Eur Arch Otorhinolaryngol (2015) 272:2885–2896
DOI 10.1007/s00405-015-3635-4

LARYNGOLOGY

Preoperative assessment and classification of benign laryngotracheal stenosis: a consensus paper of the European Laryngological Society

Ph. Monnier[1] · F. G. Dikkers[2] · H. Eckel[3] · C. Sittel[4] · C. Piazza[5] · G. Campos[6] · M. Remacle[7] · G. Peretti[8]

Received: 15 January 2015 / Accepted: 19 April 2015 / Published online: 8 May 2015

Abstract Adult and pediatric laryngotracheal stenoses (LTS) comprise a wide array of various conditions that require precise preoperative assessment and classification to improve comparison of different therapeutic modalities in a matched series of patients. This consensus paper of the European Laryngological Society proposes a five-step endoscopic airway assessment and a standardized reporting system to better differentiate fresh, incipient from mature, cicatricial LTSs, simple one-level from complex multilevel LTSs and finally "healthy" from "severely morbid" patients. The proposed scoring system, which integrates all of these parameters, may be used to help define different groups of LTS patients, choose the best treatment modality for each individual patient and assess distinct post-treatment outcomes accordingly.

Keywords Laryngotracheal stenosis · Preoperative assessment · Endoscopy · Classification and grading · Adult · Pediatric

✉ Ph. Monnier
philippe.monnier@chuv.ch

[1] Department of Otolaryngology, Head and Neck Surgery, University Hospital CHUV, Rue du Bugnon 46, 1011 Lausanne, Switzerland

[2] Department of Otorhinolaryngology/Head and Neck Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

[3] Department of Oto-Rhino-Laryngology, Klinikum Klagenfurt am Wörthersee, Klagenfurt, Austria

[4] Department of Otorhinolaryngology/Head and Neck Surgery, Klinikum Stuttgart, Stuttgart, Germany

[5] Department of Otorhinolaryngology/Head and Neck Surgery, Spedali Civili of Brescia, University of Brescia, Brescia, Italy

[6] Department of Surgery, Instituto de Laringología, Fundación Santa Fe University Hospital, Bogotá, DC, Colombia

[7] Department of Otorhinolaryngology, Head and Neck Surgery, Louvain University Hospital of Mont-Godinne, Yvoir, Belgium

[8] Department of Otorhinolaryngology, Head and Neck Surgery, University of Genoa, Genoa, Italy

Introduction

Adult and pediatric laryngotracheal stenoses (LTS) comprise a wide array of conditions that require precise preoperative assessment to select the best surgical option for each individual patient. Unfortunately, most reports of data concerning management of subglottic stenosis (SGS) from patient groups fail to give complete information on important issues that could have a potentially decisive influence on the postoperative outcome. These include: vocal fold (VF) mobility, cicatricial glottic and/or supraglottic involvement [±arytenoid joint(s) fixation], possible additional tracheal damage (stenosis, malacia) related to the stoma or the cannula, secondary airway lesions, OSA-related obstructions, swallowing difficulties with or without chronic aspiration, severe gastro-esophageal reflux, eosinophilic esophagitis, and finally medical comorbidities or congenital anomalies. The literature is replete with case mixtures of various conditions, rendering comparison of postoperative results impossible in an unmatched series of patients [1–25].

Guidelines are necessary for performing optimal pre- and postoperative assessments of LTS patients based on endoscopy, radiology and the patient's medical condition.

This article is a consensus paper of the European Laryngological Society (ELS), aimed at proposing a reporting system readily usable for surgeons managing LTS.

Endoscopic workup for LTS

Prior to any description of this endoscopic workup, it is noteworthy to make a clear distinction between incipient and mature cicatricial LTS (Fig. 1).

Incipient LTS results from acute or subacute post-intubation airway narrowing (e.g., edema, ulcerations, granulation tissue), the treatment of which aims at preventing cicatricial stenosis formation by endoscopic means or by a cricoid split procedure in newborns. The final goal is to avoid tracheotomy or allow decannulation in already tracheostomized patients.

Mature cicatricial stenoses correspond to well-established airway narrowings that can pose a therapeutic challenge to the surgeon. It is thus of paramount importance to understand the individual characteristics of the stenosis and the clinical context of each patient.

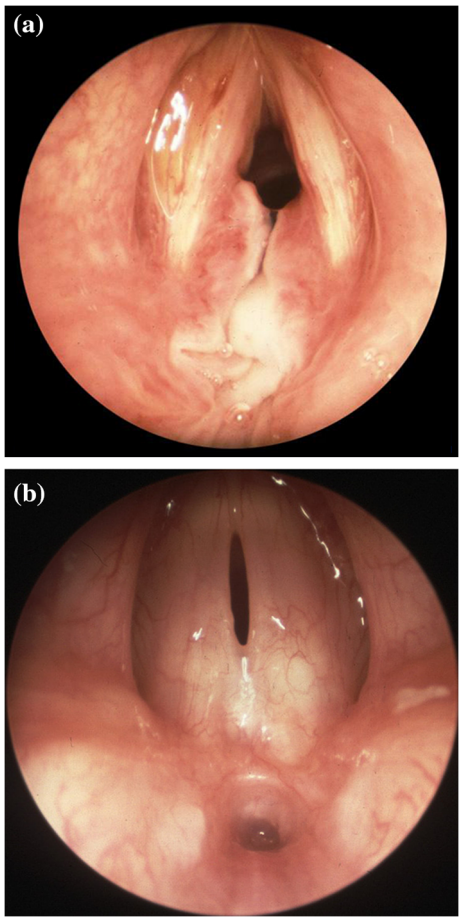

Fig. 1 Treatment of fresh, incipient versus mature, cicatricial LTS. **a** Fresh, incipient LTS: this condition is essentially treated by endoscopic means and is aimed at preventing the development of cicatricial airway stenosis. **b** Mature, cicatricial LTS: this condition is best treated by an open surgical approach, except in select cases where it can benefit from an endoscopic treatment

Preoperative endoscopic assessment of mature, cicatricial stenoses provides almost all of the required information for establishing a precise plan for therapy, once comorbidities or congenital anomalies have been clearly documented or ruled out. The Laryngotracheal Stenosis Committee of the European Laryngological Society (ELS) aims at a standardized reporting system. This requires a thorough and systematic preoperative assessment of the patient and of the stenosis. The working committee suggests the latter should consist of a combination of five endoscopic modalities:

Awake indirect laryngoscopy or transnasal fiberoptic laryngoscopy (TNFL)

This exam aims at assessing VF mobility.

In adult patients, this can be readily performed and consistently provides precise information on (a) normal VF mobility, (b) uni- or bilateral restricted VF abduction often linked to posterior glottis stenosis (PGS), and (c) uni- or bilateral VF immobility that can result from neurogenic VF paralysis or PGS with or without cricoarytenoid joint fixation.

In infants and children, awake TNFL is the most accurate way of assessing true VF mobility, but it is not always well-accepted by some children, especially in the toddler age group. In infants, gentle constraint and topical nasal anesthesia always allow TNFL to be performed under satisfactory conditions. However, due to the retroflexed position of the epiglottis and the bulk of large arytenoids, it may at times be difficult to assess true VF mobility precisely. Great care should be exercised to avoid any contact with supraglottic structures, as this may cause laryngospasm and mucosal trauma potentially leading to airway obstruction. In infants and small children, performing awake TNFL in a fully equipped setting for resuscitation is advisable in case rapid emergency intervention is required.

Toddlers may be frightened by awake TNFL and often refuse this exam, whereas older children usually accept it, if they are well informed about the procedure. In all cases, where precise VF movements cannot be assessed in the awake patient, this information should be gathered under general anesthesia using asleep TNFL. Awake laryngoscopy can be skipped if deemed impossible in a particular patient.

Asleep TNFL

This exam is carried out under general anesthesia in spontaneous respiration. It should be part of all airway assessments in the pediatric as well as in the adult age groups for four main purposes:

(a) Assessment of VF mobility in patients for whom awake TNFL failed or gave inconsistent results;
(b) Detection of OSA-related narrowings (e.g., tonsillar hyperplasia, pharyngomalacia, base of tongue prolapse) that may represent a contraindication to a single-stage procedure (LTR or PCTR);
(c) Dynamic visualization of localized or diffuse tracheo-(broncho)-malacia, especially in infants and children;
(d) Detection of secondary airway lesions (SAL) such as laryngomalacia, primary tracheomalacia or extrinsic tracheal compression secondary to cardiovascular congenital anomalies in neonates and small children. Additionally, suprastomal granulomas, localized tracheomalacia at the tracheostomy site and tip of cannula lesions (granuloma, cicatricial stenosis) in the distal trachea can be seen in both pediatric and adult age groups.

This dynamic airway assessment should be performed in a similar manner in both non-tracheostomized and tracheostomized patients.

In the non-tracheostomized patient, with respiratory distress and undiagnosed disease, TNFL is carried out through a face mask under general anesthesia and spontaneous respiration. The flexible scope is introduced through a small opening in the silicone membrane covering the center of the face mask (Fig. 2), or through a swivel connector. Inspection of the nasal cavities on both sides aims at identifying any pathology, such as vestibular stenosis, piriform aperture stenosis, deviated septum or turbinate hypertrophy. Special attention should be given to identifying anatomical or functional narrowings at the choanae or nasopharynx (choanal atresia and adenoid hyperplasia in children, tumor mass in adults). When the endoscope reaches the junction of the naso-oropharynx, the anesthetist is asked to stop supplying positive airway pressure and to release the chin lift, allowing the patient to adopt normal head and recumbent body positions. In case of obstructive sleep apnea (OSA), the exact level of obstruction should be clearly identified. Some of the most frequent causes of dynamic airway obstruction detectable by fiberoptic endoscopy include retroposition of the soft palate, hyperplasia of tonsils and tongue base, laryngomalacia, vallecular cyst or mass, epiglottic and supraglottic prolapses.

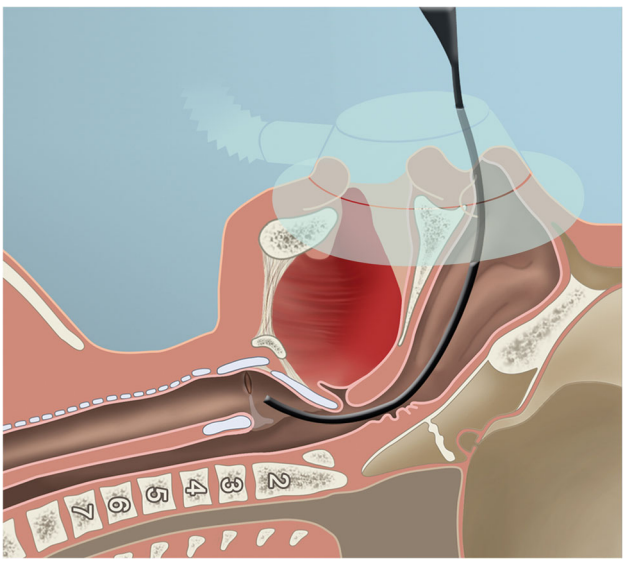

Fig. 2 Diagram of transnasal fiberoptic laryngoscopy through a face-mask in the anesthetized, spontaneously breathing patient

All of these potential sites of obstruction may be overlooked by awake indirect laryngoscopy in adults and by direct inspection of the larynx using the rigid rod-lens telescope (even under spontaneous respiration), both in adults and children. This can have an adverse effect on the final outcome of single-stage surgery for SGS with failure to decannulate in the postoperative period.

When the fiberscope is passed behind the epiglottis and reaches the laryngeal inlet, a detailed and careful assessment of VF mobility should be carried out. Although best performed in the fully awake patient, this can also be done under general anesthesia. Proper titration of anesthetic drugs is essential. The chosen anesthetic agent must preserve both spontaneous ventilatory drive and laryngeal closure reflex, and should allow the anesthesiologist to modify anesthetic levels quickly.

Prior to any definitive diagnosis of VF paralysis, the anesthetist should lighten the level of anesthesia to allow precise assessment of VF mobility, especially when neonatal paralysis is considered. Once VF mobility has clearly been assessed, examination of the infralaryngeal airway may ensue. The anesthesia must be deep enough to prevent vocal cord movements and laryngospasm. Combining remifentanil and propofol ensures similar intubation conditions as those provided by succinylcholine, while eliminating the deleterious curare effects. Another possibility is to spray the endolarynx with lidocaine prior to passing the VFs. Dynamic examination of the trachea and bronchi during inspiration, expiration and coughing is indispensable for the diagnosis of localized or diffuse tracheomalacia. Other anatomical narrowings of the lower airways can also be identified.

When assessing a compromised airway that is not secured by a tracheostomy, team work is essential to reduce the risk of potential serious complications. Whether the procedure is carried out in the ICU, the endoscopy suite or the operating theater, all personnel must be properly trained. The necessary instruments must be double-checked before initiating the procedure to ensure their proper

functioning. Anticipating potential complications is key to avoiding them.

Furthermore, it is of utmost importance to avoid any trauma to the mucosa of the stenosis. Unplanned tracheotomy for acute airway obstruction resulting from a diagnostic endoscopy should be considered as a serious adverse event.

In the tracheostomized patient, with known airway obstruction, the procedure is similar to that performed in the non-tracheostomized patient, but inhalation anesthesia and oxygenation are given through the tracheostomy tube. Under spontaneous respiration, TNFL is carried out through the nostrils. Depending on the degree and level of airway stenosis, inspection of the tracheostoma site may be difficult. However, in the postoperative period, after successful correction of an SGS, careful inspection of a dynamic airway collapse is useful not only for the naso-oropharyngeal and pharyngolaryngeal regions, but also in the trachea. Localized malacia at the site of the tracheostoma is a potential reason for failed decannulation in an otherwise patent airway. If the cannula, acting as a stent at the stoma site, is not temporarily removed during TNFL, then the condition remains undiagnosed and repeated failures to decannulate may ensue.

Direct transoral laryngotracheoscopy with a bare zero-degree rod-lens telescope

In the fully relaxed patient, the larynx is exposed using the "anesthetic" (McIntosh) or general-purpose laryngoscope while the largest possible telescope is used to assess the exact location of the stenosis with respect to the vocal cords and the tracheostoma. Nebulizing the airway with local anesthetics is helpful. In adults, this assessment can be made with an 8-mm telescope, while in the pediatric age group, 4-mm is likely to be the maximum possible size. If the 4 mm-diameter endoscope is too large, then a 2.7- or 1.9-mm telescope should be used to assess the length of the stenosis and the integrity of the distal airway. In the non-tracheostomized patient, care must be taken not to traumatize the mucosa with the telescope because the slightest injury to a small, narrow airway may decompensate a stable obstructive dyspnea and necessitate a tracheotomy (Fig. 3). This portion of the endoscopy is best performed in suspension microlaryngoscopy to avoid damage to the fragile thin telescope (See Sect. "Suspension microlaryngoscopy").

Video recordings with an HD-digital camera connected to the endoscope should be routinely taken. This allows the surgeon and the airway team to review each case in detail prior to selecting the best surgical option for each individual patient. Serial still photographs are an alternative to video recordings.

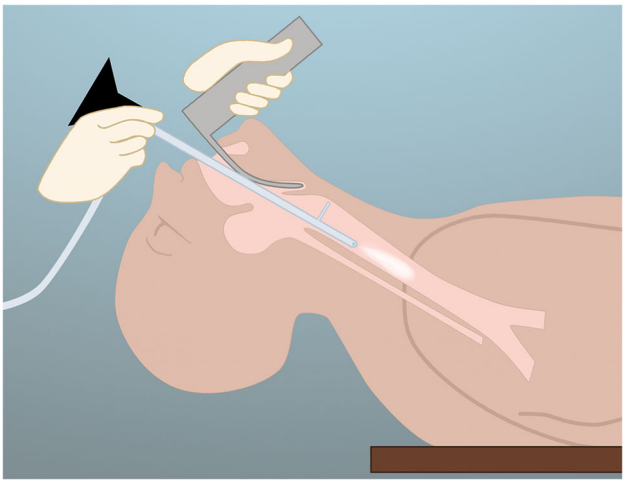

Fig. 3 Diagram of direct, transoral laryngoscopy using a bare, rigid, 0° telescope

In order to plan the surgery accurately, especially in the case of a resection-anastomosis, precise measurements of the site, grade and cranio-caudal extent of the stenosis are indispensable. Finally, the degree of stenosis is measured by passing telescopes, bougies or endotracheal tubes of different given sizes through the stricture. The Myer-Cotton Airway Grading System is routinely used: Grade I corresponds to less than 50 % airway obstruction; Grade II to 51–70 %; Grade III to 71–99 %; Grade IV to no detectable lumen (Fig. 4) [26].

Endoscopically, it is easy to assess Grade IV (complete obstruction) and severe Grade III (residual pinhole opening) stenosis without any device. For minor grades of stenosis (Grades I, II and minor Grade III), endotracheal tubes may be used, as recommended by Myer and Cotton [25].

This airway grading system has been shown to be relevant for predicting the success rate of LTRs for various degrees of stenosis, the minor grades having a much better decannulation rate than the most severe grades.

Recently, this airway grading system was found not to be relevant for predicting success rates of PCTRs because the stenotic airway segment is fully resected. In contrast, glottic involvement and comorbidities were found to play a significant role with respect to decannulation rates and time to decannulation from the date of surgery [27].

This paper proposes a way to further improve upon this scoring system so that better comparison of postoperative results between different series of matched patients may be made (see Table 2).

When VF immobility is found during TNFL, suspension microlaryngoscopy must be implemented.

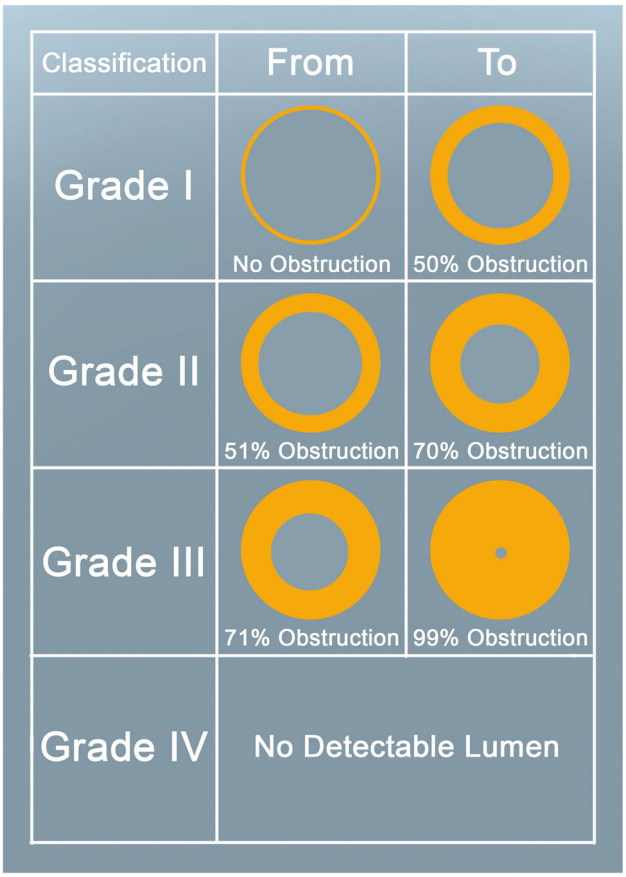

Fig. 4 Myer-Cotton airway grading system

Suspension microlaryngoscopy

In pediatric patients, Benjamin-Lindholm or Parsons laryngoscopes are usually preferred for obtaining a panoramic view of the pharyngolarynx and subglottis. Telescopes are used to measure the exact length and site of the stenosis in the cranio-caudal direction. The telescope is inserted through the laryngoscope and further advanced to the level of the vocal cords. The recorded distance is marked on the shaft of the telescope (Fig. 5). Repeated measures are similarly taken at the upper and lower margins of the stenosis and tracheostoma, and lastly at the level of the carina. If possible, a diagram with all of the measurements should be added to the endoscopy report (Fig. 6). Such measurements are indispensable when a resection and anastomosis is considered.

A Lindholm vocal cord retractor and angulated probes are very useful for differentiating bilateral VF paralysis (BVFP) from posterior glottic stenosis (PGS), with or without cricoarytenoid joint fixation. In cases of obvious PGS, arytenoid palpation is essential. When both arytenoids cannot be moved laterally with the probe, then bilateral cricoarytenoid joint fixation must be suspected. By

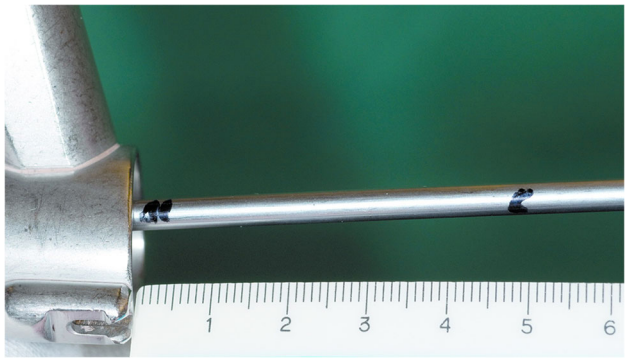

Fig. 5 Assessment of the precise location of the SGS craniocaudal extent with respect to the vocal folds and tracheostoma: the bare rod-lens telescope is used for precise measurements that are *marked* on the shaft of the instrument with an indelible pen

contrast, when one arytenoid is pushed laterally and attracts the contralateral arytenoid towards the same side, then there is no cricoarytenoid joint fixation. This information is useful for predicting possible conservation of VF mobility after surgery.

To differentiate BVFP from PGS, the Lindholm false cord retractor is key. The instrument is placed at the level of the ventricular bands and widely opened. The interarytenoid distance is restored to its normal size in the case of a neurogenic BVFP; the interarytenoid distance remains narrow and a stretched band of scar tissue may be seen from posterior commissure scarring in PGS (Fig. 7). Electromyography (EMG) is not required to differentiate between these two conditions but can be useful for predicting spontaneous recovery in cases of neonatal or recent neurogenic paralysis.

Finally, an angulated instrument is used to probe the posterior commissure to search for a laryngeal cleft. This instrument can also be used to palpate the SGS and differentiate a soft, immature from a hard mature cicatricial stenosis.

Bronchoesophagoscopy

The preoperative assessment of the patient with LTS is incomplete if the lower airways and esophagus are not examined.

The inspection of the lower airway through the tracheostoma is done either with a rigid instrument (open tube bronchoscope, bare rod-lens telescope) or a flexible bronchofiberscope. The distance from the lower edge of the tracheostoma to the carina is measured, and the number of residual normal tracheal rings is precisely counted when they are clearly visible and not obscured by a swollen, inflammatory mucosa. This is especially useful in infants, children and adolescents whose tracheae are shorter than that of adults.

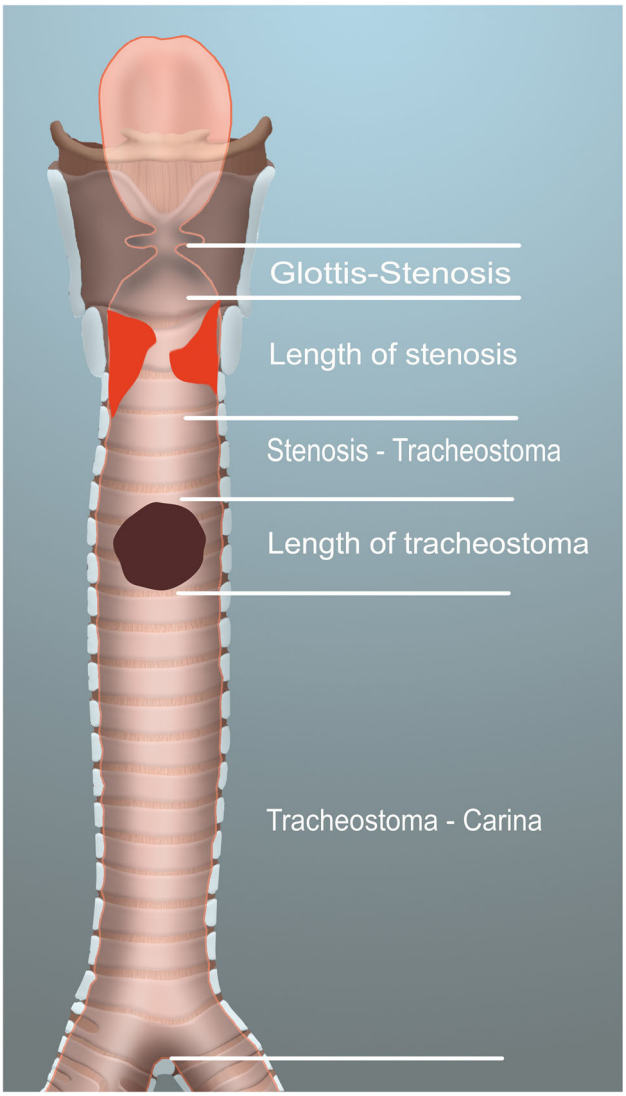

Fig. 6 Diagram of endoscopy report (example for a purely SGS): the length and precise location of the SGS with respect to the vocal folds and tracheostoma, as well as the length of the tracheostoma and residual normal trachea (in centimeters and number of normal tracheal rings) must be recorded

In the trachea and bronchi, the presence of congenital and acquired lesions such as tracheoesophageal fistula, anomalous tracheal origin of the upper lobe bronchus (bronchus suis), complete tracheal rings, localized or diffuse malacia, extrinsic compressions and abnormal distribution of the bronchial tree is investigated. Acquired lesions may originate from local trauma induced by the tracheostomy cannula, as well as suction catheters at the level of the carina or bronchial spurs further down the lower airways. A bacteriological aspirate of the tracheobronchial secretions should be obtained systematically because many patients with long standing tracheostomas are colonized by resistant bacteria (e.g., MRSA, ESBL, *Pseudomonas Aeruginosa*). Failure to diagnose infection of the airway may adversely affect the postoperative outcome of LTR and PCTR.

Retrograde subglottic inspection through the tracheostoma using a 120° sinuscope is useful when the LTS cannot be passed with a slim (1.9 or 2.7 mm) telescope. At times, it may be possible to assess the length of the suprastomal trachea.

The role of esophagoscopy is to detect gastroesophageal reflux (GER) and eosinophilic esophagitis (EE). Although GER is best diagnosed using 24-h pH-monitoring or impedancemetry [28–32], endoscopy is helpful when it reveals clear signs of erosive esophagitis. A thickened or ringed esophageal mucosa may be indicative of eosinophilic esophagitis [33, 34].

If the endoscopy workup is carefully performed, then it is often sufficient for precise planning of the surgery.

In the adult age group, LTS without evident etiology or LTS presenting with atypical endoscopic features should always be biopsied to identify possible rare conditions such as Wegener's granulomatosis [35–37], relapsing polychondritis [38, 39], other autoimmune disorders [40], tuberculosis [41–43], sarcoidosis [44, 45] or idiopathic SGS [46–48] and amyloidosis [49], to name just a few among the most frequently described in the literature.

Radiological evaluation

In children, the benefit of a thin slice CT-scan for assessing the larynx and upper trachea is questionable, since cartilaginous structures are not revealed precisely.

In contrast, CT-scan is particularly useful in evaluating extrinsic compression of the airway by cystic or solid masses [50]. With an intravenous contrast medium, abnormal mediastinal vessels or masses narrowing the trachea can readily be demonstrated without sedating an infant because of the ultrafast acquisition frames that diminish the blurring of the images on the film [51, 52]. Three-dimensional (3D) reconstructions of the laryngotracheal airway offer useful information as to the location, extent and severity of the obstruction. Virtual endoscopy cannot replace conventional laryngotracheal bronchoscopy. In addition, this technique provides no information as to the quality of the mucosa (cicatricial versus inflammatory). Furthermore, trapped secretions below the stenosis may artificially increase the extent of the narrowing. In cases of total obstruction of the airway, virtual endoscopy is helpful in visualizing the length of the stenosis and the distal portion of the airway [53].

An MRI may be indicated for assessment of vascular compression of the airway secondary to congenital cardiovascular anomalies or the mediastinal extent of a tumor

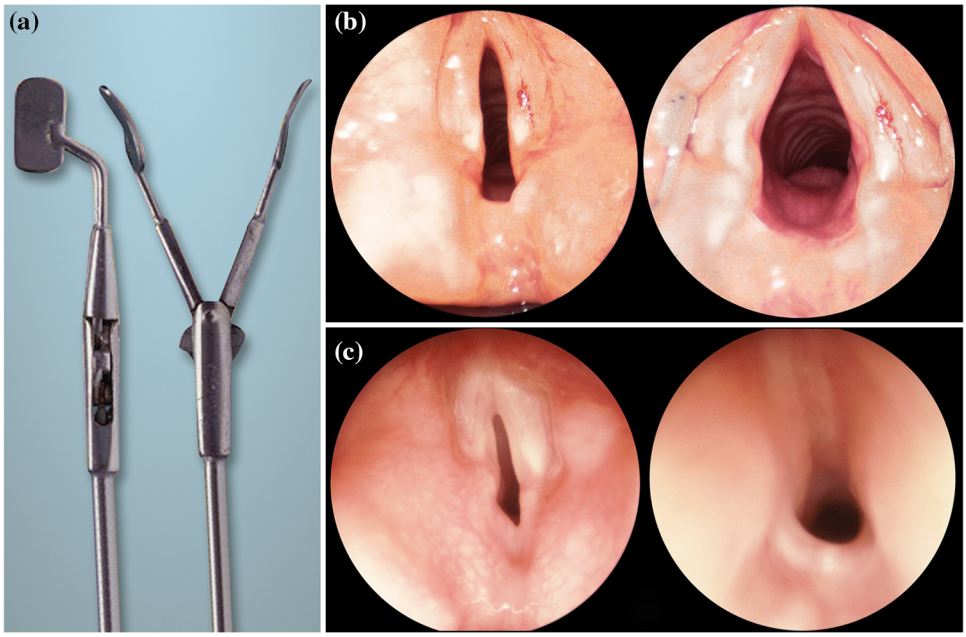

Fig. 7 Contribution of the Lindholm false vocal fold retractor in bilateral immobility of the vocal folds: **a** Lindholm's self-retaining VF retractor. **b** Bilateral VF neurogenic paralysis: the paramedian position of both VFs (*left*) is easily spread apart with retractor (*right*). **c** Posterior glottic stenosis: the paramedian position of both VFs (*left*) is not improved by the retractor, but a band of scar tissue becomes conspicuous (*right*)

mass. The contrast resolution is finer than the CT-scan's, and MRI permits imaging in any desired plane with 3D reconstructions [54]. An MRI in moderately dyspneic infants and children requires sedation.

In adults, a thin slice CT-scan of the larynx and trachea can be useful to distinguish a purely intrinsic stenosis with intact laryngotracheal framework from a panmural stenosis with laryngotracheal framework deformity or collapse [55, 56]. Purely intrinsic stenoses may benefit from endoscopic treatment, such as laser radial incisions and balloon dilatation, whereas panmural or malacic stenoses usually require an open surgical procedure to be treated correctly.

The etiology of the stenosis must also be considered to assess the need for imaging studies. Such studies are of key importance in LTS induced by blunt or penetrating trauma.

Functional assessment of respiration and voice

Since endoscopic or open surgical treatment of airway narrowings aims at improving the patient's respiratory and phonatory conditions, pre- and post-therapy assessments should be obtained in all (adult) patients. Typically, this should include a documentation of stridor (at rest/during exercise), of physical ability (number of stairs climbed without dyspnea), and of explicit lung function testing (including flow-volume loops and determination of peak expiratory and inspiratory flows) [57, 58]. Flow measurements have been shown to be effective in detecting central airway stenoses more sensitively than flow-volume-loops. Therefore, they are well suited for monitoring respiratory function in the pre- and post-therapy periods [55].

Pre- and postoperative evaluation of voice should be conducted using the GRBAS-scale [59], maximum phonation time for the vowels/e/and/a/, as well as a voice range profile [60].

In children, particularly in infants and toddlers, these measurements can be difficult or impossible to perform [61]. Therefore, they are generally not obtained and not required. In adults, however, a functional assessment should routinely be obtained [62–65].

Assessment of the patient's general condition

In infants and children, a comprehensive physical examination and a thorough examination of the head and neck are essential. The physical examination is focused on the overall appearance of the child, with the following details to be noted: body weight and height for age, structural and maxillo-facial deformities, syndromic or non-syndromic abnormalities. Furthermore, communication skills, neurological and mental abilities including the coordination of respiration and swallowing must be clearly documented. Any history of regurgitation while eating as

well as abnormal pulmonary and cardiovascular auscultatory findings should also be noted.

In the non-tracheostomized child, the degree of respiratory distress and the level of airway obstruction (based on pathological respiratory sounds and the respiratory cycle phase during which they are produced) are recorded. In the absence of conspicuous stridor, neck auscultation should be performed in all patients to detect airflow turbulences.

In the tracheostomized child, temporary occlusion of the cannula with the finger may allow the surgeon to assess the air egress through the larynx while analyzing the quality of the cry or voice. In cooperative children and under favorable conditions, it may be possible to inspect the lower airways through the cannula using a slim bronchofiberscope.

Some abnormalities are readily visible, whereas others may require examination by specialists to confirm the diagnosis. Pediatricians, pulmonologists, cardiologists, neurologists, gastroenterologists and geneticists are of great help in providing a detailed assessment of the child. Their input is invaluable for selecting the optimal surgical procedure for each individual patient or for selecting a single-stage versus a double-stage procedure. Correct diagnosis and treatment of associated comorbidities are essential to prevent surgical failures (Table 1).

In adults, a comprehensive physical examination should also be carried out prior to endoscopic assessment. Any anatomical limitation of the head and neck, oral cavity or laryngopharynx that may preclude endoscopic evaluation or treatment must be detected in advance to reduce risks and complications.

Potential comorbidities can be uncovered through a detailed medical history.

Often, cardiac, pulmonary and neurological problems are potential causes of complicated surgeries. Here again, the help of specialists is invaluable. Examinations may include:

- Lung function tests, including a flow-volume curve, peak expiratory and inspiratory flows, and possibly lung CT-scan.
- EKG, cardiac stress/diagnostic test, cardiac ultrasonography or catheterization and possibly coronarography.
- Full neurological examination including coordination of swallowing and respiration, identification of potential sequelae of brain or spine injuries and signs of myopathy or myasthenia gravis.
- 24-h pH-impedancemetry in cases of a positive medical history for gastroesophageal reflux, dysphagia and/or chocking episodes; esophagoscopy to rule out eosinophilic esophagitis.

Table 1 General condition: pediatric patient group

Overall appearance
Nutritional aspect
Bodyweight and height for age
Dysmorphic features
Syndromic or non-syndromic anomalies
Pulmonary status (conditions that might impair ventilation improvement in spite of successful surgical correction of LTS)
Chest deformity
Chronic pulmonary disease
Oxygen requirement, need for bronchodilators
Cardiac and vascular anomalies
Pulmonary hypertension
Shunts
Patent ductus arteriosus
Vascular rings
Transposition of the great vessels
Neurologic impairments
Swallowing disorders
Mental retardation
RLN palsy
Cranial nerve dysfunction
Neuromuscular disorders
Neuromuscular dysfunction associated with medications
Gastroesophageal reflux, eosinophilic esophagitis, fistulas
Craniofacial malformations, macroglossia
Infectious disease (localized/systemic)

- Serological exams (i.e., cANCA, pANCA and ACE) in select cases to rule out autoimmune disorders, or other granulomatous diseases (e.g., tuberculosis, sarcoidosis).

Data collection and final pre-operative report

All data gathered during the medical history, the physical examination, the endoscopy workup and the radiological exams should be reported on a check list to avoid missing any information. A comparison list can be used in the postoperative period to assess the quality of the surgical result (Table 2).

Final scoring is based on the Myer-Cotton airway grading system that assesses the degree of airway stenosis. To this well-known system, the letters a, b, c and d have been added to account for the cranio-caudal extent of the stenosis: (a) means only one site is involved (either supraglottis, glottis, subglottis or trachea); (b) implies involvement of two different sites in any combination (e.g., supraglottis + glottis, glottis + subglottis, subglottis + trachea); (c) indicates involvement of three different

sites; and (d) corresponds to the most severe scenario involving all four sites of the airway. An addition sign (+) is included in the final score to indicate the presence of severe comorbidities, or congenital abnormalities.

Comorbidities are considered as severe when medical or surgical treatment is required (Table 3). Congenital anomalies that have a negative influence on the surgical outcome of LTR or PCTR comprise all malformations that require either an extensive rehabilitation (e.g., swallowing disorders with aspiration, neurologic deficit) and/or surgical correction (e.g., maxillofacial anomalies, esophageal atresia with TEF, uncontrolled GER with PPI, syndromic anomalies with multiple malformations), to mention just a few.

An example of using the scoring system might be for a final score of IVc+, which corresponds to an LTS with complete luminal obstruction, involving three different sites of the airway (either a transglottic stenosis or a glotto-SGS with additional tracheal damage) in a patient suffering from severe comorbidities or congenital anomalies.

Table 2 Check list of patient's assessment for LTS

ENDOSCOPY • preoperative assessment ☐ yes ☐ no
• postoperative assessment ☐ yes ☐ no

Awake indirect laryngoscopy/Awake TNFL ☐ yes ☐ no

• **VF mobility**
normal bilaterally ☐ yes ☐ no
restricted abduction ☐ left ☐ right ☐ bilateral
VF immobility ☐ left ☐ right ☐ bilateral

Asleep TNFL (under GA in spontaneous respiration) ☐ yes ☐ no

• **OSA-related narrowings** ☐ yes ☐ no
☐ nose ☐ nasopharynx ☐ oropharynx ☐ pharyngolarynx
description :.....

• **VF mobility** (if awake TNFL was impossible) ☐ yes ☐ no (please report above)

• **Tracheomalacia** ☐ yes ☐ no ☐ diffuse ☐ localized

• **Secondary Airway Lesions** ☐ yes ☐ no
description :.....

Direct laryngotracheoscopy +/- SML (under GA)

• **Congenital LTS** ☐ yes ☐ no

• **Acquired LTS**
fresh, incipient LTS ☐ yes ☐ no
mature cicatricial LTS ☐ yes ☐ no
mixed (acquired on congenital) LTS ☐ yes ☐ no

• **Grade of stenosis**
☐ I ≤ 50 %
☐ II 51 to 70%
☐ III 71 to 99%
☐ IV no lumen

• **Cranio-caudal extent of stenosis**
≤ 5mm ☐
> 5mm ≤ 15 mm ☐
> 15mm ≤ 30mm ☐
> 30mm ☐

• **Site of stenosis** (more than one answer possible)
supraglottic ☐ yes ☐ no
glottic ☐ yes ☐ no
subglottic ☐ yes ☐ no
tracheal ☐ yes ☐ no

• **Abnormal VF mobility**
neurogenic VF paresis ☐, paralysis ☐ ☐ unilateral ☐ bilateral
VF fixation ☐ partial unilat. ☐ partial bilat.
☐ complete unilat. ☐ complete bilat.

• **Posterior glottic stenosis (PGS)** ☐ yes ☐ no
interarytenoid adhesion (cicatricial bridge) ☐
true PGS ☐ yes ☐ no
☐ without CAA ☐ with unilat. CAA ☐ with bilat. CAA

Table 2 continued

- **VF web, synechia** ☐ yes ☐ no
  ≤ 25% VF length ☐ 25% ≤ 50% VF length ☐ 50% ≤ 75% VF length ☐ > 75% VF length ☐
- **Trachea**
  - Stenosis ☐ yes ☐ no
  - Malacia ☐ yes ☐ no
    - primary diffuse ☐ yes ☐ no
    - localized post-tracheostomy ☐ yes ☐ no
      extrinsic vascular compression ☐ yes ☐ no
  - Tracheostomy ☐ yes ☐ no
    location ☐ 1st 2nd rings ☐ 3rd 4th rings ☐ ≥ 5th rings
    additional distal tracheal stenosis ☐ yes ☐ no
    localized tracheostoma malacia ☐ yes ☐ no
- **Bronchial tree and esophagus**

Bronchomalacia	☐ yes	☐ no	Bacteriological aspirate	☐ yes	☐ no
Extrinsic bronchial compression	☐ yes	☐ no	Bronchoalveolar lavage	☐ yes	☐ no
Gastroesophageal refux	☐ yes	☐ no	Esophageal biopsies	☐ yes	☐ no
Eosinophilic esophagitis	☐ yes	☐ no			

Other……..

COMORBIDITIES ☐ yes ☐ no

- **Airway** ☐ yes ☐ no
  - OSA-related narrowings ☐ yes ☐ no
  - Secondary LTS/ malacia ☐ yes ☐ no
    description :……
- **Medical** ☐ yes ☐ no

respiratory insufficiency (O_2 dependence)	☐ yes	☐ no
Symptomatic cardiac/vascular disease	☐ yes	☐ no
Neurologic sequelae/mental impairment	☐ yes	☐ no
Swallowing disorder/aspiration	☐ yes	☐ no
Symptomatic gastroesophageal reflux	☐ yes	☐ no
Eosinophilic esophagitis	☐ yes	☐ no
Syndromic/non-syndromic anomalies	☐ yes	☐ no
Other : ……..	☐ yes	☐ no

FINAL SCORING

☐ Ia	☐ Ib	☐ Ic	☐ Id
☐ IIa	☐ IIb	☐ IIc	☐ IId
☐ IIIa	☐ IIIb	☐ IIIc	☐ IIId
☐ IVa	☐ IVb	☐ IVc	☐ IVd

a = only one site involved (supraglottis/glottis/subglottis/trachea)
b = two sites involved
c = three sites involved
d = all four sites involved
} in any order
+ is added to any final score to indicate an additional severe comorbidity or congenital anomaly

TREATMENT PLAN **Primary surgery** ☐ **Salvage surgery** ☐: 1st ☐ 2nd ☐ 3rd ☐ >3rd ☐

- **Description :** **1**.....
  2.....
  3.....
  4.....

It must be realized that certain conditions resulting from blunt or penetrating trauma, caustic injuries and steam or flame burns can be difficult to classify precisely using the checklist presented in Table 2, because the injuries can involve not only the larynx but also the pharynx, the tracheobronchial tree and/or the esophagus, adding a significant therapeutic challenge to reconstructive surgery. These patients should probably be classified into a different, miscellanous category of stenosis.

Discussing each individual's data within an Airway Team consisting of otolaryngologists, thoracic surgeons, pneumologists, anesthesiologists and ICU specialists, at a minimum is invaluable in helping select the best surgical option. Similar to a tumor board, an airway board should

Table 3 Severe comorbidities and/or congenital anomalies

Cardiopulmonary disease with O_2 dependency
Uncontrolled GER despite PPI treatment
Reactive, "angry" larynx of unknown etiology
Severe neurological impairment
Severe mental disability
Discoordinate pharyngolaryngeal function with aspiration
Congenital systemic/airway anomalies requiring medical and/or surgical treatment
Airway contamination with resistant bacteria (e.g., MRSA, ESBL, *Pseudomonas Aeruginosa*)
Severe secondary airway lesions [e.g., tracheo(-broncho)-malacia, TE fistula, distal tracheal stenosis]

meet at regular intervals in tertiary centers where this type of surgery is performed on a regular basis.

Depending on the specific characteristics of the patient, input from other specialities (e.g., gastroenterologists, neurologists, geneticists, infectiologists, nutritionists) is highly recommended before initiating a difficult airway resection/reconstruction.

It is not acceptable to opt for some type of treatment (either open or endoscopic) without prior multidisciplinary consensus, only because one does not master a specific technique. Proper indications should match with the best endoscopic or open surgical option. Furthermore, the absence of adequate equipment to perform the ideal operation should not be an excuse to carry out a different surgical procedure. Improvisation is not a wise choice. Surgeons who manage airway problems must be prepared to face difficult situations, and they should be able to select the best option for each individual patient. The patient's best chance always lies in the first surgery, so there should not be any compromise when choosing the first intervention.

References

1. Zeeshan A, Detterbeck F, Hecker E (2014) Laryngotracheal resection and reconstruction. Thorac Surg Clin 24(1):67–71
2. Zhi L, Wenli W, Pengfei G, Pengcheng C, Wenxian C, Jiasheng L et al (2014) Laryngotracheal reconstruction with autogenous rib cartilage graft for complex laryngotracheal stenosis and/or anterior neck defect. Eur Arch Otorhinolaryngol 271(2):317–322
3. Deckard N, Yeh J, Soares DJ, Criddle M, Stachler R, Coticchia J (2013) Utility of two-stage laryngotracheal reconstruction in the management of subglottic stenosis in adults. Ann Otol Rhinol Laryngol 122(5):322–329
4. Chekan VL (2013) The treatment of combined cicatrical stenoses of the larynx and trachea. Vestn Otorinolaringol 1:64–67
5. Morcillo A, Wins R, Gomez-Caro A, Paradela M, Molins L, Tarrazona V (2013) Single-staged laryngotracheal reconstruction for idiopathic tracheal stenosis. Ann Thorac Surg 95(2):433–439 **(discussion 9)**
6. Jovic RM, Dragicevic D, Komazec Z, Mitrovic S, Janjevic D, Gasic J (2012) Laryngotracheal stenosis and restenosis. What has the influence on the final outcome? Eur Arch Otorhinolaryngol 269(7):1805–1811
7. Schmidt RJ, Shah G, Sobin L, Reilly JS (2011) Laryngotracheal reconstruction in infants and children: are single-stage anterior and posterior grafts a reliable intervention at all pediatric hospitals? Int J Pediatr Otorhinolaryngol 75(12):1585–1588
8. Cui P, Gao P, Luo J, Ruan Y (2011) Thyroid alar cartilage graft laryngotracheal reconstruction in adults. Otolaryngol Head Neck Surg 144(5):747–750
9. Bielecki I, Cofala M (2011) Single-stage laryngotracheoplasty in children. Auris Nasus Larynx 38(6):697–701
10. Choo KK, Tan HK, Balakrishnan A (2010) Subglottic stenosis in infants and children. Singap Med J 51(11):848–852
11. Goh BS, Roopesh S, Marina MB, Abdullah SM (2014) Partial cricotracheal resection (PCTR), a rewarding outcome for paediatric subglottic stenosis: an early experience. Med J Malays 69(1):13–15
12. Rubikas R, Matukaityte I, Jelisiejevas JJ, Rackauskas M (2014) Surgical treatment of non-malignant laryngotracheal stenosis. Eur Arch Otorhinolaryngol 271(9):2481–2487
13. Balasubramanian D, Thankappan K, Shetty S, Jayaprasad K, Mathew J, Iyer S (2013) Cricotracheal reconstruction with free radial forearm flap and titanium mesh. Head Neck 35(6):E178–E180
14. Torre M, Carlucci M, Avanzini S, Jasonni V, Monnier P, Tarantino V et al (2011) Gaslini's tracheal team: preliminary experience after one year of paediatric airway reconstructive surgery. Ital J Pediatr 37:51
15. Mutrie CJ, Eldaif SM, Rutledge CW, Force SD, Grist WJ, Mansour KA et al (2011) Cervical tracheal resection: new lessons learned. Ann Thorac Surg 91(4):1101–1106 **(discussion 6)**
16. Taylor JC, Collar RM, Wilson KF, Ohye RG, Green GE (2010) Cricotracheal resection with hilar release for pediatric airway stenosis. Arch Otolaryngol Head Neck Surg 136(3):256–259
17. Parida PK, Gupta AK (2009) Management of laryngotracheal stenosis—our experience. Indian J Otolaryngol Head Neck Surg 61(4):306–312
18. Schick B, Weidenbecher M, Miller R, Iro H (2007) Experience with laryngotracheal reconstruction in subglottic stenosis in a 30 years time period. Laryngorhinootologie 86(5):358–364
19. Primov-Fever A, Talmi YP, Yellin A, Wolf M (2006) Cricotracheal resection for airway reconstruction: the Sheba Medical Center experience. IMAJ 8(8):543–547
20. Amoros JM, Ramos R, Villalonga R, Morera R, Ferrer G, Diaz P (2006) Tracheal and cricotracheal resection for laryngotracheal stenosis: experience in 54 consecutive cases. Eur J Cardiothorac Surg 29(1):35–39
21. Alvarez-Neri H, Penchyna-Grub J, Porras-Hernandez JD, Blanco-Rodriguez G, Gonzalez R, Rutter MJ (2005) Primary cricotracheal resection with thyrotracheal anastomosis for the treatment of severe subglottic stenosis in children and adolescents. Ann Otol Rhinol Laryngol 114(1 Pt 1):2–6
22. Triglia JM, Nicollas R, Roman S (2001) Primary cricotracheal resection in children: indications, technique and outcome. Int J Pediatr Otorhinolaryngol 58(1):17–25
23. Triglia JM, Nicollas R, Roman S (2000) Management of subglottic stenosis in infancy and childhood. Eur Arch Otorhinolaryngol 257(7):382–385
24. Hartley BE, Cotton RT (2000) Paediatric airway stenosis: laryngotracheal reconstruction or cricotracheal resection? Clin Otolaryngol Allied Sci 25(5):342–349
25. Piazza C, Del Bon F, Paderno A, Grazioli P, Mangili S, Lombardi D et al (2014) Complications after tracheal and cricotracheal

resection and anastomosis for inflammatory and neoplastic stenoses. Ann Otol Rhinol Laryngol 123(11):798–804
26. Myer CM 3rd, O'Connor DM, Cotton RT (1994) Proposed grading system for subglottic stenosis based on endotracheal tube sizes. Ann Otol Rhinol Laryngol 103(4 Pt 1):319–323
27. Monnier P, Ikonomidis C, Jaquet Y, George M (2009) Proposal of a new classification for optimising outcome assessment following partial cricotracheal resections in severe pediatric subglottic stenosis. Int J Pediatrotorhinolaryngol 73(9):1217–1221
28. Little JP, Matthews BL, Glock MS, Koufman JA, Reboussin DM, Loughlin CJ et al (1997) Extraesophageal pediatric reflux: 24-hour double-probe pH monitoring of 222 children. Ann Otol Rhinol Laryngol Suppl 169:1–16
29. Nielsen RG, Kruse-Andersen S, Husby S (2003) Low reproducibility of 2 × 24-hour continuous esophageal pH monitoring in infants and children: a limiting factor for interventional studies. Dig Dis Sci 48(8):1495–1502
30. Lopez-Alonso M, Moya MJ, Cabo JA, Ribas J, del Carmen Macias M, Silny J et al (2006) Twenty-four-hour esophageal impedance-pH monitoring in healthy preterm neonates: rate and characteristics of acid, weakly acidic, and weakly alkaline gastroesophageal reflux. Pediatrics 118(2):e299–e308
31. Mazzoleni G, Vailati C, Lisma DG, Testoni PA, Passaretti S (2014) Correlation between oropharyngeal pH-monitoring and esophageal pH-impedance monitoring in patients with suspected GERD-related extra-esophageal symptoms. Neurogastroenterol Motil 26(11):1557–1564
32. Tenca A, Campagnola P, Bravi I, Benini L, Sifrim D, Penagini R (2014) Impedance pH Monitoring: intra-observer and inter-observer agreement and usefulness of a rapid analysis of symptom reflux association. J Neurogastroenterol Motil 20(2):205–211
33. Furuta GT, Liacouras CA, Collins MH, Gupta SK, Justinich C, Putnam PE et al (2007) Eosinophilic esophagitis in children and adults: a systematic review and consensus recommendations for diagnosis and treatment. Gastroenterology 133(4):1342–1363
34. Dauer EH, Freese DK, El-Youssef M, Thompson DM (2005) Clinical characteristics of eosinophilic esophagitis in children. Ann Otol Rhinol Laryngol 114(11):827–833
35. Duna GF, Galperin C, Hoffman GS (1995) Wegener's granulomatosis. Rheumc Dis Clin North Am 21(4):949–986
36. Lampman JH, Querubin R, Kondapalli P (1981) Subglottic stenosis in Wegener's granulomatosis. Chest 79(2):230–232
37. Talerman A, Wright D (1972) Laryngeal obstruction due to Wegener's granulomatosis. Arch Otolaryngol 96(4):376–379
38. Damiani JM, Levine HL (1979) Relapsing polychondritis—report of ten cases. Laryngoscope 89(6 Pt 1):929–946
39. Batsakis JG, Manning JT (1989) Relapsing polychondritis. Ann Otol Rhinol Laryngol 98(1 Pt 1):83–84
40. Caldarelli DD, Friedberg SA, Harris AA (1979) Medical and surgical aspects of the granulomatous diseases of the larynx. Otolaryngol Clin North Am 12(4):767–781
41. Auerbach O (1946) Laryngeal tuberculosis. Arch Otolaryngol 44:191–201
42. Bailey CM, Windle-Taylor PC (1981) Tuberculous laryngitis: a series of 37 patients. Laryngoscope 91(1):93–100
43. Burns JL (1993) Laryngeal tuberculosis. J Otol 22(5):398
44. Neel HB 3rd, McDonald TJ (1982) Laryngeal sarcoidosis: report of 13 patients. Ann Otol Rhinol Laryngol 91(4 Pt 1):359–362
45. Krespi YP, Mitrani M, Husain S, Meltzer CJ (1987) Treatment of laryngeal sarcoidosis with intralesional steroid injection. Ann Otol Rhinol Laryngol 96(6):713–715
46. Grillo HC, Mark EJ, Mathisen DJ, Wain JC (1993) Idiopathic laryngotracheal stenosis and its management. Ann Thorac Surg 56(1):80–87
47. Ashiku SK, Mathisen DJ (2003) Idiopathic laryngotracheal stenosis. Chest Surg Clin North Am 13(2):257–269
48. Giudice M, Piazza C, Foccoli P, Toninelli C, Cavaliere S, Peretti G (2003) Idiopathic subglottic stenosis: management by endoscopic and open-neck surgery in a series of 30 patients. Eur Arch Otorhinolaryngol 260(5):235–238
49. Piazza C, Cavaliere S, Foccoli P, Toninelli C, Bolzoni A, Peretti G (2003) Endoscopic management of laryngo-tracheobronchial amyloidosis: a series of 32 patients. Eur Arch Otorhinolaryngol 260(7):349–354
50. Schlesinger AE, Hernandez RJ (1990) Radiographic imaging of airway obstruction in pediatrics. Otolaryngol Clin North Am 23(4):609–637
51. Singh C, Gupta M, Sharma S (2006) Compression of trachea due to double aortic arch: demonstration by multi-slice CT scan (MSCT). Heart Lung Circ 15(5):332–333
52. Lambert V, Sigal-Cinqualbre A, Belli E, Planche C, Roussin R, Serraf A et al (2005) Preoperative and postoperative evaluation of airways compression in pediatric patients with 3-dimensional multislice computed tomographic scanning: effect on surgical management. J Thorac Cardiovasc Surg 129(5):1111–1118
53. Honnef D, Wildberger JE, Das M, Hohl C, Mahnken AH, Barker M et al (2006) Value of virtual tracheobronchoscopy and bronchography from 16-slice multidetector-row spiral computed tomography for assessment of suspected tracheobronchial stenosis in children. Eur Radiol 16(8):1684–1691
54. Lowe GM, Donaldson JS, Backer CL (1991) Vascular rings: 10-year review of imaging. Radiographics 11(4):637–646
55. Parida PK, Gupta AK (2008) Role of spiral computed tomography with 3-dimensional reconstruction in cases with laryngeal stenosis—a radioclinical correlation. Am J Otolaryngol 29(5):305–311
56. Jewett BS, Cook RD, Johnson KL, Logan TC, Rosbe KW, Mukherji SK et al (1999) Subglottic stenosis: correlation between computed tomography and bronchoscopy. Ann Otol Rhinol Laryngol 108(9):837–841
57. Lunn WW, Sheller JR (1995) Flow volume loops in the evaluation of upper airway obstruction. Otolaryngol Clin North Am 28(4):721–729
58. Bogaard JM, Pauw KH, Versprille A, Stam H, Verbraak AF, Maas AJ (1987) Maximal expiratory and inspiratory flow-volume curves in bilateral vocal-cord paralysis. Changes after surgical treatment and comparison with glottic resistance characteristics. ORL J Otorhinolaryngol Relat Spec 49(1):35–41
59. Hirano M (1981) Clinical examination of the voice. Disorders of Human Communication. Springer Verlag, New York, pp 1–98
60. Schutte H (2000) The phonetogram: measurement and interpretation. In: Ferlito A, Hodder A (eds) Diseases of the Larynx, pp 145–149
61. George M, Monnier P (2010) Long-term voice outcome following partial cricotracheal resection in children for severe subglottic stenosis. Int J Pediatr Otorhinolaryngol 74(2):154–160
62. Bryans L, Palmer AD, Schindler JS, Andersen PE, Cohen JI (2013) Subjective and objective parameters of the adult female voice after cricotracheal resection and dilation. Ann Otol Rhinol Laryngol 122(11):707–716
63. Houlton JJ, de Alarcon A, Johnson K, Meinzen-Derr J, Brehm SB, Weinrich B et al (2011) Voice outcomes following adult cricotracheal resection. Laryngoscope 121(9):1910–1914
64. Smith ME, Roy N, Stoddard K, Barton M (2008) How does cricotracheal resection affect the female voice? Ann Otol Rhinol Laryngol 117(2):85–89
65. Tirado Y, Chadha NK, Allegro J, Forte V, Campisi P (2011) Quality of life and voice outcomes after thyroid ala graft laryngotracheal reconstruction in young children. Otolaryngol Head Neck Surg 144(5):770–777