Endoscopic Management of Tracheal Stenosis

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Introduction

Tracheal stenosis is a problem that is increasingly facing a wide variety of practitioners (otorhinolaryngologists, thoracic surgeons, pulmonologists …). The commonest causes are traumatic either post-intubation or following external trauma. Less commonly it may be due to congenital malformations, external compression, autoimmune and infectious processes or without recognizable causes [1-3]. The wide variety of surgical and non-surgical options available is an indicator not only of the complexity of the problem but also of the shortcomings of different approaches. The final goal of any reconstructive technique is to have a stable, mucosa lined flexible structure that can transmit the air flow in and out of the lungs from a competent, patent larynx. The chosen techniques(s) must also provide long term permeability and should be easily supplemented or revised in case of restenosis. Although open surgical techniques are becoming standards of care in many centers, endoluminal techniques have their indications. In properly selected patients they can be quite successful and efficient with minimal morbidity and mortality. The aim of this article is to outline the indications, limitations and potential benefits of endoluminal management of tracheal stenosis.

Patient selection

For any surgical procedure to be successful patient selection is the critical issue. Poor patient choice endangers the patient’s life and can compromise further salvage attempts. Strict criteria were set but with more experience and additional procedures, the limits can be extended (Table 1).

Pre-operative planning

Judicious planning of the surgical procedure depends on precise data collection. The following information should be available for each patient:

- The stenotic segment:
  - Length
  - Degree
  - Distance from vocal cords
  - Distance from carina

- Other data:
  - State of the mucosa (infection, granulations)
  - State of the tracheal framework
  - Vocal cord mobility
  - Laryngopharyngeal reflux
  - Respiratory efficiency

Various diagnostic techniques must be used to gather this basic information. These include awake fiberoptic endoscopy, laryngoscopy and bronchoscopy under general anaesthesia [2,4]. Radiology is central to this diagnostic process. It includes high resolution CT scans with 3D reconstructions and virtual endoscopy [4,5], MRI and endobronchial ultrasound [6,7]. In some cases pulmonary function tests may be indicated as well as investigations to detect gastro-esophageal reflux [8]. The presence of additional comorbidities should also be explored especially cardiac or neurological diseases. In ventilator dependent patients keeping a tracheostomy may be the best option for proper ventilation and care of the respiratory tract (Table 2).

Length: Traditionally for a successful endoluminal procedure, the length of the stenotic segment must be shorter than 10 mm in craniocaudal extension. This is due to two main reasons. As the surgeon starts to re-establish the lumen from above, the diameter of the working cone keeps getting narrower and the surgeon becomes unable to achieve an adequate diameter at the lower end of the stenosis. Longer segments are usually associated with more severe damage to the mucosa and tracheal wall leading to poor support and luminal collapse. However in some cases longer segments can be managed successfully by the combined use of a laser, balloon dilatation and possibly a temporary or permanent stent.

Distance from the subglottis and carina: Proximity of the stenosis to the vocal cords indicates a combined laryngo-tracheal lesion. Such lesions may not be suitable for pure endoluminal management. Similarly in the event of stent placement there must be at least 5-10 mm of free mucosa from the vocal cords. This is important to allow free vocal cord movement and prevent granulations forming and obstructing the airway. Distally, a similar length of free mucosa must be present. Impingement on the carina and damage to the main bronchi may lead to granulation tissue or stenosis with critical airway obstruction. A stent placed too low near the carina can easily migrate or obstruct a main bronchus either directly or by granulation tissue formation.

Degree of Stenosis: Endoluminal management is usually contraindicated if there is no discernable lumen. However in certain selected cases with short well defined web-like lesions it is possible to perforate the lesion and gradually dilate it under direct vision from above as well as by retrograde endoscopy through the tracheostomy.

Table 1: Pre-requisites for endoluminal management.

<table>
<thead>
<tr>
<th>Condition/Measure</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the stenosis</td>
<td>&lt; 1 cm</td>
</tr>
<tr>
<td>Grade</td>
<td>≤ 4</td>
</tr>
<tr>
<td>Extra-aluminal damage</td>
<td>No</td>
</tr>
<tr>
<td>Endoluminal granulations</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 2: Contraindications.

- Circumferential cicatrical scarring.
- Abundant scar tissue greater than 1 cm in vertical dimension.
- Scar tissue in the interarytenoid area of the posterior commissure.
- Severe bacterial infection of the trachea after tracheotomy.
- Exposure of perichondrium or cartilage during CO2 excision.
- Combined laryngotracheal stenosis.
- Failure of previous endoscopic procedures.
- Significant loss of cartilaginous framework.
- Systemic problems

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Other Factors: An inflamed mucosa will lead to further granulation and polyp formation with obstruction. This may be due to infection and/ or reflux. Both these factors must be properly controlled until the mucosa is normalized. Some authors deny the role of reflux in restenosis after successful repair. Others (and I tend to agree) suggest that anti-reflux treatment is mandatory to prevent restenosis and granulation tissue formation.

The presence of bilateral vocal cord paralysis will jeopardize any attempt at tracheal reconstruction. This issue must be addressed before managing the trachea. However the risk- benefits of the possible resulting aspiration must be carefully weighted for each individual patient.

Respiratory function tests are not routinely performed for each patient. However a patient with poor respiratory reserve may not withstand critical airway narrowing or the extra burden of infection and reflux. In patients with documented or suspected poor respiratory efficiency the treating surgeon must be very careful in choosing the best management strategy [1,3,9-12].

Management

Anaesthetic considerations: Many of these patients have a critically narrow airway and all precautions should be taken to prevent an acute obstructive episode. Flexible bronchoscopy can be performed under conscious sedation and adequate local anaesthesia in a spontaneously breathing patient with supplemental O₂ through nasal cannula. Alternatively laryngeal mask ventilation (LMA) may be used and the bronchoscope passed through the mask. Interventions under general anaesthesia are more demanding. In tracheostomized patients, undergoing a laser-assisted procedure, a laser safe tube has to be inserted through the tracheostomy. In non-tracheostomized patients airway management may be via supraglottic jet ventilation, intermittent apneic technique or spontaneous ventilation [13-16].

Active management

The two main steps in endoluminal treatment are restoring the lumen and maintaining its patency.

Luminal restoration:
Cold knife
Laser:
CO₂ [17-20]
Nd:YAG [16,21,22]
Diathermy [9,12,23]
Argon plasma[23-25]
Cryoprobe [3,11,23]
Mechanical dilatation [3,10,12,26,27]
CRE Balloons [28-34]
Maintaining patency:
Mitomycin [20,23,27,35-37]
Steroids [38,39]
Brachytherapy [40]
Stents [2,12,15,23,28,31,32,39,41-45]

Luminal restoration: The main aim of luminal restoration is to dilate the stenotic segment to match as closely as possible the normal proximal and distal diameters. All the listed tools have their advocates and all authors report similar results. Whatever the tool used, a mucosal sparing technique should always be advocated. This entails radial type incisions of the stenotic segment leaving islands of normal mucosa to help early resurfacing and minimize scarring and restenosis. The incisions are performed through the entire vertical length of the stenotic segment usually at the 9-, 12- and 3-o’clock positions to prevent injury to the posterior tracheal wall and possible esophageal penetration.

The safest strategy is to re-establish a lumen until the distal segment is visible usually using a rigid telescope or by advancing the flexible scope followed by gradual gentle dilatation.

Gradual calibration of the stenotic segment can then proceed. This can be achieved by a variety of methods. Bronchoscopes and rigid dilators may shear the mucosa leading to further damage. Endoluminal balloons may be gentler by providing uniform radial pressure on the stenotic segment without damaging the mucosa. The choice of the balloon’s diameter depends on the normal caliber of the airway. Once a lumen is established, the deflated balloon is advanced to straddle to the stenotic segment and gradually inflated to the required size. The time of pressure application varies. For some authors it is a constant duration, for others the endpoint is when the PaO₂ starts to drop if or the pressure gauge starts to drop indicating that the stenosis does not exert any counter-pressure.

Overenthusiastic dilatation should be avoided as it can lead to extraluminal damage with subsequent scarring or more dangerously tracheal rupture.

If the optimum lumen cannot be achieved in one stage, a second stage can be planned in 4-6 weeks to give time for the tissues to stabilize.

Maintaining patency: In most cases following endoluminal dilatation, the restored lumen tends to restenose. Various measures can be taken to prevent this. The simplest is to plan repeated stages to re-dilate the lumen. This can be done either at fixed predetermined intervals or whenever the patients start to be symptomatic. This may be possible in short web-like stenoses.

In all other cases more active measures may need to be used. This includes the local application of drugs and/or stenting.

Medications

The most commonly used drugs are steroids and mitomycin C.

Steroids: Steroids are usually injected locally after luminal restoration. Most authors use a long-acting preparation (e.g triamcinolone acetonide, methyl prednisolone). Four quadrants of the stenotic segment are injected taking care to avoid deep injection which may cause cartilage resorption. Other advocate the use of inhaled steroids post-operatively in all cases even if no local injections were used.

Mitomycin C

This is the drug most commonly used. Various concentrations were advocated (0.1mg/ml up to 10 mg/ml). However the concentration is usually 0.4mg/ml and is applied topically on a cottonoid pledget. The length of application varies from 2-3 repeat applications of 2 minutes each to a single application of 5 minutes. Although seemingly effective, this is not the universal consensus and it is not without its own complications. Strict precautions should be followed during its preparation, handling and application.

Brachytherapy: High-dose rate (HDR) endobronchial brachytherapy was advocated to prevent granulation tissue formation and restenosis. It is administered as a single application of a total 10 Gy along the stent using a brachytherapy remote after loader with a 192 Ir source. If re-stenosis occurred on a follow up bronchoscopy (usually every 4 to 6 weeks for the first 6 months) then another intervention could be applied.
Stents: In many cases the re-established lumen is inherently unstable and has to be maintained patent temporarily or permanently. Stents are then indicated. They come in a variety of materials: silicon or metallic. Silicon stents are usually temporary whereas metallic stents are usually meant to be left permanently in place. They can be inserted either during the first attempt or after failure of simple dilatation to maintain the lumen until it is stable. In some patient stents can be used as a temporizing measure until more permanent surgery is possible (Table 3).

For benign stenoses, silicon removable stents are usually recommended. They are inserted for a variable period, usually 6 weeks and up to 1 year. After the lumen is deemed stable, they can be removed.

Permanent metallic stents are classically indicated for specific cases. However permanent metallic stents are being increasingly used in benign tracheal stenoses with results comparable to open surgical techniques.

Although stents offer an attractive alternative to open surgical techniques they are not without their own complications. A strict technique in application and follow up are mandatory to prevent life threatening complications (Table 4).

It should be noted that patients usually need more than one technique and most authors report various combinations to ensure a stable successful outcome [1,3,12,16,23,28,31-33,39].

Post-operative management

After endoluminal management the patient must be kept under observation in a surgical or respiratory care suite for 12-24 hours depending on the procedure performed. Antibiotics are usually advocated for 1-3 weeks, depending on wound extent and general status of the laryngotracheal mucosa.

Intensive antireflux management usually by high dose proton pump inhibitors may have to be prolonged for months to guard against restenosis.

The judicious use of steroids either systemically or by inhalation may be beneficial in preventing fibrosis.

Proper hydration is essential for a healthy mucosa. This can be achieved by maximizing the fluid intake of the patient and humidifying inspired air by the use of an ultrasonic nebulizer or a simple steamer in the patient’s room.

All patients must be reassessed 4-6 weeks after the intervention by flexible fiberoptic endoscopy. At the earliest sign of granulation tissue formation or narrowing, the patient should undergo a therapeutic endoscopy to prevent progression. This can be achieved under local anaesthesia and sedation with a flexible bronchoscope and a laser, argon plasma fiber and/or a dilating balloon. In some cases a general anesthetic is necessary if more manipulations are needed.

The main causes of failure of endoluminal treatment and restenosis are inflammation, infection, reflux and dryness. Close follow-up and timely management are imperative.

Patients are considered stable and cured if their airway is maintained for a minimum of 12 months without the need for any intervention. However some patients may relapse after a long period of time especially if a stent has been used. It is therefore wise to inform the patients that if any respiratory symptoms appear (wheezing, dyspnea, cough, recurrent infections…) they should report to their treating physician [2,3,11,12,23,39,44,46-49].

Conclusion

Minimally invasive treatment is effective in tracheal stenosis and obviates the need for open surgery in selected patients. Careful planning is mandatory. The judicious selection of the techniques and tools may widen the indications and help a larger number of patients. Close post-operative follow up for a long time and the necessity of more than one intervention improves results and may spare patients the morbidity and mortality associated with acute airway obstruction or major open surgery.

References


Malignant lesions of the airway causing obstruction
Nearby malignancies compressing or infiltrating the airway (thyroid, esophagus, lymph nodes)
Vascular compression
Tracheomalacia
Post-intubation stenosis
Long segment stenosis not amenable to surgery

Table 3: Indications of stenting.

<table>
<thead>
<tr>
<th>Procedural</th>
<th>Delayed</th>
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<tbody>
<tr>
<td>Acute airway obstruction</td>
<td>Granulation tissue formation</td>
</tr>
<tr>
<td>Perforation of the tracheal wall</td>
<td>Proximal/distal restenosis</td>
</tr>
<tr>
<td>Surgical emphysema/pneumothorax</td>
<td>Migration</td>
</tr>
<tr>
<td>Vascular injury</td>
<td>Tracheo-esophageal fistula</td>
</tr>
<tr>
<td>Bronchial obstruction</td>
<td>Infection / haitosis</td>
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<td></td>
<td>Metal fatigue and breakage</td>
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Table 4: Complications of stents.


