Anterior and posterior tracheopexy for severe tracheomalacia

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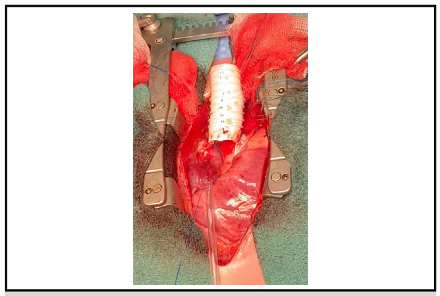
ABSTRACT

Objectives: Congenital tracheomalacia can be the cause of respiratory failure in young children. Although the indication for surgical treatment has already been discussed vigorously, no clear guidelines about the modality are available.

Methods: Through a sternotomy approach, a combination of posterior pexy and anterior tracheopexy using a tailored ringed polytetrafluoroethylene prosthesis is performed. Patient demographic characteristics, as well as operative details and postoperative outcomes, are included in the analysis.

Results: Between 2018 and 2022, 9 children underwent the operation under review. All patients showed severe clinical symptoms of tracheomalacia, which was confirmed on bronchoscopy. The median age was 9 months. There was no operative mortality. Eight patients could be weaned from the ventilator. One patient died because of interstitial lung disease with bronchomalacia and concomitant severe cardiac disease. The longest follow-up now is 4 years, and shows overall excellent clinical results, without any reintervention.

Conclusions: Surgical treatment of tracheomalacia through a combination of posterior and anterior pexy is feasible, with acceptable short- and midterm results. (JTCVS Techniques 2023;17:159-63)



Anterior tracheopexy using PTFE ringed prosthesis.

CENTRAL MESSAGE

Anterior tracheopexy using an adapted ringed PTFE prosthesis, in combination with a posterior tracheopexy, offers good short- and midterm results in young patients with severe tracheomalacia.

PERSPECTIVE

There is no consensus yet on a gold standard of tracheomalacia surgery. Our center offers a complete treatment using a combination of techniques. In this report, the technique is described and results are highlighted.

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Congenital tracheomalacia (TM) is a disease characterized by increased collapsibility of the main airway in young children. It can cause breathing problems, especially during expiration.[1] In severe cases, these patients need frequent hospitalizations for lung infections and can present with apneic spells (brief resolved unexplained events). These patients may benefit from a surgical therapy directly addressing the frailty of the airway.[2]

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Abbreviations and Acronyms
CT = computed tomography
PICU = pediatric intensive care unit
PTFE = polytetrafluoroethylene
TM = tracheomalacia

Although the main goal of surgical therapy remains airway expansion, there is no consensus about the modality of surgical treatment. This can be achieved at the membranous (posterior) and cartilaginous (anterior) part of the trachea, using suturing techniques with or without the use of prosthetic reinforcement. In this report, we present our surgical approach for TM, using a combination of posterior tracheopexy with an anterior external stenting using a polytetrafluoroethylene (PTFE) graft, thus providing 360° treatment of the trachea in a single procedure.

PATIENTS AND METHODS

Indication and Diagnostic Work-up

Hospitalized or nonhospitalized children with suspicion of TM are evaluated by a pediatric pulmonologist. When further investigation is deemed necessary, the patient receives a bronchoscopy, performed under sedation and spontaneous breathing. When severe TM is seen, all patients receive a contrast-enhanced computed tomography (CT) scan to rule out any congenital vascular anomalies possibly responsible for the TM. For TM without a vascular cause, the clinical presentation, CT examination, and bronchoscopy videos are reviewed during a multidisciplinary team meeting.

All results are discussed during a multidisciplinary team meeting. In case of life-threatening apneic events or ventilator dependency, decision for surgery is made. In case of severe infections only, a wait-and-see approach is often maintained, with institution of maintenance airway clearance physiotherapy with positive expiratory pressure mask and low threshold for antibiotic therapy during illness.

Surgical Technique

All procedures are performed under general anesthesia. After median sternotomy, the thymus is completely removed. Further mobilization of the aorta (left border), innominate vein (cranial border), superior caval vein (right border), and right pulmonary artery (inferior border) opens the region of interest. The posterior pericardium is opened and the trachea visualized. The latter is completely and circumferentially mobilized with respect for the carina, which is left untouched to respect vascularization. The recurrent laryngeal nerve is protected by blunt dissection. Additionally, the esophagus is mobilized until the prevertebral fascia can be seen. Generally, there is no need for cardiopulmonary bypass. In case of a residual pouch after previous trachea-esophageal fistula surgery, this pouch is oversewn with a polypropylene 6–0 suture. All tracheal maneuvers are performed under real-time bronchoscopy. Firstly, a posterior multilevel pexy is realized with anchoring stitches using polypropylene 5–0 sutures between the membranous part (bilaterally at the border with the cartilaginous part) and the prevertebral fascia. This is performed every 10 mm. For the anterior, external stenting, a commercially available PTFE ringed vascular prosthesis is used, and before implantation, opened longitudinally. A longitudinal segment (approximately one-third) is resected to create a free space for the membranous part and to allow further tracheal growth. For graft sizing, the latero-lateral diameter of the trachea (X) is calculated on CT of the chest. In general, a graft size X + 2 mm is chosen. The cartilaginous part of the trachea is splinted within this horseshoe-shaped scaffold by several left, midline, and right anchoring stitches of polypropylene 5–0 suture material between the cartilaginous part and the prosthesis (Figure 1). Finally, an aortopexy using polypropylene 5–0 stitches reinforced with a PTFE pledget, is performed. The pericardium is closed and local infiltration with ropivacaine is given in the wound and around the chest drain. The sternotomy is closed in a routine fashion. A final bronchoscopy evaluation concludes the procedure (Video 1).

Postoperative Course

All children are brought to the pediatric intensive care unit (PICU), where they are weaned from anesthesia and ventilator as soon as possible. They receive intensive respiratory physiotherapy and prophylactic cefazolin antibiotic treatment is given the first 24 hours. Afterward, antibiotics are given upon indication, in case of fever or positive sputum cultures. After dismissal from the PICU, children recover at the ward with further physiotherapy and analgesia.

Clinical Data

This study was approved by the hospital ethical committee (ONZ-2022-0370; approval date, September 23, 2022) waiving the need for informed consent due to the retrospective nature of the study. All patient details, including gender, age, weight, length, previous surgery, the presence of a syndrome, and symptoms were gathered. Operative details include operation time, the size of PTFE graft, and additional cardiac procedures. Postoperative data comprise the need for further antibiotics, duration of

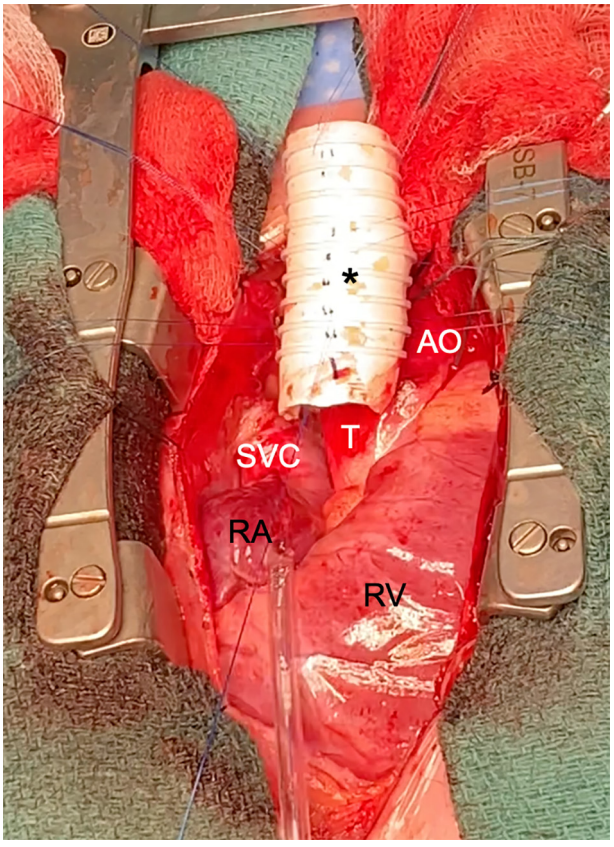
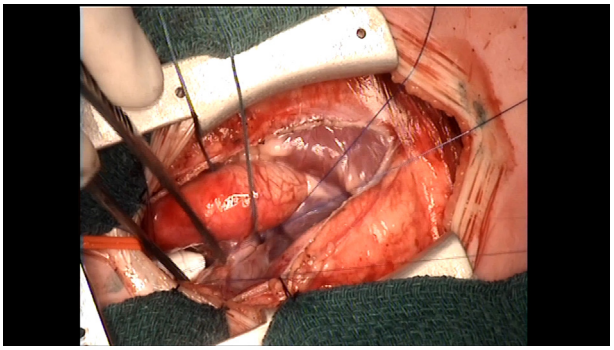


FIGURE 1. The polytetrafluoroethylene (PTFE) ringed prosthesis for the anterior external splinting (*black asterisk*). *AO*, Aorta; *SVC*, superior vena cava; *T*, trachea; *RA*, right atrium; *RV*, right ventricle.



VIDEO 1. Surgical video, imaging video, and demonstration. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00591-0/fulltext.

mechanical ventilation, and PICU and hospital stays. We highlighted readmission because of respiratory problems as a midterm outcome parameter.

Statistical Analysis

The results were analyzed using SPSS statistical software version 28 (IBM-SPSS Inc). Frequencies are described as median with minimum and maximum values.

RESULTS

Demographic Characteristics

Between August 2018 and March 2022, 9 patients underwent this procedure. Eight patients were boys. The median age at operation was 9 months (2 months, 25 months). The median weight and length were 7.7 kg (3.7 kg, 14.4 kg) and 65 cm (55 kg, 86 cm).

Six patients received prior surgical therapy for esophageal atresia with tracheoesophageal fistula Gross type C. This surgery was performed through a right thoracotomy. Two patients had a confirmed syndrome: 1 vertebral defects, anal atresia, cardiac defects, tracheo-esophageal fistula, renal anomalies, and limb abnormalities association; and 1 chromosome 2q13 13q32 deletion. Two patients had previous cardiac surgery: 1 baby for double-outlet right ventricle Fallot type and 1 child with Shone complex. Patient details are in Table 1.

Seven children were investigated because of recurrent severe chest infections and 6 patients had 1 or more life-threatening event with home or hospital resuscitation. Two children were mechanically ventilated before the operation with inability to wean from the ventilator. All nonventilated patients had stridor before surgery. In all patients, bronchoscopy revealed severe tracheomalacia with a nearly complete collapse of the tracheal lumen during expiration. The absence of vascular rings was confirmed with CT examination.

All patients underwent an operation in the previously described fashion. The median (minimum, maximum) operation time was 185 minutes (145 minutes, 321 minutes). In 2 patients, the time was prolonged (321 minutes and 315 minutes) because of concomitant cardiac procedures: 1 patient with Shone complex received aortic valve repair and arch reconstruction under deep hypothermic circulatory arrest and the other patient with double-outlet right ventricle Fallot type had pulmonary valve replacement with a Contegra valve (Medtronic). The sizes of the PTFE ringed graft varied from 10 to 14 mm. Size 12 mm was used in 6 patients, size 10 in the 2 youngest patients, and size 14 in the oldest patient. There was no operative mortality.

The median (minimum, maximum) PICU and hospital stay was 3 days (2 days, 37 days) and 12 days (5 days, 37 days). The time of postoperative mechanical ventilation ranged from 0 minutes (3 were extubated in theatre) to 37 days. The latter patient died after 37 days, mainly due to severe interstitial lung disease, bronchomalacia, and cardiac failure in a hypotonic child with severe developmental delay. Of all surviving patients, the longest mechanical ventilation time was 14 days, seen in the youngest patient (age 2 months), mainly due to postoperative edema. This patient was also on mechanical ventilation before surgery. In 7 patients, additional antibiotic

TABLE 1. Patient details

Patient No.	Age at operation	Weight (kg)	Previous TEF	Previous cardiac surgery	Recurrent chest infections	BRUE	Operative time (min)	PTFE size (mm)	Additional surgery	Mechanical ventilation time (d)	Survival
1	8 mo	5.6	Yes	No	Yes	Yes	165	12	No	4	Alive
2	10 mo	8.3	Yes	No	Yes	No	150	12	No	0.4	Alive
3	7 mo	7.7	No	No	No	Yes	145	10	No	0.8	Alive
4	2 mo	3.7	Yes	No	Yes	Yes	274	10	No	14	Alive
5	8 mo	5.9	Yes	Yes	Yes	No	315	12	PVR	37	Dead
6	2 y	13.5	No	No	Yes	Yes	185	12	No	0	Alive
7	5 mo	6.2	Yes	No	No	Yes	205	12	No	0	Alive
8	1 y	13.1	Yes	No	Yes	No	175	12	No	0	Alive
9	2 y	14.4	No	Yes	Yes	Yes	321	14	AVP + Arch	1	Alive

TEF, Tracheo esophageal fistula; *BRUE*, brief resolved unexplained event; *PTFE*, polytetrafluoroethylene; *PVR*, pulmonary valve replacement; *AVP*, aortic valve plasty.

therapy was given during the postoperative period, with excellent clinical response.

In the long run, 1 child needed a brief hospitalization because of chest infection. In all other children, no readmissions were seen. The longest follow-up now is 4.5 years. All 8 patients are doing clinically excellent. Routine bronchoscopy performed after 1 year show an open airway, with no signs of moderate or severe malacia (Figure 2).

DISCUSSION

Although the indication for surgery in symptomatic children with severe tracheomalacia is well defined,[1] no consensus has yet been delineated on the ideal surgical strategy. Large centers often describe a patient-tailored approach[3] using an armamentarium of posterior and anterior pexy, with or without anterior external splinting and aortopexy. The latter still is a good option for children with tracheomalacia[4] and can even be performed through a minimally invasive approach.[5] However, depending on the degree of malacia, the success rate of aortopexy is variable.[6,7] Prior aortopexy can complicate sternotomy in case additional airway procedures are necessary. Posterior tracheopexy addresses the frail membranous part of the trachea, often responsible for collapse because it is the most mobile part of the main airway.[8] It can be performed at multiple levels and more reports are suggesting a minimally invasive approach.[9-11] Although aortopexy and posterior tracheopexy can offer relief of symptoms, the cartilaginous part of the main airway is often weak (especially in esophageal atresia patients), and some authors suggest a combination of anterior and posterior tracheopexy[12] directly addressing both parts of the trachea. Although it can be achieved without external stent, a partially circumferential scaffold seems useful to generate optimal lumen diameter. The concept of external splinting has previously been described and has satisfactory results.[13] The use of a ringed PTFE prosthesis offers good support, is rapidly available, and is cheaper than biological 3-dimensional printed scaffolds.[14]

In our experience, the combination of both anterior and posterior tracheopexy offers the best guarantee for clinical success by a single operation, and addresses both the static and dynamic component of tracheomalacia.[15] By opening the PTFE graft and leaving a space for the membranous part (horseshoe shape), we believe this scaffold should not interfere with future growth. This report shows that the procedure is technically feasible with acceptable operative times and good perioperative bronchoscopic results. No reinterventions were necessary in this small group of patients. An external anterior PTFE stent provides semirigid stability for the cartilaginous part, whereas the membranous part is attached to the prevertebral fascia without prosthesis. The latter can be important because migrations of PTFE pledgets into this part of the airway have been described.[16] Finally, the question about tracheal growth within the PTFE scaffold remains important. We have regular clinical follow-up and perform a bronchoscopy every year. We believe that at some point, CT examination to evaluate the growth of the trachea will be necessary. However, this carries an ionizing burden and therefore we would prefer doing this (in the absence of problems) at age 5 or 6 years, when sedation is not necessary anymore. In the meantime, we remain vigilant, with frequent clinical evaluations and yearly bronchoscopy.

CONCLUSIONS

Surgical treatment of tracheomalacia through a combination of posterior and anterior pexy is feasible. For the posterior pexy, the firm prevertebral fascia is used as anchoring point. Anteriorly, the cartilage part is externally stented using a horseshoe-shaped ringed PTFE graft. This small sample series provides good clinical short- and midterm results, but long-term results are important to evaluate this technique.

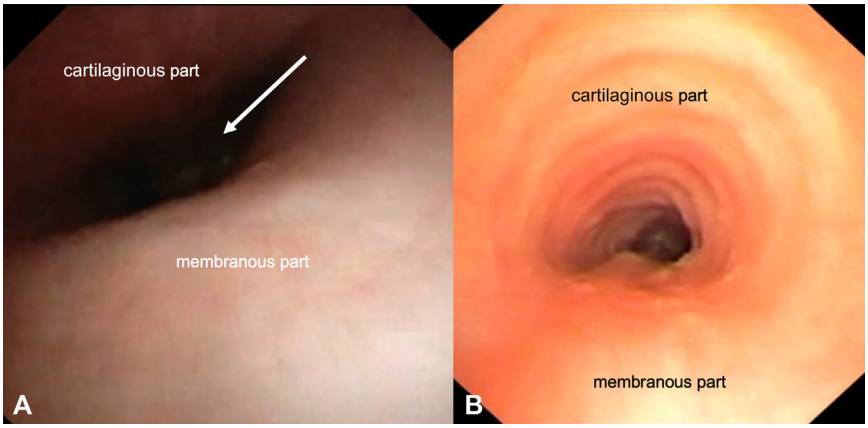


FIGURE 2. Bronchoscopy image before surgery (A) and 1 year later (B).

Webcast

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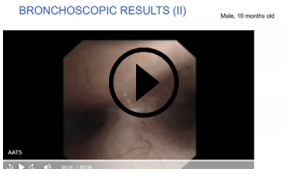

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: tracheomalacia, airway surgery, pediatric