Objective: To identify risk factors for operation-specific outcomes of pediatric cricotracheal resection (CTR).

Design: We identified the first 100 consecutive children undergoing CTR at our institution from January 1, 1993, to December 31, 2004. Retrospective review of medical records provided data on demographics, operation dates, decannulation dates, and proposed risk factors, including age, stenosis grade, vocal cord function, Down syndrome, history of distal tracheal surgery, history of open laryngotracheal surgery, presence of tracheotomy at the time of operation, use of suprahyoid release, extended CTR, and use of chin-to-chest sutures. Complete data sets were available for 93 patients. We performed multivariable logistic regression analysis to identify significant independent risk factors.

Setting: A tertiary care children’s hospital.

Patients: All patients younger than 18 years who underwent CTR at our institution.

Main Outcome Measures: Operation-specific and overall decannulation rates.

Results: Results of the preoperative evaluation showed grade III or IV stenosis in 89 patients (96%). The overall decannulation rate included 87 patients (94%); the operation-specific decannulation rate, 66 patients (71%). The only significant risk factor for failure to decannulate after 1 operation was the presence of unilateral or bilateral vocal cord paralysis (P = .007).

Conclusions: Cricotracheal resection may be safely performed in patients with multiple airway lesions. Patients with a history of vocal cord paralysis who undergo CTR often require more than 1 open airway procedure for decannulation and should be counseled appropriately. This study represents the largest reported series of pediatric CTR.


PARTIAL CRICOTRACHEAL RESECTION (CTR) for the treatment of subglottic stenosis (SGS) was first reported in an adult by Conley1 in 1953 and in a child in 1974 by Gerwat and Bryce.2 In the early 1990s, the use of CTR in children was championed by Monnier et al,3-6 beginning with publication of a case series in 1993 and followed by updates, with excellent results. Published results from London,7 France,8 and our institution9-11 have followed, with decannulation rates exceeding 90% for grades III and IV stenosis according to the Myer-Cotton grading system.12 With these reports, CTR has become an acceptable, if not preferable, method of treatment for high-grade SGS in children. Although the success rates of CTR have been widely published, little has been written about risk factors that may delay progression to decannulation. Hartley et al13 suggested that bilateral true vocal cord paralysis, history of distal tracheal surgery, and infection with methicillin-resistant Staphylococcus aureus (MRSA) may have contributed to 2 failures. Rutter et al11 and Monnier et al4 observed lower rates of decannulation after extended CTR (defined as CTR performed simultaneously with another airway procedure).

Related literature has investigated complicating factors for other airway reconstructive procedures. Ludemann et al14 found respiratory syncytial virus pneumonitis and pseudomonal wound abscess to be associated with failure to decannulate after laryngotracheal reconstruction. In addition, untreated gastroesophageal reflux (GER),14-16 stenosis grade,17 and Down syndrome18,19 have been considered risk factors for failure of laryngotracheal reconstruction. These factors have not been studied for pediatric CTR.

The goal of this study was to identify patient- and technique-related risk factors that contributed to failure of the initial procedure in children who underwent CTR at our
institution. In the process of evaluating this data, we also describe operation-specific and long-term decannulation rates for pediatric CTR at our institution.

METHODS

We obtained approval from the institutional review board at Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio, before undertaking this study. A database of all patients who have undergone CTR at our institution has been maintained prospectively from January 1, 1993, to December 31, 2004. Information on all patients aged 0 to 20 years, including sex, date of birth, history of airway surgery, preoperative stenosis grade, presence of tracheostomy tube at the time of CTR, date of CTR, decannulation status, date of decannulation, description of CTR and associated procedures (ie, extended CTR), and procedures required after CTR are incorporated into this database and were obtained for this study. Medical records were then obtained and reviewed for the following data: vocal cord function, presence of eosinophilic esophagitis, Down syndrome, history of distal tracheal surgery, previous airway reconstruction, and perioperative wound infection including MRSA-positive culture findings. Technical data were also obtained from the medical chart, including use of chin-to-chest sutures, fibrin glue, and suprahyoid release. During the past 10 years, the routine preoperative regimen at our institution has included evaluation for and successful treatment of GER disease before CTR, including Nissen fundoplication if necessary. In addition, patients with no evidence of GER are treated with perioperative proton pump inhibitors (for 6 months postoperatively). Because GER was universally treated in our patient population, analysis of GER as a risk factor could not be performed.

The medical records of 100 patients were reviewed. Only patients who had complete medical records (including data on all of the factors considered for risk factor analysis) and more than 3 months of follow-up were included. Five patients were excluded because of inadequate medical records, and 2 patients who recently underwent CTR were excluded because the length of follow-up was insufficient. The remaining 93 patients were included in our study.

Before analysis, descriptive statistics (means, standard deviations, and frequencies) were calculated for all the variables using the SAS software package, version 9.1 (SAS Institute Inc, Cary, NC). We performed χ² tests for comparing proportions and paired t tests for comparing continuous variables. For multivariate analysis, the logistic regression technique was used because the dependent variable is dichotomous. First, a logistic regression was fitted to each independent variable separately. The variables with a P value of .2 or less were retained for the multivariable analysis. The backward elimination method was chosen for the analysis.

RESULTS

Descriptive statistics are presented in the Table. Average patient age was 6.1 years (age range, 4 months to 19 years; SD, 4.6 years). Mean duration of follow-up was 5.2 years (range, 4 months to 11.2 years). Eighty-seven (94%) of 93 patients have undergone successful decannulation. Two of the remaining patients are able to keep their tracheostomy tubes plugged and are expected to undergo decannulation soon. Two have recently undergone staged airway reconstruction, and 2 are scheduled for further reconstruction. Fifty-five patients underwent CTR as a salvage procedure (performed after failed laryngotracheoplasty), and 51 (93%) of those underwent decannulation. Twenty-five patients underwent extended CTR, and 23 (92%) of those underwent decannulation. Twenty-seven patients required additional open airway procedures for decannulation after CTR, resulting in an operation-specific success rate of 71% (66 patients). Postoperative complications included acute anastomotic dehiscence in 2 patients (both underwent successful decannulation) and acquired unilateral vocal cord paralysis in 2. No deaths occurred in this series.

Initial χ² or Fisher exact test analysis demonstrated P values of less than .05 for the following factors: vocal cord dysfunction (defined as fixation or paralysis [P = .001]), Down syndrome (P = .03), presence of tracheostomy tube at the time of CTR (P = .04), use of chin-to-chest sutures (P = .02), and extended CTR (P = .02). Sex, age, history of open airway surgery, preoperative stenosis grade, date of CTR, history of distal tracheal surgery, postoperative wound infection, use of fibrin glue, and use of suprahyoid release were not associated with a higher rate of operation-specific failure. Pseudomonal wound infection was seen only twice, with no associated complications. No perioperative viral pneumonitis was seen.

Fisher exact test results demonstrated a significantly lower operation-specific success rate for eosinophilic esophagitis (P = .03) and postoperative MRSA infection (P = .01). However, because of the small sample size, these factors were not considered in the multivariable analysis.
A backward elimination logistic regression excluded chin-to-chest sutures as a significant risk factor. Multiple logistic regression analysis excluded significance for Down syndrome (P = .09), presence of a tracheostomy tube at the time of CTR (P = .09), and extended CTR (P = .06). Vocal cord dysfunction (P = .007) remained as the only significant risk factor for failure to decannulate after 1 procedure.

Based on the regression model, odds ratios were calculated for vocal cord paralysis, Down syndrome, presence of tracheostomy at the time of CTR, and extended CTR. The odds ratio for operation-specific failure in patients with vocal cord dysfunction is 5.2 (95% confidence interval [CI], 1.6-16.9), indicating that patients with vocal cord dysfunction are 5 times more likely to require an additional open airway procedure than are patients with normal vocal cord motion. Odds ratios were also high for patients with Down syndrome (8.2; 95% CI, 0.7-94.3), tracheostomy tube presence (7.1; 95% CI, 0.8-67.0), and extended CTR (2.8; 95% CI, 0.97-8.3), but 95% CIs included 1 in each case, resulting in P values of greater than .05.

Cricotracheal resection for the treatment of SGS in children has become part of the standard surgical algorithm in the past decade. Decannulation rates of greater than 90% are reported in this series, as well as in series from other institutions. The most serious surgical complications, acute dehiscence of the thyrotracheal anastomosis and injury to the recurrent laryngeal nerve, are relatively rare, each occurring in 2 (2%) of our patients. Multivariable analysis indicated preoperative vocal cord dysfunction (bilateral or unilateral, paralysis or fixation) to be a significant risk factor for failure of the initial operation, although long-term decannulation rates (20 [95%] of 21 patients) were similar to those for patients with normal vocal cord function (67 [93%] of 72 patients). Sex, age, history of open airway surgery, preoperative stenosis grade, date of CTR, history of distal tracheal surgery, Down syndrome, postoperative wound infection, extended CTR, use of fibrin glue, and use of suprathyroid release were not statistically significant risk factors for operation-specific failure.

Operation-specific decannulation, indicating no need for an additional open procedure, occurred in 66 patients (71%). Patients who had normal vocal cord function had an operation-specific decannulation rate of 79% (57 of 72 patients). These results may be skewed somewhat by our patient population. Our institution has an international referral base for airway reconstruction and, as such, we routinely see patients with complex, multilevel airway obstruction who have already had multiple failed reconstructive attempts. For extremely complex airway reconstructions, CTR is often performed as one of many steps toward decannulation. Children who were not able to undergo decannulation after CTR did so after additional procedures 78% of the time (21 of 27 patients). Only 1 of 6 patients who did not undergo decannulation in the most recent report from our institution remains tracheostomy dependent.

Because we do not routinely perform laryngeal electromyography when vocal cord function is abnormal, cricoarytenoid joint fixation could not be easily differentiated from vocal cord paralysis in this study. We use the term vocal cord dysfunction to include patients with lack of vocal cord motion (unilateral or bilateral), which may be due to paralysis or fixation. When vocal cord dysfunction was present preoperatively, patients required a second open procedure 57% of the time in our series (12 of 21 patients). Based on our regression model, an odds ratio of 5.2 indicates that children with vocal cord dysfunction who undergo CTR are more than 5 times more likely than those who have normal vocal cord function to require a second operation. Vocal cord dysfunction has been suggested as a risk factor in a review from our institution by Hartley et al,12 in which 1 of 2 children in whom primary CTR failed had preoperative bilateral vocal cord dysfunction. Children with unilateral vocal cord dysfunction typically were treated with a standard CTR. Children with bilateral vocal cord dysfunction typically undergo an extended CTR with a simultaneous posterior cricoid split and placement of a cartilage graft or vocal cord lateralization. In previous reviews of operative treatment of bilateral vocal cord paralysis as a single lesion, operation-specific decannulation rates of 60% to 79% have been reported. Unilateral vocal cord paralysis may also be a source of respiratory distress in children, albeit much less frequently than bilateral vocal cord paralysis. Because it represents a separate airway lesion that is not treated directly with CTR, the lower success rate among children with vocal cord dysfunction is not surprising. Parents should be counseled that multiple procedures may be expected when treatment of severe SGS is performed in a patient with vocal cord dysfunction.

Treatment of esophageal disorders is imperative before proceeding with CTR. The role of GER in the development of SGS and failure of laryngotracheal reconstruction has been reported by several different institutions. All patients in our series underwent evaluation for GER and other esophageal disorders before CTR, and all patients were treated with a proton pump inhibitor for a minimum of 6 months postoperatively. Because of the uniformity of treatment in our series, GER could not be analyzed separately as a risk factor. All 3 patients with eosinophilic esophagitis who underwent CTR had an initial decannulation failure. Although a Fisher exact test demonstrated significantly worse outcome for such patients when compared with other patients undergoing CTR (P = .03), the cohort was too small to include in the multivariable analysis. Early evidence indicates that laryngotracheal reconstruction is prone to failure in patients with eosinophilic esophagitis, but further investigation of this poorly understood disease is merited. At present, we recommend esophagoscopy and biopsy as part of the preoperative evaluation for CTR, with successful treatment of GER or eosinophilic esophagitis before undertaking the procedure.

Bacterial infection has been implicated in the development of SGS26 and the failure of airway reconstruction. Pseudomonas infection in particular has been reported to have a positive correlation with failure of laryngotracheoplasty with costochondral cartilage graft-
ing. In our series, 9 patients had wound infections, 2 of which were pseudomonal. Neither of these patients required reoperation. The 4 patients with wound infections who required another open procedure all had MRSA-positive wound culture findings. One of these patients had an acute dehiscence of the thyrotrochal anastomosis that required a revision procedure 1 week after the initial CTR. Results of a Fisher exact test showed a significantly lower operation-specific decannulation rate (0%) for patients with MRSA wound infection when compared with other patients (P = .001); however, this cohort was too small to include in the multivariable analysis. Patients who had no evidence of wound infection did not routinely undergo culture, so we cannot comment on colonization of the airway with MRSA or *Pseudomonas aeruginosa*. Since reviewing these data, we have begun to prospectively acquire preoperative tracheal and nasopharyngeal cultures in all patients scheduled for airway reconstruction to evaluate the role of airway colonization in postoperative complications.

Recent reviews of laryngotracheal reconstruction in children with Down syndrome have demonstrated no difference from the decannulation rates of other children, despite earlier results. The present study supports this conclusion, although the wide CI suggests that an increased cohort size is necessary before a firm conclusion can be made. Larger study cohorts may also be necessary to draw firm conclusions regarding the outcomes of patients who undergo extended CTR and patients who are not tracheostomy dependent at the time of CTR.

Extended CTR was defined by Rutter et al as CTR performed at the same time as another airway procedure, such as laser arytenoidectomy, vocal fold lateralization, or posterior cartilage grafting. Extended CTR was associated with lower decannulation rates in this report, as well as in a later review by Monnier et al. Although extended CTR was not a significant risk factor in this study, the lower end of the 95% CI was 0.97, and the P value was .06, indicating that a study with slightly more power may demonstrate significance.

**CONCLUSIONS**

Cricotracheal resection is an effective procedure for the treatment of high-grade 5Gs in children, with long-term decannulation rates of more than 90%. Vocal cord dysfunction represents a separate lesion that increases the risk that a second open airway procedure will be necessary after CTR. Eosinophilic esophagitis and postoperative MRSA wound infection may also be associated with initial failure to decannulate after CTR, but more investigation is required. Extended CTR was not associated with decreased operation-specific decannulation rates in this series, although P values approached significance (P = .06).

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**REFERENCES**


