European Journal of Cardio-Thoracic Surgery 61 (2022) 533–542
doi:10.1093/ejcts/ezab430 Advance Access publication 13 October 2021

ORIGINAL ARTICLE

Cite this article as: Dell'Amore A, Lomangino I, Cannone G, Terzi S, Pangoni A, Lorenzoni G *et al.* Comparison of operative and postoperative characteristics and outcomes between thoracoscopic segmentectomy and lobectomy for non-small-cell lung cancer: a propensity score matching study from the Italian VATS Group Registry. Eur J Cardiothorac Surg 2022;61:533–42.

Comparison of operative and postoperative characteristics and outcomes between thoracoscopic segmentectomy and lobectomy for non-small-cell lung cancer: a propensity score matching study from the Italian VATS Group Registry

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Received 16 February 2021; received in revised form 10 August 2021; accepted 19 August 2021

Key question

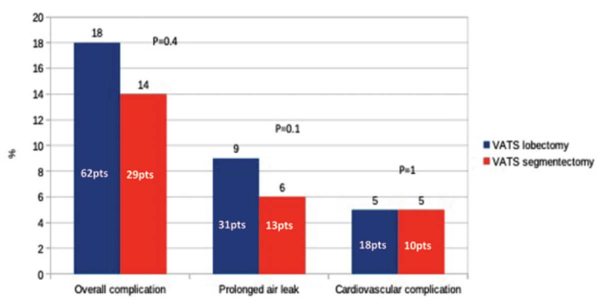
What is the postoperative outcome of VATS segmentectomies compared to that of corresponding VATS lobectomies ?

Key finding(s)

According to the Italian VATS group registry, VATS segmentectomies and lobectomies have similar postoperative outcomes.

Take-home message

A VATS segmentectomy could be a good alternative to a VATS lobectomy in selected patients with NSCLC.



Abstract

OBJECTIVES: Only few studies compared the surgical morbidity and mortality of thoracoscopic segmentectomy versus lobectomy for non-small-cell lung cancer, in particular, by relating the segmental resections with the corresponding anatomical lobes.

†The first two authors contributed equally to this work.
‡The list of collaborators of the Italian VATS Group is available in the Appendix.

THORACIC

METHODS: We enrolled a total of 7487 patients who underwent VATS lobectomy (7269) or segmentectomy (218) from January 2014 to July 2019. A propensity score matching approach was used to account for potential confounding factors between the 2 groups. After matching, 349 lobectomies and 208 segmentectomies were included in the analysis. We analysed the operative and postoperative outcomes of video-assisted anatomical segmentectomy compared with video-assisted lobectomy and, in details, the results of segmentectomy with its corresponding lobectomy in a large cohort of patients from the Italian VATS Group Registry.

RESULTS: The overall conversion rate to thoracotomy was not statistically different between the groups (27 patients 8% vs 7 patients 3%, $P = 0.1$). The lobectomy group had a greater number of resected lymph nodes (median 11 vs 8, $P = 0.006$). No significant differences were detected in 30-day mortality (1.4%, 5 patients vs 0.9%, 2 patients), overall complications (18%, 62 patients vs 14%, 29 patients) and prolonged air leakage (31 patients, 9% vs 12 patients, 6%) between lobectomy and segmentectomy, respectively. No statistical differences were found regarding the median duration of drainage (3.2 days, $P = 1$) and the overall median length of hospital stay (6.4 days, $P = 0.1$) between the 2 groups. In the context of segmentectomy versus corresponding lobectomy, the right upper lobectomy compared with right upper segmentectomy showed a higher number of resected lymph nodes ($P = 0.027$). No statistical differences were reported in terms of conversion rate and postoperative complication and mortality.

CONCLUSIONS: Segmentectomy could be considered a safe procedure without significant differences compared to thoracoscopic lobectomy in terms of postoperative morbidity and mortality.

Keywords: Video-assisted thoracic surgery • Segmentectomy • Lobectomy • Postoperative outcome • Non-small-cell lung cancer

ABBREVIATIONS

IQR	Interquartile range
NSCLC	Non-small-cell lung cancer
PSM	Propensity score matching

INTRODUCTION

Since 2000, many studies have been published, including randomized ones, which have demonstrated that anatomical segmentectomy for early-stage non-small-cell lung cancer (NSCLC) yields oncological equivalent results with respect to those of lobectomy, with a potential lung-sparing effect [1–4]. Nowadays, this scientific demonstration is very important because NSCLC is even more frequently diagnosed in the early stages, thanks to the ongoing screening programs [1, 4]. In the light of these results, the number of segmental resections has been progressively increasing over the years and, while in the past it was an intervention reserved for patients with poor respiratory reserve, the elderly, and those with multiple comorbidities, nowadays it has become an oncological indication, in particular in the treatment of early-stage NSCLC.

However, video-assisted anatomical segmentectomy requires a more extensive and complex dissection into the hilar structures with challenging identification of the intersegmental plane, which may lead to a potentially higher rate of complications, even for more experienced surgeons [5, 6]. To date, only few studies have compared the surgical outcomes after thoracoscopic segmentectomy and thoracoscopic lobectomy [6–9]. The aim of our study is to analyse, after a propensity score matching (PSM), the operative and postoperative outcomes of anatomical VATS segmentectomy compared with VATS lobectomy and weight the effect of segmentectomy versus its corresponding lobectomy, in a large cohort of patients from the Italian VATS Group Registry.

MATERIALS AND METHODS

Ethical statement

The Italian VATS Group Registry is an online voluntary database launched in January 2014. This database is open to all Italian thoracic surgery units after approval from the Italian VATS Group Committee. This study was submitted to the Italian VATS Group Committee for approval and participating patients asked to sign a written consent; patients and data from different centres were anonymized. Before the study was approved by the Institutional Review Board of University Hospital of Padua (no: PD19-27-034cht).

The data set contained clinical records from patients who received a VATS lobectomy or a segmentectomy between January 2014 and July 2019.

After induction therapy, patients with a tumour other than an NSCLC, or those who underwent a bi-lobectomy or sleeve lobectomy were excluded from the study. All the patients performed a complete oncological staging with positron emission tomography, computed tomography scan and a preoperative functional study with a spirometry. Surgical procedures were performed under general anaesthesia with a double-lumen endotracheal tube. A segmental resection was indicated in the case of early-stage lung cancer with tumour size ≤2 cm or, in patients with a functional respiratory deficit. The segmentectomy consisted in the anatomical resection of the lung parenchyma according to the intersegmental planes, together with the isolation and section of the vascular structures and of the segmental bronchus, by means of mechanical staplers. The intersegmental or interlobar planes were sectioned with staplers; both these procedures were followed by systematic hilar and mediastinal lymph node dissection. Conversion to thoracotomy was defined as the widening of the anterior access with a rib retractor. We evaluated the postoperative outcomes in terms of development of medical (cardiovascular, renal, respiratory) and surgical (prolonged air leak, empyema, haemothorax, chylothorax) complications among segmental resections and lobectomies; moreover, we compared the segment with the anatomical correspondent lobe.

Statistical analysis

Descriptive statistics were reported as median with interquartile range (IQR) for continuous variables and percentages for categorical variables.

A propensity score matching approach was employed to account for potential confounding factors related to the non-random allocation of the patients to the intervention groups. A separate propensity score matching procedure was performed to compare each segmentectomy with the corresponding lobectomy. Propensity scores were estimated using covariate balancing propensity scores algorithm [10] (Supplementary Material). A matching approach was employed using genetic algorithm with a 1:2 ratio, since it has been shown that a 1:*n* matching represents a reasonable way to improve estimates precision [11]. However, a 1:2 ratio has not been reached in the resulting matched sample since the genetic algorithm works by matching each case with one or more controls ensuring an optimization of the balance measure, i.e. the *P*-value of the covariate balance tests. The covariate balance was assessed using standardized mean differences, as recommended in literature [12, 13].

Postoperative outcomes distribution in the intervention groups was evaluated using Wilcoxon test for continuous variables and a simplified Monte Carlo significance test procedure (2000-replicates) [14] for categorical variables to account for cells with small counts (<5 observations). *P*-values of postoperative outcomes underwent Benjamini–Hochberg correction to control for the false discovery rate resulting from the multiplicity of testing.

Table 1: Resection distribution, lobes and corresponding segmentectomy

Lobectomy (349 patients)	Segmentectomy (208 patients)
130 (37%) left-sided lobectomy 75 (29%) left upper 55 (21%) left lower	130 (63%) left-sided segmentectomy 41 (20%) lingula 46 (22%) left upper segments 32 (15%) lower apical segment 11 (5%) basal pyramid
219 (63%) right-sided lobectomy 100 (34%) right upper 47 (16%) middle lobe 72 (24%) lower right	78 (37%) right-sided segmentectomy 24 (12%) right-upper segments 38 (18%) lower-apical segment 16 (8%) basal pyramid

The analyses were performed using R-software (3.6.1) with the packages covariate balancing propensity scores, MatchIt and rms.

Patient characteristics. The study included a total of 7487 patients who underwent VATS lung resection for NSCLC; among these, 7269 underwent lobectomy and 218 underwent an anatomical segmentectomy. After excluding all the patients with incomplete data (627 patients), the remaining were propensity matched to end up with a final cohort of 557 patients (349 lobectomies and 208 segments) (Table 1).

The population was subsequently divided into 7 subgroups according to the corresponding segment and lobe correlation (Table 2):

Group 1: upper left lobectomy (1578) versus lingulectomy (42), after PSM 113 patients (72 vs 41);
Group 2: upper left lobectomy (1578) versus left upper trisegmentectomy (52), after PSM 122 patients (76 vs 46);
Group 3: lower left lobectomy (1286) versus segment-6 (apical segment) LLL (32), after PSM 86 patients (54 versus 32);
Group 4: lower left lobectomy (1286) versus left basal pyramid (11), after PSM 31 patients (20 vs 11);
Group 5: upper right lobectomy (2397) versus S1/S2/S3 segmentectomy RUL (24), after PSM 64 patients (40 vs 24);
Group 6: lower right lobectomy (1381) versus segment-6 (apical segment) RLL (41), after PSM 104 patients (66 vs 38); and
Group 7: right lower lobectomy (1381) versus right basal pyramid (16), after PSM 48 patients (38 vs 16).

Preoperative population characteristics before PSM are reported as Supplementary Material. Patient characteristics, after the propensity score matching process, are summarized in Table 2. There were no significant differences in baseline data between

Table 2: Preoperative characteristics of the population after propensity score matching

Characteristics	VATS lobectomy (349 patients)	VATS segmentectomy (208 patients)	*P*-value
Gender			
Male	58 (201)	56 (117)	0.8
Female	42 (148)	44 (91)	
Age	70 (64–75)	70 (68–77)	0.4
Smoke			0.1
Active	27 (97)	23 (47)	
Former	29 (187)	31 (64)	
Chronic heart disease	9 (30)	10 (20)	0.5
Peripheral vascular disease	12 (43)	13 (27)	0.9
Cerebrovascular disease	5 (17)	6 (12)	0.7
Diabetes	15 (54)	14 (30)	0.8
Chronic renal failure	4 (13)	3 (7)	0.7
Connective tissue disease	3 (10)	3 (6)	1
Liver disease	1 (3)	1 (2)	1
COPD	25 (88)	24 (49)	0.8
FEV1%	94 (81–106)	95 (80–107)	0.9
FVC%	99 (89–111)	100 (88–112)	1
DLCO/VA%	84 (72–96)	82 (72–96)	0.6
Previous neoplastic disease	5 (17)	4 (8)	0.8

Data are percentages (absolute numbers) for categorical-variables and median (interquartile-range) for continuous-variables.
COPD: chronic obstructive pulmonary disease.

Table 3: Surgical morbidity of the 2 groups after propensity score matching

Variables	VATS lobectomy (349 patients)	VATS segmentectomy (208 patients)	*P*-value
Conversion rate	8 (27)	3 (7)	0.1
Cause for conversion			
Bleeding	41 (11)	42 (3)	
Adhesions	30 (8)	29 (2)	
Oncological reasons	26 (7)	29 (2)	
Not reported	4 (1)	–	
Rethoractomy for bleeding	1 (5)	–	1
Prolonged air leak (>7 days)	9 (31)	6 (12)	0.4
Pneumothorax	4 (14)	5 (10)	1
Cardiovascular complications	5 (18)	5 (10)	1
Atelectasis/sputum retention	3 (10)	3 (6)	1
Renal failure	1 (2)	–	0.7
Pneumonia	3 (9)	2 (4)	0.9
Empyema	3 (9)	2 (4)	0.9
Sepsis	1 (2)	1 (3)	0.8
ARDS	0.3 (1)	–	1
Pulmonary embolism	–	0.5 (1)	1
Prolonged ICU stay (>48 h)	4 (13)	3 (7)	0.2
Tracheostomy	1 (2)	–	0.7
Pleural effusion	6 (22)	7 (15)	0.6
Early readmission for pleural space complications	3 (11)	4 (8)	0.8

Data are percentages (absolute numbers). *P*-values were adjusted according to the Benjamini–Hochberg procedure.

the 2 general groups or between the detailed subgroups (Supplementary Material, Table S1). Covariate balance was evaluated using standardized mean differences and was satisfying (Supplementary Material).

In the overall analysis of the 2 groups, the median age of patients at the time of surgery was 70 ± 23 years (IQR 64–75). The comorbidities investigated after PSM (acute myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, chronic obstructive pulmonary disease, connective tissue disease, diabetes, chronic kidney disease, liver disease) were not significant between the groups. There were also no differences in terms of preoperative respiratory functional status (FEV1, FVC and DLCO).

RESULTS

Postoperative outcomes

Lobectomy versus segmentectomy. The overall conversion rate to thoracotomy was higher in the lobectomy group (9% vs 3%, $P = 0.014$) before performing PSM (Supplementary Material, Table S2). After PSM, the overall conversion rate was 6% without differences between groups (8% VATS lobectomy vs 3% VATS segmentectomy, $P = 0.1$). A greater number of resected lymph nodes was found after lobectomy, with a median of 11 lymph nodes (IQR 7–15) versus a median of 8 lymph nodes (IQR 6–12) in the case of segmentectomy ($P = 0.006$). There were no differences between lobectomy and segmentectomy in terms of operative time (151 ± 17.9 vs 176 ± 22.1 min, $P = 0.056$). The 30-day mortality was 1.4% (5/349) in the lobectomy group and 0.9% (2/208) in the segmentectomy group ($P = 0.3$). The 90-day mortality was 2% (7/349) and 1.4% (3/208) in the segmentectomy group ($P = 0.1$). The postoperative results are summarized in Table 3. A complete R0 resection was achieved in the 97% of the lobectomy group (337/12 patients) and 92% (192/16 patients) of the segmentectomy group ($P = 0.084$). Overall, 18% of patients (62 patients) experienced postoperative complications in the lobectomy group and 14% in the segmentectomy group (29 patients) ($P = 0.4$). The most frequent postoperative complication was prolonged air-leak reported in 8% of all cases (43/557 patients) without differences between the groups (9% lobectomy vs 6% segmentectomy, $P = 0.4$). The cardiovascular complications, mainly represented by atrial fibrillation, were reported in 28 patients (5%) without differences between the groups ($P = 1$). Furthermore, the type of procedure was not associated with any specific medical or surgical complication such as atelectasis/sputum retention, pneumonia, reoperation for bleeding, ARDS and empyema. The median duration of drainage was 3.2 ± 2.6 days (IQR 2–5) without difference between groups ($P = 1$). The overall median length of hospital stay was 6.4 ± 3 days (IQR 4–8) without difference between lobectomy (7.2 ± 2 days) versus segmentectomy (6.6 ± 3 days) ($P = 0.1$). Overall operative mortality was 1% (6/557 patients). The causes of death were: 1 acute respiratory distress syndrome; 2 pneumonia with sepsis; 2 acute myocardial infarction; and 1 pulmonary embolism. Operative mortality was not significantly higher in the lobectomy group (1.2% vs 0.9%, $P = 0.3$). The pathological T-value was higher in the lobectomy group ($P = 0.006$), evidently due to the different surgical indications. This was also reflected in a higher TNM 8th stage in the lobectomy group ($P = 0.01$), whereas no statistical difference was reported in terms of pN-disease between the groups (Table 4).

Segmentectomy versus corresponding lobectomy. Tables 5 and 6 summarize the results between segmentectomy and the corresponding lobectomy. The postoperative outcomes were not significantly different between the lobectomy and the corresponding segmentectomy after PSM. In particular, we found no differences between lobectomy group and the corresponding segmentectomy group in terms of conversion rate, cardiovascular

Table 4: Oncological and staging data of the population after propensity score matching

Characteristics	VATS lobectomy (349 patients)	VATS segmentectomy (208 patients)	*P*-value
pT-value			
Tis-T1	33 (116)	73 (151)	0.006
T2	47 (163)	24 (50)	
T3	20 (70)	3 (7)	
pN-value			
N0	82 (285)	93 (193)	0.06
N1	12 (41)	5 (10)	
N2	6 (23)	2 (5)	
TNM stage 8th			0.01
Stage IA1	7 (26)	16 (34)	
IA2	10 (36)	30 (63)	
IA3	28 (96)	21 (44)	
IB	23 (79)	15 (32)	
Stage IIa	14 (49)	10 (20)	
IIb	11 (37)	4 (9)	
Stage IIIa	6 (22)	2 (5)	
IIIb	1 (4)		
Histology			
Squamous	22 (77)	10 (21)	0.08
Adenocarcinoma	63 (220)	82 (170)	
Others	15 (52)	8 (17)	

Data are percentages (absolute numbers).

or respiratory complications; also, the incidence of prolonged air-leak was not statistically different. These results were consistent with the analysis performed before PSM (Supplementary Material, Table S3). Before PSM, the patients who underwent a left lobar resection compared to the corresponding segmentectomy and those who underwent a right upper lobectomy compared to the right apical segmentectomies showed a significantly higher number of resected lymph nodes. On the other hand, right lower lobectomy, when compared with the corresponding segmentectomy (right S6 or basal segments), showed no difference in terms of the number of resected lymph nodes.

After PSM, when comparing the upper right lobectomy with the segmentectomy of the apical segments (S1/S2/S3 or a combination of them), we found a higher number of resected lymph nodes after lobectomy, with a median of 11.5 versus 8, respectively ($P = 0.027$). In all the other groups, there were no differences in terms of the number of resected lymph nodes between a lobectomy and the corresponding segmentectomy. In group-6 (right lower lobectomy versus right S6), a statistical difference was found in the pT-value ($P < 0.05$). Almost all the right S6 were pTis/T1 (92%), which is the highest percentage in all segments (Table 7).

DISCUSSION

In recent years, the number of patients undergoing anatomic segmentectomies has constantly increased, not only in older patients with poor lung function, but also for oncological reasons, in particular for early-stage NSCLC [1, 4, 15–17]. We performed this study to investigate the postoperative outcomes of VATS segmentectomy compared to VATS lobectomy. The analysis of our cohort showed that the main indication for segmentectomy was tumour stage. Indeed, there were more early-stage NSCLC stages in the segmentectomy group even after PSM ($P < 0.01$). Regarding the age, some studies have suggested that lobectomy should be proposed to younger patients, with respect to segmentectomy that should be offered to older ones, due to the better perioperative outcomes in the latter category, without sacrificing the long-term oncological result [15, 18, 19]. In our study, we report that the age of the patient at the date of the intervention was similar in the 2 groups; thus, the patient's age may not be decisive in the choice of the surgical procedure [20]. We obtained similar results for preoperative morbidity profiles that were similar between the groups even before PSM and that may have little influence on the choice of the surgical strategy in our country.

Although segmentectomy leads to minor parenchymal sacrifice, this surgical procedure is more complex and requires both greater technical skills and surgical expertise than lobectomy, in particular when performed by VATS [5, 6, 21]. In the literature, the reported mortality for lobectomy operation ranges from 1.4% to 5.4%; similarly, morbidity ranges between 27% and 44% [1, 3, 4, 6, 9, 22]. No significant differences were detected for morbidity and mortality between segmentectomy and lobectomy in most reported series: operative mortality ranges between 1.7% and 7.7% and morbidity between 18% and 31% [1, 3, 4, 7, 15]. Shapiro *et al.* [16] reported similar complication rates between thoracoscopic segmentectomy and lobectomy (26% vs 27% respectively) also; the median chest tube duration and hospital stay were not statistically different. Zhong *et al.* [23], when comparing thoracoscopic lobectomy with segmentectomy, reported a comparable postoperative outcome with only a slightly longer operating time in the case of thoracoscopic segmentectomy (2.6 vs 2.4 h). Zhao *et al.* [2] demonstrated also that thoracoscopic segmentectomy is as safe and as effective as thoracoscopic lobectomy because the intraoperative and postoperative complication rates between groups were not different. Bedat *et al.* [6] focused their work on perioperative complications and reported that the risk of complication was not different between

Table 5: Left side operations, postoperative results comparing lobes with their anatomical corresponding segments (after propensity score matching)

Variables	VATS lobectomy	VATS segmentectomy	*P*-value
Left upper lobe (72 patients) versus lingula (41 patients)			
Total number of resected lymph nodes	11 (6–14)	8 (6–11)	0.2
Conversion rate	3 (2)		1
Re-thoractomy for bleeding	1 (1)		1
Prolonged air leak (>7 days)	3 (2)	2 (1)	1
Pneumothorax	3 (9)	2 (4)	0.9
Cardiovascular complications	8 (6)	2 (1)	0.2
Atelectasis/sputum retention	1 (1)		1
Pneumonia	3 (2)	2 (1)	1
Early readmission for pleural space complications	1 (1)	2 (1)	1
Left upper lobe (76 patients) versus left upper trisegmentectomy (46 patients)			
Total number of resected lymph nodes	10 (6–14)	9 (6–13)	0.8
Conversion rate	11 (8)	2 (1)	0.5
Re-thoractomy for bleeding	1 (1)	–	1
Prolonged air leak (>7 days)	11 (8)	15 (7)	0.5
Pneumothorax	1 (1)	–	1
Cardiovascular complications	12 (9)	13 (6)	1
Atelectasis/sputum retention	1 (1)	7 (3)	0.5
Pneumonia	4 (3)	2 (1)	0.7
Early readmission for pleural space complications	3 (2)	2 (1)	0.8
Left lower lobe (54 patients) versus left apical segment (S6) (32 patients)			
Total number of resected lymph nodes	9 (7–14)	6 (5–11)	0.2
Conversion rate	13 (7)	3 (1)	0.6
Re-thoractomy for bleeding	2 (1)	–	1
Prolonged air leak (>7 days)	6 (3)	3 (1)	0.7
Pneumothorax	2 (1)	3 (1)	0.8
Cardiovascular complications	9 (5)		0.1
Atelectasis/sputum retention	2 (1)		1
Pneumonia	4 (2)		0.9
Early readmission for pleural space complications	4 (2)	6 (2)	0.8
Left lower lobe (20 patients) versus left basal segments (11 patients)			
Total number of resected lymph nodes	12 (7–15)	9 (5–11)	0.4
Conversion rate	15 (3)		0.7
Re-thoractomy for bleeding	5 (1)		1
Prolonged air leak (>7 days)	10 (2)		1
Pneumothorax	5 (1)	9 (1)	0.7
Cardiovascular complications			–
Atelectasis/sputum retention		9 (1)	0.4
Pneumonia	5 (1)		1
Early readmission for pleural space complications	5 (1)	9 (1)	0.7

Data are percentages (absolute numbers) for categorical variables and median (interquartile range) for continuous variables. *P*-values were adjusted according to the Benjamini–Hochberg procedure.

VATS lobectomy and segmentectomy, with the same conversion rate but both drainage duration and length of hospital stay were shorter in the segmentectomy group. Recently, the analysis from the European Society of Thoracic Surgery database showed a lower complication rate and similar short-term outcomes in the segmentectomy group and that segmentectomy was preferably offered to compromised patients [24]. On the other hand, Deng *et al.* [8] reported a higher rate of postoperative complications in the VATS segmentectomy group versus the VATS lobectomy group (74% vs 69% respectively). This wide range of perioperative results is probably related to the marked differences in patients and tumour-related factors as well as to differentiations in surgical expertise, techniques and in-hospital volume [1–8].

In our work, we performed a PSM to remove all the confounding factors related to different preoperative and intraoperative variables that could influence postoperative morbidity and mortality, regardless of the surgical technique. Looking into the VATS Group Registry, we did not find any significant differences in the intraoperative and postoperative outcomes between VATS lobectomy and VATS segmentectomy. More precisely, complications such as conversion rate, reoperation for bleeding, prolonged air-leak, cardiovascular, respiratory and renal complications were not statistically different between groups. Conversion rate was 8% in the case of VATS lobectomy and 7% in that of VATS segmentectomy and in both cases was mainly related to bleeding events or adhesions. As reported in some studies [5, 6, 8], the incidence of prolonged air leakage appears to be higher in patients undergoing a segmentectomy; this result was not confirmed in our study, where there does not seem to be any difference between the 2 groups. This can be seen in chest tube duration and discharge times that were not significantly different between the 2 groups. To better understand the influence of the technical aspect on postoperative results, we divided and compared our study population into the different segments based on the corresponding anatomical lobe. Even after this more detailed analysis, we found no significant differences between segments and the

Table 6: Right side operations, postoperative results comparing lobes with their anatomical corresponding segments (after propensity score matching)

Variables	VATS lobectomy	VATS segmentectomy	*P*-value
Right upper lobe (40 patients) versus upper segmentectomy (S1/S2/S3 or a combination) (24 patients)			
Total number of resected lymph nodes	12 (8–16)	8 (6–9)	0.02
Conversion rate	5 (2)		0.8
Re-thoractomy for bleeding	2 (1)		1
Prolonged air leak (>7 days)	12 (5)	8 (2)	0.9
Pneumothorax	5 (2)		0.8
Cardiovascular complications	12 (5)	4 (1)	0.4
Atelectasis/sputum retention	5 (2)		0.8
Pneumonia	5 (2)		0.8
Early readmission for pleural space complications	5 (2)	4 (1)	1
Right lower lobe (66 patients) versus right apical segment (S6) (38 patients)			
Total number of resected lymph nodes	10 (7–14)	10 (6–16)	1
Conversion rate	8 (5)	11 (4)	0.9
Re-thoractomy for bleeding	2 (1)		1
Prolonged air leak (>7 days)	6 (4)	3 (1)	0.9
Pneumothorax	2 (1)	5 (1)	0.8
Cardiovascular complications	6 (4)		0.3
Atelectasis/sputum retention	2 (1)	5 (2)	0.8
Pneumonia	5 (3)		0.8
Early readmission for pleural space complications	5 (3)	5 (1)	1
Right lower lobe (32 patients) versus right basal segments (16 patients)			
Total number of resected lymph nodes	11 (9–15)	8 (7–13)	0.7
Conversion rate	9 (3)	6 (1)	1
Re-thoractomy for bleeding		6 (1)	0.8
Prolonged air leak (>7 days)	6 (2)		0.8
Pneumothorax			
Cardiovascular complications	3 (1)	12 (2)	0.6
Atelectasis/sputum retention	6 (2)		0.8
Pneumonia		12 (2)	0.8
Early readmission for pleural space complications	3 (1)	6 (1)	0.7

Data are percentages (absolute numbers) for categorical variables and median (interquartile range) for continuous variables. *P*-values were adjusted according to the Benjamini–Hochberg procedure.

corresponding lobectomy. One of the most perilous aspects of segmentectomy is to divide the intersegmental plane, which may increase the incidence of prolonged air-leaks rate [5, 6]. In our study, we found no differences in terms of PAL between segmental or lobar resection. It should also be noted that apical segmentectomy involving the right upper lung lobe, which requires the completion of 2 intersegmental planes, is not associated with an increased risk of postoperative complications when compared to upper right lobectomy.

Both 30- and 90-day mortalities were in the lower ranges as recently reported in the literature, with no statistical difference between VATS lobectomy or segmentectomy [1–4, 6, 17].

In our study, there were more lymph node dissections during a lobectomy ($P = 0.006$), but we found no difference in terms of the number of resected stations. This difference might be explained by the greater amplitude of parenchymal resection in lobectomy with, a consequently greater number of lymph nodes removed, en bloc, with the lobe. While mediastinal lymph node assessment is an important component of VATS lobectomy or segmentectomy, the advantage of complete mediastinal lymph node dissection, as opposed to systematic sampling, is still unclear. In the study by Altorki *et al.* [9], which compared anatomic segmentectomy to wedge resection in early-stage NSCLC, patients undergoing anatomic segmentectomy were more likely to have nodal sampling or dissection, which implies that more stations are sampled. Despite these differences, the oncological outcomes were similar in the 2 groups. Matsumura *et al.* [25] found that, reasonably, the extension of lymph node dissection for segmentectomy in an NSCLC of <2 cm should include hilar, mediastinal and lobar-segmental lymph nodes. Qu *et al.* [26] stressed, however, that patients with 6–10 lymph nodes examined will have the same prognosis as those with more than 10 lymph nodes, thus discouraging cut-off at 10. In our study, the average number of lymph nodes sampled was 8 for segmentectomy and 10.5 for lobectomy. Hwang *et al.* [18], after a PSM study comparing VATS segmentectomy to lobectomy, reported a significantly higher number of dissected lymph nodes in the lobectomy group (24 vs 19 nodes) while they reported no difference in disease free survival and overall survival.

After PSM only the resection of the apical segments of the right upper lobe, when compared with the right upper lobectomy, showed statistical significance in terms of resected lymph nodes. We report that, in the case of a segmentectomy involving the upper lobes, lymphadenectomy is performed with a total number of lymph nodes lower than the reference lobectomy. This could be one result of the greater difficulty of dissection in the upper lobes near the segmental branches of the artery. Furthermore, while it is possible to achieve an adequate lymph node dissection with segmentectomy, which is comparable to the one achieved after a lobectomy, the experience of the surgeon and technical ability does play an important role, especially in the VATS setting.

Table 7: Perioperative outcome after propensity score matching for each lung segment

	pT-value	VATS lobectomy	VATS segmentectomy	*P*-value
Left upper lobe (72 patients) versus lingula (41 patients)	Tis	6 (4)	7 (3)	
	T1	60 (43)	56 (23)	1
	T2	28 (20)	32 (13)	
	T3	7 (5)	5 (2)	
Left upper lobe (76 patients) versus Culmen (46 patients)	Tis	8 (6)	13 (6)	
	T1	58 (44)	50 (23)	1
	T2	30 (22)	33 (15)	
	T3	5 (4)	4 (2)	
Left lower lobe (54 patients) versus left S6 (32 patients)	Tis	6 (3)	13 (4)	
	T1	61 (33)	66 (21)	0.5
	T2	28 (15)	22 (7)	
	T3	6 (3)	–	
Left lower lobe (20 patients) versus left basal pyramid (11 patients)	Tis	10 (2)	18 (2)	
	T1	45 (9)	73 (8)	0.4
	T2	30 (6)	–	
	T3	15 (3)	9 (1)	
Right upper lobe (40 patients) versus right upper segments (24 patients)	Tis	13 (5)	17 (4)	
	T1	58 (23)	58 (14)	1
	T2	25 (10)	25 (6)	
	T3	5 (2)	–	
Right lower lobe (66 patients) versus right S6 (38 patients)	Tis	8 (5)	18 (7)	
	T1	44 (29)	74 (28)	0.05
	T2	26 (17)	8 (3)	
	T3	23 (15)	–	
Right lower lobe (32 patients) versus right basal pyramid (16 patients)	Tis	6 (2)	6 (1)	
	T1	41 (13)	44 (7)	0.8
	T2	41 (13)	38 (6)	
	T3	12 (4)	13 (2)	

Data are percentages (absolute numbers).

Limitations

This study presents several limitations; the number of patients was low when certain types of VATS segmentectomies were considered. For this reason, those results must be taken with caution since the small sample affect estimates robustness and study results generalizability, so that larger studies should be done. In particular, the comparison between segmentectomy and the corresponding lobectomy further reduced the samples size diminishing the statistical power. The propensity score matching included patient demographics but not tumour characteristics; thus, the lobectomy group had in general more advanced tumours than the segmentectomy group. Tumour stage obviously could influence the complexity of surgical procedure and perioperative outcomes. In this case, no difference in perioperative results could means that lobectomy might have been superior to segmentectomy if the 2 groups were fully matched. Thus the results should be interpreted with great caution.

The Italian VATS Group is a voluntary database, consequently, our population, although highly representative, cannot be considered as true 'national'. Information bias, consisting of measurement errors and misclassifications, was possible and missing data was about 15% leading to a loss of statistical power. In particular, we loss data about the absolute number of resected lymph nodes. The surgeons' individual experience is not evaluable from the VATS Group database and the surgical volume and thus the learning curve for minimally invasive surgery is not homogeneous among the participating centres. The analysis of mortality is limited to in-hospital or 30- and 90-day mortality, and the exact cause of death cannot be determined thus we cannot report follow-up and mid- or long-term oncological results to comate segmentectomy to lobectomy. The VATS Group database does not contain a variable that precisely classify a segmentectomy as 'intentional' or 'compromised'; thus, the study may have had disease-related, patient-related and surgeon-related selection biases, which may have influenced the choice of the procedure.

CONCLUSION

The present study confirms that VATS segmentectomy is a safe procedure with an operative outcome similar to VATS lobectomy in term or morbidity and mortality. Obviously, VATS segmentectomy was performed in early-stage lung cancer and that could influence the perioperative results. In future, large randomized clinical trials, with uniform staging measures (e.g. T and N), complete operative and postoperative data are needed to confirm the findings of this study.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: none declared.

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Andrea Dell'Amore: Conceptualization; Investigation; Methodology; Project administration; Visualization; Writing—original draft; Writing—review & editing. **Ivan Lomangino:** Conceptualization; Investigation; Project administration; Validation; Writing—original draft; Writing—review & editing. **Giorgio Cannone:** Investigation; Resources; Writing—original draft. **Stefano Terzi:** Investigation; Project administration; Resources. **Alessandro Pangoni:** Resources; Writing—review & editing. **Giulia Lorenzoni:** Data curation; Formal analysis; Methodology; Software. **Samuele Nicotra:** Validation; Visualization. **Marco Schiavon:** Validation; Visualization. **Andrea Zuin:** Validation; Visualization. **Dario Gregori:** Data curation; Formal analysis; Methodology; Software; Validation. **Roberto Crisci:** Supervision. Carlo Curcio: Supervision. **Federico Rea:** Supervision; Visualization.

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European Journal of Cardio-Thoracic Surgery thanks the anonymous reviewer(s) for their contribution to the peer review process of this article.

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APPENDIX

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