Original Article

Resection and anastomosis for benign tracheal stenosis: Single institution experience of 18 cases

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ABSTRACT

Introduction: Tracheal stenosis is a complex condition caused by altered inflammatory response to injury and subsequent excessive circumferential scar formation. Surgical resection, wherever possible, offers the best long-term results. Nonsurgical methods provide immediate relief to all can be curative in few but mostly serve as an excellent bridge to surgery in majority. The purpose of this study is to retrospectively evaluate the outcome following surgery for benign tracheal stenosis at our center. **Materials and Methods:** This retrospective analysis was conducted on 18 patients who underwent resection and anastomosis for tracheal stenosis at our center between March 2012 and December 2015. Their records were analyzed for demography, history, clinical presentation, computed tomography, bronchoscopy details, preoperative interventions, indications for and details of surgery, the procedure performed, postoperative complications, and course during 6 months follow-up. **Results:** The patients had a varied list of pathologies for which they were either intubated or tracheostomized. The length of stenosis ranged between 1 cm and 4 cm. The diameter of stenotic segment ranged between 0 mm and 10 mm. Average length of resected segment was 3 cm, and number of tracheal rings resected ranged from 2 to 9. Postoperative complications occurred in four patients (22.22%). All our patients were in the "excellent outcome" category at discharge as well as at 3 months follow-up. **Conclusions:** Surgical management of tracheal stenosis is challenging and requires multidisciplinary team approach. Thorough preoperative preparation and multidisciplinary planning regarding need for and timing of surgery, meticulous intraoperative technique, and aggressive postoperative care is key to successful surgery, which can provide long-lasting cure to these patients.

KEY WORDS: Tracheal stenosis, tracheal stricture, tracheal surgery, tracheostomy

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INTRODUCTION

Tracheal stenosis is a complex condition caused by altered inflammatory response to injury and subsequent excessive circumferential scar formation. Benign tracheal stenosis most commonly results from injury to the tracheal mucosa or cartilage as a result of prolonged intubation or tracheostomy. Despite the controversies in the management of tracheal stenosis, there is little debate regarding the management of "simple stenosis" of short length (<1 cm) and only mucosal involvement without cartilage destruction which is best managed by endoscopic interventions. However, for patients with complex stenosis who have a long segment lesion with cartilage destruction, surgery remains the preferred modality in view of excellent long-term results. Therefore, a multidisciplinary individualized treatment approach will give the best

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results. For complex lesions, nonsurgical methods such as repeated dilation, laser treatment, or stenting are chosen in cases where surgery is not possible either due to the characteristics of the stenosis or the patient is unfit. The immediate relief of an acute airway obstruction almost invariably requires emergent bronchoscopic interventions to tide over the crisis and buy time for subsequent proper evaluation and definitive management. These interventions provide immediate relief to all, can be curative in few, but mostly serve as an excellent bridge to surgery in majority. Unsuccessful attempts at pretreatment interventional bronchoscopic techniques may deteriorate the local conditions further, and for this reason, any manipulation or surgery in nonexperienced hands should be strictly avoided. Surgical resection with clear margins and anastomosis between healthy mucosa remains the most effective management of these conditions.[1-5] The purpose of this study is to retrospectively evaluate the outcome following surgery for tracheal stenosis at our center.

MATERIALS AND METHODS

This retrospective analysis was conducted on 18 patients who underwent resection and anastomosis for tracheal stenosis at our center between March 2012 and December 2015 ($n = 18$). Their files were analyzed for demography, history, clinical presentation, computed tomography (CT), bronchoscopy details, preoperative interventions, indications for and details of surgery, the procedure performed, postoperative complications, and course during 6 months follow-up.

After detailed clinical evaluation, the preoperative assessment consisted of chest X-ray, CT-scan of neck and upper chest [Figure 1] with multiplanar reconstruction [Figure 2] and bronchoscopy to evaluate the site, length and extent of stenosis, the integrity of the vocal cords, and the presence or absence of tracheomalacia. Special attention was paid to assess the state of inflammation in the tracheal mucosa above and if possible, below the site of stenosis. The indications for surgery were: symptomatic reduction in the tracheal diameter of more than 50% (with stridor or dyspnea), failure of tracheostomy decannulation, or failure of endoscopic management. All were elective, planned procedures. The patients were optimized nutritionally and explained the importance of nutrition and physiotherapy in postoperative recovery and their cooperation sought. The procedure was done under general anesthesia, administered either through the tracheostomy tube or through single lumen oral endotracheal intubation guided by a pediatric fiberoptic bronchoscope. We used micro laryngeal surgical (MLS) endotracheal tube in these cases as it is of small size and long enough to bypass the site of stenosis. If the stenosis was too narrow to be bypassed by the MLS endotracheal tube, the anesthetist positioned the tip of the tube just above the stenosis and ensured that enough amount of oxygenated air was blown distally through the stenotic segment with continuous monitoring of oxygen saturation and end-tidal carbon dioxide. Bronchoscopic examination was always done by the surgeon in all cases after induction for airway assessment before the surgery. The patients were placed in the supine position with neck extension. Collar incision, through transverse skin crease, 1.5–2 cm above the sternal notch was the standard for access to the cervical trachea. When the stenosis was extending distally, the upper partial sternotomy was added for better access. The trachea was exposed, and the stenotic segment was identified and resected [Figure 3]. In patients with tracheostomy, the stoma was also resected with the stenotic segment. A flexometallic tube was passed into the distal trachea for cross-field ventilation [Figure 4]. Various tracheal release maneuvers were performed according to the length of tracheal resection, aimed at providing adequate length for tension-free anastomosis. Cervical flexion and anterior cervico-mediastinal mobilization were done in all cases. Laryngeal drop by infrahyoid or suprahyoid release was performed for cervical trachea whereas thoracoscopic pericardial (hilar) mobilization and release of inferior pulmonary ligament were performed for lower trachea, as required. We practiced low threshold for laryngeal drop; more stress was on achieving tension-free anastomosis.

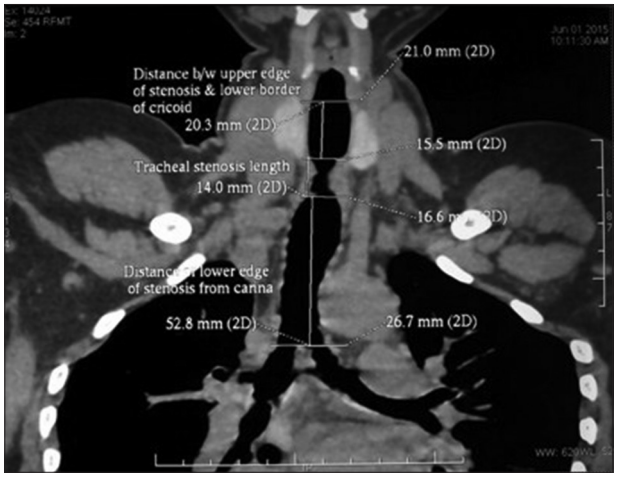

Figure 1: Computed tomography scan showing tracheal stenosis

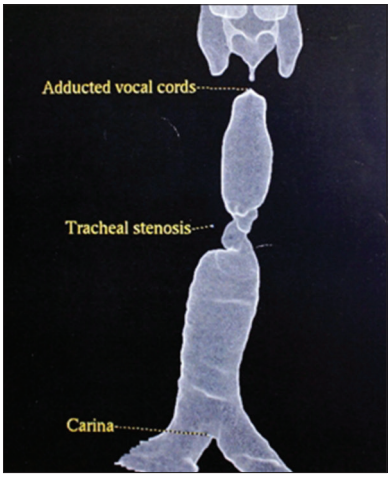

Figure 2: Multiplanar reconstruction of computed tomography scan image for tracheal stenosis

An end-to-end tracheal anastomosis was performed. After completion, the anastomosis was always checked for air leak up to pressure of 20–30 cm H_2O. No protective distal tracheostomy was performed in any patient. In one case, the stenosis involved the lower third of cricoid cartilage also and the same was resected along with the stenotic tracheal segment with anastomosis of the remaining cricoid cartilage to the healthy trachea. In another case, the stenosis involved the whole cricoid cartilage, wherein cricoid reconstruction with costal cartilage was done followed by anastomosis of reconstructed cricoid to the distal trachea. At the end of the procedure, all patients were extubated on the table under bronchoscopic guidance and shifted to surgical intensive care unit for overnight observation. They were shifted to the floor next morning and started on nasogastric tube feeds and active physiotherapy. The resumption of oral intake was linked to whether the laryngeal release was done or not. Patients without laryngeal release procedure had no swallowing difficulty and were allowed oral feeds in few days. Those with laryngeal release maneuvers, especially suprahyoid release required nasogastric feeding up to 3–4 weeks until they regained normal swallowing mechanism.[6,7] All patients resumed normal swallowing latest by 4 weeks after surgery. Patients were started on a rigorous exercise program consisting of brisk walking on treadmill and stair climbing from the first postoperative day. By the time of discharge, all were able to climb seven floors at a time several times a day and were instructed to continue same after discharge too, for a minimum of 6 months. The patients were followed up in the outdoor, and all were subjected to a check bronchoscopy at 6 months.

RESULTS

Out of 18 patients in the study, there were 15 males (83.33%) and three females (16.66%) with a median age of 27 years (range 10–81 years). The patients had a broad list of pathologies for which they were either intubated or tracheostomized [Table 1]. Sixteen patients had history of prolonged ventilation ranging from 2 to 26 days (average - 9.94 days), four among whom were later tracheostomized for weaning them off ventilator. Two patients were initially tracheostomized for different pathologies with average duration of 9.5 months with multiple attempts at failed decannulation. Causes for which these patients were put on mechanical ventilation or tracheostomized were, polytrauma in seven (38.8%), poisoning and pneumonia in two (11.11%) each, cerebrovascular accident in two (11.11%) and gunshot injury, tetanus, Guillain–Barre syndrome and postcesarean complication in one (5.55%) each. All patients were symptomatic with dyspnea, stridor, and cough being the most common complaints. The average duration of symptoms was 19.11 months with a range of 1–120 months [Table 2]. Six patients had tracheostomy at presentation and one patient; a 10-year-old boy had an endotracheal

Table 1: Demographic data of 18 tracheal stenosis patients

Characteristic	Value
Gender (male:female)	15:3
Age (year), median (range)	27 (10-81)
Underlying disease (%)	
Polytrauma	7 (38.8)
Cerebrovascular accident	3 (16.6)
Poisoning	2 (11.1)
Pneumonia	2 (11.1)
Gunshot injury	1 (5.55)
Tetanus	1 (5.55)
Guillain-Barry syndrome	1 (5.55)
Postcesarean complication	1 (5.55)
Etiology of stenosis (%)	
Postintubation	16 (88.8)
Posttracheostomy	2 (11.1)
Follow-up (months), average (range)	19.66 (6-48)

Table 2: Features of stenosis

Characteristic	Value
Duration of symptoms (months), average (range)	19.11 (1-120)
Length of stenosis, cm (range, average)	1-4, 1.86
Diameter of stenosis, mm (range)	0-10, 5.6
Grade of stenosis (I: II: III: IV)	0:10:6:2
Location (cervical: cervico-thoracic)	12:6
Length of trachea resected (cm), average (range)	3 (1.5-4.5)
Number of rings resected (range, average)	2-9, 4.38
Results (excellent: good: satisfactory: poor)	18:0:0:0

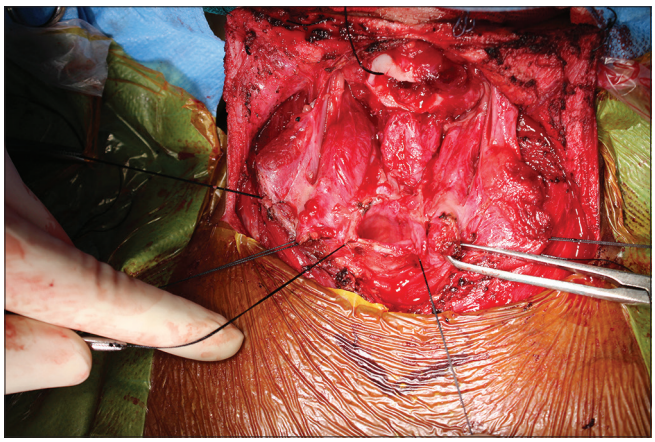

Figure 3: Resected ends of trachea with stay sutures

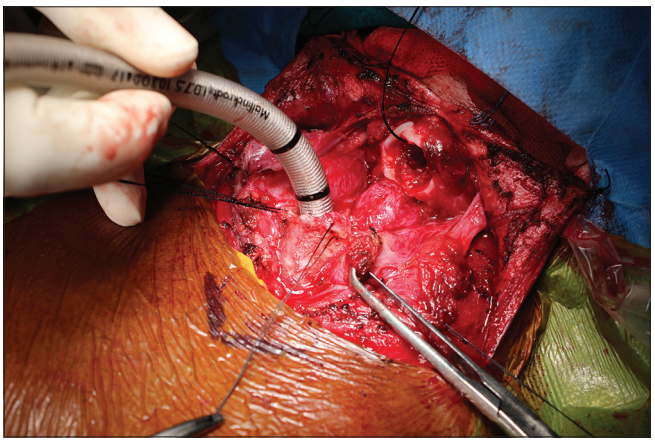

Figure 4: Cross-field ventilation during anastomosis

tube in place due to respiratory distress following an attempt at tracheal dilatation. The exercise capacity was severely restricted in all with none of them able to walk without breathlessness.

All our patients had complex stenosis. According to preoperative CT findings, the starting point of stenosis ranged between 1 cm and 5 cm distal to vocal cords. The length of stenosis ranged between 1 cm and 4 cm (average 1.86 cm). The diameter of stenotic segment ranged between 0 cm and 10 mm (average - 5.6 mm), two patients (11.11%) showed complete tracheal fusion above the tracheostomy tube. According to the Cotton-Myer grading system,[8] ten patients (55.55%) had Grade II stenosis, six patients (33.33%) had Grade III stenosis, and two patients (11.11%) had Grade IV stenosis. Preoperative fiberoptic bronchoscopy showed mobile vocal cords in all patients. The lesions were in cervical trachea in 12 (66.66%) patients and at cervicothoracic junction level in six (34.44%) cases [Table 2]. In one case (5.55%), the stenosis involved the lower third of cricoid cartilage also. In another case (5.55%), the stenosis involved the whole cricoid cartilage. Fiberoptic bronchoscopy did not show tracheomalacia in any case. Presurgical interventions had been done in all patients in an overlapping manner which consisted of tracheostomy in seven patients, single or multiple dilatations in 17 (average number of dilatation per patient were three), electrocautery in one and stenting in three patients, which were subsequently removed before surgery. At surgery, upper sternal split was needed in six patients for better access and mobilization. Infrahyoid laryngeal release was performed in 11 cases and suprahyoid release in ten. One patient required right-sided thoracoscopic pericardial (hilar) mobilization and inferior pulmonary ligament release for additional tracheal length. Average length of resected segment was 3 cm (range - 1.5–4.5 cm) and number of tracheal rings resected ranged from 2 to 9 (average - 4.3). Postoperative complications occurred in four patients (22.22%) and consisted of wound infection in three (16.66%) and transient quadriparesis in one patient (5.55%). Postoperative outcome was classified as excellent, good, satisfactory, or poor and was analyzed at the time of discharge and 3 months postoperatively. The postoperative result was considered excellent if voice, respiration and bronchoscopic examination were completely normal, good if there was lessening of maximal volume of voice after use with adequate breathing for normal activity, satisfactory in case of mild hoarseness with shortness of breath on exercise not sufficient to impair normal activities, and poor if patient developed some major complication such as anastomotic dehiscence restenosis or vocal cord paralysis. All our patients were in the "excellent outcome" category at discharge as well as at 3 months follow-up [Table 2]. The follow-up ranged from 6 to 48 months with an average of 19.66 months. There was no surgical mortality. All patients returned to their normal predisease lifestyle with no restrictions.

DISCUSSION

Tracheal stenosis is an abnormal narrowing of the tracheal lumen which can affect adequate airflow. The most common cause is injury secondary to intubation or tracheostomy. Other causes include infectious tracheobronchitis, systemic diseases such as amyloidosis, inflammatory bowel disease, relapsing polychondritis, sarcoidosis, Wegener's granulomatosis, saber sheath deformity of the trachea, tracheobronchopathia osteochrondroplastica, and broncholithiasis.[9] In postintubation or posttracheostomy cases, the tracheal injury is usually due to cuff pressure which impedes the tracheal capillary circulation, with resultant ischemic necrosis of the mucosa. This is followed by granulation tissue formation and fibrosis. Posttracheostomy stenosis occurs most commonly at the stoma site or less commonly at the site where the tip of the tube has impinged on the tracheal mucosa.[9] Increasing number of intubations and tracheostomies, expanding indications for mechanical ventilation, the prolonged survival and as a consequence, increasing number of days spent in Intensive Care Units have led to increasing incidence of tracheal stenosis. 2%–3% of patients who undergo intubations and/or tracheostomy develop tracheal stenosis.[10] The tracheal stenosis is classified as simple, which is a soft, short segment web-like narrowing often limited to the mucosa only or complex stenosis, which is a hard, long-segment stricture with destruction of tracheal cartilages and fibrosis.[10]

As the tracheal narrowing progresses, the patients develop obstructive symptoms and need intervention. Detailed preoperative assessment by CT scan of neck and chest with multiplanar reconstruction and fiber optic bronchoscopy is mandatory to know exact site and length of the stenosis, integrity of vocal cords, associated mucosal inflammation or edema above and below the site of stenosis, tracheomalacia, and any other coexistent pathology.[11] Patients with severe inflammation should be initially managed conservatively, reevaluated after a suitable period of observation, and should have intervention after the inflammation has settled. Symptomatic patients always need treatment. The decision for upfront surgery or bronchoscopic intervention should be guided by the severity of clinical symptoms. The available literature does not have any randomized trials comparing endoscopic and surgical intervention. Most reports suggest surgical treatment as a preferred approach for complex stenosis. Endoscopic interventions in the form of dilatation and stenting may work in very selected cases of complex stenosis, but are mostly reserved for inoperable cases or for those not fit for surgery. There are several reports on the use of topical mitomycin C in tracheal stenosis which has a theoretical role in the management of this disease because of its ability to inhibit fibroblast proliferation both *in vivo* and *in vitro*. A study done by Wang *et al*. in 2015 on 263 patients found mitomycin C to be an independent risk factor for postsurgical resection anastomotic complications and recommend not using it.[12] Another study done by Gangar and Bent in 2014

concluded that mitomycin C has been used for the past 16 years to inhibit airway fibroblast proliferation but its benefit remains more hypothetical than proven and its future role remains uncertain.[13] A study by Madan *et al*. from a tertiary center in India concluded that mitomycin C is not an effective treatment for postintubation tracheal stenosis.[14] In our opinion, patients with complex stenosis who are not in severe acute airway obstruction should be evaluated for surgical fitness and segmental resection of the stricture with end-to-end anastomosis should be offered. On the other hand patients with severe symptoms may require an initial bronchoscopic intervention such as dilatation of the stenosis with or without the use of electrocautery or laser for luminal enhancement, with or without stenting to tide over the crisis and buy time for proper evaluation. These measures provide immediate relief to all may be curative in some and provide an excellent bridge to surgical management in the rest. Unfortunately, these measures are not always successful and many reports show high recurrence rate after dilatation therapy.[1,2] Dilatation, electrocautery as well as lasers are more successful in short segment, web-like simple strictures with mild stenosis of Grade I or II[15] whereas long segment, complex strictures, with destruction of cartilage tend to restenose or develop tracheomalacia leading to worsening of symptoms. In a meta-analysis done in 2011 by Yamamoto *et al*., pooled success rates of laryngotracheal resection and anastomosis (12 articles) was 95%. Success rates of endoscopic dilatation and laser resection (six articles) varied between 40% and 82%. Meta-regression analysis showed a significant difference in the success rates between laryngotracheal resection and reconstruction and an endoscopic procedure. When the indication for endoscopic management was a lesion size <1 cm without framework destruction, the results were significantly better than in patients with stenosis lengths >1 cm. The authors also conclude that failed endoscopic attempts make involved lesions both worse and longer and therefore endoscopic intervention should not be repeated after failure of the first or second attempt, especially in patients with stenosis longer than 1 cm.[16] Multiple recent studies also stress on the use of endoscopic intervention in simple stenosis only.[10,15] It is important to highlight here that all our patients were having complex stenosis and 17 out of 18 patients had history of failed endoscopic interventions. Endotracheal prosthesis (stents) should not be used as a definitive treatment in benign tracheal stenosis. The stents may lengthen luminal damage, incite subglottic strictures, may cause esophagorespiratory fistulas and tend to develop granulations which block the stents requiring multiple endoscopic intervention. The injury to the trachea caused by the stents may be severe may occur even after a short duration of stenting and may preclude definitive surgical treatment or require more extensive tracheal resection. The present generation of stents is recommended in benign tracheal stenosis only if the patient is unfit for or refuses surgery or as a bridge to surgery.[17] A multidisciplinary approach in decision-making will mostly lead to better patient outcomes.

The indications for surgery have been highlighted above. The surgical management of these patients is challenging and requires close coordination between surgeons and interventional pulmonology colleagues. The surgical principles were enunciated by Grillo *et al*. and Pearson and Andrews all tracheal resections are done as per their guidelines.[1,18] The key surgical issues are enumerated in Table 3 and consist of measures to preserve tracheal blood supply, prevent injury to the recurrent laryngeal nerve, and achieve a tension-free anastomosis.[1,19,20] The blood supply to the trachea comes from lateral and posterior aspect. Therefore, lateral tracheal dissection should be restricted only to the stenosed segment to avoid ischemia to the tracheal ends. During lateral dissection around the stenosed segment, one must be cautious to avoid injury to the recurrent laryngeal nerves. The key is to stay "on" the trachea during dissection to displace para-tracheal tissue away from the trachea. Only bipolar cautery should be used in this dissection. It is important to excise the stenosed segment completely along with adjacent inflamed and diseased mucosa, if needed, till normal tracheal mucosa on both ends is reached. This sometimes requires removal of one or two extra rings on either side but is an important step to avoid restenosis. Release maneuvers should be tailored to the need of each case as per the tracheal length resected, with the intent of securing a tension-free anastomosis.[1,19] All these measures help in proper healing of the anastomosis. Anastomotic dehiscence is the most feared postoperative complication whereas restenosis is a problem during follow-up. The reported incidence of these complications has varied from 3.6%–5.7% to 5.4%–7.1%, respectively.[1,21] None of our patients suffered anastomotic dehiscence or restenosis, and all had excellent outcome after surgery. We attribute this success to rigid adherence to the basic principles of tracheal surgery and the fact that most of our patients were young, did not have any comorbidity and were nutritionally well prepared before surgery. Comorbidities such as diabetes mellitus, renal failure, heart disease, malnutrition, and steroid intake

Table 3: Key issues in the success of tracheal surgery

Preoperative
Adequate control of comorbidities
Nutritional correction
Physical therapy training
Intraoperative
Minimal dissection staying "on" the tracheal wall to avoid injury to the recurrent laryngeal nerves
Sharp dissection or bipolar cautery, no monopolar cautery
No lateral dissection and no circumferential dissection except in the area of stenosis: To preserve vascularity of the trachea
Adequate mobilization of trachea by anterior cervico-mediastinal dissection, flexion of the neck, suprahyoid and infrahyoid laryngeal release, and pericardial (hilar) and inferior pulmonary ligament mobilization, as per the need
Tension-free anastomosis
Keep the neck in flexed position postoperatively
Postoperative
Adequate pulmonary toileting
Aggressive chest physiotherapy
Nutritional care

increase the chances of anastomotic dehiscence as well as restenosis.[1,20,22] Excessive circumferential dissection of the trachea leading to ischemia of the tracheal ends, anastomotic tension, and incomplete resection of the diseased tracheal segment also affect the dehiscence and restenosis rates. The suture material used for anastomosis has also been linked to restenosis. Friedel *et al*. reported granulation tissue in 70.5% of the anastomosis using nonabsorbable sutures but 0% using absorbable sutures.[21] We used absorbable sutures in all our cases.

The major postoperative complication in our series was sudden onset quadriparesis (lower limb more than upper limb) along with loss of bladder and bowel function on the first postoperative day in one patient. The chin to chest stitch was immediately removed; cervical spine was immobilized by Philadelphia collar, and he was rushed for an immediate magnetic resonance imaging cervical spine. It revealed acute ischemic insult in the spinal cord on the right side at C3–C4 level and on the left side at C5–C6 level with edematous changes in the posterior elements of the upper cervical vertebrae and posterior spinal muscles. The patient was immediately administered intravenous methyl prednisolone 1.5 g over 1 h, and the same was repeated on day 2 and 3 as per the protocol of National Acute Spinal Cord Injury Study III.[23,24] Within few hours, he started improving and regained normal power in all four limbs during the next 48 h. This patient had history of road accident and had injury to neck including trachea at that time. Although cervical spine evaluation was grossly normal, probably there was minor trauma to cord blood supply at that time. Postoperatively, as his neck was fixed in flexion position by chin to chest suture, it led to further aggravation of the same, leading to segmental ischemic insult of the spinal cord at that level with quadriparesis. As the quadriparesis was detected while it was setting in and corrective measures such as removal of flexion, cervical collar, and intravenous methyl prednisolone were instituted within minutes, there was complete recovery with no residual deficit. We now practice a policy of maximum 20° flexion or neutral position of the neck after tracheal surgery. The presence of tracheostomy at the time of surgery is a risk factor for wound infection, and three such patients developed minor wound infections which were managed with dressings and antibiotics.

Our results are in consonance with the literature evidence that surgical resection and anastomosis of the involved segment is safe and effective and offers a chance of cure for patients with tracheal stenosis. Meticulous preoperative assessment and preparation associated with a perfect surgical technique are mandatory to obtain good results.

CONCLUSION

Surgical management of tracheal stenosis is challenging and requires multidisciplinary team approach. Simple stenosis has excellent results with bronchoscopic interventions. However, for complex stenosis, surgery is preferred. Thorough preoperative preparation and planning regarding need for and timing of surgery, meticulous intraoperative technique, and aggressive postoperative care are key to successful surgery, which provides long lasting cure to patients with complex tracheal stenosis.

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Conflicts of interest
There are no conflicts of interest.

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