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Robotics in laryngeal surgery

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While transoral laser microsurgery has been the gold standard for laryngeal surgery for many years, recently transoral robotic surgery (TORS) has become a new treatment option not being restricted to a straight line of view which can be an obstacle during resection. In combination with specifically designed retractors TORS can provide a superior visualization and allows tissue manipulation especially in the narrow working space of the larynx. The present article describes the commercially available robotic systems suitable for transoral surgery in adult benign laryngeal masses and highlights on the use of TORS retractors. Additionally, the most relevant benign laryngeal masses in adults will be addressed with special emphasis on transoral robotic accessibility, visualization, and surgical resection techniques.
Additionally, using the Medrobotics system TORS was evaluated for surgery of benign laryngeal masses in 37 adults suffering from cysts, polpys, papillomas, dysplasias, and leukoplakias: Excellent visualization, surgical access to all lesions and complete resection without any severe side effects could be achieved. In conclusion, TORS can be a valuable tool in surgery for adult benign laryngeal masses.

Introduction

During the last decades transoral laser microsurgery has become the gold standard for the resection of lesions of the larynx in adults due to its low morbidity, good visualization, and excellent postoperative results. Moreover, it is a cost-effective method. Excellent results have been achieved with this technology, as emphasized by the many publications on the resection of malignant tumors over the past decades.[1-6] However, in some cases of transoral laser microsurgery, the limitation to a straight line of view can be an obstacle during resection, particularly in difficult-to-reach regions of the larynx. This holds true for both malignant as well as benign lesions. A superior visualization of the region of interest can be beneficial to enable complete resection while preserving the surrounding structures as well as postoperative function, ie speech and swallowing. Here, the introduction of TORS can be valuable to improve visualization and limit the extent of resection to the necessary minimum.[7-11]

Robotic systems

In 2000 the FDA approved the *da Vinci*-System (Intuitive Surgical Inc., Sunnyvale, CA) for laparoscopic surgery. Since then indications have been expanded to include also urologic, gynecologic, general surgery, thoracic, cardiothoracic, orthopedic as well as head and neck surgery.[12,13] Being a master-slave-system the surgeon

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Figure 1 Flex Robotic System: Moveable Flex Cart carrying the robot, Flex Retractor, and Flex Control for steering the Robot.

steers the robot via a console equipped with a 3D HD monitor.

The principle of remote access surgery was transferred to head and neck in 2005 when McLeod und Melder reported on the first transoral resection of a vallecula cyst using the da Vinci-System in humans.[14] Since then the system was used for transoral resection of benign as well as malignant lesions yielding satisfying postoperative results.[12,13,15-17]

In contrast to well-known systems originally designed for large cavity surgery the new Flex Robotic System (Medrobotics Corporation, Raynham, MA) was developed in order to enhance the spectrum of TORS and to overcome existing limitations by being specifically tailored to the needs of head and neck surgeons. The Flex Robotic System is an operator-controlled, computer assisted flexible endoscope that enables the physician to easily access and visualize structures within the oropharynx and laryngopharynx down to and including the vocal cords (Figure 1). Like other endoscopes, visualization is provided by a chip on tip 3D 1080P reusable camera incorporated in the distal end of the scope. The Flex Robotic System endoscope also provides 2 accessory channels for various compatible flexible instruments which are easily viewed when extended from the distal end of the scope. While other robotic systems require surgeons to sit at a remote console, losing direct contact with the patient, the Flex Robotic System keeps the surgeon in direct contact with the patient thus providing tactile feedback. As compared to other systems offering instruments being either 5 or 8 mm in size and being straight except for the tip region, the Flex instruments are flexible and articulate 85 degrees in any direction. With end effectors ranging in size from 1.5 to 4 mm they are specifically designed to work in small anatomical locations such as the larynx.

Retractors

To expose the relevant anatomical regions in TORS the use of appropriate retractors is mandatory. Various retractors have been introduced in order to achieve an adequate exposure of the surgical field allowing to introduce a robotic device. The most commonly used retractors are the Feyh-Kastenbauer–Weinstein-O'Malley (FK–WO) Retractor, the Flex Retractor, the Dingman Mouth Retractor, the Crow Davis mouth gag, and the Laryngeal Advanced Retractor System (LARS).[18,19] Modern retractor systems such as the FK-WO-Retractor, LARS, and the Flex Retractor were designed to facilitate exceptional exposure in advanced transoral surgeries, including robotic and laser microsurgery procedures. A rounded frame shape in the Flex Retractor and LARS allows access to the mouth for robotic devices and additional instrumentation during surgery. In order to access the different anatomical regions such as oropharynx, hypopharynx, and larynx properly, differently shaped blades area available: Shorter blades for oropharynx and base of tongue, longer blades for supraglottic lesions, and long curved blades to access the glottic level. Most of the retractors include cheek paddles to achieve a wider mouth opening. The Flex and the Crow Davis Retractor provide blades with an integrated suction for smoke evacuation during surgery, which is useful particularly in laser procedures. The Flex and FK-WO Retractor allow to adjust the insertion depth and the insertion angle of the blades. Additionally, the Flex Retractor incorporates the first axial tongue blade rotation capability, which allows surgeons to create unprecedented exposure in certain procedures involving the base of tongue.

Modern retractor systems are providing a wide access even to deeper anatomical structures such as hypopharynx and larynx while minimizing mucosal and tissue damage thus making them an essential tool for TORS in the larynx.

Surgical technique

Indications for TORS in benign lesions of the pharynx

Although many benign laryngeal lesions can be surgically managed by standard surgical techniques, transoral endoscopic robotic surgery may provide advantages in exposition and visualization of several pathologies. Indications for TORS in benign lesions are: Cysts, leukoplakia, or dysplasia, benign tumors such as fibroma, chondroma, adenoma, or papilloma, Reinke edema, and vascular malformations.

Surgical procedures for supraglottis and glottis

For exposure of the supraglottic region, medium sized spatula in combination with either the Flex Retractor or the

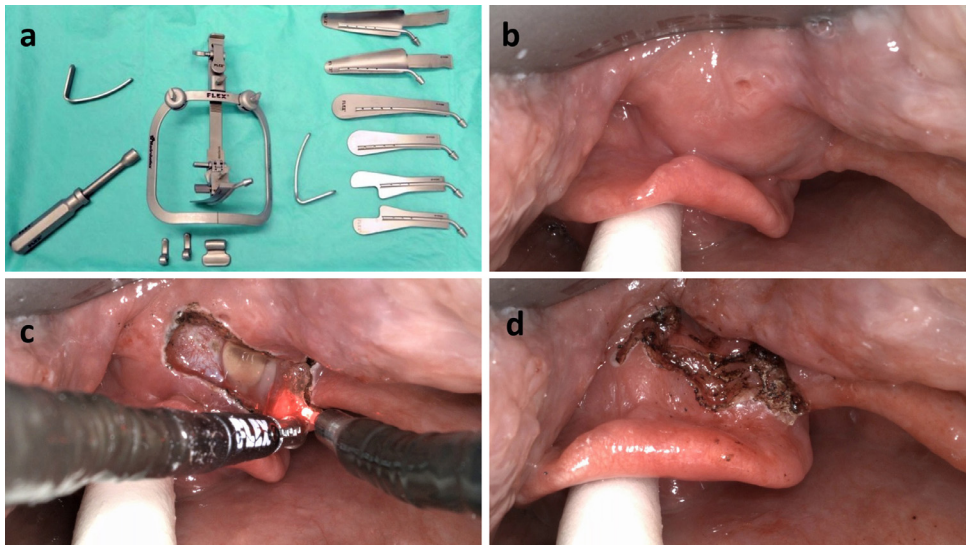

Figure 2 **(a)** Flex Retractor can be equipped with different spatula depending on the location of the lesion. **(b)** Supraglottic cyst right vallecula. **(c)** Marsupialization of the vallecular cyst. **(d)** Situation after marsupialization.

FK-WO Retractor are used. In most cases the tip of the spatula is placed in the vallecula in order to elevate the epiglottis and the larynx from the posterior pharyngeal wall for opening up the supraglottic pharyngeal space. For lesions located on the arytenoid cartilage or extending to the postcricoid region or the aryepiglottic fold it is useful to place the tip of the spatula under the epiglottis thus allowing further elevation of the epiglottis.

Exposure of the glottis is achieved by inserting curved laryngeal blades, which are placed underneath the epiglottis and being able to open up the endolaryngeal supraglottic and glottic space.

For resection of laryngeal lesions different cutting-tools are available for TORS: Cold steel micro scissors provide a clean cut of mucosal tissue without causing thermal damage to healthy tissue. However, no hemostasis is achieved while using them. Monopolar (needle) knives are able to cut different kind of tissues such as cartilage, muscle fibers, or mucosa and also provide sufficient hemostasis. Disadvantages are muscle fibrillation and broad thermal damage zones on both sides of the incision line. Different lasers are available for TORS: Diode lasers provide sufficient hemostasis while also causing a broad coagulation zone. Pulsed CO_2 lasers show excellent cutting properties, provide hemostasis for mucosal vessels, and cause only small zones of carbonization and coagulation at the border of the incision.

Supraglottic cysts

After exposure of the lesion–and depending on size and localization–cysts can be resected completely or are marsupialized by using a monopolar knife or CO_2 laser (Figure 2).

Laryngoceles

Internal laryngoceles are dilations of the laryngeal ventricle and show a lining of respiratory epithelium. They are typically located at the level of the false vocal cords and are ventilated or filled with mucus. A CO_2 laser fiber for resection is recommended.

Papillomas

Access and visualization can be achieved by the use of adequate pharyngeal or laryngeal retractors. The surgical treatment of choice is the complete vaporization of the papilloma using a flexible CO_2 laser fiber sparing healthy laryngeal tissue.

Vocal cord nodules, polyps, leukoplakias, dysplasias

Access and visualization are achieved by using laryngeal retractors. The Flex Robotic System provides 2 mm laryngeal instruments which allow subtle manipulation at the level of the vocal cords. Lesions can be resected with the help of micrograspers and microscissors or a flexible CO_2 laser fiber (Figure 3).

Reinke's edema

Vocal cord mucosa is held by a blunt instrument and incised with microscissors or the CO_2 laser followed by suctioning of the edema. Pay attention not to abundantly resect loose mucosal tissue.

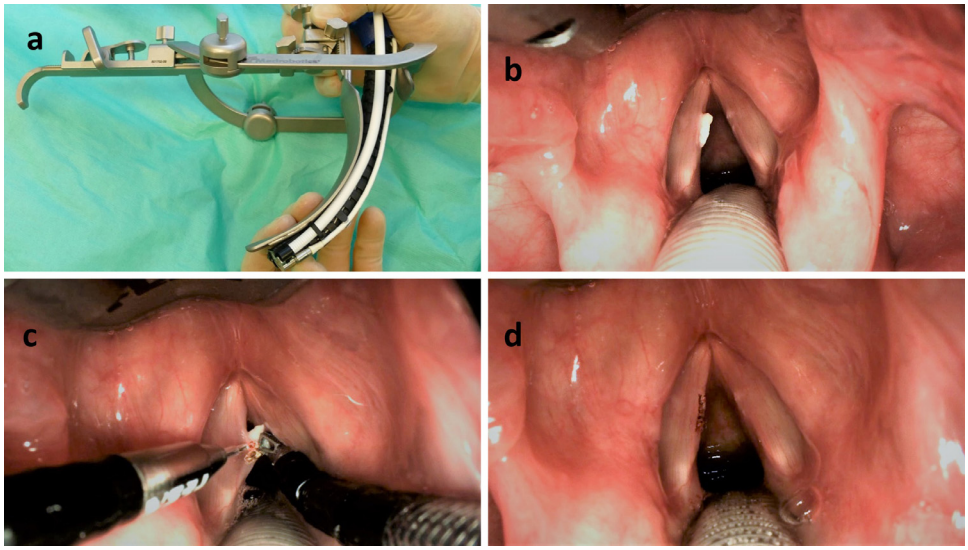

Figure 3 **(a)** Curved laryngeal blade for laryngeal exposure. **(b)** Glottic leukoplakia. **(c)** Resection of the glottic leukoplakia using a laser fiber. **(d)** Situation after resection of the glottic leukoplakia.

Vascular malformations

The most common vascular malformations of the larynx are venous malformations, lymphatic malformations, or combinations of them. Therapeutic strategies are complete or incomplete resection and/or sclerotherapy. Preoperative MRI and/or angiography show the extend of the lesion. Depending on the size and localization of the lesion a temporary tracheostomy can be indicated.

Smaller lesions will be resected by using a laser fiber or a monopolar needle-knife. Always maintain meticulous hemostasis by monopolar suction cautery or bipolar forceps.

Transoral intralesional sclerotherapy of vascular lesions is an alternative treatment of venous malformations and lymphangiomas. After exposing the malformation transorally a sclerosant will be injected intralesionally. Possible sclerosants are Bleomycin, Sodium Tetradecyl Sulfate or OK-432.

Due to the fact that the Medrobotics Flex System was specifically designed for head and neck surgery a study was performed in our hospital in order to evaluate the system for surgery for adult benign laryngeal masses. After institutional review board approval 37 patients have been included, lesions have been located in the area of the epiglottis (n = 10), the arytenoid (n = 9), the false vocal chords (n = 4), and the vocal chords (n = 14) and were histologically classified as being cysts, polpys, papillomas, dysplasias, and leukoplakias upon removal. The Flex System in combination with the Flex Retractor equipped with a paddle specifically designed for laryngeal surgery provided excellent visualization and allowed surgical access to all lesions. By doing so all operations have been successfully completed without any severe side effects. Set up time for the robot was under 10 minutes. In conclusion, transoral robotic surgery can be a valuable tool in surgery for adult benign laryngeal masses.

Disclosures

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.otot.2019.09.012.

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