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LARYNGOLOGY

Preliminary experience in transoral laryngeal surgery with a flexible robotic system for benign lesions of the vocal folds

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Abstract

Purpose This purpose of this case series is to present the first four cases utilizing micro-phonosurgical instrumentation designed specifically for use with a semi-flexible 'robotic' system—the Medrobotics Flex system and to evaluate the accessibility and feasibility of this platform in the context of transoral robotic surgery (TORS) for laryngeal surgery.

Methods Four patients (3 female, 1 male; age range 49–79 years) were operated by the senior author at CHL—a tertiary hospital centre between 2016 and 2017. The 'robot' was deployed in all cases to assess its accessibility and ability to perform surgery in the larynx.

Results All four patients were successfully treated using the system along with newly developed instrumentation specifically focused on phonosurgery.

Conclusion This series has demonstrated accessibility and ability for laryngeal surgery using a novel semi-rigid operator-controlled 'robotic' system. We encountered no device failures and were able to perform all the selected cases uneventfully.

Keywords TORS · Phonosurgery · Laryngeal lesions · Robotics

Introduction

The indications for laryngeal surgery are for the improvement or restoration of laryngeal function (phonation, airway protection during deglutition, airway patency) and the removal of neoplastic lesions of a benign or malignant nature. We have traditionally performed microphonosurgery using suspension laryngoscopy with cold steel instruments and lasers at our tertiary referral centre. In the last decade, transoral endoscopic surgery has benefited from wider application through technological and engineering breakthroughs replacing open surgery because of its advantages which include avoidance of skin incisions, division of the thyroid cartilage and tracheotomy. Consequently, there is less surgical trauma and morbidity compared to open surgery. The latter option, however, has its indications when there are complex oncological cases with ablative or reconstructive surgery of the cartilaginous framework of the larynx [1].

Transoral robotic surgery (TORS), which combines three-dimensional visualization, robotic technology and miniature instruments, has taken the traditional endoscopic approach to a whole new level in terms of precision with tremor filtration and greater freedom of instrument movement providing improved ability to manipulate tissue during resection for a more accurate procedure [2].

Transoral robotic surgery (TORS) is a general technique which has grown in acceptance as an integral part of minimally invasive surgery in the head and neck [3]. TORS has become a safe and effective alternative for benign and malignant conditions of mainly the oropharynx and hypopharynx although its successful application in the larynx and nasopharynx has only been reported more recently [4, 5]. The first robotic system used in head and neck surgery is the ubiquitous da Vinci system. The da Vinci Robotic Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) until recently was the only medically approved robotic system by the United States of America Food and Drug Administration (FDA) and its European counterpart, i.e. with the Conformité Européen (CE) mark. It was, however, not designed primarily for natural orifice use and TORS therefore was an

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adaptation of the technology to the anatomy of the oropharynx—primarily the palatine tonsil and the tongue base. The FDA approval for use of the da Vinci system for TORS was primarily in the oropharynx and tongue base [6].

The main difficulty with laryngeal application of the da Vinci robot was getting a good visualization and exposure of the larynx due to the bend around the tongue base. The rigid endoscope of the da Vinci cannot do so, and hence a complete appreciation of lesions of the larynx is not always possible. The Medrobotics Flex system (hereafter designated 'Flex') was developed in June 2014 [7]. Over the last 2 years, this novel single-port operator-controlled computer-assisted semi-rigid transoral 'robotic' system was initially trialed in several centres in Western Europe, and thereafter in North America [8]. The major differences between the two systems reside in the fact that the 'Flex' was designed specifically for the needs of head and neck surgery while the da Vinci system has a wider field of applications.

Controversy surrounding the use of the term 'robot-assisted surgery' does exist. This system is essentially an endoscopic system that is steered using a joystick 'robotically' by the operating surgeon who negotiates the curvilinear anatomy of the upper aerodigestive tract. It is therefore not a 'line-of-sight' system requiring angled endoscopes to 'see' around corners and does not utilize rigid 'straight' instrumentation. The system is therefore 'robotic' in the manipulation of the flexible endoscope to the site of surgery but should not be confused as 'robotic assisted'. Unlike pre-programmable robotic systems with no human involvement whatsoever, this platform does require human manipulation of a remote joystick controlled console that electronically links up to a semi-flexible endoscopic system. It is not robot assisted as the operative aspect is entirely by the surgeon with no 'assistance' by the platform (once locked in position within the larynx) in performing the procedure.

The instruments are not 'wristed' like the da Vinci but are rotatable using flexible wire technology. Additionally, the use of flexible instrumentation is manual and there are no robotic enhancements in surgical precision, tremor reduction and scaling of motion. Visualization is provided by a high definition digital camera incorporated in the distal end of the scope. The endoscope can currently extend as far as 17 cm; hence access to the larynx and subglottis is well within reach. The original instruments are 3.5 mm and can project through the two side instrument ports 20 mm beyond the tip of the endoscope but the newer phonosurgical instruments are a fraction of this size, i.e. 1.5 mm. The 'Flex' supports flexible instruments and currently includes the newly designed instrumentation including a laser holder, an alligator grasper, triangle forceps, a micro scissors and sickle knife [9] (Fig. 1).

The purpose of this study is to present the feasibility of this system on the first four cases with its newly designed laryngeal phonosurgical instrumentation (rather than the voice outcome) at Centre Hospitalier Luxembourgeois (CHL).

Subjects and materials

Four patients (3 female, 1 male; age range 49–79 years) were operated by the senior author at CHL—a tertiary hospital centre between 2016 and 2017. Full informed consent was obtained from all patients prior to surgery and the local hospital Ethics Committee protocols were adhered to accordingly, i.e. Local Ethics committees of CHL-Eich, Luxembourg and approval of the study was given by the hospital's Ethics committee. Full informed consent from the subjects for publication of the cases was obtained at the time of the study.

All patients were operated on under a general anaesthetic. The flex retractor (Fig. 2) was used to expose the mouth and pharynx while retracting the tongue. A range of laryngeal blades were available to depress the tongue, expose the

Fig. 1 Microflex instruments (L–R): laser holder, alligator forceps, triangle forceps, scissors, sickle knife

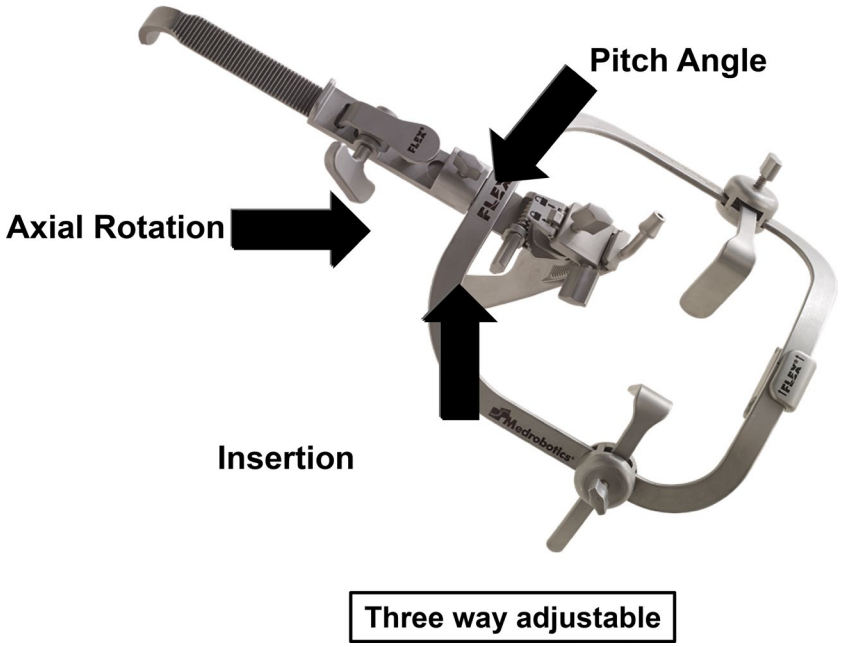

Fig. 2 Flex Retractor with three ranges of movement of blade

valleculae or the larynx. An armoured endotracheal laser safe tube was used in all laser cases.

Summary of cases

Case 1

A 62-year-old lady with dysphonia due to smoking-related Reinke's oedema presented to our clinic. She was also found to have a patch of keratosis and polypoidal mucosa on her left vocal fold. She underwent surgery using the carbon dioxide (CO_2) laser (Lumenis Duo, Lumenis, Yoakem. Israel) assisted by the Medrobotics Flex System. The polyp and keratosis on the left vocal fold were resected with the CO_2 laser fiber using the 'ultrapulse' mode at a continuous power setting of 7 W. Histopathology demonstrated hyperkeratosis and a parakeratosis of the patch and polypoidal mucosa, respectively. The patient made a full recovery and was discharged home the same day after the procedure.

Case 2

A 50-year-old female who previously had a resection of a telangiectatic right vocal cord polyp in the context of autoimmune polyarthritis 6 months prior, presented with an exudative laryngitis and a 'polypoidal' lesion on the middle third of her left vocal fold with bilateral vocal fold sulci. A decision was taken during the follow-up examination for exploratory microsurgery and coagulation with CO_2 laser assisted using the Flex system. The polyp was resected, the floors of the two sulci were ablated with the CO_2 laser Acublade using the ultrapulse mode at single pulse, 100 ms contact time and 9 W power. Histology confirmed a vocal fold nodule. The patient made a full recovery and was discharged home the same day of the procedure.

Case 3

A 79-year-old male smoker with a fluctuating dysphonia for 4 weeks was presented to our service. He was diagnosed with bilateral vocal fold keratosis. He underwent surgery using the CO_2 laser fiber by the Flex system (Fig. 3). A European Laryngological Society (ELS) type I subepithelial cordectomy was performed on both sides. Histology results reported squamous-cell hyperplasia without dysplasia. The patient made a full recovery and was discharged home the same day after the procedure.

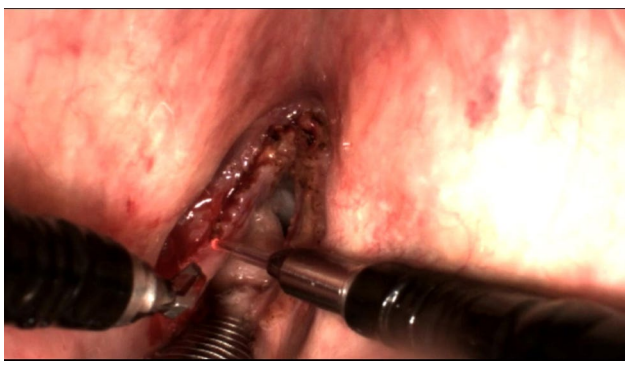

Fig. 3 ELS type I laser cordectomy for bilateral keratosis with CO_2 laser holder, fiber and alligator forceps

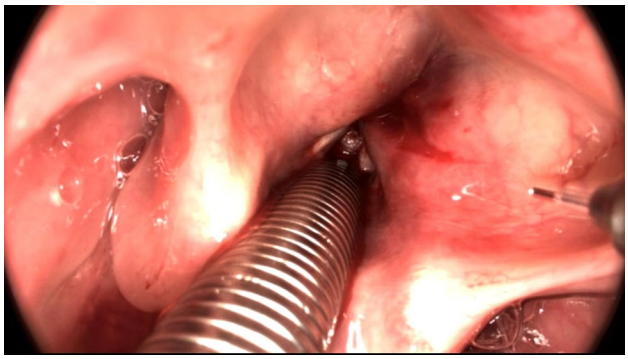

Fig. 4 Amyloidosis of both vestibular folds extending to petiole

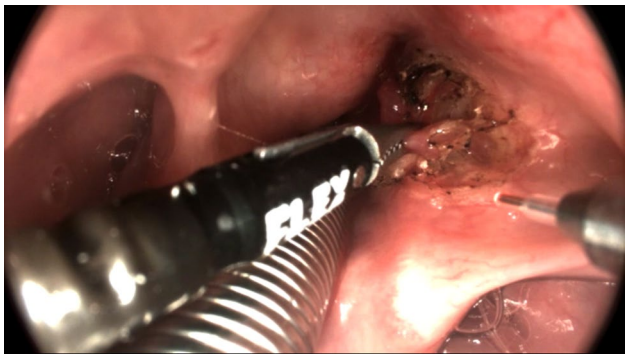

Fig. 5 Resection of laryngeal amyloidosis using a CO_2 laser holder and fiber with Maryland grasper

Case 4

A 49-year-old lady was suffering from dysphonia due to isolated laryngeal amyloidosis. The flexible nasendoscopy showed a swelling on both vestibular folds extending to the upper surface of the two true vocal cords (Fig. 4). The lesion progressed anteriorly to the petiole of the epiglottis. There was no subglottic extension. The lesions were progressively resected with the CO_2 laser fiber assisted by the Flex in continuous mode, ultrapulse at 10 W (Fig. 5). Haemostasis was achieved with both laser and monopolar suction diathermy. Both vocal folds were completely free of amyloidosis on completion of the procedure. The free edges of the two vocal cords were untouched as was the anterior commissure. Routine 'wiping' of carbonization followed by application of fibrin glue was instituted at the end of the procedure. There was no peri-operative oedema. The patient made a full recovery and was discharged home the same day of the procedure.

Summary

We were able to treat all four cases effectively using the newly designed flexible phonosurgical instrumentation for Flex. Our usual timing for all four cases was increased by 20 min on average to set up the platform and insert the retractor.

Discussion

Flexible endoscopes are used widely in otolaryngology for mainly diagnostic procedures through the nose and occasionally, the oral route. Most fine flexible endoscopes do not possess an instrument channel. This novel system allows for precisely this option and in this regard can possibly be considered a paradigm shift in the development of 'robotics' in surgery. The non-line of sight technology with firm yet flexible instruments provides adequate tissue handling capacity with the added option of using cautery, laser fibres and cold steel techniques.

Our series was aimed at assessing the versatility, visualization and resectability of laryngeal lesions using specific instrumentation for TORS phonosurgery. To our knowledge, no single-centre study of this nature has been performed thus far. All patients were found to have adequate access to perform surgery in the larynx for a variety of conditions. None of the patients suffered from any intra or post-operative complications. Access was adequate and the array of laryngeal blades of varying width and length that can be rotated in three different planes using the flex retractor was found to help improve access for the robotically driven endoscope.

Current robotic technology is inhibited by the size of the instruments to perform such delicate work. Also, automatic suture and stapling devices used endoscopically are not available yet in TORS. Future technological improvements will hopefully address these shortcomings. As with the da Vinci, the Flex has the advantages of better illumination, optics and flexibility of instrumentation but its maneuverability when negotiating corners is better. It may also obviate the need to constantly re-position the rigid laryngoscope.

Finally, microphonosurgery has traditionally been performed using suspension laryngoscopy with the aid of fine phonosurgical instruments and lasers. While many cases are performed successfully, we are aware of the challenges facing the laryngologist in the 'difficult to access' larynx as well as the rigid neck and mouth. Our opinion is that this flexible system will improve both in its array of instruments and miniaturization which will enhance exposure as well as visualization (3D is now available). Further refinements such as tremor negation may help provide the surgeon with improved precision in this small and delicate area.

Conclusion

This series has demonstrated accessibility and ability for laryngeal surgery using a novel semi-rigid operator-controlled 'robotic' system. We encountered no device failures and were able to perform all the selected cases uneventfully. Given the early successes, we are optimistic that this technology may be able to provide our patients better treatment in the future for areas that have traditionally been challenging to reach in the upper aerodigestive tract.

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Compliance with ethical standards

Conflict of interest No conflicts of interest to declare.

Informed consent Informed consent was obtained from all subjects in this study.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards

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