Operative Techniques in Otolaryngology (2008) 19, 67-71

ELSEVIER

Operative Techniques in

Otolaryngology

Transoral robotic surgery

Neil G. Hockstein, MD,[a,b] Bert W. O'Malley, Jr, MD[b]

From the [a]Division of Otolaryngology, Christiana Care Health System, Newark, Delaware; and the [b]Department of Otorhinolaryngology–Head and Neck Surgery, University of Pennsylvania, Philadelphia, Pennsylvania.

KEYWORDS
DaVinci;
Robotic surgery;
Robotics;
Minimally invasive surgery;
Head and neck surgery

Surgical robotics is a rapidly developing field. The application of robotic technology to head and neck procedures potentially offers patients alternatives to conventional open surgical procedures with decreased morbidity. Additionally, transoral robotic surgery (TORS) may extend minimally invasive head and neck surgery beyond transoral laser microsurgery with the ability to work around corners while avoiding certain line-of-site limitations. This article describes the history of TORS including original laboratory data, early clinical data, and a description of technical aspects of the procedures.

Adaptation and miniaturization of commercial robotic technology has facilitated its introduction into clinical medicine. Surgical robots emerged after the development of automated robotic arms for industrial and aerospace applications. The miniaturization of both the mechanical robotic components and the solid-state components has allowed these miniaturized robotic arms to work within the human body. By coupling the robotic instruments with improved 3-dimensional (3-D) optic technology, surgeons have the advantages of precise instrument movement and virtual immersion into the surgical field (Figure 1).

Many of the advantages that surgical robots have brought to abdominal and thoracic surgery can be applied transorally.[1-5] The initial primary obstacles to the performance of robotic assisted pharyngeal and laryngeal surgery were (1) the means of introducing the relatively large robotic arms and instruments into the narrow funnel created by the oral cavity, pharynx, and larynx, (2) the means of suspending and exposing the laryngopharynx to allow for adequate exposure without interfering with introduction of the robotic arms, and (3) the ability to achieve hemostasis. These obstacles proved manageable, and surgeons at the University of Pennsylvania have reported on successful early experience with transoral robotic surgery (TORS) in both experimental preclinical models and in early clinical experience.

Initial preclinical experience with TORS involved attempts to identify optimal positioning and exposure of the laryngopharynx using an airway mannequin. In the initial reports by Hockstein and coworkers, it was suggested that exposure and the introduction of the robotic end-effector instrumentation was superior using mouthgags rather than conventional closed-tube laryngoscopes.[6,7] The only limitation in this setup occurred when working at the extremes of the exposed operative field. In these far lateral, anterior, and posterior locations, movement was restricted when the back of the instrument arms contacted the ring of the mouthgag.

Cadaver model experiments demonstrated many potential applications of the daVinci Surgical Robot in TORS. Hockstein and coworkers describe using a Dingman mouthgag, with its integrated cheek retractors, and a medium length tongue blade, to expose the pharynx.[7] In this initial cadaver model, a 2-0 Prolene suture placed through the midline of the oral tongue and suspended on the Dingman mouthgag's outer ring was required to achieve optimal exposure of the larynx. The robotic arms could then be introduced through the mouthgag into the pharynx and larynx. A 4-0 Prolene suture placed through the midline of the suprahyoid epiglottis allowed better suspension of the supraglottic larynx and exposure of the endolarynx. Dissections were performed using a variety of 5-mm and 8-mm robotic instruments. Dissections performed included (1) bilateral true vocal cord stripping, (2) rotation of a mucosal flap from the epiglottis to the anterior commissure, (3) partial vocal cordectomy, (4) arytenoidectomy, (5) partial epiglottectomy, and (6) partial resection of the base of tongue with primary closure.

Following these early reports on both preclinical and human clinical application of TORS, Rahbar and coworkers

Address reprint requests and correspondence: Neil G. Hockstein, MD, Family Ear, Nose, and Throat, 1941 Limestone Road, Suite 210, Wilmington, DE 19808.
E-mail address: neilhockstein@verizon.net.

1043-1810/$ -see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.otot.2008.03.005

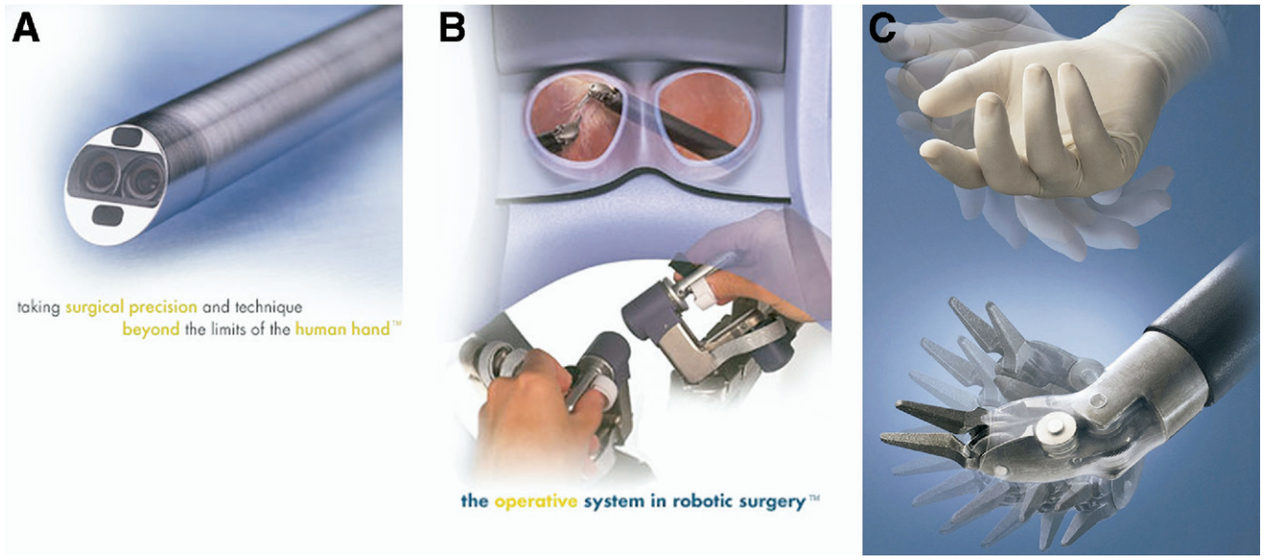

Figure 1 (A) 3D vision is provided by 2 in-line, rigid telescopes. (B) The 2 telescopes feed different cameras and are viewed in 2 eyepieces. (C) An 8-mm instrument with simulated flexion, extension, pronation, and supination mimics movements of the human wrist. (Images © 2005 Intuitive Surgical, Inc.) (Color version of figure is available online.)

reported similar experiences in 2 pediatric patients by using a Crowe–Davis mouthgag and a Lindholm laryngoscope.[8] In both cases, exposure was easily achieved with the laryngoscope and mouthgag, but instrument movement was less encumbered using the mouthgag. Robot setup was achieved by placing the patient in the supine position with the operating table rotated approximately 30° relative to the robot tower as had been described with TORS. A report of pediatric transoral robotic surgery describes the successful closure of posterior laryngeal clefts in two patients. The same procedure was attempted in 3 other children, but exposure limited successful performance of the procedure. The use of the robot, in this initial series added 40 minutes to the total procedure duration.[8]

Multiple methods for maintaining hemostasis have been described and documented in a canine model. These include: (1) preinjection of tissues with lidocaine and epinephrine, (2) coagulation of mucosal and muscle tissues using monopolar and bipolar cautery, and (3) ligation of vessels with surgical hemoclips. Management of secretions and blood in the operative field has been performed by an assistant surgeon with a Yankauer suction watching on a video monitor and by a flexible suction catheter placed in the operative field which was grasped and manipulated by the robotically controlled forceps.[9]

Safety of the application of the daVinci Surgical System to transoral surgery has also been described and tested in canine and cadaver models. Attempts to intentionally fracture the cervical spine or mandible were unsuccessful. In this model, the forces generated by the robotic arms were inadequate to cause significant injury, even with gross misuse of the robot.[10]

The first report of the use of the daVinci Surgical System for transoral surgery described the successful marsupialization of a vallecular cyst by surgeons at Walter Reed Army Hospital. For the procedure, surgeons used a 3-dimensional endoscope and only one of the robotic arms. There were no complications.[11]

An initial study by O'Malley and coworkers describes the preclinical development and then application of TORS to three patients with early (T1 or T2) base of tongue cancers.[12] Regarding the human patients, complete resection of the tumors were achieved with histopathologically confirmed negative margins. There were no device-related or patient complications, and all patients maintained normal speech and swallowing was normal at 3 to 4 weeks postoperative. Blood loss was less than 150 mL, and hospital length of stay was 5 days in 2 patients and 7 days in 1 patient. Robotic device setup time ranged from 7 minutes to 28 minutes with overall operative time less than 2.5 hours.[12] In another study, these same researchers at the University of Pennsylvania described TORS treatment of 3 patients with T2 or T3 supraglottic carcinoma who underwent robotic supraglottic laryngectomy. Again, there were no device-related or patient complications, all surgical margins were histologically confirmed to be negative, and operating time and blood loss were less than or comparable with open surgical resection or endoscopic laser resection.[13]

The largest report of TORS includes 63 patients treated under an IRB approved prospective human clinical trial at the University of Pennsylvania for a variety of benign and malignant lesions of the laryngopharynx. Again, operating room time, blood loss, and morbidity were comparable to open or conventional endoscopic surgery.[14]

Indications

The indications for TORS are identical to those for conventional endoscopic or open pharyngeal procedures. The term "TORS" describes the application of robotic devices to a variety of well-described procedures that already are clinically accepted. Potential treatment alternatives for these patients include definitive radiation therapy, combined chemotherapy and radiation therapy, and open surgical excision, including mandibulotomy or lateral pharyngotomy. Carbon dioxide laser endoscopic surgery may be a therapeutic alter-