Division of the intersegmental plane during thoracoscopic segmentectomy: is stapling an issue?

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Background: Stapling is becoming the method of choice for dividing the intersegmental plane during thoracoscopic segmentectomies. The technique however is controversial as it can impair re-expansion of preserved segments. We have analyzed the morbidity and lung re-expansion on a series of 175 thoracoscopic segmentectomies.

Methods: A total of 175 patients underwent a thoracoscopic anatomic segmentectomy. Ten patients were excluded due to conversion into thoracotomy. There were 89 females (54%) and 76 males (46%). Mean age was 63 years (range, 18–83 years). Indications for segmentectomy were as follows: primary lung cancer (n=100, 61%), metastases (n=27, 16%), benign non-infectious lesions (n=20, 12%) and benign infectious lesions (n=18, 11%). The intersegmental plane was divided with an endostapler in all patients. Lung re-expansion assessment included chest roentgenograms at discharge and at one-month consultation.

Results: The overall complication rate was 17%. There were 0.6% major complications and 16% minor complications. The average duration of drainage was 3 days (range, 1–13 days) and average length of stay was 5.7 days (range, 2–22 days). At discharge and at 1-month follow-up chest radiography, incomplete lung re-expansion was observed in 12 (7.4%) and 4 patients (2.8%) respectively. Patients who underwent upper lobe segmentectomy had significantly more incomplete re-expansion at discharge and at 1-month follow-up. On univariate analysis, mean drainage duration was significantly longer in patients who underwent upper segmentectomy (mean 3.7 days; range, 1–13) than those who underwent lower segmentectomy (mean 2.7 days; range, 1–5).

Conclusions: Although stapling of the intersegmental plane most likely slightly impairs lung re-expansion, clinical and radiological consequences are minimal.

Keywords: Segmentectomy; thoracoscopy; techniques

Introduction

Although pulmonary lobectomy remains the standard treatment of operable early stage non-small cell lung cancer (NSCLC) (1), the interest for anatomic segmentectomy has grown over the past years as many elderly and/or fragile patients cannot tolerate a lobectomy but can undergo a sublobar resection, especially if performed without thoracotomy (2). For patients presenting with metastases or benign lesions, the need for sparing valid parenchyma is even more important and a thoracoscopic limited sublobar resection is more and more considered as the procedure of choice. However, segmentectomies are considered technically challenging, especially when performed by
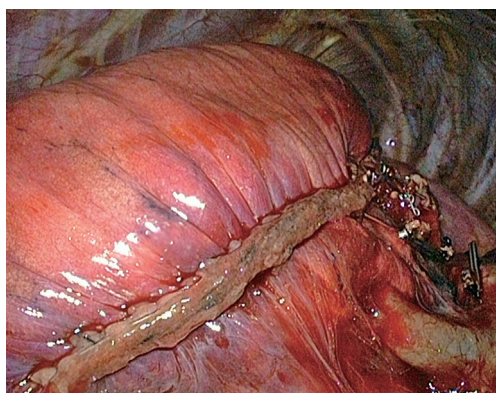
Figure 1 Example of plication of the parenchyma of the lingula after stapling the intersegmental plane during a left upper lobe trisegmentectomy.

thoracoscopy. One of the most problematic steps of the operation is the division of the intersegmental plane. As the surgeon cannot rely on digital handling as he/she would do during an open peeling technique, stapling the demarcation line is becoming the preferred method. However, the use of stapling is criticized as it can plicate the parenchyma of the preserved segments (*Figure 1*), leading loosing valid parenchyma and impairing pulmonary re-expansion (3). Asakura *et al.* noted that stapling interferes with the expansion of preserved lung in comparison to mere cutting with scissors due to the visceral pleura being caught in the staple line (3). It is unclear whether this issue has any impact on the postoperative course, some authors claiming they did not noticed any difference when comparing stapling to other methods of dividing the intersegmental plane (4). For this reason, we have analyzed two postoperative features, i.e., postoperative air leak and pulmonary re-expansion, in our series of thoracoscopic segmentectomies where the intersegmental plane was divided with an endostapler.

Methods

The records of a consecutive series of 175 thoracoscopic anatomic pulmonary segmentectomies were reviewed. The study was approved by our Institutional Review Board N° 2012-10.

Technical aspects

A full thoracoscopic approach was used to perform all segmentectomies of this series, according to a previously reported technique (5). Briefly, we used a deflectable scope housing a distal charged-coupled device connected to a high-definition camera. Only endoscopic instruments were used. These were inserted through 3 to 4 trocars, according to the necessity of dissection or exposure. No utility incision was used. On completion of the pulmonary resection, the specimen was placed into an endobag and retrieved through one of the port sites that was enlarged to a length of 2 to 4 cm, depending on specimen size. The control of large vessels was accomplished with endostaplers while haemostasis of small-calibre vessels was performed with clips or with a bipolar vessel-sealing device or with a combination of both. Demarcation between the resected and preserved segments was made possible by re-ventilation. The demarcation line was marked with cautery dots and a dedicated long and narrow lung forceps was applied on the parenchyma, in order to compress it and ease the application of the stapler. In all patients division of the intersegmental plane and of the fissure was made using endostaplers of two types: before 2011 regular 4.8 mm staples (Endo-GIA, Covidien©, Plymouth, MN, USA) were used while after 2011, cartridges including staples ranging from 4.3 to 5.0 mm (Tri-stapled technology, Covidien©) were used.

For patients operated on for lung cancer, intersegmental lymph nodes, if present, were analysed by frozen section to confirm segmentectomy (if malignant, the procedure was converted into a lobectomy). An additional radical mediastinal lymphadenectomy was performed in all patients. The bronchus stump and portion of the staple line adjacent to the nodule were also examined by frozen section if close to the tumour. If margins were positive or doubtful, the procedure was transformed into lobectomy. Those patients are not included in this study.

Data analysis

The series was analyzed retrospectively from a prospectively collected data which was approved by our IRB (CEPAR 2013-002) including demographic criteria, type of resection, diagnosis, duration of surgery and blood loss, chest tube duration, hospital stay duration and complications. Lung re-expansion assessment included chest roentgenograms at discharge and at one-month consultation. The chest X-rays of each patient were included into the database and analyzed by an independent observer. Digital radiography (Picture-Archiving Communication System, PACS) workstation

Table 1 Demographic characteristics (165 patients)

Variable	n	%
Age, years		
Mean: 63 (range, 18–83)		
<70	52	32
≥70	113	68
Gender		
Female	89	54
Male	76	46
Indications		
Non-small cell lung cancer	100	61
Metastasis	27	16
Benign non-infectious lesion	20	12
Benign infectious lesion	18	11

Table 2 Types of segmentectomy (N=165)

Types	n	%
Right =78 procedures		
Upper lobe		
S1+2	38	23
S3	1	0.6
Lower lobe		
Basilar segments	18	11
S6	17	10
S7 + S8	2	1.2
S8	1	0.6
S9 + S10	1	0.6
Left =87 procedures		
Upper lobe		
S1+2	13	8
Lingula sparing	16	10
Lingula	12	7
S2	1	0.6
Lower lobe		
Basilar segments	16	10
S6	23	14
S9+10	6	4

was used for image review. Cursor auxiliary function enabled to estimate the shift of the pleural line. The size of pneumothorax was determined as the measure of the longest axis from lung margin to chest wall.

Statistical analysis

The statistical analysis was performed using SPSS 17.0 software (Chicago, IL, USA). Unless otherwise specified, continuous variables were expressed as mean + range and categorical variables as percentages. Between-group comparisons were performed using the χ^2 test for qualitative variables or Fisher's exact test when needed. To compare multiple categorical variables one-way analysis of variance was adopted. A P value <0.05 was considered statistically significant.

Results

Between 2007 and 2014, 175 thoracoscopic anatomic segmentectomies were performed in our department. Out of these patients, 10 (5.7%) were excluded from our study because of conversion to thoracotomy for the following reasons: vascular injury in 6 cases, nodule not found in 3 patients, and ischemia of adjacent segments in 1 patient.

Among the 165 remaining patients, there were 89 females (54%) and 76 males (46%), with a mean age of 63 years (range, 18–83 years). Most of the patients (n=113, 68%) were 70 years or older. Indications for segmentectomy were as follows: primary lung cancer (n=100, 61%), metastases (n=27, 16%), benign lesions (n=20, 12%), and infectious lesions (n=18, 11%) (*Table 1*). The type of segmentectomy is reported in *Table 2*. We used the nomenclature of segmentectomies as described by Nomori and Okada (6). Intraoperative adverse events occurred in 8 (5%) patients. There were four cases of stapling line disruption that required endoscopic suturing, all occurring with the use of regular 4.8 mm staples (no disruption was noticed after the introduction of black cartridges with 3-staples technology), 1 case of venous injury during a S^{7+8} segmentectomy, 1 arterial branch injury caused by the application of a vascular clip. All these adverse events complications were managed thoracoscopically. There were two conversions from a planned S8 and S^{7+8} resection to a basilar segmentectomy because of invaded resection margin at frozen section. The overall postoperative complication rate was 17%. There was 1 (0.6%) major complication consisting of acute respiratory failure due to pulmonary edema requiring non-invasive mechanical ventilation. Minor complications occurred in 27 patients (16%) and were mainly of respiratory order: 7 prolonged air leaks (PALs), 3 pneumothorax, 3 pneumonia, 2 atelectasis requiring bronchoscopy, 2 subcutaneous emphysema and other complications in 10 (4 atrial fibrillation, 2 renal failure, 2 pulmonary embolism, 1 hepatic

Table 3 Number of patients with incomplete re-expansion at discharge and at one month follow-up chest X-ray

Control chest X-ray	Incomplete re-expansion, n (%)
At discharge (N=165)	12 (7.2)
At 1-month consultation (N=162)	4 (2.5)

Table 4 Relationship between type of segmentectomy and incomplete lung re-expansion

Control chest X-ray	Upper segment, n (%)	Lower segment, n (%)	P value
At discharge	10 (6.1)	1 (1.2)	<0.01
At 1-month follow-up	4 (2.8)	0 (0)	0.04

Table 5 Measure of incomplete re-expansion by segmentectomy at discharge and at one-month consultation

Patient	Segmentectomy	At discharge (cm)	At one month (cm)
1	Right S6	2	0
2	Right S1+2	1.5	0
3	Right S1+2	4	3.96
4	Left S1+2 + S3	2	0
5	Right basilar segments	1.35	0
6	Right S1+2	1.12	0
7	Right S1+2	1.41	0
8	Left S1+2 + S3	4.12	2
9	Right S1+2	1.6	1.8
10	Right S1+2	1.41	0
11	Right S1+2	3.66	2
12	Left S1+2 + S3	1.92	0

failure and 1 thrombocytopenia). The mean duration of surgery was 162 minutes (range, 50–315 minutes) and the mean blood loss was 74 mL (range, 0–450 mL). The mean drainage duration was 3 days (range, 1–13 days) and mean stay 5.7 days (range, 2–22 days).

Prolonged air leaks

PALS, defined as air leaking lasting 7 or more days, are observed after any type of lung resection. They can be related with the condition of pulmonary parenchyma or with technical issues. In order avoiding underestimation of our complication rate, we did consider that all PALs could be more or less related to the method used for division of the intersegmental plane. There were 7 PALs (4.2%), with a maximum chest tube duration of 13 days. None of the PALs required pleurodesis or reoperation.

Lung re-expansion

All patients had a chest roentgenogram at discharge. A not fully re-expanded lung was observed and measured in 10 patients (6%) as follows: 7 pneumothorax and 3 apical pleural effusions with measured average size of 2.2 cm (range, 1.1–4.1 cm).

At follow-up at 1 month, 3 patients were controlled at their referral institution and no chest X-ray was available. Out of the remaining 162 patients, there were only 4 cases of apical cap (2.5%), whose average size was 2.3 cm (range, 1.2–3.9 cm) (*Table 3*). All these 4 patients had prior non re-expanded lung at discharge.

Patients who underwent an upper lobe segmentectomy presented significantly more frequently with an incomplete re-expansion both at discharge (P<0.01) and at 1-month follow-up (P=0.04), compared to patients with lower lobe segmentectomy (*Table 4*). Descriptive data concerning the type of segmentectomy and measure of incomplete lung re-expansion are reflected in *Table 5*. In addition, on univariate analysis, the mean drainage duration was significantly longer (P<0.01) in patients who underwent upper segmentectomy (mean 3.7 days; range, 1–13) than those who underwent lower segmentectomy (mean 2.7 days; range, 1–5).

Discussion

Although lobectomy remains the gold standard resection in most NSCLC, many publications have stressed the interest of sublobar resection in ground glass opacities (GGO) and in clinical stage Ia carcinomas, especially in elderly and/or fragile patients (7). Sublobar resections spare more parenchyma than lobectomies and their postoperative course is usually easier and faster (2,8). In some metastatic lung diseases (9) and benign lesions (10) that are not amenable to wedge resection because they are deeply located or because of their close relationship to bronchovascular elements, an anatomic segmentectomy is the method of choice. Several studies have demonstrated that the outcome of sublobar resections is even better when the procedure is performed thoracoscopically. We have shown that a thoracoscopic approach for segmentectomy resulted in a significantly

shorter hospital stay and lower rate of complications (11). Similar results have been recently reported (2) and it has also been demonstrated that the thoracoscopic approach allows operating with a much lower FEV_1 than the one usually accepted for a thoracotomy (7).

However, mastering thoracoscopic segmentectomy can be technically challenging and identifying the anatomy and the intersegmental plane is of concern (12,13). Once the demarcation line has been identified, choosing the adequate method of division can also be a dilemma. The conventional way of dividing the intersegmental plane is to cut the parenchyma along the segmental vein. Until now, cutting was performed with electrocautery (and more recently with an electrothermal bipolar vessel sealing device), reinforced or not with fibrin sealant or covered or not with a mesh. This technique is supposed to preserve the parenchyma but is at risk of bleeding and air leaking. The rapid development of the thoracoscopic approach has favored the stapling method, which is considered as more straightforward. Stapling seems safer but could result in some loss of valid parenchyma with impaired lung re-expansion (3).

Studying this issue is difficult as there are few objective facts to compare. The studies can be based on experimental data obtained from *ex vivo* tissues, or on the measurement of pulmonary function, or on specific postoperative complications (mainly PALs) or on radiologic measurements of lung re-expansion as we did in this study.

Air leakage

Although stapling may have some limitations, it seems it causes less air leaks. In our series, we noticed 7 prolonged air leaks (4.2%) but none of them required pleurodesis or reoperation. All of them had predictive factors of prolonged air leakage (emphysema n=3, tuberculosis n=1, incomplete fissure n=3). Miyasaka *et al.* compared electrocautery and the use of staplers for dividing the intersegmental plane (4). All segmentectomies were performed by an open approach. Sample size was 49 patients, with 18 patients in the stapling group and 31 in the electrocautery group. Prolonged air leaks were observed in 4 patients (8.2%), all in the latter group (P=0.005). Three of these 4 patients had to undergo a chemical pleurodesis and one of them was reoperared for closing the air leak. In a series of 102 hybrid video assisted thoracic surgery (VATS) segmentectomy, electrocautery alone, i.e., without stapler, was used to divide the intersegmental plane and a fibrin sealant was applied along the raw surface of the remaining lung to prevent air leakage. PALs were observed in 4 patients (3.9%) and 3 (2.9%) had a late alveolo-pleural fistula requiring tube drainage (14). In our series, none of the 7 PALs (4.2%), required pleurodesis or reoperation. Ohtsuka *et al.* compared two groups of patients having the intersegmental plane divided by electrocautery alone and electrocautery combined with stapling (15). The incidence of PAL was higher in the group electrocautery alone than in the group combination of electrocautery and staplers [14% (3/22) *vs.* 4 % (1/25), P=0.025]. Thus, as mentioned by Miyasaka *et al.*, dividing the intersegmental plane by electrocautery may result in more prolonged air leaks (4). Besides, an indirect sign suggesting that splitting the intersegmental by electrocautery is a concern, is the number of studies dealing with reinforcement of the parenchymal plane by various types of sealant and/or mesh (15-18).

Lung re-expansion

Asakura *et al.* compared the lung expansion depending on the method used to develop the intersegmental plane based on an *ex vivo* swine model (3). The authors stated that stapler interferes with the expansion of preserved lung in comparison to scissors, or to a combination of scissors for thin parenchyma and stapler for thick parenchyma, due to the visceral pleura being caught in the staple line that causes atelectasis. The sample size for each group was limited (8, 8 and 3 respectively) so that no definite conclusion can be drawn from this work. Other surgeons recommend division of the intersegmental plane by electrocautery because it allows complete expansion of the residual segments (15,19). In our series, the overall rate of incomplete re-expansion at 1 month follow-up was finally limited (2.5%) and none of the patients has to undergo specific measure, such as chest drainage or reoperation. A higher incidence of incomplete lung re-expansion was noted when upper lobe segmentectomy was performed. It has been suggested that small alveolopleural fistulae may produce a low flow air leakage and thus, a neutral air space, that usually reabsorbs with gradual expansion. After lower lobe segmentectomy, those alveolopleural fistulae might be immediately covered by surrounding parenchyma, whereas, after upper lobe segmentectomy, the remaining raw lung surface remain exposed (20).

In addition our results for thoracoscopic segmentectomies compared favorably to our own institutional data on segmentectomies performed by thoracotomy where both the mean drainage duration and mean hospital stay were longer (11).

Other issues related with stapling

Stapling the intersegmental plane—despite advantages in terms of safety—is not yet the ideal method. Its handling is not that easy, especially in patients with narrow or small chest cavity. Loading thick tissues can be tedious, as their opening is still limited, and disruption of the staple line can occur (21), an adverse event that we faced four times in our series. The consequences were minimal, but led to troublesome blood loss and required hand suturing. This pitfall has been dramatically reduced with the availability of larger staples. Cost is another issue. Stapling costs more than other methods as it can require using many reloads, up to 5 in the series of Watanabe *et al.* (22)

Another theoretical concern is the non-preservation and/or compression of the intersegmental vein, which, according to Asakura *et al.*, could impair gas exchanges in the preserved segment (3). To our knowledge, this has not been demonstrated. Nakano *et al.* have suspected that some so-called stump consolidations, i.e., partial atelectasis, observed several months after thoracoscopic segmentectomies—10% in their series of 70 cases—could be related with misidentification of the intersegmental plane (19). Whether this complication is due to the technique for identification or to the stapling method, is not clear.

In conclusion, stapling the intersegmental plane can have some drawbacks (cost, difficult handling in some patients, parenchyma plication in the preserved segments), but clinical consequences are very limited. There are few prolonged air leaks and few incomplete pulmonary re-expansions, none of them leading to chest drainage or reoperation. Stapling seems to be an acceptable compromise in terms of safety.

Acknowledgements

Footnote

Conflicts of Interest: Dr. Gossot work as consultant for instrumentation manufacturer (Delacroix Chevalier Company). The other authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by our Institutional Review Board N° 2012-10.

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