Larynx and Airway

Ambesh Singh, Prajwal S Dange, and Rupa Mehta

1 Introduction

The larynx coordinates a vital role in the various functions of the upper aerodigestive tract, including speech, swallowing and respiration. Squamous cell carcinoma in the head and neck frequently develops in the larynx due to repeated exposure to carcinogens like alcohol and tobacco.

The larynx is mainly divided into:

- The supraglottic region
- The glottic region
- The subglottic region

These embryologic-based anatomical divides have significant clinical ramifications. Compared to the sparse lymphatic network in the submucosal plane of the genuine vocal cords, the lymphatic drainage of the supraglottic larynx is extremely rich. Laryngeal cancer's patterns of regional spread are thus influenced by the main tumour's local size and place of genesis. The larynx is separated into three different areas or sites. The laryngeal surface of the epiglottis, the aryepiglottic folds, the arytenoids, the ventricular bands or false vocal cords and the ventricles—possible areas between the false and real vocal cords—are the locations in the supraglottic region. The right and left vocal cords, together with the anterior commissure, are the three specified places in the glottic larynx. The right and left lateral walls of the subglottic area, which is commonly regarded as one site, serve as its boundaries.

More than 95% of the primary malignant tumours of the larynx are squamous cell carcinomas; the remaining tumours come from the small salivary glands, neuroepithelial tumours, soft tissue tumours and, in rare cases, the cartilaginous laryngeal framework. The majority of initial malignant tumours in the larynx are found in the glottic area. In contrast to almost 70% of patients with supraglottic carcinoma, who present with advanced disease, nearly 75% of patients with glottic carcinoma had localised disease at the time of diagnosis.

Laryngeal cancer is the tenth most prevalent cancer in India overall, and head and neck cancer is the second most common malignancy after cancers of the lips and oral cavity, according to the GLOBOCAN 2020 statistics. In India, laryngeal cancer diagnoses were discovered in 34,687 instances in the year 2020 [1].

2 Aetiology and Pathology

2.1 Smoking

- Despite alcohol being an independent risk factor for developing laryngeal cancer in the

A. Singh (✉) · P. S. Dange
All India Institute of Medical Sciences, Raipur, Chhattisgarh, India

R. Mehta
Department of ENT, All India Institute of Medical Sciences, Raipur, Chhattisgarh, India

N. M. Nagarkar et al. (eds.), *Atlas of Head Neck and Skull-base Surgery*,
https://doi.org/10.1007/978-981-99-6132-0_10

absence of smoking, smoking remains the most frequent aetiological cause for malignancies of the larynx.
- Alcohol and smoking seem to increase the risk in different ways [2].
- Smokers are most at risk of getting laryngeal cancer, and that risk rises with cigarette consumption.
- After quitting smoking and drinking, there is a relative risk decrease for laryngeal cancer, with the risk reduction reaching the same level as never smokers after around 20 years [2, 3].

2.2 HPV Infection

- Although they are strongly associated with oropharyngeal tumours, there is less epidemiological evidence connecting them to laryngeal tumours [4, 5].
- Existing retrospective studies have not shown a favourable prognostic factor for HPV-positive laryngeal tumours, in contrast to oropharyngeal cancer [6, 7].

2.3 Other Factors

- Occupational toxicants including asbestos, polycyclic aromatic hydrocarbons, wood dust, coal dust and cement dust are other recognised risk factors [8, 9].
- The chance of having laryngeal cancer is increased for people with lower socioeconomic level [8].
- Certain genetic syndromes, such as congenital dyskeratosis and [10] Fanconi anaemia [11], are also associated with a higher risk of developing laryngeal tumours in addition to tumours in other parts of the body.

The most common type of laryngeal cancer is squamous cell carcinoma; however, many other histological types of cancers can be seen in the larynx. Optimal pathological assessment of specimens requires a coordinated approach between the pathologist and surgeon or oncologist. The Royal College of Pathologists in the UK has published guidelines for the dataset required to report cases. Important factors include the type, size and grade of the primary carcinoma, the pattern of invasion and the proximity of the carcinoma to resection margins. All are important prognostic features [12]. In cases where a total laryngectomy has been performed, whole-organ section analysis is usually performed to consider patterns of spread and resection margins. HPV testing is not considered routine but may be important in a subset of patients.

3 Pathway of Cancer Spread

Depending on where it originates, laryngeal squamous cell carcinoma spreads in several ways. The lymphatic spread is initially controlled by the borders between embryological anlagen (arches III–VI), particularly at the free edge of the glottis, although local spread occurs along tissue planes. But contrary to long-held ideas, Kirchner's painstaking whole-organ dissections from 1969 showed that there is no real physical barrier to restrain the spread between the supra- and subglottis [13].

3.1 Anterior Commissure

Because early invasion through Broyles' ligament straight into the cartilage was believed to be unavoidable, it was formerly common knowledge that glottic cancer might extend to the anterior commissure (AC). This was thought to be caused by the absence of an inner perichondrium there. Recent research has revealed that although the ligament serves as a useful barrier, the prognosis is worsened by expansion superiorly and inferiorly (through the subglottic wedge and, consequently, the cricothyroid membrane). Direct spread may extend posteriorly to infect the arytenoid cartilage or may proceed via the AC to the opposing cord.

3.2 Glottic Tumours

The embryological barrier, located superiorly, and the conus elasticus, located inferiorly, may constrict glottic tumours to Reinke's space. Tumours must cross both the vocal ligament and the vocalis muscle to enter the paraglottic region and then easily migrate cranially and caudally. Ossified regions appear to be less resistant to invasion than the rest of the laryngeal skeleton. However, direct external extension through the cartilage is frequently observed. Glottic cancer lymphatic dissemination is less frequent than at other subsites. It has been proposed that this is caused by the absence of submucosal lymphatics. Mucosal cell transport has not yet been thoroughly studied to support this, though. When the spread happens, it affects levels II, III, IV and VI. According to estimates, the incidence of macroscopic lymph node metastasis varies depending on the stage of the disease: 5% (T1), 7% (T2), 14% (T3) and 33% (T4) (T4). The so-called "Delphian" node, sometimes referred to as the midline anterior metastatic node or Poirier's prelaryngeal ganglia node, is extremely uncommon but is believed to be connected to T3 or T4 tumours with notable subglottic extension.

3.3 Supraglottic Tumours

Even with pre-epiglottic or nodal dissemination, supraglottic malignancies typically don't spread beyond their local subsite until rather late. As a result, even for large tumours, a supraglottic laryngectomy is frequently a good option. There isn't really an anatomical barrier to inferior spread, though, as was already mentioned. Indeed, the accurate selection of patients who are candidates for supraglottic partial laryngectomy is made possible by the routine use of angled Hopkins rods during staging procedures to examine the cavity of the laryngeal ventricle. This method reveals a steady transmucosal progression of tumours similar to those found in other subsites. According to a number of studies, over 50% of supraglottic malignancies move to the glottic area.

The epiglottic cartilage is less of a barrier to spread than the other cartilages since it has foramina inside it. However, since hyoid invasion is rather uncommon (2–4%), it is frequently possible to keep it during surgical clearing. "Suprahyoid supraglottic" carcinomas often expand mucosally into the pyriform fossae rather than the paraglottic space, invading the pre-epiglottic region and the deep muscles of the tongue.

Additionally, supraglottic tumours are more likely to develop bilateral nodal metastases. Compared to significantly lower rates of 20% in advanced glottic cases, supraglottic carcinoma had a positive nodal rate of over 60% in reports of advanced illness.

3.4 Subglottic Tumours

Caudally and circumferentially extending subglottic cancer is common. By the time a condition is diagnosed, 50% of cases have already invaded the cricoid, and 75% have spread outside. Although a microscopic incidence of one in three places this illness into the category of necessitating elective nodal dissection, clinically apparent nodal metastases is surprisingly rare. The paratracheal/mediastinal nodes should be included in the nodal dissection for subglottic carcinoma due to the tendency for inferior extension.

Transglottic carcinoma is identified by its progression across all three laryngeal subsites, both superficially and into the paraglottic region. Although it is hard to pinpoint the exact origin of true primary transglottic cancer in practice, it is considered to start in the laryngeal ventricle. By definition, it is at least T3 upon presentation; therefore advanced malignancies will be taken into consideration moving forward.

Thyroid gland invasion has been explored in resected tissues, and Kumar et al. studied the incidence of this in a systematic review [14]. This study's analysis of data from 1287 individuals revealed that the overall incidence of thyroid gland invasion is 10.7% [95% confidence interval (CI) 7.6–14.2]. The relative risk of thyroid gland invasion is considerably greater in patients with initial subglottic tumours [relative risk 7.5; 95% confidence interval (CI) 4.3–13.0] and disease extension into the subglottis (relative risk 4.3; 95% CI 2.5–7.2). Other locations did not present this increased danger. Since thyroid gland invasion is uncommon overall, thyroidectomy can be deferred for instances that are thought to be at risk rather than being a standard procedure for all total laryngectomies.

4 Clinical Presentation

Laryngeal cancer, like other malignancies, can exhibit local symptoms as well as those brought on by metastatic dissemination to nodes or elsewhere. Rarely many individuals with laryngeal cancer exhibit general systemic symptoms in the absence of local symptoms, such as anaemia or weight loss. As a consequence, primary care practitioners (and the general public) can have a pretty accurate understanding of the "warning/red flag" symptoms that call for an immediate referral to an otolaryngologist.

4.1 Glottic Cancer

It is fortunate that even the early glottic malignancy modifies the voice by changing the way the vocal cord's wave pattern behaves. Even cancer in situ may cause a considerable alteration in voice since regular voice production depends on the health of a six-cell thick epithelium and a fragile, jelly-like superficial lamina propria.

Therefore, anyone whose hoarseness has persisted for 3 weeks or longer—some even shorter time—should be referred immediately for a checkup with an otolaryngologist and head and neck surgical oncologist.

Maximum phonation time decreases with increasing lesion size, and breathiness with varying degrees of aspiration may be added with the commencement of cord fixation. Progressive dyspnoea and stridor may result from airway obstruction caused by advanced lesions. Larger tumours are typically linked to haemoptysis. Referred otalgia is a dangerous indication that suggests a profound invasion and is detected by the vagal complex. In simple glottic malignancy, dysphagia and odynophagia are quite uncommon. Rarely are neck nodes the initial complaint; when they are, they indicate a severe invasion and extension into the supraglottis.

4.2 Supraglottic Cancer

The quality of the altered voice is distinct from that associated with glottic and subglottic malignancy. Globus or foreign body feeling and paresthesia may be present in small supraglottic lesions that do not extend to the glottis. They may result in haemoptysis if exophytic. Phonation changes as tumour size grows, taking on a "hot potato" sound. As with glottic illness, hoarseness results if tumours spread to the cords.

Lateral extension that is too far may result in genuine dysphagia, referred otalgia and odynophagia. Although tumours may not cause symptoms until they are fairly big, it is normal for cervical nodal metastases to cause a neck lump to be the first symptom to develop.

4.3 Subglottic Cancer

Early symptoms might also be hazy and include a sense of a "globus" or foreign mass in the throat. Hoarseness comes from any glottis or recurrent laryngeal nerve involvement. Diplophonia may occur with paralysis and has a shorter maximum phonation time. Therefore, especially in high-risk situations, this diagnosis should always be taken into account while evaluating the potential alternative causes of "idiopathic" cord paralysis. Progressive dyspnoea and stridor are brought on by circumferential progression, which also causes voice fatigue quickly. A thyroid isthmus lesion may be masked by direct extension into the thyroid.

5 Assessment

5.1 Outpatient Setting

The flexible nasal laryngoscope is the ideal tool for evaluating the larynx in an outpatient situation. Endoscopy can provide significant information that can help with decision-making. If more research is needed, the outpatient endoscopic assessment might also point the examiner in that direction. For instance, the discovery of salivary pooling in the pyriform sinus in the presence of a tiny glottic tumour should raise suspicion and necessitate a checkup of the upper oesophagus and hypopharynx. Laryngeal dysplasia (LD) is a condition that often affects the glottis but can occur elsewhere in the larynx. The larynx has an erythematous, inflammatory look with leukoplakia or erythroleukoplakia. However, histological signs of LD are not necessarily present in the larynx's clinically aberrant regions, and LD can be seen under a microscope in the epithelium that seems clinically normal. Cancer can manifest as lesions that proliferate, infiltrate or both. These are quickly identified during an endoscopic examination as abnormalities. Malignancies, often non-squamous cancers, can occasionally manifest as submucosal tumours. These lesions might create minor abnormalities that may go unnoticed upon initial observation.

5.2 Imaging

Cross-sectional imaging for all tumour stages should be included as a minimum in imaging for laryngeal mass lesions. Magnetic resonance imaging (MRI) or computed tomography (CT) are two options, with the chest also being scanned. Comparing cartilage invasion, MRI scans are more sensitive than CT scans. Each imaging technique has benefits and disadvantages of its own.

5.3 Assessment Under General Anaesthesia

This should be carried out by the operating surgeon and assessment regarding the feasibility of transoral excision to be done in the same sitting. Complete laryngoscopic examination should be carried out to check for arytenoid fixity, subglottic extension, and to map the extent of the tumor.

6 Management of Laryngeal Cancer

6.1 Surgical Anatomy

Anatomically, the larynx extends from the bottom edge of the cricoid cartilage to the tip of the epiglottis. It has a continuous lower boundary with the cervical trachea. Its anterosuperior border is the base of the tongue, and its posterolateral border is the hypopharynx and cervical oesophagus.

Laryngeal cartilages consist of:

- Thyroid
- Cricoid
- Arytenoid
- Epiglottis
- Corniculate
- Cuneiform cartilages

The height of the anterior midline of the thyroid cartilage varies depending on where the anterior commissure is located. The anterior commissure is often found below the midway in men and at or above the midpoint in women of the anterior midline of the thyroid cartilage. Despite not being a part of the laryngeal structure, the hyoid bone, which is connected to the thyroid cartilage by the thyrohyoid membrane, is crucial to the upper aerodigestive tract's functionality. The laryngeal cartilages can calcify in different ways, which might make it difficult to diagnose tumour invasion from radiographic images.

The larynx's surface mucosa is made up of squamous epithelium with scattered mucous glands. Stratified squamous epithelium lines the vocal cords. The internal branch of the superior laryngeal nerve, which enters the larynx through the thyrohyoid membrane, provides the sensory nerve supply to the supraglottic larynx. The superior laryngeal and recurrent laryngeal nerves provide dual sensory nerve supply to the mucosa of the true vocal cords, whereas the subglottic larynx receives sensory nerve input from the recurrent laryngeal nerve. Except for the cricothyroid muscle, which is innervated by the external laryngeal branch of the superior laryngeal nerve, the intrinsic musculature of the larynx receives its innervation from the recurrent laryngeal nerve. The superior and inferior thyroid arteries' branches feed the larynx with blood. The superior and recurrent laryngeal nerves also enter the larynx via these arteries. A robust lymphatic network drains from the supraglottic larynx into first-echelon lymph nodes at levels II and III via the thyrohyoid membrane. The glottic larynx has a relatively scant lymphatic network, notably around the free border of the true vocal cord, which is lymphatic-free. The cricothyroid membrane is the exit point for the lymphatic drainage of the subglottic larynx, which drains into the paratracheal and deep jugular lymph nodes. The larynx also drains the lymph to the parathyroid and Delphian lymph nodes.

6.2 Operative Techniques and Caveats

For patients with:

(1) Advanced laryngeal or hypopharyngeal cancers (T4a) that have invaded thyroid cartilage and extra laryngeal soft tissues.
(2) Tumours that have not responded to the larynx preservation treatment programme of radiotherapy or chemotherapy/radiotherapy.
(3) Extensive tumours of minor salivary origin and other histologic entities not suitable for a partial laryngectomy: a total laryngectomy is indicated as the initial definitive treatment.

Wide-field total laryngectomy is the preferred procedure if a total laryngectomy is being considered for primary laryngeal cancer.

This process includes:

- The lymph nodes in the jugular chain (levels II, III and IV) on the ipsilateral side as well as the lymph nodes in the tracheoesophageal groove on the same side. The whole larynx with its connected prelaryngeal strap muscles.
- To ensure that the ipsilateral tracheoesophageal groove lymph nodes are sufficiently cleared, an ipsilateral thyroid lobectomy should be done for lesions that include the glottic larynx and have extensive subglottic extension.
- Bilateral jugular node dissection (levels II, III and IV) should be carried out if the laryngeal lesion necessitating complete laryngectomy extends on both sides of the midline. If palpable metastatic nodes are present, a modified radical neck dissection with accessory nerve preservation should be carried out.

The operative procedure is described as follows:

- An orotracheal tube is used to administer general endotracheal anaesthesia when the patient is placed on the operating table. The planned permanent tracheostome is a 2.5-cm-diameter circular patch of the skin in the suprasternal notch. If tracheotomy was done before laryngectomy, the stoma will be incorporated in the incision.
- To expose the prelaryngeal strap muscles, the skin incision is deepened into the platysma.
- Elevate the upper neck flap cephalad to expose hyoid bone and suprahyoid muscles. Split and ligate anterior jugular veins. Detach muscles at the superior end of the hyoid to mobilise larynx. Secure the hyoid with Adair clamp, and separate the suprahyoid muscles with electrocautery up to greater cornua's tip.
- The lingual artery is at risk of harm if not exercised with care during operation.
- Note the superior thyroid artery's superior laryngeal branch, which must be identified and handled with care to avoid injury during dissection. Early detection of the superior laryngeal artery reduces haemorrhage during larynx mobility. When thyroid lobectomy and laryngectomy are planned, the superior thyroid artery is split and ligated. The distal stump of the superior thyroid artery is then withdrawn with the specimen and secured with a haemostat.
- Retract the sternomastoid muscle to view the carotid sheath near bulb. Levels II, III and IV deep jugular lymph nodes are directed towards the specimen.
- Split the superior belly of the omohyoid and the sternohyoid/sternothyroid muscles low in the neck, retracting the sternomastoid muscle laterally. Upon division, their stumps will retract cephalad.
- An Adair clamp is used to hold the hyoid bone while gently pulling the larynx towards the chin.

- Split and ligate inferior thyroid artery.
- Detach the isthmus from the trachea with blunt dissection.
- Divide the isthmus with two Kocher clamps.
- Ligate the left thyroid lobe stump with continuous interlocking 3-0 chromic catgut suture.
- The cervical trachea is visible by dividing the thyroid gland's isthmus and the left strap muscles up to the thyrohyoid membrane.
- Preserve superior thyroid arteries when dividing the left lobe from the trachea.
- The left side's superior laryngeal nerves and arteries are separated.
- Electrocautery used to split the inferior constrictor muscle from the thyroid cartilage's posterior margin.
- A knife is used to make the skin incision, and electrocautery separates tissues and haemostasis of the skin's edge.
- An incision is made at the necessary level in the tracheal wall; the trachea is split into long posterior and short anterior wall and the tracheostome has larger circumference due to the trachea's bevel-shaped stump.
- Nylon sutures attach from the distal trachea to tracheostome skin margins, pulling the trachea's stump up from the larynx.
- Direct endotracheal tubes now used to maintain anaesthesia, replacing former orotracheal tubes via tracheostome. The tracheal stump's bevel-shaped creates an oval form for the tracheostome.
- Separate the trachea and larynx from the oesophagus by sharp dissection, apply cephalad tension to the tracheal stump, use electrocautery to reduce blood loss and mobilise the larynx cephalad in the postcricoid area.
- Electrocautery can separate the larynx and oesophageal mucosa with mild traction to the tracheal stump. Entry into the pharynx is achieved through the vallecula when the tumour is endolaryngeal or postcricoid area when the tumour is supraglottic and involves the aryepiglottic fold/epiglottis.
- Make an incision in the mucosa around the larynx to create an opening wide enough for a retractor. Remove the larynx by cutting its mucosal attachments.
- Evaluate the mucosal margins histologically if near the main tumour to rule out a microscopic spread.
- At this point, a nasogastric feeding tube is placed.
- If tracheoesophageal puncture (TEP) is needed, the plane posterior to the tracheostome is dissected. A right-angled haemostat is inserted into the cervical oesophagus and pushed through the anterior oesophageal wall behind the tracheostome at the 12 o'clock position, about 8 mm from the tracheocutaneous suture line. The membranous trachea is cut with a No. 15 scalpel, and the hole is widened by 3–4 mm. A No. 14 red rubber catheter is then inserted into the distal oesophagus. Attach the catheter's outside end to the skin under the clavicle with silk suture. From 7 to 10 days post-op, the red rubber catheter is replaced with a vocal prosthesis.
- A suture is placed at the base of tongue and the oesophageal wall, converting the circular pharyngeal defect into two elliptical ones. When not strained, primary closure of the pharyngeal defect is usually possible.
- Preferably, the pharynx should be closed transversally with a 2-0 chromic catgut suture knotted at the midline of the tongue with the mucosa and muscle of the anterior wall of the oesophagus. Each side of the pharyngeal defect should be sealed with an interrupted inverting suture, beginning at the lateral borders and moving towards the midline. Care should be taken to flip the mucosal edges and avoid inverting and burying them under the suture when tying knots. The pharyngeal closure is complete when done with care.
- Position suction drains lateral to the throat; remove them via skin stab incisions. Seal the skin and platysma with nylon and Vicryl sutures. Avoid tension in closure.

6.3 Case 1

A 56-year-old man who had been a known smoker and alcoholic for the past 25 years presented with hoarseness of voice for 1 month and respiratory problems for 1 week. On video laryngoscopic examination, the right true vocal cords showed an ulceroproliferative growth with right-side vocal cord fixation. On CT scan, the right side of the glottic area showed a heterogeneous lesion with expansion into the paraglottic space and erosion of the thyroid cartilage.

The patient was planned for a total laryngectomy.

The operative surgical steps, surgical specimen of laryngectomy and follow-up of the same patient are depicted in Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

Fig. 1 Marking of skin incision from one mastoid tip to the opposite mastoid tip: tracheostoma is included in the incision, and the marking for skin excision is made around the tracheostoma

Fig. 2 Lateral view of the marking of the skin incision

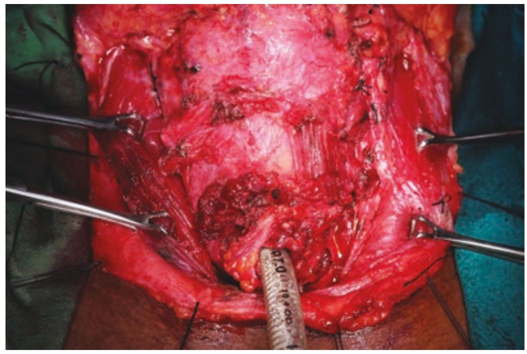


Fig. 3 Anterior view of the larynx after the elevation of the upper and the lower skin flaps with retraction of the sternocleidomastoid muscles on both sides laterally

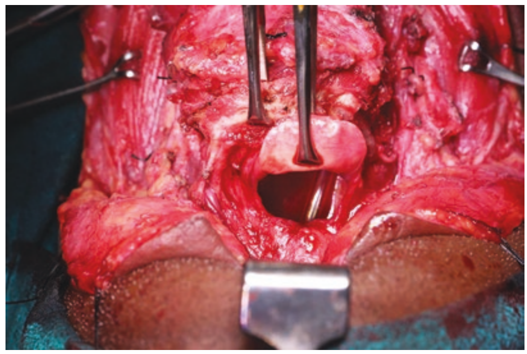


Fig. 4 Entering the pharynx through the vallecula

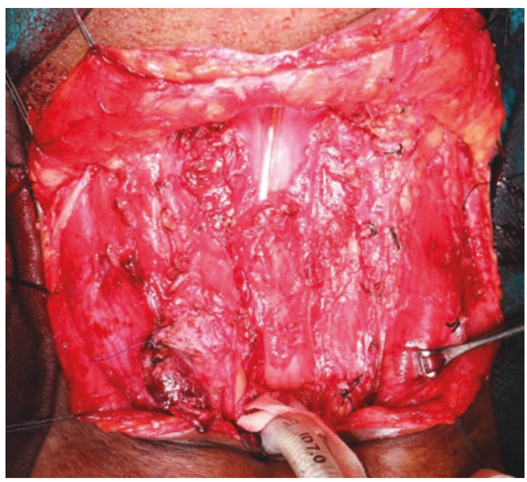


Fig. 5 Surgical site after removal of the larynx and the anterior pharyngeal defect can be visualised

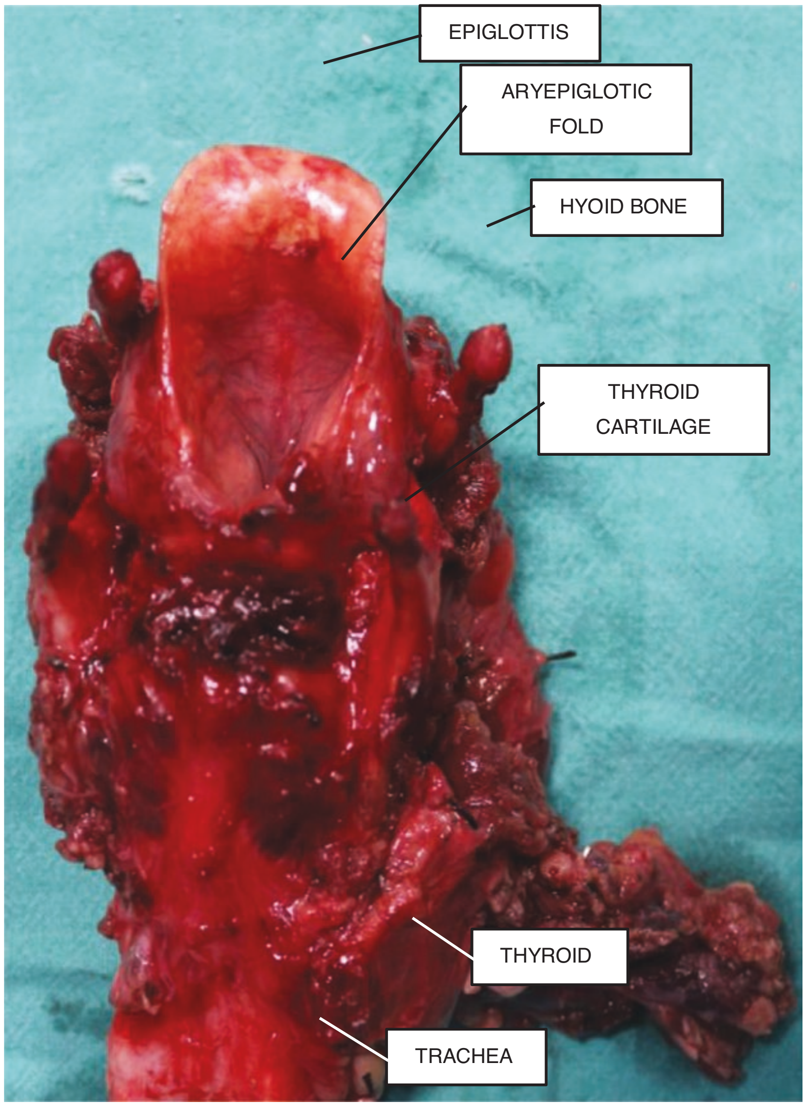


Fig. 6 Posterior view of the surgical specimen of total laryngectomy

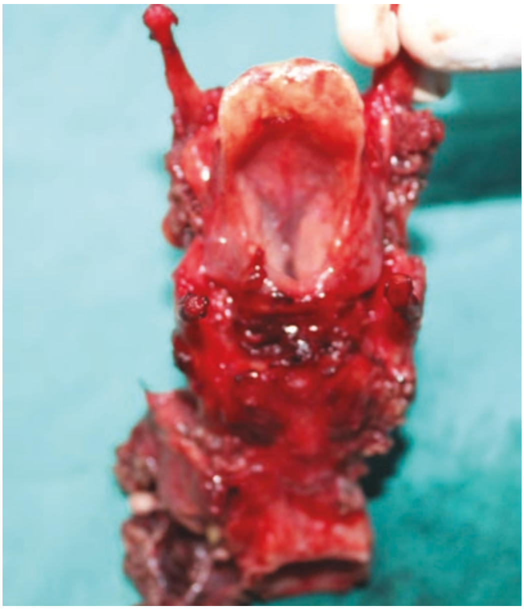


Fig. 7 Posterior view showing the hyoid bone, the epiglottis, the aryepiglottic fold and the cut end of the trachea of the total laryngectomy specimen

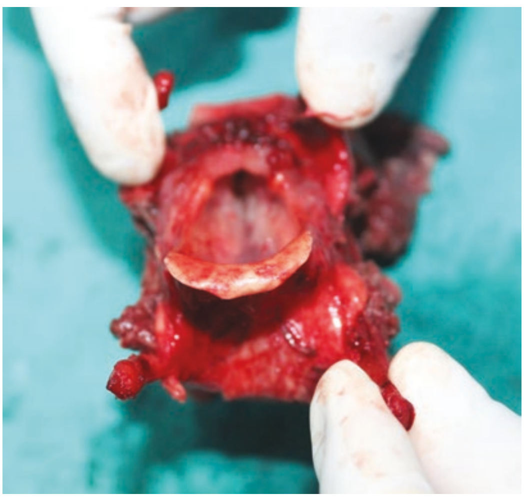


Fig. 8 Superior view of the surgical specimen

6.4 Post-operative Care

- Nasogastric tube feedings are necessary, and they might start within 24 hours.
- When they stop working, suction drains are removed.
- In 7 to 8 days, oral fluids and a puréed food may be introduced if the skin incision and neck flaps are fully healed.
- At 2 weeks, tracheostome sutures are taken out.
- Speech therapy for the oesophagus might start as soon as 3 weeks following surgery.
- The red rubber catheter is withdrawn on the tenth day if an instantaneous TEP is carried out, and a vocal prosthesis is put in its place (Blom-Singer or Provox).
- As soon as 3 weeks following surgery, TEP speech therapy can start.
- To prevent stenosis of the post-laryngectomy stoma, a tracheostomy tube must be inserted through it.

6.5 Case 2

A 43-year-old male patient, a known smoker and alcoholic, presented with a history of change in voice; on video laryngoscopic examination, an ulceroproliferative growth was present over the right true vocal cord. The patient underwent a direct laryngoscopic examination and biopsy under general anaesthesia. The final HPE report was well-differentiated squamous cell carcinoma. The patient underwent radical radiotherapy. The patient was disease-free for 8 months, following which the patient again presented with similar complaints of change in voice. The patient had recurrence, and he was planned for salvage laryngectomy.

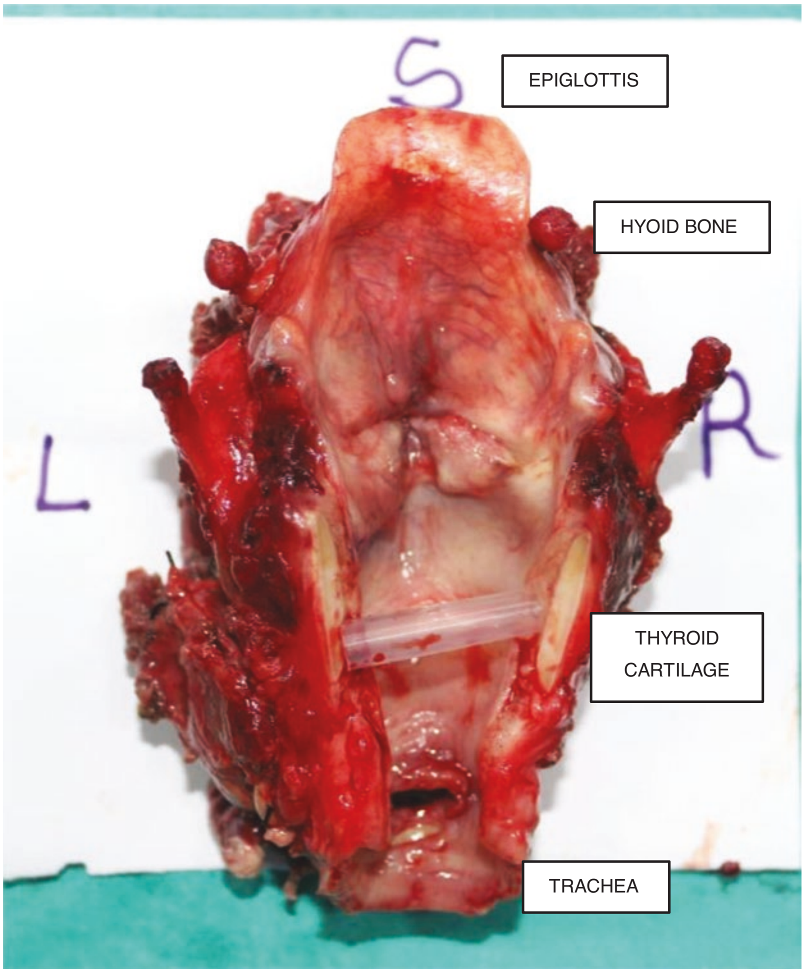


Fig. 9 Posterior view of the total laryngectomy surgical specimen after the posterior cricoid split to visualise the true vocal cords showing the lesion in the right true vocal cords

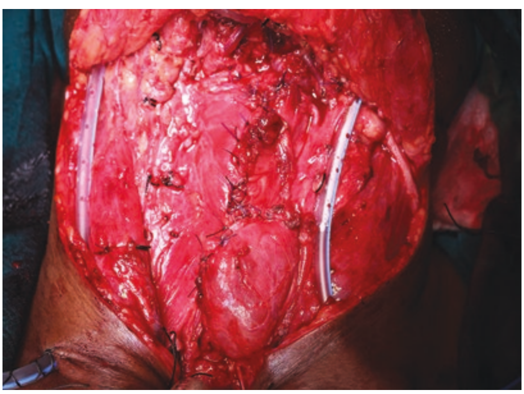


Fig. 10 Vertical closure of the pharyngeal defect in layers with the left lobe of the thyroid in the surgical bed and bilateral neck drains placed

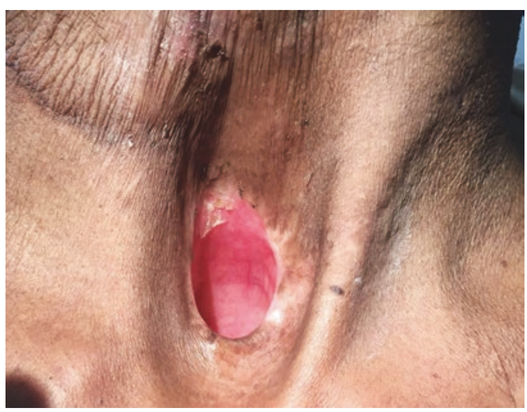


Fig. 11 Follow-up after 6 months with well-healed laryngectomy stoma

The operative surgical steps of salvage laryngectomy, surgical specimen and follow-up of the same patient are depicted in Figs. 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24.

Fig. 12 Marking for skin incision with marking for stoma

Fig. 13 Lateral view of the skin incision

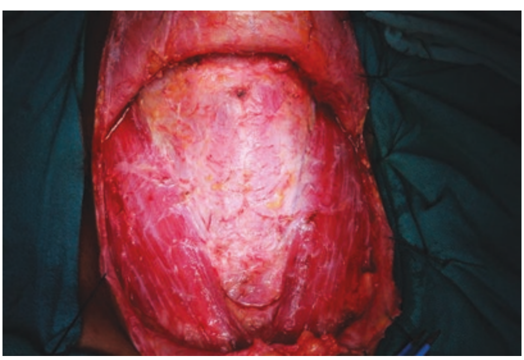


Fig. 14 Elevation of upper and lower skin flaps

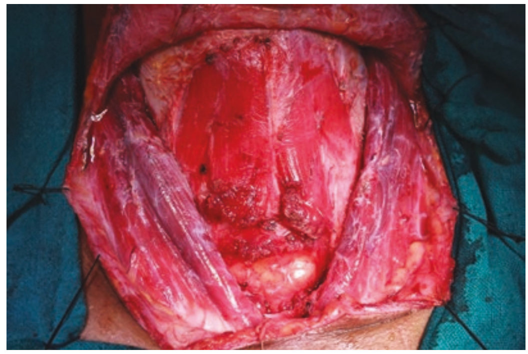


Fig. 15 Exposing the strap muscles and the sternocleidomastoid muscle with the inferior end of the strap muscles cut to expose the trachea

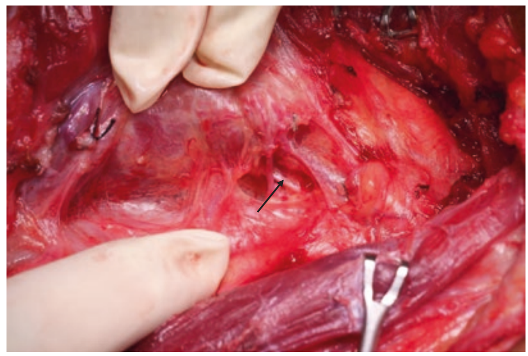


Fig. 16 The arrow shows the recurrent laryngeal nerve after retraction of the right lobe of the thyroid

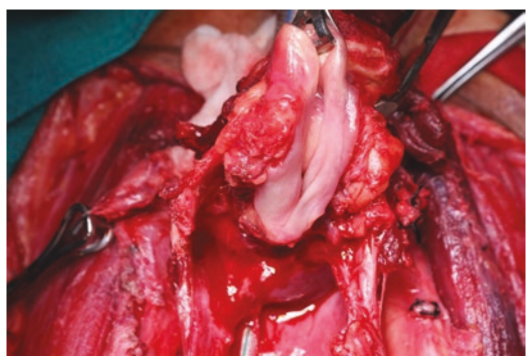


Fig. 17 Entering the pharynx superiorly through the vallecula

Fig. 18 Separating the larynx from the pharynx, Pharyngeal defect can be visualised. * is used to show the carotid artery

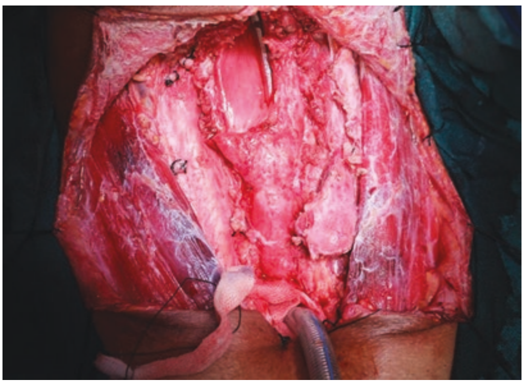


Fig. 19 Post-laryngectomy surgical bed, showing the pharyngeal defect along with the preserved left lobe of the thyroid

Fig. 20 Connell suturing of the pharyngeal mucosa

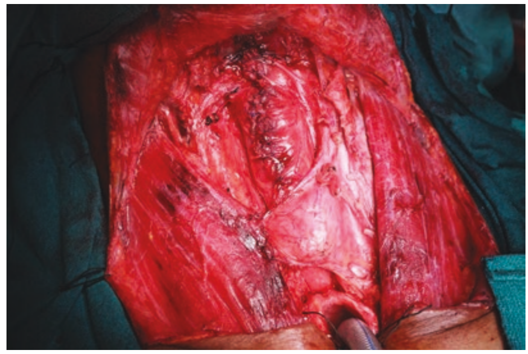


Fig. 21 Closure of the pharyngeal defect by suturing the pharyngeal mucosa, T-shaped closure done. The pharyngeal mucosa closed in two layers

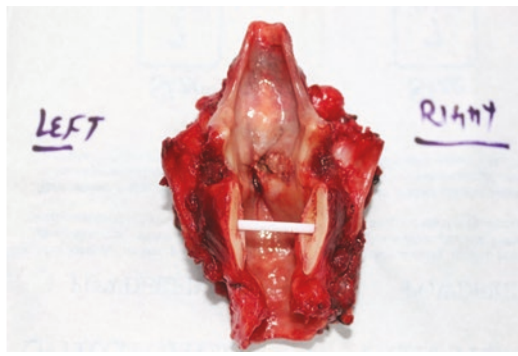


Fig. 22 Post-laryngectomy specimen showing ulceroproliferative growth in the right true vocal cords, and the lesion is seen extending to the anterior commissure

Fig. 23 Closure of the total laryngectomy neck wound

Fig. 24 Third-week follow-up post-salvage laryngectomy with well-healed neck wound and laryngectomy stoma

7 Airway Management

7.1 Introduction

Laryngotracheal stenosis care continues to be a difficult surgical issue, particularly in the juvenile age range. The intricacy of the numerous preoperative circumstances suggests that the issue cannot be resolved by a single therapeutic approach.

One must take this into account:

- The type of the stenosis:
  - Congenital
  - Acquired
- Location:
  - Supraglottic
  - Glottic
  - Subglottic
  - Combined
- Degree of obstruction
- Length in the craniocaudal axis
- Association with vocal cord ankylosis or neurogenic paralysis

Furthermore, significant comorbidities or congenital defects in both adults and children, as well as the existence of tracheal injury (stenosis or localised malacia) connected to the tracheostoma or to the tracheotomy cannula, might further complicate surgical care.

7.2 Aetiology

7.2.1 Subglottis

Prolonged intubation is the most frequent cause of subglottic stenosis (SGS) in children.

The most prevalent laryngeal anomalies in infants are listed below in a descending order of incidence [15]:

1. Laryngomalacia
2. Bilateral vocal fold paralysis
3. Congenital SGS

Congenital SGS is divided into cartilaginous and soft tissue stenoses, according to Holinger [16]. When the cricoid region's lumen is less than 4 millimetres in diameter in a full-term baby or 3 millimetres in a preterm baby, it is present. After the eighth week of pregnancy, there is incomplete recanalization of the laryngeal lumen, which leads to the cartilaginous type. The cricoid may have different defects such as overall thickening of the cricoid ring, a big anterior or posterior lamina or an elliptical form, or it may be normal in shape but too small for the infant's size.

A congenital SGS is connected to mediastinal abnormalities such cardiovascular, tracheobronchial or oesophageal defects in about 50% of patients [17]. This suggests that any mediastinal malformation necessitates broncho-oesophagoscopy before treatment to rule out a mild asymptomatic congenital SGS for the otolaryngologist, thoracic surgeon and anaesthesiologist.

Infants and children are more likely to sustain injuries that result in acquired SGS following traumatic intubation for resuscitation, after intubation for severe cranial injuries, when laryngoscopy is challenging due to anatomical issues or when a mild congenital subglottic stenosis has been disregarded. The subglottic damage brought on by the indwelling ET tube, as well as gastroesophageal reflux, will be exacerbated by any systemic disease that reduces capillary perfusion (e.g. shock, anaemia) or increases susceptibility to infection (e.g. diabetes, immuno-suppression). Benjamin in 1993 provided a detailed description of the transformation of acute intubation lesions into cicatricial sequelae of the glottis and subglottis [18]. They are comparable in both adults and children, although children's glottis involvement is more pronounced. Although many conditions, including blunt trauma, inhalation injuries, high tracheotomies, thyroidectomies, Wegener's granulomatosis and idiopathic causes, can result in benign SGS in adults, post-intubation injury is still by far the most frequent cause of SGS that can be treated with resection and primary reconstruction. Endotracheal intubation consequences are often nonexistent or minor in the supraglottic area. They primarily appear as bands of the scar tissue tying the vocal cords posteriorly, either with or without cricoarytenoid ankylosis, at the level of the glottis. This condition is known as posterior glottic stenosis (PGS). A fusion of the voice cords is also occasionally seen. Circumferential ulcerations in the subglottis can result in the development of granulation tissue, which evolves into contracting scars and causes SGS.

Grading System

The Cotton-Myer grading scale is used in the paediatric community [19] and is frequently employed to grade SGS. SGS is graded using this approach in four categories.

Cotton-Myer Grading System for Subglottic Stenosis

Cotton came up with the traditional SGS grading method, which is used all around the world. The updated Cotton-Myer grading system [19] was first used in 1994 and is based on the estimation of the stenotic diameter obtained by putting an endotracheal tube through the stenosis to determine the percentage of blockage (Table 1).

Table 1 Cotton-Myer grading system for subglottic stenosis

Classification	From	To
Grade I	No obstruction	50% obstruction
Grade II	51% obstruction	70% obstruction
Grade III	71% obstruction	99% obstruction
Grade IV	No detectable lumen	

McCaffrey Grading System for Laryngotracheal Stenosis

McCaffrey's grading scale for laryngotracheal stenosis in adults [20] is the most often used, and it would categorize laryngotracheal stenosis according to severity. It would also serve as a foundation for evaluating the outcomes of various treatment methods for this ailment and as a predictive tool (Table 2).

Table 2 McCaffrey grading system for laryngotracheal stenosis

Stage	Location of stenosis
I	Subglottic or trachea <1 cm long
II	Subglottic within the cricoid ring >1 cm long
III	Subglottic + upper trachea
IV	Subglottic + glottic (vocal cord fixation or paralysis

7.2.2 Trachea

Tracheal stenosis in infants is typically brought on by either intrinsic compressions from cardiovascular defects or congenital deformities of the trachea itself (tracheomalacia, web, long-segment stenosis with circular "O" rings of cartilage). A localized tracheomalacia may require more precise tracheal surgery even after the vascular defect is corrected.

Adults may develop benign tracheal stenosis as a consequence of cuff lesions brought on by endotracheal or tracheostomy tubes or as a result of tracheostomy complications, such as anterior granuloma or stenosis and suprastomal granuloma or collapse at the location of the previous stoma.

7.3 History of T-Tube

William Montgomery, a physician at Massachusetts General Hospital's Department of Otorhinolaryngology and Harvard Medical School, created the T-tube for the first time in 1962.

After tracheal surgery, the T-tube was initially used to prevent tracheal stenosis [21]. The first T-tube was made of acrylic, which was too inflexible to be intubated and negatively impacted the tracheal cilia's ability to expectorate.

The "safe-T-tube" was created by Boston Medical Products in 1986, and it was subsequently made of implantable silicone [22].

The T-tube was first used to temporarily prepare for tracheal repair or tracheotomy and anastomosis as well as to treat acute tracheal injuries and stenosis.

Additionally, it was used to transitionally treat benign tracheal lesions before surgery and for individuals with laryngotracheal stenosis who were not candidates for surgical therapy [23].

7.4 Features of T-Tube

These are the design characteristics of the T-tube in comparison to other tracheal stent designs:

(I) When compared to metallic-coated stents, T-tubes have smooth inner and outer walls and preserve the mucociliary expectoration function the most. Additionally, the T-highly tube's polished surface prevents scabbing and adhesion, and the connection's cone-shaped design on the edge gives comfort without encouraging granulation tissue hyperplasia.

(II) The internal branch of the T-tube is used to support and mould the trachea, and the exterior branch is utilized to secure the T-tube, which overcomes the straight silicone stent's frequent displacement propensity. According to reports, 6–18% of patients who get straight silicone DUMON stent insertions experience stent displacement [24, 25]. Additionally, the external branch's ring and groove design makes it possible to secure the spacer and utterance valve, preventing the T-tube from shifting when the patient breathes or speaks.

(III) Patients with various tracheal thicknesses have alternatives thanks to the various models and widths of the internal branch of the T-tube. The length of the stenotic tracheal portion and the tracheostomy site, which necessitates careful and exact measurement and evaluation before putting the T-tube, can be used by the operating physician to calculate the upper and lower branch lengths.

(IV) When the external branch is opened, ventilation and sputum aspiration can be safely carried out externally or through the ventilator in situations of upper T-tube stenosis or a secretion blockage.

It is straightforward and secure to insert and remove the T-tube [26], and following implantation, the patient may speak and breathe normally once more.

In summary, the Montgomery T-tube is a superior option for subglottic stenosis than the traditional self-expanding metal stents and straight silicone DUMON stents.

7.5 Laryngofissure and T-Tube Insertion

7.5.1 Operative Procedure and Caveats

- Since Montgomery first detailed the basic technique of insertion, other surgeons have developed small adjustments to make the insertion process simpler and quicker.
- Here, we describe how to introduce a laryngofissure T-tube using our method.
- The installation of the T-tube requires a tracheotomy opening, which may already exist or be made just before the surgery.
- Based on radiographic information, such as computed tomography (CT) of the airways with exterior (3-D reconstruction) or interior (virtual bronchoscopy) depiction, the diameter of the T-tube is determined.
- Alternatively, the diameter can be calculated while being directly seen via a bronchoscope.
- The optimal diameter would result in the T-tube fitting the airways tightly with the least amount of anterior-posterior displacement.
- The distance between the vocal cords and the tracheotomy stoma and the length of the tracheal lesion distal to the tracheotomy stoma are carefully measured using a bronchoscopic

procedure to determine the optimal length of the T-tube.

- The intraluminal limb's edges are polished with sandpaper after being cut with a scalpel to the required length.
- Midway between the thyroid prominence and the cricoid cartilage, a transverse skin incision is made.
- In the subplatysmal plane, superior and inferior skin flaps are elevated.
- After locating the midline raphe between the sternohyoid muscles, the soft tissue is dissected until the thyroid cartilage is reached.
- The cricothyroid membrane, cricoid cartilage and thyroid cartilage are all exposed.
- A midline incision is made over the thyroid perichondrium, which is then exposed vertically and removed of its cartilage.
- A midline incision is made over the thyroid cartilage to split it vertically.
- The lower end of the stenotic segment is reached by extending the incision inferiorly over the trachea.
- To reveal the stenotic segment, the trachea and incised thyroid cartilage are laterally pulled back.
- Either the cold steel technique or the CO_2 laser is used to carefully dissect the stenotic fibrous tissue.
- A laryngofissure is used to implant the vertical limb of the T-tube.
- The T-tube is positioned at the level of the now-removed stenotic section.
- The tube's superior end should be positioned so that it touches neither the true vocal cords nor their lower end at any point.
- Vicryl 3-0 suture is used to seal the laryngofissure.
- On either side of the surgical incision, corrugated rubber drains or glove drains are positioned.
- The horizontal limb of the tube is removed, and layers of the skin and soft tissue are closed around it.

7.5.2 Case 1

A 64-year-old man who had respiratory problems for a month, which worsened for a week, now complains that he is unable to engage in intensive activities. Due to a lower respiratory tract infection, the patient had previously had prolonged intubation and mechanical ventilator support for roughly 25 days. After being extubated, the patient had respiratory problems but was still able to do daily tasks. The patient received an emergency low tracheostomy when he arrived at our hospital, and after that, he was thoroughly examined to determine the degree and scope of the stenosis.

The patient's laryngofissure procedure was then scheduled to include the stenotic segment's removal and the implantation of a T-tube.

Preoperative radiological imaging, intraoperative surgical steps of laryngotracheal fissure and insertion of T-tube, follow-up endoscopy and the follow-up soft tissue neck are depicted in Figs. 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37 and 38.

7.5.3 Care of T-Tube

- To maintain phonation and enable appropriate humidification of air entering the respiratory tree, the T-tube should always be blocked. Dryness of respiratory secretions and luminal blockage are encouraged by open T-tubes. When the T-tube is blocked, breathing becomes difficult, which may be an early sign of laryngeal oedema or a later sign of the development of subglottic granulation tissue.
- Respiratory secretions can be kept moist if the T-tube needs to be left open for a brief period of time by using humidified air, mucolytic drugs (acetylcysteine) or expectorants (Guaifenesin).
- With the first 1 or 2 weeks following surgery, it is advised to wipe the extraluminal limb with a Q-tip soaked in hydrogen peroxide and provide two to three daily instillations of 1 cc to 2 cc of normal saline into the T-tube's lumen.
- Similar to this, regular suctioning of the T-tube is recommended during the first few days following surgery, but if the tube remains blocked, subsequent suctioning is seldom required.

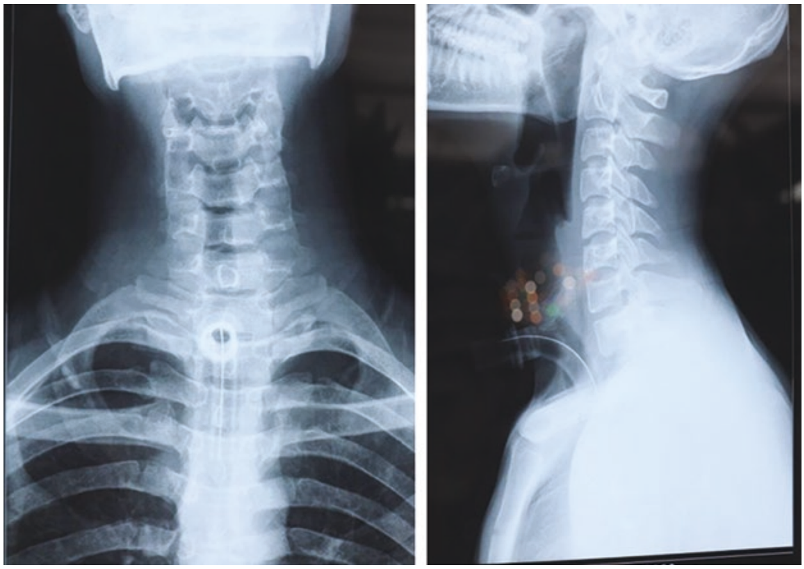


Fig. 25 X-ray anteroposterior view showing suprastomal stenosis in the upper tracheal regin

Fig. 26 CT scan sagittal cuts showing stenosis in the upper tracheal region above the level of tracheostomy site

- To help steer the suction catheter up and down, the extraluminal limb of the T-tube can be angled superiorly and inferiorly.
- To prevent irritating the mucosa, the suction catheter shouldn't be advanced past the intraluminal parts of the T-tube.
- To replace the T-tube that is critically blocked, the patient should always have access to a replacement tracheostomy tube in a size chosen to accommodate the tracheotomy orifice.

7.5.4 Removal of the T-Tube

- The extraluminal limb can be pulled anteriorly with a strong pull to remove the T-tube. Except in cases of malpositioning in the initial postoperative period, failure to remove residual secretions leading to chronic partial blockage or acute total obstruction, T-tube removal is seldom indicated [27].
- T-tubes have been observed to plug in and remain there for extended periods of time without frequently needing to be changed.

Fig. 27 Marking of the skin incision

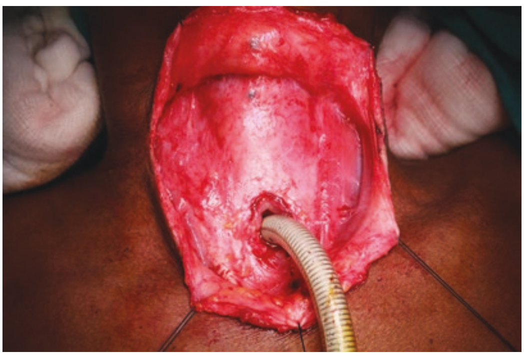


Fig. 28 Elevation of the upper and the lower skin flaps in the subplatysmal plane and stomal freshening

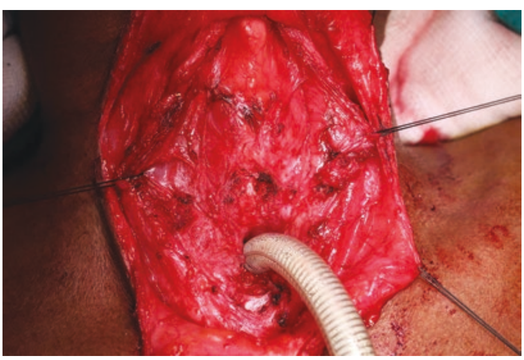


Fig. 29 Exposure of strap muscles and strap muscles being retracted laterally

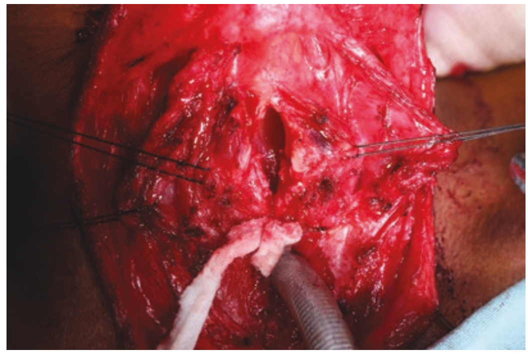


Fig. 30 Laryngofissure: Midline incision over the thyroid cartilage and thyroid cartilage being retracted laterally

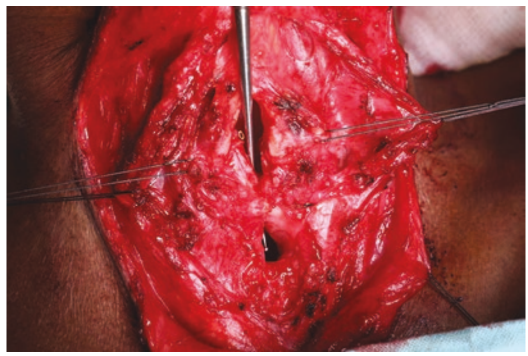


Fig. 31 Intact anterior tracheal wall which is below the laryngofissure incision and above the tracheostoma

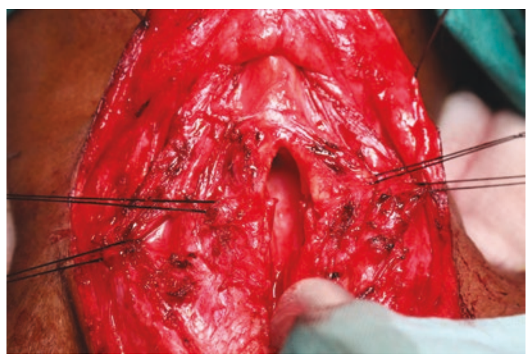


Fig. 32 Complete exposure of the upper trachea and subglottis after removal of the stenotic segment using CO_2 laser and coblator with T-tube placement

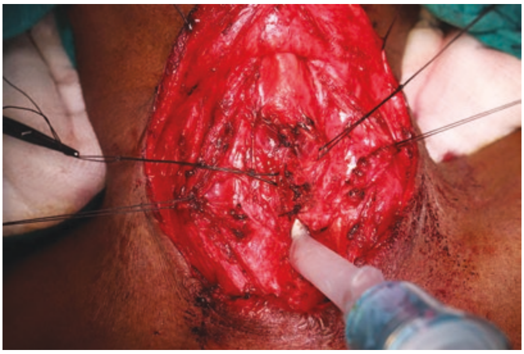


Fig. 33 Vertical limb of the T-tube is placed in the upper trachea, and the anterior wall of the trachea is closed around the horizontal limb of the T-tube

Fig. 34 Skin and soft tissue closed in layers around the horizontal limb of the T-tube with glove drains on either side

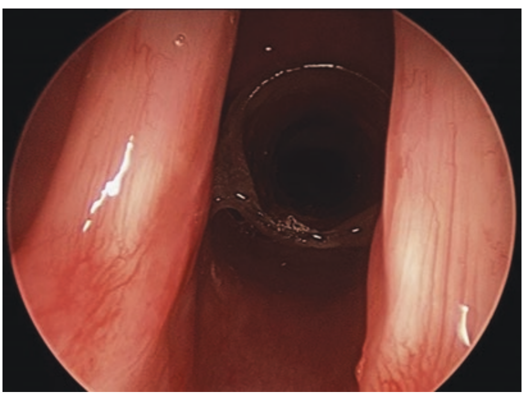


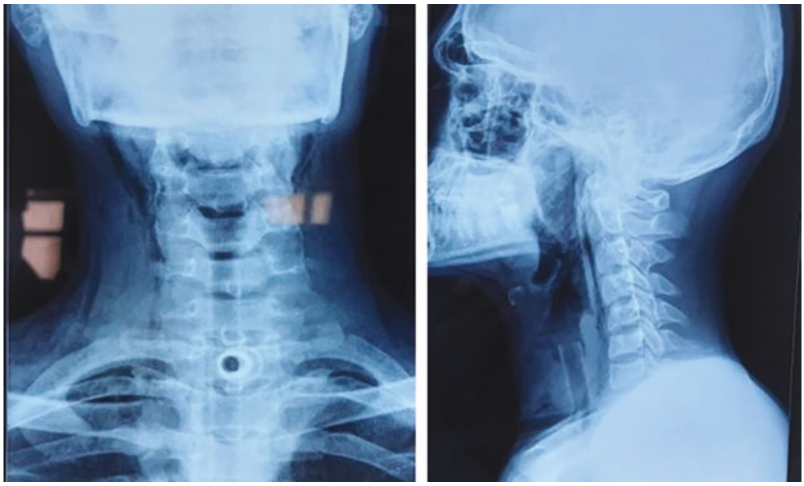
Fig. 35 Endoscopy in the immediate post-operative period showing the upper end of the T-tube just below the level of the true vocal cords but not touching them

Fig. 36 Surgical wound in the immediate post-operative period

Fig. 37 Follow-up after 9 months with a well-healed surgical scar, and horizontal limb of the T-tube is plugged

- In benign tracheal disorders, it is advised to periodically remove the T-tube and evaluate the stenotic tracheal segment beneath it to determine if the T-tube still needs to be used as a stenting device.
- Unknown is the appropriate time frame for such an evaluation. The observations made in the T-tube series are consistent with a 6- to 12-month time frame.

Fig. 38 X-ray anteroposterior and lateral view in post-operative period showing the T-tube in place and an adequate airway



References

1. Global Cancer Observatory. International Agency for Research on Cancer, World Health Organization. [Internet]. [cited 2022 Sep 8]. Available from: https://gco.iarc.fr/.
2. Pelucchi C, Gallus S, Garavello W, Bosetti C, La Vecchia C. Alcohol and tobacco use, and cancer risk for upper aerodigestive tract and liver. Eur J Cancer Prev Off J Eur Cancer Prev Organ ECP. 2008;17(4):340–4.
3. Marron M, Boffetta P, Zhang ZF, Zaridze D, Wünsch-Filho V, Winn DM, et al. Cessation of alcohol drinking, tobacco smoking and the reversal of head and neck cancer risk. Int J Epidemiol. 2010;39(1):182–96.
4. Heck JE, Berthiller J, Vaccarella S, Winn DM, Smith EM, Shan'gina O, et al. Sexual behaviours and the risk of head and neck cancers: a pooled analysis in the International Head and Neck Cancer Epidemiology (INHANCE) consortium. Int J Epidemiol. 2010;39(1):166–81.
5. Hobbs CGL, Sterne JAC, Bailey M, Heyderman RS, Birchall MA, Thomas SJ. Human papillomavirus and head and neck cancer: a systematic review and meta-analysis. Clin Otolaryngol Off J ENT-UK Off J Neth Soc Oto-Rhino-Laryngol Cervico-Facial Surg. 2006;31(4):259–66.
6. Chung CH, Zhang Q, Kong CS, Harris J, Fertig EJ, Harari PM, et al. p16 protein expression and human papillomavirus status as prognostic biomarkers of nonoropharyngeal head and neck squamous cell carcinoma. J Clin Oncol Off J Am Soc Clin Oncol. 2014;32(35):3930–8.
7. Salazar CR, Anayannis N, Smith RV, Wang Y, Haigentz M, Garg M, et al. Combined P16 and human papillomavirus testing predicts head and neck cancer survival. Int J Cancer. 2014;135(10):2404–12.
8. Bayer O, Cámara R, Zeissig SR, Ressing M, Dietz A, Locati LD, et al. Occupation and cancer of the larynx: a systematic review and meta-analysis. Eur Arch Oto-Rhino-Laryngol Off J Eur Fed Oto-Rhino-Laryngol Soc EUFOS Affil Ger Soc Oto-Rhino-Laryngol—Head Neck Surg. 2016;273(1):9–20.
9. Richiardi L, Corbin M, Marron M, Ahrens W, Pohlabeln H, Lagiou P, et al. Occupation and risk of upper aerodigestive tract cancer: the ARCAGE study. Int J Cancer. 2012;130(10):2397–406.
10. Komune N, Hara T, Tamae A, Izu K, Tokura Y, Joe AK, et al. A case of laryngeal carcinoma in a young adult with dyskeratosis congenita. Int J Clin Oncol. 2010;15(4):428–32.
11. Oksüzoğlu B, Yalçin S. Squamous cell carcinoma of the tongue in a patient with Fanconi's anemia: a case report and review of the literature. Ann Hematol. 2002;81(5):294–8.
12. Helliwell T, Woolgar J. Dataset for histopathology reporting of mucosal malignancies of the larynx. Stand datasets report cancers. Liverp R Coll Pathol. 2013;
13. Kirchner JA. One hundred laryngeal cancers studies by serial section. Ann Otol Rhinol Laryngol. 1969;78(4):689–709.
14. Kumar R, Drinnan M, Robinson M, Meikle D, Stafford F, Welch A, et al. Thyroid gland invasion in total laryngectomy and total laryngopharyngectomy: a systematic review and meta-analysis of the English literature. Clin Otolaryngol Off J ENT-UK Off J Neth Soc Oto-Rhino-Laryngol Cervico-Facial Surg. 2013;38(5):372–8.
15. Holinger LD. Etiology of stridor in the neonate, infant and child. Ann Otol Rhinol Laryngol. 1980;89(5 Pt 1):397–400.
16. Holinger LD. Congenital laryngeal anomalies. In: Holinger LD, Lusk RP, Green CG, editors. Pediatric laryngology and bronchoesophagology. Lippincott-Raven; 1997.
17. Morimitsu T, Matsumoto I, Okada S, Takahashi M, Kosugi T. Congenital cricoid stenosis. Laryngoscope. 1981;91(8):1356–64.

18. Benjamin B. Prolonged intubation injuries of the larynx: endoscopic diagnosis, classification, and treatment. Ann Otol Rhinol Laryngol. 1993;102(Suppl. 4):1–16.
19. Myer CM, O’Connor DM, Cotton RT. Proposed grading system for subglottic stenosis based on endotracheal tube sizes. Ann Otol Rhinol Laryngol. 1994;103(4):319–23.
20. McCaffrey TV. Classification of laryngotracheal stenosis. Laryngoscope. 1992;102(12):1335–40.
21. Montgomery WW. T-Tube tracheal stent. Arch Otolaryngol Chic Ill. 1960;1965(82):320–1.
22. Saghebi SR, Zangi M, Tajali T, Farzanegan R, Farsad SM, Abbasidezfouli A, et al. The role of T-tubes in the management of airway stenosis. Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg. 2013;43(5):934–9.
23. Prasanna Kumar S, Ravikumar A, Senthil K, Somu L, Nazrin MI. Role of Montgomery T-tube stent for laryngotracheal stenosis. Auris Nasus Larynx. 2014;41(2):195–200.
24. Mitsuoka M, Sakuragi T, Itoh T. Clinical benefits and complications of Dumon stent insertion for the treatment of severe central airway stenosis or airway fistula. Gen Thorac Cardiovasc Surg. 2007;55(7):275–80.
25. Martinez-Ballarin JI, Diaz-Jimenez JP, Castro MJ, Moya JA. Silicone stents in the management of benign tracheobronchial stenoses. Tolerance and early results in 63 patients. Chest. 1996;109(3):626–9.
26. Puma F, Farabi R, Urbani M, Santoprete S, Daddi N, Di Meo A, et al. Long-term safety and tolerance of silicone and self-expandable airway stents: an experimental study. Ann Thorac Surg. 2000;69(4):1030–4.
27. Montgomery WW, Montgomery SK. Manual for use of Montgomery laryngeal, tracheal, and esophageal prostheses: update 1990. Ann Otol Rhinol Laryngol Suppl. 1990;150:2–28.