Triple-layer sealing with absorptive mesh and fibrin glue is effective in preventing air leakage after segmentectomy: results from experiments and clinical study

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Abstract

OBJECTIVES: Fibrin glue in combination with polyglycolic acid (PGA) mesh is effective in preventing air leakage after segmentectomy, but we frequently experienced air leakage with single-layer application. To investigate improved usage, we compared the sealing effect among single-, double- and triple-layer PGA mesh and fibrin glue in both experimental and clinical segmentectomy.

METHODS: Ex vivo pig lungs were used for experiments. As a model of segmentectomy, the lateral segment of the left lung was removed using electrocautery. As a model of peripheral lung defect, peripheral lung tissue was resected with scissors. The inter-segmental plane and the peripheral lung defect were sealed using one of the following four methods: (i) fibrin glue alone (Group 1, n = 8), (ii) single-layer with PGA mesh and fibrin glue (Group 2, n = 8), (iii) double-layer (Group 3, n = 8) and (iv) triple-layer (Group 4, n = 8). The seal-breaking pressures among them were compared. In clinical segmentectomy, the periods of chest-drainage were compared retrospectively between 17 patients treated by the single-layer and 17 treated by the triple-layer method.

RESULTS: In experimental segmentectomy, the seal-breaking pressure in the triple-layer (100 ± 25 cmH2O) was significantly higher than those in the other methods (26 ± 17, 48 ± 12 and 69 ± 19 cmH2O in the Groups 1, 2 and 3, respectively, P < 0.001–0.05), while there were no significant differences among other methods. For peripheral lung defect, the seal-breaking pressures did not differ among the methods. In clinical segmentectomy, the mean chest-drainage period with the triple-layer was 2 ± 0.9 days, which was significantly shorter than 3.6 ± 2.8 days with the single-layer (P = 0.009).

CONCLUSIONS: Stronger sealants are required to prevent air leakage from inter-segmental planes than from peripheral lung. To prevent air leakage after segmentectomy, triple-layer PGA mesh and fibrin glue is recommended.

Keywords: Segmentectomy • Lung cancer • Air leakage • Polyglycolic acid • Fibrin glue

INTRODUCTION

Increasing prevalence of small-sized non-small-cell lung cancer (NSCLC) has increased the emphasis on pulmonary segmentectomy as a treatment method [1–3]. During segmentectomy, electrocautery is preferable to stapling for cutting the inter-segmental plane to preserve pulmonary function in the remaining lung lobe [4]; however, cutting lung tissue by electrocautery has a risk of postoperative air leakage, because an electrocautery cannot always cut lung tissue along the inter-segmental plane. Even if the lung tissue could be cut accurately along the inter-segmental plane by an electrocautery, the air leakage could arise from Kohn’s pore. Sealing by using both PGA mesh and fibrin glue has been reported to be more effective than fibrin glue alone in preventing air leakage from pleural defects [5–7]. However, we have sometimes experienced air leakage after segmentectomy even using PGA mesh and fibrin glue as a single-layer. Recently, we noticed that triple-layer sealing with PGA mesh and fibrin glue prevented air leakage after segmentectomy more effectively than single-layer sealing. To confirm the effectiveness of the triple-layer method, we compared the sealing effects among the single-, double- and triple-layer methods by using ex vivo pig lung. We also compared chest-drainage periods after segmentectomy to examine the difference of postoperative air leakage between the single- and triple-layer methods by retrospective analysis of clinical cases.

MATERIALS AND METHODS

Model of air leakage from the inter-segmental plane

Ex vivo bilateral lungs obtained from slaughtered pigs, aged 6–10 months and weighing ~100 kg, were used in the present study. The lateral segment no. 2 (L2 segment) of the left lung was used for segmentectomy, because it is the largest segment (Fig. 1). We examined the removed L2 segment for the experiment, because it...
was easier to examine air leakage and measure the lung volume in a tank of water. To harvest the L2 segment, a flexible 12-Fr catheter was inserted into the L2 segmental bronchus, followed by ligation of the root of the bronchus. Air was infused into the catheter to create a visible border between the inflated L2 segment and deflated remaining lung tissue (Fig. 2). The L2-segmental bronchus was closed. The border between the inflated and deflated lung tissue was cut using electrocautery, as performed in clinical practice [1–3, 8]. The removed L2 segments were used for experiments. Because the L2 segment could be resected without damaging any lung tissue, the whole surface of the inter-segmental plane of L2 segment was lacerated to a depth of 1 mm by electrocautery to create air leakage similar to that in a clinical situation.

Model of air leakage from peripheral lung tissue

To create air leakage from peripheral lung tissue, an incision 3 cm in length and 0.5 cm in depth was made in the peripheral lung tissue at the middle lobe of the pig right lung by using scissors.

Tissue sealants

Fibrin glue (Bolheal®; Chemo-Sero-Therapeutic Research Institute, Kumamoto, Japan) and polyglycolic acid (PGA) mesh 0.15 mm in thickness (Neoveil®; Gunze Ltd Co., Kyoto, Japan) were used as tissue sealants for air leakage.

Sealing methods

The inter-segmental plane or peripheral lung defect was sealed using one of the following four methods: (i) Group 1 (fibrin glue alone): first fibrinogen solution and then thrombin solution were rubbed on the damaged lung tissue (n = 8); (ii) Group 2 (single-layer method): fibrin glue was applied, followed by PGA mesh cut into a 1 × 1 cm square, and then additional fibrinogen and thrombin solutions were rubbed on the mesh (Fig. 3) (n = 8); (iii) Group 3 (double-layer method): a second PGA mesh and fibrin glue layer were applied on the single-layer sealant (n = 8) and (4) Group 4 (triple-layer method): a third PGA mesh and fibrin glue layer were applied on the double-layer sealant (Fig. 4) (n = 8). The numbers of PGA mesh covered was ~10 pieces per layer on the inter-segmental plane and 3 per layer on the peripheral lung defect. The volumes of fibrinogen and thrombin solutions were each 0.5 ml per layer on the inter-segmental plane and 0.2 ml per layer on the peripheral lung defect.

Measurement of seal-breaking pressure

The pressure resistance of the sealed sites was measured 5 min after sealing. Seal-breaking pressure was determined by immersing the lung in the tank of water and measuring the minimum airway pressure that produced air leakage.

Measurement of lung volume under inflation

To examine the effects of the sealants on lung expansibility, the inflated lung volumes of the L2 segment were measured as follows: using the catheter inserted into the L2 segmental bronchus, the L2 segment was inflated under an airway pressure of 20 cmH₂O and the volume was measured by the volume-displacement method [9].

Clinical application

Our main technique for dissecting the inter-segmental plane during segmentectomy was electrocautery. PGA mesh was cut...
into 2 × 2 cm squares, and the sheets were placed over the inter-
segmental plane together with fibrin glue. From August 2012
through December 2012, 17 patients with lung cancer were
treated by segmentectomy with sealing inter-segmental plane
with the single-layer method. Because of unsatisfactory sealing
effects, we started using the triple-layer method from January
2013. From January 2013 to April 2013, 17 patients with lung
cancer were treated by segmentectomy with sealing of the inter-
segmental plane with the triple-layer method. There was no sig-
nificant difference in patient characteristics between the two
groups (Table 1). We determined the period of chest-tube drain-
age as follows: After disappearing air leakage, the chest tube was
clamped for at least 4 h; if the lung was not collapsed on chest
radiographs, the chest tube was removed. The periods of chest
drainage were compared between the two groups. Written
informed consent for using the PGA sheet and fibrin glue was
obtained from each patient before surgery.

Data analysis

The data of seal-breaking pressures and lung volumes for each
method were compared by the Tukey test (Stat View; Abacus,
Berkeley, CA, USA). The difference in chest drainage periods in
clinical study was analysed by the Mann–Whitney U-test. P < 0.05
was considered statistically significant. All data are expressed as
mean ± standard deviation.

RESULTS

Seal-breaking pressure for segmentectomy

The mean values of seal-breaking pressure for the inter-segmental
plane after segmentectomy were 26 ± 17 cmH2O in Group 1,
48 ± 12 cmH2O in Group 2, 69 ± 19 cmH2O in Group 3 and
100 ± 25 cmH2O in Group 4 (Fig. 5). The seal-breaking pressures
increased as the number of PGA sheets and fibrin glue layers
increased. The differences were significant between Groups 1 and
3 (P = 0.001), Groups 1 and 4 (P < 0.0001), Groups 2 and 4
(P = 0.0001) and Groups 3 and 4 (P = 0.02), while the differences
between Groups 1 and 2 and between Groups 2 and 3 did not
reach significance (P = 0.1 and 0.2, respectively).

Seal-breaking pressure for peripheral lung defect

The mean values of seal-breaking pressure for the peripheral lung
defect were 32 ± 17 cmH2O in Group 1, 54 ± 17 cmH2O in Group
2, 67 ± 13 cmH2O in Group 3 and 70 ± 44 cmH2O in Group 4
(Fig. 6). There was no significant difference among the groups.

Effect of sealants on lung expansibility

The mean volumes of the inflated L2 segment were 217 ± 67 ml in
Group 1, 222 ± 74 ml in Group 2, 221 ± 78 ml in Group 3 and
296 ± 35 ml in Group 4. There was no significant difference among
the groups.

Clinical study

The mean period of chest-tube drainage was 3.6 ± 2.8 days (range:
2–12 days) in the patients treated by the single-layer method,

<table>
<thead>
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<th>Table 1: Patient characteristics between the single- and triple-layer groups</th>
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<td>Single-layer group</td>
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<td>Age (years)</td>
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<td>Male/female</td>
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<td>Tumor location</td>
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<td>Right upper lobe</td>
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<tr>
<td>T2aN0M0</td>
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Figure 5: Seal-breaking pressures on inter-segmental plane. Group 1: fibrin
glue alone; Group 2: single-layer method; Group 3: double-layer method;
are 6.0, 4.6, 7.5 and 8.8 cmH2O in Group 1, 2, 3 and 4, respectively.

Figure 6: Seal-breaking pressures on peripheral lung defect. Group 1: fibrin
glue alone; Group 2: single-layer method; Group 3: double-layer method;
are 6.3, 8.0, 6.3 and 22.2 cmH2O in Group 1, 2, 3 and 4, respectively.
while it was 2 ± 0.9 days (range: 1–4 days) in the patients treated by the triple-layer method (Fig. 7). The latter was significantly shorter than the former (P = 0.009). While 3 patients treated by the single-layer method (18%) experienced air leakage for >7 days, none of the patients treated by the triple-layer method (0%) displayed prolonged air leakage. None of the patients in both groups suffered delayed pneumothorax after removal of the chest tubes. None of the patients suffered any other postoperative complications.

COMMENT

While a few reports have shown that the sealing by using both PGA mesh and fibrin glue with single-layer is more effective than that by fibrin glue alone in preventing the air leakage from pleural defect [5–7], there have been no reports of its sealing effect with the triple-layer method and that for the exposed segmental plane after segmentectomy. Four important points arise from this study: (i) In experimental segmentectomy, triple-layer sealing with PGA mesh and fibrin glue could prevent air leakage more effectively than other methods including the single- and double-layer methods and use of fibrin glue alone. (ii) For the peripheral lung defect, the four methods did not show any difference in sealing effect. (iii) Sealing with PGA mesh and fibrin glue did not impair lung expansibility even with the triple-layer method. (iv) In clinical segmentectomy, the chest-tube drainage period was shorter with the triple-layer than the single-layer method.

While the triple-layer method showed more effective sealing than the single-layer method in both experimental and clinical segmentectomy, there was no difference between the two for the peripheral lung defect. While the lung-part examined in the experiment was different between the segmentectomy and wedge resection, i.e. the left segment in the former and the middle lobe in the latter, we consider the air pressure to be loaded similarly throughout the whole part of the pig lung. Even the method using fibrin glue alone did not show any difference in sealing effect, compared with the other methods, including single-, double- and triple-layer sealing, for the peripheral lung defect. In our opinion, the reason is as follows: during clinical segmentectomy, the intersegmental plane in the human lung is often difficult to identify, especially near the hilar region, which frequently causes a fistula near the central bronchus of neighbouring segments and results in greater air pressure than that loading at a fistula in the peripheral lung. While our experiment models the clinical segmentectomy, we used the removed segment for the experiment, which was different from the clinical practice. However, we consider that the pressure resistance loading on the inter-segmental plane would not differ between the two. The size of each PGA sheet was different between experiment and clinical practice (1 × 1 vs 2 × 2 cm squares, respectively), which was due to that the intersegmental plane in the experiment was too small to use the 2 × 2 cm square sheets. However, we believe that the sealing effect was not different between these two sizes. We consider that the fistula in the inter-segmental plane requires tougher sealants than that in the peripheral lung.

The retrospective study comparing single- and triple-layer methods also showed a superior sealing effect with the latter method. The mean period of chest-tube drainage was only 2 days with the triple-layer method, which did not differ from the general drainage period after lobectomy. We conclude that use of a triple-layer of PGA mesh and fibrin glue on the inter-segmental plane could reduce the risk of postoperative air leakage after segmentectomy to equal that of general lobectomy.

Conflict of interest: none declared.

REFERENCES