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Single Port Thoracoscopic Anatomic Segmentectomy: Three-Year Experience

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Abstract

Objective: To evaluate the safety and feasibility of single port thoracoscopic anatomic segmentectomy in the treatment of pulmonary diseases.

Methods: Clinical data of 161 consecutive patients undergoing single port thoracoscopic anatomic segmentectomy from May 2014 to June 2017 were retrospectively analyzed.

Results: There were 51 male and 110 female, aged 57.76 years on average (28-85 years). The mean operation time was 130 (35-280) min. The mean intraoperative hemorrhage volume was 47.5 (5-400) ml. The mean postoperative extubation time was 3.16 (1-9) d. The mean postoperative length of hospital stay was 4.63 (2-20) d. One case was switched to open surgery intraoperatively. No patient died during postoperative 30 d. Among them, 134 patients underwent simple segmentectomy, 15 receiving combined segmentectomy, 8 undergoing segmentectomy combined with lobectomy and 4 receiving sub-segmentectomy. Among them, 153 patients were diagnosed with non-small cell lung cancer and 8 with benign lung diseases. The incidence of postoperative complications was 6.8% mainly including pulmonary air leakage and pulmonary infection.

Conclusion: Single port thoracoscopic anatomic segmentectomy is a safe and feasible approach for lung diseases. Single port thoracoscopic anatomic segmentectomy combined with systematic lymph node dissection or sampling serves as one of the options for the treatment of early lung cancer.

Keywords: Single port; Thoracoscopy; Anatomic pulmonary segmentectomy

Introduction

In 1939, Churchill and Belsey [1] first applied segmentectomy to treat bronchiectasis. In 1973, it was first applied for the treatment of lung cancer [2]. Recently, multiple retrospective studies have demonstrated that the recurrence rate of malignant tumors and long-term survival rate do not significantly differ between anatomic pulmonary segmentectomy and lobectomy in the treatment of stage I lung cancer [3-5,15]. In recent years, single-port thoracoscopy is an emerging endoscopic technique. Current researches have suggested that compared with the multi-port thoracoscopy, single-port thoracoscopy yields similar clinical efficacy whereas induces less surgical trauma and faster postoperative recovery [6,7]. In our hospital, single-port thoracoscopic resection of the pulmonary lobe and segment and sleeve-shaped surgery have been performed. From May 2014 to June 2017, clinical data of 161 patients undergoing single port thoracoscopic anatomic segmentectomy were retrospectively analyzed to evaluate the safety and feasibility in the treatment of lung diseases.

Subjects and Methods

Subjects

From May 2014 to June 2017, single port thoracoscopic anatomic segmentectomy was conducted in 161 cases. Relevant clinical data included gender, age, preoperative comorbidities, preoperative examinations, operation time, intraoperative hemorrhage volume, quantity of lymph node dissection, postoperative drainage, and postoperative length of hospital stay, postoperative complications, postoperative pathological status and 30-d postoperative mortality rate. Among 161 patients undergoing thoracoscopic anatomic segmentectomy, 51 cases were male and 110 female, aged 57.76 years (28-85 years) on average.

Methods

Preoperative preparation: Routine preoperative examinations included electrocardiogram,

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Figure 1: Routine CT medical examination of a 44-year-old female revealed a mix 6mm GGO nodule within the right S6.

Figure 2: Osirix was utilized for three dimensional reconstruction of the pulmonary artery, vein and bronchia. The A^6, B^6 and V^6a are showed.

lung function test and enhanced chest CT scan. In partial patients, three dimensional CT reconstruction was performed to identify the incidence of anatomical changes of the vessels and bronchia in the target segment. The patients initially diagnosed with lung cancer received routine head MRI and systemic radionuclide bone imaging or PET-CT to exclude the possibility of extra-pulmonary metastasis.

Surgical methods: All patients underwent double-lumen endotracheal intubation under general aneasthesia, lung ventilation on the normal side in a lateral decubitus position. A 3-4 cm incision was created in the 4^{th} or 5^{th} intercostal space between anterior axillary line and midaxillary line. Electrocautery hook and harmonic scalpel (Johnson & Johnson, USA) were utilized to isolate the vein, artery and bronchia of the target segments and incisional closure was conducted by the endoscopic linear stapling device. The Electrocautery hook, harmonic scalpel or stapling device was utilized to process the planes between lung segments. The follow items should be cautioned intraoperatively. First, adequate incisional margins should be guaranteed. The incisional margin should be >2 cm or exceed the diameter of malignant tumors. If the incisional margins were insufficient, combined segmentectomy or pulmonary lobectomy should be performed. Second, the middle mediastinum, lung hilus, inter-lobe, inter-segment lymph nodes, target segments and incisional margins were prepared for frozen pathological section. If the lymph nodes were positive, the scheduled segmentectomy should be substituted by lobectomy.

Results

The distribution of the resected pulmonary segments in 161 patients undergoing single port thoracoscopic anatomic segmentectomy was illustrated in Table 1. Among 161 cases, 8 were benign and 153 were malignant. The pathological outcomes were illustrated in Table 2. Among 161 surgeries, the mean operation

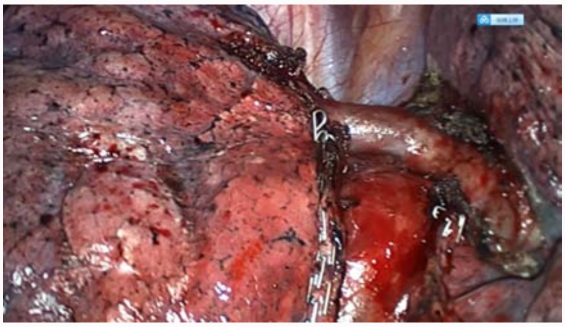

Figure 3a: This patient had two vessels of A^6, when the fissure between S^2 and S^6 was cut, the first A^6 was exposed.

Figure 3b: The other A^6 was exposed.

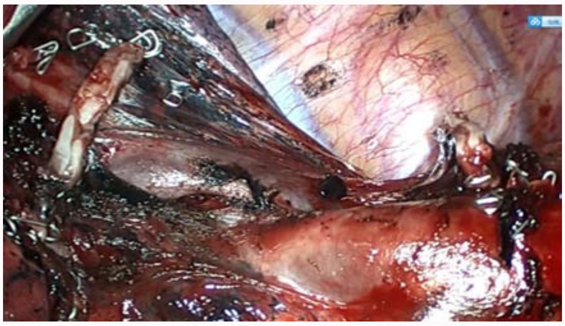

Figure 3c: After the B^6 was cut, the V^6a was exposed.

time was 130 (35-280) min. The mean intraoperative hemorrhage volume was 47.5 (5-400) ml. No case received intraoperative and postoperative blood transfusion. The mean postoperative of thoracic drainage time was 3.16 (1-9) d. The mean postoperative length of hospital stay was 4.6 (2-20) d. Relevant results among different types of surgeries were illustrated in Table 3. The apicoposterior segment of the left upper lung, the lingular segment of the left upper lung and the basal segment of the lower lobe were included into the simple segmentectomy group for statistical analysis.

In this study, the incidence of postoperative complications was 6.8%, illustrated in Table 4. No patient died at postoperative 30 d.

Discussion

Thoracoscopic segmentectomy was reported in 1993 for the first time. Raviaro et al. [8] from Italy reported the first case of thoracoscope-assisted small incision segmentectomy worldwide. In 2004, total thoracoscope-assisted segmentectomy was first applied to treat lung cancer [9]. At present, single-port thoracoscopic anatomic

Table 1: Distribution of the resected pulmonary segments.

Surgical type of the left lung	No. of cases (n)	Surgical type of the right lung	No. of cases (n)
S^{1+2}	31	S^{1}	22
S^{3}	3	S^{3}	4
S^{1+2+3}	28	S^{2}	7
S^{4+5}	7	S^{6}	15
S^{6}	12	S^{8}	4
S^{8}	3	S^{1+2}	3
S^{8+9}	1	S^{2+3}	1
S^{9+10}	1	S^{6+S8}	1
S^{8+9+10}	1	$S^{6}+S^{10}$	1
$S^{1+2}+S^{6}$	1	S^{7+8}	1
$S^{3+4+5}+S^{6}$	1	S^{6}+The upper lobe	2
S^{3}+the lower lobe	1	S^{1}+the lower lobe	2
S^{1+2}a	3	S^{2}+The lower lobe	1
S^{3}a	1	S^{6}+The middle lobe	2
S^{1+2}c+S^{4+5}	1		
Total	95	Total	66

Table 2: Pathological status.

Pathological type	No. of cases (n)	Percentage (%)
Lung cancer		
Carcinoma *in situ*	25	15.5
Adenocarcinoma	128	79.5
Benign diseases		
Sclerosingpneumocytoma	1	0.6
Pulmonary abscess	1	0.6
Chronic inflammation	2	1.2
Bronchogenic cyst	1	0.6
Hamartoma	1	0.6
Aspergillosis	2	1.2

segmentectomy has been gradually introduced at home and abroad. In this investigation, the inclusion criteria comply with international guidelines and standards.

The following indications should be strictly met: 1. Those aged>75 years; Those cannot tolerate lobectomy due to poor cardiopulmonary function or other complications (compromised resection). 2. Those with peripheral lung nodes ≤2 cm in diameter. At least one of the characteristics should be met: simple adenocarcinoma *in situ*, ground glass-like opacity (GGO) ≥ 50% detected by CT scan and

Table 4: Postoperative complications.

Type of complications	No. of cases (n)	Percentage (%)
Intraoperative hemorrhage		
Endoscopic vascular repairing	1	0.6
Switch to open surgery	1	0.6
Pulmonary infection	1	0.6
Pulmonary air leakage (>7 d)	2	1.2
Pneumohypoderma	3	1.8
Atrial fibrillation	2	1.2
Chylothorax	1	0.6
Total	11	6.8

the node doubling time ≥ 400 d by imaging diagnosis. 3. Those with solitary metastatic tumors or benign lesions which do not necessarily require lobectomy (relatively large lesions, deep lesions or the lesions constrained to the pulmonary segment); 4. Those with a medical history of pneumonectomy or multiple intra-pulmonary lesions which should be resected by multiple cycles of surgeries. The lung function should be retained as possible. Multiple carcinomas (compromised surgery).

Precise anatomy of the target pulmonary segments can be performed during anatomic pulmonary segmentectomy. In this study, the enrolled patients received routine preoperative chest contrast-enhanced CT scan. For a majority of cases, Deep Insight software or Osirix software was utilized for three dimensional reconstructions of the pulmonary artery, vein and bronchia. Partial lesions adjacent to intersegmental fissure were localized by CT-guided lung mass puncture. During the early stage of research, Hookwire needle was used for localization and metal spring coil was utilized during the late stage of the study [16]. The latter technique yields mild injury, mitigates the pain, is well tolerated and properly fixed. Figure 1-3 show one example of lung cancer that was resected via single port thoracoscopic anatomic segmentectomy.

Selection of surgical incisions: during the early stage of research, the incisions were created in the 4th intercostal space between anterior axillary line and the midaxillary line during the surgery of the upper lobe of the left lung. During the surgeries of other lung lobes, the incisions were made in the 5th space between intercostal anterior axillary line and the midaxillary line. The 4th intercostal incisions allows for convenient processing of the anterior artery at the apex of the left upper lung. Along with the maturation of the surgical technologies, the surgical incisions have been gradually transited and fixed to the 5th intercostal site during routine lung surgery. This position is located at the middle point between the upper and lower

Table 3: Relevant results among different types of surgeries.

Surgical type	No. of cases (n)	Operation time (min)	Hemorrhage volume (ml)	Drainage volume at postoperative 1 d (ml)	Extubation time (d)	Postoperative length of hospital stay (d)
Segmentectomy	134	125	45.5	246	3	4.3
Combined with segmentectomy	15	159.7	52.7	270	4.5	5.6
P		0.001	0.568	0.551	<0.01	0.01
Segmentectomy combined with lobectomy	8	199.2	85	340	4.5	7.6
P		<0.01	0.061	0.106	0.005	0.122
Sub-segmentectomy	4	101.7	20	221	2.5	4.25
P		0.199	0.374	0.769	0.529	0.914

The result of p-value is compared with simple segmentectomy group fissure and the oblique fissure, which allows for convenient access to each position and anatomical structure within the thoracic cavity.

Processing of anatomical structures: Pulmonary segments possess respective bronchia, pulmonary artery and vein, constantly accompanied by deformity and changes. However, the lung tissues between two lung segments are connected without anatomic isolation plane. Comparatively, the morphology of pulmonary artery and bronchia is almost stable with slight variations. The pulmonary artery was accompanied by the bronchia, which can be mutually referenced. Combined with preoperative CT scan and three dimensional reconstructions, the tissues in the target segments can be identified and determined. The main branches of the pulmonary segmental veins stretch among the pulmonary segments, which are known as inter-segmental veins accompanied with intra-segmental veins stretching within the pulmonary segments and among the sub-segments. When processing pulmonary segmental veins, intra-segmental veins should be cut off and inter-segmental veins stretching between the target segment and adjacent pulmonary segments should be preserved as possible. If the inter-segmental veins could not be identified, the target segments of each inter-segmental vein should be isolated to the distal end. After the inter-segmental interface was determined, inter-segmental veins along with lung parenchyma were excised to avoid injury and misdiagnosis.

In this study, the following approaches were adopted to determine the inter-segmental phones: first, lung insufflation: the lung was insufflated after the clamping of the bronchia of the target segments to determine the unaffected pulmonary segments; Second, collapse of the insufflated lung: the lung was insufflated initially, followed by unilateral lung ventilation after the bronchia of the target segments were clamped. The other pulmonary segments were collapsed, which formed boundaries with the insufflated target lung segments. Throughout this process, it was recommended to utilize pure oxygen for lung insufflation because the exchange and absorption rates of oxygen were higher than those of nitrogen. Use of pure oxygen could reduce the collapse speed of the other pulmonary segments. Third, bronchial injection method: initially, the lung tissues were collapsed, the bronchia of the target segments were excised, and subsequently a syringe was used to inflate the bronchia of the target segments to expand the lung tissues; Fourth, if the lung tissue boundaries of the target segments could not be determined by using the methods above, the lung tissues of the target segments could be excised according to the anatomical position of preoperative reconstruction outcomes.

Processing of inter-segmental plane: first, electro-scalpel and harmonic scalpel were used to incise the inter-segmental interface. Second, stapling device was utilized to incise the inter-segmental interface. Third, both two methods were adopted. Ohtsuka T et al. [12] comparatively analyzed the electro-scalpel and electro-scalpel combined with stapling device and demonstrated that the incidence of postoperative pulmonary air leakage was increased and the surgical expense was decreased in the electro-scalpel alone group compared with the combined group. No statistical significance was noted in the loss of lung function, postoperative indwelling time and length of hospital stay between two groups. Tao H statistically compared the stapling device with electro-scalpel combined with stapling device and revealed no statistical significance in the loss of lung function between two approaches [11]. In this study, electro-scalpel, harmonic scalpel and stapling device were collectively utilized to process the inter-segmental plane. Under normal circumstances, electro-scalpel and harmonic scalpel were used to process the tissues adjacent to the lung hilus, and stapling device was utilized for the tissues surrounding visceral peritoneum. For individual cases, merely one of the electro-scalpel, harmonic scalpel and stapling device was utilized. Nevertheless, the effect of different methods upon the time of postoperative pulmonary air leakage and long-term lung function remains to be elucidated. Pleural suture or pravastatin + biological glue was performed to treat the air leakage of the inter-segmental plane after isolation. Saito H et al. [13] retrospectively analyzed these two approaches in 133 patients and concluded that pleural suture was superior in terms of postoperative pulmonary air leakage and could shorten the air leakage time. No statistical significance was observed in the lung function at postoperative 1 and 6 months between two approaches. In this study, pleural suture or pravastatin + biological glue was adopted based upon specific circumstances. Pleural suture was mainly adopted for severe air leakage, whereas pravastatin + biological glue was chosen for slight air leakage or air leakage adjacent to the pulmonary segmental root.

In this study, pulmonary segmentectomy alone was adopted in a majority of patients, and combined pulmonary segmentectomy and pulmonary segmentectomy in combination with lobectomy were performed in a minority of cases. Pulmonary segmentectomy alone basically covered all types of common lung segments. All patients successfully completed the surgery and recovered. The operation time, intraoperative hemorrhage volume, postoperative extubation time and postoperative length of hospital stay were the least in the pulmonary segmentectomy group, whereas the most in the segmentectomy combined with lobectomy group, which were almost consistent with the quantity of intraoperative structural treatment and trauma size.

During the late stage of this study, sub-segmentectomy was performed in 5 cases. Four patients underwent sub-segmentectomy alone including 3 sub-segmentectomy of the apicoposterior segment of the left upper lung and 1 sub-segmentectomy of the anterior segment of the left upper lung. Another case received sub-segmentectomy of the lingular segment combined with the apicoposterior segment of the left upper lung, who was included into the combined segmentectomy group. Sub-segmentectomy was selected after careful consideration and full preparation. First, surgical experience was accumulated after daily surgery and over 100 segmentectomy. Second, sub-segmentectomy was gradually applied along with the development of minimally invasive surgery. In this study, we chose patients with early-stage lesions which were limited to specific sub-pulmonary segments. Prior to sub-segmentectomy, three dimensional reconstruction was performed to identify anatomical lung structures and localize the lesions. Intraoperative procedures of sub-segmentectomy were almost identical to those of segmentectomy, in which the artery, bronchia and intra-segmental vein could be precisely excised. All cases successfully completed the surgery and recovered. The operation time, intraoperative hemorrhage volume, postoperative extubation time and postoperative length of hospital stay were superior to those in the pulmonary segmentectomy alone group.

Intraoperative hemorrhage, switch to open surgery and postoperative complication: in this investigation, 2 patients presented with pulmonary arterial injury and hemorrhage. One case received endoscopic vascular repairing and the other was switched to open surgery. Approximately 5.5% of the patients suffered from postoperative complications including pulmonary air leakage, pneumohypoderma and chylothorax, which were healed after active treatment. Compared with non-single port thoracoscopic technique, the incidence rates of intraoperative hemorrhage, switch to open surgery and postoperative complications were not increased.

Taken together, single-port thoracoscopic technique is relatively mature, safe and feasible and inclined to become the mainstream technique. We consider that any anatomic pulmonary segmentectomy can be accomplished under single-port thoracoscope. There are several limitations to be acknowledged. The sample size is relatively small due to strict criteria of surgical indications. The follow-up time is short. The random control group is lacking. The conclusion obtained from this investigation remains to be validated by subsequent research with large sample size.

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