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Laparo- and thoracoscopic aortic aneurysm neck optimization and treatment of potential endoleaks type IA and II in a porcine model

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HIGHLIGHTS

- Laparo-/thoracoscopic approaches for treating endoleaks can be simulated in a pig model.
- Laparo-/thoracoscopic approaches to optimize a challenging aortic aneurysm neck can be simulated in a pig model.
- Endoscopic aortic surgery is challenging and a learning curve must be expected.
- A pig model with aortic aneurysm can be used as a realistic surgical learning tool before human application.

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ABSTRACT

Background: Endovascular repair of aortic aneurysms has a higher incidence of late complications, and open conversion (OC) associated with high mortality may be required. As alternatives to OCs, we propose minimal invasive laparo-/thoracoscopic approaches, either to control endoleaks after endovascular repair, or to convert non-endovascular treatable cases due to a hostile neck anatomy by inserting a peri-aortic PTFE collar before endovascular repair. Such interventions may reduce complications and the necessity for OCs in the future.
Methods: In twelve pigs, were 10 had infra-/juxtrarenal AAAs, externally placed collars/aneuwraps around the proximal AAA neck and just below the left subclavian artery and division of the aortic side branches were carried out laparo-and thoracoscopically.
Results: For the laparoscopic and thoracoscopic procedures respectively, mean operative time was 143 ± 41 min and 86 ± 51 min and a mean of 2.6 and 2.25 aortic side branches were ligated/divided. For both procedures, the last half in the series were carried out significantly faster ($p < 0.05$) indicating a learning curve. Blood loss was minimal and no procedure related complications were seen.
Conclusion: Using these minimal invasive endoscopic approaches, it seems feasible to externally band aneurysm necks and ligate aortic side branches in a pig model. These procedures could potentially be considered as alternatives to OCs in controlling endoleaks and in improving the safety of endovascular interventions. As endoscopic aortic surgery is challenging a learning curve is expected. Practicing the described procedures using this model, can be used as a learning tool prior to similar interventions on humans.

1. Introduction

Aortic aneurysms are most often asymptomatic but highly lethal with an overall mortality around 80–90% when rupture occurs [1]. Especially abdominal aortic aneurysms (AAA) is a major health problem as it for the age group between 65 and 80 years has a prevalence of about 5–9% in men and 1.3–2.2% in women [2–4], while the prevalence of thoracic aneurysms is estimated to 10.4–16.3 and 7.1–9.1 per 100.000 in men and woman respectively [5,6].

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Traditionally the treatment was an open surgical repair (OSR). However, since the introduction of endovascular aortic aneurysm repair, for the elective management of thoracic and abdominal aortic aneurysms (TEVAR and EVAR), first described over two decades ago by Volodos et al. and Parodi et al. [7–9], the treatment of choice for these conditions has been revolutionized. Retrospective analysis of U.S. cases found that 84.5% treated for AAAs in the period 2003–2007 underwent an endovascular procedure [10]. Similarly, in 2007 22% with thoracic aneurysms underwent an endovascular procedure [11]. Despite the technological advances during the past 20 years, there are still concerns related to the long-term patency of the stent grafts, due to a higher incidence of late complications requiring reinterventions (especially in cases with type 1 endoleaks) after EVAR when compared to OSR (23.4% vs. 13.1%) [12]. Most reinterventions are endovascular, but in some instances an open conversion (OC) may be required. A review by Kouvelos et al. [13] reported an OC rate of 3.7% from 1991 to 2014 and in 62.4% of the cases endoleaks was found to be the indication (42% of these were type 1 and 26.8% were type 2) and the 30-day mortality was 3.2% and 29.2% for elective and nonelective cases respectively.

A hostile neck anatomy (HNA), i.e. an angulated neck >60° and/or a short/wide neck (<15 mm/> 28 mm) increases the risk of late type 1 endoleaks, and remain the most common reason why patients aren't elected for the procedure, although fenestrated grafts have been introduced [14,15].

In this paper, we wish to present possible minimal invasive laparo-/thoracoscopic approaches, as alternatives to OCs. The procedures include externally placed wraps around the proximal AAA neck and just below the left subclavian artery and division of the aortic sidebranches, that may potentially be used to treat late type 1 and 2 endoleaks after EVAR/TEVAR, and/or create a more favorable and stable neck anatomy in cases with short/wide and/or angulated HNA prior to EVAR/TEVAR and hereby increase the proportion of patients that can be safely treated endovascularly.

We wish to assess the feasibility of such procedures using a customized peri-aortic PTFE collar/Aneuwrap in a reproducible porcine model with AAA disease, and assess as to how far this model is comparable to the clinical setting, and whether it can be used as a learning tool in order to practice the described procedures prior to human application.

2. Materials and methods

Twelve female Danish Landrace pigs (Mean weight = 55.1 kg (Range 17 kg)) were used. 2 pigs (Mean weight = 57.5 (Range 5 kg)) had no previous intervention, while 10 pigs (Mean weight = 50.4 kg (Range 11 kg)) who 28 days earlier by means of elastase infusion and balloon dilatation underwent an infra-/juxtrarenal aortic aneurysm inducing procedure resulting in a mean AAA AP-diameter of 16.26 mm ± 0.93 SD (Range 2.9 mm), equivalent to a 57% mean increase as compared with a weight-matched control group [16]. The lumbar arteries were left intact.

2.1. Anesthesia and positioning

Anesthesia was induced by intramuscular injection (mg/kg BW) of 1.25 mg tiletamine, 1.25 mg zolazepam, 0.25 mg butorphanol, 1.25 mg ketamine and 1.25 mg xylazine. With the pigs in the sedated supine position a transabdominal ultrasound scan of the infrarenal aorta in the systolic state was performed in both the transverse and longitudinal plane to measure the preoperative external AAA AP-diameter.

After intubation using a right-sided Ch. 39 Carlens double-lumen endotracheal tube, with the longer tube placed in the right main bronchus and access to an ear vein had been established, the pigs were positioned in a full right flank position equivalent to a left kidney position at an angle of approximately 95° and mechanically ventilated with oxygen 4 L/min and atm. air (1:1, v/v). Anesthesia was extended by continuous intravenous infusion of 10 mg propofol and 25 μg fentanyl per kg BW/h throughout the operation.

2.2. Laparoscopic procedure

Approximately 6–8 cm lateral to the umbilicus on the left side Veress needle was introduced to establish pneumoperitoneum whereafter the Veress needle was converted to a 12 mm laparoscopic trocar for insertion of a 30° laparoscope. Two additional 12 mm working trocars were placed pararectally in the left hypogastric and epigastric region respectively at a distance of approximately 10 cm to the camera port. If needed a 5 mm assisting port would be placed laterally in the left flank just ventral to the anterior axillary line.

A left retrocolic prerenal transperitoneal approach as described by Coggia et al. [17] to the infrarenal aorta was performed by displacing the viscera by reflecting the left colon and small bowel medially across the midline and opening the retroperitoneum to provide an adequate visualization of the retroperitoneal space.

Using the Harmonic Ace, the aneurysmatic aorta was dissected circumferentially from the moderate to severe surrounding fibrosis from the lowest renal artery to the trifurcation. The infrarenal aortic side branches (Fig. 2A) that could result in potential endoleaks type 2 i.e. the lumbars and the inferior mesenteric artery were ligated with non-absorbable polymeric hem-o-lock clips and divided.

To create a stable and cylindrical proximal 20 mm in length and 12 mm wide aneurysm neck, simulating a suitable landing site neck for EVAR and preventing a type 1A endoleak, an external aortic wrap (Aneuwrap) as described by Kudo et al. [18] was made with slight modifications (Fig. 1). After insertion of the wrap through the 12 mm port it was by the use of laparoscopic graspers from the left side with the PTFE sheet ventrally placed posteriorly to the aorta just inferiorly to the lowest renal artery with the buckle ends to the left. Each of the two straps were maneuvered into their corresponding buckle ends (Fig. 2B–C) and tightened until the entire circumference of the aorta was covered by the PTFE sheet resulting in the desired cylindrical 20 mm long x 12 mm wide aneurysm neck (Fig. 2D).

2.3. Thoracoscopic procedure

With the pigs in the right lateral position a 3 cm incision inferior to the inferior angle of the left scapulae was made, corresponding to the posterior axillary line, and in the 6th or 7th intercostal space the first 12 mm trocar was inserted and a 30° endoscope was initially inserted. After deflation of the left lung by blocking its ventilation another 5 mm trocar was introduced about 3 cm ventral to the anterior axillary line in the 7th or 8th intercostal space where an endoscopic retractor was introduced to hold the deflated lung ventrally exposing the mediastinum and its underlying structures (Fig. 3A). Finally, two 12 mm trocars were introduced in the 9th or 10th intercostal space in the midaxillary line and in the 5th or 6th intercostal space in the anterior axillary line, whereafter the endoscope was placed in the midaxillary port.

The mediastinum was opened and the descending aorta was exposed and dissected circumferentially from the left subclavian artery and about 10–12 cm distally (Fig. 3B). The thoracic aortic side branches that could result in potential endoleaks type 2 i.e. the bronchial, mediastinal, oesophageal branches and the posterior intercostals were coagulated or ligated with non-absorbable polymeric hem-o-lock clips and divided (Fig. 3E).

In order to simulate the creation of a suitable and stable