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A Continuous Suture Anastomosis Outperforms a Simple Interrupted Suture Anastomosis in Esophageal Elongation

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Abstract

Introduction Long-gap esophageal atresia represents a distinct entity among the esophageal atresia spectrum. In many patients, achieving a reasonable anastomosis depends on some millimeters of tissue. We aimed to determine what effect the suturing technique would have on esophageal ex vivo elongation as it may determine the strength of a primary anastomosis.

Materials and Methods In an analysis of porcine esophagi from animals for slaughter (100–120 days old with a weight of 100–120 kg), we determined esophageal length gain of simple continuous and simple interrupted suture anastomoses subjected to linear traction until linear breaking strength was reached. Statistical power of 80% was ensured based on an a priori power analysis using five specimens per group in a separate exploratory experiment.

Results The simple continuous suture anastomosis in 15 porcine esophagi ($\bar{x} = 4.47$ cm, 95% confidence interval: 4.08–4.74 cm) outperformed the simple interrupted suture anastomosis in another 15 esophagi ($\bar{x} = 3.03$ cm, 95% confidence interval: 2.59–3.43 cm) in length gain ($\Delta = 1.44$ cm, 95% confidence interval: 0.87–2.01 cm, $p < 0.0001$).

Conclusion Simple continuous anastomoses achieved higher length gain compared with simple interrupted suture anastomoses. This effect warrants an experimental assessment in vivo to assess its potential merits for clinical applicability.

Keywords
- esophageal biomechanics
- surgical suturing
- esophageal surgery
- swine

Introduction

Long-gap forms of esophageal atresia represent a separate entity within the esophageal atresia disease spectrum and pose a variety of challenges in their management.[1] Foker described holding the ends of the esophagus under tension for several minutes to enabling a primary repair of long-gap esophageal atresia by the resulting elongation.[2] However, as he acknowledges, this maneuver results in anastomotic tension.[3] Tension on the other hand has been blamed to be a reproducible risk factor for anastomotic stricture[4,5] as well as anastomotic leakage[5–7] in esophageal anastomoses, among others.[8,9] We have recently been able to prove experimentally that several minutes of constant traction results in more pronounced esophageal elongation than a similar steady increase of traction forces.[10] In the same report, we also investigated the durability of different anastomotic techniques and found that the simple

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continuous suture outperforms the simple interrupted suture in terms of anastomotic resilience.[10] We conducted a secondary analysis of these data to investigate whether the more durable simple continuous anastomosis would also allow for more esophageal elongation than the simple interrupted suture anastomosis.

Materials and Methods

The data on the resistance to traction forces of several anastomotic techniques is available elsewhere.[10] In this experiment, we measured the elongation of the specimens during application of traction forces until failure of the anastomoses for simple continuous and simple interrupted suture anastomoses. Our methodology has been described in detail before.[10,11] In brief, esophagi of swine (*Sus scrofa domestica*, weighing 100–120 kg at an age of 100–120 days) were obtained from a local abattoir (Färber, Alzey, Germany), stored in a humid atmosphere, and processed to the end of the experiment within 5 hours of slaughtering as described previously for the investigation of biomechanical tissue properties.[11–15] Esophagi were freed from its surrounding tissue, mounted in a motorized horizontal test stand (Sauter THM, Sauter, Balingen, Germany), and subjected to linear traction until visible disruption of the circumferential muscular layer occurred. This was objectified by traction forces that did not increase beyond this point. A video of the endpoint has been published before to make this abstract description more accessible for the reader by its visual depiction.[10] All anastomoses were constructed by the same surgeon (C.O.) at 13 cm distal to the upper esophageal sphincter using USP 4–0 polydioxanone (Ethicon, Norderstedt, Germany) sutures. Initial length of all esophagi was around 26 cm as depicted elsewhere.[10] Suture bite length was 8 mm to the cut surface, with a 5-mm lateral advancement (►Fig. 1). This summed up to a relatively uniform number of 10 stitches per anastomosis.[10] All endpoints were verified by a second researcher (A.L.).

We used an exploratory investigation of five specimens per group to conduct an a priori power analysis using G*Power[16] (version 3.9.1.2) to achieve statistical power of 80% for a two-tailed *t*-test for independent groups with an α-level of 5%. The measurements for the simple continuous anastomoses were randomly drawn from the basis of 28 measurements in the original study[10] using R's random number generating algorithm to achieve a balanced experimental design. We conducted all statistical analyses using R (version 3.4.3) with the stats4 package (version 3.4.3). A Gaussian distribution within our results was confirmed with the Shapiro–Wilk test and homoscedasticity was tested by Bartlett's test. Comparisons were conducted by using Student's *t*-test. We used the bias corrected, accelerated bootstrap procedure[17] to calculate the 95% confidence interval of the group mean with 10,000 iterations as recommended elsewhere[18] using the groupwiseMean function from the rcompanion package (version 1.13.2).[19]

Results

The simple continuous suture anastomosis ($\bar{x} = 4.47$ cm, 95% confidence interval: 4.08–4.74 cm) outperformed the simple interrupted suture anastomosis ($\bar{x} = 3.03$ cm, 95% confidence interval: 2.59–3.43 cm) in length gain ($\Delta = 1.44$ cm, 95% confidence interval: 0.87–2.01cm, $p < 0.0001$) (►Fig. 2).

Discussion

Pigs were the traditional model in experimental pediatric esophageal surgery,[20] but have largely been replaced by rodent models.[21] Recently, swine experienced a revival as a favorite model for experimental esophageal surgery,[22–30] because porcine closely mimics human anatomy.[20–22] Moreover, tissue equivalence of porcine and human esophagi[31] supports using swine as an experimental model, in particular because tissue equivalence is a feature unique to the esophagus, but not to other organs, for example, the colon.[32]

There has been an ongoing debate on the right anastomotic technique in adult esophageal surgery. The most common techniques have narrowed to stapled versus continuous hand-sewn anastomoses,[33] but recently also included robotic-assisted anastomoses.[34] In pediatric esophageal surgery, robot-assisted esophageal surgery has only been conducted experimentally in swine.[35,36] Concerning staplers, we have previously shown that their use is currently not advisable due to size discrepancy between staplers and patient's anatomy.[37] Moreover, the vast majority of operations for esophageal atresia are still conducted via the open approach,[38,39] which also suggests the comparison of hand-sewn techniques would have the widest relevance for the practicing pediatric surgeon.

Interestingly, the continuous outperformed the simple interrupted suture anastomosis for esophageal elongation, most probably due to a different dispersal of traction forces within the tissue: Traction might propagate along the suture into the organ and because the continuous suture has a higher contact surface compared with the simple interrupted suture anastomosis, enabling larger amplitude of esophageal elongation. This might explain why simple interrupted suture anastomoses did not achieve anastomotic resiliencies similar to the native organ.[10,40]

Our experiment has a statistical power sufficient enough to ensure that we were not investigating noise but a true effect based on the a priori power analysis. Given the equivalence of reaction of porcine and human esophageal tissue to traction, our results strongly encourage the transition into an experiment with live animals to further investigate the phenomenon before transition into everyday clinical practice. The implementation of Myers' decades old dictum "the best oesophagus is the patient's own oesophagus"[41] might be achieved by esophageal elongation following several minutes of traction,[2] but it also requires securing the length gain by prevention of anastomotic leakages. They are linked to anastomotic tension,[5–7] which could be modified by using continuous suturing that tolerates more anastomotic tension[10] and thereby esophageal elongation before anastomotic failure.

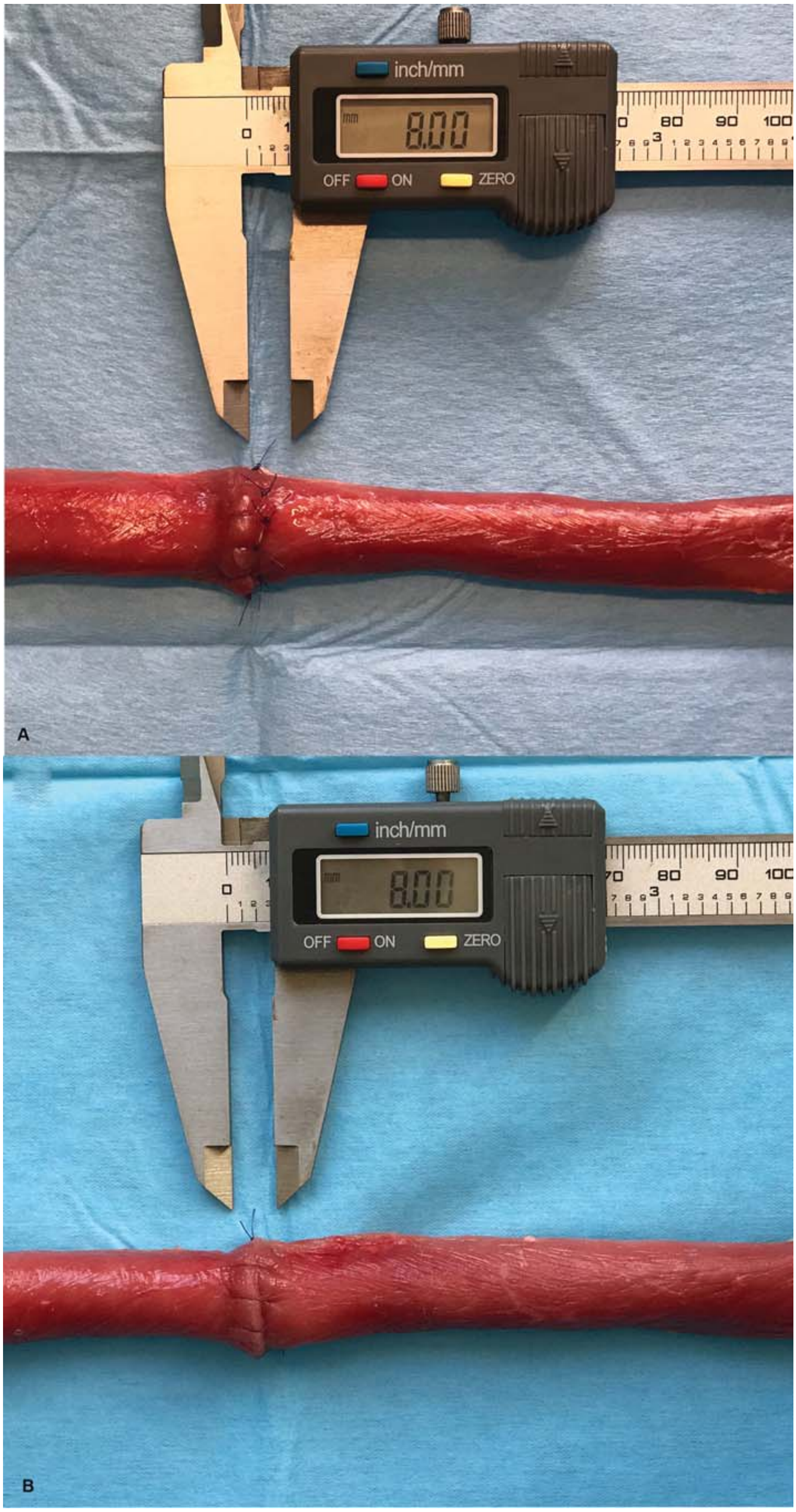

Fig. 1 Photographic documentation of the experimental procedures. (**A**) Simple interrupted suture anastomosis of 8 mm distance to cut surface and 5 mm lateral distance between the stitches. (**B**) Simple continuous anastomosis of 8 mm distance to the cut surface and 5 mm lateral distance between the stitches.

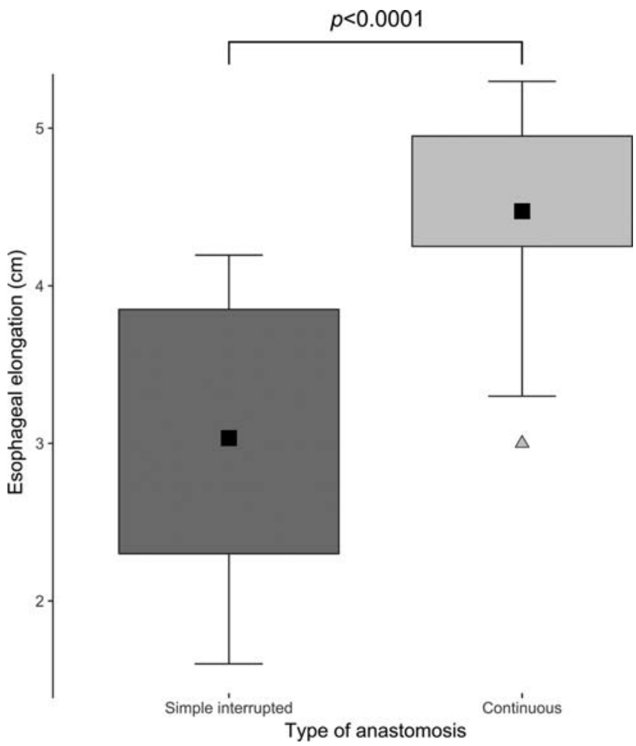

Fig. 2 Esophageal elongation of simple interrupted and continuous suture anastomoses. Simple interrupted suture anastomoses ($n = 15$). Data followed a normal distribution ($W = 0.933$, $p = 0.2991$). Continuous suture anastomoses ($n = 15$). Data had a normal distribution ($W = 0.906$, $p = 0.1163$). Homoscedasticity was present according to Bartlett's test ($K^2 = 0.942$, $p = 0.3317$). Tukey boxplot representing the interquartile range within the box with whiskers up to 1.5× the interquartile range. The black rectangle represents the mean and the triangle an outlier. Groups were compared with Student's *t*-test.

Conclusion

The simple continuous esophageal anastomosis outperforms the simple interrupted suture anastomosis in esophageal elongation and resistance to traction forces ex vivo. This result should be corroborated in an in vivo experiment to explore its suitability for clinical practice.

Conflict of Interest

None declared.

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