



# Minimally-invasive segmentectomy for pulmonary tuberculosis: single center experience

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**Abstract:** Thoracoscopic pulmonary resections are widely used by thoracic surgeons in the world. Nevertheless, infectious diseases of the lung are associated with a lot of difficulties for implementing of minimally invasive approaches. Four years single-center experience in robot- and video-assisted thoracoscopic segmentectomies for pulmonary tuberculosis was studied in this paper to evaluate the main features of these surgical procedures for infectious disease. From 2016 to 2019 years we were performed 262 anatomical segmentectomy due to localized TB lesions, including 144 patients underwent uniportal video-assisted thoracoscopic surgery, 108 underwent muscle sparing lateral thoracotomy, and 10 cases of robot-assisted thoracoscopic surgery. Conversion rate from uVATS to open surgery was 8%. The advantages of the uVATS approach compared to thoracotomy approach are less blood loss during surgery (56.74 *vs.* 74.26 mL,  $P=0.0001$ ); lower consumption of narcotic analgesics (4.35 injections *vs.* 5.50 injections,  $P=0.0001$ ) and a lower incidence of complications after surgery (21.5% *vs.* 36.1%,  $P=0.015$ ). There were no significant differences in duration of operation ( $P=0.102$ ), air leak ( $P=0.981$ ), chest tube drainage ( $P=0.417$ ), hospital stay ( $P=0.134$ ) between the uVATS and thoracotomy groups. There was no perioperative mortality. In addition, after bacteriological examination, 13% of patients ( $n=35$ ) showed amplification of MTB drug resistance. Minimally invasive segmentectomy is effective and safe procedure in the complex treatment of localized forms of pulmonary tuberculosis.

**Keywords:** Surgical treatment of pulmonary tuberculosis; VATS segmentectomy; uniportal segmentectomy; robotic segmentectomy

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## Background

Lung resections are known as effective adjuvant options, when medical treatments fail. This is especially important

when the patient has drug resistance and immediately from the time of the drug susceptibility test, doctor thinks about the low effectiveness of anti-tuberculosis drugs. In 2016, the

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Fox and colleagues showed in the individual patient data meta-analysis that of all surgical methods, it is the pulmonary resection that provides the best treatment result in patients with tuberculosis (1). The clinical efficacy of the anatomical segmental resection for localized forms of pulmonary tuberculosis in TB-surgery has long been known (2). The main trends in the field of thoracic surgery are the use of minimally invasive approaches to preservation of the functioning pulmonary tissue, to reduce surgical trauma and to improve the rehabilitation of patients after surgery (2-4). Ubiquitous use of thoracotomy for segmentectomies (SE) in the era of minimally invasive surgery leaves more questions than answers today. However, there is no consensus on this issue. The main objective of this paper was to show the effectiveness and safety of the minimally invasive approaches for performing lung segmentectomies in patients with tuberculosis using the experience in our thoracic center.

### Indications for pulmonary segmentectomy

Current indications for surgery were described by World Health Organization (WHO) in 2014 (5). Segmentectomy are performed as a rule for elective situations, such as localized forms of cavitary tuberculosis with continuous *Mycobacterium tuberculosis* (MTB) excretion confirmed by bacteriological examination and drug-susceptibility testing (DST) after 4 to 6 months of supervised antituberculosis chemotherapy or multidrug-resistant (MDR)/extensively drug-resistant (XDR) tuberculosis characterized by failure of anti-tuberculosis chemotherapy. Sometimes complications and sequelae of the tuberculosis process could be the reason for sublobar anatomical pulmonary resection (5).

### Basic principles

Timing of surgery, contraindications, perioperative care and postoperative treatment are the same for all pulmonary resections. This strategy is detailed in WHO consensus [2014]. In addition, we believe that the most severe limitations for minimally invasive approaches for segmentectomy in patients with pulmonary TB are: previous surgery (anatomical resection) on the same side and uncertainty about the final volume of the operation (dissemination which requires manual determination of borders of the lung resection) (5).

## Methods

### *Patient characteristics*

Retrospective analysis of consecutive patients were operated from 2016 to 2019 years. Two hundred and sixty-two patients were selected for anatomical segmentectomy due to localized TB lesions according to National guideline and WHO consensus statement (5). Demographic parameters and functional status of patients are presented in *Table 1* (6).

Indications for surgery were tuberculomas (n=136), cavernous tuberculosis (n=61), fibrous-cavernous tuberculosis (n=65). Half of all patients was operated for tuberculomas, and most of them (72 cases) had destruction in tuberculomas and treatment was determined as a failure. Bacteriological parameters of patients are presented in *Table 2*.

Median duration of preoperative medication treatment was  $9.86 \pm 5$  months. All cases were discussed on multidisciplinary meeting and decision included: indications, volume of surgery and surgical approach (2,7-9). There were three modern approaches used for pulmonary segmentectomies:

- ❖ Muscle sparing lateral thoracotomy (7,8) (single incision up to 14 cm in IV–V ICS with ribs spreading)—108 cases;
- ❖ Uniportal video-assisted thoracoscopic surgery (uVATS) (single incision up to 4.5 cm in IV–V ICS without ribs spreading)—144 cases;
- ❖ Robot-assisted thoracoscopic surgery (RATS) (VATS-based with three-arm and four-ports technique)—10 cases.

The distribution of patients depending on surgical access by years is shown on the *Figure 1*.

Standard technique of anatomical segmentectomy was used with consecutive isolation and closure of the hilar structures (10). Finding and division of intersegmental plane were performed with inflation/deflation test and with identification of the intersegmental vein.

Retrospective analysis of intraoperative and postoperative parameters was performed.

### *Statistical analysis*

Descriptive methods were used to characterize groups (mean, median, standard deviation). Nonparametric methods were used for comparing groups (U-test, Kruskal-Wallis and Chi-squared tests). Statistical analysis was

**Table 1** Demographic parameters and functional status

Parameters	Means
Median age, years	36±11
FEV1, %	101±14
FEV1/FVC, %	79±8
ASA physical status	2±0.5
CCI	1±1.5
Male	152 (58%)
Smokers	186 (71%)

FEV1, forced expiratory volume in 1 second; FEV1/FVC, forced expiratory volume in 1 second/forced vital capacity ratio; ASA physical status, physical status calculated by American society classification system; CCI, Charlson comorbidity index.

**Table 2** Results of bacteriological investigations

Parameter	n	%
Positivity of sputum on MTB		
Negative sputum on time of surgery	230	87.8
Positive sputum on time of surgery	32	12.2
Initial drug resistance of MTB		
Not available	71	27.1
Drug susceptible MTB	50	19.1
Drug resistant MTB (not MDR or XDR)	16	6.1
MDR-TB	89	34.0
XDR-TB	36	13.7

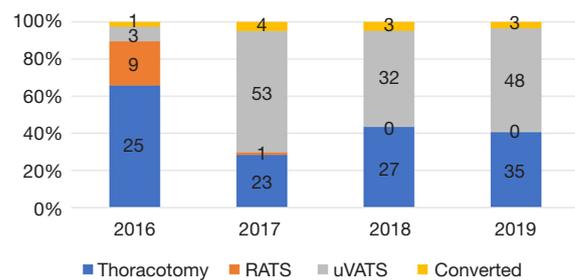
MTB, Mycobacterium tuberculosis; MDR-TB, multi-drug-resistant tuberculosis; XDR-TB, extensively drug-resistant tuberculosis.

performed on software IBM SPSS Statistics v22.

## Results

### VATS segmentectomy for pulmonary tuberculosis

One hundred and forty-four uVATS anatomical segmentectomies were performed. There were 47 simple (division of the one intersegmental planes) and 97 complex (division of two or more intersegmental planes) segmental resections. The most common uVATS operations were apicoposterior segmentectomy on the both sides. 133 operations (92%) were ended successfully by uVATS and 11 operations (8%) were converted to a thoracotomy.



**Figure 1** Surgical access by years. RATS, robot-assisted thoracoscopic approach; uVATS, uniportal video-assisted thoracoscopic approach.

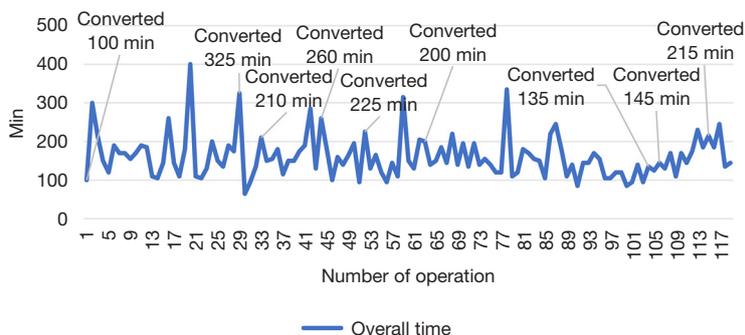
Indications for conversion were: hard pleural adhesions (2 cases), injury of the bronchial structures (2 cases), bleeding from bronchial artery (1 case), perivascular and peribronchial adhesive process (5 cases); video equipment breakdown (1 case). Overall operative time was 168.99±59.10 min, overall intraoperative blood loss -56.74±85.09 mL. Cases with conversion were associated with longer operative time (209.55±68.21 vs. 165.64±57.30 minutes, P=0.023) and higher intraoperative blood loss (120.91±133.97 vs. 51.43±78.18 mL, P=0.039) than successfully uVATS segmentectomy. Learning curve of VATS segmentectomy is shown on the *Figure 2*.

Learning curve has shown, that overall operative time decreased slowly and gradually with experience. Nevertheless, rate of conversions to a thoracotomy was higher between 25<sup>th</sup> and 65<sup>th</sup> operations after learning basic skills of uniportal uVATS technique. Next increase in the conversion rate was after 100<sup>th</sup> operation. It could be due to wider spreading of technology and reduced preoperative selection of patients.

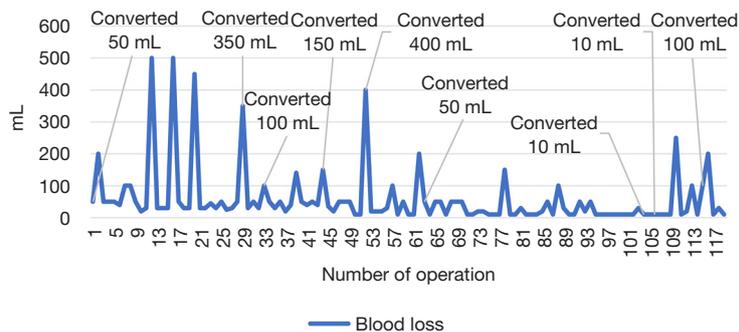
Intraoperative blood loss volume mainly depended on the prevalence of pleural adhesions and intraoperative events. Curve of intraoperative blood loss is presented on *Figure 3*.

Difficulties with isolation of the hilar structures or adhesiolysis on the first time after beginning could be solved minimally invasively in some cases, but sometimes they require thoracotomy. Radiological finds such as emphysema and bullous changes (11), adhesions in the pleural cavity, incompleteness of interlobar fissures (12), fibrotic changes in the hilum were factors which directly increased of operative time and blood loss (*Table 3*).

Major postoperative complications (13) after uVATS segmentectomy were in 21.5% (31 cases). In general,



**Figure 2** Learning curve of uVATS segmentectomy: overall operative time. uVATS, uniportal video-assisted thoracoscopic surgery.



**Figure 3** Learning curve of uVATS segmentectomy: intraoperative blood loss. uVATS, uniportal video-assisted thoracoscopic surgery.

they were presented by pulmonary (partial atelectasis treated by bronchoscopy) and pleural (prolonged air leak) complications. There was no perioperative mortality.

Statistical analysis showed not significant differences between simple and complex uVATS segmentectomy in the operation time ( $172 \pm 60$  vs.  $168 \pm 59$  min;  $P=0.552$ ), blood loss ( $65 \pm 107$  vs.  $52 \pm 72$  mL;  $P=0.638$ ), and major postoperative complications (8.5 % vs. 13% respectively;  $P=0.184$ ).

#### ***uVATS vs. open segmentectomy for pulmonary tuberculosis***

Preoperative characteristics (demographic data, comorbidities, radiological findings and bacteriological characteristics) were comparable between uVATS and open segmentectomy groups. Perioperative results of 144 uVATS and 110 open segmentectomies were investigated. There were no significant differences in demographic and functional parameters, disease characteristics (forms of tuberculosis, duration of treatment, bacteriological data) and volume of surgery between the groups. Results of compare two groups are presented in the *Table 4*.

Overall operative time was the same in uVATS and open groups. The volume of intraoperative blood loss was larger in open group which is logically justified by a larger operating trauma and length of incision. Duration of pleural drainage, duration of air leak and postoperative hospital stay were the same in both groups. The assessment of postoperative pain was performed according to narcotic analgetics intake. This parameter was significantly less in uVATS group. Postoperative hospital stay did not differ depending on surgical access. The most of patients from both groups were discharged to sanatorium for prolongation of anti-tuberculosis treatment. Postoperative morbidity (major complications) was less in uVATS group also (21.5% vs. 36.1% in uVATS and open groups respectively,  $P=0.015$ ). Kinds of complications are shown in *Table 5*.

#### ***Initial experience in RATS segmentectomy for pulmonary tuberculosis***

Initial experience of RATS segmentectomy includes 10 patients with localized forms of pulmonary tuberculosis.

**Table 3** Factors affecting the duration of the uVATS segmentectomy and the volume of intraoperative blood loss

Factor	Blood loss	P	Operative time	P
Fibrotic changes in the hilum		0.014		0.00001
Yes, n=36	119±119		232±70	
No, n=108	68±76		156±56	
Interlobar fissure, grade (Craig and Walker classification)		0.003		0.0001
NA, n=37	72±81		157±54	
1, n=36	53±45		138±42	
2, n=41	72±97		172±60	
3, n=21	89±50		218±70	
4, n=7	213±176		248±94	
Pleural adhesions		0.0002		0.00004
No, n=45	52±33		155±57	
Small, n=55	68±73		153±55	
Up to half pleural cavity, n=34	65±42		184±49	
Total, n=10	269±158		288±69	
Conversion		0.39		0.23
No, n=133	51±78		166±57	
Yes, n=11	121±134		210±68	
Chronic obstructive pulmonary disease		0.007		0.004
No, n=130	66±63		163±60	
Yes, n=14	175±166		229±80	
Side of the operation		0.421		0.0001
Right, n=62	49±65		148±49	
Left, n=82	63±97		185±62	
Bullous disease		0.021		0.00005
No, n=101	67±77		155±58	
In the boundaries of removal segments, n=14	108±64		248±70	
Diffuse, n=27	116±131		200±61	

Statistical analysis was performed by Kruskal-Wallis test. uVATS, uniportal video-assisted thoracoscopic surgery.

The operation time for segmentectomies ranged from 65 to 320 min, intraoperative blood loss—from 10 to 200 mL. Two patients (20%) were undergoing conversion to a thoracotomy due to the bleeding (single case of endoscopic stapler breakdown during apicoposterior right segmentectomy, blood loss was 1,200 mL) and injury of the segmental bronchus (apicoposterior left segmentectomy in patient with bronchi nodular fistula). In these group two

patients (20%) had a major complication like prolonged air-leak. This complication was treated with additional chest tube in the first case and with endobronchial valving in another case. It was a small group, so it was impossible to adequately compare it statistically with uVATS and open groups. Most of the operations were performed in the early stages of development of robotic technology. Nevertheless, we are confident that future research will show better

**Table 4** Perioperative outcomes uniportal video-assisted thoracoscopic surgery (uVATS) vs. open segmentectomy

Parameters	uVATS	Open	P
Operative time (min)	168.99±59.10	156.85±51.58	0.102
Blood loss (mL)	56.74±85.09	74.26±82.11	0.0001
Air leak, days	1.33±5.13	1.83±5.49	0.981
Chest tube, days	4.12±5.12	5.10±5.59	0.417
Narcotic analgesics, number of injections	4.35±1.10	5.50±1.43	0.0001
Postoperative hospital stay, days	11.00±5.69	14.65±14.63	0.134

**Table 5** Major postoperative complications after uniportal video-assisted thoracoscopic surgery (uVATS) vs. open segmentectomy

Complications	uVATS		Open		P
	n	%	n	%	
Pneumothorax	7	4.9	7	6.5	0.604
Prolonged alveolar air leak	12	8.3	11	10.2	0.647
Atelectasis	14	9.7	16	14.8	0.238
Hemothorax	0	0.0	5	5.4	0.031
Pulmonary vein thrombosis	0	0.0	1	1.1	0.429
Pleural effusion	0	3.3	2	2.2	0.183
Chylothorax	0	0.0	1	1.1	0.429
Pneumonia	0	0.0	1	1.1	0.429
Reoperation	0	0.0	6	6.5	0.006
All	31	21.5	39	36.1	0.015

results for this modern approach.

### **Additional results**

In addition to perioperative results, we obtained data in the study of specimen. Bacteriological and morphological studies were performed. Moreover, in all cases, the diagnosis was confirmed. During bacteriological examination, 13% of patients (n=35) showed amplification of MTB drug resistance. Thus, patients received a chance for an adequate selection of therapy after surgery.

### **Discussion**

History of thoracoscopy has begun from tuberculosis cases (Jacobeus, 1910). Nevertheless, tuberculosis is the rare indication for VATS anatomical pulmonary resections today (14). Few surgeons had effective attempts to use mini-

thoracotomy for the same purposes, but use of a retractor refutes the current principles of thoracoscopy. It is well known that VATS lung resections are accompanied by less pain, which is confirmed in our study with significantly less use of narcotic analgesics after uVATS (3,4). There are small series of minimally invasive segmentectomies for pulmonary TB with a high incidence of intra- and postoperative complications in a current literature (11,14-18). Overall operative time of uVATS segmentectomy in our trial was similar to the time in most published series (Table 6) (3,19-21).

Simple segmentectomies have been often performed by VATS. According to the literature, complex segmentectomies are technically demanding with a longer operative time and a higher postoperative morbidity. Our trial showed that uVATS complex segmentectomy for pulmonary tuberculosis is feasible, and is characterized by the same duration of surgery, volume of intraoperative

**Table 6** Duration of video-assisted thoracoscopic surgery (VATS) segmentectomy

First author, year	Diagnosis	n	Operative time, min
Cheng K., 2016	Lung cancer	40	174±51 (pts with adhesions were excluded)
Hamada A., 2018	Lung cancer	252	188±61
Shirahashi K., 2018	Lung cancer	62	260±81
Tseng Y.L., 2018	Pulmonary tuberculosis	64	181±71
Current study	Pulmonary tuberculosis	144	169±59

blood loss and morbidity (22). Tseng and coauthors in comparative analysis of uVATS segmentectomy versus open segmentectomy in 2018 showed the advantages of minimally invasive approach. The authors did not reveal significant differences in the duration of the surgery, but VATS segmentectomy was accompanied by less volume of blood loss and a longer hospital stay. Noteworthy, the most common complication was bronchopleural fistula in 6 cases, more often in the group after access conversion (9). Major complications were found in 21.5% of patients in our series of 144 uVATS segmentectomies, and bronchopleural fistulas have not been found. uVATS versus open segmentectomy is characterized by a comparable duration of the surgery, less volume of blood loss, less pain level and morbidity. Morphological irreversible changes in the lung and pleura after long tuberculous inflammation were not contraindications for uVATS. Nevertheless, these factors are accompanied by an increase of the duration of surgery and higher volume of blood loss. It is necessary to conduct an adequate comparison of RATS with open and VATS segmentectomies on comparable material for future research. Undoubtedly, it is necessary to study the long-term outcomes for a comprehensive assessment of the effectiveness of minimally invasive anatomical segmental resections in complex treatment of pulmonary TB.

## Conclusions

Minimally invasive segmentectomy is effective and safe procedure in the complex treatment of localized forms of pulmonary tuberculosis. The main advantages of uVATS approach are less blood loss during surgery; less consumption of narcotic analgesics and a lower incidence of complications after surgery. Additional studies are required in the field of comparing RATS with uVATS and open segmentectomy for tuberculosis.

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