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Sparing internal thoracic vessels in thoracoscopic or submuscular correction of pectus carinatum: A porcine model study

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ABSTRACT

Background: External compression is used for *pectus carinatum* (PC) treatment, but many patients are noncompliant. Costal cartilage resection (CCR) has been described as an alternative, but these approaches sacrifice the internal thoracic arteries (ITA). We aim to assess the feasibility of CCR sparing ITA comparing thoracoscopic and subcutaneous endoscopic approaches.
Methods: Twelve pigs were used as models for surgical PC correction and randomized for 2 groups: thoracoscopy (T) and subcutaneous (subpectoralis) endoscopy (SP). In both groups, CCR from 3rd 4th and 5th ribs was performed avoiding ITA damage. ITA preservation was confirmed by Doppler-ultrasound as well as *postmortem* injection of methylene blue. Four persons evaluated the procedures being difficult, using a 6-item modified validated scale.
Results: In both techniques, the procedure was accomplished in all animals sparing ITAs. CCR was faster in T than in SP (49 ± 5 *vs.* 65 ± 16 minutes, $p < 0.05$). T was classified as easier than SP ($p < 0.001$) with a significantly higher score for all items, especially better image and tissue handling.
Discussion: Sparing the ITAs during CCR for correction of PC is feasible in a porcine model and might be a goal in humans. The thoracoscopic approach allows for a faster and easier procedure.

Pectus carinatum (PC) is defined as the protrusion of the sternum or the ribs. The overall prevalence is around 0.6% being the second most common chest wall deformity with up to 80% of the cases occurring in male patients [1,2]. Most cases of PC are sporadic, however there seems to be a congenital or hereditary origin, as it can occur as part of a genetic disorder or syndrome (i.e., Ehlers–Danlos syndrome, Marfan syndrome, trisomy 18, homocystinuria or Morquio syndrome) [3]. Hereditary links are suggested by the observation of PC in monozygotic twins, by the neonatal presentation and by increased incidence of other chest wall abnormalities in family members [3]. Although there is no established etiology, an abnormal pattern of cartilage growth and metabolism is thought to be involved in its etiophatogenesis [4,5]. This condition is usually asymptomatic and rarely associated with respiratory symptoms [6]. The unaesthetic appearance of the deformity however, may have psychological impact leading to insecurity, decreased confidence and low self-esteem.

During the last half-century, the standard procedure in the correction of PC was the open approach involving costal cartilage resection, wide pectoralis muscle dissection and sternal osteotomy [7]. The application of pressure over the protruded chest wall using orthosis was a nonsurgical alternative proposed during the nineties, but this alternative is not always successful [8,9]. For these patients, minimally invasive surgical approaches have been proposed, following two main inspiring ideas: the correction of the thoracic malformation by compression of the sternum with a subcutaneous bar [7,10] and the correction by costal cartilage resection [11,12]. Isolated cartilage resection may not be enough to correct bilateral and chondromanubrial deformities associated with sternal defects. However, multiple costal cartilage resections seem to be a good option for asymmetric unilateral PC avoiding the need for a bar and its subsequent removal reoperation [11,12]. Also in severe asymmetric PC, compressive techniques are not straightforwardly applied, as some patients are noncompliant.

Cartilage resection has been achieved either by thoracoscopic approach [11,12] or by creating an epicostal space, that is, inflating CO_2 under the pectoralis major muscle [13]. The number of reported cases is not large and, in the authors' knowledge, there is no previously published comparison between these two different strategies [11,12].

Kim and Idowu's [11] and Varela and Torre's [12] thoracoscopic approaches differ from each other in the extent of cartilage resection; from Varela and Torre's point of view a more extensive cartilage resection may alter the need for postoperative external compression. However,

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a wider resection is not fully harmless; in order to reach the most medial portions of costal cartilages, obliteration of the internal thoracic vessels is required. This could be exceptionable because coronary heart disease is the worldwide leading cause of death and in selected patients coronary artery bypass graft will improve tremendously these patients outcome [14,15,16,17]. Graft patency is associated with long-term survival and left internal thoracic artery (ITA) graft has proved a higher rate of patency at 10 years [18,19,20]. Moreover, in multiple arteries bypass graft, right ITA might be the second best graft as it can further improve long-term survival and reduce adverse events [21].

Given the importance of internal thoracic arteries, this work aims to simulate and assess the feasibility of unilateral pectus carinatum repair with preservation of the internal thoracic vessels by resecting costal cartilages and compare thoracoscopic and subcutaneous (submuscular) endoscopic approaches.

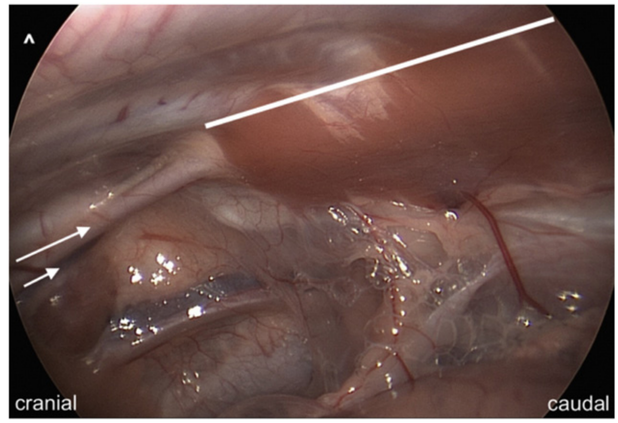

Fig. 2. Thoracoscopic operative view: long arrow—right internal thoracic artery; short arrow—right internal thoracic vein; line—lateral insertion of right transverse thoracic muscle, sectioned for caudal preservation the vessels; the arrow head marks what is anterior.

1. Materials and methods

1.1. Design

Twelve pigs (*Sus scrofus domesticus*) weighing 25 to 35 kg were alternately assigned to a thoracoscopic group (T) and a subpectoralis group (SP), to avoid the effect of a learning curve. In T, 3rd to 5th costal cartilages were resected by thoracoscopy; whereas in SP, the same cartilages were resected by endoscopic approach with subpectoralis CO_2 inflation.

Preservation of the internal thoracic vessels was attempted in both groups. The operative details, acute and postmortem outcomes were assessed and compared. This study was approved by the ethical review board of Minho University (Braga, Portugal).

1.2. Pig preparation

All procedures were performed under general anesthesia with endotracheal intubation and mechanical ventilation. Pigs were submitted to preoperative 8-hour food-fasting or 4-hour water-fasting. The animals were premedicated with a combination of azaperone (4 mg/kg, intramuscular), midazolam (1 mg/kg, intramuscular), and atropine (0.05 mg/kg, intramuscular). Anesthesia was induced with propofol (6 mg/kg, intravenous) and maintained with continuous propofol infusion (20 mg/kg/h, intravenous) and buprenorphine (0.05 mg/kg, intramuscular).

1.3. Surgical technique

In T (Video 1), the pig was placed in lateral decubitus. A 10 mm variable view angle endoscope (EndoCAMeleon® Hopkins®, 26003AE, Karl Storz, Tuttlingen, Germany) was introduced through a 11 mm trocar (30123TPS, Karl Storz) located in the fifth intercostal space (ICS) in the posterior axillary line. The capnothorax was established with an inflation rate of 1 L/min and maintained with a pressure up to 6 mm Hg. Two additional 5 mm working ports (30120TRX, Karl Storz) were placed in the forth ICS (posteriorly) and sixth ICS (anteriorly to the telescope trocar) as shown in Fig. 1A. Using a 5 mm grasping forceps (CLICK'line, 33310ML, Karl Storz) and the hook (Cadiere Monopolar Dissecting L-shaped Electrode, 26775CL, Karl Storz), the lateral insertion of the transverse thoracic muscle was sectioned (Fig. 2). The internal thoracic vessels are then identified, isolated and pushed away from the costal cartilage (medially and posteriorly); special care was taken to coagulate small braches (mediastinal, sternal and perforating branches) to prevent bleeding. With combined use of monopolar hook, endoscopic 45° *rongeur* (Medtronic Sofamor-Danek, Memphis, TN, USA) and endoscopic perichondrium elevator (Medtronic Sofamor-Danek, Memphis, TN, USA) the perichondrium was opened and 3rd, 4th and 5th costal cartilages were almost totally resected, leaving cartilage stumps of less than a centimeter.

In SP (Video 2), the pig was placed in lateral position. A 10 mm incision was made in the posterior axillary line (Fig. 1B) and a working space was created beneath the pectoralis major muscle using forceps. An 11 mm trocar (30123TPS, Karl Storz) was introduced and the CO_2 inflated with a pressure up to 18 mm Hg and inflation rate up to 5 L/min. As in T, the same endoscope was introduced and two additional 5 mm working-ports (30120TRX, Karl Storz) were placed under visualization. Further dissection was performed toward the midline and special caution was needed to promptly coagulate any perforating branches of the internal thoracic vessels. The same instruments were used as in T. The pectoralis major, rectus abdominis and serratus anterior muscles were bluntly dissected and eventually cut. The perichondrium was opened and cartilage resected using monopolar hook and the

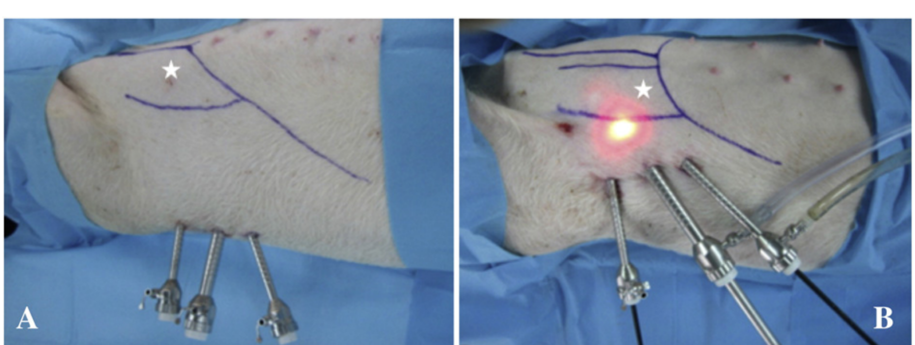

Fig. 1. Trocars position in the T (A) and SP (B). Rib cage limits, sternum and costal cartilage location (star) were marked with blue marking pen (preoperative ultrasound was used to identify the cartilage/bone transition).