Posterior Cricoidotomy Lumen Augmentation for Treatment of Subglottic Stenosis in Children

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**Objectives:** To determine the results of posterior cricoidotomy lumen augmentation in the treatment of moderate and severe subglottic stenosis in children, and to assess the effect of this surgery on the growth of the larynx in young children.

**Design:** A 17-year retrospective study.

**Patients and Methods:** Thirteen children with moderate and severe subglottic stenosis who underwent posterior cricoidotomy lumen augmentation from 1980 to 1996. Eight children (62%) were male and 5 (38%) were female. The average age was 4.7 years (age range, 8 months to 15 years). Six (46%) of the 13 children were younger than 3 years. Nine children (69%) had acquired subglottic stenosis, 3 of whom had a combined subglottic–posterior glottic stenosis, and 4 (31%) had congenital subglottic stenosis. All the children already had a tracheotomy tube placed and had undergone treatment at our clinic or at other institutions. The surgical procedure we used included a cricoid lamina split with grafting (2 children with costal cartilage graft and 11 with buccal mucosal graft) and stenting.

**Results:** Twelve (92%) of the 13 children underwent decannulation, and 1 (8%) is still undergoing treatment: decannulation is expected to be carried out in the near future. Of the 12 children who underwent decannulation, 9 demonstrated good postoperative voice quality and 3, who had combined subglottic–posterior glottic stenosis, developed impaired voice function. Following stent removal, all children experienced some degree of difficulty in swallowing saliva and liquids, which was soon overcome. No evidence of surgery-induced laryngeal growth impairment in younger children was observed.

**Conclusions:** The posterior cricoidotomy lumen augmentation is a safe and effective technique for the treatment of moderate and severe subglottic stenosis in children of any age. This study lends further support to the assertion that external surgery does not affect the growth of the larynx in younger children.


The most significant progress in the treatment of laryngeal stenosis in children during the last 25 years has been the introduction of external surgical procedures, which have offered a new dimension in the solution of this problem. For decades, the general rule was not to perform surgery on children with laryngeal stenosis. The accepted treatment of stenosis in the pediatric age group was the use of conservative techniques. This attitude was based on 2 arguments: surgical manipulation of the young cartilage in the growing child might result in the underdevelopment of the larynx and the belief that, since the larynx increases in size when the child grows older, this growth itself could be the eventual solution to the problem. Unfortunately, dilatation failed to produce consistently good results in moderate and severe stenosis, and surgical reconstruction of stenosis was delayed until laryngeal growth and maturity were complete. During the waiting period, sometimes a child would experience serious complications directly attributable to long-term placement of a tracheotomy tube, in particular tracheotomy cannula obstruction by a mucus plug, accidental decannulation, and respiratory tract infections. Furthermore, the cricoid cartilage was always considered surgically untouchable. It was generally accepted that surgical procedures performed on this cartilage would cause loss of the structural support necessary to maintain the lumen patency of the larynx. Careful experimental and clinical reports7 demonstrate that these long-held concepts were invalid. Nevertheless, despite the remarkable advances resulting from the use of external surgery and the improvement in surgical reconstruction techniques, treatment of laryngeal stenosis in children continues to present serious problems. Due to the great variety and severity of laryngeal stenosis, there is no single method of treatment available for all cases, as evidenced by the numerous reconstruction techniques currently in use. Indeed, it is not uncommon for different procedures to be required in the same child to obtain successful results. We evaluated the results of posterior cricoidotomy lumen augmentation for the treatment of children with moder-
PATIENTS AND METHODS

PATIENTS

Between January 1980 and December 1996, 16 children with moderate and severe subglottic stenosis were surgically treated by posterior split of the cricoid cartilage (modified Rethi\textsuperscript{8} technique) at our clinic. Of these 16 children, 3 were excluded: 2 children were unavailable for follow-up after decannulation and 1 child abandoned the treatment after stent removal with a tracheotomy tube in place. In the resulting group of 13 children, 8 (62%) were male and 5 (38%) were female. The age at surgery ranged from 8 months to 15 years, with an average age of 4.7 years; 6 (46%) of the 13 children were younger than 3 years. Of these 13 children, 9 (69%) had acquired stenosis, 3 had combined subglottic–posterior glottic stenosis with fixation of the vocal folds. The other 10 children had normal vocal fold mobility. All the children already had a tracheotomy tube in place at the time of initial presentation and had received treatment at our clinic or at other institutions.

METHODS

The procedure included an anterior midline incision, performed through the lower third of the thyroid cartilage, just below the anterior commissure, the cricoid arch, and upper tracheal cartilages (Figure 1). Depending on the extent of the stenosis or the presence of a deformity at the suprastomal anterior tracheal wall, this incision should not reach the tracheotomy site to leave intact a trachea bridge and thus reduce the possibility of the surgical area becoming contaminated. The scar tissue was not resected. A midline vertical incision was carried out through the mucosa-lined scar tissue of the posterior subglottic wall down to the cricoid lamina. This incision was extended at least 1 cm below the inferior border of the cricoid lamina in the normal mucosa of the posterior tracheal wall, thereby preventing tearing of this mucosa during further stages of the technique. A vertical division of the cricoid lamina in the midline was carried out, splitting it in half, starting below the interarytenoid area. Following this, lateral retraction

ate and severe subglottic stenosis and assessed the effect of this surgery on laryngeal growth in younger children.

RESULTS

Twelve (92%) of the 13 children underwent decannulation and 1 (8%) is still receiving treatment. Two of the 12 children undergoing decannulation showed no symptoms of upper airway obstruction when resting, but slight stridor occurred during exercise or a respiratory tract infection, the result of a collapsible anterior tracheal wall during inspiration. The degree of tracheomalacia has decreased as the children have grown. One child who had congenital stenosis died of a disease (leukemia) unrelated to the surgery 1 year following decannulation. Another child expelled the stent during vigorous coughing on the ninth postoperative day. The stent was replaced and this complication did not affect the result. Two children required further endoscopic procedures to trim the redundant mucosal graft area. Three children had posterior displacement of the suprastomal anterior tracheal wall and underwent endoscopic or tracheotomy site procedures. This was followed by the placement of a Montgomery Silastic T-tube (Boston Medical Products Inc, Boston, Mass),\textsuperscript{9} which also helped to prepare the children for decannulation. Despite favorable findings of radiographic and endoscopic evaluations, the child still undergoing treatment has the tracheotomy cannula plugged during the day and unplugged at night to sleep; hopefully, the tube can be removed soon.

The number of procedures required per child ranged from 3 to 5, with an average of 3.2. The time between the posterior cricoidotomy and the decannulation varied from 2 to 14 months: 2 to 3 months in 6 children, 4 to 6 months in 3 children, and 10 to 14 months in 3 children. Of the 12 children who underwent decannulation, 9 who had normal vocal fold mobility demonstrated good postoperative

VOICE EVALUATION

Postoperative voice results were evaluated subjectively. An objective measurement of voice quality was performed by a speech and language therapist only in the 3 children in whom the fibroed interarytenoid muscle was resected. In the follow-up of quarterly visits for the first year and yearly visits in subsequent years, the younger children were also examined through functional, endoscopic, and radiographic studies for a possible relationship between the surgical technique used and impairment of laryngeal growth.
voice quality. The voices of 4 children whose anterior commissure had been preserved were determined to have the best voice quality. The 3 children who had combined subglottic–posterior glottic stenosis with fixation of the vocal folds, and in whom the interarytenoid muscle was resected, developed impaired voice function due to supraglottic compensation caused by glottic incompetence. These 3 children developed a hoarse and breathy voice, low fundamental frequency, and decreased phonation time. However, significant voice improvement was obtained with voice therapy. Following stent removal, all children experienced some degree of difficulty in swallowing saliva and liquids; this complication soon disappeared.

In summary, 12 (92%) children underwent decannulation, and 1 (8%) is still undergoing treatment with decannulation expected to be carried out in the near future. Of the 12 children who underwent decannulation, 9 demonstrated good postoperative voice quality and 3 children developed impaired voice function. Following stent removal, the children experienced some degree of aspiration with saliva and liquids; this was soon overcome. There was no functional, endoscopic, or radiographic evidence that this surgical technique impaired normal laryngeal growth in young children.

Currently, external surgical reconstruction must be considered the most appropriate treatment for moderate and severe laryngeal stenosis in children. The selection of the surgical technique to be used depends primarily on which region of the larynx is involved and how severe the stenosis is. No objective parameters have been uniformly adopted for the purpose of preoperative assessment of the severity of laryngeal stenosis. This lack of standards only serves to complicate a number of related areas: treatment decision making, comparison of the efficacy of different procedures available for the treatment of stenosis, comparison of data collated by different surgeons and institutions, and the ability to forecast the likelihood of a successful outcome.

In 1955 Rethi introduced a method of posterior split lumen augmentation—midline vertical cricoid lamina split and prolonged stenting—to stabilize the lateralization of the cricoid lamina halves. The stent was usually left in place for 6 months or longer, until the hemilaminas scarred in a lateral position and there was no tendency toward contraction. Rethi places emphasis on the avoidance of scar tissue resection because it will produce a raw surface with further granulation tissue and subsequent scar formation.
In our series, the cricoid lamina was thickened due to perichondritis, as noted by other authors. Thus, it is preferable to cut the cricoid lamina gradually, being careful to feel the cartilage resistance, to avoid the deepening of and inadvertent injury to the postcricoid and esophagus walls.

Despite the continued acceptance and validity of the principle of Rethi's method, a number of modifications to his original technique have been advocated. Aubry et al and Aboulker et al recommended partial thyrotomy to expose the posterior wall of the larynx, without dividing the anterior commissure. We prefer this approach: when exposure of the posterior wall is poor, we provide increased exposure through a complete thyrotomy. If complete thyrotomy is necessary, care must be taken to ensure the proper alignment of the vocal folds at the time of closure to reconstruct the anterior commissure.

Another modification to Rethi's technique is the interposition of an autogenous graft between the cricoid lamina halves, which will result in the stabilization of the laterally retracted cricoid lamina halves. The interposition of the graft reduces the duration of stenting—4 weeks instead of 4 to 6 months when a graft is not used—and the...
length of time from surgery until decannulation. Cartilage has proved to be excellent graft material for laryngeal reconstruction. Studies of the costal cartilage graft show viable and normal cartilage architecture; fibrous replacement of the cartilage graft occurs to a variable extent. Some authors believe that interposition of the autogenous graft between the halves of the cricoid lamina is not necessary to obtain a stable lateralization, but rather that long-term stenting is required to allow the healing process to occur and to reduce wound contraction. The stent is usually left in place for 4 to 6 months.

There seems to be relative agreement in relation to 2 points. First, all patients need stenting, and second, a graft reduces the time of stenting. Although we recognize that both techniques are effective, we prefer the procedure without cartilage grafting (the interposition of a costal cartilage graft was used in this series in 2 of 13 children), despite the fact that insertion of a cartilage graft allows for a shorter duration between surgery and decannulation. Our opinion is based on the experience gained with the modified Rethi technique in adults, which convinced us that the division of the posterior cricoid cartilage and the appropriate lateral retraction, with simultaneous detachment of the cricoid lamina halves from postcricoid and esophageal walls until herniation occurs between them, are the key surgical maneuvers required to eliminate the tendency toward midline reapproximation of the hemilamnas. Resurfacing the denuded area resulting from lateralization of the cricoid lamina halves, to eliminate raw surfaces, promotes conditions favorable for primary healing. Resurfacing is an important part of the procedure and responsible for reducing granulation and fibrous tissue formation. Although the duration of stenting may be less than that required when a cartilage graft is not inserted, it must be no shorter than 8 weeks. In addition, those procedures that do not involve a cartilage graft are less subject to possible complications, such as cartilage graft displacement from the site of insertion or resorption.

Despite careful suturing of the cartilage graft, the placement of a stent helps to immobilize the graft in the proper anatomical position. In addition, the stent maintains the cartilaginous graft perichondrium on a level with the larynx mucosa and also prevents the graft from protruding into the lumen. Without cartilage graft placement, the stent keeps the new enlarged lumen patent in place until the cricoid halves have stabilized in the lateral position. With a buccal mucosal graft, the stent is also important because it provides better contact between the mucosal graft and vascularized tissue while preventing the formation of any dead space where a hematoma might form. While stenting is necessary, the presence of a stent itself may cause the formation of granulation tissue, which requires endoscopic resection once the stent is removed. We used a custom-made solid stent fashioned from a soft Silastic block. The anterior central portion of the stent is triangular so that positioning of the anterior commissure may be achieved to avoid the possible formation of a web. Prior to 1980, the stent was hollow and attached to a metal tracheotomy tube through an appropriately positioned hole in the stent. This technique was abandoned soon after, with the stent being fixed in position by through-and-through tracheal sutures permitting the replacement of the tracheotomy tube on a daily basis. With this technique of securing the stent in position, dislodgment has been uncommon, but it occurred in 1 of our children. The cause of this complication was found to be excessive tension adjustments to the sutures, which were probably inserted too tightly. Reconstructive surgery was carried out safely in the younger children and technically is no more difficult than with a teenager or adult. It is important to note that those children in our study with successful outcomes had all undergone failed attempts to resolve the stenosis.

**CONCLUSIONS**

Posterior cricoidotomy lumen augmentation, with grafting and stenting, is a safe and effective technique for the treatment of moderate and severe subglottic stenosis in children of any age. Underdevelopment of the larynx resulting from surgery on the cricoid cartilage was not observed in the follow-up of the younger children in this series.

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**REFERENCES**