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The application of TORS –into the larynx

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Summary
Laryngeal squamous cell carcinoma is one of the most common head and neck cancer, and it occurs more commonly in men than in women. The thought of losing phonatory and swallowing function has become the driving force of advancements in laryngeal cancer treatment.
Transoral robotic surgery (TORS) is one of the fastest growing areas of head and neck surgery. This technology is assisted by remote-controlled miniaturized surgical instruments and magnified visualization with a high-definition three-dimensional camera. TORS is increasingly being used and was described in the context of laryngeal cancer surgery. It has been explored as minimally invasive surgery for supraglottic and glottic lesions, as well as for total laryngectomy. Transoral organ-preserving approaches have shown favorable oncologic and functional outcomes with good quality of life. Rapidly advancing TORS technique affords surgeons exceptional views of the larynx and hypopharynx with facile maneuverability in difficult to access areas. Thus, achieving negative margins and preserving normal laryngeal structures has become increasingly possible. The use of the robot for laryngeal cancer falls into three main categories: supraglottic laryngectomy, total laryngectomy and glottic cordectomy. Transoral robotic surgery for laryngeal cancer has been shown to be feasible for minimally invasive partial laryngectomy for either supraglottic or glottic cancer, as well as for total laryngectomy, in selected patients. TORS supraglottic laryngectomy and TORS total laryngectomy have demonstrated good functional and oncologic outcomes.

Key words: laryngeal cancer; robotic surgery; da Vinci system; head and neck cancer

Introduction

The larynx is a part of the throat, between the base of the tongue and the trachea. There are three main parts of the larynx: supraglottis, glottis and subglottis. Laryngeal squamous cell carcinoma is one of the most common head and neck cancer and it occurs more commonly in men than in women. The incidence of laryngeal caner has a male to female ratio of 5:1. In addition, there are racial disparities observed in laryngeal cancer, with African Americans presenting at a younger age and having a higher incidence and mortality compared with Caucasians [1]. The major risk factors for laryngeal cancer are tobacco and alcohol. The other risk factors include human papillomavirus infection and environmental or occupational exposures. The role that both gastroesophageal and laryngopharyngeal reflux play in the disease process is still controversial and under investigation. The role of human papillomavirus as a risk factor for laryngeal cancer in young nonsmokers is under further investigation [2].
Symptoms which should prompt further workup for laryngeal cancer are hoarseness, dysphonia, dyspnea, and swallowing dysfunction. Patients with glottic tumors may often present with persistent hoarseness, referred otalgia, dysphagia, chronic cough, stridor, and hemoptysis. Those with subglottic tumors may present with stridor and dyspnea on exertion, symptoms typical of fixed airway lesions [2].
Carcinomas of the upper larynx (epiglottis) are characterized by quite dynamic local growth and early appearance of metastases in nearby lymph nodes. Distant metastases are not

common, although their risk increases in cases of low-differentiated cancers. Cancers of the central part (glottis) are usually characterized by slow local growth, and lymph node metastases are rare, which is caused by a slight lymphatic vascularization of this area. Cancers of the lower larynx (subglottis) are characterized by moderately dynamic local growth and more frequent metastases to lymph nodes, not only in the neck, but also in the chest [1,2].

Laryngeal cancer is a disease in which the 5-year survival rate has decreased over the past 40 years, from 66% to 63%, although the overall incidence is declining [1,2]. The initial stage of disease is related to the chances of survival, with cure rates of up to 80% to 90% for early stage T1 and T2 tumors [2].

The basis of prevention in this type of cancer is to avoid smoking and drinking high-percentage alcohol. Non-smokers and non-drinkers are more likely to have glottis cancer. Alcohol consumption more often increases the risk of cancer of the epiglottis.

The current treatment paradigms in the management of laryngeal cancer has aimed to preserve the larynx and improving the quality of life, without sacrificing survival rates. The thought of losing phonatory and swallowing function has become the driving force of advancements in laryngeal cancer treatment. Minimally invasive surgery ensures radical treatment, while maintaining quality of life. The main method of surgical treatment is transoral access using transoral laser microsurgery (TLM), electrosurgical methods and TORS. The overriding goal of minimally invasive surgical approaches is to gain broad insight into the surgical field while minimizing the need for surgical procedures that significantly reduce the quality of life of patients. Transoral robotic surgery (TORS) is one of the fastest growing areas of head and neck surgery. This technology is assisted by remote-controlled miniaturized surgical instruments and magnified visualization with a high-definition three-dimensional camera. The underlying principle of TORS is to be able to reliably perform oncological resection of the primary tumor through a minimally invasive transoral approach. For a large number of authors, it has become a standard-of-care among other treatment modalities in oropharyngeal squamous cell carcinoma staged T1–T2. Currently, TORS is also used in minimally invasive surgery in patients with primary T3 and T4a tumors [3]. It has proven to be an effective alternative to open surgery, with or without a mandibulotomy approach for oropharyngeal cancer in a large number of studies with satisfactory oncological and functional outcomes [4]. The carefully consideration of patient and disease factors are critical in successful treatment. TORS is increasingly being used and was described in the context of laryngeal cancer surgery. It has been explored as minimally invasive surgery for supraglottic and glottic lesions, as well as for total laryngectomy. TORS for laryngeal cancer offers technical improvements over traditional transoral microsurgery (TMS) by widening the magnified field of view and increasing manual dexterity [5].

Purpose Analysis of the latest literature reports on the use of TORS in the treatment of laryngeal cancer.

Description of the state of knowledge

TORS applications in laryngeal neoplasms using the da Vinci Surgical System have been developed and broadcast worldwide since the publications by Weinstein et al. and O'Malley et al. [6]. The da Vinci Surgical System received the approval of the US Food and Drug Administration (FDA) and CE marking in 2009 for transoral otolaryngology.

Transoral organ-preserving approaches have shown favorable oncologic and functional outcomes with good quality of life. Rapidly advancing TORS technique affords surgeons exceptional views of the larynx with facile maneuverability in difficult to access areas. Thus, achieving negative margins and preserving normal laryngeal structures has become increasingly possible [7].

The Da Vinci robot has advantages useful in the minimally invasive surgeries. High definition, wide-angled dual telescopes provide three-dimensional, magnified views. It offers wide-field visualization of the entire operative field while still being able to magnify the area of interest. The da Vinci instruments feature 7 degrees of freedom with precise movement control (including grip). This increased dexterity is advantageous during complex operations that require fine dissection and has advantages over static directionality of long-handled laryngeal microsurgical instruments. Thus, the movement scaling of the robotic system provides a tremor-free surgical action along with graded motion. Additionally , the placement of the cutting instrument in the field of surgery provides a two-handed surgical experience.

Laryngeal TORS approach also adds improvement with education and training of future surgeons. Surgical training via on-screen allows to see the operation in first-person view, which would have previously been limited to watching over a shoulder or monocular eye piece. Surgeons-in-training can observe the surgical procedures from the exact perspective of the operative surgeon.

It is important to optimize transoral retraction to provide access to the larynx and hypopharynx. The facilitation techniques has been described as follows: use of muscle relaxants, transnasal intubation and anterior traction of the tongue, use of the FK retractor with a narrow opening to the larynx, use of the Laryngeal Advanced Retraction System (LARS) pharyngoscope, angled endoscopes [7].

The robotic arms are fitted with a grasper in one arm, a bovie in the other and a camera in the middle. After equipping, the robotic arms are inserted transorally and must be positioned to avoid contact with the retractor and teeth. The first surgeon operates from a video console. A second surgeon or assistant operates at the head of the bed and is responsible for suctioning smoke, secretions, and blood, retracting and facilitating haemostasis with cautery and hemostatic clips.

1. Transoral robotic supraglottic laryngectomy (TORS-SGL)

TORS supraglottic laryngectomy is the most common application of robotic-assisted surgery for laryngeal cancer. Criteria for TORS-SGL include: complete visualization of the cancer and adequate margins; ability to visualize and maneuver the robotic arms without obstructing the view of the tumor; T1 or T2 supraglottic lesions; selected T3 supraglottic lesions. This technique must allow complete oncological resection of the supraglottic tumor and also preserve anatomical and neurophysiological functions of the glottic larynx and of the base of the tongue.

The T3 cancers are suitable for TORS-SGL when a negative margin in pre-epiglottic space can be achieved, vocal cords are mobile and oncologic resection can preserve 50% of the base of the tongue [4].
Contradictions for TORS-SGL: poor transoral exposure (trismus, inability to flex neck, large incisors, interincisor distance <4 cm); posterior commissure invasion; impaired vocal cord mobility or arytenoid mobility; paraglottic space invasion; thyroid or cricoid cartilage invasion; ipsilateral arytenoids cartilage involvement [4,7].
Relative contraindications to TORS-SGL include pulmonary disease and a respiratory insufficiency given the risk of postoperative aspirations [7].

Exposure is obtained utilizing the operative pharyngoscope of choice. The exposure must remain adequate and allow complete visualization of the tumor for oncological monobloc resection.
Initial incisions are made through the level of the vallecula or base of tongue. The pharyngoepiglottic folds are divided first contralateral to the side of the tumor to allow tumor visualization. Next, the branches of superior laryngeal vessels are often encountered during dissection of the pharyngoepiglottic folds. These should be controlled with generous cautery or hemostatic clips. After that, cuts are then deepened to the hyoid bone to include the contents of the pre-epiglottic space. Dissection is then carried inferiorly to the petiole of the epiglottis without entering the anterior commissure. Lateral incisions are then deepened into the ventricle on the side contralateral to disease and then on the cancer side. The aryepiglottic folds are divided/resected superior and lateral to the arytenoids cartilages. After completion of these steps, the specimen can readily be removed [4,7].
The mean set-up time for TORS-SGL is around 25 min. Operating time range from 25–90 min. [7].

Oncologic outcomes following TORS supraglottic laryngectomy continue to demonstrate excellent disease control. TORS supraglottic laryngectomy can be offered with the infrequent need for upfront tracheostomy or gastrostomy and can expect about a 4-day hospital stay [5].
In almost all of the cases reported in literature, the patient selection and the exposure were sufficient to ensure complete oncological resection *via* the transoral robotic approach [4,5,7].
The rate of complete resection with free margins was between 60 and 100% in series comprising at least 10 patients. The 2-year overall survival were reported in two series and ranged from 66.7 to 88.9% [4,12]. The reported rates of postoperative complications are low.

Potential intraoperative complications include: injury to the teeth/lips/gums, poor exposure leading to procedure abandonment, severe bleeding. Early postoperative complications include: tongue numbness, airway edema/obstruction, swallowing dysfunction, hoarseness and bleeding. Late postoperative complications include: prolonged swallowing dysfunction or the need for a G-Tube and laryngeal stricture [5,7].
Swallowing during the initial postoperative period is generally assisted with nasogastric feeding with rapid transition to oral intake typically within the first postoperative week. Minimizing airway edema post operatively is enhanced by the use of peri-operative antibiotics, protonpump inhibitors, and a short course of intravenous steroids. Speech and

swallowing rehabilitation is begun on post-operative day one with the guidance of a speech-language pathologist [4].

Additional case series publications should be supported to allow for improved evaluation of TORS supraglottic laryngectomy through meta-analyses and increased public awareness of a TORS approach as a viable treatment option.

2. Transoral Robotic Total Laryngectomy (TORS-TL)

The motivation of TORS total laryngectomy was to provide a minimally invasive approach, which potentially could improve healing, and to speed up the recovery time. It was designed to decrease treatment related morbidities and to increase postoperative quality of life. TORS total laryngectomy is still under further research and it has been described in only several cases [7,10].

Compared to standard open laryngectomy, the TORS approach allows for substantial reduction in pharyngotomy size with maximal mucosa-sparing incisions. The second advantage of TORS laryngectomy is to minimize lateral dissection and preserve fascial barriers between the nasopharynx and the carotid sheath, thus lowering the risk for carotid rupture [7].

TORS-TL can be used in the indications where neck dissections can be avoided [4]. The first indication is salvage surgery for locally limited failure of the primary lesion after radiotherapy or chemoradiotherapy that is not amenable to a salvage partial laryngectomy due to local or general contraindications. The second indication is for benign or malignant laryngeal tumors with limited local extensions requiring a primary total laryngectomy for oncological or functional reasons, while not requiring extensive perilaryngeal dissection. The third indication is refractory laryngeal dysfunction with long-term tracheotomy and enteral feeding [4].

However, careful patient selection is required to ensure that primary pharyngeal closure can be achieved and that no significant dissection is needed beyond the confines of the larynx.

The procedure begins with a standard tracheostomy skin incision, where the planned stoma will be. The thyroid isthmus is divided. A tracheostoma is created and the party wall is divided along with the recurrent laryngeal nerves. The inferior side of the stoma is sutured.

The second part of the procedure begins as a transoral robotic supraglottic laryngectomy. Supraglottic exposure is achieved transorally with the intraoral retractor. The pharyngoepiglottic folds are divided, superior laryngeal vascular bundles are clipped, and the mucosa of the vallecula is incised. Dissection is carried to the hyoid bone while preserving the preepiglottic fat pad. Inferior dissection exposes the superior border of the thyroid cartilage. The thyroid alas are freed by dissection and moved posteriorly, while preserving the outer perichondrium along with the infrahyoid muscles. Next, the antero-medial pyriform sinus mucosa is incised as close to the larynx as oncologicaly possible [4, 7].

Finally, the postcricoid mucosa is sectioned under direct transoral visualization, and the specimen is removed through the oral cavity. The pharyngotomy is closed with horizontal mattress sutures from within the nasopharynx [7].

A technical limitation of TORS-TL that has been reported by several authors is exposure of the larynx during the transoral procedure. Exposure has been described in some cases to be insufficient [4].

The following complications have been described in TORS total laryngectomy: poor exposure requiring conversion to an open approach, post-operative hemorrhage, and pharyngocutaneous fistula.

Pharyngocutaneous fistula is the most prevalent postlarygectomy complication. TORS-TL may in fact improve the treatment and outcome of this frequent complication by limiting associated morbidities [4,5]

Average operating times have been reported to be on the order of 4 h 22 min and average length of stay is 9.6 days [7].

The application of TORS for TL could alleviate the strain on patients and the cost of health care. Substantial clinical experience must still be accumulated to demonstrate the potential benefits of TORS-TL. Although the initial outcomes are promising following TORS, long-term follow-up and additional case series are needed to understand the benefits of this minimally invasive approach.

3. Transoral Robotic Glottic Cordectomy

Transoral laser microsurgery (TLM) is established as a standard-of- care for minimal-invasive surgery in early glottic cancer. Adequate exposure of the glottic larynx is sometimes a serious limitation in TLM in a small number of patients with early-stage neoplasms.

Published clinical experience with TORS for glottic carcinoma demonstrated robotic-assisted cordectomy for T1-T2 glottic lesions with reliable achievement of negative margins [7]. Although the management of thyroid cartilage remains an issue in these patients irrespective of the procedure.

All of the patients in the published series had a successful procedure, including adequate exposure and satisfactory resection. The 3-year local control, laryngeal preservation, and overall survival were 100% [4].

However, until further experience with TORS glottic surgery it is unclear how this approach offers a noticeable improvement from standard transoral laser microsurgery. It has been shown that the CO2 laser is the preferred cutting tool in the glottis due to less heat transmission and less disruption of delicate normal tissues in the area. By combining the CO_2 laser with the robot, it is possible that the robot may become comparable to TLM [7].

Summary

Transoral robotic surgery for laryngeal cancer has been shown to be feasible for minimally invasive partial laryngectomy for either supraglottic or glottic cancer, as well as for total laryngectomy, in selected patients. Most noticeable, TORS supraglottic laryngectomy and TORS total laryngectomy have demonstrated good functional and oncologic outcomes. As demonstrated in the TORS experience, minimally invasive head and neck surgical approaches decrease hospital stay and hasten recuperation**.** If a lesion is amenable to TLM it will be approachable with the robot. The advantages of TORS include a magnified-angled three-dimensional view, instrument movement mimicking natural hand maneuvers and the ability to suture in deep structures. Major issue with TORS in laryngeal cancer is the underlying

necessity for access and adequate exposure, as instrument size and individual patient anatomy can present serious limitations**.**

Future technological developments and miniaturization should improve the feasibility in a larger number of patients. As the TORS technique improves and cameras become smaller, robotic arms become more flexible, it is likely that TORS will become as accepted as TLM for laryngeal and hypopharyngeal lesions.

However, the level of evidence for oncological safety as compared with other conventional treatment modalities remains low due to the small number of published series to date and the lack of randomized trials. Furthermore, it is still to be proved that TORS provide satisfied oncological and functional outcomes.

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