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Strength of Esophageal Closure Techniques With and Without Tissue Reinforcement

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Abstract

Objectives The purpose of this study was to investigate the effects of esophagotomy closure techniques on the esophageal bursting pressure.

Materials and methods Altogether, 122 freshly dead sheep esophagi received from the local slaughterhouse were prepared for manual closure. After esophagotomy, the specimens were divided into four groups. An interrupted mucosal suture pattern ($n = 30$), an interrupted mucosal-submucosal suture pattern ($n = 30$), an interrupted mucosal-submucosal + over-over continuous muscular suture pattern ($n = 32$), and an interrupted mucosal-submucosal + reinforcement with a diaphragmatic part with full-thickness interrupted U suture pattern ($n = 30$) were used for esophagotomy closure; 4-0 silk was used in all specimens. Bursting pressures were measured with a sphygmomanometer.

Results We found a statistically significant difference among the bursting pressures of all groups ($p < 0.001$). The bursting pressure values gradually increased from group 1 to group 4 (47.6 ± 22.7, 86.2 ± 49.5, 185.4 ± 53.5, and 226.8 ± 62.4 mmHg, respectively). Reinforcing the esophageal suture line with tissue significantly increased the bursting pressure compared to the other groups.

Conclusions Each layer of the esophagus significantly contributes to strengthening esophageal wall tension with primary esophageal closure, and reinforcement of the esophageal suture with tissue provides an additional significant increase in the bursting pressure of the esophagus.

Despite major advances in esophageal surgical techniques, leakage and dehiscence are the complications commonly encountered after primary esophageal closure. Factors involved in the high incidence of leakage after primary repair suture include poor blood supply to the esophagus at this level, absence of protective omentum, lack of a serosal layer, and friable submucosa [1]. To prevent of these complications, reinforcing the primary closure with viable tissue has been recommended [2]. Despite the noted benefits of a viable flap reinforcement, we could not find any report in the literature on how this reinforcement affects the early esophageal bursting pressure. The purpose of this study was to investigate the bursting pressure of esophageal suture techniques with and without added tissue.

Materials and method

A total of 122 freshly dead sheep esophagi received from the local slaughterhouse were dissected from the pharynx to the cardia and prepared for manual closure. One- to two-year-old sheep weighing 40 to 50 kg were used for the study. Whole esophagi were removed en bloc, washed, and saved in lactated Ringer's solution at 1°C to 4°C until the procedure. The procedures were completed a maximum of 4 hours after the specimens were received. The specimens were randomly divided into four groups.

A 2 cm longitudinal esophagotomy incision was carried out in the distal one-third of the esophagus. Esophagotomy closure was accomplished in group 1 ($n = 30$) using an

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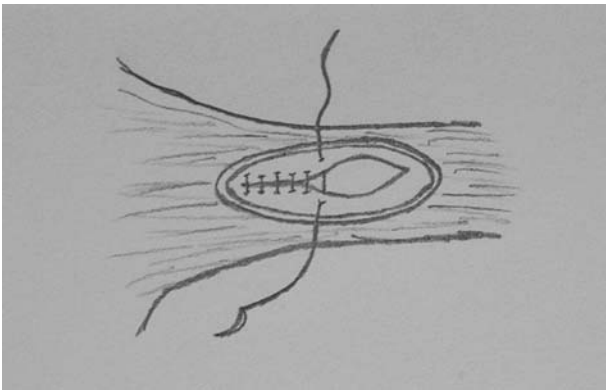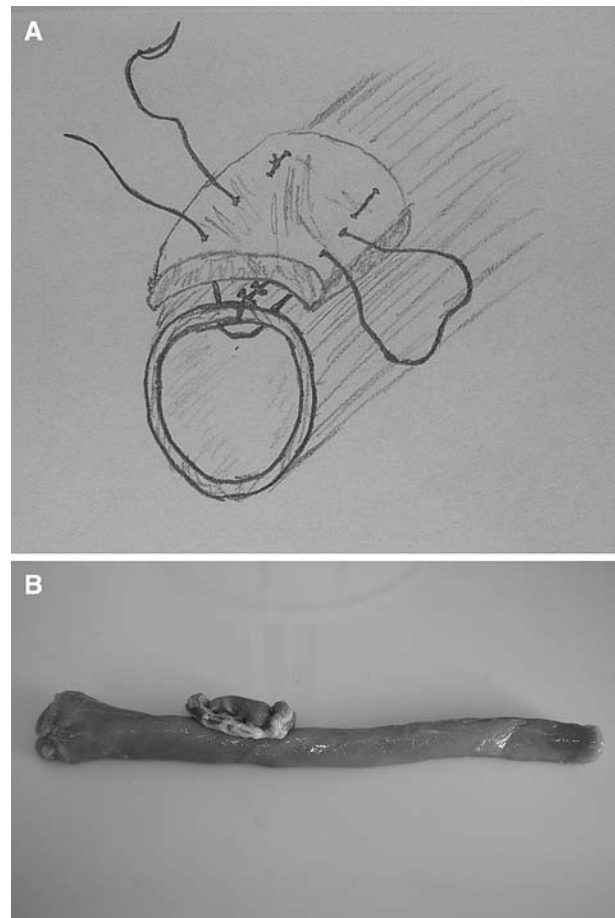
Fig. 1 Interrupted mucosal or mucosal-submucosal suture pattern
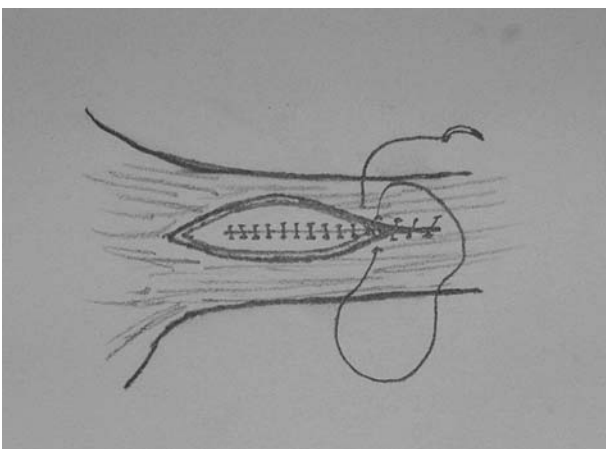
Fig. 2 Interrupted mucosal-submucosal and over-over continous muscularis suture pattern

Fig. 3 A Diaphragmatic flap reinfocement. After the esophagus was closed with interrupted mucosal-submucosal and over-over continuous muscularis suture pattern, the diaphragmatic part was sutured over the suture line with an interrupted U-suture pattern. **B** Diaphragmatic reinforcement of the esophageal suture line

interrupted mucosal suture pattern (Fig. 1), in group 2 ($n = 30$) with an interrupted mucosal-submucosal suture pattern (Fig. 1), in group 3 ($n = 32$) with an interrupted mucosal-submucosal and over-over continuous muscular suture pattern (Fig. 2), and in group 4 ($n = 30$) with an interrupted mucosal-submucosal suture and reinforcement with a piece of diaphragm with a full-thickness interrupted U suture pattern that included the diaphragm, muscularis, and mucosal-submucosal layers (Fig. 3); 4-0 silk suture was used in all specimens. The sutures were spaced 2 mm from the cut edge. After the primary esophageal repair was completed, specimens were mounted on a sphygmomanometer (Riester, Germany); the distal end of the esophagus was clamped and subsequently placed under water. Measurements were recorded with visual observation by a person who was blinded to the study. The insufflation rate was adjusted as one total restriction of the insufflator per second. The bursting pressure level at which we detected air bubbles indicated the limits of the technique.

Statistical analysis

SPSS 14.0 (SPSS for Windows; SPSS, Chicago, IL, USA) demo program was used for statistical analysis. The bursting pressure values were expressed as mean ± SD. One-way analysis of variance (ANOVA) was used for the comparison of parametric data. For post hoc multiple comparison, Tamhane's T squared test was used. Significance was set at $p < 0.05$.

Results

Whereas group 1 had the lowest bursting pressure (47.6 ± 22.7 mmHg), group 4 had the highest (226.8 ± 62.4 mmHg). Bursting pressure of group 2 (86.2 ± 49.5 mmHg) was higher than that of group 1 but was lower than that of group 3 (185.4 ± 53.5 mmHg). We demonstrated that suturing more layers provided a higher bursting pressure.

Table 1 Statistical analysis of the bursting pressure values among the groups with one-way ANOVA and post-hoc multiple comparisons of Tamhane's T square test

Group	Bursting pressure (mmHg)	P
Group 1 ($n = 30$)	47.6 ± 22.7	< 0.001*
Group 2 ($n = 30$)	86.2 ± 49.5	
Group 3 ($n = 32$)	185.4 ± 53.5	
Group 4 ($n = 30$)	226.8 ± 62.4	

Results are the mean ± SD

Multiple comparisons: group 1 vs. group 2, $p = 0.002$*; group 1 vs. group 3, $p < 0.001$*; group 1 vs. group 4, $p < 0.001$*; group 2 vs. group 3, $p < 0.001$*; group 2 vs. group 4, $p < 0.001$*; and group 3 vs. group 4, $p = 0.042$*

*The mean difference is significant

Hence, reinforcement of the esophageal suture line with tissue significantly increased the bursting pressure compared to the methods. There was a statistically significant difference among the bursting pressures of all groups ($p < 0.001$). Post hoc multiple comparisons showed that each group had a significant difference from the others. Statistical analyses are showed in Table 1.

Discussion

There is still some controversy about how an ideal esophageal closure should be done. Although some authors showed that suturing esophageal incisions with a single layer (mucosal-submucosal or only submucosal layer) was a rapid, safe technique [3–5], many others have emphasized the superiority of a double-layer (mucosal-submucosal and muscularis) closure [2, 6]. Our study confirmed the latter reports and additionally showed that reinforcement of the esophageal suture line with tissue made a significant contribution to increasing the bursting pressure of the esophagus.

Among the digestive organs, native esophagus has the highest bursting pressure (1407 ± 121 mmHg) but the lowest tissue strength against suturing [7, 8]. Submucosa and muscularis are the main layers that provide mechanical strength, and they have the highest suture-holding capacity in the esophagus [9–11]. Our study additionally showed that each of the esophageal layers contributed to strengthening esophageal wall tension after primary esophageal closure.

Multiple factors, such as surgical technique, patient characteristics, ischemia, and infection, may affect wound healing. The major factor that influences healing of esophageal closure is collagen metabolism. After surgery, polymerized collagen is degraded, and synthesis starts with immature collagen production, which has low mechanical stability [12]. The mechanical strength of the anastomosis during healing depends on the balance between lysis, synthesis, and maturation of collagenous tissue. The most vulnerable period of the healing anastomosis is between days 4 and 7 [13, 14]. For this period of esophageal healing, establishing mechanical integrity is crucial for maintaining an air/water-tight barrier against gastric contents that directly access the mediastinum and pleural cavity, leading to severe mediastinitis, empyema, and ultimately multiorgan failure.

To minimize the incidence of esophageal leakage, buttressing the primary closure with viable tissue has been recommended [2]. The wound can be covered by a well vascularized pedicle flap constructed from pleura, diaphragm, intercostal muscle, gastric fundus, lung, or pericardium [2]. The aim of buttressing is to provide additional blood supply to the tissues. Hayari et al. reported that omentopexy improved vascularization and decreased stricture formation of esophageal anastomoses in a dog model [15]. In addition to the benefical effects of using viable tissue flaps for esophageal closure, our study showed that reinforcement of the esophageal suture line with tissue contributed to establishing early mechanical integrity of the esophageal suture line. To provide this contribution after mucosal-submucosal closure, reinforcement should be carried out with full-thickness sutures that include the tissue, muscularis, and mucosal-submucosal layers.

Ogurtan reported that leakage may occur through suture holes or between sutures after gastrointestinal repair and that it might not be due only to the anastomotic technique but also to differences of elongation of intestine and suture material [7]. In our study, we also observed that leakage occurred either through a torn suture hole or between sutures, which might have been due to longitudinal elongation of the esophageal tissue. We speculated that reinforcement of the esophageal suture line with tissue increased the bursting pressure by obstructing the suture hole, preventing tearing of the esophageal layer by suture materials, and restricting the elongation of esophageal tissue.

Bursting strength measurement is an acceptable method for assessing longitudinal and circular forces in hollow organs [3, 16]. Esophageal bursting pressure measurements can be done on both water laekage [3] and air leakage [17]. Although test pressures probably exceed physiologic pressures, bursting strength testing enables a relative comparison of suture patterns using physiologic stresses [3]. Some conditions that increase intraesophageal pressure, such as retching or vomiting, may cause spontaneous esophageal rupture. Such pressure may tear the esophageal wound during the postoperative period. On the other hand, an acceptable bursting pressure for this model has not been reported. It should be kept in mind that bursting strength

does not always indicate the likelihood of overall successful healing, and in some instances greater initial mechanical strength may lead to tissue ischemia and necrosis.

In this ex vivo study, we used sheep esophagus because of its similarities with human esophagus regarding thickness and histologic structure [18]. We used a piece of diaphragm to reinforce the esophageal line, mimicking a viable tissue flap, because diaphragm is one of the viable flaps used clinically for esophageal reinforcement. Our study was designed only to measure instant mechanical stress and pressure after manual esophageal closure. We focused only on primary esophageal closure, not end-to-end anastomoses. Use of a mechanical stapler device and the effects of the healing process and granulation on leakage pressure were not considered in our study. These factors may constitute a limitation of our study. At this point, we cannot state that there would be a difference among methods in a living animal model with vascularized tissues. Further in vivo studies are needed to establish this point.

Conclusions

Each of the esophageal layers contributed to strengthening the esophageal wall tension after primary esophageal closure. Reinforcing the esophageal suture line with tissue made a significant additional contribution to increasing the bursting pressure of the esophagus.

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