Original Article

Thoracoscopic segmentectomy with simple routine bronchoscopic inflation for intersegmental plane identification: short and mid-term outcomes compared with lobectomy

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Background: The technical concepts of thoracoscopic segmentectomy are still evolving. In this study we present a simple bronchoscopy-based intersegmental demarcation technique with short- and mid-term outcomes compared between thoracoscopic segmentectomy and lobectomy.

Methods: All 105 consecutive patients with lung cancer intended to treat with video-assisted thoracoscopic surgery (VATS) segmentectomy were compared to 110 consecutive VATS lobectomies. Short- and mid-term outcome comparison included complications, length of hospital stay, pulmonary functions, and 3-year progression-free and overall survival. Mid-term outcomes were adjusted for age, sex, comorbidities, pulmonary functions, histology, stage and adjuvant treatment.

Results: Segmentectomy patients had more comorbidities (P=0.006), worse pulmonary functions (FEV1%, P=0.005; DLCO/va, P=0.011), poor exercise capacity (P=0.043) and were considered high-risk patients more often (41.9% *vs.* 25.5%, P=0.011). Major complication rates did not differ between the groups (P=0.718). Mean length of hospital stay decreased after segmentectomy (4.7 *vs.* 5.9 days, P=0.033). Following segmentectomy, FEV1% slightly improved (1.0%). After lobectomy, the mean decline of FEV1% was 8.1% (P<0.001). Respectively, in high-risk patients, 2.1% improvement and 9.9% decline (P=0.027) were observed. Overall mortality hazard after segmentectomy was similar to that for lobectomy (unadjusted HR 0.80, 95% CI: 0.45–1.44, adjusted HR 0.87, 95% CI: 0.43–1.76). When considering only stage I non-small cell lung cancer, 3-year overall survival after segmentectomy and lobectomy were 86.8% *vs.* 79.8% (P=0.412) and 3-year recurrence-free survival 93.0% *vs.* 89.7%, P=0.450.

Conclusions: Following segmentectomy, regardless of worse surgical candidates, hospital stay was shorter. Furthermore, preservation of lung function also in high-risk patients, was observed without compromising mid-term oncologic outcomes.

Keywords: Lung cancer; video-assisted thoracoscopic surgery (VATS); segmentectomy; lobectomy; surgical technique

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Introduction

Lung cancer is the leading cause of cancer-related mortality worldwide (1). For cure in the early stage of the disease, the best chance is offered by surgery (2). Lobectomy is recommended as the standard approach (3,4).

Segmentectomy is currently indicated in predominantly ground glass opacities and in solid tumors in high-risk patients (1,3). Apace with population aging and lung cancer screening programs, the number of such patients is increasing. Other potential indications are neuroendocrine, special cases such as bilateral or multifocal tumors or deeply located metastases. Although many propensity-matched evaluations suggest that anatomical segmentectomy is equivalent to lobectomy in solid tumors of a size less than 2 cm diameter, we are still waiting the results of prospective randomized studies (5,6).

The long-term benefits of video-assisted thoracoscopic surgery (VATS) segmentectomy over lobectomy in patients with poor lung function have not been firmly established (7). This may be due to the difference in the number of resected segments or due to those potential issues during VATS in venous drainage, arterial supply or intersegmental plane identification. For target segment identification several techniques including various inflation-deflation approaches or intravenous or intrabronchial indocyanine green injections have been developed (8,9). None of these have gained wide acceptance and there is room for a simple and reproduceable technique.

We describe a simple bronchoscopic inflation technique for target segment identification during VATS segmentectomy. Our aim was to compare the short- and mid-term outcomes between VATS segmentectomy and lobectomy after implementation of this new technique. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/jtd-20-656).

Methods

Design

All patients with primary lung cancer treated with VATS in Central Finland Central Hospital from September 1, 2012 to June 31, 2019 were included in the study. A further 29 consecutive VATS segmentectomies performed in Helsinki University Hospital by the same surgeon (ES) between November 2007 and May 2012 were included. The final study population consisted of patients with intention to treat with either VATS segmentectomy (n=105) or VATS lobectomy (n=110). The indication for VATS segmentectomy was an increased surgical risk in stage I non-small cell lung cancer (NSCLC) in 56 patients, carcinoid tumors in 15, a solid type NSCLC of a size smaller that 2 cm in 13 patients, a ground-glass opacity with maximum of 6 mm solid component in 11 patients and a special indication in 10 patients (bilateral tumors in 3, synchronous ipsilateral tumors in 2, synchronous other major surgery in 3, metachronous tumor in one and fissure-crossing tumor in one). Resected segments and number of patients are listed in *Table 1*. The two approaches were compared regarding baseline differences in patient risk profile, short-term outcomes including postoperative complications, length of hospital stay, and mid-term outcomes regarding recurrence-free and overall survival. Pre- and postoperative lung function was measured. A prospective surgical database was maintained throughout the study period confirmed from the hospital records, including information on cancer recurrence. Survival data was further confirmed from Statistics Finland. Median follow-up time in segmentectomy group was 27.1 (IQR, 13.9–55.8), in lobectomy group 27.1 (IQR, 15.9–46.5), and in respective groups including only stage I NSCLC (excluding neuroendocrine tumors) 33.2 (IQR, 14.4–54.5) and 33.8 (IQR, 16.7–54.4) months. In patients with neuroendocrine tumors, follow-up time was 20.5 (IQR, 10.0–79.0) months. The study was approved by the local hospital districts.

Surgical technique

This was an intent to treat analysis. Of 105 patients, the planned segmentectomy was converted in five patients: to VATS lobectomy due to inadequate marginals in one, to VATS wedge resection due to unstable hemodynamics in one, to open wedge resection due to dense adhesions in one, and to two open segmentectomies due to dense adhesions in one and bleeding in one patient.

Surgical planning was based on multidetector CT. Tumor location and the bronchial and vessel anatomy of the target segment were identified in CT. Bronchoscopic evaluation by the operating surgeon at the beginning of surgery confirmed the bronchial anatomy. One surgeon (ES) performed all operations using the posterior four-port approach using 2-D thoracoscopy up to May 2018 and 3-D optics (Aesculap, B.Braun, Melsungen, Germany) from there on. Segmental vessel branches and bronchus were isolated separately. The order of division of these structures

Table 1 Resected segments

Lung/lobe	No. of patients	Resected segments
Right lung		
Upper lobe	4	Apical
	1	Apical and posterior
	2	Posterior
	4	Anterior
Middle lobe	1	Lateral
	1	Medial
Lower lobe	15	Superior
	1	Lateral and posterior basal
	1	Posterior
	3	Basilar segment
Combination	1	Apical and superior
	1	Posterior and superior
Left lung		
Upper lobe	1	Apical
	22	Apicoposterior
	2	Posterior
	2	Anterior
	20	Upper division
	1	Lingular and anterior
	3	Lingular
	2	Lingular inferior
Lower lobe	10	Superior
	4	Posterior
	1	Lateral and posterior basal
	2	Basilar segment

depended on the target segment. Vessels were divided using either staplers, clips or Ligasure (Medtronic, Fridley, MN) as appropriate. The segmental bronchus was encircled by a vessel loop and bronchoscope Olympus, Tokyo, Japan) was brought to the isolated segmental bronchus and often further to a branch adjacent to the intersegmental plane. Next, O_2 inflow with 2 L/min controlled by a rotameter was connected to the suction valve of the bronchoscope. In this set-up, this valve controlled the inflow of oxygen. The controlled inflow of oxygen inflated the segment or at least the area of lung tissue adjacent to the intersegmental plane. After inflation the segmental bronchus was divided using a stapler. Lifting the distal bronchial stump enables central dissection along the intersegmental vein branches (*Figure 1A,B,C,D,E*). These centrally dissected intersegmental vein(s) and the inflation-deflation line guided the division of more peripheral parts of intersegmental border by stapler. Routine lymphadenectomy or at least sampling of segmental, lobar, hilar, and mediastinal lymph nodes was also carried during surgery. The resected segment(s) was removed from the chest cavity inside a specimen bag and palpated to confirm a minimum macroscopic margin of 2 cm at the collapsed lung tissue. No mesh or sealants were used to cover the intersegmental plane. At the end of surgery, a single chest tube was inserted and the lung was inflated under direct thoracoscopic vision to reveal the likelihood of any kinking of the remaining segments. During the closing of the port site, the anesthetist reported the extent of respiratory air leak. A leak of less than 100 mL per a single breath was accepted and the chest tube was connected to a suction of −10 cmH_2O.

Definitions

The 8th edition of TNM classification was used in staging. The Charlson comorbidity index and ASA-grade were used in risk assessment. High-risk patients were defined with at least one of the following: age ≥80 years, FEV1 ≤50%, DLCO ≤50%, Charlson comorbidity index ≥5, maximal VO_2 10–12 mL/kg/min, or stair-climbing of only two flights of stairs (7.2 m). In the stair-climbing test, the measured maximum climb was four flights (14.4 m). The categorization of segmentectomy into technically simple or complex procedure was done according to a recent Japanese randomized study (6). In addition, the upper division of left upper lobe and basal segmentectomy was categorized as simple segmentectomy.

Statistical analysis

Kaplan-Meier survival curves were calculated according to the life table method to visualize the crude recurrence-free and overall survival up to 3 years after surgery. Multivariable Cox regression was used to calculate hazard ratios (HRs) with 95% confidence intervals (CIs) of recurrence and overall mortality. Lobectomy was used as the reference group. The regression models were adjusted for eight potential confounding factors: age (continuous), sex (male,

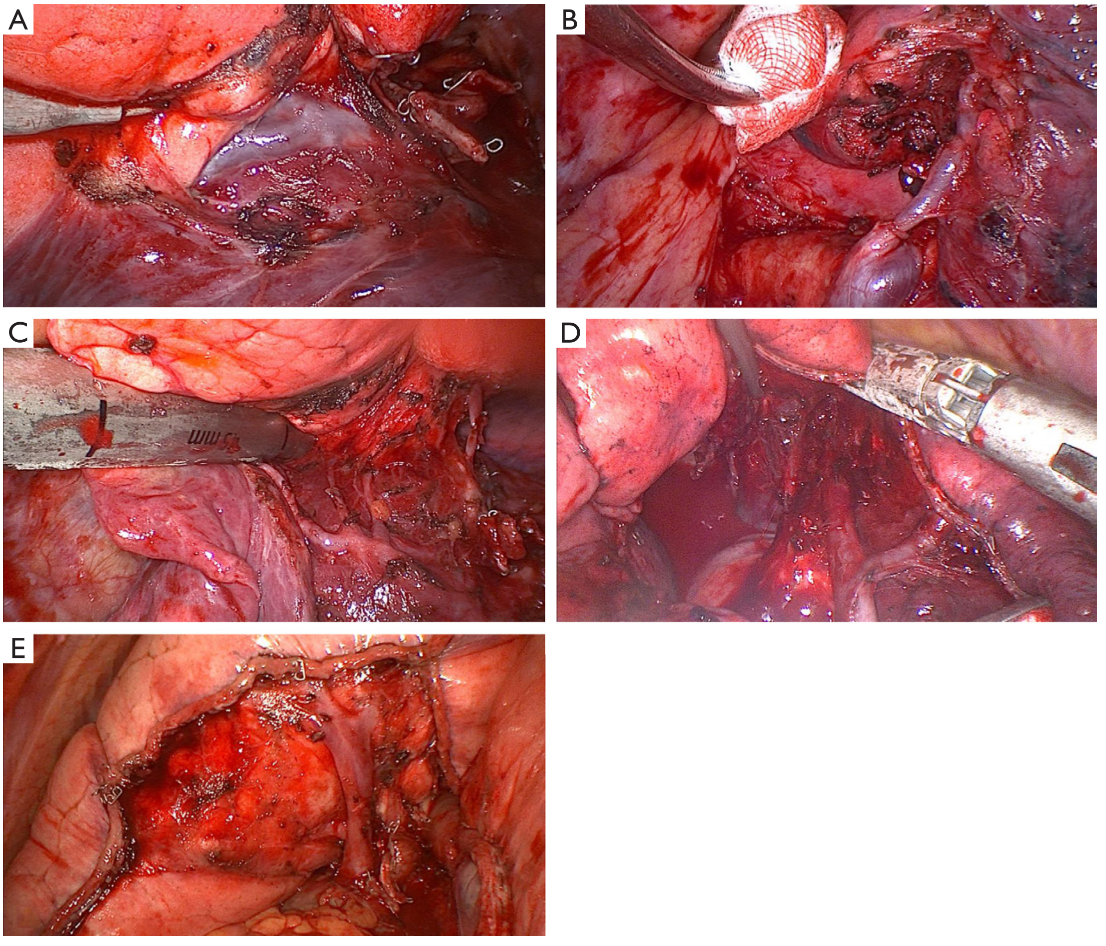

Figure 1 Anterior basal segment of RLL (S8) is inflated (A) and intersegmental dissection between anterior (S8) and lateral basal (S9) segments is started along intersegmental vein (V8b). After inflation of apicoposterior (S1+2) segment (B) dissection of intersegmental vein between apicoposterior and anterior (S3) segments is ongoing. After completion of intersegmental vein (V8b) dissection (C) peripheral intersegmental plane between anterior (S8) and lateral (S9) segments is stapled. Inflated posterior segment (S2) (D) is stapled along the intersegmental plane between posterior (S2) and anterior (S3) segments, where intersegmental vein between S2 and S3 runs anteriorly (V2c) and a centrally located combined vein (V1a+V2a) of intersegmental branch between posterior and apical segments (V2a) and branch to central areas of apical segment (V1a) runs apically. After lingulectomy (E), preserved vein between anterior and superior lingular segments (V3b) is visible and upper segments are well inflated regardless of partial stapling of the intersegmental plane.

female), Charlson comorbidity index (0–4, ≥5), FEV1 (0–50, >50), DLCO (0–50, >50), histological type (neuroendocrine, other), pathological stage (stage I, >stage I), and adjuvant treatment (yes/no). For patients receiving neoadjuvant treatment, clinical Stage was used instead of pathological Stage in the regression analysis. Comparison of proportions, mean, and median values of other measured variables was made with chi-square test, Mann-Whitney U-test and T-test as appropriate. All statistical analyses were conducted using IBM SPSS 25.0 (IBM corp., Armonk, NY, USA).

Results

Preoperative patient evaluation and risk profile

A total of 215 patients with intention to treat with either VATS segmentectomy (n=105) or VATS lobectomy (n=110) were included in the study. All patients underwent

Table 2 Pre- and postoperative lung functions

Lung functions	Segmentectomy (n=105)	Lobectomy (n=110)	P value	High-risk segmentectomy (n=44)	High-risk lobectomy (n=28)	P value
Preoperative, all patients						
FEV1%, mean (SD)	73.9 (19.5)	81.1 (17.6)	0.005	65.0 (18.7)	76.8 (21.3)	0.016
DLCO, mean (SD)	69.9 (23.5)	78.7 (25.3)	0.011	64.7 (22.8)	65.4 (30.8)	0.909
In patients with both pre- and postoperative values available	n=50	n=48		n=19	n=11	
Preoperative						
FEV1%, mean (SD)	72.2 (18.3)	78.7 (17.4)	0.076	60.3 (15.6)	71.2 (20.7)	0.114
Postoperative						
FEV1%, mean (SD)	73.2 (19.9)	70.6 (16.8)	0.485	62.4 (19.6)	61.3 (14.3)	0.867
Change in FEV1%, mean (SD)	+1.0 (9.8)	–8.1 (10.6)	<0.001	+2.1 (8.2)	–9.9 (14.8)	0.027

preoperative pulmonary function tests (*Table 2*) and physical evaluation including stair-climbing test (*Table 3*). Patients in the segmentectomy group had lower preoperative mean FEV1% and DLCO than the lobectomy group (*Table 2*). Patients in the segmentectomy group had more comorbidities, higher ASA grade, and performed worse on the stair climbing test (*Table 3*). In all, 41.9% of patients in the segmentectomy group were considered high-risk patients compared to 25.5% in the lobectomy group (P=0.011, *Table 3*). High-risk patients are also presented separately in the tables.

Staging

PET-CT was performed on 67.6% of patients in the segmentectomy and 76.4% in the lobectomy group (P=0.187), and invasive mediastinal staging in 14.3% and 23.6% respectively (P=0.127). Patients in the lobectomy group had generally larger tumors (median 1.8 *vs.* 3.1 cm, P<0.001) and also more advanced clinical stage (*Table 4*). There was no difference in the proportion of patients receiving neoadjuvant treatment (5.7% *vs.* 9.1%, P=0.356).

Segmentectomy indications

Of 105 segmentectomies, 56 (53%) underwent sublobar resection due to high age, comorbidities, poor exercise capacity or limited cardiopulmonary reserve (*Tables 2,3*). Fifteen patients (14.3%) had carcinoid tumors and 11 (10.5%) predominant ground glass opacities. Of 13 (12.4%) solid low-risk solid cancer patients, 12 had a tumor size smaller than 2 cm and one of a size of 3 cm at the optimal location. Ten patients were considered to have a special indication: four synchronous cancers, one metachronous cancer, two synchronous other solid cancers requiring surgery, one fissure-crossing tumor, one patient less than 2 months post contralateral thoracotomy due to empyema and bronchopleural fistula, and one was suspected of having a metastasis.

Outcomes

This was an intention-to-treat analysis. Lymph node yield in segmentectomy was lower than in the lobectomy group [median yield 8 (IQR: 5–11) *vs.* 13 (IQR: 9–18), P<0.001]. This was also observed when including high-risk patients only (*Table 4*). With a learning curve, the difference in lymph node yield decreased (*Figure 2*). Furthermore, the complexity of segmentectomy from the first half of the series to second half rose from 18.9% to 34.6% (P=0.010).

Pathological staging

In the segmentectomy group, final tumor histology was more often neuroendocrine tumor (14.3% *vs.* 2.7%, P=0.002). The lobectomy group had generally more

Table 3 Baseline characteristics

Variable	Segmentectomy (n=105)	Lobectomy (n=110)	P value	High-risk segmentectomy (n=44)	High-risk lobectomy (n=28)	P value
Age, years, median [IQR]	71 [64–77]	73 [66–77]	0.137	75 [67–80]	80 [73–83]	0.030
BMI, kg/m^2 (median, IQR)	24.4 (22.5–29.5)	25.4 (23.1–28.1)	0.747	24.3 (22.2–29.8)	23.3 (22.0–28.4)	0.625
Male, n (%)	54 (52)	74 (67.3)	0.037	27 (61.4)	16 (57.1)	0.722
Charlson comorbidity index			0.198			0.397
0	18 (17.1)	28 (25.5)		1 (2.3)	2 (7.1)	
1	31 (29.5)	36 (32.7)		18 (40.9)	11 (39.3)	
2	22 (21.0)	28 (25.5)		8 (18.2)	9 (32.1)	
3-4	22 (21)	13 (11.8)		9 (20.5)	1 (3.6)	
5 or higher	12 (11.4)	5 (4.5)		8 (18.2)	5 (17.9)	
CCI, mean (SD)	2.1 (1.9)	1.5 (1.4)	0.006	2.7 (2.2)	2.2 (1.9)	0.335
ASA status, n (%)			0.053			0.062
Grade I	4 (3.8)	5 (4.5)		0	1 (3.6)	
Grade II	41 (39.0)	64 (58.2)		16 (36.4)	18 (64.3)	
Grade III	53 (50.5)	38 (34.5)		23 (52.3)	7 (25.0)	
Grade IV	3 (2.9)	3 (2.7)		3 (6.8)	2 (7.1)	
Stair climbing test, median [IQR]	4 [3–4]	4 [3–4]	0.043	3 [2–4]	4 [2–4]	0.410
Percentage of patients climbing ≤2 flights	13.0%	7.1%	0.222	32.1%	27.3%	0.709
Percentage of patients climbing ≤3 flights	42.9%	28.6%	0.064	62.1%	50.0%	0.389
High-risk patient, n (%)[1]	44 (41.9)	28 (25.5)	0.011			

[1], high-risk patients (at least one of the following): age ≥80 years, FEV1 ≤50%, DLCO ≤50%, Charlson comorbidity index ≥5, maximal VO_2 10–12 mL/kg/min, or stair-climbing of only 2 flights (7.2 m).

advanced pathological stage (*Table 4*).

Short-term outcomes

Overall (29.5% *vs.* 32.7%, P=0.581) and major complication rates (8.6% *vs.* 10.0%, P=0.718) were similar between the segmentectomy and lobectomy groups. This was also observed in high-risk patients only (*Table 5*). No patients died during the first 30 postoperative days, and one high-risk patient in each group died within 90 days. Median hospital stay was 4 days in both groups (P=0.108). Mean stay was shorter in the segmentectomy group (4.7 *vs.* 5.9 days, P=0.029). The majority of patients were discharged home in both groups (86% *vs.* 84%, P=0.659), *Table 5*.

Mid-term outcomes

Overall 3-year survival in the segmentectomy and lobectomy groups was 86.0% *vs.* 71.7% (P=0.042, *Figure 3A*) and recurrence-free 3-year survival 92.4% *vs.* 76.3% (P=0.002, *Figure 3B*). All patients were alive after surgery for neuroendocrine tumors. When including only stage I NCSLC (excluding neuroendocrine tumors), 3-year overall survival rates were 86.8% *vs.* 79.8% (P=0.412, *Figure*

Table 4 Tumor characteristics in patients undergoing segmentectomy or lobectomy

Variable	Segmentectomy (n=105)	Lobectomy (n=110)	P value	High-risk segmentectomy (n=44)	High-risk lobectomy (n=28)	P value
Histology, n (%)			0.049			0.809
Adenocarcinoma	58 (55.2)	73 (66.4)		23 (52.3)	14 (50.0)	
Squamous cell cancer	26 (24.8)	32 (29.1)		17 (38.6)	13 (46.4)	
Other	21 (20.0)	5 (4.5)		4 (9.1)	1 (3.6)	
Tumor size cm, median (IQR)	1.8 (1.4–2.4)	3.1 (2.1–4.4)	<0.001	2.1 (1.5–3.2)	3.2 (2.1–4.5)	0.002
PET-CT, n (%)	71 (67.6)	84 (76.4)	0.187	33 (75.0)	21 (75.0)	1.000
Invasive staging, n (%)	15 (14.3)	26 (23.6)	0.127	8 (18.2)	11 (39.3)	0.048
Lymph node dissection			<0.001			0.001
No harvested lymph nodes	3 (2.9)	1 (0.9)		3 (6.8)	0	
N1	13 (12.4)	1 (0.9)		5 (11.4)	1 (3.6)	
Limited N2 sampling[1]	21 (20.0)	7 (6.4)		13 (29.5)	1 (3.6)	
Systematic N2 dissection	64 (61.0)	101 (91.8)		23 (52.3)	26 (92.9)	
Lymph node yield, median (IQR)	8 (5–11)	13 (9–18)	<0.001	6 (3–10)	12 (8–17)	<0.001
Oncological therapy						
Neoadjuvant	6 (5.7)	10 (9.1)	0.356	3 (6.8)	2 (7.1)	0.979
Adjuvant	10 (9.5)	22 (20.0)	0.031	6 (13.6)	5 (17.9)	0.627
Clinical stage, n (%)			<0.001			0.042
IA1	12 (11.4)	1 (0.9)		3 (6.8)	0	
IA2	38 (36.2)	17 (15.5)		13 (29.5)	1 (3.6)	
IA3	29 (27.6)	33 (30.0)		11 (25.0)	10 (35.7)	
IB	10 (9.5)	14 (12.7)		7 (15.9)	6 (21.4)	
IIA	1 (1.0)	9 (8.2)		1 (2.3)	2 (7.1)	
IIB	11 (10.5)	27 (24.5)		7 (15.9)	9 (32.1)	
IIIA	4 (3.8)	6 (5.5)		2 (4.5)		
IIIB		3 (2.7)				
Pathological stage, n (%)[2]			<0.001			0.057
0	1 (1.0)	1 (0.9)		0	0	
IA1	10 (9.5)	1 (0.9)		3 (6.8)	0	
IA2	48 (45.7)	18 (16.4)		16 (36.4)	2 (7.1)	
IA3	17 (16.2)	18 (16.4)		6 (13.6)	6 (21.4)	
IB	10 (9.5)	18 (16.4)		7 (15.9)	5 (17.9)	
IIA	3 (2.9)	16 (14.5)		3 (6.8)	4 (14.3)	
IIB	8 (7.6)	21 (19.1)		6 (13.6)	9 (32.1)	
IIIA	8 (7.6)	12 (10.9)		3 (6.8)	2 (7.1)	
IIIB		4 (3.6)				

[1], one or two N2 stations. [2], patients who underwent neoadjuvant therapy were classified by clinical stage.

3C) and 3-year recurrence-free survival 93.0% *vs.* 89.7% (P=0.450, *Figure 3D*). In high-risk patients, the respective overall survival rates were 69.1% and 62.9% (P=0.645) and recurrence-free survival 86.7% *vs.* 71.8% (P=0.132).

In adjusted analysis, HR for overall mortality was similar between segmentectomy and lobectomy (HR 0.89, 95% CI: 0.43–1.84). Recurrence risk in adjusted analysis was lower after segmentectomy (HR 0.26, 95% CI: 0.09–0.80, *Table 6*). Of 7 recurrences after segmentectomy, 3 were systemic, 2 mediastinal and one in separate ipsilateral lobe. One patient had synchronous recurrence in liver, mediastinum and in the resected lobe.

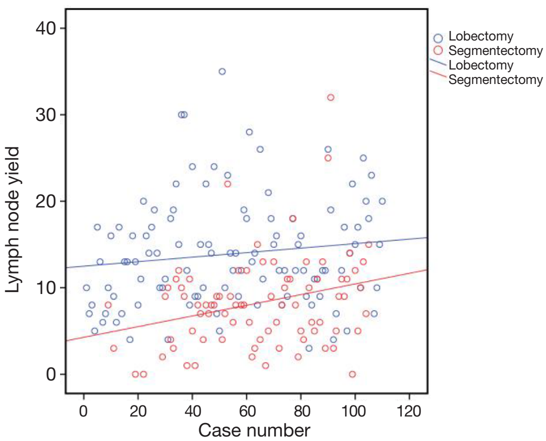

Figure 2 Scatterplot presenting changes in lymph node yield during the study period

Postoperative pulmonary function

Following segmentectomy, FEV1% improved by 1.0%, whereas after lobectomy FEV1% declined by a mean of 8.1% (P<0.001). In high-risk patients, respective changes in FEV1% were 2.1% improvement and 9.9% decline (P=0.027, *Figure 4*, *Table 2*).

Discussion

This study with a simple intersegmental plane identification technique shows shorter hospital stay in patients with more comorbidities, decreased preoperative pulmonary functions, and worse exercise capacity after VATS segmentectomy compared to better surgical candidates after VATS lobectomy. Furthermore, the preservation of lung function also in high-risk patients, was observed without any compromise in mid-term oncologic outcomes.

In comparison of short- and mid-term results after segmentectomy and lobectomy, varying surgical techniques and indications, differences in lymph node dissection and tumor margins cause problems even after matching. In this study, the main strengths were consistent indications and surgical technique as all patients in both groups were

Table 5 Outcomes after segmentectomy and lobectomy

Variable	Segmentectomy (n=105)	Lobectomy (n=110)	P value	High-risk segmentectomy (n=44)	High-risk lobectomy (n=28)	P value
Complications, n (%)						
Any type	31 (29.5)	36 (32.7)	0.581	16 (36.4)	14 (50.0)	0.253
Minor (CDC grade I–II)	23 (21.9)	27 (24.5)	0.647	11 (25.0)	9 (32.1)	0.509
Major (CDC grade IIIa–V)	9 (8.6)	11 (10.0)	0.718	6 (13.6)	5 (17.9)	0.627
Prolonged air leak	9 (8.6)	9 (8.2)	0.918	5 (11.4)	4 (14.3)	0.715
Hospital stay, mean (SD)	4.7 (2.5)	5.9 (4.9)	0.033	5.3 (2.8)	8.2 (7.8)	0.030
Hospital stay, median [IQR]	4 [3–5]	4 [3–6]	0.124	5 [3–7]	5 [4–11]	0.229
Discharged to			0.810			0.477
Home, n (%)	90 (85.7)	93 (84.5)		33 (75.0)	23 (82.1)	
Mortality, n (%)						
30-day	0	0		0	0	
90-day	1 (1.0)	1 (0.9)	0.974	1 (2.3)	1 (3.6)	0.744

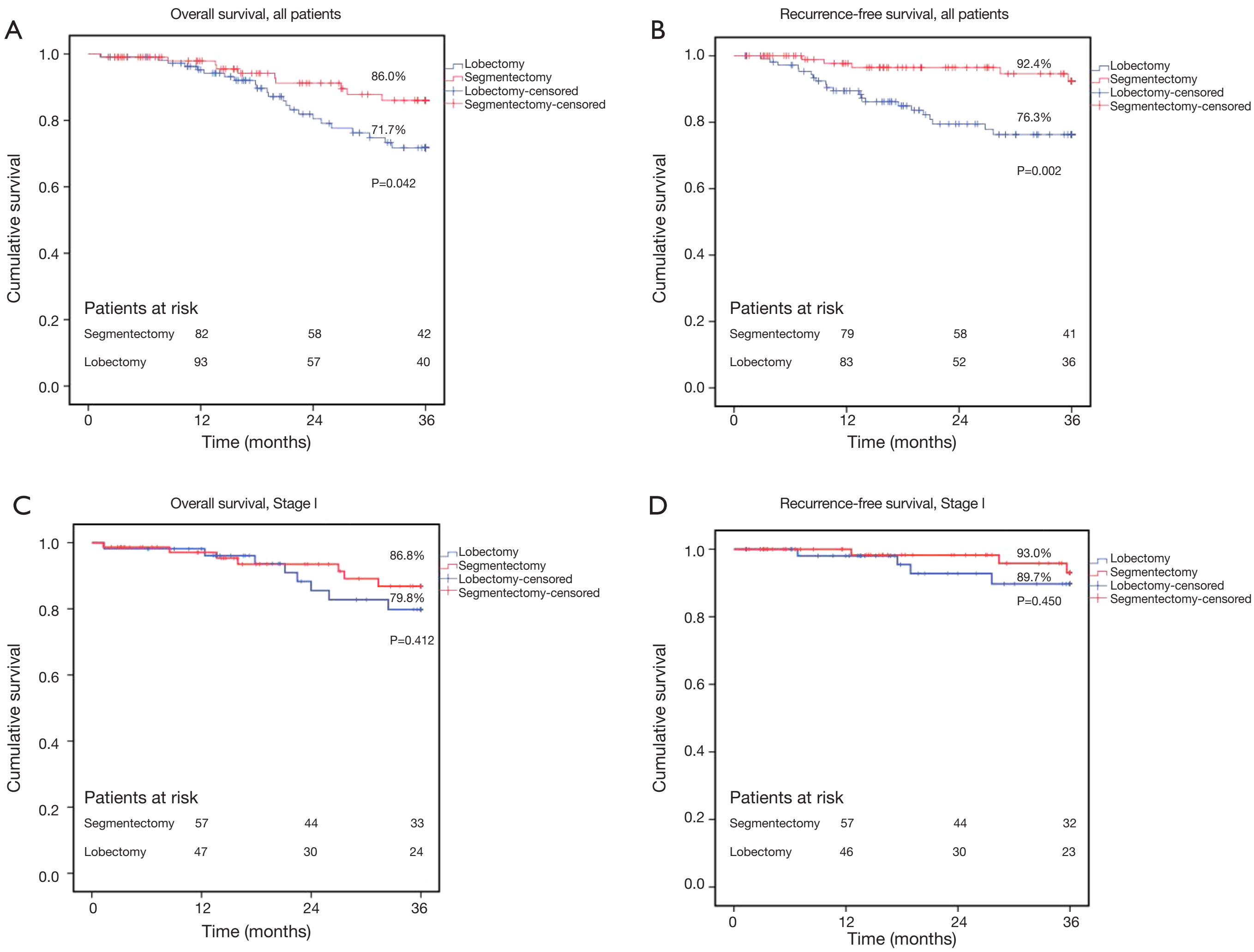

Figure 3 Kaplan-Meier survival curves. (A) Overall survival stratified by segmentectomy and lobectomy; (B) recurrence-free survival stratified by segmentectomy and lobectomy; (C) overall survival of stage I lung cancer (excluding neuroendocrine tumors) stratified by segmentectomy and lobectomy; (D) recurrence-free survival of stage I lung cancer (excluding neuroendocrine tumors) stratified by segmentectomy and lobectomy.

operated on by a single surgeon, and the results favored segmentectomy. Further strengths were prospective database with the possibility to confirm data from hospital records and complete follow-up information without any limitations of register-based data. With the limited sample size and multiple causes for increased surgical risk, the potential long-term benefits of segmentectomy in high-risk patients remain inconclusive. Thus, the main finding of this study concerns the short-term benefits with preservation of lung function without compromising oncologic outcome. Overall, the technique described still needs to be replicated in future studies.

Lobectomy has remained the gold standard for operable NSCLC in terms of long-term outcomes (3,4). Many single-center and register-based studies have recently reported segmentectomy as an alternative to lobectomy in solid tumors less than 2 cm in size with similar survival (10-14). Our similar mid-term results likewise support the use of segmentectomy for T1a and T1b solid tumors. In guidelines, segmentectomy is still mainly considered appropriate for pure or predominantly ground glass opacities and for solid tumors only in high-risk patients (1,3). In the high-risk patients in our study segmentectomy shortened hospital stay and preserved lung function, thereby

Table 6 Hazard ratios (HRs) with 95% confidence intervals (CI) of mortality and recurrence comparing segmentectomy and lobectomy (reference group) for lung cancer

Variable	Surgical approach		P value
	Lobectomy, HR (95% CI)	Segmentectomy, HR (95% CI)	
Overall mortality			
Crude	1 (reference)	0.80 (0.45–1.44)	0.459
Adjusted[1]	1 (reference)	0.87 (0.43–1.76)	0.701
Recurrence			
Crude	1 (reference)	0.25 (0.10–0.60)	0.002
Adjusted[1]	1 (reference)	0.25 (0.08–0.76)	0.015

[1], adjustment for age (continuous), sex (male, female), Charlson comorbidity index (0–4, ≥5), FEV1 (0–50, >50), DLCO (0–50, >50), histological type (neuroendocrine, other), pathological stage (stage I, >stage I) and adjuvant treatment (yes/no).

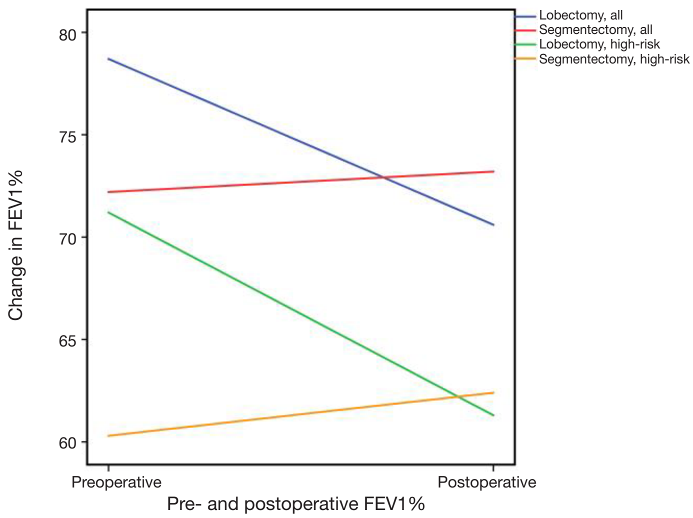

Figure 4 Pre- and postoperative FEV1% after segmentectomy and lobectomy (high-risk groups presented separately).

supporting the use of this technique. It seems plausible that the preservation of lung function also has beneficial long-term effects. Another major group undergoing segmentectomy in our study was carcinoid tumors. A recent study reported anatomical resection (lobectomy or segmentectomy) to be superior to wedge resection in Stage 1 neuroendocrine tumors (15,16). In our study, none of the patients operated on for neuroendocrine tumors died during 3-year follow-up after surgery, suggesting the possibility of routine use of segmentectomy in any technically suitable anatomical resection.

For good short-term and long-term outcomes and for the preservation of functional lung tissue, the important concepts are the preservation of venous drainage and arterial supply to the remaining segments, proper lymph node assessment and accurate determination of intersegmental planes. For this identification a number of techniques have been proposed, including intravenous or intrabronchial indocyanine green injections and inflation-deflation, but none has gained wide acceptance (8,9). This inflation technique, in principle, is very similar to bronchoscopic jet inflation with no need for special equipment. A rotameter is standard equipment in every operating room. The suction valve helps to control the inflation itself. In case of any over-inflation in an emphysematous lung, after closure of the target bronchus the open bronchial branches of the remaining segments deflate the intersegmental area. The inflation-deflation line and the central dissection along intersegmental veins provide landmarks for more peripheral stapling of intersegmental borders. The more central intersegmental raw surface does not seem to need any coverage with similar air-leak rates compared to lobectomy and well-preserved lung functions even in high-risk patients. With this simple technique in this study, more widespread use of VATS segmentectomies could be achieved. In fact, the rate of segmentectomy in a population-based setting has recently been as low as 3% (17) and in the STS and ESTS databases respectively 3.9% and 7.4% (18). Some have raised the issue of inadequate lymph node yield in VATS segmentectomy compared to lobectomy (19). Systematic lymph node dissection is also considered a standard approach in stage I NSCLC (3). In our study lymph node yield was lower after segmentectomy than after lobectomy, but is at least partly explained by the learning curve.

Although in several studies segmentectomy is preferable to lobectomy, the functional benefit of VATS segmentectomy over VATS lobectomy in patients with poor lung function has been questioned (7,20,21). In a recent review, a mean early loss of FEV1% within two months after lobectomy and segmentectomy were 25% and 18%, and after 12 months 11% and 5% respectively (7). In our study, after a medium of nine months postoperatively, changes in FEV1% after VATS segmentectomy and VATS lobectomy were +1% and −8.1%. In high-risk patients, the difference between segmentectomy and lobectomy was even higher. This can be considered a clear clinically significant advantage supporting the use of segmentectomy over lobectomy when appropriate, especially in high-risk patients. Because in real-world practice the causes of increased surgical risks are multi-factorial, as in this study, it will be difficult to evaluate the possibility to lower the functional limit of surgery with properly conducted segmentectomy.

In conclusion, in this study we present a simple bronchoscopic inflation technique for intersegmental plane identification. With this technique, an improvement in short-term outcomes compared to VATS lobectomy can be achieved with preservation of pulmonary function even in high-risk patients without compromising the oncological outcome. VATS segmentectomy is still rarely used over VATS lobectomy despite clear indications and advantages. With this new simple and reproducible technique, we aim at wider use of anatomical sublobar resections.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jtd-20-656). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved by the Hospital districts. Because of the retrospective nature of the study, patient informed consent or ethical statement was not required.

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