0.668 (0.254–1.758)	
IIIA	Ref.		Ref.	
Tumour size ≤2 cm	0.770 (0.512–1.157)	0.209		
Histological type		0.040*		0.168
Adenocarcinoma	0.722 (0.430–1.215)		0.804 (0.467–1.383)	
Squamous-cell carcinoma	Ref.		Ref.	
Large-cell carcinoma	1.583 (0.745–3.361)		1.473 (0.678–3.198)	
TSS				
Age <75 years	0.783 (0.392–1.564)	0.488		
Female gender	0.516 (0.294–0.905)	0.021*	0.582 (0.326–1.039)	0.067
Lobar resection	0.668 (0.366–1.221)	0.190	0.462 (0.240–0.888)	0.020*
Blood loss per decilitre	0.990 (0.865–1.134)	0.888		
Pathological stage		0.002*		0.002*
IA	0.210 (0.090–0.487)		0.195 (0.083–0.462)	
IB	0.447 (0.206–0.969)		0.394 (0.180–0.865)	
IIA	0.905 (0.367–2.230)		0.827 (0.330–2.071)	
IIB	0.334 (0.073–1.524)		0.332 (0.073–1.519)	
IIIA	Ref.		Ref.	
Tumour size ≤2 cm	0.593 (0.331–1.062)	0.079	0.711 (0.369–1.372)	0.310
Histological type		0.322		
Adenocarcinoma	1.551 (0.613–3.926)			
Squamous-cell carcinoma	Ref.			
Large-cell carcinoma	2.592 (0.748–8.980)			

*Statistically significant ($P < 0.05$).

CI: confidence interval; HR: hazard ratio; Ref.: reference category.

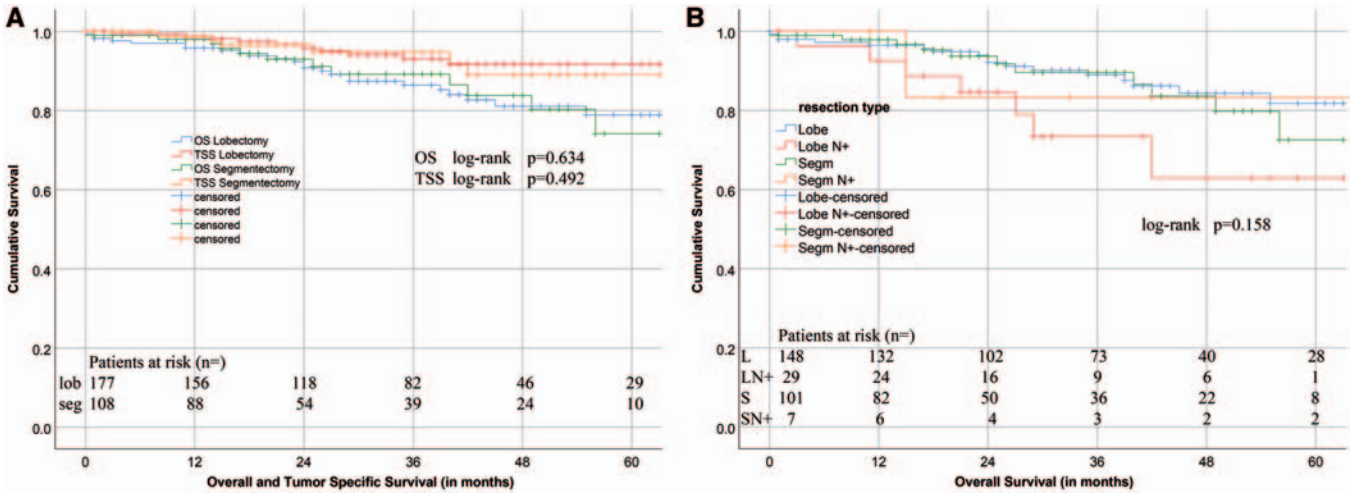


Figure 2: (**A** and **B**) Comparison of OS and TSS after lobectomy and segmentectomy. (**A**) OS and TSS lobectomy versus segmentectomy for tumour size ≤2 cm (n = 285). (**B**) OS lobectomy versus segmentectomy for tumour size ≤2 cm, stratified by pathological nodal status (n = 285). OS: overall survival; TSS: tumour-specific survival.

86.4% (95% confidence interval 82.3–90.5, Fig. 1A). There was a significant difference ($P = 0.05$) in 5-year OS between clinical Stage IA (76.4%, 70.3–82.5%) and IB patients (70.9%, 61.1–80.7%, Fig. 1B). Five-year OS of the whole cohort was 79.5%, 76.9%, 63.9%, 75% and 62% for Stage IA, IB, IIA, IIB and IIIA, and DFS was 71.1%, 63.6%, 38.7%, 45.7% and 36.7%, respectively. Details are shown in Fig. 1C and D. Based on the univariable Cox regression analysis for OS, we selected age <75 years, female gender,

Table 6: Survival after VATS major pulmonary resections in published studies

Author	Year of publication	Number of patients	5-Year OS (%)	Conversion (%)	Mortality (%)	Morbidity (%)
This series	2018	632	75.0	6.3	0.95	29.3
Yang *et al.* [31]	2016	141	73.5 (I)	6	1	NR
Liu *et al.* [32]	2014	123	71.6	NR	0	25.2
Lee *et al.* [33]	2013	188	76.5 (I)	2	0	13.9
Kuritzky *et al.* [34]	2013	40	97 (IA)	10	2.5	27.5
Port *et al.* [35]	2011	40	76	15	0	35
Yamamoto *et al.* [36]	2010	325	85 (IA)	6.4	0.3	28
Flores *et al.* [37]	2009	398	79	17	0.3	24
McKenna *et al.* [38]	2006	1015	72	2.5	0.8	15.3

NR: not reported; OS: overall survival; VATS: video-assisted thoracic surgery.

low blood loss and pathological stage for a multivariable analysis. Age <75 years, female gender and pathological stage showed significant effects in the multivariable analysis (Table 5). In the Cox analysis for TSS, the pathological stage and the type of resection were significant.

With progressive change in our patients' profile, the proportion of SLRs rose from 8% in 2007–2008 to 37.6% in 2016. Fig. 2A shows the survival curve (OS and TSS) for lobectomy versus segmentectomy in patients with tumours ≤2 cm, for which segmentectomy was intended. The difference in OS was not statistically different ($P = 0.634$, 78.9%, 70.5–87.3% vs 74.2%, 58.3–90.1%). However, the groups are not matched, and there is a tumour size difference between the groups: 1.7 cm (1.5–2 cm) in the lobectomy group and 1.5 cm (1.2–1.8 cm, $P < 0.001$) in the segmentectomy group. Nodal upstaging (N1: 17 vs 1, N2: 12 vs 6, $P = 0.024$) and number of LNs resected (19 vs 14, $P < 0.001$) were significantly higher in lobectomy than in segmentectomy. This had no impact on OS as seen in Fig. 2B. On the other hand, a subgroup of patients ($n = 33$) had no systematic radical lymphadenectomy. This group was significantly older [77 years (62–83 years) vs 65 years (59–71 years), $P < 0.001$] and had a higher percentage of SLR ($n = 15$, 45.5% vs $n = 145$, 24.2%, $P = 0.006$). Excluding this subgroup from the analysis had no significant impact on 5-year OS (75.3% vs 75.%), and we decided to keep them included to reflect the results of our clinical practice.

DISCUSSION

Acceptance of a thoracoscopic approach for major pulmonary resections took time, mainly because of doubts about its oncological validity. However, over the recent years, a rise in the use of VATS has been observed, and the ACCP guidelines now recommend the VATS approach for Stage I NSCLC [3]. As recently stressed by Treasure [14], surgeons performing VATS lobectomy want to reach multiples goals: safety, efficacy and oncological effectiveness measured by OS and DFS. We will use this framework to comment our results.

Safety

Establishing a VATS lobectomy programme means a steep learning curve, and even specialized centres cannot avoid major intraoperative and postoperative complications, as reported by the survey of the European Society of Thoracic Surgeons [7]. Nevertheless, most studies report comparable or better perioperative morbidity and mortality with VATS lobectomy compared to the open approach, which was even more pronounced in high-volume centres [5]. Similar conclusions are reached when focusing on VATS resections for lung cancer, with a significant reduction in the length of stay in high-volume centres [5].

Efficacy

Efficacy is defined as 'whether the technique achieves the initial intention of the treatment which is to remove the lobe or the segment successfully' [14]. The full thoracoscopic approach did not seem to result in an oncological compromise. Planned segmentectomy were extended to lobectomy if intersegmental LNs were positive at 'frozen section examination' and/or if the safety margin was not sufficient [15]. If the principles of an oncological resection could not be matched [16], thoracoscopy was converted to thoracotomy. Finally, all patients had the initially planned surgery (lobectomy/segmentectomy) or—in the segmentectomy group—a more extensive resection (adjacent segmentectomy of lobectomy) if needed [15]. In the group of patients who underwent a more extensive resection than initially planned, there was no conversion.

Oncological effectiveness

Oncological effectiveness refers to whether VATS major pulmonary resection achieves similar oncological results as conventional thoracotomy. In lung cancer surgery, resections must be performed according to the oncological principles defined by the International Association for the Study of Lung Cancer (IASLC): free resection margins proved microscopically, systematic nodal dissection or lobe-specific systematic nodal dissection, no extracapsular nodal extension of the tumour and the highest mediastinal node removed must be negative [16]. Effectiveness can only be definitively evaluated by the study of DFS and long-term survival. As setting randomized trials comparing different approaches and using such criteria appear unrealistic, evaluating the fulfilment of the aforementioned resection criteria can be achieved by studying and comparing OS and DFS of a large series. Analysing these parameters in our intention-to-treat VATS series was the main reason of this study. In a published series, long-term survival after VATS lobectomy for NSCLC ranges from

63.6% to 97% (Table 6). In a large meta-analysis published in 2009, Yan *et al.* [2] demonstrated that VATS lobectomy for early-stage NSCLC could become a valid alternative to open surgery. In a matching study by Paul *et al.* [17], OS, cancer-specific survival and DFS in 2 groups of 1195 patients were similar, and there was no indication that VATS was inferior to thoracotomy. Several authors have reported better or at least equivalent long-term survival rates for VATS lobectomy [17–20]. Our long-term outcome measured by OS and DFS rates was comparable with that of other studies analysing VATS lobectomies performed by any other VATS technique or by open surgery.

Does the technique influence long-term outcome?

There is no precise standard technique for VATS lobectomy, and the favoured surgical approach varies dramatically among surgeons. Dissections can begin in the fissure or in the hilum (anterior to posterior). In our department, all operations were performed according to a previously reported technique based on a full thoracoscopic and fissure-first approach [12]. The reason for favouring this approach was to allow an extensive dissection of LNs in the fissure with a frozen section if needed, to detect variations of vascular anatomy and to dissect and clear the origin of the lobar or segmental bronchus. Recently, Samejima *et al.* [21] have demonstrated that a fissure-first approach does not increase the prevalence of air leaks, operating time and duration of chest drainage, while enabling a better LN dissection. This approach has been criticized for being challenging and more stressful in case of vascular injury and conversion because of the lack of utility incision. However, these criticisms do not seem to be supported by the operative time, intraoperative blood loss, conversions and complications rates and eventually by the long-term survival [9].

Our upstaging rate of 22.5% could be split into T-upstaging (8.2%), which was mainly explained by the discovery of a second tumour in the same lobe and an N-upstaging of 15.8%. An FT enables LN dissection as complete as through a thoracotomy, as demonstrated by our team [12]. This is made possible, thanks to the use of a deflectable endoscope that provides a bird's eye view on all LN stations and several instruments that facilitate exposure and LN grasping. In our series, the final rate of nodal upstaging in clinical Stage I patients was 7.9% for N1 and 7.9% for N2. This is comparable to the rates obtained by thoracotomy in our department [12] and higher than the 3.6% reported by Khullar *et al.* [22] for the VATS approach or the 11.9% reported by Medbery *et al.* [23] for open approach. However, there is still an ongoing debate on the efficacy of VATS lymphadenectomy. Results of the American College of Surgery Oncology Group Z0030 Trial showed no difference in the number of LNs removed by VATS compared with open thoracotomy, but conclusions of other studies vary. Boffa *et al.* [24] reported that N1 upstaging was significantly lower in the VATS group than in the thoracotomy group. This difference disappeared as experience increased.

Segmentectomies

A substantial proportion of the patients had an anatomical SLR. The main indications were metachronous or synchronous NSCLC in patients with poor lung function and/or major comorbidities. However, oncological results of SLR are still a matter of debate. Whitson *et al.* [25] analysed the survival of 14 473 patients who underwent either lobectomy or SLR for Stage I NSCLCs from the Surveillance Epidemiology and End Results (SEER) database. They demonstrated that lobectomy had a significantly better survival, even for tumours less than 2.1 cm in diameter. However, in such a multicentric analysis, information on technical details and on intraoperative study of resection margins and intersegmental LNs is unavailable. Most likely, some SLR patients were understaged, which might explain a pejoration of survival. If all patients had an intraoperative examination of an LN and of the resection margins, some would be converted into lobectomy, and the results could be more adequately compared [16].

Compared to lobectomies, SLRs comprise an increased risk of local recurrence as resection margins tend to be closer to the tumour. Schuchert *et al.* [26] demonstrated that outcomes of segmentectomies compare favourably with lobectomy for Stage I NSCLC but that margin/tumour ratios of less than 1 are associated with a higher rate of recurrence. As suggested by other authors [27], we routinely use a modelling software before SLR, which comprises a virtual safety margin that helps the decision-making and the planning of an adequate resection.

Finally, intersegmental LN clearance appears to be of major importance during thoracoscopic segmentectomies [25, 28]. Wolf *et al.* [28] have demonstrated in patients with small-sized NSCLCs that local recurrence rate and OS and recurrence-free survival distributions were similar between segmentectomy and lobectomy when LNs were sampled during segmentectomy. Although an intraoperative frozen section is time-consuming, systematic examination of Stations 10–12 LNs and resection margin measurement were performed in the present study, which may explain the similar 5-year OS and DFS between the segmentectomy and lobectomy groups in our series. Okada *et al.* [29] also reported that long-term survival was equivalent for segmentectomy and lobectomy in patients with Stage IA adenocarcinomas. Similarly, Cao *et al.* [30] demonstrated in a large meta-analysis that patients intentionally treated by an SLR for an early-stage peripheral NSCLC had OS and DFS that were not significantly different from those treated by lobectomy. They also showed that the lower OS in the 'compromised group' of patients who underwent segmentectomies due to medical comorbidities or cardiopulmonary limitations were probably explained by non-cancer-related deaths in these fragile patients rather than the oncological inferiority of SLR (30).

CONCLUSION

Despite the lack of randomized studies comparing thoracoscopy and thoracotomy, it is now known, based on large cohort studies, that the early outcome of major pulmonary resection is more favourable when performed by thoracoscopy. There is also a growing body of evidence that long-term survival is not compromised by a video-assisted or thoracoscopic approach. This study adds the results of a full-closed-chest technique and shows that a utility incision is not a condition for achieving satisfactory oncological results in terms of nodal upstaging and survival.

Conflict of interest: Dominique Gossot is a consultant for the instrument manufacturer (Delacroix Chevalier). All other authors declared no conflict of interest.

REFERENCES

[1] Scott W, Howington J, Feigenberg S, Movsas B, Pisters K. Treatment of non-small cell lung cancer stage I and stage II: ACCP evidence-based clinical practice guidelines (2nd edition). Chest 2007;132:234S–42S.

[2] Yan T, Black D, Bannon P, McCaughan B. Systematic review and meta-analysis of randomized and nonrandomized trials on safety and efficacy of video-assisted thoracic surgery lobectomy for early-stage non-small-cell lung cancer. J Clin Oncol 2009;27:2553–62.

[3] Howington J, Blum M, Chang A, Balekian A, Murthy S. Treatment of stage I and II non-small cell lung cancer: diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest 2013;143:e278S–313S.

[4] D'Amico TA. VATS lobectomy facilitates the delivery of adjuvant docetaxel-carboplatin chemotherapy in patients with non-small cell lung cancer. J Thorac Dis 2016;8:296–7.

[5] Park H, Detterbeck F, Boffa D, Kim A. Impact of hospital volume of thoracoscopic lobectomy on primary lung cancer outcomes. Ann Thorac Surg 2012;93:372–9.

[6] Paul S, Sedrakyan A, Chiu Y-L, Nasar A, Port JL, Lee PC *et al*. Outcomes after lobectomy using thoracoscopy vs thoracotomy: a comparative effectiveness analysis utilizing the Nationwide Inpatient Sample database. Eur J Cardiothor Surg 2013;43:813–17.

[7] Decaluwe H, Petersen RH, Hansen H, Piwkowski C, Augustin F, Brunelli A *et al*. Major intraoperative complications during video-assisted thoracoscopic anatomical lung resections: an intention-to-treat analysis. Eur J Cardiothorac Surg 2015;48:588–98.

[8] Fournel L, Zaimi R, Grigoroiu M, Stern JB, Gossot D. Totally thoracoscopic major pulmonary resections: an analysis of perioperative complications. Ann Thorac Surg 2014;97:419–24.

[9] Taioli E, Lee D, Lesser M, Flores R. Long-term survival in video-assisted thoracoscopic lobectomy vs open lobectomy in lung-cancer patients: a meta-analysis. Eur J Cardiothorac Surg 2013;44:591–7.

[10] Okada M, Sakamoto T, Yuki T, Mimura T, Miyoshi K, Tsubota N. Hybrid surgical approach of video-assisted minithoracotomy for lung cancer: significance of direct visualization on quality of surgery. Chest 2005;128:2696–701.

[11] Gossot D, Ramos R, Brian E, Raynaud C, Girard P, Strauss C. A totally thoracoscopic approach for pulmonary anatomic segmentectomies. Interact CardioVasc Thorac Surg 2011;12:529–32.

[12] Ramos R, Girard P, Masuet C, Validire P, Gossot D. Mediastinal lymph node dissection in early-stage non-small cell lung carcinoma: totally thoracoscopic vs thoracotomy. Eur J Cardiothorac Surg 2012;41:1342–8.

[13] Richards J, Dunning J, Oparka J, Carnochan F, Walker W. Video-assisted thoracoscopic lobectomy: the Edinburg posterior approach. Ann Cardiothoracic Surg 2012;1:61–9.

[14] Treasure T. Videothoracoscopic resection for lung cancer: moving towards a "standard of care". J Thorac Dis 2016;8:E772–4.

[15] Gossot D, Lutz JA, Grigoroiu M, Brian E, Seguin-Givelet A. Unplanned procedures during thoracoscopic segmentectomies. Ann Thorac Surg 2017;104:1710–17.

[16] Rami-Porta R, Wittekind C, Goldstraw P. Complete resection in lung cancer surgery: proposed definition. Lung Cancer 2005;49:25–33.

[17] Paul S, Isaacs A, Treasure T, Altorki N, Sedrakyan A. Long term survival with thoracoscopic versus open lobectomy: propensity matched comparative analysis using SEER-Medicare database. BMJ 2014;349:g5575.

[18] Falcoz P-E, Puyraveau M, Thomas P-A, Decaluwe H, Hürtgen M, Petersen RH *et al*. Video-assisted thoracoscopic surgery versus open lobectomy for primary non-small-cell lung cancer: a propensity-matched analysis of outcome from the European Society of Thoracic Surgeon database. Eur J Cardiothorac Surg 2016;49:602–9.

[19] Murakawa T, Ichinose J, Hino H, Kitano K, Konoeda C, Nakajima J. Long-term outcomes of open and video-assisted thoracoscopic lung lobectomy for the treatment of early stage non-small cell lung cancer are similar: a propensity-matched study. World J Surg 2015;39:1084–91.

[20] Nwogu C, D'Cunha J, Pang H, Gu L, Wang X, Richards W *et al*. VATS lobectomy has better perioperative outcomes than open lobectomy: CALGB 31001, an ancillary analysis of CALGB 140202 (Alliance). Ann Thorac Surg 2015;99:399–405.

[21] Samejima J, Mun M, Matsuura Y, Nakao M, Uehara H, Nakagawa K *et al*. Thoracoscopic anterior 'fissure first' technique for left lung cancer with an incomplete fissure. J Thorac Dis 2016;8:3105–11.

[22] Khullar O, Liu Y, Gillespie T, Higgins K, Ramalingam S, Lipscomb J *et al*. Survival after sublobar resection versus lobectomy for clinical stage IA lung cancer: an analysis from the National Cancer Data Base. J Thorac Oncol 2015;10:1625–33.

[23] Medbery R, Gillespie T, Liu Y, Nickleach D, Lipscomb J, Sancheti M *et al*. Nodal upstaging is more common with thoracotomy than with VATS during lobectomy for early-stage lung cancer: an analysis from the National Cancer Data Base. J Thorac Oncol 2016;11:222–33.

[24] Boffa D, Kosinski A, Paul S, Mitchell J, Onaitis M. Lymph node evaluation by open or video-assisted approaches in 11,500 anatomic lung cancer resections. Ann Thorac Surg 2012;94:347–53.

[25] Whitson BA, Groth SS, Andrade RS, Maddaus MA, Habermann EB, D'Cunha J. Survival after lobectomy versus segmentectomy for stage I non-small cell lung cancer: a population-based analysis. Ann Thorac Surg 2011;92:1943–50.

[26] Schuchert M, Abbas G, Awais O, Pennathur A, Nason K, Wilson D *et al*. Anatomic segmentectomy for the solitary pulmonary nodule and early-stage lung cancer. Ann Thorac Surg 2012;93:1780.

[27] Iwano S, Yokoi K, Taniguchi T, Kawaguchi K, Fukui T, Naganawa S. Planning of segmentectomy using three-dimensional computed tomography angiography with a virtual safety margin: technique and initial experience. Lung Cancer 2013;81:410–15.

[28] Wolf A, Richards W, Jaklitsch M, Gill R, Chirieac L, Colson Y *et al*. Lobectomy versus sublobar resection for small (2 cm or less) non-small cell lung cancers. Ann Thorac Surg 2011;92:1819–23.

[29] Okada M, Mimae T, Tsutani Y, Nakayama H, Okumura S, Yoshimura M *et al*. Segmentectomy versus lobectomy for clinical stage IA lung adenocarcinoma. Ann Cardiothorac Surg 2014;3:153–9.

[30] Cao C, Chandrakumar D, Gupta S, Yan T, Tian D. Could less be more?—A systematic review and meta-analysis of sublobar resections versus lobectomy for non-small cell lung cancer according to patient selection. Lung Cancer 2015;89:121–32.

[31] Yang HX, Woo KM, Sima CS, Bains MS, Adusumilli PS, Huang J *et al*. Long-term Survival Based on the Surgical Approach to Lobectomy For Clinical Stage I Nonsmall Cell Lung Cancer: Comparison of Robotic, Video-assisted Thoracic Surgery, and Thoracotomy Lobectomy. Ann Surg 2017;265:431-37.

[32] Liu C, Li Z, Bai C, Wang L, Shi X, Song Y. Video-assisted thoracoscopic surgery and thoracotomy during lobectomy for clinical stage I non-small-cell lung cancer have equivalent oncological outcomes: a single-center experience of 212 consecutive resections. Oncology Letters 2015;9:1364-72.

[33] Lee PC, Nasar A, Port JL, Paul S, Stiles B, Chiu YL *et al*. Long-term survival after lobectomy for non-small cell lung cancer by video-assisted thoracic surgery versus thoracotomy. Ann Thorac Surg 2013;96:951-61.

[34] Kuritzky AM, Ryder BA, Ng Th. Long-term survival outcomes of Video-assisted Thoracic Surgery (VATS) lobectomy after transitioning from open lobectomy. Ann Surg Oncol 2013;20:2734-40.

[35] Port JL, Mirza FM, Lee PC, Paul S, Stiles BM, Altorki NK. Lobectomy in octogenarians with non-small cell lung cancer: ramifications of increasing life expectancy and the benefits of minimally invasive surgery. Ann Thorac Surg 2011;92:1951-57.

[36] Yamamoto K, Ohsumi A, Kojima F, Imanashi N, Matsuoka K, Ueda M *et al*. Long-term survival after video-assisted thoracic surgery lobectomy for primary lung cancer. Ann Thorac Surg 2010:89:353-9.

[37] Flores RM, Park BJ, Dycoco J, Aronova A, Hirth Y, Rizk NP *et al*. Lobectomy by video-assisted thoracic surgery (VATS) versus thoracotomy for lung cancer. J Thorac Cardiovasc Surg 2009;138:11-18.

[38] McKenna RJ, Houck W, Beeman Fuller C. Video-assisted thoracic surgery lobectomy: experience with 1,100 cases. Ann Thorac Surg 2006;81:421-6.