Хирургия. Журнал имени Н.И. Пирогова
2019, №10, с. 5-12
https://doi.org/10.17116/hirurgia20191015

Pirogov Journal of Surgery
2019, №10, pp. 5-12
https://doi.org/10.17116/hirurgia20191015

Segmentectomy in patients with primary pulmonary malignancies

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ABSTRACT

Objective — to analyze immediate and long-term results of anatomical resections for lung cancer with subsequent comparison of the results of segmentectomy and lobectomy in patients with peripheral NSCLC stage IA1—2.

Material and methods. There were 52 sublobular anatomical resections of the lung for peripheral non-small cell carcinoma and carcinoid T1a-bN0M0, IA1—2 stage. 3D-CT reconstruction with separation of bronchial and vascular structures was used to schedule complex segmentectomy. We retrospectively analyzed 200 patients with cT1a-bN0M0 peripheral non-small cell lung cancer (NSCLC) and tumor dimension ≤2 cm who underwent lobectomy (n=148) and segmentectomy (n=52). Mortality, morbidity and overall 5-year survival were compared in two propensity score matched groups (46 pairs, segmentectomy vs. lobectomy).

Results. There was no mortality in both groups. Morbidity was similar after segmentectomy and lobectomy (8.69 and 6.52%; p=0.32). 3D-CT with separation of bronchial and vascular structures enabled surgeons to perform atypical segmentectomies and VATS procedures more often (from 13.5 to 31.3%; p>0.05 and from 11.5 to 50.0%; p<0.05). Five-year survival was 82 and 86% (p=0.652) after segmentectomy and lobectomy, respectively.

Conclusion. Postoperative results and long-term outcome after segmentectomy and lobectomy are comparable in patients with NSCLC cT1a-bN0M0, stage IA1—2. Segmentectomy is advisable surgery in patients with low pulmonary capacity and severe comorbidities.

Keywords: lung cancer, segmentectomy, sublobar anatomic resection, 3D-CT reconstruction.

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TO CITE THIS ARTICLE:

Amiraliev AM, Pikin OV, Ryabov AB, Khalimon AI, Bagrov VA, Barmin VV. Segmentectomy in patients with primary pulmonary malignancies. *Pirogov Russian Journal of Surgery = Khirurgiya. Zurnal imeni N.I. Pirogova*. 2019;10:1-8. (In Russ.). https://doi.org/10.17116/hirurgia20191011

Introduction

Anatomical lung resection with mediastinal lymphadenectomy is currently the most common approach among conventional methods of treatment in patients with peripheral non-small cell lung carcinoma (NSCLC) stage I [1, 2]. Contradictions among oncologists and thoracic surgeons are only determined by the choice of optimal volume of pulmonary parenchyma resection for ensuring local control of continued tumor growth and disease-free period. So, minimum allowable volume of lung resection from oncological point of view is discussable [3, 4]. Segmentectomy for lung cancer was first described by R. Jensik et al. [5] in 1973. It should be noted that lobectomy remained the gold standard of surgical treatment of patients with NSCLC stage I for many decades. However, various enthusiasts among thoracic surgeons and oncologists justify the feasibility of segmentectomy for early peripheral NSCLC with tumor size less than 2.0 cm [6]. On the other hand, improved methods of X-ray diagnosis result increased number of patients with early stage of lung cancer, primary multiple synchronous and metachronous tumors, resectable lung metastases [7]. Considering these features, function- and organ-sparing procedures are advisable in thoracic oncology. Currently, segmentectomy is becoming important in surgical oncology as alternative to lobectomy for early stage of lung cancer in advanced age patients with significant comorbidities and reduced respiratory capacity [8].

Objective — analysis of immediate and long-term results of sublobar anatomical resections for lung cancer with subsequent comparison of the results of segmentectomy and lobectomy in patients with peripheral NSCLC stage IA 1—2 and tumor size less than 2 cm.

Material and methods. There were 52 sublobar anatomical resections for peripheral non-small cell lung carcinoma and carcinoid stage T1a-bN0M0, IA1-2. All procedures were performed at the thoracic department of the Herzen Moscow Research Institute for the period 2000—2017 [9]. Types of segmentectomy were divided into typical and complex. Typical segmentectomy was determined by lung parenchyma dissection in 2 intersegmental planes (including interlobar surfaces in case of adhesions). Complex segmentectomies included other procedures followed by parenchymal dissection in 3 or more intersegmental planes. Thus, typical sublobar anatomical resection includes resection of S VI and bilateral basal segments; resection of S I—III and lingular segments of the left lung. The examples of atypical (complex) segmentectomy are resections of S I—II, S III, S IX—X on both sides, S VII—VIII on the left [10]. 3D-CT reconstruction with separation of segmental bronchial and vascular structures was used prior to complex anatomical resections, as well as typical segmentectomy with tumor placement on the border of the segments. Additional criteria in favorable of sublobar surgery were low functional capacity, severe comorbidities and advanced age.

A retrospective analysis of the results of anatomical resections enrolled 200 patients with peripheral NSCLC stage IA 1—2 and tumor size less than 2 cm (52 segmentectomies and 148 lobectomies). Paired case-control study was applied for the most reliable statistical comparison of retrospective groups. Thus, there were 46 pairs divided into 2 groups. The main group consisted of 46 patients who underwent segmentectomy, the control group — 46 patients after lobectomy. The following key criteria were used to divide patients: age (years), sex (male/female), smoking (yes/no), forced expiratory volume during the 1st second (FEV1, %); comorbidities: chronic obstructive pulmonary disease (COPD), arterial hypertension (AH), previous myocardial infarction (MI), primary multiple tumors (yes/no in all cases); histological structure (adenocarcinoma, squamous cell carcinoma, carcinoid) and preoperative assessment of primary tumor size (cm).

Demographic data and characteristics of tumors are shown in **Table 1**.

Table 1. **Demographic data and characteristics of tumors**

Variable	Segmentectomy (*n*=46)		Lobectomy (*n*=46)		*p*-value
	abs.	%	abs.	%	
Age, years					
mean	67.4		67.8		0.96
SD	8.7		8.7		
Sex					
male	28	60.7	25	54.3	0.72
female	18	39.1	21	45.7	
Comorbidities					
COPD	32	69.6	29	63.0	0.69
AH	26	56.5	25	54.3	0.93
previous MI	12	26.1	11	23.9	0.91
DM	8	17.4	9	19.6	0.86
PMMMT or PMSMT	6	13.0	5	10.9	0.74
Smoking					0.38
yes	40	87.0	36	78.3	
no	6	13.0	10	21.7	
FEV1, %					0.67
mean	68.7		70.4		
SD	19.5		20.3		
Histology data					
adenocarcinoma	31	67.4	29	63.0	0.83
squamous cell carcinoma	12	26.1	15	32.6	0.77
carcinoid	3	6.5	2	4.4	0.65
Tumor size					0.68
mean	1.7		1.9		
SD	0.8		1.0		
Surgical approach					1.00
thoracotomy	25	54.3	25	54.3	
thoracoscopy	21	45.7	21	45.7	
Stage					0.65
IA1	2	4.4	3	6.5	
IA2	44	95.6	43	93.5	
Number of excised lymph nodes					0.56
mean	22.3		24.5		
SD	7.4		8.2		
Follow-up, years	5.2		5.3		0.87

Note. Abbreviations: COPD — chronic obstructive pulmonary disease, AH — arterial hypertension, MI — myocardial infarction, PMSMT — primary multiple synchronous malignant tumors, PMMMT — primary multiple metachronous malignant tumors; SD — standard deviation.

Technique of segmentectomy

Surgical intervention was performed under one-lung ventilation in lateral position of patient. Surgical approach was anterolateral thoracotomy in V intercostal space. In case of thoracoscopic surgery, we used a 4-cm incision in IV or V intercostal space anterior to the front edge of musculus latissimus dorsi with subsequent insertion of flexible silicone tissue restrictor. Three additional thoracoports were also installed: 11-mm trocar in VII intercostal space along posterior axillary line for optics and endostapler and two 5-mm manipulation trocars with variable arrangement depending on the side of surgical intervention and anatomical features. Similarly to lobectomy, surgical intervention was preferably initiated from mediastinal lymphadenectomy in standard fashion regardless type of resection and surgical approach (thoracotomy or thoracoscopy). In accordance with the recommendations of the European Society of Thoracic Surgeons (ESTS, 2006), systematic lymphadenectomy was performed. This technique implies obligatory excision of intrapulmonary lymph nodes and at least 6 ones from the root and mediastinal groups with surrounding tissue. Mediastinal lymph nodes were removed from at least 3 different zones. One of these areas is bifurcation [11—13]. According to the classification of the International Association for the Study of Lung Cancer (IASLC, 2009), the following groups of lymph nodes were removed: on the right — 2R, 4R, 7, 8, 9, 10—14; on the left - 4L, 5, 6, 7, 8, 9, 10—14 [14]. The following stage was segmentectomy *per se*. Segmental arteries were determined and dissected in accordance with preoperative 3D-CT modeling and separation of the bronchi and vascular structures **(Fig. 1)**.

Dissection of segmental arteries was followed by isolation of segmental bronchus. Bronchopulmonary lymph nodes were removed or displaced towards excised segment. A ligature was placed under the bronchus. The following manipulation was bronchotomy or intersection of the bronchus using stapling devices. Surgeon dissected lung tissue using mono-bipolar cautery, ultrasonic scalpel or stapling device. Dissection was made considering demarcation line formed by one of the below-described methods. Veins were ligated or clipped at the intersegmental level during dissection of intersegmental plane. Central segmental vein was separately ligated after previous verification of no large tributaries from adjacent segments in accordance with 3D-CT data. Lung segment was removed. Dissection surface of intact pulmonary segments was covered with a fibrin-based glue. Filling of pleural cavity with an antiseptic solution was followed by resuming of ventilation to control impermeability of the lung tissue. Pleural cavity was drained by two silicone drainage tubes before closure of the wounds.

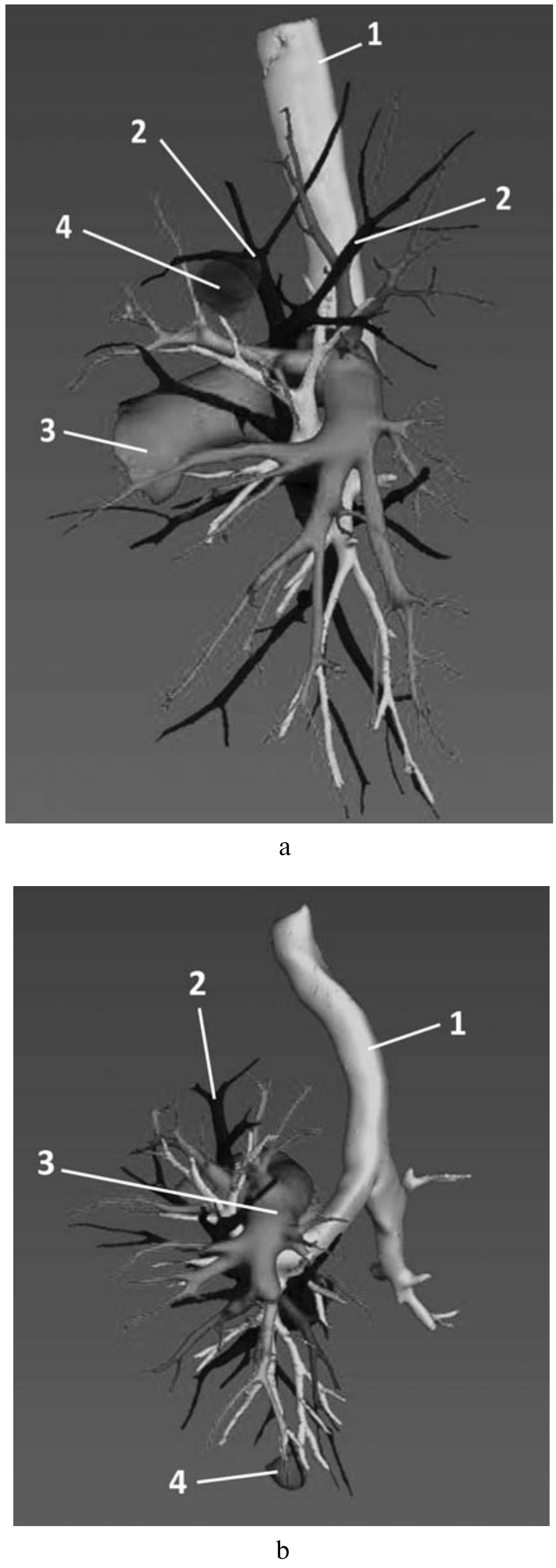

Fig. 1. **Images of mapped bronchovascular structures: bronchial tree (yellow), pulmonary veins (blue), pulmonary arteries (red), tumor (green);**

a — tumor is located in S3 segment, arteries A1+2 and A3 are assigned by separate colors; b — tumor is located in S10 segment, arteries A8, A9 and A10 are assigned separate colors.

Methods for determining the intersegmental boundaries

Ventilation method. Intersection of segmental bronchus was followed by insertion of Foley catheter into dis-

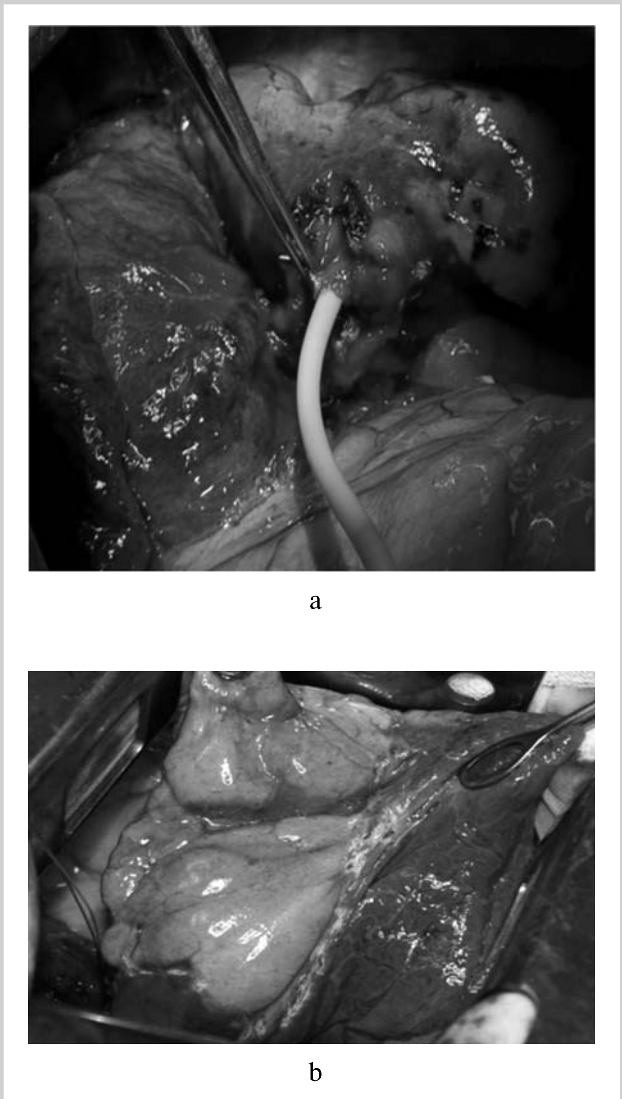

Fig. 2. **Intraoperative images of ventilation technique for determining the intersegmental boundaries.**

a — air insufflation into segmental bronchus through a Foley catheter; b — boundaries of the segment being removed filled with air.

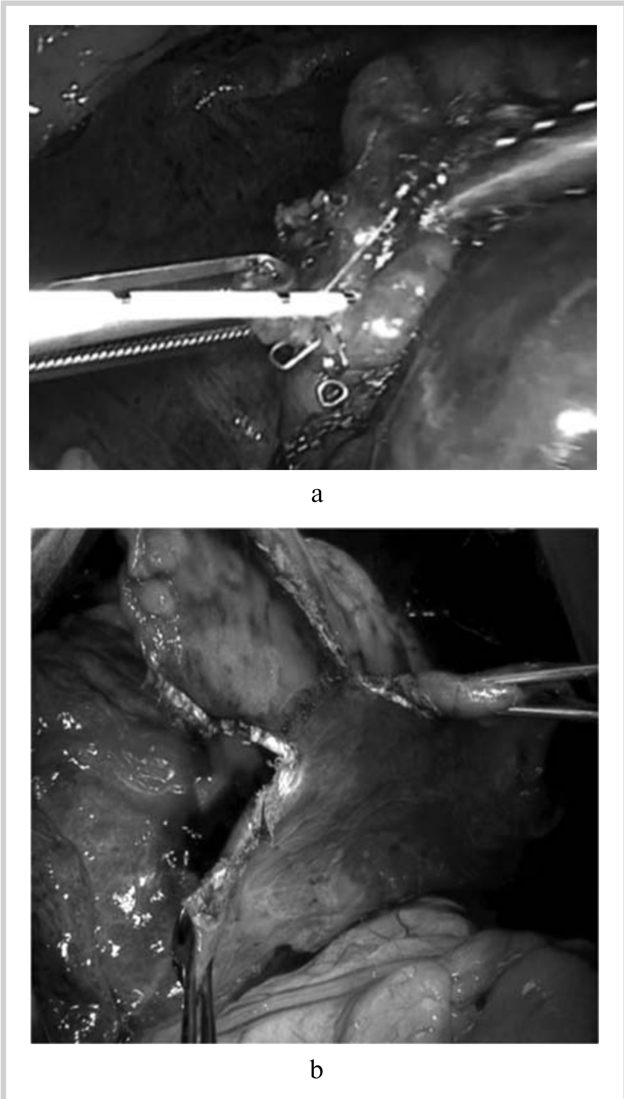

Fig. 3. **Intraoperative images of ventilation technique for determining the intersegmental boundaries during thoracoscopy.**

a — air insufflation through a needle inserted into sutured segmental bronchus; b — pulmonary parenchyma dissection by a coagulator in accordance with the boundaries of the segment.

tal bronchial stump with subsequent inflation of the cuff **(Fig. 2, a)**. Catheter was held using tweezers or soft clamp to prevent its dislocation. We performed air insufflation into the lumen of the bronchus through the catheter using insufflator, Janet's syringe or medical pear. Inflated lung segment acquired a pink color and was lighter in comparison with surrounding collapsed lung. Inflation-deflation line corresponding to intersegmental plane was clearly determined **(Fig. 2, b)**.

Above-mentioned technique was protected by the patent for invention No. 0002635860: «A method for determining the intersegmental border during segmentectomy in patients with lung malignancies» [15].

In case of thoracoscopic sublobar anatomical lung resection, intersegmental border was determined by air insufflation into lung segment using with long endoscopic needle and syringe. The needle was tangentially inserted into distal stump of the segmental bronchus after its previous suturing and intersection by endoscopic stapler **(Fig. 3)**.

Perfusion method with indocyanine green (ICG)

This method implies determination of the boundaries between perfused and non-perfused segments by systemic injection of special dye (indocyanine green — ICG) through central or peripheral vein. After intersection of segmental vessels and bronchus, the dye injected into systemic circulation resulted fluorescence in perfused lung segment. Luminescence is absent in the removed segment because ICG does not permeate parenchyma in this area **(Fig. 4)**. This method does not require lung ventilation,

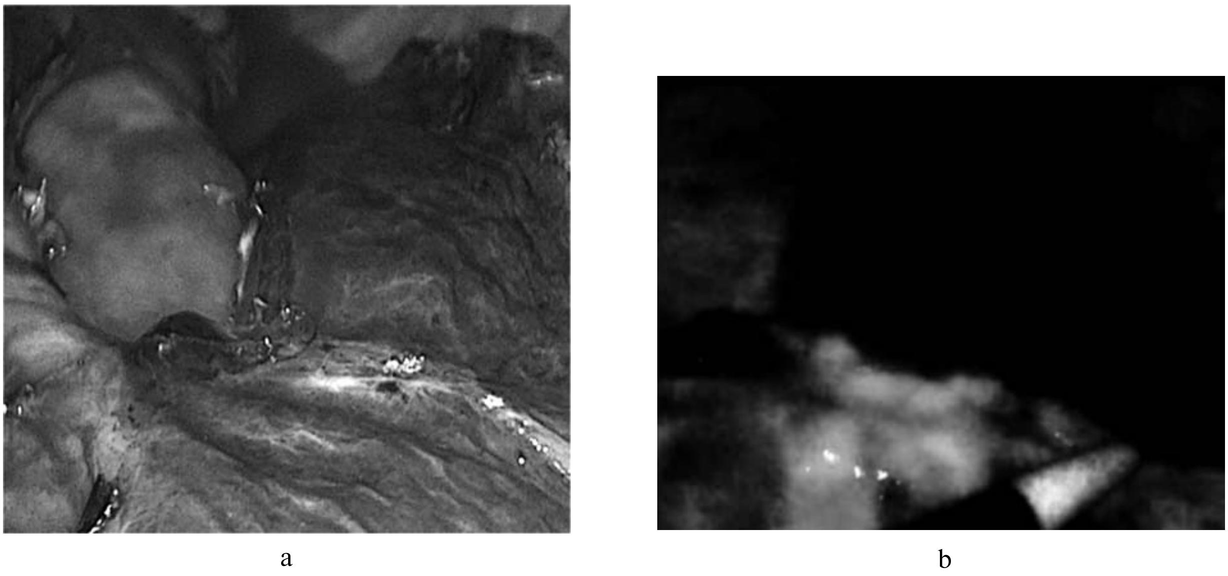

Fig. 4. **Intraoperative image of determining the intersegmental boundaries during S6 segmentectomy in normal light (a) and near infrared range (b)**

Table 2. **Incidence and severity of postoperative complications**

Complication	Number of patients, %		*p*-value
	segmentectomy	lobectomy	
Air leakage	3 (6.52)	2 (4.35)	
Pneumonia	1 (2.17)		
Atrial fibrillation		1 (2.17)	
Postoperative wound suppuration		1 (2.17)	
Maximum TMM grade	3a	3b	
In all	4 (8.69)	3 (6.52)	0.320

Note. TMM — Thoracic Mortality and Morbidity score (scale for mortality and complication severity in thoracic surgery).

that significantly improves thoracoscopic visualization especially in case of severe pulmonary emphysema.

Results

There were no deaths in both groups. Complications grade 3a by Thoracic Mortality and Morbidity scoring system (TMM) were the most severe in our sample. Adverse events occurred in 4 (8.69%) and 3 (6.52%, p=0.320) patients after segmentectomy and lobectomy, respectively. Significant differences were absent **(Table 2)**.

The main complication (air leakage for over 7 days) was noted in 3 patients after segmentectomy and in 2 patients after lobectomy. Mean length of postoperative hospital-stay was 8 days in both groups (range 5—14). Video-assisted segmentectomy was performed in 36 (33%) patients. 3D-modeling with separation of bronchovascular structures resulted increase of the percentage of complex anatomical sublobar resections and thoracoscopic surgeries (from 13.5 to 31.3%; p=0.144 and from 11.5 to 50.0%; p=0.038, respectively).

There was similar 5-year survival after segmentectomy and lobectomy for NSCLC stage IA1-2 with tumor size <2 cm (82% vs. 86%; p=0.652) **(Fig. 5)**.

Conclusion

Segmentectomy is organ-sparing procedure in patients with early forms of primary lung malignancies. Sublobar anatomical resection and lobectomy result similar early and long-term outcomes in patients with NSCLC stage IA1—2, T1a-bN0M0. Radical surgical technique of sub-

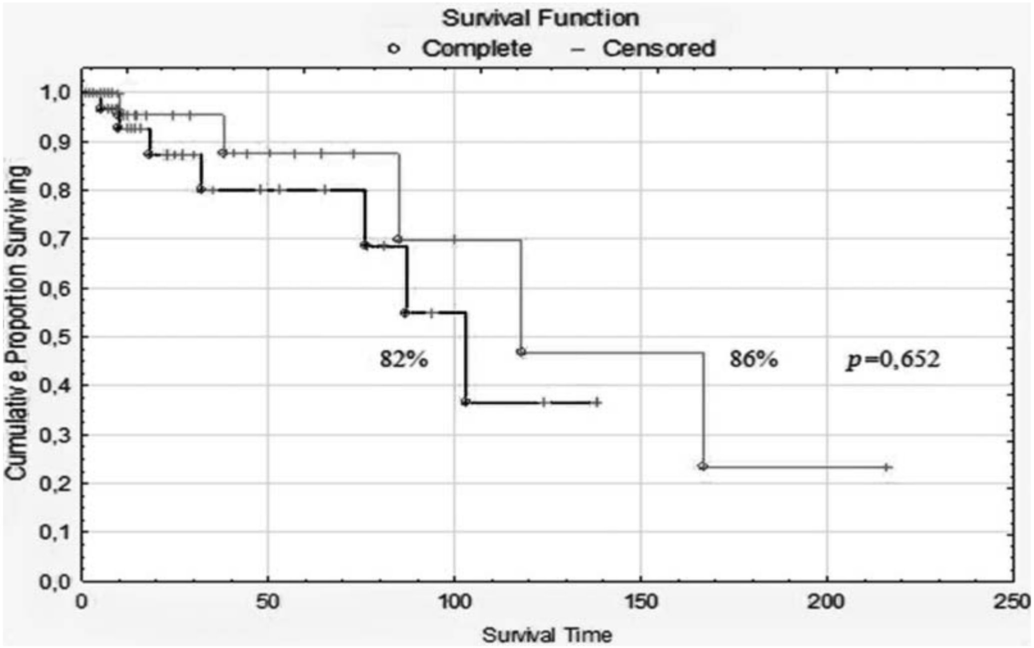

Fig. 5. **Kaplan—Meier overall survival after lobectomy (▬) and segmentectomy (▬).**

lobar anatomical resection is associated with preservation of pulmonary parenchyma and respiratory function. Preoperative 3D-CT reconstruction of vascular and bronchial architectonics of lungs ensures optimal individual planning of sublobar resections, especially in case of thoracoscopic and video-assisted approach.

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Amiraliev AM, Pikin OV, Ryabov AB, Glushko VA, Kolbanov KI, Vursol DA, Bagrov VA, Barmin VV. Patent RF na isobretenie No 2635860/6.11.17. Bull. No 32. Sposob opredeleniya mezhsegmentaroy granitsi pri segmentektomii u bolnykh zlokachestvennymi novoobrazovaniyami legkikh.

Поступила 00.00.19
Received 00.00.19
Принята в печать 00.00.19
Accepted 00.00.19