Effect of cutting technique at the intersegmental plane during segmentectomy on expansion of the preserved segment: comparison between staplers and scissors in ex vivo pig lung

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Abstract

Objective: Cutting the intersegmental plane by using a stapler during segmentectomy might interfere with the expansion of the preserved lung due to visceral pleura caught in a staple line, especially in a large regional segmentectomy, such as left upper division or basal segmentectomy. We compared the preserved lung volume after segmentectomy among the methods using stapler, sharp dissection, and their combination for cutting the intersegmental plane in ex vivo pig lungs. We also examined a covering effect of polyglycolic acid mesh and fibrin glue. Methods: To assume a large regional segmentectomy in clinical practice, segments of the left caudal lobe except the lateral segment 2 (L2 segment) were resected, and the lung volume of the preserved L2 segment was measured. The intersegmental plane was cut by the following three methods: (1) stapler (n = 8); (2) scissors (n = 8); and (3) the combined method, that is, cutting the shallow lung tissue with scissors and the deep one with stapler (n = 8). The opened intersegmental plane was covered with polyglycolic acid mesh and fibrin glue. The air leakage was checked by injecting air through the bronchus at pressures of up to 30 cmH2O. Thereafter, normal saline was injected through the bronchus at pressures of 10, 20, and 30 cmH2O, to measure lung volumes by the volume-displacement method. Results: Polyglycolic acid mesh and fibrin glue prevented air leakage completely at up to 30 cmH2O. At the saline injection pressures of 10, 20, and 30 cmH2O, the mean volumes of L2 segment were 72 ± 14, 96 ± 14, and 109 ± 26 ml with the stapler; 86 ± 11, 117 ± 19, and 135 ± 39 ml with scissors; and 98 ± 10, 140 ± 20, and 155 ± 40 ml with the combined methods, respectively. The volume of the preserved L2 segment was significantly lower with the stapler method than with either the scissors or combined method at each pressure (p < 0.01). The difference was not significant between the scissors and combined methods. Conclusions: Coverage with polyglycolic acid mesh and fibrin glue prevented air leakage from the opened intersegmental plane. The stapler interferes with the expansion of preserved lung in comparison to scissors or combined methods in a large regional segmentectomy.

Keywords: Lung cancer; Segmentectomy; Pulmonary function; Air leakage

1. Introduction

With an increasing number of patients with small-sized non-small-cell lung cancer, the importance of pulmonary segmentectomy has been growing. Some Japanese surgeons have reported the superiority of segmentectomy over lobectomy for preserving pulmonary function [1,2], but others refute this [3], of which difference may relate to the method used to cut the intersegmental plane during segmentectomy, that is, using a stapler versus an electric scalpel. The advantages of the former are its simplicity and less postoperative air leakage, but it may interfere with lung expansion due to the visceral pleura caught in the staple line. Therefore, to expand the preserved lung sufficiently, some surgeons cut the intersegmental plane by using an electric scalpel along the intersegmental plane, which is depicted between the inflated segment and deflated one [4–8]. We previously reported that a large regional segmentectomy, such as a left upper division segmentectomy, and the resection of more than three segments, such as a basal segmentectomy, could not preserve sufficient pulmonary function [2]. Therefore, the cutting procedure for intersegmental plane would be critical for preserving pulmonary function, especially in large regional segmentectomy. However, the technique using an electric scalpel might cause postoperative air leakage from the opened intersegmental plane. While the deflated—inflated line at the intersegmental plane is sharply defined at the shallow lung tissue, it sometimes becomes blurred at the deep tissue. In addition, to take a sufficient margin from the tumor, the lung
should be frequently cut beyond the intersegmental plane, which also causes the air leakage. Therefore, even in the technique by using the electric scalpel, the stapler would be helpful for cutting deep intersegmental planes.

Therefore, the present experiment, using ex vivo pig lung, examined the following points: (1) whether or not the stapler method for cutting the whole lung tissue on intersegmental plane interferes with the expansion of preserved lung compared with that using scissors; and (2) whether or not the combined technique, that is, cutting the shallow lung tissue with scissors and the deep one with a stapler, interferes with the expansion of the preserved lung. To mimic a large regional segmentectomy in clinical practice, we removed all segments except the lateral segment 2 (L2 segment) from the left caudal lobe and measured the volume of the preserved L2 segment. In addition, to evaluate the usefulness of polyglycolic acid (PGA) mesh and fibrin glue for covering the intersegmental plane, pressure resistance test was also examined.

2. Materials and methods

2.1. Experimental protocol

The ex vivo left lungs obtained from slaughtered pigs, aged from 6 to 10 months and weighing approximately 100 kg, were used in the present study. The left lung consists of middle lobe and caudal lobe. Of these, the L2 segment is the largest segment (Fig. 1). To assume a large regional segmentectomy in clinical practice, all segments of the left caudal lobe except the L2 segment were resected, preserving the L2 segment. A flexible 12-Fr catheter was inserted into the L2 segmental bronchus, followed by ligation of the root of bronchus. Air was pumped into the catheter to create a border between the inflated L2 segment and deflated other lung tissue, as previously reported [4—7] (Fig. 2). The border between the inflated and deflated lung tissue was cut using the following three techniques: (1) stapler method (GIA: 6 cm in length and 4.8 mm in thickness; Covidien Co. USA) \((n=8)\); (2) scissors method \((n=8)\); and (3) combined method, that is, cutting more than half of the shallow border by scissors, followed by cutting the deep one by stapler \((n=8)\) (Fig. 3(A)–(C)). The intersegmental plane opened with scissors was covered with PGA mesh (Neoveil®, Kyoto Ika, Co., Kyoto, Japan) and fibrin glue (Bolheal®, The Chemo-Sero-Therapeutic Research Institute, Kumamoto, Japan), as reported previously (Fig. 3(D)) [9]. Briefly, a PGA mesh was used to completely cover the opened intersegmental plane, followed by coating with 1 ml each of fibrinogen and thrombin.

Prior to resection, the weight of the whole left lung and the L2 segment was measured to take into account the difference of lung size among the animals. The weight of the preserved L2 segment was measured after resection. Through the catheter inserted into the bronchus of L2 segment, air was injected to examine the air leakage before measuring lung volume. The air was injected consistently at the pressures of 10, 20, and 30 cmH2O while dripping saline on the intersegmental plane to check for the absence of air bubbles. The absence of air leakage was mandatory for the accuracy of the following measurement of lung volume.

Fig. 1. Schematic lateral aspect of the pig left lung. The left caudal lobe consists of dorsal segments 2—7, medial segments 4 and 5, ventral segments 2—5, and the lateral segments 2—6. Dorsal and medial segments cannot be seen in the lateral aspect.

Because the lung inflated with air could not be submerged in water for measurement of lung volume by the volume-displacement method [10], we injected normal saline into the segmental bronchus after checking air leakage. Normal saline was injected into L2 segmental bronchus at pressures of 10, 20, and 30 cmH2O. The lung volume at each pressure was measured by the volume-displacement method. The volume/weight ratio of the L2 segment at each pressure was calculated as follows: volume of L2 segment with infusion of saline (ml)/weight of L2 segment before infusion of normal saline (g). Lung expansion around the intersegmental plane was also compared macroscopically among the three methods.

All animal studies were approved by the School of Medicine, Keio University Institutional Animal Care and Use Committee, and were carried out in accordance with the Guide for the Care and Use of Laboratory Animals published by the National Academies Press.

2.2. Statistical analysis

Data are expressed as means ± standard deviations. The data for each method were compared by the Mann–Whitney
The p value < 0.01 was considered statistically significant.

3. Results

In all three methods, air leakage from the intersegmental plane was never seen, at the pressure up to 30 cmH2O.

There were no significant differences in the weights of the whole left lung and the L2 segment, or in the volume/weight ratio between the left lung and L2 segment among the methods (Table 1).

Figs. 4—6 show the volume/weight ratio of the L2 segment at the injected pressures of 10, 20, and 30 cmH2O, respectively. At the pressure of 10 cmH2O, the mean volumes of the L2 segment were 72 ± 14, 96 ± 14, and 109 ± 26 ml with the stapler, scissors, and combined methods, respectively. Those volume/weights were 2.8 ± 0.7, 3.9 ± 0.4, and 4.3 ± 0.4 ml g⁻¹ for the stapler, scissors, and combined methods, respectively (Fig. 4). The mean volume/weight ratio with the stapling method was significantly lower than those with the scissors and combined ones (p = 0.006 and 0.0008, respectively). There was no significant difference in the volume/weight ratio between the scissors and combined methods.

At 20 cmH2O, the mean volumes of the L2 segment were 86 ± 11, 117 ± 19, and 135 ± 39 ml with the stapler scissors, and combined methods, respectively. The volume/weight ratios were 3.3 ± 0.7, 4.8 ± 0.6, and 5.3 ± 0.5 ml g⁻¹ for the stapler, scissors, and combined methods, respectively (Fig. 5). The value with the stapler method was significantly lower than those with the scissors and combined ones (p = 0.005 and 0.0008, respectively). There were no significant differences in the volume/weight ratio between the scissors and combined methods.

At 30 cmH2O, the mean volume of the L2 segment was 98 ± 10, 140 ± 20, and 155 ± 40 ml with the stapler, scissors, and combined methods, respectively. The volume/weight ratios were 3.8 ± 0.6, 5.7 ± 0.6, and 6.0 ± 0.6 ml g⁻¹ for the

<table>
<thead>
<tr>
<th>Weight of the lung</th>
<th>St (n = 8)</th>
<th>Sc (n = 8)</th>
<th>C (n = 8)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The left whole lung (g)</td>
<td>238 ± 18</td>
<td>243 ± 16</td>
<td>239 ± 33</td>
<td>N.S.</td>
</tr>
<tr>
<td>Left L2 (g)</td>
<td>26 ± 6</td>
<td>25 ± 2</td>
<td>26 ± 7</td>
<td>N.S.</td>
</tr>
<tr>
<td>Left L2/the left whole lung (%)</td>
<td>11 ± 2</td>
<td>10 ± 1</td>
<td>11 ± 1</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

St, stapler method; Sc, scissors method; C, combined method; N.S.; not significant.
The value with the stapler method was significantly lower than those with the scissors and combined ones ($p = 0.002$ and $0.0008$, respectively). There was no significant difference in the volume/weight ratio between the scissors and combined methods.

Fig. 7 shows gross sections of L2 segment cut by the three methods. While the intersegmental plane was caught in the staple line on using the stapler, causing partial atelectasis, it was expanded well without any atelectasis by the scissors and combined methods.

4. Discussion

Three important points arise from this study: (1) the stapler method decreased the volume of the preserved segment significantly more than the scissors or combined method in the large regional segmentectomy; (2) there was no significant difference in the preserved volume between the scissors and combined methods; and (3) PGA mesh and fibrin glue successfully blocked air leakage from the opened intersegmental plane at up to 30 cmH₂O of airway pressure.

Decrease in the lung volume by the stapler method in comparison to the scissors or combined method should be due to the finding that the lung tissue including visceral pleura was caught in a staple line, causing partial atelectasis. Because the weights of L2 segment were not different among the three methods, the stapler method did cut the lung tissue accurately at the intersegmental plane similar to the other two methods. While the stapler method can cut the lung tissue simply, the interference for lung expansion would be a major weakness. The present study was carried out in ex vivo lungs, rather than in live pigs, so that accurate volume evaluation by the volume-displacement method was possible. However, because of this, long-term outcomes on the atelectasis around the staple line could not be followed up. While long-term follow up is necessary to address this issue, the results may be difficult to interpret due to postoperative changes, however.

When cutting the intersegmental plane along its deflated—inflated line, the line sometimes becomes blurred in the deep lung tissue in clinical practice. In addition, to take a sufficient surgical margin from a tumor, the cutting line often has to exceed over the intersegmental plane. These conditions often cause postoperative air leakage. The present experiment showed that using the stapler for the deep lung tissue not only secured the expansion of preserved lung but also would be effective for preventing air leakage.

In the present study, we assumed a large regional segmentectomy in clinical practice, such as left upper segmentectomy and basal segmentectomy. To reproduce a large regional segmentectomy in a pig lung, there is no choice except the present procedure, that is, preserving the L2 stapler, scissors, and combined methods (Fig. 6). The value with the stapler method was significantly lower than those with the scissors and combined ones ($p = 0.002$ and $0.0008$, respectively). There was no significant difference in the volume/weight ratio between the scissors and combined methods.

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segment, because the anatomy of the other segmental bronchus is complicated, which makes the other types of segmentectomy impossible. The L2 segment is the largest among these segments. Therefore, the preserved L2 segment is similar to a preserved small segment after large regional segmentectomy in clinical practice, such as lingular segment in left upper division segmentectomy and apical segment in the basal segmentectomy. Of course, it is possible that the differences between the stapler group and the scissors group may not have been as significant if the preserved segment had been larger.

In addition to the partial atelectasis at the staple line, the stapler method cannot preserve the intersegmental vein, which has a role of venous flow of nearly half of the preserved segment. The block of venous flow along the intersegmental plane by stapler therefore causes an impairment of gas exchange leading to decrease in pulmonary function. By contrast, the scissors or combined method can preserve the intersegmental pulmonary vein, enabling preservation of gas exchange of the preserved segment.

It has been reported that the covering the opened intersegmental plane with PGA mesh and fibrin glue is useful for preventing postoperative air leakage [9]. PGA mesh is a soft and thin (0.15 mm in thickness) absorbable material, which, together with fibrin glue, makes it possible to block air leakage from the peripheral lung tissue without significant interference with lung expansion because of the excellent elasticity of both materials. In the present experiment, covering the opened intersegmental plane with these materials could prevent the air leakage even at the pressure of 30 cmH2O, which would be useful in clinical practice.

We conclude that a stapler for cutting intersegmental plane interferes with the expansion of the preserved lung comparing with the scissors or combined methods in large regional segmentectomy. However, a stapler for cutting the deep intersegmental plane not only does not interfere with the lung expansion but also would be useful for preventing air leakage. Coverage with PGA mesh and fibrin glue can prevent air leakage from the opened intersegmental plane.

References