Laryngeal Disease and Tumours and Its Related Surgery

12

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12.1 Introduction

The larynx plays a role in breathing and phonation and is involved in swallowing through its sphincter function in order to protect the lower airways. Therefore, laryngeal pathology, whether benign or malignant, often manifests itself with dysphonia, dyspnoea and/or dysphagia, as well as with other less specific symptoms such as cough, ear pain, pharyngeal globe and sore throat. Furthermore, in most cases, laryngeal pathologies require surgical treatment as anti-inflammatory and/or antibiotic medical therapy alone is seldom sufficient [1, 2]. In any case, for a correct diagnostic and therapeutic classification of the pathology, it is advisable, first of all, to begin with the study of the larynx from an embryological, anatomical and physiological point of view and then to move on to the characteristics of the various laryngeal pathologies and, therefore, how these impair the structure and function of the organ.

12.2 Anatomy of the Larynx

The larynx consists of a cartilaginous and membranous skeleton internally coated by mucosa. Based on the structures that compose it, this organ can be divided into three regions: supraglottic, glottic and subglottic. In particular, the *supraglottic region*, in turn, consists of the following structures:

- The epiglottis, which, with its free edge anteriorly, delimits the aditus laryngis (or epilarynx) and, with its infrahyoid portion, defines the anterior limit of the laryngeal vestibule
- The ary-epiglottic folds, which constitute the lateral limit of the epilarynx
- The false vocal folds, which laterally delimit the laryngeal vestibule
- Morgagni's ventricle, which represents a virtual space bordered below by the true vocal cord, above by the false vocal fold and laterally by the thyroid ala
- The corniculate cartilages of Santorini, above the arytenoids

As regards, instead, the *glottic plane* consists of the following anatomical structures:

- The arytenoids, which are articulated with the cricoid cartilage.
- The anterior commissure, which, at the top, is ventrally delimited by the intermediate lamina

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of thyroid cartilage at the superior thyroid notch ventrally and by the insertion of the true vocal cords, of the Broyles' ligament and of the conoid ligament dorsally, below from the lower edge of the thyroid cartilage and laterally from a sagittal plane passing through the anterior third of the true vocal cords [3, 4].
– The true vocal cords, which, from the most superficial to the deepest plane, consist of five histological layers: the stratified squamous epithelium, the intermediate lamina with its three layers—superficial (or Reinke's space), intermediate and deep (or vocal ligament)—and finally the thyroarytenoid muscle.

Finally, the *subglottis* is defined as the portion of the larynx between the glottis and the lower edge of the cricoid cartilage. Superiorly, its ventral and dorsal limits do not match: the former is 1 cm higher than the posterior one. Furthermore, for a correct surgical treatment of laryngeal pathology, especially malignant, it is also advisable to know the so-called pre-epiglottic and upper and lower para-glottic spaces. In particular, the *pre-epiglottic space* is superiorly delimited by the hyo-epiglottic ligament and the glosso-epiglottic valleculae, anteriorly by the thyro-hyoid membrane and the upper border of the thyroid cartilage and inferiorly by the thyro-epiglottic ligament [5].

Laterally, the pre-epiglottic space extends beyond the lateral margin of the epiglottis and, at the level of the small cornu of the hyoid bone, it continues as an *upper para-glottic space*. The latter is medially delimited by the Morgagni's ventricle and by the quadrangular membrane at the top and by the conus elasticus at the bottom, antero-laterally by the thyroid cartilage and posterolaterally by the mucosa of the piriform sinus; postero-inferiorly it extends to the crico-arytenoid joint [6]. As regards, instead, the lateral limit of the *lower para-glottic space* is represented by the thyroid cartilage and the crico-thyroid membrane, its medial limit by the conus elasticus and the posterior one by the arytenoids. Furthermore, according to a first definition, the thyroid-arytenoid muscle is considered part of this space [7]; according to others, however, it represents only its medial limit [8] (Fig. 12.1).

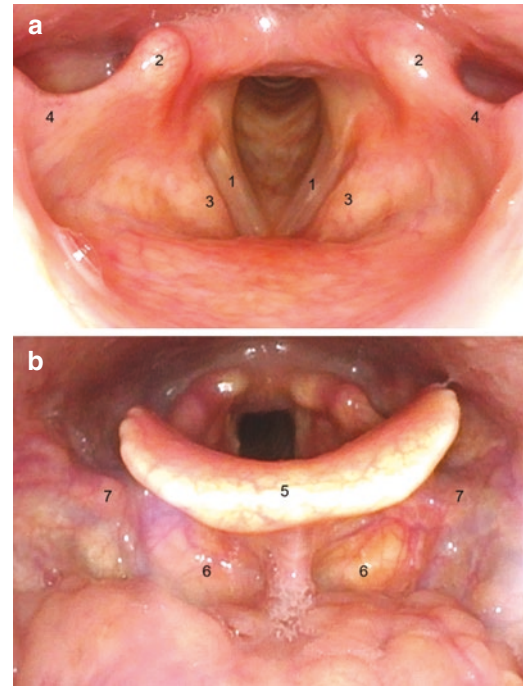


Fig. 12.1 Anatomy of larynx: (**a**) true vocal cords (1), arytenoids (2), false vocal folds (3), ary-epiglottic folds (4) and (**b**) free edge of epiglottis (5), glosso-epiglottic valleculae (6), glosso-epiglottic folds (7)

12.3 Laryngeal Diseases

The diseases that can affect the larynx are numerous and different: benign and malignant lesions, neurological disorders, systemic pathologies, traumatic and infectious diseases, as well as structural anomalies are found. The most frequent benign pathologies are polyps, nodules, cysts [9], granulomas and Reinke's oedema [10]. The laryngeal malignancies occupy the second place in frequency among the head and neck cancers [11, 12]. Laryngeal squamous cell carcinoma (LSCC) is the most frequent laryngeal tumour (approximately 95% of cases) [13, 14]; rarer (remaining about 5% of cases) are other histotypes such as chondrosarcoma, leiomyosarcoma and melanoma [15, 16].

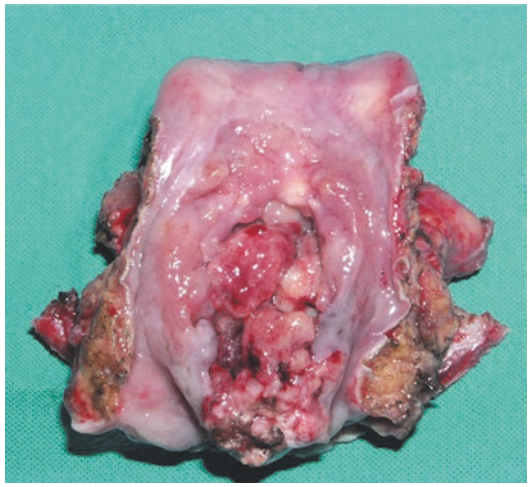


Fig. 12.2 Supraglottic carcinoma

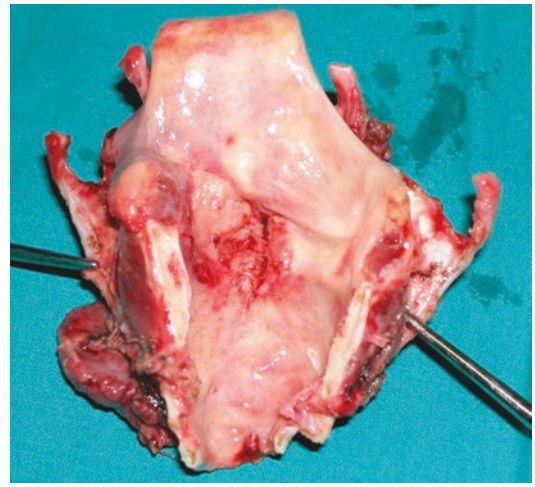


Fig. 12.3 Glottic-supraglottic carcinoma

12.4 Supraglottic Carcinoma

Supraglottic carcinoma accounts for about one-third of laryngeal tumours and, in most cases, they are squamous cell carcinomas [17]. In consideration of its anatomical structure, the onset of symptoms is rather late and this, together with an early lymph node involvement, explains the worse prognosis of cancers that arise in this region compared to glottic carcinomas [18]. Therefore, since the anatomical structures of the supraglottic plane are mainly involved in swallowing, in the case of supraglottic carcinoma, the symptoms will be characterized by dysphagia, pharyngeal globe, sore throat, haemoptysis and otalgia. Vestibular carcinoma is an exception, since it originates from the false vocal fold and, therefore, manifests itself early with dysphonia (Fig. 12.2).

12.5 Glottic Carcinoma

The glottic plane represents the most frequent site of laryngeal carcinoma [19]. Furthermore, unlike the supraglottis, the glottic plane has a poor lymphatic vascularization. So, the early onset of dysphonia and the late lymph node involvement often allow an early diagnosis of glottic carcinoma and, consequently, a less invasive therapeutic approach with a good prognosis [20]. The most frequent symptom is hoarseness, with changes in the tone of voice. The dysphonia, in this case, is persistent and does not tend to regress or improve with medical therapy, contrary to what happens in the case of inflammatory disease. Other symptoms of suspicion, less specific but more frequent in case of advanced-stage glottic carcinoma, are dyspnoea, odynophagia, otalgia, haemoptysis and foreign-body sensation (Fig. 12.3).

12.6 Subglottic Carcinoma

Subglottic carcinoma accounts for about 5% of laryngeal cancers [21]. It correlates with a late onset of symptoms, characterized above all by stridor and dyspnoea, and this feature, together with the low incidence of subglottic carcinoma, is responsible for a poor prognosis. The involvement of the mediastinal and paratracheal lymph nodes in 20% of cases as well as the tendency to relapse at the level of tracheal stoma are two other relevant details (Fig. 12.4).

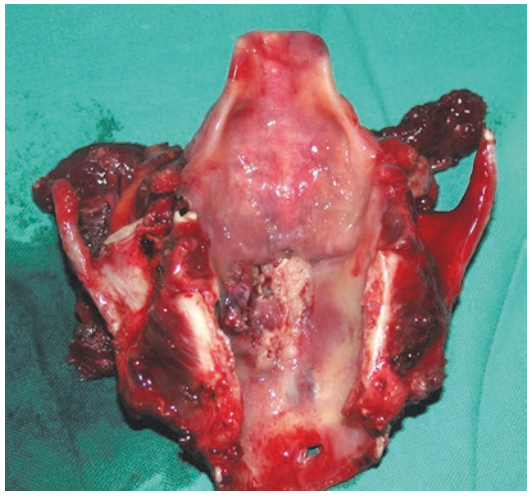


Fig. 12.4 Glottic-subglottic carcinoma

12.7 Diagnosis: Investigation Tools

Regardless of the nature of the laryngeal disease, the diagnostic protocol provides for a multistep evaluation with progressively more advanced and invasive tests and technologies. The first step is represented by *fibre-optic laryngoscopy* [22], which allows to study the morphology and functionality (motility) of the pharyngeal and laryngeal structures during phonation and respiration. Furthermore, for a more in-depth study of vocal cord motility, *videostroboscopic examination* can be performed since it allows to observe the vocal cord movement in slow motion during phonation [23]. For a more accurate and precise study of the epithelial and submucosal laryngeal vascularization, *narrowband imaging (NBI)* can be used, since it allows to formulate a first diagnostic hypothesis of the laryngeal lesion according to the pattern of vascularization based on intraepithelial papillary capillary loops (IPCL) [24, 25]. The next diagnostic step is the *neck computed tomography (CT)* with and without contrast medium, which allows to evaluate the locoregional extension of the neoplasm. For this reason, CT represents a fundamental examination for the staging of the carcinoma and for the correct therapeutic classification. Finally, where CT does not provide sufficient information, *magnetic resonance imaging* can provide additional data, especially in cases of extension to the pre-epiglottic and/or para-glottic spaces [26].

12.8 Surgical Treatment

Laryngeal surgery could be divided into functional and lesional. The former corresponds to laryngoplasty with a mainly reparative purpose; the second surgery, on the other hand, corresponds to laryngectomies with excisional purposes. Therefore, the latter allows the radical excision of malignant lesion with the consequent temporary or permanent impairment of some laryngeal functions (respiratory, phonatory, sphincter) based on the location and extent of the tumour and, consequently, on the type of surgery. Anyway, this surgery can be considered as valid and effective only when it is able to guarantee the oncological radicality and, at the same time, the restoration of the sphincter and respiratory function of the larynx.

In particular, laryngectomy can be partial and total, depending on the pathology, its location, and extent and degree of infiltration. Until the 1950s, total laryngectomy was performed in case of tumours with involvement or extension beyond the glottic plane [27, 28]. Over the years, however, efforts have been made progressively to develop new conservative surgical techniques in order to ensure organ preservation, where possible [27, 28]. Indeed, the applicability of conservative and reconstructive techniques depends on several factors: histotype and pattern of tumour growth, tumour location, TNM stage and general status of the patient [29]. At the beginning of conservative surgery, two main types of partial laryngectomy were defined: the vertical partial laryngectomy, including the frontal-lateral introduced by Leroux-Robert between the 1950s and the 1970s [30], now no longer in use, and partial horizontal laryngectomy, which includes, first of all, the supraglottic laryngectomy designed by Alonso in 1947. In 2014, the European Laryngological Society (ELS) proposed a new classification of open partial horizontal laryngectomies (OPHL), based on the lower resection

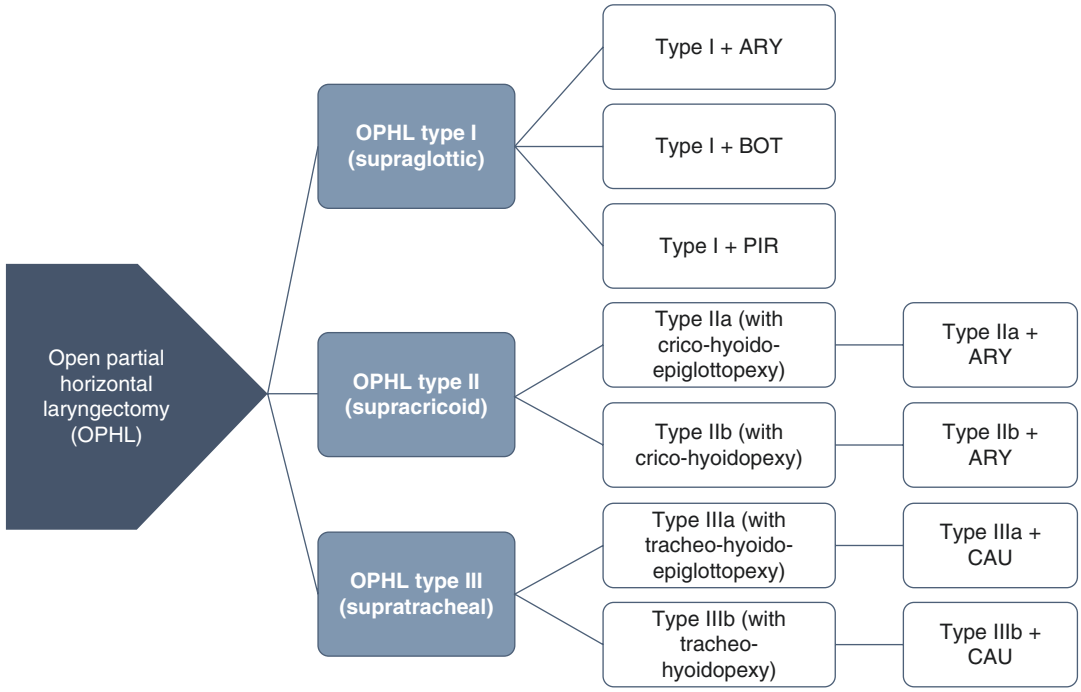


Fig. 12.5 Classification of open partial horizontal laryngectomy according to ELS. ARY: arytenoid, BOT: base tongue, PIR: piriform sinus, CAU: crico-arytenoid unit

limit of the specific surgery [31]. Thus, supraglottic (OPHL type I), supracricoid (OPHL type II) and supratracheal (OPHL type III) partial horizontal laryngectomies are distinguished. Furthermore, every single type of intervention can be extended to other nearby structures, laryngeal and/or pharyngeal, such as the arytenoid (ARY), the base tongue (BOT), the piriform sinus (PIR) or the crico-arytenoid unit (CAU) (Fig. 12.5).

12.9 Surgical Steps Common to All Types of Laryngectomies

12.9.1 Skin Incision

Cervical skin incisions with cephalad pedicle are the most frequently used; as often laryngeal surgery is associated with mono- or bilateral neck dissection, a Paul Andrè-type incision or a modified L-shaped incision is made. The most used incision starts from the mastoid tip and descends vertically to encompass the inferior insertion of sternomastoid muscle, describing a curve with internal concavity; at this point, the incision continues horizontally passing about 2–3 cm from the sternal manubrium to the contralateral mastoid (bi-mastoid incision). This type of skin incision is preferred because it has several advantages. It allows to respect the vascularization of the skin flap while preserving the main pedicles: supero-medial and infero-lateral. In addition, it guarantees an excellent visualization of the surgical site, from the submandibular region to the jugulum and supraclavicular fossae, allowing the identification and isolation of the vasculo-nervous and muscular structures of the neck, as well as of the pharynx, larynx and thyroid. Finally, another advantage of this technique is represented by the good aesthetic result of the scar with low risk of complications such as fistulas or skin necrosis (Fig. 12.6).

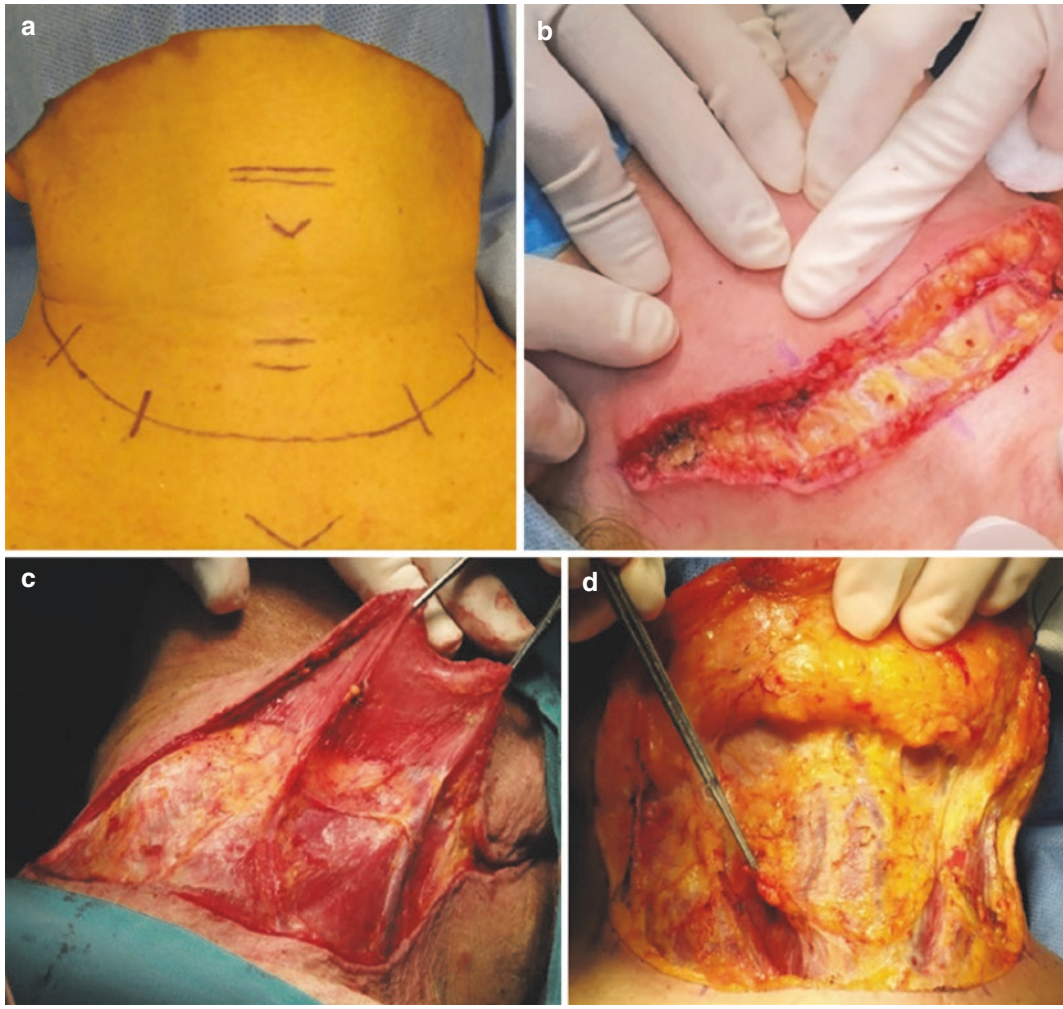


Fig. 12.6 (**a**) Skin incision marking, (**b**) skin incision, (**c**) detachment of the myo-cutaneous flap, (**d**) incision of the deep cervical fascia

12.9.2 Detachment of the Myo-cutaneous Flap

The incision includes skin, subcutis and platysma muscle. So, a myo-cutaneous flap is created which should be detached until it exceeds the body of hyoid bone by 1–2 cm. The superficial layer of the deep cervical fascia is now exposed. Dissection should be performed superficially to the external jugular vein, the greater auricular nerve and the superficial anterior branches of the cervical plexus (transverse cervical nerve and superficial cervical nerve) (Fig. 12.6).

12.9.3 Incision of the Deep Cervical Fascia Along the Anterior Border of the Sternocleidomastoid Muscle

In this surgical time, the section of the nerve branches originating from the point of Erb is performed. The superior portion of external jugular vein, anterolateral to the sternocleidomastoid muscle, can be preserved in the case of total laryngectomy with or without neck dissection. This is followed by the ligation and section of the anterior jugular veins, inferiorly at the sternal level and superiorly at the hyoid level (Fig. 12.6).

12.9.4 Exposure of the Larynx

Once the myo-cutaneous flap has been elevated, the plane of the extrinsic laryngeal muscles is exposed. The prelaryngeal muscles can be preserved and repositioned at the end of the surgery to protect and cover the residual larynx only when the demolition surgery does not include a contextual mono- or bilateral neck dissection. If, on the other hand, a mono- or bilateral neck dissection must be performed, the prelaryngeal muscles would most likely be devascularized and denervated; therefore, their preservation could be a disadvantage, as they will be exposed to necrosis and/or fibrosis. If their preservation is planned, the prelaryngeal muscles can be dissected at their hyoid insertion, turned downwards, or they can be dissected in their hyoid insertion and at the jugulum, with a lateral hinge on the omohyoid which is not dissected. As regards the musculature deep layer, the sternothyroid muscle can be preserved or dissected, depending on the type of surgery: spared in supraglottic laryngectomy, and dissected in supracricoid laryngectomy. The thyro-hyoid muscle is dissected at the hyoid insertion and completely resected (Fig. 12.7).

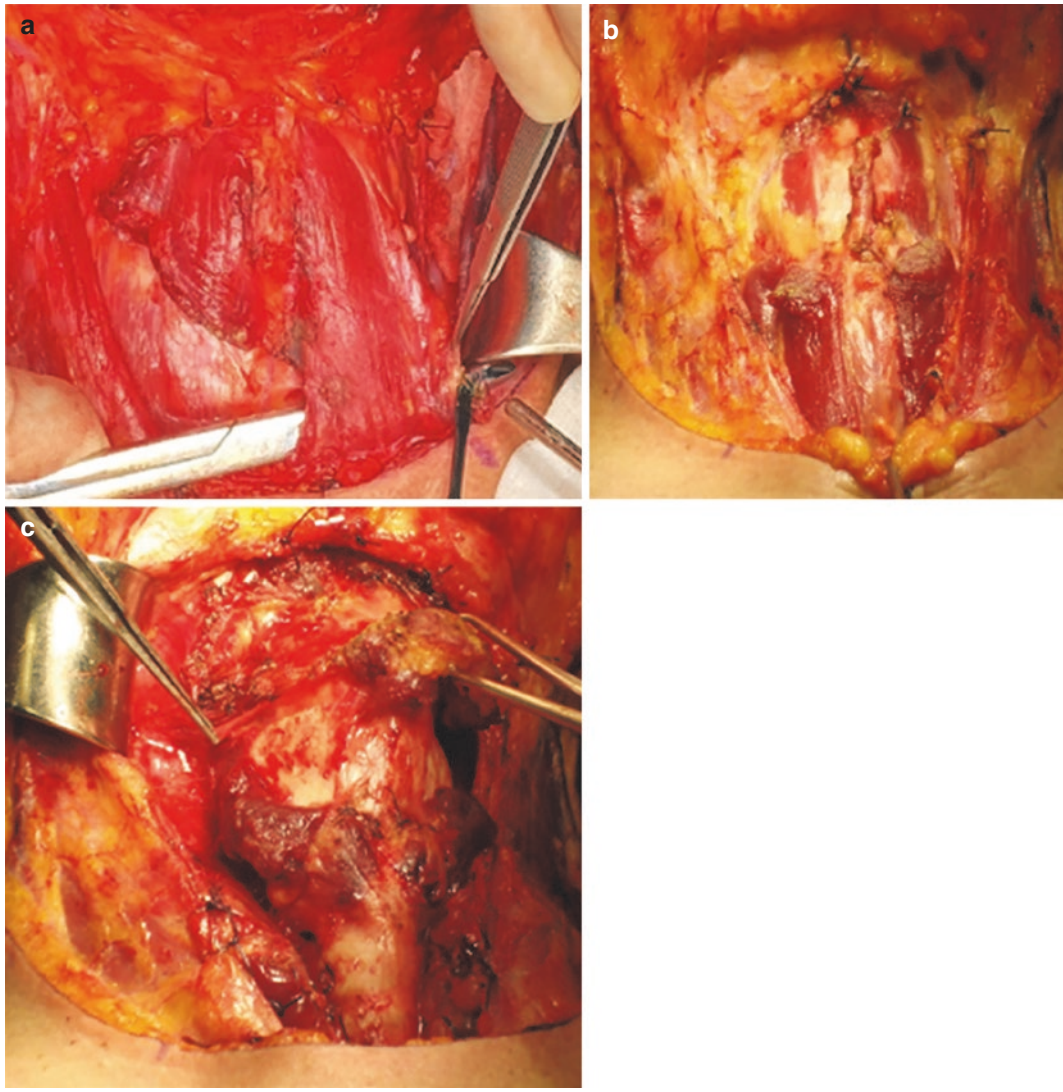


Fig. 12.7 (**a**) Dissection of superficial layer of strap muscles, (**b**) dissection of deep layer of strap muscles, (**c**) exposition of larynx

12.9.5 Larynx Skeletonization

- *Section of the inferior constrictor pharyngeal muscles* inserted into the thyroid cartilage, making an incision along the lateral thyroid border, while the larynx is rotated contralaterally.
- *Detachment of both piriform sinuses* from lateral to medial wall: this step can be limited on the upper third in case of supraglottic laryngectomy or complete in case of total or supracricoid laryngectomy.

12.9.6 Management of the Laryngeal Neurovascular Pedicle

As a rule, the ligation of the vascular pedicle is performed when the thyro-hyoid membrane is exposed. Artery and vein are on a superficial plane to the internal branch of the superior laryngeal nerve, which must be respected. Pedicle ligation can be avoided when the surgeon chooses to perform a narrow "V" thyrotomy (Fig. 12.8).

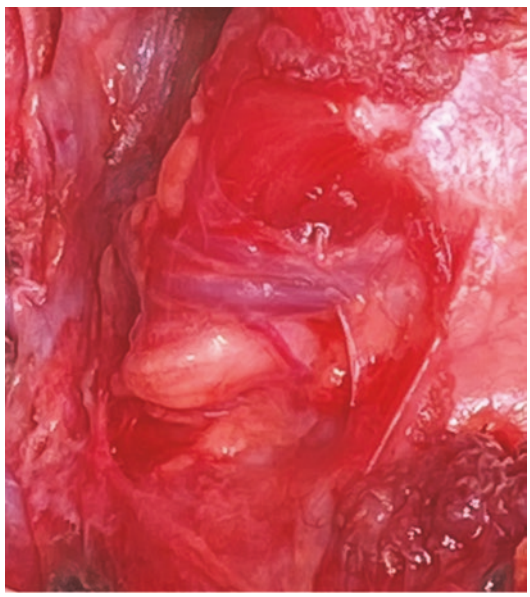


Fig. 12.8 Laryngeal neurovascular pedicle

12.10 Open Partial Horizontal Laryngectomy (OPHL)

Unlike total laryngectomy, conservative surgery allows to preserve organ function without the need for permanent tracheostomy [32]. Furthermore, OPHL is also indicated in case of recurrence of laryngeal carcinoma after transoral laser microsurgery (TLM) [33] or radiotherapy [34], with excellent results in terms of oncological radicality and functional preservation.

As regards the swallowing function, in the immediate post-operative period, high rate of aspiration and dysphagia is reported in the literature [35], which drastically reduces over time within the first year after surgery, in about 90% of cases. Especially in the case of OPHL type II and III, this surgery causes an alteration of the voice that appears deep, hoarse, breathy and tiring because it demands excessive effort to close the neoglottis and allows the emission of phonemes [36]. In particular, the sphincter function of the neoglottis, in the case of OPHL type IIa and IIIa, is obtained by the anterior movement of arytenoid(s) towards the tongue base which, together with the residual epiglottis, allows the vibration of the mucosa and therefore the phonation [37]. Thus, overall, OPHL is a valid therapeutic alternative to radiotherapy and TLM with values between 70% and 90% in terms of local disease control (LC), disease-free survival (DFS) and overall survival (OS) [38–40].

12.10.1 Horizontal Supraglottic Laryngectomy: OPHL Type I

Horizontal supraglottic laryngectomy (Table 12.1) is performed in case of vestibular, marginal and laryngeal tumours of the three folds (pharyngo-epiglottic, glosso-epiglottic, ary-epiglottic). Superiorly, the resection involves the removal of the thyroid-hyo-epiglottic lodge, which represents a structure that anteriorly acts as a barrier to neoplastic progression. Inferiorly, the section must reach the ventricular floor, up to

Table 12.1 Horizontal supraglottic laryngectomy

OPHL type I	
OPHL type I + ARY	
OPHL type I + BOT	
OPHL type I + PIR	

ARY: arytenoid, BOT: base tongue, PIR: piriform sinus
Images drawn by Vincenzo Verro

the superior arcuate line, that is, the so-called *biological wall* between the supraglottic and glottic regions.

From the prognostic point of view, this type of surgery allows to obtain results that are mostly comparable to TLM; therefore, it is indicated where there is difficult transoral laryngeal exposure, in the case of bulky tumour [12, 36] or where there is an invasion of the lower portion of the pre-epiglottic space. Furthermore, comparing this type of surgery with TLM, Chiesa Estomba et al. found no statistically significant differences in terms of overall (OS) and specific survival (SS), as well as in terms of risk of aspiration pneumonia and dysphagia. Actually, in the literature, it has been reported that the recovery of swallowing function is faster in case of surgery performed by TLM but it should be noted that the same parameter, evaluated in the long term, does not show significant differences between the two surgical techniques [12].

12.10.1.1 Surgical Technique

In laryngeal horizontal surgery, the residual larynx is raised up to reach the hyoid bone and the tongue base, so the fixed point is represented by the set of hyoid bone, tongue and suprahyoid musculature.

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy

   A subisthmic tracheostomy is usually performed to prevent compromising the vascularity of the cricoid cartilage and of the trachea. During the procedure, the Lalouette pyramid and the prelaryngeal lymph node are removed to expose the space between the cricoid and the lower edge of the thyroid cartilage. After this, the thyroid-pericardial lamina is incised and the thyroid ima veins are ligated. Once the anterior wall of trachea is exposed, we can choose the level of tracheostomy: between third and fourth or between fourth and fifth tracheal rings. Then, horizontal incision is made between the two tracheal rings and bilateral section of the anterior part of the ring is performed in order to create a lower hinged flap (Bjork's flap). This flap is then sutured to the skin with single stitches (Fig. 12.9).
8. Exeresis of the pre-epiglottic space

   Once the larynx has been exposed and the vascular pedicle has been ligated, and the amount of thyroid cartilage to be resected has been decided, the pre-epiglottic space will be excised by incising the thyro-hyoid membrane at its attachment to the lower edge of the hyoid bone. The detachment will continue on the inner face of the hyoid bone until the hyo-epiglottic ligament is dissected (Fig. 12.10).

   Once the hyoid bone, the thyro-hyoid membrane and the thyroid shield have been exposed, the external perichondrium must be detached by incising it on the upper edge of the thyroid ala for all its extension, which varies according to the thyrotomy decided by the surgeon: narrow V, wide V or horizontal. The different angulation of the thyrotomy affects the next step, which is the detachment of the piriform sinus in its upper third, and therefore also the section of the constrictor at the lateral edge of the thyroid ala, with extension of the detachment depending on the height of the thyrotomy itself.

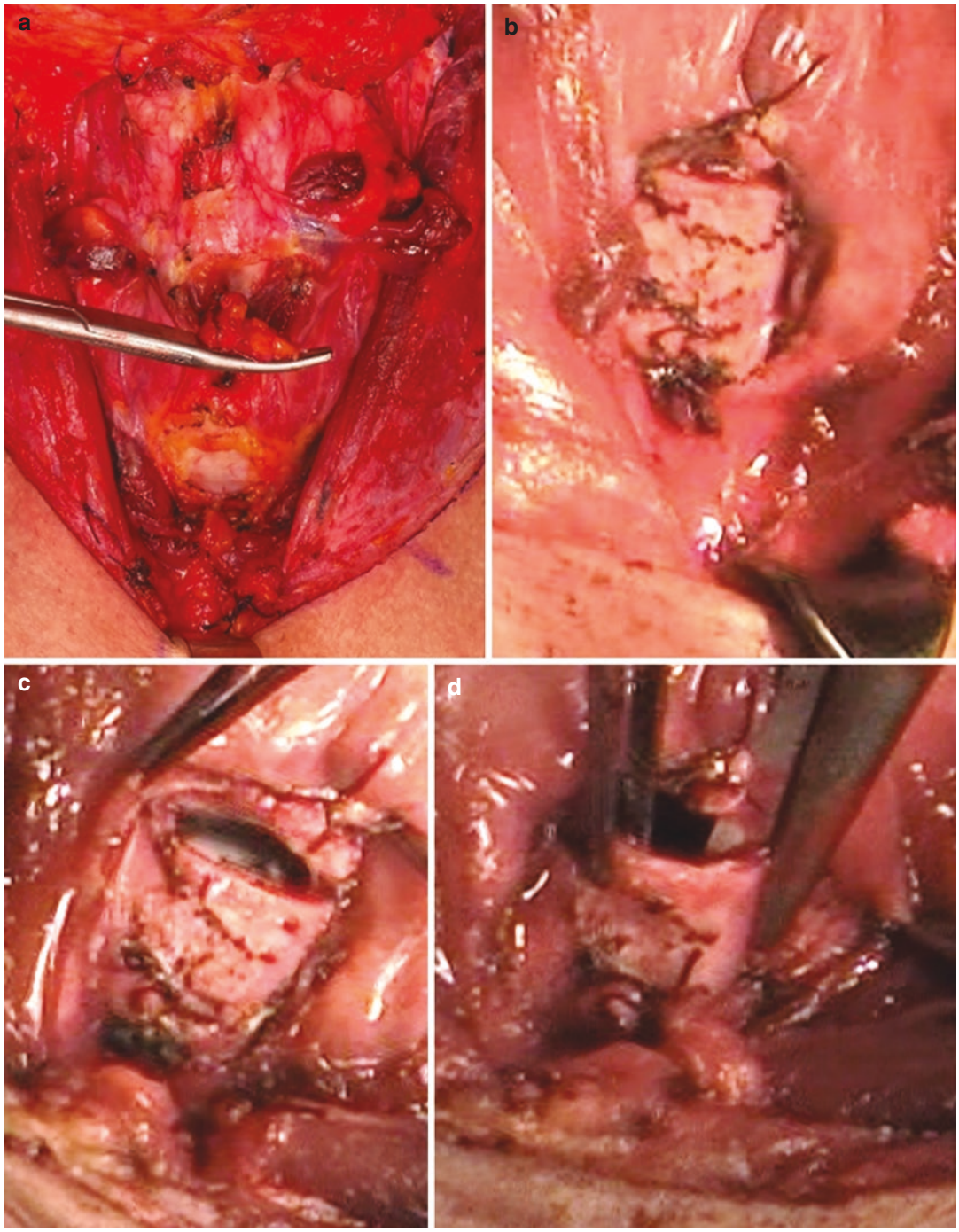


Fig. 12.9 Subisthmic tracheostomy: (**a**) incision of thyroid-pericardial lamina, (**b**) ligation of ima veins, (**c**) horizontal incision between two tracheal rings, (**d**) creation of Bjork's flap

9. Pharyngotomy

   Access to the hypopharynx will be performed by horizontal pharyngotomy, superiorly and medially to the pedicle, allowing to dissect the mucosa of the glosso-epiglottic vallecula. This pharyngotomy will allow the epiglottis to be overturned outwards by tractioning with a transfixed stitch or grasping forceps (Fig. 12.11).

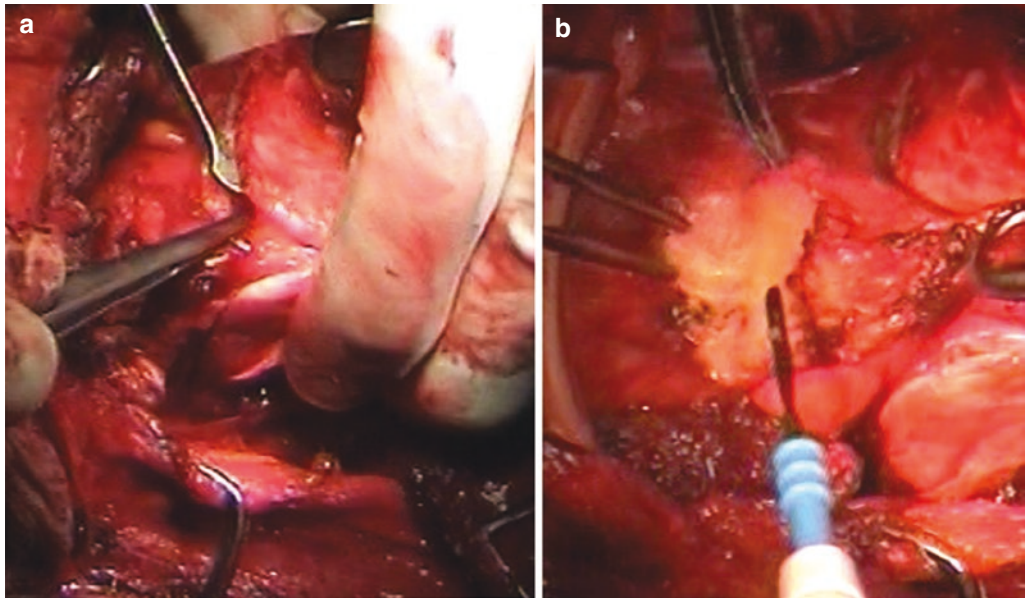


Fig. 12.10 Exeresis of the pre-epiglottic space: (**a**) detachment of external perichondrium of thyroid cartilage, (**b**) section of thyro-hyoid membrane

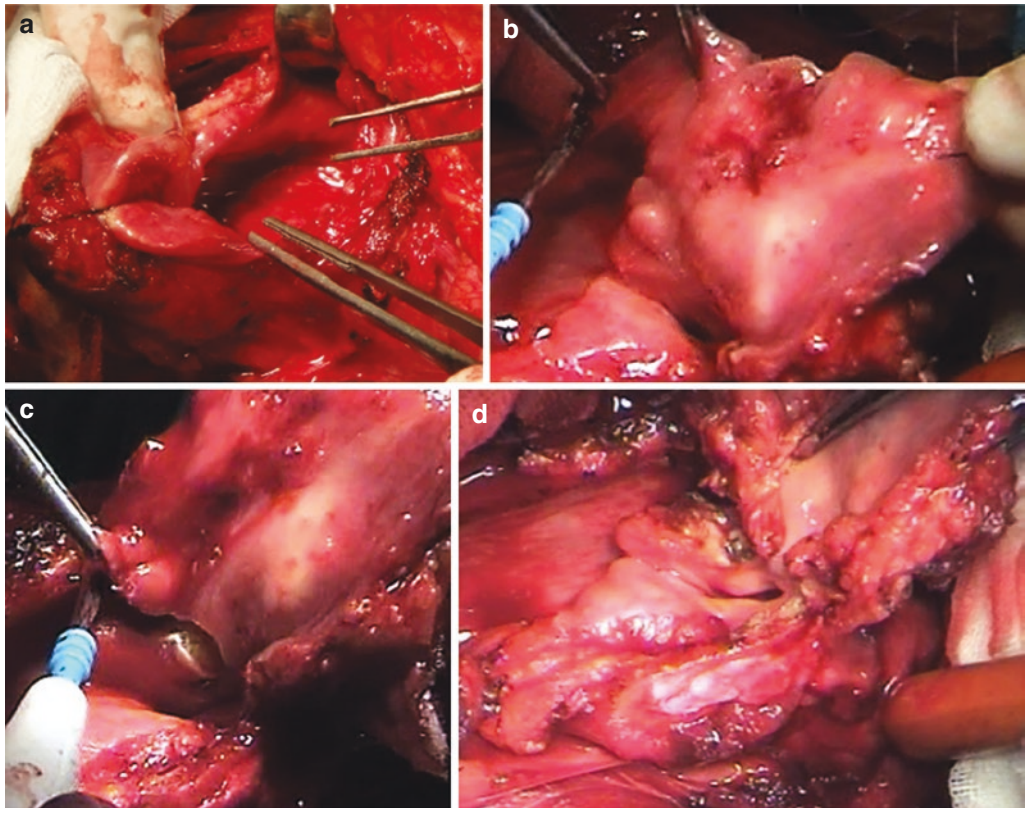


Fig. 12.11 (**a**) Epiglottis' traction by a transfixed stitch, (**b**) vertical section of pharyngo-laryngeal wall, (**c**) horizontal section through the ventricular floor, (**d**) detachment of the supraglottis from the glottis

10. Section of ary-epiglottic fold, false vocal fold and medial wall of the piriform sinus up to the ventricular floor (pharyngolaryngeal wall)
11. Vertical section of the pharyngoepiglottic fold (Fig. 12.11)
12. Horizontal section through the ventricular floor (Fig. 12.11)
13. Detachment of the supraglottis from the glottis (Fig. 12.11)

    The section line passes from the floor of the ventricle, along the previously performed thyrotomy line, to the anterior commissure. The same will be performed contralaterally.
14. Laryngeal closure and suspension

    The perichondrium, previously spared, can be sutured to the ventricle floor in order to cover the exposed para-glottic space. The pexy can start laterally by suturing the mucosa of the lateral wall of the piriform sinus with the mucosa of the lateral pharynx wall (Fig. 12.12).
15. Pexy

    Pexy is usually performed with three single stitches (Fig. 12.12):
    - A median passing from the lower border of the thyroid cartilage to include the tongue base and the hyoid bone.
    - Two laterals that pass the lower edge of the thyroid cartilage and internally follow the medial wall of the thyroid ala, lateral to the vocal cord: Superiorly, the needle passes above the intermediate digastric tendon avoiding the lingual artery. The

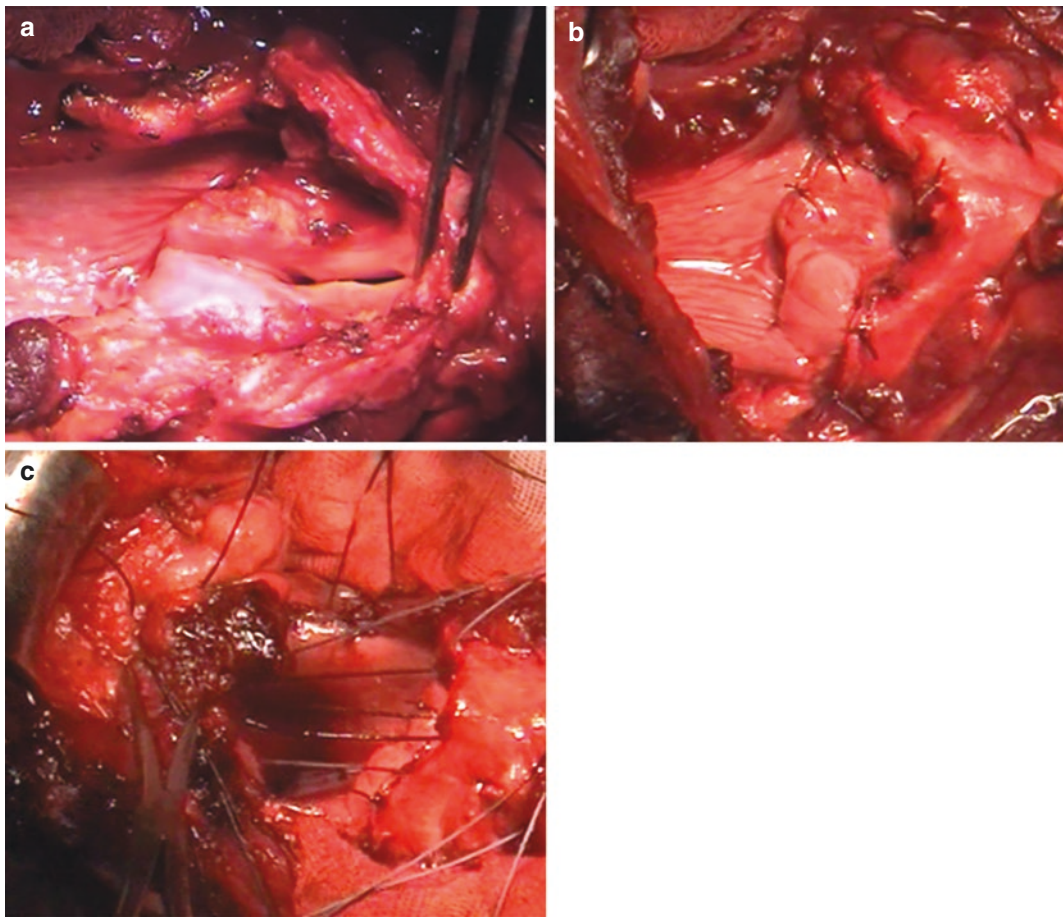


Fig. 12.12 (**a**) Glottic plane with arytenoids, (**b**) perichondrium sutured to ventricle floor in order to cover the paraglottic space, (**c**) pexy with three single stitches

suture used is absorbable, 0 or 1, with a curved atraumatic needle, with a diameter of 48 mm.

12.10.2 Horizontal Supracricoid Laryngectomy: OPHL Type II

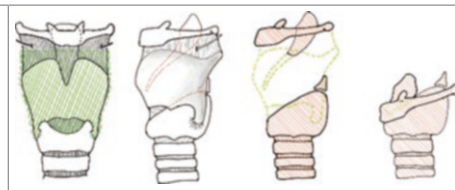
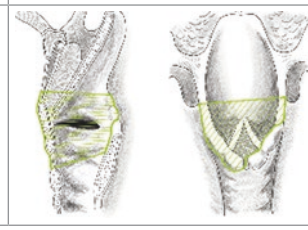
Succo et al. defined OPHL type II as the gold standard procedure in case of supraglottic T3 and glottic T3 carcinoma with true vocal cord fixity [29]. It consists of the removal of the epiglottis, the entire thyroid cartilage, Morgagni's ventricle, both true and false vocal cords and the pre-epiglottic and para-glottic spaces. Therefore, the only preserved structures are the cricoid cartilage, at least one mobile arytenoid cartilage and the hyoid bone [41]. Therefore, this surgery allows radical oncology and preservation of organ function with a better quality of life than that of patients who have undergone total laryngectomy with voice prosthesis placement [42], with a 5-year OS rate greater than 82.10%, a 5-year SS rate greater than 89.19% and a 5-year LC rate greater than 82.46% [41, 43, 44].

Furthermore, as regards the main indications for OPHL type II, the surgical procedure must be distinguished in the two subtypes. OPHL type IIa or CHEP (crico-hyoido-epiglottopexy) (Table 12.2) is indicated in these stages: (1) glottic T2 tumours with fixity of the vocal cord without involvement of the corresponding arytenoid and (2) glottic T2 tumours with extension to the ventricle, at the false vocal fold, to the infrahyoid epiglottis and/or with impaired vocal cord motility. OPHL type IIb with CHP (crico-hyoidopexy) (Table 12.3) is indicated in (1) glottic T2 tumours with bilateral invasion, (2) glottic T3 tumours originating from the anterior commissure and involving the pre-epiglottic space, (3) supraglottic or transglottic T2 tumours with invasion of the pre-epiglottic space and/or vocal cord fixity with normal motility of the corresponding arytenoid and (4) supraglottic or transglottic T4 tumours with partial involvement of the thyroid ala without exceeding the external perichondrium [41, 45].

However, OPHL type II is contraindicated in the following situations: (1) fixity of both arytenoid cartilages, (2) invasion of the crico-thyroid membrane, (3) invasion of the cricoid cartilage, (4) extension of the tumour to the glosso-epiglottic vallecula and/or invasion of the thyro-hyoid membrane, (5) invasion of the hyoid bone and (6) extension of the tumour beyond the external perichondrium of the thyroid cartilage [45].

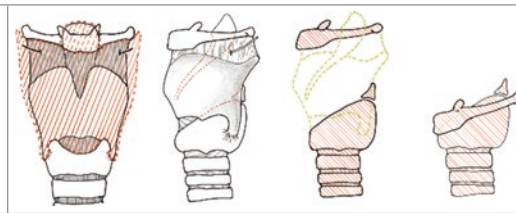
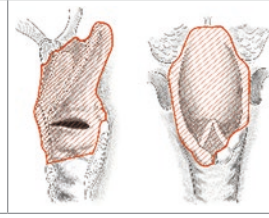
Finally, the main problem related to this surgery is represented by the impairment of

Table 12.2 Horizontal supracricoid laryngectomy with crico-hyoido-epiglottopexy

OPHL type IIa	
OPHL type IIa + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

Table 12.3 Horizontal supracricoid laryngectomy with crico-hyoidopexy

OPHL type IIb (with crico-hyoidopexy)	
OPHL type IIb + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

swallowing function with consequent risk of aspiration and aspiration pneumonia [46]. Anyway, over time, the patient will implement a compensation mechanism represented by the antero-medial rotation of the residual arytenoid with closure of the airways during swallowing [43].

12.10.2.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization (Fig. 12.13)
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
   - Section of the small cornu of the thyroid cartilage, which is always performed in order to avoid recurrent nerve injuries during the disarticulation manoeuvre
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy
8. Inferior endolaryngeal access (Fig. 12.14)

   Transection of the crico-thyroid muscles and of the crico-thyroid membrane, at the upper edge of the cricoid ring: The mucous membrane of the cricoid ring can be detached and removed in order to have an additional margin of healthy tissue. This surgical step is common to OPHL type IIa and IIb.
9. Superior endolaryngeal access (Figs. 12.14 and 12.15)
   - *OPHL type IIa:* Horizontal section of the thyro-hyoid membrane, of the tissues of the pre-epiglottic space and of the epiglottis, along the plane corresponding to the upper edge of the thyroid cartilage and within two vertical lines passing through the small thyroid cornu. Preservation of the suprahyoid portion of the epiglottis will ensure good tension of the ary-epiglottic folds
   - *OPHL type IIb*: Access is the same as that of OPHL type I
10. Endolaryngeal resection

    After the two accesses are performed and thus entering the larynx inferiorly and superiorly, the endolaryngeal inspection is reached by a full-thickness cut from the less involved side, taking care to spare the lateral crico-arytenoid muscle and the crico-arytenoid unit. This section encompasses the false cord, the posterior ventricular cornu

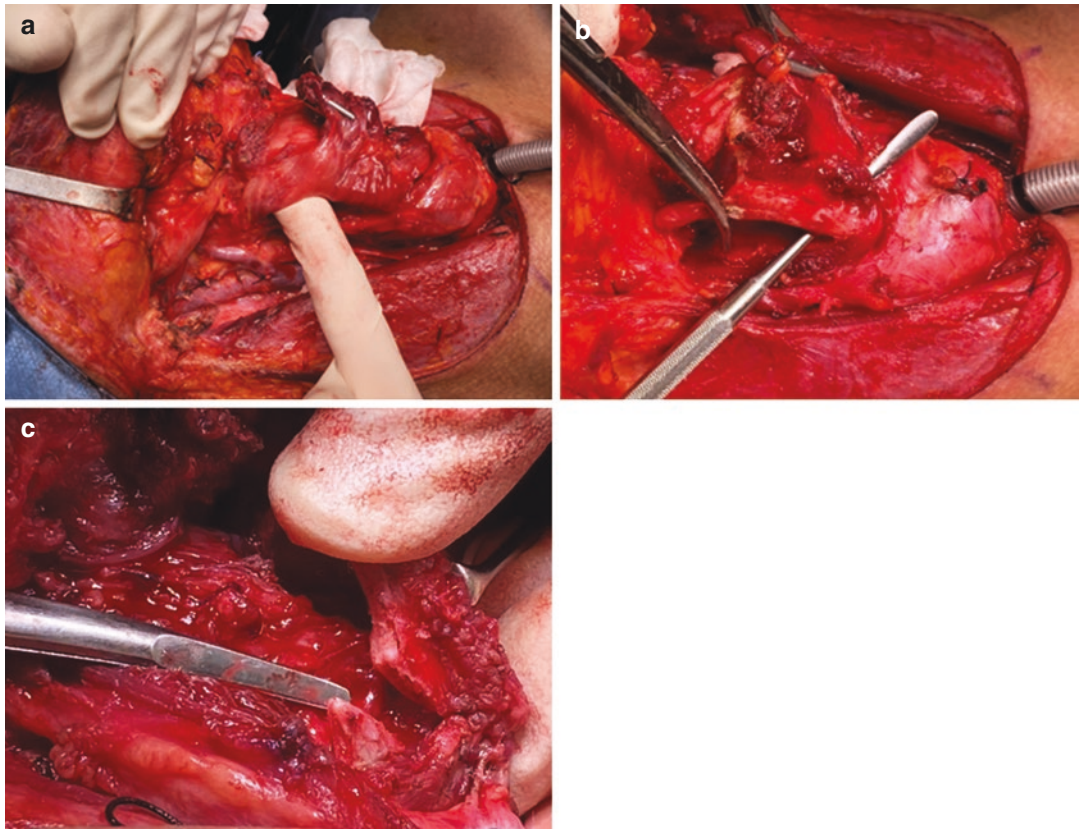


Fig. 12.13 (**a**) Detachment of piriform sinus, (**b**, **c**) section of the small cornu of the thyroid cartilage

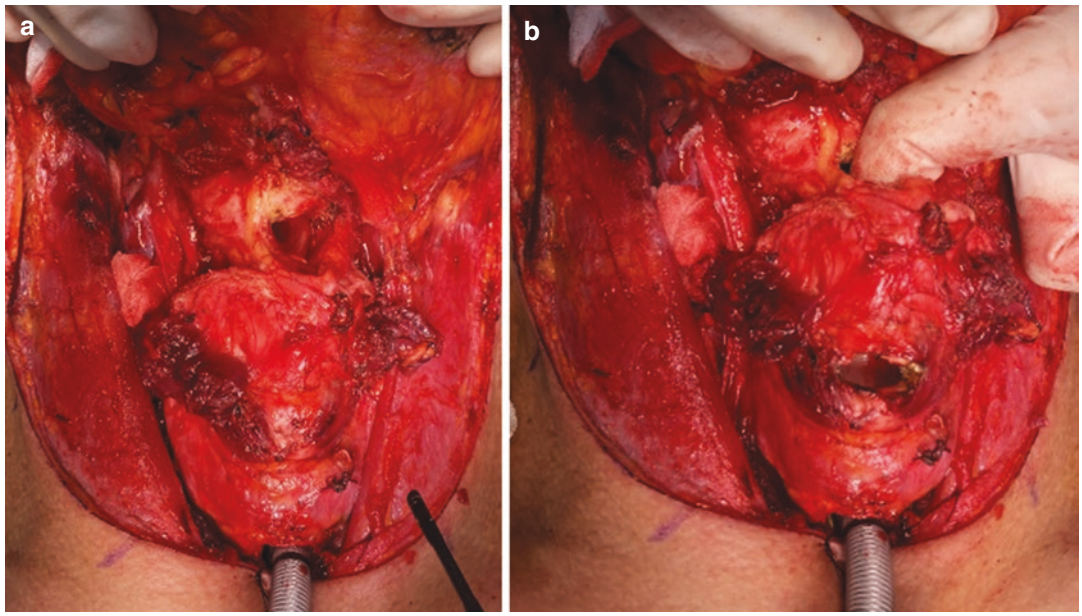


Fig. 12.14 OPHL type II: (**a**) superior endolaryngeal access, (**b**) superior and inferior endolaryngeal accesses

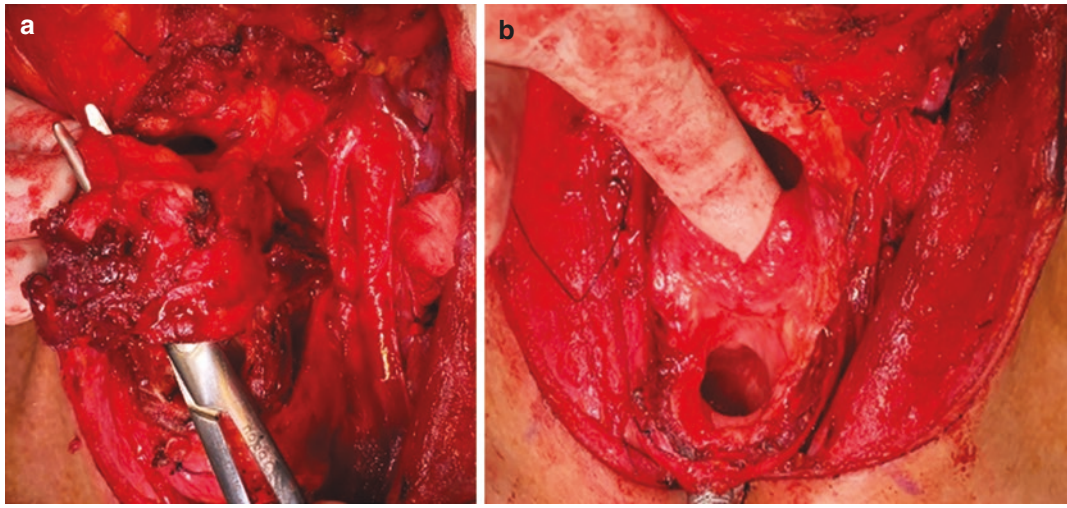


Fig. 12.15 OPHL type IIa: (**a**) horizontal section along the upper edge of the thyroid cartilage, (**b**) after endolarynx section and exeresis

and the true vocal cord at the vocal apophysis. The integrity of the piriform sinus is guaranteed. This section is also performed contralaterally in case of sparing of both arytenoids.

– *OPHL type II + ARY:* The sectioned muco-cartilage flap is reversed contralaterally after manual fracture of the thyroid shield in order to assess the real extension of the tumour and to continue with the next section under visual control. Endolaryngeal incisions should be made no less than 2 mm away from the lesion. This surgical time includes:

  • A hypoglottic horizontal section up to the midline, below the crico-arytenoid joint
  • A section of the mucosa along the edge of the arytenoid
  • A section along the ary-epiglottic fold bordering the medial wall of the piriform sinus

  • In this case, the excision of one arytenoid includes the detachment of the lateral crico-arytenoid muscle from the cricoid in order to ensure complete exeresis of the lower para-glottic space.

If the maintenance of both arytenoids is expected, the external detachment must be performed laterally to the lateral crico-arytenoid muscles in order to safeguard their integrity.

Once the exeresis is complete, on the side where the arytenoid is removed, it is advisable to reposition the medial wall of the piriform sinus to the cricoid in order to ensure a wider piriform sinus. Actually, on the side where the arytenoid is present, the tension of the piriform sinus' inlet will be guaranteed by the pexy.

11. Pexy

It is carried out by three single points, one median and two laterals, passing through the lower edge of the cricoid with 0 and 1–0 thread, 38 mm diameter, atraumatic needle (Fig. 12.16).

– *OPHL type IIa:* The median suture point will include, as the first step, the residual epiglottis and a portion of the tongue base, as close as possible to the lingual V; as the second step, the body of the hyoid bone is included. This suture can include

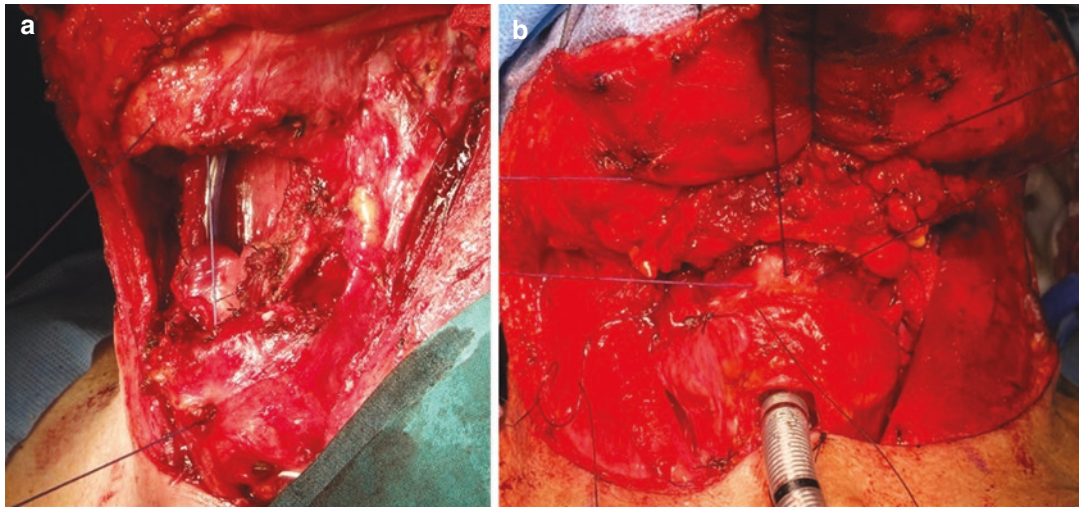


Fig. 12.16 (**a**) Crico-hyoido-epiglottopexy, (**b**) crico-hyoidopexy

the epiglottis, tongue base and hyoid bone in one step. The two lateral stitches will pass laterally to the median point, at the limit between the plate and the ring. These will also include the residual epiglottis and the tongue base and will pass centrally to the small cornu of the hyoid bone to avoid the lingual artery

– *OPHL type IIb*: The superior passage to the tongue base occurs as per the supraglottic laryngectomy (OPHL type I)

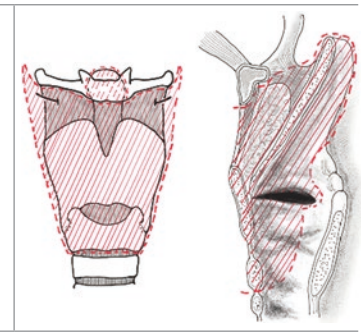
12. Pexy protection (optional)

The thyroid gland can be used to protect and reinforce the crico-hyoid-pexy. Being free on the lower side from the thyro-pericardial membrane, its raising will be facilitated. Then, the thyroid body is sutured to the suprahyoid muscles with stitches passing through the upper edge of the gland, avoiding the medial branch of superior thyroid artery.

12.10.3 Horizontal Supratracheal Laryngectomy: OPHL Type III

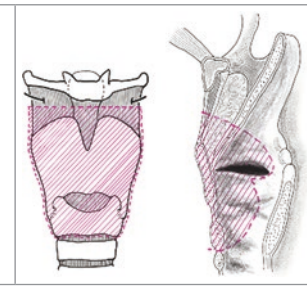
The horizontal supratracheal laryngectomy (Tables 12.4 and 12.5) was introduced in 2006 to

Table 12.5 Horizontal supratracheal laryngectomy with tracheo-hyoidopexy

OPHL type IIIb (with tracheo-hyoidopexy)	
OPHL type IIIb + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

Table 12.4 Horizontal supratracheal laryngectomy with tracheo-hyoido-epiglottopexy

OPHL type IIIa (with tracheo-hyoido-epiglottopexy)	
OPHL type IIIa + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

respond to the need of a surgery that would guarantee the preservation of the laryngeal function with an excellent long-term locoregional control in those cases which cannot be solved by a less extensive demolition, i.e. OPHL type II [29].

Therefore, this type of OPHL is indicated in the case of (1) glottic T2 tumours with anterior or lateral extension at the subglottic level and invasion of the elastic cone up to the cricoid ring; (2) T3 transglottic tumours with involvement of the upper para-glottic space and subglottic extension; (3) T3 glottic-subglottic tumours with involvement of the para-glottic space, elastic cone and external perichondrium of the thyroid cartilage; and (4) T4a tumours with limited extralaryngeal, anterior or lateral extension [29, 47]. Conversely, it is contraindicated in case of (1) T4a supraglottic carcinoma with involvement of the tongue base or invasion of the hyoid bone, (2) N3, (3) T4a tumours with involvement of the first tracheal ring and (4) T3 glottic-subglottic tumours involving the posterior crico-arytenoid muscle and the submucosa of the sinus piriform [29, 47].

This surgical technique includes the resection of the glottic and subglottic plane, thyroid cartilage and amount of the cricoid cartilage depending on the tumour extension but always with preservation of at least one crico-arytenoid unit [48]. Assuming that a more extensive exeresis is correlated with a more compromised laryngeal function, Schindler et al. compared various parameters (swallowing, voice and speech and quality of life) between OPHL type IIa and IIIa and demonstrated the absence of statistically significant differences between the two long-term surgical techniques [37]. The most frequently reported complication is known as post-operative laryngeal obstruction (POLO), which can be treated with CO2 laser surgery [19, 29].

In conclusion, OPHL type III can be considered an effective therapeutic strategy in the case of glottic or transglottic tumours with subglottic extension as an alternative to the chemoradiotherapy protocol, with oncological radicality and, at the same time, partial preservation of the larynx [48].

12.10.3.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy
8. Inferior access

   The horizontal section passes through the lower edge of the cricoid cartilage.
9. Superior access
   - OPHL type IIIa: the superior approach is comparable to an OPHL type IIa
   - OPHL type IIIb: the superior approach is the same as OPHL type I and IIb
10. Cricoid resection

    There are two types of cricoid resection
    - Cricoid arches
    - Cricoid arches + half cricoid plate + CAU
11. Piriform sinuses

    If the resection does not involve half cricoid plate, the piriform sinuses will be fixed with sutures to the lateral part of the plate and possibly also to the first tracheal ring.

    In the case of resection of a half cricoid plate, the ipsilateral retro-cricoid mucosa will be fixed with sutures to the residual plate, the section line on the plate and the pars membranacea of trachea.
12. Pexy

    In this case, the pexy is performed between the first tracheal ring at the bottom and follows the same steps as OPHL type I and type II above.

12.11 Total Laryngectomy

Total laryngectomy was performed for the first time in 1873 by Billroth [49] and, until a few decades ago, has represented the therapeutic gold

standard for advanced laryngeal cancers. To date, the conservative surgery has reduced total laryngectomy only in limited cases, i.e. in case of T3 and T4a laryngeal carcinoma, where conservative laryngectomy or non-surgical therapy failed (the so-called "salvage surgery") [50, 51]. Several studies have demonstrated the advantage of total laryngectomy over chemoradiotherapy in terms of survival and quality of life [52, 53], even in case of T4a where the surgical approach represents the best therapeutic option [54]. Obviously, the surgical indication and its effectiveness in terms of OS, LC and quality of life depend on the patient, his/her age and comorbidities.

Total laryngectomy involves impairment in breathing, speech and swallowing; therefore, the rehabilitation phase is also fundamental as well as the demolition phase. Thus, breathing is ensured by the tracheostomy which, differently from OPHL interventions, in this case will be permanent. With regard to phonation, instead, various strategies for voice rehabilitation have been developed over the years: the tracheoesophageal prosthesis (TEP), the oesophageal speech or the electronic larynx [55]. According to many studies, TEP would represent the best solution for voice restoration because it is more similar to normal phonation in terms of sound and functioning [56, 57]. Despite this, it would not be correct to define TEP as an absolute gold standard, since the best voice restoration strategy depends on the patient with his/her comorbidities and preferences [58]. Swallowing can be affected by total laryngectomy; about 40% of laryngectomized patients can develop dysphagia even years after surgery and especially after adjuvant chemoradiotherapy [59, 60]. Actually, laryngectomy inevitably causes an alteration of the physiology of swallowing with an increased pharyngeal transit time of the bolus and pharyngeal residue and a reduced peristaltic contraction of the oesophagus [61].

Moreover, other complications may affect the post-operative course of total laryngectomy: pharyngocutaneous fistula (about 28% of cases) or tracheo-oesophageal fistula (5% of cases), pharyngeal stenosis (about 14% of cases) or tracheostomy stenosis (about 20% of cases) [62]. Nevertheless, total laryngectomy remains the most preferable choice in case of stage IV laryngeal cancer compared to chemoradiotherapy [63].

12.11.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Dissection of the fascia in the latero-medial direction
5. Section of omohyoid and sternohyoid muscles

   Section of the omohyoid muscle along the anterior edge of the sternocleidomastoid muscle and lower section of the sternohyoid muscle are performed. Superiorly, these muscles are dissected at the hyoid attachment.
6. Lower section of the sternothyroid muscle
7. Section of the thyro-hyoid muscle at insertion on the hyoid

   NB: Management of strap muscles: the strap muscles can be removed before laryngectomy or left and removed in en bloc modality with larynx, especially in case of T4a with infiltration of strap muscles, platysma and skin.
8. Thyroid time

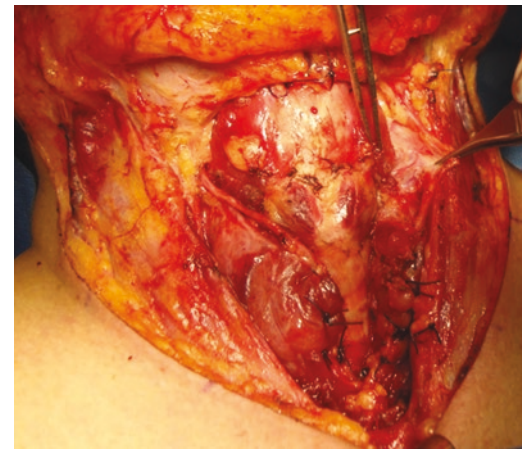


Fig. 12.17 Detachment of thyroid lobes from the laryngeal-tracheal axis

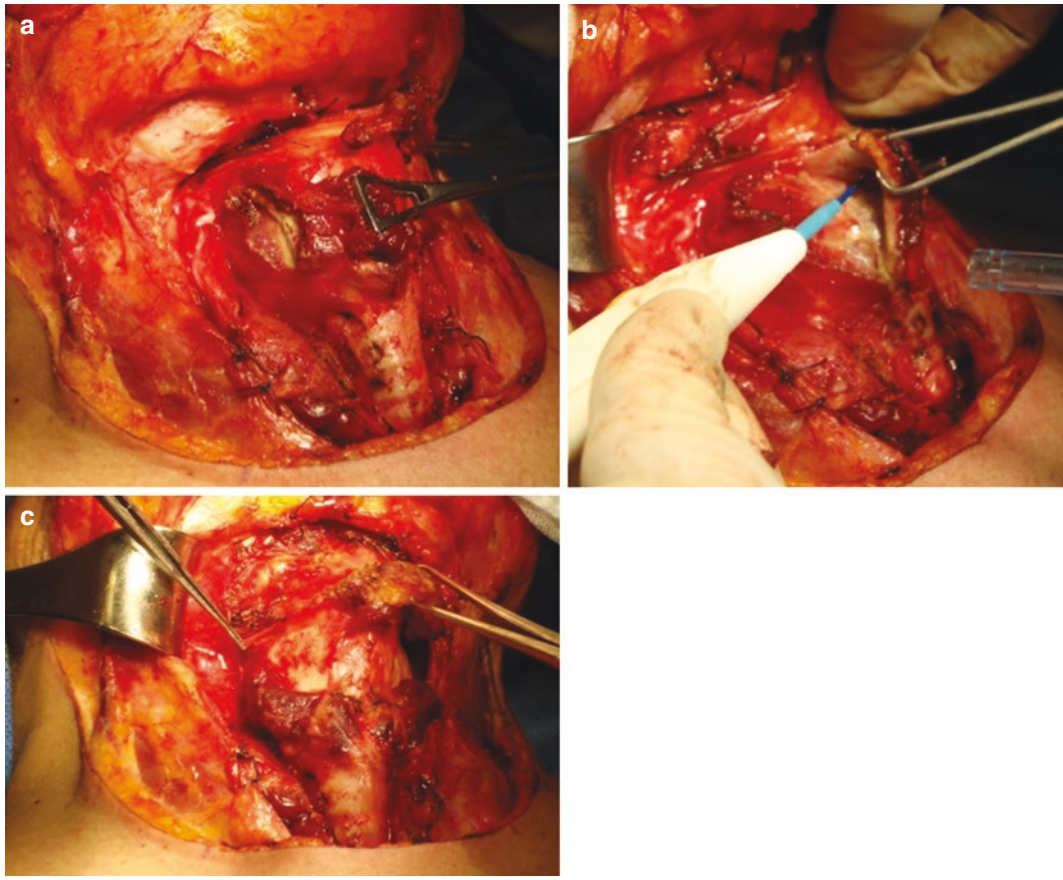


Fig. 12.18 (**a**) Contralateral rotation of the larynx, (**b**) dissection of the piriform sinus, (**c**) section of the suprahyoid muscles' insertion to the hyoid bone

Detachment of thyroid lobes from the laryngeal-tracheal axis is performed. Separate the two thyroid lobes by performing an isthmotomy or isthmectomy, according to need (Fig. 12.17).

9. Ligature of the laryngeal pedicle
10. Contralateral rotation of the larynx with positioning of the finger behind the thyroid ala (Fig. 12.18)
11. Section of the constrictor muscles along the lateral edge of the thyroid ala up to the upper cornu and, inferiorly, to detach the crico-pharyngeal muscle
12. Blunt dissection of the piriform sinus via the internal sub-perichondrium (Fig. 12.18)
13. Section of the suprahyoid muscles' insertion to the hyoid bone (Fig. 12.18)
14. Incision along the upper edge of the hyoid bone from the body up to the large cornu which are separated from the lateral walls of the hypopharynx
15. Section of the hyo-glossus ligament
16. Tracheostomy

    It is usually performed by including two tracheal rings, between the second and the third rings. If the tracheostomy was per-

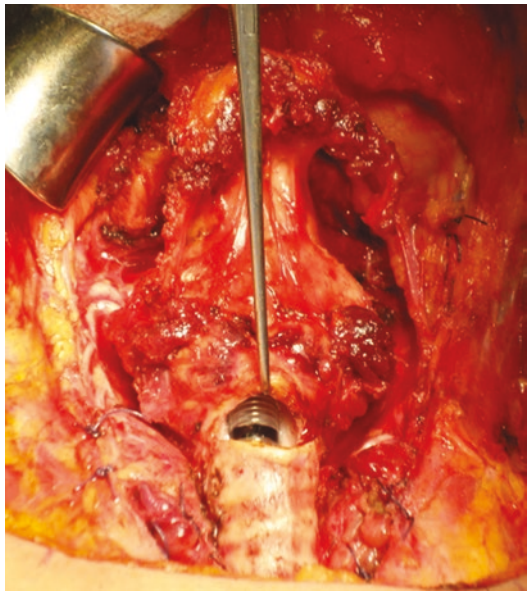


Fig. 12.19 Tracheotomy

formed previously, the tracheal section should be performed inferiorly to the previous tracheostomy, including only one tracheal ring (Fig. 12.19).

17. Detachment of larynx and trachea from hypopharynx and oesophagus

    Once the posterior membranous wall of the trachea is dissected, the laryngo-tracheal axis is detached by blunt dissection, from the bottom upwards. Section of recurrent nerves follows. Detachment can reach up to the upper edge of the cricoid plate (Fig. 12.20).

18. Pharyngotomy

    This can be performed at the top along the glosso-epiglottic fossae or, below, at the height of the upper edge of the cricoid in the interarytenoid region. At this point, once the approach to the hypopharynx has been chosen, the section must follow the ary-epiglottic fold, curving medially along the glosso-epiglottic fossae until it surrounds the contralateral ary-epiglottic fold. Access, upper or lower, is performed on the side less affected by the tumour (Fig. 12.20).

19. Examination of the endolaryngeal tumour

    Examination of endolaryngeal tumour's extension to evaluate the need of wider resections on its margins should be carried out.

20. Crico-pharyngeal myotomy

    This step is critical in view of voice prosthesis placement. Before closing the pharynx, the finger is put at the level of the pharyngotomy opening in order to stretch the muscle that is dissected along the lateral wall of the hypopharynx. This manoeuvre should be performed carefully in order to dissect only the muscle fibres in order to spare the underlying mucosa (Fig. 12.20).

21. Tracheo-oesophageal fistula

    Tracheo-oesophageal fistula and insertion of voice prostheses can be performed (Fig. 12.21).

22. Closure of the pharynx

    The suture is performed in a T shape: the horizontal branch along the upper edge of the piriform sinuses and the vertical branch along the retro-cricoid region (Fig. 12.22). Usually, the suture is performed in interrupted sutures and involves three layers:

    (a) Inverting suture: mucosa-mucosa
    (b) Submucosal-serous
    (c) Constrictor muscle layer

    This suture can also be performed in two layers:

    (a) Serous-serous
    (b) Constrictor muscle layer

23. Packaging of the tracheostomy

    Once the tracheal section is performed, the anterior edge of the trachea is fixed with interrupted suture to the skin of the jugulum. Laterally, the sternal head of the sternocleidomastoid muscle should be used to fix the tracheostomy in order to avoid possible

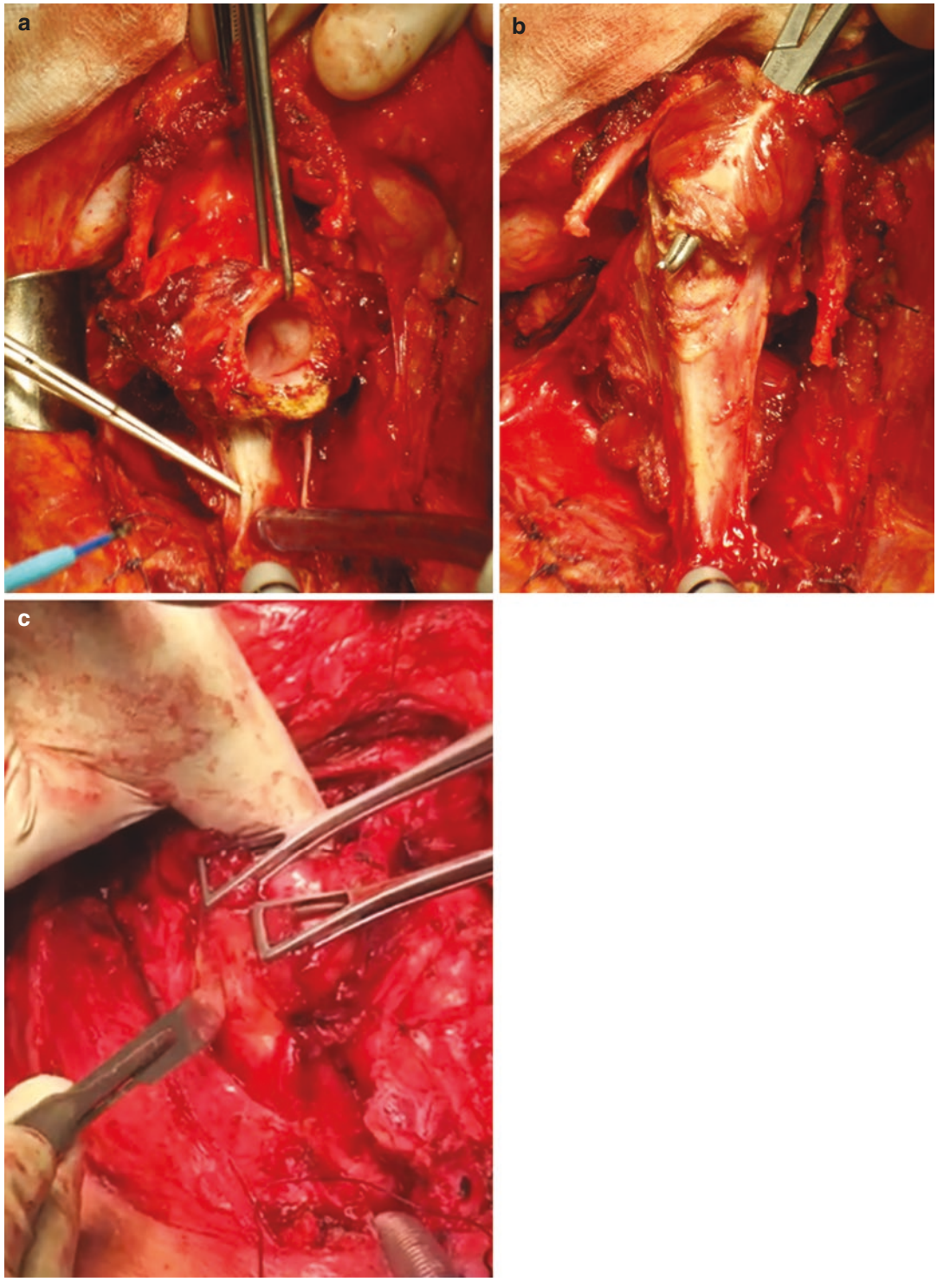


Fig. 12.20 (**a**) Detachment of larynx from hypopharynx and oesophagus, (**b**) pharyngotomy, (**c**) crico-pharyngeal myotomy

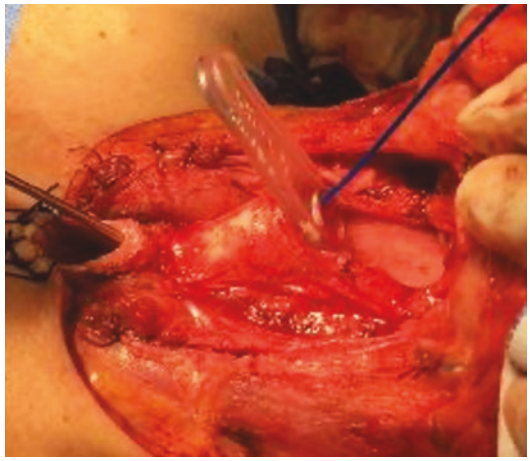


Fig. 12.21 Trache-oesophageal fistula

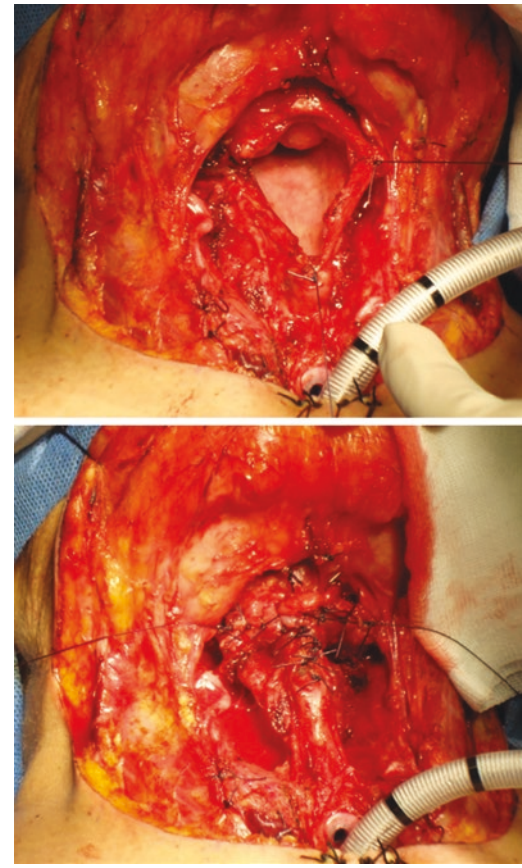


Fig. 12.22 Closure of the pharynx

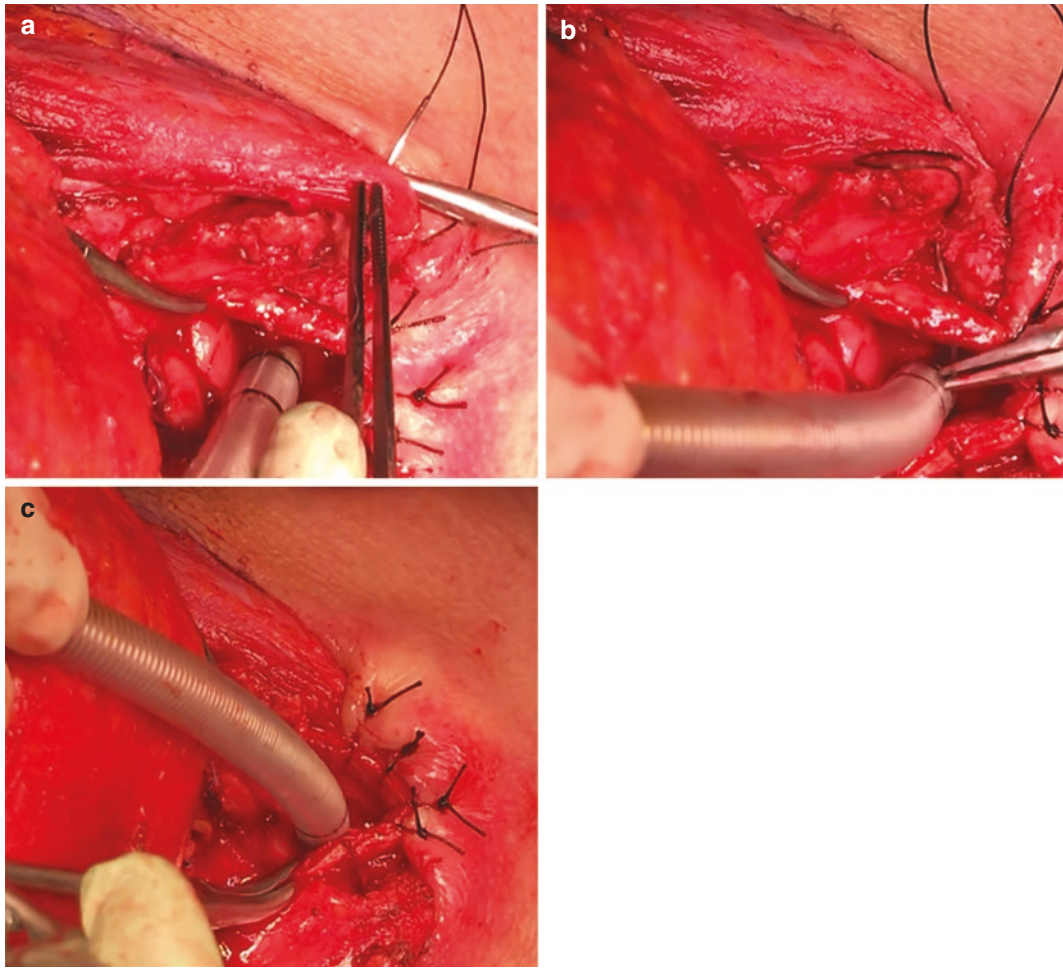


Fig. 12.23 Packaging of the tracheostomy including in a single suture point: (**a**) skin, (**b**) sternomastoid muscle, (**c**) lateral part of the tracheal ring

circular stenosis of the tracheostoma or its sliding behind the sternal manubrium and to ensure stable flattening of the tracheostoma: this procedure is performed including the lateral part of the tracheal ring, the sternomastoid muscle and the skin in a single suture point (Fig. 12.23).

12.12 Future Challenges

As previously written, in the case of total laryngectomy, there is a significant impairment of patient's quality of life due to dependence on the tracheostomy for breathing, for unnatural speech strategies and for swallowing difficulties. This is the reason why, in the last 50 years, new strategies have been theorized in order to recreate the organ with its functions. In particular, implanting an artificial laryngeal prosthesis has been hypothesized: this experiment to date has only been performed on animals with various serious complications such as infections, erosion and migration of the prosthesis with a serious danger to life [64]. In 2001, Strome et al. performed a laryngeal transplant on a male patient [65]. Forty months after transplant, the patient presented voice and swallowing ability near to normal condition; but it was not possible to close the tracheal stoma and restore the normal and physiological airway.

If to date the surgical techniques, in the case of both OPHL and total laryngectomy, are well defined and globally accepted, the strategies for recreating the larynx post-total laryngectomy have not yet been studied and the proposed hypotheses are still in the initial stages of experimentation. Therefore, the future challenge is to identify the best strategy to recover all laryngeal functions near to normal.

12.13 Conclusion

The larynx performs important and difficult functions with an elegant simplicity [51]. Oncological laryngeal surgery must be carried out with care both in the demolition phase and in the reconstructive phase. So, two main objectives have to be reached: radicality of resection and function preservation guaranteeing the best quality of life for the patient.

According to this, over the years, different surgical techniques have been proposed in order to couple a less demolitive surgery with oncological radicality in order to limit total laryngectomy as much as possible. For the same reason, the strategies for phonatory and respiratory rehabilitation are equally important and fruitful. Unfortunately, due to its fundamental role in three essential functions for humans (breathing, speaking, eating), recreating the larynx remains the most difficult challenge but also the most important in order to give back to the patient "simply" his/her normality.

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