Chapter 4

Transoral Laser Microsurgery for Laryngeal Cancer

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Introduction

Cancer of the larynx is the third most common malignancy of the upper aerodigestive tract [1]. 85–95 % of these are squamous cell carcinoma, a result of malignant transformation of the epithelial layer of the larynx [2]. In the United States, 60 % of laryngeal cancer will affect the glottis, 35 % will affect the supraglottis, and the remaining 5 % will affect the subglottis. Historically, treatment of laryngeal cancer has been in the form of open transcervical surgery, endoscopic transoral surgery using cold steel instrumentation, and external beam radiation therapy (RT). The advances of direct laryngoscopy, microscopic instrumentation, and lasers in the twentieth century have paved the way for transoral laser microsurgery (TLM), which now competes with, and often replaces, the traditional modalities to treat laryngeal cancer (Fig. 1).

Alfred Kirstein developed the first direct laryngoscope with electric lighting in 1895 [3]. 20 years later, Chevalier Jackson reported the endoscopic resection of an epiglottic cancer with punch biopsy forceps. In the mid-twentieth century, Scalco described the use of the microscope in conjunction with the suspension laryngoscope, which, along with the use of general endotracheal anesthesia, allowed for a leap in precision with regard to surgery of the vocal cords. Shortly thereafter, Kleinsasser designed further instrumentation and introduced the 400-mm lens [4], which increased the working distance between the microscope and the laryngoscope, allowing for the use of long-shafted laryngeal instruments [5].

The development of lasers in the late 1950s in many ways revolutionized the management of laryngeal disease. Michael Polanyi coupled the CO_2 laser to a microscopic attachment [6], which was used by Jako to evaporate discrete areas of tissue on the vocal cord

Brian J.-F. Wong and Justus Ilgner (eds.), *Biomedical Optics in Otorhinolaryngology: Head and Neck Surgery*, DOI 10.1007/978-1-4939-1758-7_4, © Springer Science+Business Media New York 2016

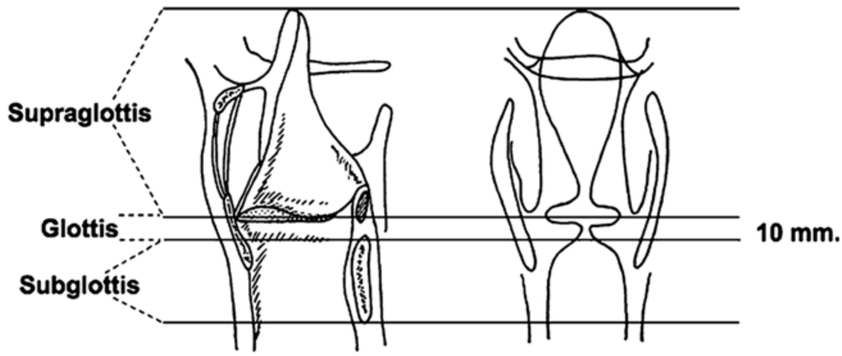

Fig. 1 Sagittal and coronal sections of the larynx showing the cancer subsites (adapted from Coates GM, Schenck HP. Otolaryngology. W.F. Prior Co., Hagerstown, MD. 1966, Vol. 5, Chapter 7, page 4)

surface in a rapid and bloodless manner [7]. The development of the micromanipulator by Polanyi and Jako was a landmark development that allowed for microscopic precision on the vocal cord target with a no-touch technique, the other hand being free to grasp the pathology and/or suction the operative field free of secretions or debris [8]. The concurrent use of CO_2 laser with microlaryngoscopy by Polanyi, Jako, and Strong has greatly facilitated the now common practice of endoscopic excision of papillomas and early carcinomas [9].

With relatively little change in mortality since the 1970s, current clinical focus is not simply on improving survival, but on expanding the application of and indications for laryngeal preservation modalities to improve function and quality of life. Transoral laser microsurgery (TLM) is now a readily accepted modality of treatment of early stage laryngeal carcinoma, with indications for advanced stage tumors as well. It allows for the resection of tumor through a transoral approach with or without endoscopes using operating microscope visualization and laser tissue excision. It has provided a useful alternative to open laryngeal surgery and external beam radiation.

Principles of TLM

The term “LASER” was introduced as an acronym for light amplification by stimulated emission of radiation. The carbon dioxide laser was developed in 1963 by Kumar Patel (Bell Labs) and has become the workhouse for TLM of the larynx. The CO_2 laser functions primarily as a hemostatic scalpel when the beam is focused, with the ability to simultaneously cut and coagulate tissue. When the beam is defocused, the CO_2 laser can also be used effectively to ablate and cytoreduce epithelial disease such as diffuse papillomatosis [10]. Operating at a wavelength 10.6 μm in the infrared region, CO_2 lasers deliver nonionizing electromagnetic radiation that is well absorbed by water, which is ubiquitous in the laryngeal soft tissues.

The goal of TLM is no different than that of traditional open and endoscopic surgical techniques: to remove tumor completely with clear surgical margins. What distinguishes TLM from open surgery is that healing is allowed to occur by secondary intention and the tumor block can be subdivided into manageable units by the laser (in situ). While this violates the classic Halstedian principle of en bloc resection, extensive study by Steiner [11, 12] and others [13–15] has demonstrated that there is no sacrifice of oncologic control using a blockwise resection of the tumor in discrete segments. Successful oncologic and functional outcomes are routinely achieved, as long as several guiding principles are followed.

The first is that high powered magnification and bright illumination are used to visualize the cut surface. This represents a stark advantage over open surgery, in which tumor margins are grossly visualized with the naked eye or under minimal loupe magnification with a headlight. Under microscopic visualization, tissues reveal subtle information about their consistency as they are retracted. Cancer is either stiff or soft and friable, with dysmorphic architecture. Beyond the tumor, the expected microarchitecture is striated muscle, fat, seromucinous glands, fibrous perichondrium, cartilage, or bone, which can be distinguished by an experienced surgeon [16]. Additionally, tumor tissue takes on a different appearance than normal tissue after laser ablation, with more char on the tumor tissue. The ability to see these subtle differences in tissue content and vascularity allows for detailed real-time assessment of margins.

The second principle is that laser cutting with a spot size that can be focused to 250 μm and emitted in brief, microsecond pulses can be used to make precise cuts while allowing the tissue to cool in between pulses, thereby minimizing thermal damage to the surrounding tissue. Within the past decade, the development of the flexible fiber to deliver the CO_2 laser beam has added to the precision and also allowed for the ability to make tangential cuts out of the line of sight of straight laryngoscope delivery. The fiber consists of a hollow-core tube surrounded by a dielectric mirror, which allows the use of CO_2 either within a flexible endoscope or delivered through a hand-piece. Use of the CO_2 laser has been shown to seal the lymphatic vessels of the wound margin, which remain sealed for about 10 days after laser surgery [17, 18].

A third principle is to perform stepwise resection of blocks of tumor with clearance at each region or subsite before proceeding to the next area (Fig. 2). It is particularly important to carefully label and orient each specimen. Once the pathologist evaluates the

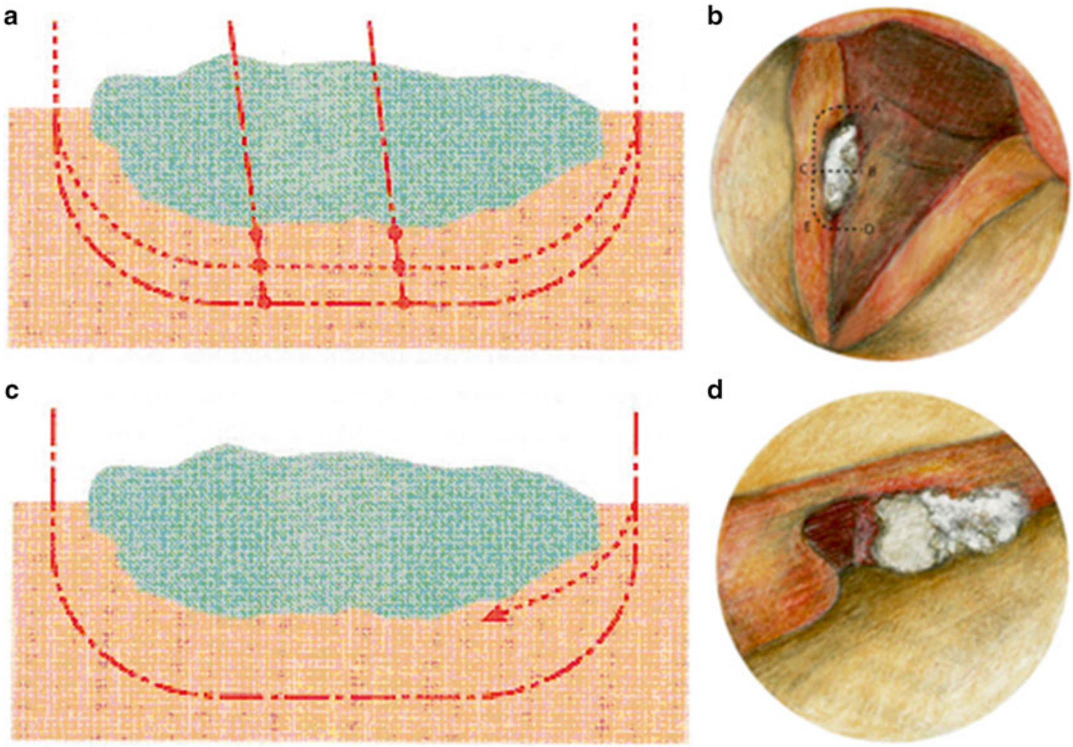

Fig. 2 Schematic and drawings showing (**a**, **b**) piecemeal removal of tumor and (**c**, **d**) en bloc resection

depth of tumor infiltration, basal clearance, and margins, re-excision of tissue at any positive or close margins can occur incrementally. This can be done at any time, since the wound is left open to heal and there is no risk of burying tumor under a reconstructive flap.

There are a number of reasons why en bloc resection is not required. First of all, cancer in the airway is already exposed. There is an open surface that allows direct visualization of an entire border of the cancer. Also, as the laser beam cuts through the tissue, there is no adherence of the cancer cells to it. With cold steel instrumentation, one of the concerns is that cancer cells can be seeded by the passage of the knife from diseased to healthy tissue. As mentioned above, lymphatics and small blood vessels are sealed with the laser cut, helping to prevent spread of cancer through those channels. The laser itself allows for photocoagulation of surface tumor cells and leaves a hostile environment for any cells that do get seeded.

The advantages of TLM are multiple. First, treatment of the larynx with TLM does not preclude any future possibilities for treatment, should there be recurrence or a second primary tumor. Re-excision with the laser, open excision, and radiation all remain treatment options. This is in contrast to external beam radiation, which leaves a salvage total laryngectomy as the only possibility in cases of recurrence [19].

Second, TLM has less morbidity than open approaches, which in many cases requires a temporary tracheostomy and possible feeding tube. With an approach to the tumor from inside the airway, there is no dissection through normal muscle, nerves, and cartilage, and the laryngeal framework continues to support and provide structure to the airway. This results in decreased rates of postoperative stenosis and allows for healing by secondary intention. There is also a decreased risk of fistula formation and lower chance of postoperative infection. All of this contributes to improved functional outcome and decreased length of hospital stay.

The precision of TLM results in minimal damage to adjacent tissue, which reduces healing time, wound contraction, scarring, and postoperative edema [20, 21]. There is also a delayed acute inflammatory reaction and reduced myofibroblast activity, which results in improved postoperative function with swallowing and speech [21]. Initial concerns about the accuracy of pathologic assessment of margins in TLM have largely been alleviated by studies that have shown that thermal damage on the borders of biopsy specimens does not interfere with the pathologist's establishment of a firm diagnosis [21].

Operative Technique

A thorough preoperative evaluation with accurate staging is critical for operative success. The lesion must be accurately visualized either in the office or through operative endoscopy, and histological confirmation of malignancy is mandatory. For larger tumors, preoperative MRI or CT scan imaging should be performed to evaluate depth of tumor invasion and presence of nodal metastases. Once the patient is in the operating room under general anesthesia, a confirmatory direct laryngoscopy is performed.

Prior to starting the laser resection, several laser safety measures should be implemented to minimize the risk of complications (Fig. 3a). The primary risks of the laser are burns to the patient and members of the operative team, so it is important to protect the patient's eyes with protective eye pads moistened with saline. Likewise, all operative personnel must wear protective eyeglasses. Signs are placed outside the operating room to indicate that a laser is in use. The facial skin is protected using surgical towels soaked in saline solution, and these towels need to be kept moist during the entire procedure. A smoke evacuator is used to remove laser plume created by the laser. A protected endotracheal tube designed to decrease the risk of ignition from laser impact is used. The cuff of the laser-protected tube is inflated using saline with methylene blue dye to help identify endotracheal tube cuff rupture and help prevent tube

Fig. 3 (**a**) Setup of patient with laser-safe eye protection and insertion of laryngoscope. (**b**) Laser surgery being performed under visualization with the operating microscope. Moist towels are used around the face to protect from the laser

ignition if there is cuff damage during the procedure. Irrigation solution is immediately available in the event of ignition of the drapes or other flammable materials. The oxygen concentration is also lowered to below 30 % FiO_2 when using the laser to decrease the likelihood of airway fire [22]. In the event of an airway fire, the endotracheal tube is immediately removed, the flow of airway gases halted, flammable material such as sponges are removed, and saline poured into the airway [23]. Once the fire is extinguished, the airway is re-secured, the endotracheal tube examined for missing fragments, bronchoscopy is performed, and the procedure is terminated.

Once the patient is prepared, the patient is placed in a supine position with the head fully extended. Upper dentition is protected using either a plastic or metal tooth guard. Using one of a variety of rigid laryngoscopes selected to visualize the desired structures, the larynx is visualized. Once adequate exposure of the tumor and surround structures is obtained, the laryngoscope is fixed using a suspension arm, which frees both hands for operative manipulation. The microscope is brought into position and the laser is coupled to the micromanipulator (Fig. 3b). Along with the invisible CO_2 laser beam, a coaxial helium–neon (He–Ne) laser aiming beam is used to align the laser to the target. Prior to surgery, the laser is tested to ensure both proper function and alignment of the CO_2 and He–Ne beams.

The procedure is begun by marking the peripheral margins using the CO_2 laser. The size of the margin depends on the location and stage of the tumor and whether the patient is undergoing primary treatment or resection of recurrent disease. If there has been prior RT, wider margins are taken because of the higher risk of an infiltrative pattern of spread through the tissues. For small glottic tumors, a margin of as little as 1 mm is necessary. For deep margins, several millimeters, and ideally a connective tissue barrier, are chosen for margins of resection.

Successful resection of tumors requires different techniques, laser energies, spot sizes, and pulse modes in order to perform the various tasks of tissue ablation, precise cutting, and coagulation of tissues. It is important to emphasize that for a given application, there are no fixed settings, and that practice patterns vary significantly by physician. Several laser parameters are selected for each particular case, including (a) power, (b) spot size, (c) exposure time, and (d) power (pulse) delivery. Laser energy can be delivered through intermittent pulses, repeated pulses, continuous wave (CW), or the use of very rapid (millisecond) pulse delivery in the form of ultrapulse or superpulse mode.

CW mode produces surrounding tissue damage from thermal spread of the laser energy. In order to produce adequate cutting and hemostasis with limited char formation and thermal spread, alternative pulse delivery modes have been developed to allow tissue cutting and hemostasis while limiting thermal damage to surrounding tissues. By producing high-energy, short-duration pulses in rapid succession, tissue ablation can occur with limited heat damage to surrounding tissues. The two most common modes, ultrapulse and superpulse, utilize slightly different strategies to produce rapidly pulsed waves that incorporate high peak power delivered in millisecond pulses.

Superpulse mode delivers short bursts (less than 1 ms) in rapid succession. The energy profile of the beam is characterized by a high initial peak energy spike with rapid drop in energy over duration of the pulse. The ultrapulse mode delivers a short pulse with a rapid peak onset, relatively constant energy delivery for the duration of the pulse, and rapid decline in power at the end of the pulse, approximating a square wave. The superpulse mode has higher peak energy but less total energy delivery per pulse and more rapid pulse delivery, while ultrapulse mode has lower peak energy in each pulse, higher energy delivered with each pulse, and longer duration between pulses [24, 25]. From a practical standpoint, the clinical differences between the two pulse modes are subtle, although the thermal damage from the superpulse mode is reported to be slightly greater than with ultrapulse mode [25].

Specially designed instrumentation, including microlaryngeal forceps, scissors, and insulated suction cannulae for cution and unipolar coagulation, are used to retract tissue or remove debris as the surgeon uses the micromanipulator to excise tissue (Fig. 4). As the tumor is removed in sections, the specimens are carefully labeled and oriented for the pathologist. Often, the marking ink used by pathologists is placed on the true margins in the operating room by the surgeon. Precise communication and collaboration with the pathologist is key in correctly interpreting margin status for these complex, three-dimensional specimens. In complicated cases, the specimen should be delivered to the pathologist by the surgeon to ensure correct orientation of the specimen.

Frozen-section margins are sent based on the surgeon's judgment of areas at greatest risk for recurrence. If positive margins are reported by the pathologist, additional tissue is removed until the margins are clear. Following resection, hemostasis is ensured, and the wound is left open without reconstruction to heal by secondary intention.

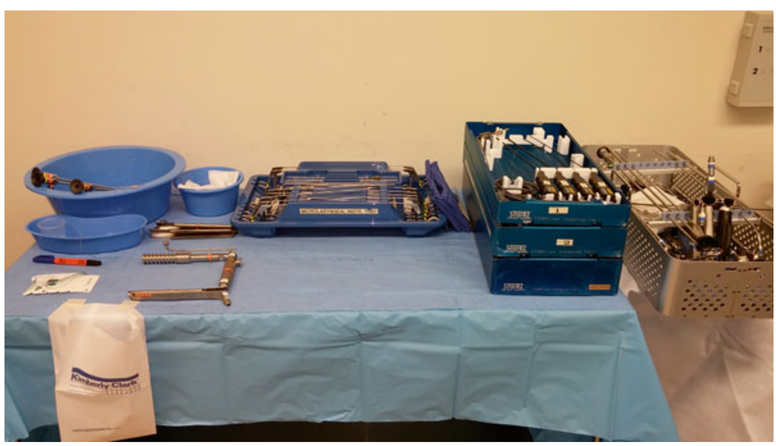

Fig. 4 Laser instrument table setup, with microlaryngeal instrumentation, endoscopes, insulated cannula suctions, and laryngoscope

Treatment of Glottic Cancer

Currently, regardless of treatment modality, the prognosis for Carcinoma in situ (Tis) and T1 lesions of the vocal cords is very good. Because of that, the goal of treatment has moved beyond simply cure and laryngeal preservation to include optimizing voice outcomes and minimizing cost and postoperative complications [19].

Small mid-cord tumors can be resected en bloc. When excised with narrow margins, the effect on the voice is comparable to treatment with RT. More extensive lesions are removed in sections with 1–3 mm margins (Fig. 5). A review performed by Ambrosch in 2007 revealed a 5-year local control rate of 80–94 % for Tis-T2a glottic carcinomas [19]. This is comparable to the local control rate of open partial laryngectomy (90–98 %) and avoids the short-term complications of open surgery [26, 27]. Because the approach to the tumor is from the inside of the airway, no breach of the laryngeal framework is needed for access. This allows for preservation of the strap muscles and obviates the need for a tracheostomy, thus resulting in shorter hospital stays and improved swallowing outcomes postoperatively.

The 5-year local control rate for TLM is also equivalent to that of external beam RT (approximately 81–90 %). Additionally, postoperative voice quality of life is comparable between the two treatment modalities [28]. However, TLM has been shown to be a much more cost-effective option [29, 30]. Furthermore, for T1 tumors, occasionally the tumor is removed with the initial diagnostic biopsy. TLM allows for assessment of residual tumor intraoperatively, thus avoiding unnecessary radiation in such cases. With organ preservation rates being similar (>94 %) in all three modalities, TLM remains a very attractive option for treatment of Tis and T1 tumors of the glottis. With regard to T2 lesions, the local control rate of TLM is actually higher than XRT (64–87 %), with better organ preservation rates (75–87 %) [26, 31, 32].

When early glottic carcinoma involves the anterior commissure, there is conflicting data about the effectiveness of TLM [33]. Steiner reviewed 263 cases and found that involvement of the anterior commissure affects local tumor control and organ preservation in T1/2 lesions, but does not affect overall survival [34]. Others have shown much higher recurrence rates than reported by Steiner after TLM in cases with anterior commissure involvement and recommended supracricoid partial laryngectomy as the treatment of choice in those cases [35].

While this may partially be attributed to inadequate tangential exposure at the anterior commissure, it is thought that inadequate diagnostic (under)-staging plays a contributing role to high recurrence rates. RT has also been shown to have high recurrence rates in anterior commissure involvement 57–85 % [36], supporting the

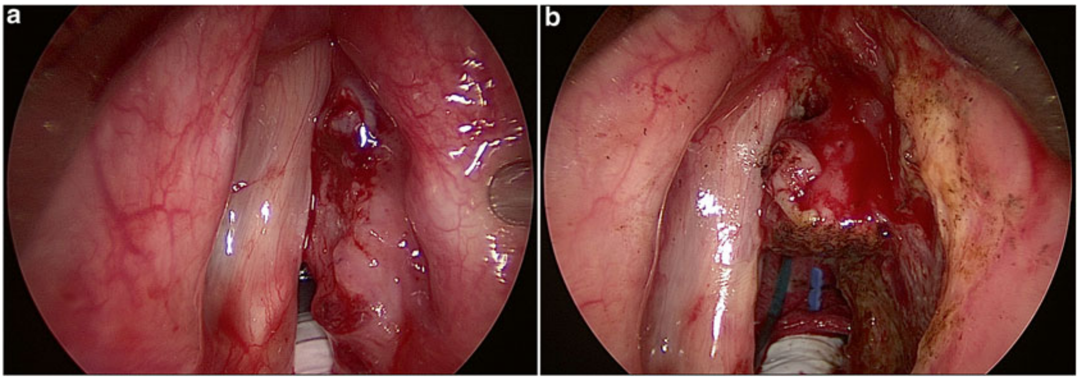

Fig. 5 (**a**) T1 right true vocal cord squamous cell carcinoma prior to laser excision, as viewed through laryngoscope. (**b**) Undergoing piecemeal excision, with the posterior portion removed. Laser-safe endotracheal tube is in view

notion that recurrence is not simply a matter of obtaining surgical exposure and proper operative technique.

Other studies have demonstrated that initial clinical evaluation failed to identify tumor invasion of the laryngeal cartilages and extra-laryngeal soft tissues resulting in a low staging accuracy of 45 %. The combination of clinical evaluation, endoscopic evaluation, and either CT or MRI imaging resulted in significantly improved staging accuracy of 80–87 % [37–39]. Because of this, it is recommended that tumors involving the anterior commissure receive axial helical CT scans reformatted with sagittal and coronal 1.0 mm cuts as part of the diagnostic workup [39].

For more advanced glottic carcinomas (T2b-3), published data on TLM is more scarce. If there is invasion into the paraglottic space, incisions are made laterally into the thyroid cartilage and inferiorly to the cricoid cartilage in order to clear disease. Ambrosch et al. published the largest series of T2b-3 lesions ($n = 167$) and found the 5-year local control rate was 74 % for pT2b carcinomas and 68 % for pT3 carcinomas. The respective secondary laryngectomy rates were 13.4 and 14.3 % [40]. The 5-year disease-free survival rate for both groups was 62 %. No patients required tracheostomy during the initial surgery, and postoperative speech and swallow function was fully rehabilitated.

Treatment of Supraglottic Cancer

Early stage supraglottic cancers have a tendency to be contained to within the boundaries of the supraglottic larynx and pre-epiglottic space. The traditional open approaches to these tumors have been the horizontal supraglottic laryngectomy, developed in 1939 by Alonso [41], and the supracricoid partial laryngectomy with cricohyoidopexy (SCPL-CHP), popularized within the last 25 years by Laccourreye [42]. For T1 lesions, the local control rates are reported to be 90–100 %, and 80–97 % for T2 lesions with open surgery. External beam radiation has shown local control rates of 77–100 % for T1 and 62–83 % for T2 lesions [19]. Tumor volume as assessed by preoperative CT imaging was the most significant prognostic factor involved in local control [43].

The first description of TLM for supraglottic cancer was by Vaughan in 1978 [44]. Subsequent refinement of the laryngoscopy equipment over the next 15 years, led by Steiner and his Goettingen University group, allowed for maximal exposure of the surgical working field. Working with Karl Storz, Inc, he helped to develop instruments that were robust enough to grasp tissue, coagulate, and apply clips endoscopically. Typically, ordinary tubular laryngoscopes are not suitable for procedures in this area and bivalved laryngoscopes with spreadable blades are used [45]. With increasing experience and meticulous follow-up, Steiner and his group were able to expand the indications of TLM from early glottic carcinoma to more advanced T stages of all sites of the larynx [11]. Based on the extent of resection that can be safely performed, most authors currently consider T1, T2, and selected T3 supraglottic cancers as indications for TLM.

Smaller tumors along the free margin of the epiglottis and the aryepiglottic fold can be excised en bloc. In fact, excisional biopsy alone of suspicious lesions may be curative in some cases of T1 and T2 tumors [46]. A review by Rodrigo et al. in 2008 revealed a 5-year local control rate of 88 % in T1 lesions and 89 % in T2 lesions [47], with a number of studies showing 100 % control in either T1 or T2 lesions using TLM [14, 48, 49].

Larger tumors require resection of the tumor in multiple sections with intraoperative frozen-section analysis. However, local control rates for T3 lesions are somewhat less favorable after treatment with TLM. Iro et al. found a 33.3 % recurrence rate in a series of 15 T3 lesions [50]. Rudert found a 22 % recurrence rate in a series of 9 T3 lesions [14] and concluded that those tumors that are upstaged due to pre-epiglottic space invasion are amenable to endoscopic resection. This was corroborated by Ambrosch et al., who reviewed a series of 41 T3 lesions, mostly as staged as a result of pre-epiglottic space invasion. 13 (26 %) of these required postoperative external beam radiotherapy due mostly to cervical metastases. The 5-year local control rate was 86 %, though 4 % of patients required total laryngectomy for recurrent disease [40].

With open supraglottic laryngectomy, local control rates exceed 90 % for T1 and T2 cancers, but the results drop to between 70 and 90 % for T3 cancer [19, 51]. The SCPL-CHP has been shown to have very low recurrence rates for T3 lesions (0–7 %) and may be an oncologically more effective alternative to TLM and standard open approaches when available. In the last 25 years, it has broadened the options available for treating larynx cancer by bridging the gap between the partial supraglottic laryngectomy and total laryngectomy [52]. SCPL-CHP includes resection of the entire epiglottis and the pre-epiglottic space, anterior vocal folds, and anterior commissure. In order for speech and swallow to be possible after this surgery, the resection must allow for preservation of at least one intact cricoarytenoid unit and an intact cricoid cartilage. However, even with this, voice outcome is poor, with a rough, low-frequency phonation from vibration of the arytenoids against the tongue base impacted onto the cricoid. Aspiration, which can be intractable, is more likely with this procedure, especially when arytenoid function and height is affected. Data has shown primary radiotherapy to be an inferior treatment alternative to either open or TLM surgery for early supraglottic lesions, with local control rates of 77–100 % for T1 cancers and 62–83 % for T2 cancers.

The endoscopic approach of TLM provides several distinct advantages over open resection: tracheotomies can generally be avoided, the incidence of pharyngocutaneous fistulas is markedly reduced, rehabilitation of swallowing is faster, the incidence of aspiration pneumonia is lower, and hospital stay is shorter [47]. Regardless of the surgical technique employed, negative margins are essential in limiting local recurrence. Additionally, supraglottic carcinomas have a high incidence of regional lymph node metastasis, ranging from 25 to 50 %. Lymph node metastasis is the most important prognostic factor in supraglottic cancer [47]. Because of this, most authors recommend that selective neck dissection be performed even in patients with stage I and II disease. In patients with known cervical metastasis, neck dissection combined with postoperative external beam radiotherapy offers the best chance of regional control.

Complications

In general, TLM is well tolerated with low complication rates and generally improved functional outcome compared to corresponding open procedures resecting the same size tumor. Early postoperative hemorrhage is a potentially lethal complication. The incidence of postoperative hemorrhage is similar in both endoscopic and open approaches and ranges from 3 to 14 % [47]. Often there will be a small amount of bleeding, but significant bleeding from a major artery in the larynx can result in aspiration of blood into the airway. Because TLM patients typically do not undergo a tracheotomy, endolaryngeal bleeding is especially concerning due to the risk of blood loss, aspiration, and hypoxia. It is thus recommended that larger vessels are clipped rather than cauterized intraoperatively. In the case of a severe postoperative bleed, it is critical to secure the airway, either by endotracheal intubation or by performing an urgent tracheostomy, followed by operative control of hemorrhage.

Airway obstruction is uncommon, as resection of the tumor generally provides an airway that is more widely patent following surgery. Since the neck is not incised, there is much less postoperative swelling and edema that characterizes open surgical procedures on the larynx. However, prolonged tongue retraction and compression during long operations can result in soft tissue ischemia and in tongue edema postoperatively. Additionally, prolonged displacement of the tongue by the laryngoscope during surgery can cause temporary lingual or hypoglossal paresis. In cases lasting more than 1–2 h, periodically releasing suspension to allow blood flow to the tongue markedly decreases the likelihood of developing postoperative tongue swelling or nerve dysfunction. The neuropathy caused by retraction is temporary and generally resolves over several weeks.

Aspiration can be caused by extensive resection, preexisting laryngeal impairment, advanced age, or poor health. Preoperative and postoperative assessment to determine the risk for aspiration is necessary to prevent development of aspiration pneumonia. Other complications encountered include mucosal burns of the lips, oral cavity, or oropharynx, dental injuries (loosened or chipped teeth), infection, dysphagia, chondroma or granuloma formation, and airway fires or burns.

Future Directions/Challenges

The functional and oncologic efficacy of TLM for early stage glottic lesions has been proven and is now well accepted as an effective treatment approach. Along with transcervical surgery, SCPL-CHP, and external beam radiation, it is an important piece of the surgeons' armamentarium against laryngeal carcinoma. There are extensive data on oncologic control and increasing data on voice outcome.

There is a steep learning curve for TLM. One of the keys to successful TLM surgery is exposure of the larynx, which requires both an adequate assortment of laryngoscope and advanced endoscopy skills. Additionally, time must be dedicated to becoming skillful at using the laser and microscope, whether it is with a micromanipulator or a handheld flexible fiber. TLM also necessitates an understanding of the detailed anatomy of the larynx from the "inside out." It requires the surgeon to be able to visualize and three dimensionally reconstruct endoscopic views.

An additional challenge of TLM is that it is difficult to teach to surgeons-in-training. The tactile feedback of dissecting tissues with the laser can only be honed with experience. Additionally, it can be difficult to maintain orientation of the three-dimensional (3-D) field when surgeons take turns alternating visualization through the primary lens. Visualization in a teaching arm or two-dimensional monitor does not capture the same views, and it is thus difficult to ensure oncologic resection.

Over the last decade, transoral robotic surgery (TORS) has emerged as a treatment option, with the ultimate goal of optimizing oncologic management while even further reducing treatment morbidity. Hockstein et al. demonstrated the ability of the robot to provide 3-D images through a dual endoscope mechanism within laryngeal mannequins [53]. Weinstein and O'Malley subsequently showed efficacy in humans with supraglottic laryngectomy and partial pharyngectomy [54–56]. In addition to 3-D images, robotic instrumentation provides a wide range of motions unavailable with traditional endoscopic instruments, scaling of movement, where large movements of the hands produce only small movements in the robotic instruments, and robotic dampening of hand tremors. Because of the maneuverability of the robotic arms, TORS has a benefit over traditional transoral laser surgery that is limited by the laser's line of sight. While it is commonly used in the oropharynx, it has yet to garner widespread acceptance in the larynx, where the ability to expose structures and manipulate instruments is limited by the size of the currently available robotic arms and the limited available instrumentation designed for prostate and gynecologic procedures. As advancements in robotics and optics continue to be made, further refinements will expand the indications and uses of robotic approaches.

Currently, TLM is a proven, minimally invasive alternative to open surgery for T1, T2, and selected T3 tumors of the glottis and supraglottis. The results of TLM are comparable to open partial laryngectomy procedures and RT in terms of local control and survival rates. With its low postoperative morbidity, TLM represents an attractive means to surgically remove cancer while preserving the laryngeal framework. In an era of emphasis on organ preservation and minimizing the cost of healthcare, TLM is an affordable option that allows for optimization of functional outcomes without sacrificing oncologic principles.

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