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Surgical approaches to aortopexy for severe tracheomalacia

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ABSTRACT

Purpose: The purpose of this study was to determine the outcomes among three different surgical approaches for performing an aortopexy to treat severe tracheomalacia (STM).
Methods: A retrospective review was performed for all patients who underwent an aortopexy by pediatric surgeons at a single institution during 1997–2012. Data collected included details of the operative approaches and clinical results. The data were analyzed using Chi-square and Fisher exact test.
Results: Forty-one patients underwent an aortopexy. The operation was chosen by the surgeon and not randomized. Exposure was by partial sternotomy (PS) (20), open thoracotomy (12), or thoracoscopic approach (7). Only the PS approach was done by a single team. All groups showed improvement in work of breathing, prevention of severe respiratory distress, and acute life threatening events. These effects were more dramatic for the PS group, especially regarding oxygen and/or ventilator dependence and the ability to undergo tracheostomy decannulation. Among the sixteen patients with failure-to-thrive before successful aortopexy by any technique, ten demonstrated significant improvement in their growth ($p = 0.025$). The recurrence rate for the thoracoscopic approach was 38%, and there were no recurrences in the partial sternotomy and the thoracotomy groups, 38% vs 0% vs 0%, $p = 0.005$. Simultaneous bronchoscopy was utilized more commonly in the PS group compared to the thoracotomy and thoracoscopic group, 95% vs 62% vs 38%.
Conclusions: In this series, the partial sternotomy technique had the most reliable resolution of symptoms and no recurrence requiring reoperation. The PS approach to STM has the technical advantages of an improved exposure with equal access to the vessels over the right and left mainstem bronchi, as well as the trachea and a more specific elevation of the arteries, including suspension of the pulmonary arteries and trachea itself when desirable. Simultaneous bronchoscopy during aortopexy and an experienced team also likely contribute to improved outcomes. The variations in populations, follow-up, and use of continuous intraoperative bronchoscopy, however, make firm conclusions difficult.

Severe tracheomalacia (STM) and bronchomalacia may require treatment which is most commonly accomplished by an "aortopexy". In this paper, aortopexy is the operation, but the procedure details may involve suture support of other mediastinal structures in addition to the aorta. By pulling the overlying vessels and other structures anteriorly to open up the airway, an aortopexy limits collapse during the active exhalation phase of breathing; however, it does not directly treat tracheomalacia. With the airway attached anteriorly to the vessels and posteriorly to mediastinal structures by connective tissue, suture elevation of the aorta and, usually, the innominate artery to the back of the sternum will maintain an adequate airway. By this indirect mechanism, aortopexy has been found to be generally beneficial in relieving the consequences of STM.

An effective aortopexy, we believe, has several components. Foremost is bringing the vessels up nearly to the back of the sternum which elevates the anterior aspect of the trachea and may, also open the proximal portion of the main stem bronchi. Occasionally, with significant malacia of the mainstem bronchi, elevation of the pulmonary arteries and even the adjacent pericardium must be carried out to hold the mainstem bronchi open. Occasionally these maneuvers have proven insufficient, and direct suture placement into the tracheal and/or bronchial cartilages has been required to provide adequate airway support. The sutures placed in the vessel walls are of obvious importance and must balance holding power without causing bleeding. Finally, because an aortopexy is an indirect solution, the ability to assess the effects of the elevation of the vessels and other structures on the airway by bronchoscopy while the procedure is being carried out is valuable to ensure the desired result.

Several surgical approaches have been used to reach the arteries and bring them forward to the sternum. Right and left anterior as well

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as more lateral thoracotomy incisions have been used and also cervical, mediastinal and thoracoscopic approaches have been reported [1–3]. The many techniques indicate that, so far, no one approach has proven superior for all cases.

We report a review of all patients who underwent aortopexy by one of three techniques by pediatric surgeons over 15 years at a single institution. This review allowed comparison of the standard open thoracotomy and thoracoscopic techniques with the more recently used partial sternotomy (PS) approach.

1. Materials and methods

A retrospective chart review was performed on all patients who underwent an aortopexy for STM by pediatric surgeons between 1997 and 2012 at Boston Children's Hospital (IRB P00007671). The patients were grouped by the operative approach and the preoperative status, and the aortopexy results were reviewed.

The operative approach was chosen by the surgeon and not randomized. Only the PS procedures were done by a single surgical team. The patients in this review often had a complex clinical history and frequently STM was not the only significant airway or pulmonary problem. Among the partial sternotomy patients for example, 17/20 (85%) had a prior EA repair done elsewhere and many had significant pre-transfer complications, further compromising overall pulmonary function.

Among the clinical manifestations evaluated as ascribable to STM were: acute life threatening events (ALTE) defined as a significant apneic episode, or a "blue spell" or transient breathing distress with marked air hunger and/or very loud breathing. Oxygen dependence was less specific but was considered present when supplemental oxygen was necessary to maintain a saturation of 90%. Similarly, it was judged whether or not tracheomalacia was mainly responsible for preoperative intubation or for the presence of a tracheostomy. All patients were evaluated for other causes of respiratory compromise including laryngeal and upper airway difficulties and previous correction of trachea-esophageal fistulas with large residual tracheal pouches producing significant airway intrusion. All patients were evaluated for gastro-esophageal reflux which was treated as appropriate with fundoplication and/or medications.

Evaluation of TM was performed by rigid bronchoscopy while spontaneously breathing in all patients, and more recently also by dynamic airway CT. The TM was classified by location in the trachea (upper third, middle third, lower third) and mainstem bronchi (right, left), and by the degree of airway collapse during exhalation. The TM was judged to be severe when there was near complete collapse of the airway or coaptation of the tracheal walls shown either by bronchoscopy and/or or CT.

The operative data tabulated included the method of aortopexy performed, the details of the elevation of the vessels and pericardium and the use of intraoperative bronchoscopy. Postoperative data included symptom resolution, evidence for recurrence of TM, or the need for reoperation.

Operative Methods: Partial sternotomy: A 3-cm transverse incision was made at the manubrial–sternal junction and a partial upper sternotomy along with partial thymectomy allowed the upper portion of the pericardium to be opened to reveal the innominate artery and ascending aorta. With the vessels well-visualized, partial thickness horizontal mattress sutures of pledgeted 5-0 Tevdek were placed into the antero-lateral aspects of the artery walls (Fig. 1). A flexible bronchoscope passed down the endotracheal tube assessed the result. When the mainstem bronchi remained collapsed despite innominate artery and aortic elevation, sutures were placed in the wall of the pulmonary artery and, for some, in the pericardium adjacent to the pulmonary artery. In a very few cases, non-pledgeted sutures were also placed in the tracheal and/or bronchial cartilages for more direct elevation of the trachea and bronchus. The sutures were then placed into the posterior sternal fascia or through the sternum itself. A final evaluation of the airway was made by bronchoscopy and an echocardiogram assessed the great vessels after closing.

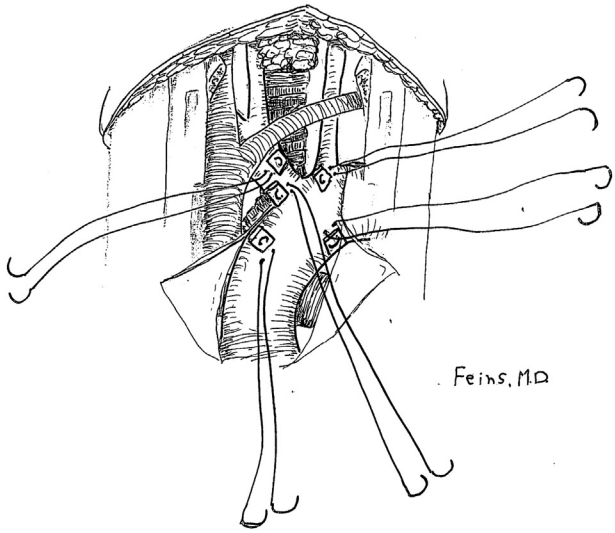

Fig. 1. Partial sternotomy technique. After performing a partial sternotomy, removing a portion of the thymus and opening the upper portion of the pericardium for exposure, the innominate artery and aortic arch are elevated and sutured to the sternum. This exposure allows pledgetted horizontal mattress to be placed in the lateral aspect of the arteries producing a more even elevation and also the ability to continuously observe the effect by bronchoscopy.

Thoracoscopic aortopexy (Illustration 2): The thoracoscopic approach has previously been described [4,5]. Three left-sided ports were typically used, although a right sided approach was also done. The sutures were placed along the most anterior portion of the upper ascending aorta and into the sternum (Fig. 2). In 3 cases the sutures were placed into the pericardium overlying the aorta without opening the pericardium. Bronchoscopy was sometimes performed during the case, and was usually done at the end of the case to assess the aortopexy effects on the airway.

Thoracotomy: A left or right anterior thoracotomy incision allowed the pericardium overlying the aorta to be opened. Sutures were passed through the anterior aspect of the upper ascending aorta and

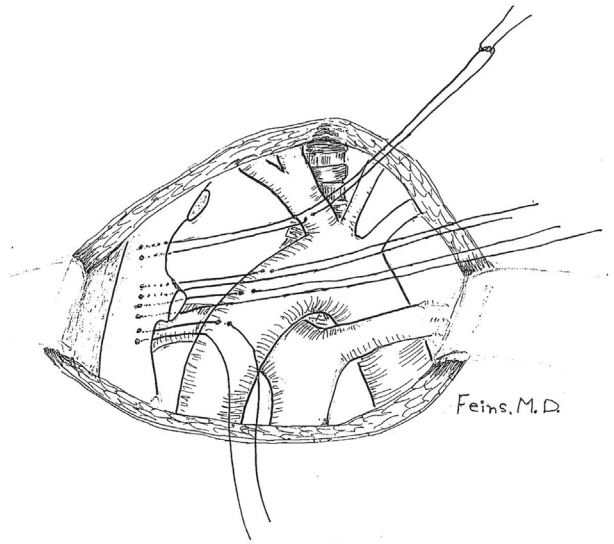

Fig. 2. Thoracotomy technique. After performing a limited anterior thoracotomy, either right or left, the near thymic lobe is removed and the ascending aorta and sometimes the innominate artery is sutured to the sternum. These sutures are placed along the anterior surface of the arteries.