Transoral Robotic Surgery: Supraglottic Laryngectomy in a Canine Model

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OBJECTIVES/HYPOTHESIS: To develop a technique for computer enhanced robotic transoral supraglottic partial laryngectomy in the canine model. Study Design: Surgical procedure on the larynx in a canine model with a commercially available surgical robot. Methods: With use of the da Vinci Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, CA), the supraglottic partial laryngectomy was performed on a mongrel dog that had been orotracheally intubated using general anesthesia. The videoscope and the 8 mm end-effectors of the robotic system were introduced through three ports, transorally. The surgical procedure was performed remotely from the robotic system console. The procedure was documented with still and video photography. Results: Supraglottic partial laryngectomy was successfully performed using the da Vinci Surgical Robot, with 8 mm instrumentation. The robotic system allowed for celerity and accuracy secondary to findings specific to the surgical approach, including excellent hemostasis, superb visualization of the operative field with expeditious identification of laryngeal submucosal soft tissue and skeletal landmarks, and multiplanar transection of tissues. In addition, the use of the robotic system also was found to have technical advantages inherent in robotic surgery, including the use of “wristed” instrumentation, tremor abolition, motion scaling, and three-dimensional vision. Conclusions: The da Vinci Surgical Robot allowed for successful robotic transoral supraglottic partial laryngectomy in the canine model. Key Words: Robotic, endoscopic, minimally invasive surgery, microsurgery, larynx, partial laryngectomy, laryngeal cancer, da Vinci, transoral robotic surgery (TORS).

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INTRODUCTION

The surgical management of supraglottic carcinoma has evolved from the exclusive use of total laryngectomy in the 19th century, to the use of open supraglottic partial laryngectomy for selected cases in the mid to late 20th century, to the use of transoral laser supraglottic partial laryngectomy for selected cases in the late 20th and early 21st century. Each subsequent surgical technique was functionally superior to its predecessor. The open supraglottic partial laryngectomy was superior to the total laryngectomy in allowing the surgeon to preserve enough of the larynx to perform a temporary tracheostomy and feeding tube, thus avoiding a permanent tracheostoma. The transoral laser supraglottic partial laryngectomy was superior to the open supraglottic partial laryngectomy in that it allowed most patients to avoid even a temporary tracheostomy and shortened the time course of swallowing rehabilitation. In an effort to build on the foundation created by the pioneers of transoral laser supraglottic partial laryngectomy, we decided to consider the application of the da Vinci Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, CA) to transoral supraglottic partial laryngectomy in the canine model.

Robotic surgery has thus far found its major niche in cardiac and urologic surgery, with approximately 10% of radical prostatectomies performed in the United States in 2004 being robotically assisted. Among the other areas that have been developing robotic techniques have been bariatric and gynecologic surgery. Research using the da Vinci Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, CA) in the area of otolaryngology—head and neck surgery has been in the area of surgery of the neck, including procedures such as selective neck dissection. The da Vinci Surgical Robot consists of a master control and a remote-manipulator station in which there is a surgeon’s console (master-control) and a robotic cart (remote-manipulator), which is next to the patient, with three arms, two placed laterally for the instruments and the middle one for the endoscopic camera. Hockstein et al. from the Department of Otorhinolaryngology—Head and Neck Surgery at the University of Pennsylvania, have recently demonstrated the feasibility of using robotic surgery in mannequin and human cadaver models for transoral laryngopharyngeal dissections. We present the results of a pilot study of the first transoral robotic...
surgery (TORS) supraglottic partial laryngectomy in the canine model.

MATERIALS AND METHODS
The procedure was performed in accordance with the “Guide for the Care and Use of Laboratory Animals.” The protocol was approved by the institutional animal care and use committee.

One mongrel dog weighing 28.20 kg was used in this study. The dog underwent TORS supraglottic partial laryngectomy using the da Vinci Surgical Robot. The preanesthesia used for the dog was intramuscular atropine sulfate (AmVet, Neogen Corporation, Lexington, KY) then a mixture of tiletamine HCL and zolazepam HCL (Telazol, Fort Dodge Animal Health, Fort Dodge, IA) and xylazine base (Tranquived Injection, Vedco Inc., St. Joseph, MO) intramuscularly. For induction, propofol (Propoflo, Abbott laboratories, N. Chicago, IL) was used followed by orotracheal intubation with a number nine cuffed endotracheal tube and with maintenance inhalation anesthesia with isoflurane (Isosol, Rhodia Organique Fine, Ltd., Avonmouth, Bristol, UK). Paralysis was achieved with intravenous pancuronium bromide (Isosol, Rhodia Organique Fine, Ltd., Avonmouth, Bristol, UK). Inhalation anesthesia was used for maintenance.

Inhalational anesthesia was continued with isoflurane (Baxter, Irvine, CA). Positive pressure ventilatory support was achieved throughout the procedure with an Ohmeda 7000 Ventilator, (Ohmeda BOC Health Care, Madison, WI). Monitoring of cardiac status and oxygenation was performed using a Datex-Ohmeda S/5 (Datex-Ohmeda Division, Instrumentarium Corp, Helsinki, Finland). The dog’s blood pressure was monitored throughout the procedure and found to be approximately 100 systolic over 50 diastolic. At the end of the procedure, the animal was killed.

TORS Supraglottic Partial Laryngectomy Technique
The procedure was performed by the first author (G.S.W.) and concurrently evaluated by the coauthors (B.W.O., N.G.H.). The dog was positioned in the supine position, and the operating room table was rotated 30 degrees relative to the robotic cart, as previously described. The tongue was retracted using 2–0 silk sutures passed through the tongue and attached to a suspension apparatus. The surgical technique that was used was a modification of the transoral supraglottic partial laryngectomy described by Rudert et al. Although Rudert et al. described using a laryngoscope, an operating microscope, and a CO2 laser, none of these were used in the current study. Visualization of the laryngopharynx was achieved with a 30 degree, upward facing, three-dimensional endoscope inserted transorally in the midline, and the ports for the 8 mm robotic instrumentation were introduced transorally into the laryngopharynx at approximately 30 degree angles from the axis created by the midline position of the endoscope. The surgeon was seated at the surgical console, approximately 10 feet from the surgical table and robotic cart. The surgeon viewed the operative field by way of a three-dimensional image while his hands held the master controls at a comfortable distance below the display. The procedure was documented with both still and video photography.

The first step in the surgical procedure is the vertical division of the epiglottis (Fig. 1). The incision is followed laterally to find the hyoid bone. The excision is carried inferiorly along the thyrohyoid membrane until the superior aspect of the thyroid cartilage is identified (Fig. 2). The entirety of the preepiglottic space is dissected from the inner aspect of the thyrohyoid membrane and thyroid cartilage from superior to inferior toward the anterior commissure and lateral angle of the laryngeal ventricle. Although Rudert et al. recommend resection of the supraypharyngeal portion of the epiglottis when necessary for visualization, this is not needed for the canine TORS supraglottic partial laryngectomy. The dissection is continued laterally through the pharyngoepiglottic fold.
way of the right sided port was the cautery with spatula, which is a small monopolar cautery unit (Figs. 3, 4, and 5). The cautery with spatula was replaced with the permanent cautery hook during the resection of the first half of the procedure (Fig. 4). The tips of the monopolar cautery could be cleaned of debris either with the forceps in the opposite hand or by having an assistant wipe the tips with a gauze pad. The monopolar cautery unit Force FX (Valley Lab, Boulder, CO) was set to “cautery blend,” initially at 25, and was then increased to 30. A harmonic scalpel was also available but not used because this instrument is not “wristed” and therefore had limited utility.

**RESULTS**

**Operative Time**

The operating room setup and animal positioning was accomplished in under 30 minutes. The length of time of the resection was 20 minutes, 57 seconds.

**Hemostasis**

Both the cautery with spatula and the permanent cautery hook transected mucosa, fat, and muscle with minimal residual bleeding and minimal residual char. The need for additional cauterization of either mucosal or submucosal soft tissue bleeders was minimal. There was no need to suction blood to improve visualization, nor was there a need to use suction cautery to achieve hemostasis. A suction catheter was used to evacuate smoke created by the monopolar cautery.

**Visualization of Operative Field**

The TORS technique allowed for excellent visualization of the operative field. The use of a 30 degree, three-dimensional endoscope allowed the surgeon excellent depth perception during the resection. The ability to move the endoscope farther or closer from the tissues being resected allowed for excellent magnification on close-up views. The combination of foot pedal and hand motions at the surgical console allows for changing the position of the tip of the endoscope to the right, left, up, or down in an arc of rotation, which is limited only by the size of the opening in the oral cavity rather than by the limitations of line of sight that are inherent when using laryngoscopes in traditional microscopic laryngeal surgery. The light source provided excellent and consistent illumination for all angles of view. All key surgical landmarks including the epiglottis, hyoid bone, thyroid cartilage, pharyngoepiglottic folds, pyriform sinuses, false cords, arytenoids, vocal cords, and laryngeal ventricle were clearly and readily identifiable.
**Multiplanar Transection of Tissues**

An articulating joint is present just proximal to the end of the forceps and the cautery unit (Figs. 1, 2, and 3). Movement around this joint corresponds to the wrist movements of the surgeon at the surgical console (Fig. 5). This allows the surgeon to use the tip or entire surface of the cautery to cut in the axial or sagittal or coronal plane, or any combination of the three planes, with great accuracy. The permanent cautery hook could be placed under structures such as the false cord and could then be used to cut the tissues from a caudal to cranial direction. Caudal to cranial transactions could also be made with the cautery with spatula.

**Impact of Technical Advantages Inherent in Robotic Surgery on the TORS Supraglottic Partial Laryngectomy**

The well-established advantages of robotic surgery, noted in the literature, include the use of “wristed” instrumentation, tremor abolition, motion scaling, and three-dimensional vision. All of these were found to facilitate the surgical procedure.

**DISCUSSION**

The transoral laser supraglottic partial laryngectomy is functionally superior to open supraglottic partial laryngectomy because, in almost all cases, it obviates the need for a tracheostomy and shortens the period of postoperative dysphagia. Robotic surgery offers several advantages to the surgeon including three-dimensional visualization, tremor abolition, motion scaling, and wristed instrumentation. The major potential necessity for TORS, if it is to become a clinically viable approach, is the availability of robotic systems, which at present are limited to 205 systems in 34 states. The differences between this pilot study of TORS supraglottic partial laryngectomy and the transoral laser supraglottic partial laryngectomy are outlined in Table I.

The experimental data on wound healing and tissue injury when comparing monopolar electrocautery with CO₂ laser, and its impact on clinical management, remains inconclusive. Carew et al., in a study that evaluated the impact of different types of oral tongue incisions in rats, reported that the depth of wound healing was greater with the CO₂ laser than with the electrocautery unit. Liboon et al. noted that the acute width of injury for incisions was greater for wounds made with electrocautery than with the CO₂ laser in a porcine oral mucosal model. However, by 3 days, Liboon et al. reported no statistical difference in inflammation between the CO₂ laser and the electrocautery unit. Finally, both epithelialization as well as formation of granulation tissue was similar for electrosurgery and CO₂ laser at 4 weeks.

The problem with studies comparing similar linear incisions in animal models is that they may not accurately reflect clinical practice. In fact, the laser cuts through tissue at a much slower rate than does the monopolar cautery unit, and it takes many passes with a laser to make the same incision that can be made with a single swift cut with the robotic cautery arm. For instance, using the laser to make a vertical midline transaction through the epiglottis is time consuming and requires multiple passes with the laser and typically a significant amount of suction monopolar electrocautery, whereas vertical transaction in the canine model required fewer passes with the electrocautery unit. It is not clear whether multiple laser passes create more or less tissue damage than do fewer passes with the electrocautery.

Clinical data concerning the use of monopolar electrocautery in the supraglottis is sparse. Oluwasmni and Mal performed monopolar diathermy partial epiglottectomy in four patients because of snoring or sleep apnea and found no significant problems with bleeding or airway edema, and three patients were discharged on the first postoperative day and one on the second postoperative day. Although these authors did suggest performing total epiglottectomy using monopolar diathermy was safe, from the perspective of bleeding and airway swelling, to date this has not been reported.

Suction monopolar cautery has been used, as indicated above, close to the glottis or the arytenoids to control bleeding during transoral laser endoscopic supraglottic partial laryngectomy without ill effect. Although the dog in this procedure was killed after TORS supraglottic partial laryngectomy, gross examination of the tissues after the resection indicated minimal edema and minimal char.

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<td>TORS Supraglottic Partial Laryngectomy</td>
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with normal appearing mucosa at margins of resection (Fig. 5).

CONCLUSIONS
The da Vinci Surgical Robot allowed for successful completion the TORS supraglottic partial laryngectomy in the canine pilot study. Further study is indicated.

BIBLIOGRAPHY