Cricotracheal Resection for Airway Reconstruction: The Sheba Medical Center Experience

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Abstract

Background: Intubation and tracheostomy are the most common causes of benign acquired airway stenosis. Management varies according to different conceptions and techniques.

Objectives: To review our experience with cricotracheal resection and to assess related pitfalls and complications.

Methods: We examined the records of all patients who underwent CTR in a tertiary referral medical center during the period January 1995 to April 2005.

Results: The study included 61 patients (16 women and 45 men) aged 15–81 years. In 17 patients previous interventions had failed, mostly dilatation and T-tube insertion. Complete obstruction was noted in 19 patients and stenosis > 70% in 26. Concomitant lesions included impaired vocal cord mobility (n=8) and tracheo-esophageal fistula (n=5). Cricotracheal anastomosis was performed in 42 patients, thyrotracheal in 12 and tracheotracheal in 7. A staged procedure was planned for quadriplegic patients and for three others with bilateral impaired vocal cord mobility. Restenosis occurred in six patients who were immediately revised with T-tube stenting. Decanulation was eventually achieved in 57 patients (93.4%). Complications occurred in 25 patients, the most common being subcutaneous emphysema (n=5). One patient died of acute myocardial infarction on the 14th postoperative day.

Conclusions: CTR is a relatively safe procedure with a high success rate in primary and revised procedures. A staged procedure should be planned in specific situations, namely, quadriplegics and patients with bilateral impaired vocal cord mobility.

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Benign acquired laryngotracheal stenosis is a well-recognized complication of prolonged intubation and tracheotomy. Contrary to tracheal stenosis in which segmental resection is accepted as the preferred modality of repair [1], other methods have been used for reconstruction of the most proximal tracheal segment and the subglottis.

Laryngotracheal reconstruction, denoting a variety of grafting techniques, was extensively described in the otolaryngology literature during past decades [2]. These techniques were based on the incorporation of tissue grafts (costal, nasal and auricular cartilage) into the airway skeleton in order to break down the circular pattern of scar formation, widen the lumen and augment the cartilaginous skeleton. These techniques may be used in combination with CTR in complex lesions and are primarily indicated in various subglottic and glottic lesions. Chen et al. [3] reported 45 tracheostomy-dependent patients who underwent LTR with a sternohyoid myocutaneous rotary door flap. Decanulation was achieved in 90%. However, multi-staged procedures and a relatively long interval from surgery to successful decanulation was noted [3,4]. Lano and co-workers [5] reported their 10 year experience with 41 patients who underwent 46 reconstructions: LTR (21 patients), CTR (21 patients), and combined procedures (3 patients). Their results emphasized the advantage of immediate decanulation achieved in CTR cases as compared to successful LTR cases that achieved decanulation within 1 year.

The use of CO_2 laser surgery for removal of cicatricial tissues is limited to fibrotic scarring involving short segments of limited extent that do not involve the airway skeleton. The role of stenting is limited, by consensus, to primary use in short segments of scarring that do not significantly involve the cartilaginous skeleton [4]. Nonetheless, the T-tube was also considered effective in the most complicated cases as either an adjuvant or last resort [6].

Until recently, CTR was primarily reported in the thoracic surgery literature [7-9] and only a few cases were described in the otolaryngology literature [10-12]. The present study summarizes a decade of experience with this particular technique and discusses practical problems encountered both operatively and peri-operatively.

Patients and Methods

Altogether, 61 patients underwent CTR in our facility between January 1995 and April 2005. The age range of the 45 men and 16 women was 15 to 81 (mean 47.1 years). The patients' medical histories were associated mainly with motor vehicle accident (in 22), acute myocardial infarction (in 11), major cardiothoracic surgery (in 9), and stroke (in 8).

Preoperative evaluations included fiber-optic endoscopy, plain chest X-ray and computerized tomography scan of the larynx and trachea in most patients. For precise evaluation of the extent of the lesion and its characteristics, as well as possible glottic involvement and distal tracheomalacia, rigid laryngotracheoscopy under general anesthesia was routinely performed. Because of its simplicity and convenience, the pediatric grading system for subglottic stenosis suggested by Myer et al. [13] was adopted for our adult patients. It encompasses four grades of stenosis:

CTR = cricotracheal resection

LTR = laryngotracheal reconstruction

1 = 0–50% of airway lumen, 2 = 50–70%, 3 = 70–99%, and 4 = complete obstruction. Grade 2 narrowing of the cross-section airway area was found in 16 patients, grade 3 narrowing in 26, and complete subglottic or suprastomal obstruction (grade 4) was noted in 19 patients.

Impaired glottic function was noted in nine patients: unilateral vocal cord paralysis (n=3), unilateral paralysis with impaired mobility of the other side (n=3), posterior glottic scar (n=2) and anterior glottic web (n=1). Five patients presented concomitant tracheo-esophageal fistulae.

Nine patients (15%) were not tracheotomized prior to surgery: two were extubated following prolonged mechanical ventilation and due to propagating symptoms of airway obstruction required urgent tracheal dilatation; the other seven suffered from airway obstruction of varying severity and duration. The longest period of airway stenosis of clinical significance was noted in a 55 year old woman who had been restricted to minor physical exertions since childhood. One patient suffered from extrusion of a metal mesh stent, manifesting as hemoptysis, and required urgent intervention. All others were scheduled for surgery after stabilization of their general condition. Eighteen patients, including 3 from our department, had undergone previous attempts for airway reconstruction, the most common being CO_2 laser vaporization with or without dilatation and Montgomery T-tube insertion [Table 1].

The surgery technique

A horizontal skin incision including the stoma was used and flaps were raised to the hyoid bone level and down to the suprasternal notch. Tracheal release was performed by a blunt dissection of the pre-tracheal tissues down to the carina and posteriorly, approximately 2–3 cm distal to the resected segment, with care taken to keep the lateral vascular bands intact. No attempt was made to identify the recurrent laryngeal nerves. The trachea was exposed immediately above the stoma, enabling the surgeon to evaluate the extent of cricoid involvement. Trachea to thyroid anastomosis was indicated if subglottic stenosis was manifested by destruction of the anterior cricoid ring or by extensive scarring, sparing the crico-arythenoid joints; the fibrous tissue including the anterior cricoid lamina was then resected. The dissection in the posterior table of the cricoid lamina, adjacent to the recurrent laryngeal nerves, was maintained at the sub-perichondrial plane. Laryngeal release was performed via a suprahyoid release. In 15 early cases, tracheal traction sutures were used between the distal stump and the cricoid in order to lessen tension in the anastomosis suture line. Absorbable (polyglycolic acid) 2/0 and 3/0 sutures were used for the anastomosis with the knots tied outside the lumen. A chin-to-chest fixation with a heavy suture was added at the end of the procedure.

The postoperative protocol included peri-operative antibiotic, antacid and anti-reflux medications as well as pulmonary physical therapy. Postoperative evaluation included office fiber-optic endoscopy 1 week and 1, 3 and 6 months after surgery, with a mean follow-up of 9.5 months. Technical notes and modifications, in comparison to our previous report [10], include:

- P*atient's preparation*: The canula was replaced by an endotracheal tube enabling cleaning and scrubbing of the skin around the stoma and the stoma itself. The tube was then replaced again by a J-shaped tracheotomy tube, under sterile conditions. The control for deflation-inflation of the cuff was kept in the operative field, while the connection to the ventilation machine was kept in the non-sterile field, allowing access to the anesthetist.
- O*perative technique*: a) Suprahyoid laryngeal release was performed in only 9 of the last 20 cases (compared to nearly all cases before). b) The resected stump, left adhered to the anterior wall of the distal trachea, was used to pull the trachea upward (instead of tracheal traction sutures) until the rest of the tracheal circumference was sutured

Table 1. Characteristics of revised CTR procedures

Patient no	Gender, age	Primary procedure/s	Characteristics of restenosis
1	M, 25	CO_2 laser & T-tube (x1)	Left vocal cord paralysis, impaired right vocal cord mobility. Severe posterior commissure scar, suprastomal collapse
2	M, 18	CO_2 laser & T-tube (x3), anterior cricoid graft	Severe peristomal malacia, subglottic obstruction (80%), partially necrotic graft
3	M,18	CO_2 laser & T-tube (x2)	Complete upper tracheal and subglottic obstruction
4	M, 45	CO_2 laser & T-tube (x5)	Hyper-ossification of cricoid, severe suprastomal collapse
5	F, 60	Anterior cricoid graft	Facial burn and inhalation injury, posterior glottic scar, subglottic scar, suprastomal collapse
6	F, 70	CO_2 laser (x2)	Subglottic circumferential scar
7	M, 58	Dilatation & T-tube (x1)	Suprastomal collapse, peristomal malacia
8	M, 69	Mesh metal stent	Hemoptysis, extratracheal extrusion
9	F, 49	Mesh metal stent, costal cartilage graft	Granulations, mid-tracheal severe malacia
10	M, 70	Mesh metal stent, hyoid interposition	Granulation, upper tracheal malacia, necrotic graft
11	M, 47	CO_2 laser & T-tube (x6)	Complete subglottic and upper tracheal stenosis
12	M, 73	Hyoid interposition	Necrotic graft, left vocal cord paralysis
13	F, 46	Nasal septum graft	Peristomal malacia
14	F, 55	Tracheal T-tube	Severe tracheomalacia
15	M, 22	CO_2 laser (x3)	Complete tracheal destruction, cricoid distortion and scarring
16	M, 18	CO_2 laser (x2), costal cartilage graft	Anterior scarring, viable graft, restenosis at the cricoid level
17	M, 25	CO_2 laser & T-tube	Restenosis > 70%

to the larynx. c) The anastomotic sutures (polyglycolic acid 2/0 or 3/0) were purposely introduced through the cartilaginous cricoid plates (instead of reframing from cartilaginous invasion). d) Extubation was performed immediately in the operating room (instead of the recovery room), based on clinical judgment regarding the extent of air leak around the tube.

- *Postoperative care*: Candidates for immediate extubation remained overnight in the recovery room rather than the intensive care unit, and were then transferred to the ear, nose and throat department.

Results

Thyrotracheal anastomosis was performed in 12 patients, cricotracheal anastomosis (including resection of an anterior cricoid segment with sparing of the cricothyroid membrane) in 42 and tracheal end-to-end anastomosis in 7. Of the 61 patients, 57 (93.4%) were eventually decanulated, or uneventfully extubated – most of them in a single stage. Two female patients failed decanulation: one suffered burns and inhalation injury with severe subglottic scarring which required thyrotracheal anastomosis, and the other underwent resection of five tracheal rings with cricotracheal anastomosis due to extensive peristomal scarring and malacia. A third female patient died on the 14th postoperative day due to myocardial infarction. One patient, with bilateral vocal cord paralysis, is still canulated.

Extubation was delayed in 16 patients: 10 with thyrotracheal anastomosis (mean 3.5 days), 3 with severe chronic obstructive pulmonary disease (mean 5 days), and 3 with high cervical spine injury (mean 3.5 days). Two patients with preoperative diagnosis of significant impaired bilateral vocal cord mobility were left with a small stoma distal to the anastomosis: one for 5 days and the other for 6 months. A 17 year old patient with complete subglottic obstruction following intracranial atriovenous malformation bleeding was diagnosed as suffering from bilateral vocal cord impaired mobility only after surgery necessitating recanulation. The majority of patients stayed overnight in the recovery room for less than 24 hours.

Restenosis at the anastomosis site was encountered in the early postoperative period (days 2–7) in five patients and on the 25th day in one patient. These six patients underwent immediate dilatation and insertion of a Montgomery T-tube, through the anterior suture line (four patients) or through a distally placed stoma (two patients). Four of these six were decanulated within 3–6 months.

Delayed airway obstruction did not develop in any of the decanulated patients. Complications were encountered in 27 patients, the most common being subcutaneous emphysema (7 patients) [Table 2]. Mild dysphagia for several days was noted in seven patients who underwent laryngeal release; however, one patient with protracted dysphagia needed training in swallowing. The 30 day operative mortality rate was 1.6% (1 patient). Two young adult quadriplegic aphonic patients, who suffered from complete subglottic obstruction, were recanulated at the completion of surgery with small (6 and 7 mm) canulae enabling intermittent ventilation support. One was decanulated on the 11th postoperative day and the other was eventually decanulated after one year. Five patients with concomitant tracheo-esophageal fistulae were successfully operated on in a single-stage procedure.

Table 2. Postoperative complications in 62 patients following CTR (n)

Complications	Patients	Treatment
Subcutaneous emphysema	7	Suture release (5), drainage (2)
Restenosis	6	Dilatation and T-tube
Lung atelectasis	4	Physiotherapy (4), re-intubation (2)
Granulations	4	CO_2 laser (3)
Hematoma of neck	2	Exploration (1)
Pneumonia	2	
Cardiac arrhythmia	2	
Pneumomediastinum	1	Cervical drainage
Aspirations (protracted)	1	Swallowing training
Wound infection	1	Antibiotics
Distal migration of Dumon stent	1	Repositioning
Urosepsis	1	

Airway patency was considered near normal in 55 patients. Dyspnea during moderate physical effort was noted in four patients and on mild physical effort in two patients. The quality of phonation was considered good to excellent in all cases.

Discussion

CTR gained popularity due to it being a single-stage procedure with a high rate of success and minimal morbidity [7-9]. The involvement of the subglottic and glottic areas naturally called for laryngologic expertise, which attracted head and neck surgeons to this procedure. Recently, CTR was reported by several groups, in a large joint number of patients, all sharing high rates of operative success [Table 3].

Several parameters were considered to limit surgical success: the need for mechanical ventilation and systemic steroid treatment, as well as inadequate glottic functioning [17]. Yet, none of the clinical variables examined by Laccourreye et al. [11] was statistically related to the airway patency or to the complications encountered. Except for the patients' age, our previous report did not disclose differences in the rate of success or postoperative

Table 3. Decannulation rate following CTR

Author [ref]	No. of patients	% decanulation	Type of anastomosis (n)
Rea et al. [14]	65	95	Cricotracheal (15), thyrotracheal (5), 54 revisions
Pena et al. [12]	48*	91	Thyrotracheal
Macchiarini et al. [15]	45	95.5	Thyrotracheal (45), 24 revisions
Laccourreye et al. [11]	41	94.8	Cricotracheal (22), thyrotracheal (19), 25 revisions
George et al. [16]	20		Thyrotracheal (5)

* 48 patients with stenosis related to prolonged intubation

morbidity regarding a variety of clinical parameters detected either in primary or in revised procedures [10].

Several technical factors were noted to affect the success rate of CTR, the most detrimental being the anastomosis tension [10,18]. Difficulties may be encountered when long tracheal segments need to be removed. Taller patients and those with excellent cervical flexibility may enable a longer resection [19]. Approximation is gained by blunt release of the distal tracheal segment and careful preservation of the lateral segmental blood supply, with cervical flexion and, at times, proximal laryngeal (suprahyoid) release performed via a cervical approach [10,19]. Laryngeal release, more relevant to infrahyoid than suprahyoid, was reported to cause dysphagia and aspirations [11,18]. Several authors used laryngeal release for approximation, albeit infrequently: in 1 of 41 patients [11] and in 1 of 65 who underwent suprahyoid rather than infrahyoid release with consequent dysphagia [14]; 23 of 45 patients [15], most of whom underwent thyrohyoid release; and suprahyoid laryngeal release performed in 25% of 75 patients who underwent revision surgery [18]. Though laryngeal release was previously routinely performed in our patients, dysphagia was seldom encountered and only one patient required training in swallowing.

Tracheal and laryngeal dimensions differ significantly between males and females. Since some constriction at the anastomotic site is practically inevitable, it is reasonable to expect a higher incidence of compromised airway patency in females, expressed either sub-clinically or clinically. Though our failures occurred exclusively in women, we could not trace differences of significance by gender in the postoperative airway dimensions relative to the patient's own dimensions [20]; neither could we find reports addressing this issue.

Early extubation at the end of the operation is highly recommended [15,18]. We found that clinical judgment based on the extent of air leak around the oral tube was a sufficient indicator in most cases. Minimal intraoperative aspirations of blood or pharyngeal secretions (during the suturing of the posterior wall of the trachea) or inadvertent transient one-lung intubation (following transfer of the tube to the distal tracheal stem) may delay extubation, especially in severe COPD patients [5]. Also, patients undergoing thyrotracheal anastomosis were left intubated, the tube serving as a stent, for several days. Interestingly, Pena and colleagues [12] performed distal tracheotomy that was maintained for 5–6 days in all anastomosis cases, thereby avoiding prolonged sedation, ICU admission and possible friction of the suture line. We propose similar measures and staged decanulation in quadriplegic patients and in patients with bilateral impaired vocal cord mobility. The availability of placement in the ICU is limited and appropriate solutions need to be found for the individual patient. However, a routine overnight stay in a recovery room needs a well-prepared, skilled and fully cooperative medical and nursing staff.

Grillo and team [21] summarized 416 primary and 21 staged reconstructions that were performed over a 20 year period, 279 of which were performed for airway stenosis. Complications were divided into those related to technique and others related to failure of diagnosis. Technical errors included granulation tissue (mainly due to the past use of non-absorbable sutures), separation of anastomosis (n=4) due to excessive tension, partial (n=6) and complete (n=15) restenosis due to circumferential proliferating scar, brachiocephalic artery hemorrhage (n=2), tracheo-esophageal fistulae (n=1), vocal cord paralysis (n=5) and aspirations (n=1). They emphasized that tensionless anastomosis and preservation of tracheal vascularization were the key to operative success. Failed diagnosis included glottic incompetence (n=2) and residual malacia (n=3). They suggested careful evaluation of proximal and distal airways. However, when a tracheotomy is in place, distal malacia may still be overlooked [10].

Granulations, previously reported to be a major concern due to the use of silk sutures, are infrequently encountered today [18]. Mansour et al. [22] described atelectasis and pneumonia in 10 and 5 of 38 patients, respectively. It is our opinion that intraoperative monitoring of distal tracheal hygiene as well as immediate postoperative support of coughing and ventilation by physical therapy is of paramount importance to minimize these complications. The approximation of the anastomosis to the cricothyroid joints and the recurrent laryngeal nerves may result in impaired vocal cord mobility. Though not occurring in our study, unilateral and bilateral vocal cord paralysis has been reported in non-negligible numbers: 3/41 [11], 2/65 with bilateral injury [14], 3/75 (improved with time in two) [18], 5/437 [1], 1/38 [22] and 1/45 with bilateral involvement [15]. The importance of sub-perichondrial dissection of the cricoid plate and close tracheal dissection for preventing recurrent laryngeal nerve injury cannot be overemphasized [19].

Partial dehiscence of the anastomosis may manifest as an air leak and subcutaneous emphysema. It was described in up to 7% of patients [15] and appeared in our series in two forms: non-significant slow-developing emphysema of limited extent (5 patients, 8%) and abrupt leak of air demanding prompt intervention (2 patients, 3.2%). Failure of re-intubation was reported to be the cause of death in one patient who underwent single-stage laryngotracheoplasty with composite nasal septal graft without stenting [23]. This threat is also relevant in LTR cases. The medical staff should be alert to the change in laryngeal position and the resultant difficulties that may be encountered in re-intubation following laryngeal release, as well as to the limited extent of safe neck extension during re-intubation.

The mortality rate due to myocardial infarction, anastomosis dehiscence and mediastinitis and accidental extubation was reported to be as high as 3.3% [15,18,21].

Donahue and collaborators [18] reported the most comprehensive series on revised CTR in 75 patients. They emphasized that revision should be delayed for 4–6 months following previous CTR, and that a T-tube should be replaced by a canula a few days prior to revision to ensure mucosal healing from the T-tube friction. They used traction sutures of 2/0 polyglycolic acid placed at the mid-lateral walls of the proximal end of the

COPD = chronic obstructive pulmonary disease
ICU = intensive care unit

trachea. However, we felt that traction sutures not entirely in parallel with the tracheal axis may impose angular tension at the site of the anastomosis.

In summary, CTR performed in a variety of patients either as primary or revised procedures has resulted in a high success rate and low morbidity. Technical precision is most important in thyrotracheal anastomosis. Delayed extubation may be expected in patients with chronic lung disease and those undergoing thyrotracheal anastomosis. Failure may occur in the early post-operative period and should be immediately revised. A staged procedure should be planned in quadriplegic patients and in patients with bilateral impaired vocal cord mobility.

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