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CLINICAL STUDY

Uniportal thoracoscopic sublobar anatomical resections for small pulmonary nodules

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ABSTRACT
OBJECTIVES: The study aims to compare the thoracoscopic lobectomy and segmentectomy outcomes.
BACKGROUND: Lobectomy is considered the standard treatment method for operable non-small cell lung cancer. Recent studies have suggested that segmentectomy seems to be an acceptable alternative to lobectomy for surgical management of early-stage non-small cell lung cancer.
MATERIAL AND METHODS: This retrospective study included 475 patients who underwent thoracoscopic anatomical resection at the Thoracic Surgery Department at University Hospital Bratislava for malignant or benign pathology from October 2012 to December 2021. Thoracoscopic lobectomy was offered to 438 patients, and 37 were treated by thoracoscopic segmentectomy.
RESULTS: We recorded no difference between groups considering age and gender. The most common findings in the thoracoscopic lobectomy and segmentectomy groups were primary lung cancer (73.44 %) and pulmonary metastases (59.5 %). Thoracoscopic lobectomy was associated with longer operative time (80.00 vs 110.00 min; $p<0.001$) and postoperative hospital stay (3.00 vs 4.00 days; $p<0.001$). Both procedures were associated with a similar incidence of both intraoperative (0 % vs 4.8 %; $p=0.394$) and postoperative complications (16 % vs 23 %; $p=0.353$).
CONCLUSION: Thoracoscopic segmentectomy is a safe and effective procedure. This technique is a viable alternative to thoracoscopic lobectomy in indicated cases. It is still not accepted as a standard procedure for lung cancer, and we would like to start a discussion on this topic *(Tab. 5, Fig. 2, Ref. 20)*. Text in PDF *www.elis.sk*
KEY WORDS: lung cancer, metastasectomy, VATS lobectomy, VATS segmentectomy.

Introduction

Lobectomy is still the standard surgical treatment modality for lung cancer. Less extensive resections are reserved for patients with limited lung functions or other limiting factors when lobectomy is contraindicated for these reasons. The utilization of a more sensitive CT brought up an increased number of findings of small lung nodules, including ground-glass opacities (GGOs). Within that context, some randomized controlled trials, retrospective cohorts and meta-analytic studies proved that it was possible to achieve similar results with sublobar anatomical resections in patients with lobectomy in case of nodules smaller than two centimeters in diameter, especially with anatomical segmentectomy which is considered to be superior to the wedge resection (1, 2). However, based on recent assignments, the existing TNM classification for lung cancer will require revision. Recent studies show that the patient's prognosis with a tumor smaller than two centimeters is significantly better than in case of larger tumors. The importance of anatomic sublobar resections in lung cancer, along with the expansion of mini-invasive operation techniques, attracted a significant interest. Maintaining better lung function, less morbidity and mortality, and shorter hospital stay are factors in favor of this practice (3).

Sublobar resections

A removal of less than the lung lobe is considered to be a sublobar resection. It is possible to remove the targeted zone using a stapler without considering anatomical boundaries. This technique is called a wedge or atypical resection of the lung. However, we speak of segmentectomy if the lung parenchyma is removed within anatomical boundaries. The evolution of operation techniques makes it even possible to provide anatomical subsegmentectomies in indicated cases.

Most common indications for sublobar resections are CT findings of GGOs and pulmonary nodules when we cannot achieve histological verification or eventual removal of pathological lesions with curative intent.

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Sublobar resections are frequently indicated in cases of metastatic lung disease. In these cases, the resection is considered radical when we achieve a sufficient resection margin.

Sublobar resection was not considered a radical surgical treatment in primary lung cancer patients and was provided only in patients with limited lung functions and other biological limitations.

Segmentectomy is an operation technique when one or more segments are removed considering anatomical boundaries. Contrary to the atypical resection, segmental vessels and bronchus are identified and divided. If the lesion is located near the intersegmental plane, either both segments are removed, or the segment with dominant infliction is removed and the edge of the adjacent segment is atypically resected. It is required to obtain a sufficient resection margin. The resection line is sufficient when its distance from the tumor is the same or longer than the larger diameter of the lesion. Therefore, it is necessary to obtain a two-centimeter-wide resection margin in a tumor with two centimeters in diameter (4). Thoracoscopic sublobar resections at the Thoracic Surgery Department University Hospital Bratislava are performed with an uniportal approach. A three-centimeter-long incision provides access to the pleural cavity without using the rib spreader. Implemented ERAS (Enhanced Recovery After Surgery) protocol ensures early mobility by verticalization of the patient 4 hours after the operation. The patient is usually discharged from the hospital on day 1 or 2 after the surgery. This practice results in a better quality of life, maintenance of pulmonary functions, and the possibility of getting further oncological treatment faster if needed. With these possibilities of thoracic surgery, the question remains whether it is necessary to expand the indications for sublobar resection in the early stage of lung cancer independently of the tumor size.

Sublobar resections in the early-stage lung cancer

Currently, there are apparent changes in the epidemiological situation within lung cancer patients. Elderly patients with severe comorbidities and higher COPD stages are no exception. Besides that, imaging methods noted the progress that brought more small pulmonary lesions like GGOs and small nodules. It is impossible to classify them for cancer based singly on CT, but such lesions often appear to be malignancies. Within the context of that, new algorithms for assessing GGOs have been developed.

According to some papers, the size of the tumor is a significant predictive factor of survival. Currently, the cut-off value of the tumor size is three centimeters. However, a significant improvement in survival rate was confirmed with the tumor size equal to or smaller than two centimeters. It was proved that patients with tumor size of 11–20 mm have a significantly better survival than in cases with tumors in size of 21–30 mm. It was found out that there are no significant differences in survival in patients with tumor size of 21–30 mm and in those with tumor size above 30mm in early stages (3, 5).

The histological type of the tumor is also an essential factor. Some of the papers show the difference in survival in different types of lung cancer. The difference is insignificant in early-stage lung carcinoma with less than two centimeters in diameter. Bronchioloalveolar carcinoma, which showed up like GGO, is considered low-grade carcinoma (6).

As a result of these studies, it is evident that sublobar resection is an adequate alternative for patients with tumor size smaller than two centimeters and provides a similar survival with better maintenance of pulmonary functions and lower morbidity than the more extensive resections do.

Technical aspects

Segmentectomy requires precise planning of the surgical procedure. It requires perfect anatomical knowledge of segmental pulmonary structuring. Correct CT interpretation and definition of the precise location of the lesion is inevitable. Surgical skills and experience are required. Segmentectomy should be planned if safe margins can be obtained. Otherwise, it is obligatory to perform a more extensive resection (7).

Thoracotomy used in the past as the standard approach leads to complications and postoperative pain, often long-lasting and resulting in chronicity. Nowadays, mini-invasive techniques have spread widely, and thoracoscopic lung resections have become standard. Segmentectomy is performed thoracoscopically according to the custom; the uniportal approach via one incision appears to be the most progressive. A three centimeter-long incision is created on the lateral aspect of the chest or subxiphoidally. The subxiphoid approach avoids manipulation in the intercostal space and decreases postoperative pain. The operation technique is much like that used during the lobectomy. The difference is that the hilar structures are more precise, and delicate preparation is thus needed to recognize properly the structures that are to be divided, so as not to compromise the procedure.

Another critical factor affecting the operation result is the recognition of the intersegmental margins. There are several

Tab. 1. Demographic and clinical characteristics.

	VATS segmentectomy (n=37)	VATS lobectomy (n=438)	p
Age (years)	61.81±26.18 (Mean±SD) 63.00 (16) (Median (IQR))	63.78±9.55 (Mean±SD) 65.00 (12) (Median (IQR))	0.286
Male, n (%)	17 (45.9)	231 (52.7)	0.427
Diagnosis, n (%)			<0.001
Primary malignancy	6 (16.2)	323 (73.7)	
Adenocarcinoma	5 (13.51)	195 (44.5)	
Neuroendocrine malignancy	1 (2.71)	51 (11.6)	
Squamous cell carcinoma	–	58 (13.2)	
Other lung cancer	–	19 (4.3)	
Solitary fibrous tumor	–	1 (0.2)	
Metastatic disease	22 (59.5)	59 (13.5)	
Benign pathology	9 (24.3)	56 (12.8)	
Benign tumour	5 (13.5)	9 (2.0)	
Other benign pathology	4 (10.8)	48 (10.96)	

methods to identify it intraoperatively, but the surgeon´s experience is the most significant factor. It could be evident that the easiest way is the reexpansion of the lung after the division of the segmental bronchus, but often many intersegmental bronchial connections are developed, and consequently, the intersegmental surface margins are not seen clearly.

Some surgeons developed the air insufflation technique into the divided segmental bronchus while the rest of the lung parenchyma remains collapsed. Another way to identify the intersegmental plane is to inflate the lung before dividing the segmental bronchus. Once the bronchus is divided, the rest of the lung parenchyma needs to deflate. Closed bronchus does not allow the segment's collapse, and the intersegmental plane becomes visible.

Material and methods

This single-center retrospective study included 475 patients who underwent VATS (video-assisted thoracic surgery) anatomical resection at our institution from October 2012 to December 2021. We offered VATS lobectomy to 438 patients (231 males, 207 women), and we treated 37 patients (17 males, 20 women) by VATS segmentectomy (Tab. 1) of whom 25 patients underwent simple thoracoscopic segmentectomies while 12 were subjected to complex segmentectomies (Figs 1 and 2). We provide the distribution of segmentectomies in form of a table (Tab. 2). The patients' age in the VATS lobectomy group ranged from 21 to 86 years (mean: 63.78 ± 9.55; median: 65; IQR: 12). The mean age of the patients in the VATS segmentectomy group was 61.1 ± 26.18 (range, 15–62 years; median: 63; IQR: 16) (Tab. 1).

There was an evolution of the surgical approach within our group of patients. We operated on 93 VATS lobectomy patients with a multiportal approach (4-port, 3-port, or 2-port technique) between 2012 and 2016. Our thoracic surgeons adopted the uniportal VATS approach over 2016, and since July 2016, most of our VATS anatomical resections were provided strictly with this technique. VATS segmentectomies have been offered in indicated cases to our patients since 2017. We decided to retrospectively analyze the safety and short-time results within our VAST segmentectomy

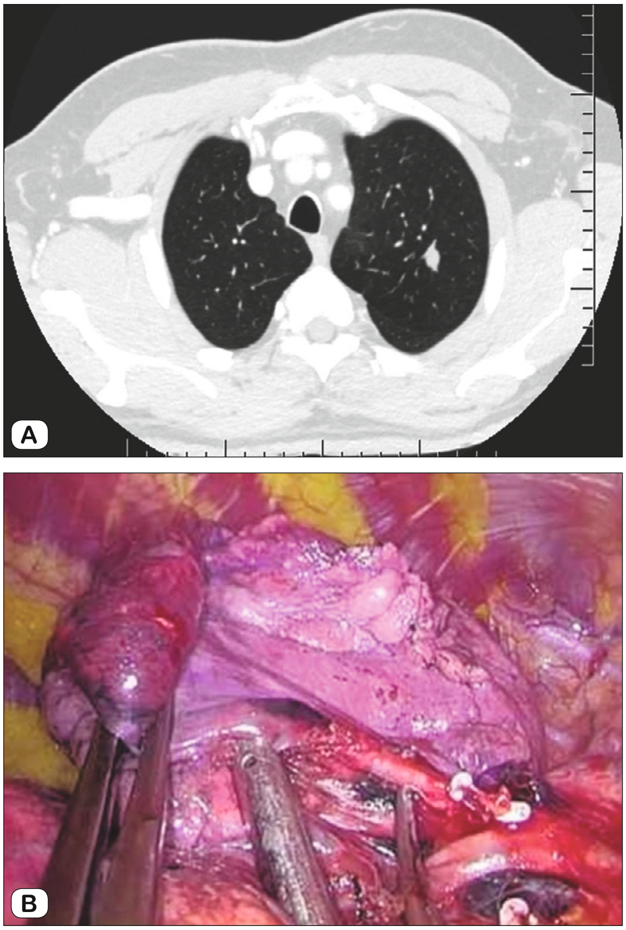

Fig. 1. Patient with colorectal cancer and multiple pulmonary metastatic lesions in the anterior and apicoposterior segment of the left upper lobe. A. CT scan with a metastatic lesion in the apicoposterior segment of the left upper lobe, B. Intraoperative view of the left upper division segmentectomy.

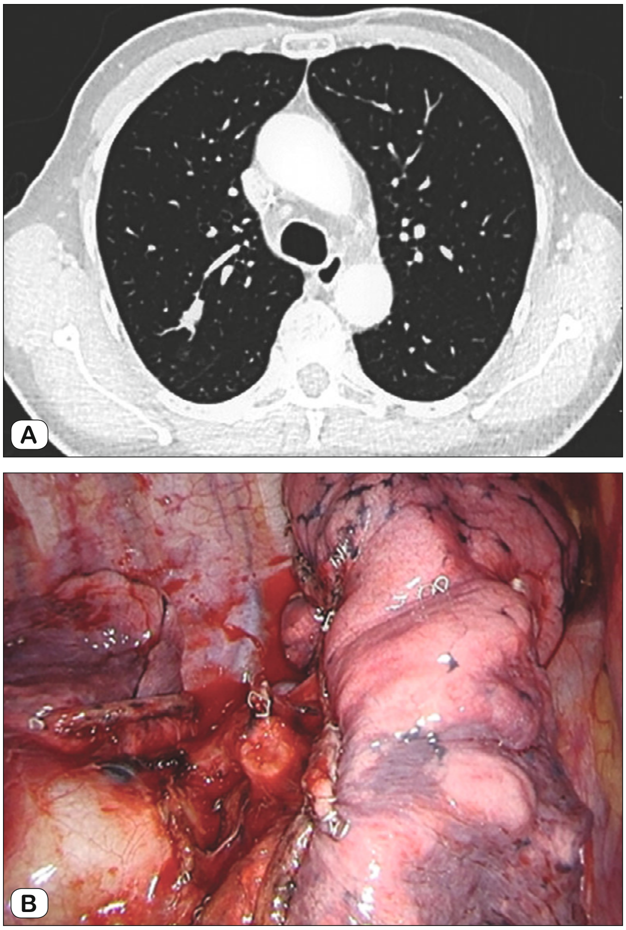

Fig. 2. Patient with colorectal cancer and pulmonary metastatic lesion in the posterior segment of the right upper lobe. A. CT scan with a metastatic lesion in the posterior segment of the right upper lobe, B. Intraoperative view of the right dorsal (S2) segmentectomy.

Tab. 2. Surgical segment distribution.

Location		Complex segmentectomy	Simple segmentectomy
Right side			
S2	4	4	
S3	6	6	
S6	7		7
Left side			
S1+S2+S3	6		6
S3	1	1	
S4+S5	7		7
S6	5		5
S8	1	1	
Total	37	12	25

group of patients as compared to our control group (VATS lobectomy cases). Primary lung cancer, metastatic pulmonary disease, or suspicious pulmonary nodules with inconclusive results of the pathological evaluation were the indications for segmentectomy. Mediastinal lymphadenectomy was offered to all patients with primary lung cancer.

Patients' personal and clinical data were extracted from their medical records. Operative time, postoperative length of stay (LOS), complication rate, complication type, conversion rate, need for rehospitalization or reoperation were recorded and compared between the groups. Differences between groups with categorical variables were assessed by the chi-square test or the Fisher's exact test. The Mann-Whitney test was used to assess differences when the variables were not distributed normally. Statistically significant differences were set as $p < 0.05$. Statistical analysis was conducted using SPSS 22.0 for Windows (SPSS Inc. Chicago, Illinois, USA) software.

The institutional ethics committee approved the study. Informed consent was not required from study participants.

Results

We recorded no statistical difference between the groups considering age and gender (Tab. 1). The diagnosis that was the indication for surgical procedure varied between the groups. Metastatic disease was the most frequent diagnosis treated in the VATS segmentectomy group with 59.46 % of cases. Primary lung cancer was present in 73.44 % of cases which made it the most common finding within VATS lobectomy patients and metastatic pulmonary disease in the VATS segmentectomy group (Tab. 1). VATS lobectomy was associated with a significantly longer operative time (80.0 vs 110.00 min, $p < 0.001$) and postoperative LOS (3.00 vs 4.00 days, $p < 0.001$) (Tab. 3).

Standard mediastinal lymphadenectomy was an integral part of the surgery in 323 (74 %) patients with VATS lobectomy and only in 6 (16 %) VATS segmentectomy patients. VATS lobectomy was also associated with a higher complication rate (27.1 % vs 16 %, $p = 0.132$), but this difference was not statistically significant (Tab. 4). None of these two techniques was associated with a high number of intraoperative (0 % vs 4.8 %, $p = 0.394$) or postoperative complications (16 % vs 23 %, $p = 0.353$) (Tab. 4).

Prolonged air-leak followed by pneumothorax were leading postoperative complications in the lobectomy group, and intraoperative hemorrhage was the most common intraoperative complication with this procedure. Pneumothorax was present in one-third of the postoperative complications in the VATS segmentectomy group (Tab. 5). We recorded 27 (6.2 %) conversions to thoracotomy in the VATS lobectomy group (Tab. 4). Intraoperative hemorrhage was the reason for the emergent conversion in 16 cases (59 %). Anatomical reasons (dense adhesions, tumor localization) and oncological reasons (tumor, presence of lymph nodes) led to a planned conversion in the rest of the cases. We recorded no conversion to open surgery in the segmentectomy group. A conversion to the right upper VATS segmentectomy was decided intraoperatively in one patient after the frozen section because the pathologist reported no presence of tumor in the resected S3 segment. The patients' CT was re-evaluated after the procedure, and we concluded that the tumor was localized in the apical segment. Two patients in the segmentectomy group were reoperated. In one of them, intraparenchymal hemorrhage after right-sided S3 segmentectomy indicated right upper lobectomy on postoperative day 2. The second patient underwent right-sided S6 segmentectomy. He was readmitted with hemothorax on day 4 after the procedure. A chest tube was inserted, but hemothorax remained partially undrained. It was evacuated thoracoscopically on day 9 after the initial VATS segmentectomy. Another VATS segmentectomy patient was readmitted to our department with pneumothorax on day 4 after the surgery. He was treated with chest tube insertion.

Tab. 3. Intraoperative data.

	VATS segmentectomy			VATS lobectomy			p
	mean ± SD	median	IQR	mean ± SD	median	IQR	
Operative time, min	84.59±26.18	80.00	20	114.00±37.13	110.00	50	*<0.001*
Postoperative LOS, days	3.65±4.09	3.00	1.00	4.97±3.58	4.00	3.00	*<0.001*

Tab. 4. Postoperative data.

	VATS segmentectomy n (%)	VATS lobectomy n (%)	OR (95% CI)	P
Complications	6 (16.2)	121 (27.6)	0.507 (0.206. 1.246)	0.132
Intraoperative complications	0 (0.0)	21 (4.8)	0.952 (0.932. 0.972)	0.394
Postoperative complications	6 (16.2)	97 (22.8)	0.654 (0.265. 1.613)	0.353
Conversion to open surgery	0 (0.0)	27 (6.2%)	0.917 (0.892. 0.943)	0.254
Conversion to VATS lobectomy	1 (2.7)	N/A	–	–
Rehospitalization	2 (5.4)	32 (7.3)	0.725 (0.167. 3.152)	1.000
Reoperation	2 (5.4)	14 (3.2)	1.731 (0.378. 7.922)	0.359

Discussion

VATS segmentectomy is a technically demanding surgical procedure that could be more challenging than standard VATS

Tab. 5. Complications.

	VATS Segmentectomy (n)	VATS Lobectomy (n)
Prolonged air-leak	–	36
Pneumothorax	2	23
Intraoperative bleeding	–	16
Pleural effusion	–	15
Pneumonia	1	8
Wound infection	–	7
Massive subcutaneous emphysema	1	4
Chylothorax	–	2
Technical error	–	2
Hemothorax	1	1
Bronchial stump dehiscence with empyema	–	1
Pulmonary hemorrhage	1	1
Lung herniation	–	1
Pulmonary embolism	–	1
Cerebral ischemic stroke	–	1
Atrial fibrillation		1
Acute respiratory insufficiency	–	1
Total	6	121

lobectomy. Operative times of thoracoscopic segmentectomy in published studies ranged from 94 to 211 minutes in patients predominantly treated for lung cancer (8, 9, 10, 11, 12). Some centers published no significant differences between these two thoracoscopic procedures regarding operation time (9, 13, 14).

Our operative times in patients with VATS segmentectomy are shorter than those published by other centers. We recorded statistically significant differences between VATS segmentectomy and lobectomy in terms of duration of the surgery and postoperative hospital stay that are in favor of sublobar anatomic resection. The difference in histological results and learning curve between these two groups were probably the most critical factors influencing the length of the procedure. Primary lung carcinoma was the dominant diagnosis treated in the VATS lobectomy group (74 %), and mediastinal lymph node dissection (MLND) was the obligatory part of the surgery. Metastatic pulmonary disease (60 %), followed by benign pathology (24 %), was prevalent in patients who underwent VATS segmentectomy. Contrary to lung cancer patients, performing MLND in patients with pulmonary metastasectomy is controversial due to the lack of evidence (15). Only 16 % of VATS segmentectomy patients underwent MLND, which could have influenced positively the operative times.

The learning curve impacted our results because we introduced uniportal VATS segmentectomy to our patients shortly after adopting basic skills with multiportal and uniportal VATS lobectomies. The learning curve for uniportal segmentectomy is shorter when compared with that for multiportal anatomical resections (12).

Postoperative LOS after VATS segmentectomy ranges from 2 to 6 days. Some centers recorded no significant variance between these two procedures regarding the postoperative LOS (9, 13, 14). In contrast to these results, we recorded a significantly shorter postoperative LOS in our group of VATS segmentectomy patients. We assume that the higher number of patients with a prolonged air leak in the VATS lobectomy group (8.2%) resulted in longer chest tube duration, directly influencing the LOS.

The complication rate in our segmentectomy patients was comparable with the results published in various papers (6.3–30 %) (9, 10, 11, 16, 17). Moreover, we recorded no significant difference in intraoperative and postoperative complications between VATS segmentectomy and lobectomy groups.

Lobectomy remains the golden standard surgical treatment of lung cancer. The surgical treatment should be proposed to all patients in the early stage. Anatomical resection is considered to be superior to wedge resection (18). Thoracoscopic resections gained popularity with the evolution of operation techniques; however, the matter of oncological radicality remains open for discussion. Many mostly retrospective studies showed that it was possible to accept segmentectomy as a good and proper alternative to VATS lobectomy in some cases. Based on the gained knowledge, it is clear that the cut-off point of 2 cm of the tumor size and its convenient location in some of the segments are in favor of segmentectomy. Some benefits come from segmentectomy, such as maintenance of the pulmonary function and the benefits of mini-invasive techniques. The survival rate of the patients with the tumor size of 2 cm after sublobar anatomical resection is comparable with the survival rate of those who underwent more extensive resections (19, 20).

It is necessary to wait for more randomized prospective studies comparing the survival rates after lobectomies and sublobar resections in early stages of lung cancer with the size of a tumor smaller than 2 cm. Such a study is not easy to design due to ethical reasons. However, based on published data, it is possible to consider the sublobar anatomical resection as a radical operation method for primary lung cancer.

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