Laryngeal Robotic Surgery

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9.1 Background

Laryngeal cancer has seen a variety of treatment modalities through history. Originally in a surgical disease managed by total laryngectomy, larynx-preserving treatments evolved with the development of partial laryngectomy techniques (both open and endoscopic). These partial techniques allow for the maintenance of a unified aerodigestive tract through which a patient is able to phonate, breath, and swallow. Since the publication of the Department of Veterans Affairs Laryngeal Cancer Study Group results, showing patients with advanced laryngeal cancer who received chemoradiation therapy had equivalent survival to patients treated surgically, and 64% of patients were able to preserve their laryngeal function for some period of time after surgery [1]. Therefore, partial laryngeal surgery and total laryngectomy became less commonplace as chemoradiation became the favored treatment modality for early-stage disease. Initial laryngectomy does tend toward improved survival in patients with T4 disease, and generally these patients have poor function to begin with and are good candidates for laryngectomy [2]. As patients who have received chemoradiation are followed longer, late complications of chemoradiation therapy have been found to be extremely debilitating, causing long-term problems with swallowing, breathing, and vocal function. The addition of chemotherapy to radiation improves survival between 8% and 15% [3], but also increases the severity of the functional side effects [4]. These effects significantly impact patient quality of life, and a significant portion of patients ultimately requires total laryngectomy for nonfunctional larynx [5]. Therefore, there is an increasing interest in minimally invasive partial laryngeal surgery to treat limited disease and prevent the need for functionally devastating adjuvant treatment.

As for minimally invasive, natural orifice surgery, there are two major treatment modalities for the larynx: transoral laser microsurgery (TLM) and transoral robotic surgery (TORS). TLM has a fairly long history, with descriptions of use for laryngeal cancers as early as 2002 [6]. TLM has been shown to be successful and equivalent to open partial laryngeal surgery in terms of survival and cure of primary cancer with excellent

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functional outcomes [7–14]. In TLM, a microscope, laser, and microdissection instruments are used to remove tumor through a rigid endoscope. Generally the tumor is removed in sections, and the margins are evaluated intraoperatively to insure clearance of the tumor. TORS for laryngeal surgery on the other hand has a more limited history. Initial work in 2005 in a canine model showed the ability to perform glottic and supraglottic procedures with the assistance of the da Vinci robot [15, 16]. The first case series of supraglottic laryngectomy in three humans was published in 2007 by Weinstein et al. [17]. TORS differs from laser microsurgery in several regards. First, a binocular endoscope provides a high-definition three-dimensional image of the surgical field. Second, the wristed action of the instruments allows for increased dexterity. Furthermore, the robot can reduce tremor allowing for increased precision. These attributes often allow the tumor to be completely resected under direct visualization. There has been no direct study of survival or functional outcomes comparing TLM and TORS. However, these endoscopic methods have improved swallowing outcomes as compared to chemoradiation therapy [11, 18–22]. With transoral robotic resection of the supraglottic larynx, the need for tracheostomy, as standard in open partial laryngeal surgery, is avoided. This chapter will focus on the current status and future of robotic laryngeal surgery.

9.2 Anatomical Considerations

The larynx is the gatekeeper to the airway and has three important functions. First, the larynx must divert solid and liquid boluses from the airway and into the hypopharynx. Second, it must open to allow air passage during respiration. Finally, it must allow contact of mucosal edges to generate acoustic vibration during phonation. The ultimate goal of partial laryngeal surgery is to maintain a unified aerodigestive tract and preserve these three functions. Therefore, patients should have an intact glottis with normally functioning vocal cords to be a candidate for TORS supraglottic laryngectomy and expect a reasonable functional outcome. The glottic level is the only barrier to aspiration after supraglottic laryngectomy and thus must be preserved.

As with all transoral surgery, the surgeon must be familiar with inside-out anatomy when performing robotic laryngeal surgery. In this chapter, we focus on the supraglottic larynx where robotic surgery has proven most useful to date. The supraglottic larynx is comprised of the laryngeal surface of the epiglottis, the aryepiglottic folds, the arytenoids, the false vocal cords, and the laryngeal ventricle. The region is bound by the vallecula, preepiglottic space, and hyoid bone anteriorly, the pharynx and hypopharynx posteriorly, and the true vocal cords inferiorly. The anatomical subunit removed in

TORS supraglottic laryngectomy includes the epiglottis, the preepiglottic space and paraglottic space contents, the aryepiglottic folds, the false vocal cords, and the ventricular mucosa. Extended approaches can be utilized where a small amount of tongue base, limited portions of the medial piriform sinus wall, and small amounts of arytenoid mucosa can be resected to gain adequate margins.

Endoscopic inspection of the supraglottis reveals the pharyngoepiglottic fold, through which runs the superior laryngeal artery and the internal branch of the superior laryngeal nerve as seen in Fig. 9.1. This neurovascular bundle provides the majority of the blood flow and sensory input to the supraglottic larynx. Surgical control of the artery and its branches with either hemoclips or electrocautery is essential to prevent postoperative bleeding complications. In our experience, branches of the artery medial to the hyoid bone can be controlled with targeted electrocautery alone. Any branches of the superior laryngeal nerve should be preserved if possible to allow for sensation to the superior glottis to help with prevention of aspiration. However, it often must be transected to allow for appropriate oncologic resection [23].

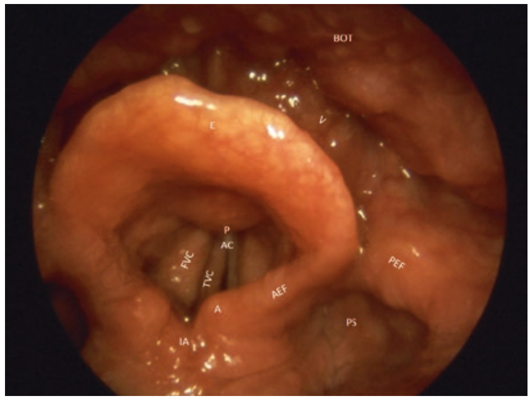

Fig. 9.1 Endoscopic view of the normal larynx, labeled with surface anatomy. base of tongue (BOT); Vallecula (V); Petiole (P); false vocal cord (FVC); true vocal cord (TVC); arytenoid (A); aryepiglottic fold (AEF); epiglottis (E); Anterior commussure (AC); interarytenoid (IA); Pyriform sinus (PS); Pyriform epiglottis fold (PEF)

9.3 Preoperative Planning

Through experience with open partial laryngectomy and TLM procedures, guidelines for patient selection for transoral supraglottic laryngectomy have been developed. The authors have organized this into inclusion and exclusion criteria as shown in Table 9.1 and Table 9.2 [24]. TORS supraglottic laryngectomy is not necessarily contraindicated in patients with a history of prior radiation therapy; however, exposure may be challenging secondary to trismus and neck scarring, and tissue planes may not be well preserved.

Exposure of the supraglottis is perhaps the most challenging portion of a transoral robotic supraglottic laryngectomy. There are several major commercial retractors for obtaining adequate exposure, namely, the Feyh-Kastenbauer retractor, the Fentex Medical LARS retractor, and the Medrobotics Flex retractor. The LARS and Flex retractors were designed specifically for robotic use, whereas the Feyh-Kastenbauer retractor predates transoral robotic surgery and was modified by O'Malley and Weinstein for use in TORS. Both are adequate and retractor selection is ultimately a matter of personal preference. It is a luxury to have both available to optimize exposure in individual patients. Placing the operating bed in a slight Trendelenburg position may be useful in accommodating the robotic arms.

Often when exposure is difficult, the instinct is to open the retractor as wide as possible. However, experience indicates that increasing the mouth opening at the level of the teeth is not helpful in better exposing the supraglottic larynx and is in fact counterproductive. As the mouth opens wider, the tongue blade actually begins to rotate toward the posterior pharyngeal wall blocking access for the endoscope and robotic arms. The key to exposure is opening the mouth just enough to allow entry of the instruments while lifting the tongue base forward. As compared to oropharyngeal exposure, the angle of the workspace is more parallel to the axis of the posterior pharyngeal wall as shown in Fig. 9.2.

Table 9.1 Indications for TORS-SGL

T1 or T2 supraglottic carcinoma
Selected T3 supraglottic carcinoma
Preepiglottic space invasion
Ability to preserve 50% of the tongue base with an oncological resection
Mobile vocal cords
Minimal piriform sinus involvement
Ability to achieve adequate transoral exposure of the tumor and its margins

Table 9.2 Contraindications for TORS-SGL

Vocal cord fixation
Bilateral arytenoid cartilage involvement
Thyroid or cricoid cartilage involvement
Anterior or posterior commissure involvement
Poor pulmonary reserve (FEV1/FVC <50%)

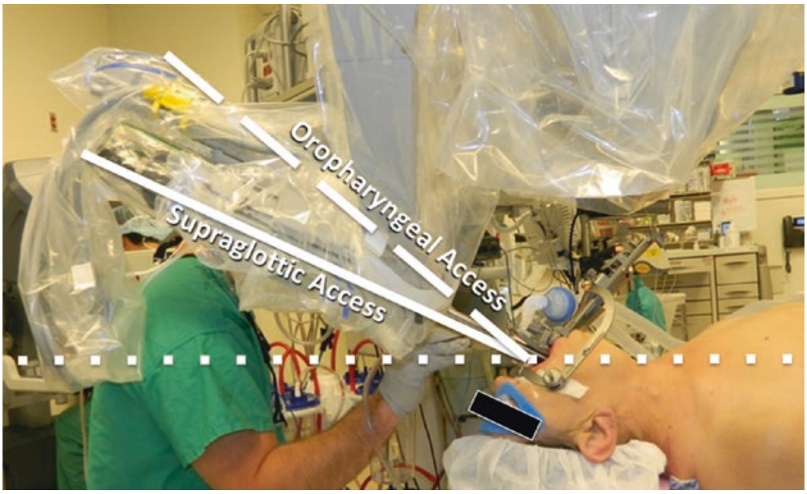

Fig. 9.2 Positioning of the robotic arms for TORS supraglottic laryngectomy differs as compared to oropharyngeal surgery. The angle of approach is less steep as demonstrated in this diagram. The dotted line represents the long access of the patient's body. The dashed line represents the steep trajectory utilized for oropharyngeal TORS with a 0° endoscope. The solid line demonstrates the more gradual angulation of the robotic arms used to access the supraglottis and visualize this area with the 30° endoscope

9.4 Procedural Considerations for TORS Supraglottic Laryngectomy

Transnasal intubation is preferred for supraglottic laryngectomy, as this allows the tube to lie along the posterior pharyngeal wall. A reinforced or laser safe tube may be considered to decrease risk of violating the tube with the electrocautery. The fraction of inspired oxygen should be kept at or below 30% to prevent airway fires while electrocautery is being utilized. Intraoperative airway dose steroids (i.e., 10 mg dexamethasone IV) are given to help reduce edema.

An articulating Bovie, a Maryland dissector, and an anteriorly facing 30-degree endoscope are the most commonly utilized instruments for this procedure. An assistant at the head of the bed, as seen in Fig. 9.2, utilizes two Yankauer suctions to evacuate smoke, secretions, and blood, while also providing additional tissue retraction as needed.

The preferred retractor is placed carefully into the oral cavity, using caution to prevent damage to the teeth and lips. Once the retractor is in place, the 30-degree endoscope can be used to check the exposure before docking the robot.

Once exposure is adequate, the robot is docked and the arms are positioned. The Bovie and the Maryland dissector may need to be switched at some point through the case to prevent crossing of the robotic arms and to provide adequate tissue retraction.

Some authors have advocated splitting the supraglottic laryngectomy specimen and begin the procedure by dividing the epiglottis down the midline. With adequate exposure, the authors advocate for an en bloc resection.

9.5 Step-by-Step TORS Supraglottic Laryngectomy

A case example is given here to demonstrate the steps of a TORS supraglottic laryngectomy. Figure 9.3 demonstrates the preoperative in office endoscopy showing a supraglottic tumor on the laryngeal surface of the epiglottis. Figure 9.4 shows the step-by-step procedure with corresponding commentary below.

Image 1 Robotic exposure of the supraglottic larynx is shown here. The tongue blade is placed in the vallecula holding the tongue base forward. The ulcerative lesion can be seen on the laryngeal surface of the epiglottis. A reinforced endotracheal tube is utilized to prevent damage to the tube and decrease risk of airway fire

Image 2 Prior to making mucosal incisions, the tumor is inspected under 3D HD visualization to verify candidacy for TORS supraglottic laryngectomy. Demonstrated here the right arytenoid complex and true vocal cord are visualized to ensure they are free of tumor. Other key areas to examine include the anterior commissure, the vallecula, and the contralateral arytenoid and true vocal cord

Image 3 The right-sided mucosal incision is made in the vallecula and toward the tongue base, cutting toward the tongue blade. As this area is traversed, the branches of the superior laryngeal neurovascular bundle may be encountered. Generally the bleeding can be controlled with electrocautery when these vessels are transected medial to the hyoid bone. Any large vessels should be controlled with hemoclips applied transorally

Image 4 A similar mucosal incision is made in the contralateral lateral vallecular region and onto the tongue base. This incision is deepened down and carried forward including a small cuff of tongue base anterior to the vallecula

Image 5 Dissection is carried on in an anterior direction, almost cutting upward and beyond the tip of the tongue blade as shown here. The internal surface of the hyoid bone should be identified. The hyoid can be identified by palpation of the tissue with the robot. This results in mass movement of the entire hyoid bone, making a bilateral mass movement that is distinct from the movement seen when palpating soft tissue alone. Transcervical palpation can also aid in identification of the hyoid bone. Note that the tongue blade can push the hyoid bone anteriorly, and the hyoid will not be encountered with dissection, as it will be on the other side of the retractor. Adjusting the retractor to release the hyoid bone may be necessary

Image 6 Here the two vallecular cuts have been joined in the midline. Dissection has been carried down to reveal the superior border of the thyroid cartilage. Again, palpation is useful in identifying this landmark. At this point, the pre-epiglottic contents are removed off of the internal aspect of the thyroid cartilage. Dissection is carried only partially inferiorly in this region to prevent disruption of the anterior commissure

Image 7 With the anterior attachments released, dissection focuses on the posterior aspect attachments. In this example, the lesion was essentially midline; however, it is generally best to start on the side with the least amount of disease. As the procedure continues, the exposure of the contralateral side will improve allowing for better determination of adequate margins

Image 8 Here the aryepiglottic fold is being transected just anterior to the arytenoid complex. Small portions of the superior arytenoid and the arytenoid mucosa can be resected to gain adequate margins. At times, extension of these cuts onto the medial wall of the piriform sinus and removing some of this mucosa may be necessary

Image 9 The paraglottic space contents and false cords are released from their posterior attachments near the arytenoid, and the ventricle is identified. Here the posterior aspect of the laryngeal ventricle is being entered. Anterior to the Bovie tip, a small hole in the false cord can be seen showing the ventricular space and the true vocal cord lying below

Image 10 The dissection is then carried forward toward the anterior commissure, releasing all of the paraglottic space contents on the right. The anterior commissure is checked carefully again to ensure the disease is completely cleared

Image 11 The petiole region is divided and the contralateral vocal cord is now visible. Anterior attachments are divided at the level of the laryngeal ventricle. Placing the tip of the electrocautery in the ventricle and cutting upward through the false cord, while ensuring no contact with the true vocal cord below, can be a useful maneuver to release this area

Image 12 Now the posterior cuts are made on the contralateral arytenoid region. Here a mucosal incision from the posterior ventricle along the anterior surface of the arytenoid is made leaving the arytenoid and its mucosa intact

Image 13 The remaining lateral attachments of the paraglottic space contents, false cords, and ventricular mucosa are released

Image 14 The specimen is nearly free at this point and the uninjured vocal cord can be seen deep to the ventricle

Image 15 The assistant grasps the tip of the epiglottis to remove the supraglottis en bloc. The orientation of the lesion is noted prior to removal from the pharynx. The specimen should be immediately oriented with sutures or surgical clips once it is removed

Image 16 The final defect shows the bilateral true vocal cords and preserved arytenoids with absent false cords and the surrounding paraglottic tissues. The anterior commissure is preserved without injury

Following removal of the specimen, margins may be taken from the specimen itself or from the surgical bed. Taking adequate tissue and preventing char are critical in margin analysis. Often standard cupped forceps can be utilized to take samples from the margins and prevent further cautery artifact. The surgical site is then irrigated copiously and complete hemostasis is achieved.

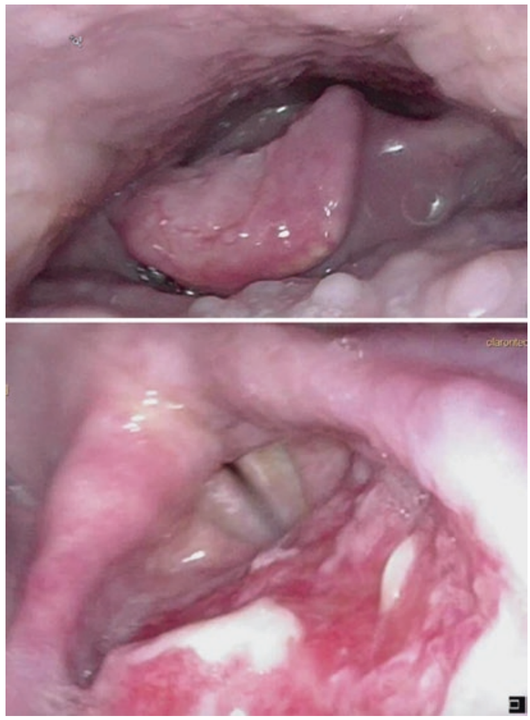

Fig. 9.3 Preoperative endoscopy demonstrating an ulcerative lesion on the laryngeal surface of the epiglottis. Preoperative evaluation consists of careful inspection of the lesion to determine candidacy for supraglottic laryngectomy. The arytenoids, aryepiglottic folds, vallecula, tongue base, piriform sinuses, anterior commissure, and true vocal cords. Here there is ulceration extending to the tip of the epiglottis from the laryngeal surface; however, the lingual surface, vallecula, and tongue base are clear. The disease is contained within the limits of the aryepiglottic folds and extends toward the anterior commissure, but on closer inspection (not shown here), there was adequate margin between the lesion and the commissure

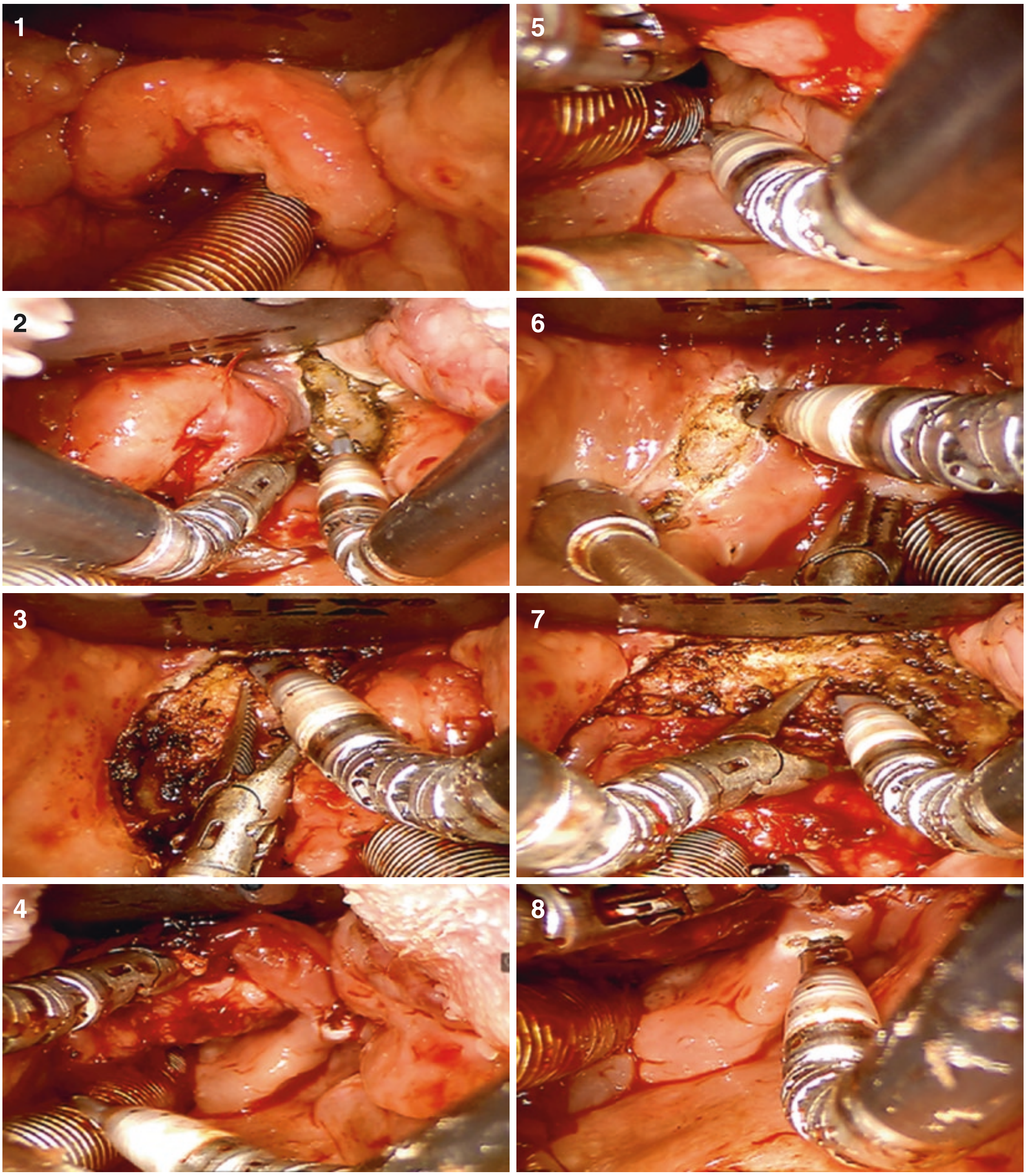

Fig. 9.4 Step-by-step TORS supraglottic laryngectomy intraoperative photos. See text for descriptions of each step depicted

Fig. 9.4 (continued)

9.6 Postoperative Considerations

Patients are generally able to be extubated in the operating room; however, delayed intubation may be considered if the surgeon has concern for airway obstruction postoperatively. Following recovery from anesthesia, patients are transferred to a monitored unit. Emergency airway equipment should be readily available. Dexamethasone can be given at an interval of every 6–8 h to assist with airway edema during the first 24–48 h. Three days of antibiotics and 6 weeks of proton pump inhibitors are prescribed during the postoperative phase. The speech and swallow therapy team sees the patient on postoperative day one, and a bedside swallow evaluation is conducted, and the diet is advanced as tolerated. The majority of these patients are able to resume adequate nutrition transorally and a nasogastric tube is not required.

Patients are discharged from the hospital once they achieve adequate nutrition either orally or via nasogastric tube, vital signs are stable, and pain is controlled. Average hospital stay at the author's institution is 4 days [18, 24].

9.7 Complications of TORS Supraglottic Laryngectomy

Complications arising from TORS supraglottic laryngectomy are no different than other TORS subsites. Airway compromise and bleeding are two major immediate postoperative concerns, and they should be managed as in other subsites. Acute airway compromise warrants reintubation. Bleeding patients should be intubated or have a tracheostomy performed to protect the airway. Bleeding should be controlled in the operative setting using electrocautery and hemoclips as indicated. Endovascular or open control of cervical blood vessels may also be indicated if transoral control cannot be obtained. Late complications include dysphagia, dysphonia, and laryngeal stricture. Dysphagia and dysphonia are managed conservatively with the use of speech and swallow therapy. Laryngeal stricture may require revision surgery with lysis of adhesions. During the initial procedure, care should be taken to prevent violation of opposing mucosal surfaces to prevent adhesive scarring. The anterior and posterior commissures are most prone to this type of scarring.

9.8 Outcomes of TORS Supraglottic Laryngectomy

Robotic supraglottic laryngectomy is now a standard TORS procedure, although compared to oropharyngeal TORS, there is substantially less data. Ozer et al. published a case series of 13 patients who underwent TORS supraglottic laryngectomy demonstrating safety and good functional outcomes. All 13 patients were able to be resected to negative margins and 11 were able to tolerate an oral diet within 24 h [18]. Survival data in this population is limited, with Olsen first reporting a 2-year disease-specific survival of 88% in 9 patients [25] and Mendelsohn et al. reporting 2-year survival data in 18 patients (local regional control 83%, disease-specific survival 100%, overall survival 89%) [19]. Park et al. showed a 2 year disease-free survival rate of 91%. These patients were matched to a cohort of patients who underwent open supraglottic laryngectomy, and the TORS group demonstrated earlier oral feeding, decreased time to decannulation, and decreased hospital stay [26]. Factors predictive of difficulty with swallowing include being male, patients with T3 tumors, postoperative vocal fold hypomobility, or undergoing simultaneous neck dissection [19]. These results suggest that TORS supraglottic laryngectomy is a valuable tool for managing patients with supraglottic tumors and warrants continued study.

9.9 Frontiers in Laryngeal TORS

Several other robotic laryngeal procedures other than supraglottic laryngectomy have been described in the literature. These include cordectomy and the removal of an assortment of benign laryngeal lesions [27, 28, 29]. Perhaps the most intriguing newly described procedure is the robotic-assisted total laryngectomy. Smith et al. published a multi-institutional series of seven patients who underwent attempted transoral robotic laryngectomy [30, 31]. Five of the procedures were completed successfully, while two required conversion to a standard open approach. The authors suggest that this procedure might be particularly valuable in surgical salvage patients and in patients with nonfunctional larynx after radiation therapy. The limited dissection is thought to potentially lead to fewer wound healing complications. Further study is required before this technique will become widely endorsed. A description of the procedure can be found in the original articles [18, 19].

Conclusion

TORS laryngeal surgery is a useful tool for patients with laryngeal disease. Supraglottic laryngectomy has become a standard procedure for patients with limited supraglottic disease. To date, the results indicate equivalent local control and survival to other standard approaches. Outcomes also suggest acceptable morbidity of the TORS approach. The future role of robotic laryngeal surgery may include robot-assisted total laryngectomy. As technology improves and new robotic systems are developed, the ability to perform intricate tasks within the larynx will likely expand our abilities to better treat glottic and subglottic lesions.

References

1. Induction chemotherapy plus radiation compared with surgery plus radiation in patients with advanced laryngeal cancer. N Engl J Med. 1991;324(24):1685–90. doi:10.1056/NEJM199106133242402.
2. Gourin CG, Conger BT, Chris Sheils W, Bilodeau PA, Coleman TA, Porubsky ES. The effect of treatment on survival in patients with advanced laryngeal carcinoma. Laryngoscope. 2009;119(7):1312–7. doi:10.1002/lary.20477.
3. Pignon JP, le Maître A, Bourhis J, and MACH-NC Collaborative Group. Meta-analyses of chemotherapy in head and neck cancer (MACH-NC): an update. Int J Radiat Oncol Biol Phys. 2007;69(2 Suppl):S112–14. doi:10.1016/j.ijrobp.2007.04.088.
4. Machtay M, Moughan J, Trotti A, Garden AS, Weber RS, Cooper JS, Forastiere A, Ang KK. Factors associated with severe late toxicity after concurrent chemoradiation for locally advanced head and neck cancer: an RTOG analysis. J Clin Oncol. 2008;26(21):3582–9. doi:10.1200/JCO.2007.14.8841.
5. Theunissen EAR, Timmermans AJ, Zuur CL, Hamming-Vrieze O, de Boer JP, Hilgers FJM, van den Brekel MWM. Total laryngectomy for a dysfunctional larynx after (Chemo)radiotherapy. Arch Otolaryngol Head Neck Surg. 2012;138(6):548. doi:10.1001/archoto.2012.862.
6. Gallo A, de Vincentiis M, Manciocco V, Simonelli M, Fiorella ML, Shah JP. CO2 laser cordectomy for early-stage glottic carcinoma: a long-term follow-up of 156 cases. Laryngoscope. 2002;112(2):370–4. doi:10.1097/00005537-200202000-00030.
7. Lee HS, Chun B-G, Kim SW, Kim ST, Oh JH, Hong JC, Lee KD. Transoral laser microsurgery for early glottic cancer as one-stage single-modality therapy: transoral laser microsurgery. Laryngoscope. 2013;123(11):2670–4. doi:10.1002/lary.24080.
8. Arshad H, Jayaprakash V, Gupta V, Cohan DM, Ambujakshan D, Rigual NR, Singh AK, Hicks WL. Survival differences between organ preservation surgery and definitive radiotherapy in early supraglottic squamous cell carcinoma. Otolaryngol Head Neck Surg. 2014;150(2):237–44. doi:10.1177/0194599813512783.
9. Peretti G, Piazza C, Cocco D, De Benedetto L, Del Bon F, De Zinis LOR, Nicolai P. Transoral CO2 laser treatment for Tis-T3 glottic cancer: The University of Brescia experience on 595 patients. Head Neck. 2009;32(8):977–83. doi:10.1002/hed.21278.
10. Peretti G, Piazza C, Cattaneo A, De Benedetto L, Martin E, Nicolai P. Comparison of functional outcomes after endoscopic versus open-neck supraglottic laryngectomies. Ann Otol Rhinol Laryngol. 2006;115(11):827–32. doi:10.1177/000348940611501106.
11. Peretti G, Piazza C, Del Bon F, Mora R, Grazioli P, Barbieri D, Mangili S, Nicolai P. Function preservation using transoral laser surgery for T2–T3 glottic cancer: oncologic, vocal, and swallowing outcomes. Eur Arch Otorhinolaryngol. 2013;270(8):2275–81. doi:10.1007/s00405-013-2461-9.
12. Mantsopoulos K, Psychogios G, Koch M, Zenk J, Waldfahrer F, Iro H. Comparison of different surgical approaches in T2 glottic cancer. Head Neck. 2012;34(1):73–7. doi:10.1002/hed.21687.
13. Canis M, Martin A, Ihler F, Wolff HA, Kron M, Matthias C, Steiner W. Results of transoral laser microsurgery for supraglottic carcinoma in 277 patients. Eur Arch Otorhinolaryngol. 2013;270(8):2315–26. doi:10.1007/s00405-012-2327-6.
14. Bussu F, Almadori G, De Corso E, Rizzo D, Rigante M, Parrilla C, Valentini V, Paludetti G. Endoscopic horizontal partial laryngectomy by CO_2 laser in the management of supraglottic squamous cell carcinoma. Head Neck. 2009;31(9):1196–206. doi:10.1002/hed.21085.

15. O'Malley BW, Weinstein GS, Hockstein NG. Transoral robotic surgery (TORS): glottic microsurgery in a canine model. J Voice. 2006;20(2):263–8. doi:10.1016/j.jvoice.2005.10.004.
16. Weinstein GS, O'Malley BW, Hockstein NG. Transoral robotic surgery: supraglottic laryngectomy in a canine model. Laryngoscope. 2005;115(7):1315–9. doi:10.1097/01.MLG.0000170848.76045.47.
17. Weinstein GS, O'Malley BW, Snyder W, Hockstein NG. Transoral robotic surgery: supraglottic partial laryngectomy. Ann Otol Rhinol Laryngol. 2007;116(1):19–23. doi:10.1177/000348940711600104.
18. Ozer E, Alvarez B, Kakarala K, Durmus K, Teknos TN, Carrau RL. Clinical outcomes of transoral robotic supraglottic laryngectomy. Head Neck. 2013;35(8):1158–61. doi:10.1002/hed.23101.
19. Mendelsohn AH, Remacle M, Van Der Vorst S, Bachy V, Lawson G. Outcomes following transoral robotic surgery: supraglottic laryngectomy: TORS supraglottic laryngectomy. Laryngoscope. 2013;123(1):208–14. doi:10.1002/lary.23621.
20. Hurtuk AM, Marcinow A, Agrawal A, Old M, Teknos TN, Ozer E. Quality-of-life outcomes in transoral robotic surgery. Otolaryngol Head Neck Surg. 2012;146(1):68–73. doi:10.1177/0194599811421298.
21. More YI, Tsue TT, Girod DA, Harbison J, Sykes KJ, Williams C, Shnayder Y. Functional swallowing outcomes following transoral robotic surgery vs primary chemoradiotherapy in patients with advanced-stage oropharynx and supraglottis cancers. JAMA Otolaryngol Head Neck Surg. 2013;139(1):43. doi:10.1001/jamaoto.2013.1074.
22. Hinni ML, Salassa JR, Grant DG, Pearson BW, Hayden RE, Martin A, Christiansen H, Haughey BH, Nussenbaum B, Steiner W. Transoral laser microsurgery for advanced laryngeal cancer. Arch Otolaryngol–Head Neck Surg. 2007;133(12):1198. doi:10.1001/archotol.133.12.1198.
23. Gun R, Ozer E. Surgical anatomy of oropharynx and supraglottic larynx for transoral robotic surgery: transoral surgical anatomy for TORS. J Surg Oncol. 2015;112(7):690–6. doi:10.1002/jso.24020.
24. Dziegielewski PT, Ozer E. Transoral robotic surgery: supraglottic laryngectomy. Oper Tech Otolaryngol Head Neck Surg Robot. 2013;24(2):86–91. doi:10.1016/j.otot.2013.04.003.
25. Olsen SM, Moore EJ, Koch CA, Price DL, Kasperbauer JL, Olsen KD. Transoral robotic surgery for supraglottic squamous cell carcinoma. Am J Otolaryngol. 2012;33(4):379–84. doi:10.1016/j.amjoto.2011.10.007.
26. Park YM, Kim WS, Byeon HK, Lee SY, Kim S-H. Surgical techniques and treatment outcomes of transoral robotic supraglottic partial laryngectomy. Laryngoscope. 2013;123(3):670–7. doi:10.1002/lary.23767.
27. Kayhan FT, Kaya KH, Sayin I. Transoral robotic cordectomy for early glottic carcinoma. Ann Otol Rhinol Laryngol. August 2012;121(8):497–502.
28. Kayhan FT, Kaya KH, Ylmazbayhan ED. Transoral robotic approach for Schwannoma of the larynx. J Craniofac Surg. 2011;22(3):1000–2. doi:10.1097/SCS.0b013e3182101580.
29. Ciabatti PG, Burali G, D'Ascanio L. Transoral robotic surgery for large mixed laryngocoele. J Laryngol Otol. 2013;127(04):435–7. doi:10.1017/S0022215113000236.
30. Smith RV, Schiff BA, Sarta C, Hans S, Brasnu D. Transoral robotic total laryngectomy. Laryngoscope. 2013;123(3):678–82. doi:10.1002/lary.23842.
31. Dowthwaite S, Nichols AC, Yoo J, Smith RV, Dhaliwal S, Basmaji J, Franklin JH, Fung K. Transoral robotic total laryngectomy: report of 3 cases: Head Neck. 2013;35(11):E338–42. doi:10.1002/hed.23226.