Slide Tracheoplasty Applied to Acquired Subglottic and Upper Tracheal Stenosis

An Experimental Study in a Canine Model

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Objective: To assess the applicability and complications of slide tracheoplasty in the management of subglottic and upper tracheal stenosis in experimental animals.

Design: Subglottic stenosis was induced in 10 dogs by cauterizing the subglottic area and the upper 3 to 4 cm of the trachea. After 21 days, the severity of stenosis ranged from 30% to 60%. The subglottic area was reconstructed with slide tracheoplasty, and the results were evaluated at 4, 12, and 24 weeks postoperatively.

Subjects: Ten mongrel dogs (Canis familiaris) were included in the study, each weighing between 12 and 17 kg.

Intervention: Slide tracheoplasty.

Main Outcome Measure: Patency of the reconstructed segment.

Results: Follow-up examination revealed no airway obstruction in any animal. Examination of the reconstructed segment revealed good healing without granulation tissue and a patent endotracheal lumen in all cases. Histopathological examination of sections taken at the suture line confirmed complete healing without granulation tissue.

Conclusions: Slide tracheoplasty can be applied successfully to the subglottic area. It offers many advantages in tracheal reconstruction and can be used for the management of acquired subglottic stenosis. The vascularized tracheal cartilage heals without granulation tissue often seen after cartilage interposition grafts. Furthermore, this technique reduces the need for tracheal and laryngeal mobilization for the treatment of longer areas of stenosis.

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Subglottic stenosis is a fibroproliferative disorder that may affect persons of all ages owing to a variety of causes, including prolonged endotracheal intubation, gastroesophageal reflux, autoimmune disorders, and iatrogenic disorders. Management of subglottic stenosis constitutes a challenge because of the high incidence of restenosis. Conservative measures include dilatation, stents, steroid injection, cryotherapy, and laser therapy. Open surgical procedures include anterior and posterior cricoid split, placement of stents, mucosal and cutaneous grafts, and free grafts of cartilage, pedicled hyoid, and cutaneous flaps variously supported with cartilage. Success is limited with these procedures because of restenosis and development of granulation tissue that requires repeated endoscopic management.

Cricotracheal resection removes the stenotic area with good healing, especially with tension-free approximation of tracheal ends. However, a tension-free closure is difficult when the resection is more than 3 cm. Many measures are available to mobilize the proximal and distal tracheal segments to reduce tension on the anastomosis including cervical flexion, hilar dissection, intrapericardial freeing, and right main stem bronchus transposition; however, the maneuvers are not without morbidity including injury to the superior laryngeal nerve and vessels, dysphagia, pneumomediastinum, and mediastinal vascular and visceral injuries.

Tsang et al first described slide tracheoplasty in 1989 as a new surgical technique for congenital funnel shape tracheal stenosis. The trachea is exposed, circumferentially mobilized, and divided transversely at the midpoint of its narrowed segment. The distal segment of the tracheal stenosis is divided longitudinally along its posterior wall, and the proximal end is divided longitudinally along its anterior border. The 2 segments are advanced over each other and sutured together. The slide tracheoplasty results in doubling the circumference of the trachea and a 4-fold increase in the cross-sectional area of the airway. The stenotic segment is shortened by one half of its length rather than by its full length, which would be the case with resection and end-to-end anastomosis. Ven-
propriate size. The larynx was sprayed with topical anesthetic was visualized using a standard operating laryngoscope of ap-

ported on each other and sutured using interrupted 4-0 Vicryl (Ethicon Inc, Piscataway, NJ), followed by suturing of the re-

This study was performed to assess the application of slide tracheoplasty in acquired long-segment subglottic and tracheal stenosis using an experimental canine model, with the hypothesis that slide tracheoplasty, previously used for congenital tracheal stenosis, can be applied to acquired subglottic and upper tracheal stenosis.

**METHODS**

This study was approved by the Suez Canal University Research Committee (Ismailia, Egypt) and was conducted using the animal care facilities in the Faculty of Veterinary Medicine. The animals received humane care in compliance with the principles of laboratory animal care. Ten mongrel dogs (*Canis familiaris*) were included in the study, each weighing between 12 and 17 kg.

**INDUCTION OF SUBGLOTTIC STENOSIS**

Stenosis was induced using a successfully proven technique for induction of subglottic stenosis described by Eliasher et al13 in 2000. Each dog was anesthetized with intramuscular ketamine hydrochloride (20 mg/kg) and intramuscular xylazine hydro-

Subglottic stenosis longer than 3 cm is difficult to re-

These release procedures can be avoided by using slide tracheoplasty. In slide tracheoplasty native vascularized tracheal cartilage is used for reconstruction, which may result in better healing without granulation tissue for-

**RESULTS**

After induction of subglottic stenosis, the degree of stenosis varied from 30% to 60% (grades 1 and 2 stenosis,
Mayer-Cotton classification of subglottic stenosis.18 The acquired stenosis was circumferential along the injured segment.

There were no signs of respiratory tract obstruction that required emergency intervention in the postinduction period, but all of the dogs developed a weakened bark and had slightly reduced food intake. None of the dogs developed any sign of respiratory tract obstruction after tracheal reconstruction. Tracheotomy was not needed in any of the cases before or after reconstruction. Bilateral vocal cord mobility was confirmed by means of laryngoscopic evaluation after reconstruction. Barking returned to normal or near normal after the third postoperative week.

One dog developed surgical wound infection at postoperative day 4, which was treated with antibiotics for 1 week without the need for surgical drainage.

After reconstruction, the cross-sectional diameter of the stenotic segment was nearly doubled in all of the dogs (Table). In group 1 (killed after 4 weeks), the lumen of the trachea was patent and mucosal healing was obvious; no granulation tissue was detected inside the lumen or at the suture line. Microscopic examination revealed mucosal healing.

In group 2 (killed after 12 weeks), the lumen was patent, no contractures or scarring were found in the trachea, no granulation tissue was found in the lumen or at the suture line, and no breakdowns were detected at the suture line. Microscopic examination revealed continuous respiratory epithelium over the suture line and fibrosis between the 2 ends of the cartilage (Figure 2).

In group 3 (killed after 24 weeks), microscopic examination revealed mature fibrosis detected between the 2 ends of the cartilage. Gross examination of the specimens confirmed the widening of the tracheal lumen compared with the previous diameter of the trachea without gross deformities in the reconstructed segments and good healing at the suture line without granulation tissue formation (Figure 3).

### Table. Cross-sectional Diameter of the Stenotic Segment Before and After Reconstruction

<table>
<thead>
<tr>
<th>Group</th>
<th>Dog No.</th>
<th>Length of Stenotic Segment, cm</th>
<th>Cross-sectional Luminal Diameter Before Reconstruction, cm*</th>
<th>Cross-sectional Luminal Diameter After Reconstruction, cm†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (killed after 4 wk)</td>
<td>1</td>
<td>5.00</td>
<td>0.50</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.50</td>
<td>0.70</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5.00</td>
<td>0.55</td>
<td>1.00</td>
</tr>
<tr>
<td>Group 2 (killed after 12 wk)</td>
<td>4</td>
<td>4.00</td>
<td>0.75</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6.00</td>
<td>0.65</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5.50</td>
<td>0.70</td>
<td>1.30</td>
</tr>
<tr>
<td>Group 3 (killed after 24 wk)</td>
<td>7</td>
<td>4.50</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>5.00</td>
<td>0.60</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>5.50</td>
<td>0.70</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6.00</td>
<td>0.70</td>
<td>1.20</td>
</tr>
</tbody>
</table>

* Luminal diameter was taken at the narrowest part of the tracheal circumference at the midpoint of the stenotic segment.

† Luminal diameter was taken at the proximal end (the narrowest part) of the reconstructed segment before being sutured to the thyroid cartilage.

In this study, we achieved our goal of demonstrating the feasibility of applying slide tracheoplasty to long-segment acquired subglottic and upper tracheal stenosis. The surgical sites healed without granulation tissue or restenosis in all animals. The goal of this study was not to compare this technique with untreated surgically induced subglottic stenosis or to compare it with other surgical techniques; therefore, an untreated control group was not used.

The advantages of using the slide tracheoplasty technique in reconstructing the stenotic segment of the trachea include the avoidance of granulation tissue and restenosis, which enables early mobilization of the animal and reduces postoperative complications. This technique offers a promising alternative for the treatment of acquired subglottic and upper tracheal stenosis.
chea are pointed out in the literature, especially in children with congenital long-segment tracheal stenosis. The primary technical advantage is reduction of the tension on the anastomosis produced by reducing the approximation distance. Furthermore, the vascularity of the tracheal cartilage is preserved, resulting in better healing.13

A few modifications in the technique were needed to apply it to the subglottic area. The proximal segment including the cricoid and the upper tracheal rings was split along its anterior wall and the distal segment along its posterior wall. This minimizes the possibility of injury to the recurrent laryngeal nerve, which comes into close proximity to the cricoid and first tracheal ring. The mucosal healing was evident at all 3 examination times without any evidence of granulation tissue formation inside the tracheal lumen. Cartilage healing by fibrous tissue was seen at 4 weeks and progressed to mature fibrosis by 12 weeks. There were no anastomotic complications, granulation tissue formation, or disruption at the suture line at the last time of observation at 24 weeks.

Slide tracheoplasty in the management of acquired subglottic and upper tracheal stenosis is not meant to replace cricotracheal resection, but it can be of potential value in cases with mild to moderate stenosis and longer than 3 cm. It is actually like splitting and grafting the stenotic segment, but the graft is the anterior wall of the distal half of the stenotic segment. Resection of a long segment of the trachea (≥3 cm) was shown previously to be a statistically significant risk factor for anastomotic complications after tracheal resection, probably because of the increased tension at the suture line.17 Slide tracheoplasty reduces the approximation distance by half and may result in reduction of this problem.

The application of slide tracheoplasty in the management of acquired subglottic and upper tracheal stenosis has some limitations including cases with grade 3 or 4 stenosis with thick scar tissue where cricotracheal resection will be the best option. Short stenotic segments (<3 cm) where cricotracheal resection could be performed without difficulty and stenotic segments with tracheomalacia when there is no cartilage can be used for reconstruction.

In conclusion, slide tracheoplasty can be used for the management of acquired subglottic and upper tracheal stenosis with a relatively long segment, with the following benefits: the use of native vascularized tracheal cartilage, which leads to better healing without granulation tissue formation; healing without a circumferential suture line, which would be a constrictive ring with further growth of the trachea; and decreasing the need for tracheal and laryngeal mobilization in acquired long-segment subglottic and upper tracheal stenosis by reducing the approximation distance by half.

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Author Contributions: All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Abdelkafy, El Atriby, Iskandar, and Mansour. Acquisition of data: Abdelkafy and Iskandar. Analysis and interpretation of data: Abdelkafy, Iskandar, and Mattox. Drafting of the manuscript: Abdelkafy, Mattox, and Mansour. Critical revision of the manuscript for important intellectual content: Abdelkafy, El Atriby, Iskandar, Mattox, and Mansour. Administrative, technical, and material support: Abdelkafy, El Atriby, Iskandar, and Mattox. Study supervision: Abdelkafy, El Atriby, Iskandar, Mattox, and Mansour.

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REFERENCES