Transoral Robotic Surgery (TORS) for Base of Tongue Neoplasms

Bert W. O'Malley, Jr., MD; Gregory S. Weinstein, MD; Wendy Snyder, BS; Neil G. Hockstein, MD

Objective: To develop a minimally invasive surgical technique for the treatment of base of tongue neoplasms using the optical and technical advantages of robotic surgical instrumentation. Study Design: Ten experimental procedures including tongue base exposure and dissections were performed on three cadavers and two mongrel dogs. Transoral robotic surgery (TORS) was then performed on three human patients with tongue base cancers in a prospective human trial. Methods: Using the da Vinci Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, CA), we performed a total of 10 base of tongue resections on edentulous and dentate cadavers as well as live mongrel dogs. In the cadaver models, exposure was evaluated using three different retractors, the Dingman, Crowe Davis, and FK retractors. The three human patients underwent TORS surgery of their tongue base cancers under an institutional review board approved prospective clinical trial. The ability to identify and preserve or resect key anatomic structures such as the glossopharyngeal, hypoglossal, and lingual nerves as well as techniques for identifying the lingual artery and achieving hemostasis were developed. Results: The da Vinci Surgical Robot provided excellent visualization and enabled removal of the posterior one third to one half of the oral tongue in cadavers, dogs, and human patients. Among the three retractors evaluated, the FK retractor offered the greatest versatility and overall exposure for robotic instrument maneuverability. Complete resection to negative surgical margins with excellent hemostasis and no complications was achieved in the live patient surgeries. Conclusions: TORS provided excellent three-dimensional visualization and instrument access that allowed successful surgical resections from cadaver models to human patients. TORS is a novel and minimally invasive approach to tongue neoplasms that has significant advantages over classic open surgery or endoscopic transoral laser surgery. Key Words: Robotic, endoscopic, minimally invasive surgery, microsurgery, base of tongue cancer, base of tongue surgery, da Vinci, transoral robotic surgery.


INTRODUCTION

Robot-assisted cardiac and urologic surgery are becoming widely accepted for treating cardiac valve disease and prostate cancer; however, there have been no rational applications in the field of head and neck surgery until very recently. Proponents of robotic cardiac and urologic surgery claim that large, open and high morbidity procedures are now performed through small incisions and with less blood loss and complications using robotic surgical technology.1 Furthermore, reports to date have shown that actual operative time, intensive care stays, and overall patient hospitalization is reduced after robotic procedures as compared with classic open procedures.2 We previously hypothesized that the three-dimensional optical and technical advantages of robotic surgery can be applied to classic open or radical head and neck surgery and have developed and established a novel procedure of transoral robotic surgery (TORS) in preclinical experimental models.3–5 Our previous works established the feasibility of positioning both the cadaver patient and robotic arms to gain access to the oral cavity, supraglottis, and glottis and have introduced very basic concepts on controlling active bleeding.6,7

The management of base of tongue carcinoma at the University of Pennsylvania Center for Head and Neck Cancer has paralleled treatment trends nationally. Machtay et al.,8 in a report of the treatment of tongue base carcinoma at the University of Pennsylvania, noted that the treatment preference between 1980 and 1991 was to perform partial glossectomy followed by planned postoperative radiation. This approach was consistent with the data from the National Cancer Database, which indicates that in the United States between 1985 and 1996, the majority of patients with tongue base carcinomas in all stages were treated with an approach that included primary surgical resection.9 In the PENN series by Machtay et al.,8 surgery achieved negative
margins in all cases and stages, which resulted in excellent local control. However, open surgical approaches demonstrated a major negative impact on functional outcome, with 29% of patients requiring either long-term gastrostomy tube or tracheostomy with speech and swallowing dysfunction. Another study at the University of Pennsylvania, published in 2001, evaluated outcomes after primary surgical treatment followed by radiation for tonsil and tongue base carcinoma and revealed that although the 3 year local and regional control of 73% was excellent, the rate of distant metastasis of 29% was high and the functional outcome suboptimal, even in the era of complex free flap reconstruction.10 Because of the dual concerns of high rate of distant metastasis and less than optimal functional outcome with a primary surgical approach, a subsequent PENN study was instituted using a combination chemotherapy and radiation for the primary treatment of selected advanced oropharyngeal carcinomas.11 Sixty-two percent of the patients in this PENN study had cancers confined to the tongue base, and the eligibility criteria required that the patients be resectable before initiation of treatment. The clear success in this PENN chemoradiation study was the rate of distant metastases, which was lower at 15% compared with 29% for the surgical series. Nonetheless, the PENN oropharyngeal chemoradiation trial demonstrated significant acute and chronic toxicity resulting from nonsurgical organ preservation, and there was a treatment related mortality rate of 4%, a late grade 3 toxicity rate of 24%, and a 3 year actuarial functional event-free survival rate (defined as freedom from radical surgery, permanent gastrostomy, or permanent tracheostomy) of 59%. Despite the lack of conclusive evidence for the benefits of chemoradiation over the various open or endoscopic primary surgery followed by radiation or chemoradiation, there appears to be a national trend toward using chemotherapy as a primary modality for oropharyngeal carcinomas.12 Although our chemotherapy and radiation organ preservation studies at the University of Pennsylvania indicated advantages in terms of decreased distant metastases, the issues of local control and overall survival as well as functional outcome for any treatment approach remains a significant issue.

Revisiting our surgical data, we noted that negative surgical margins always resulted in local control.8 In addition, there is recent evidence that postoperative combined chemotherapy and radiation improved survival and local regional control over postoperative radiation alone.13 Finally, a series of endoscopic laser resections of tongue base carcinomas indicated that a transoral approach yielded a 92% normalcy in diet, presumably from avoiding the surgical morbidity of open approaches.14 The synthesis of these concepts led us to postulate that a multimodality treatment including minimally invasive TORS for tongue base resection coupled with appropriate use of postoperative radiation alone or in combination with chemotherapy may maximize both functional and oncologic outcome.

The present experiments were designed to test the hypothesis that TORS is technically feasible and can be applied for base of tongue resections in conjunction with commercially available oral and pharyngeal retractors. Both cadaver and animal experiments were used to determine visualization and technical feasibility for base of tongue resections before testing our hypothesis on human patients. The preclinical experiments also defined techniques for identifying critical nerve and vascular structures before their transection. On satisfactory completion of the 10 preclinical cadaver and mongrel procedures, we tested TORS on three human patients under an institutional review board approved human trial. Two primary experimental end points were exposure and access for complete robotic instrument resection of the tumor, and secondary endpoints included safety and surgical time. Although three patients are only a limited human clinical experience, complete tumor resection with relatively brief set-up and operative time was achieved, with no adverse events encountered. This study, therefore, establishes the foundation for application of this procedure on a large-scale study in human patients. Future plans include a prospective study that would compare TORS with or without radiation versus primary chemotherapy and radiation for base of tongue malignancies.

**MATERIALS AND METHODS**

The *da Vinci* Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, CA) was used for three cadaver and two live canine experiments for a total of 10 preclinical base of tongue resection experiments. For all canine experiments, the procedures were performed in accordance with PHS Policy on Human Care and Use of Laboratory Animals, the NIH Guide for the Care and Use of Laboratory Animals, and the Animal Welfare Act (7 U.S.C. et seq.). The protocol was approved by the Institutional Animal Care and Use Committee at the University of Pennsylvania. The two mongrel dogs weighed between 25 and 30 kg, and each received preanesthesia with intramuscular injections of atropine sulfate (AmVet, Neogen Corporation, Lexington, KY), then a mixture of tiletamine HCL and zolazepam HCL (Telazol, Fort Dodge animal Helth, Fort Dodge, IO), and then xylazine base (Tranquived In- jection, Vedco, Inc., St. Joseph, MO). For induction, Propofol (Propfofo, Abbott laboratories, N. Chicago, IL) was used, followed by orotracheal intubation with a number nine cuffs endotra- cheal tube and with maintenance inhalation anesthesia with isoflurane (Isoesol, Rhodia Organique Fine, Ltd., Avonmouth, Bristol, UK). Paralysis was achieved with intravenous pancuronium bromide injection (Baxter, Irvine, CA). Positive pressure ventilatory support was achieved throughout the procedure with an Ohmeda 7000 Ventilator, (Ohmeda BOC Health Care, Madi- son, WI). Monitoring was performed of cardiac status and oxy- genations using a Datex-Ohmeda S/6 (Datex-Ohmeda Division, Instrumentarium Corp, Helsinki, Finland). The tongue was sus- pended with a 0 Prolene suture, and no oral retractors were required.

For the preclinical and human evaluations, operating room space constraints and tongue base exposure were managed as previously described, with the robot aligned at 30 degrees relative to the cadaver, dog, or patient and positioned to the right side of the head.4 For the cadaver studies, we tested three different retractors to assess adequacy of pharyngeal exposure, the Dingman, Crow Davis, and FK retractors. Both a 0 degree high magnification and a 30 degree, upward facing, high-magnification, three-dimensional endoscope was inserted through the retractor to visual- ize the pharynx. Dissections were performed using a variety of 8 mm robotic instruments. All experiments were documented with both still and video photography.

For the human patient evaluations, the *da Vinci* Surgical Robot was used for three base of tongue resections on dentate patients. The pathologic diagnosis was squamous cell carcinoma for each patient, and there were two patients with a T2 and one
patient with a T1 tumor. Details including staging and site are depicted in Table I. Each of these patients was enrolled in an open disease site, prospective human clinical trial for TORS, with access to the tumor and safety as primary end points. Access was defined as adequate visualization and instrument mobility that would allow complete surgical resection to negative frozen section histology. Included in our evaluations were standard oral retractor and exposure set-up and preparation time versus added time for robotic set up plus surgical procedure time.

**RESULTS**

**Pharyngeal and Base of Tongue Access and Technical Feasibility in Cadavers**

Two edentulous and one dentate cadaver were used in these experiments. Exposure to the base of tongue was successfully achieved using the Dingman, Crowe Davis, and FK retractors (Fig. 1A to C). Each of these retractors provided adequate exposure to the right and left base of tongues; however, each posed advantages and disadvantages for performing the surgical procedures. The Crowe Davis, commonly used in tonsil surgery, is easy and quick to apply and has either an open left or right instrument border that allows greater lateral excursion of the robotic instruments. Unlike the Dingman or the FK retractor, the Crowe Davis does not have a spring or articulating mechanism on its lateral ends that allows either sutures to be attached or lateral cheek or tongue retractors to be applied. The Dingman retractor has springs located on each side that allow various positioning of sutures for palate or tongue retraction; however, the working space defined by the circumferential rectangular metal frame is somewhat limiting for broad robotic instrument movement. The FK has a wider rectangular opening and is thus less limiting than the Dingman, and it has two small articulating clamps that allow various tongue or cheek retractors to be attached and manipulated. Furthermore, the FK has a broad range of anterior and dorsal tongue blades including blades that have cutouts in the right or left side that facilitate exposure and right or left base of tongue resection (Fig. 2).

Tongue base resections were easily performed in both edentulous and dentate cadavers using the 0 or 30 degree three-dimensional robotic telescope with one forceps instrument and either the spatula or hook cautery instrument. The benefit of the 30 degree scope was that it allowed a deeper visualization from the base of the tongue into the vallecula. The lingual artery was identified approximately 1.0 cm medial to the posterior lateral base of tongue border and 1.5 to 2.0 cm deep into the musculature. The glossopharyngeal nerve was also identified just

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**TABLE I. Demographics and Pathology Data on TORS Base of Tongue Patients.**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Race</th>
<th>Site</th>
<th>Stage (TNM)</th>
<th>Histology</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>52</td>
<td>White</td>
<td>Right</td>
<td>BOT T2N2bM0</td>
<td>SCC</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>61</td>
<td>White</td>
<td>Right</td>
<td>BOT T1N2aM0</td>
<td>SCC</td>
<td>3</td>
</tr>
<tr>
<td>M</td>
<td>64</td>
<td>White</td>
<td>Left</td>
<td>BOT T2N1M0</td>
<td>SCC 1–2</td>
<td></td>
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</tbody>
</table>

SCC = squamous cell carcinoma; BOT = base of tongue.

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Fig. 1. Base of tongue exposure in preclinical experiments was evaluated using Dingman, Crowe Davis, and FK retractors. (A) Dingman retractor that has rectangular opening and tongue blade with lateral cheek retractors (thin arrows). Inferior and superior sides have springs attached for which silk sutures can be passed and stabilized for tongue, pharynx, or palate retraction (thick arrows). (B) Crowe Davis retractor that has open lateral side for wider instrument maneuverability but with no tissue retraction capability and limited tongue blade options. (C) FK retractor, which offers best combination of tissue exposure and retraction, including suction retractors (arrow) with widest instrument working space.
medial to the lingual artery, and the hypoglossal nerve was approximately 1.0 cm deep to the lingual artery.

**Live Canine Base of Tongue Resections and Hemostasis Control**

We used two mongrel dogs for the preclinical live technical feasibility and anatomy dissection experiments. After general anesthesia in the supine position, the oral cavity and anterior tongue were suspended with a 0 Prolene suture tied to a bar and side arm attached to the lateral edge of the surgical table. Both 0 and 30 degree high-magnification scopes were used during the procedures. Dissections were performed with the same selection of instruments used in the cadaver studies with the addition of a robotic bipolar instrument in place of the grasping forceps. The combination of the bipolar and monopolar robotic cautery was adequate to control basic muscle bleeding and small vessel feeders from the lingual artery. However, the lingual artery was best controlled with either small hemoclips applied with the robotic hemoclip instrument or by an endoscopic hemoclip instrument passed transorally. With the exceptional three-dimensional telescopic visualization, vascular and nerve structures could be readily identified and carefully dissected using the cautery instruments mentioned above.

**TORS for Human Patients with Base of Tongue Cancers**

TORS was performed on three male dentate patients with squamous cell carcinomas of the tongue base. All three patients were diagnosed with invasive squamous cell carcinoma with metastatic disease to the lymph nodes of the neck. Two patients were diagnosed with a T2 tumor, whereas one was diagnosed with a T1. The preoperative computed tomography (CT) scan with positron emission tomography merging of the patient with a T2 right base of tongue cancer is depicted in Figure 3. Neck dissections were completed postrobotic tongue base resection as a separate procedure to avoid entry into the pharynx at the time of robotic resection. In the human patients, we chose to evaluate either the Crowe Davis or FK retractor for access. On the basis of the cadaver studies, we determined that the Dingman did not offer any significant advantages over the Crowe Davis or FK, and the FK had significant advantages with its lateral retractor attachments and its variety of tongue blades. The primary endpoints of the human clinical component of this TORS study were exposure and instrument access to the tumor that allows complete tumor resection. Secondary endpoints were safety and times for set-up. In each patient, both the Crowe Davis and FK retractors were placed to determine which provided the best exposure. Although the Crowe Davis provided reasonable access the base of tongue, the “cut-out” blades and vallecular blade of the FK with three-directional adjustment capability in addition to the attachment of cheek retractors provided the most versatility for achieving ideal exposure. Therefore, the FK retractor was used to perform the actual surgical procedures.

The three human tongue base resections were completed with the da Vinci Surgical Robot and the FK retractor and the cutout tongue blades. The primary robotic instruments used were the Endowrist (Intuitive Surgical) 8 mm forceps or the 8 mm bipolar cautery in conjunction with the 8 mm permanent cautery spatula. Visualization was achieved with both the 0 degree high-magnification...
and a 30-degree high-magnification, three-dimensional endoscope inserted through the FK retractor (Fig. 4). The robot was set up on the right side of the patient table at a 30-degree angle. Tooth and eye guards were in place for patient protection. The surgeon was seated at the remote console approximately 10 feet from the operating table.

For each procedure, the time required to turn and drape the patient and introduce the chosen oral retractor was recorded as standard set-up time. We then recorded the additional time required for the robotic component. Robot set-up time included camera calibration with both black and white balancing, mobilization and positioning of the robot base and arms, and placement of the selected robotic instruments into the oral cavity at the surgical site. We then recorded the time to complete each tongue base resection. The times for set up and surgery are depicted in Table II. Each procedure was safely completed, and all tumors were resected en bloc to both frozen section, and final histopathology confirmed negative margins. The lingual artery was identified, dissected, and all tumors were hemoclip ligated during each procedure. The surgery was recorded as standard set-up time. We then recorded the additional time required for the robotic component.

Table II. Comparison of Intraoperative Set-Up Time Standard versus Robotic.

<table>
<thead>
<tr>
<th>Standard Set-Up Time</th>
<th>Standard Plus Robotic Set-Up Time</th>
<th>Robotic Set-Up Time Only (s)</th>
<th>Surgical Time</th>
<th>Blood Loss (mL)</th>
<th>Hospitalized (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:28:05</td>
<td>00:38:21</td>
<td>12 min 16</td>
<td>2:11:00</td>
<td>150</td>
<td>7</td>
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<tr>
<td>00:44:29</td>
<td>00:52:09</td>
<td>7 min 8</td>
<td>1:31:25</td>
<td>&lt;100</td>
<td>5</td>
</tr>
<tr>
<td>00:12:04</td>
<td>00:40:19</td>
<td>28 min 5</td>
<td>1:33:50</td>
<td>&lt;100</td>
<td>5</td>
</tr>
</tbody>
</table>

One key issue that we want to emphasize is that complete en bloc tumor resection was achieved for each tumor versus the piecemeal or cutting through tumor resection technique mandated by the transoral laser surgery procedures. In the course of our preclinical to human evaluations, we developed a technique that involved exposing the junction of the epiglottis and base of tongue initially using the open laryngeal blade and then making the vallecular cuts as the first component of the surgery. We then repositioned the retractor using the adjustment mechanisms built into the FK or we switch to the cutout tongue blades to make the superior and lateral cuts and then complete the operation. The advantage in this technique is that we define the inferior and lateral limits and cuts, which we believe aids in both maintaining appropriate depth of resection and adequate margin resection while reducing the risk of inadvertent injury to the epiglottis such as transaction or mucosal stripping. The en bloc resection with clear deep margins is achieved by connecting the superior cuts to the inferior cuts at the depth defined by these initial tissue incisions and using the excellent three-dimensional visualization offered by the robotic optics (Fig. 5).

On completion of the surgical procedures, the robotic instruments, the endoscope, and the retractors were removed. There was no inadvertent trauma or injury to the lips, gums, palate, pharyngeal walls, or remaining tongue. Hemostasis was controlled in all live surgical procedures with either monopolar or bipolar cautery or hemoclip application. Each patient was successfully brought out of anesthesia with no evidence of bleeding or oropharyngeal or tongue base edema. Overall, there were no surgical complications or adverse events. The level of pain control was minimal, and patients were able to begin taking clear liquids immediately after the surgery.

With respect to postoperative evaluation, the first patient was hospitalized for 7 days for observation reasons only. The subsequent two patients were hospitalized for 5 days, which was empirically chosen as a sufficient clinical period to observe for bleeding or airway complications. Each of the three patients showed no signs of bleeding or airway edema or compromise, and they had only minimal pain. For the patient with the right base of tongue T2 squamous cell carcinoma. Excellent one view exposure of tumor, dorsal and medial base of tongue, tonsillar region, and posterior lateral pharynx is achieved using FK retractor and its variety of tongue blades.

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cancer, a postoperative CT scan at 1 month showed complete tumor resection with minimal postoperative scar tissue (Fig. 6).

Although no one had significant edema or complications, we recommended that each patient continue using their percutaneous endoscopic gastrostomy (PEG) tube to provide efficient nutritional intake until full solid foods could be reintroduced into the diet. All patients were able to eat a full, solid diet by way of mouth without any PEG supplement within approximately 6 weeks after the surgery. Each patient was evaluated within 2 weeks postoperatively and had no complaints. At a postoperative visit on day 12, one patient experienced bleeding from the surgical bed at the time of indirect laryngoscopy and underwent successful transoral coagulation of the bleeding with no sequelae. Two patients went on to receive chemoradiation, whereas the T1 patient received radiation therapy alone. From a functional standpoint, one patient is swallowing well 3 weeks into chemotherapy and radiation, and the other two patients have completed either radiation or chemoradiation and are presently swallowing all consistencies without the need for gastrostomy tube supplementation.

DISCUSSION

Over the past 10 years, there have been increasing reports of the use of primary radiation or combined chemotherapy and radiation for tongue base neoplasms. The key factor driving this movement away from primary surgery was the reported morbidity of such surgical procedures. Cervical incisions and dissections with mandibulotomy or pharyngotomy were typically required to remove base of tongue neoplasms even in the early stages. These approaches left the patient with various levels of significant speech and swallowing dysfunction as well as cosmetic deformity depending on the size and location of the tumor and extent of resection. Nonetheless, combined chemotherapy and radiation is also associated with significant to severe speech and swallowing dysfunction along with varying degrees of chronic pain and xerostomia. In addition, based on a retrospective analysis of a large number of patients in the National Cancer Data Base, survival may be better with surgery plus radiation when compared with either radiation alone or combined chemoradiation.

The introduction of endoscopic laser microsurgery for tongue base cancer has been reported by Steiner et al. Transoral CO2 laser pharyngeal surgery reintroduced primary surgery as a means of treating base of tongue cancer, but this technique is technically challenging, has a steep learning curve, and a limited operative field of view because it is performed through a laryngoscope. Furthermore, the transoral laser surgery requires cutting directly through the tumor to determine extent of resection. It is possible that these limitations have contributed to the lack of widespread appeal of this approach. Nonetheless, the transoral approach did reveal that 92% of patients achieved swallowing without permanent gastrostomy tube. These excellent swallowing function results led us to postulate that TORS for tongue base neoplasm should yield similar functional outcomes while overcoming some of the disadvantages of endoscopic laser surgery outlined above.

On the basis of our preclinical development and early patient experience, we believe that TORS for tongue base lesions has significant advantages over both classical open tongue base surgery and laser microsurgery. With respect to open approaches, it is well known and widely reported that open surgery of the tongue base has obvious negative
impact on both functional and cosmetic outcomes. TORS eliminates the need for mandibulotomy with a lip split or visor flap or transpharyngeal approaches that adversely affect mastication, swallowing and speech function, and cosmesis. Furthermore, open approaches have a known risk of fistula and infections because they create a communication created between the oral cavity and the neck. In addition, we believe that TORS tongue base resections can be performed safely without tracheostomy, which is typically used for open approaches. As a safety precaution, our first two tongue base patients underwent tracheostomies but were decannulated within 1 to 2 weeks after surgery. Because neither patient demonstrated tongue or airway edema or compromise or evidence of aspiration, we concluded that tracheostomy is not necessary. Our third patient who had a T2 tumor did not undergo a tracheostomy and had no airway compromise or aspiration.

Although we do not have extensive human clinical trial data, our preclinical data suggest that TORS offers several potential advantages over laser pharyngeal and base of tongue surgery as well. The actual technical aspects of laser microsurgical base of tongue resection are challenging, and published data indicate that significant experience is required to decrease complication rates. Although no formal learning curve studies have been performed for TORS, our personal experience with both procedures and our attempts to teach TORS to residents and fellows strongly suggest that the learning curve is significantly shorter than the learning curve for transoral laser resections. This finding of a short learning curve is consistent with the learning curve studies for robotic surgery in other anatomic sites. Although the standard operating microscope used in laser procedures provides excellent direct visualization to an exposed area, it cannot view around corners or cannot be rotated along three-dimensional axes. The 0 or 30 degree angles and the maneuverability of the robotic endoscopes is a key issue in the ability to achieve en bloc resections of the tumors with negative margins. In addition, there is significantly less working space constraints with the robotic approach than with surgery performed through a laryngoscope. Laser microsurgery is essentially one-handed surgery, whereas robotic surgery is two- or even four-handed (if the assistant is included), and tissue manipulation and retraction is comparable with open surgery.

In all of our preclinical canine experiments and human patient procedures, the excellent three-dimensional high magnification allowed visualization of the vessels, whereas the two instruments enable dissection of the vessels before they were transected. However, in the case of transaction or laceration of these vessels, the robotic forceps allows straightforward grasping of the vessel or surrounding tissues. Bipolar forceps or monopolar instruments may then be used to cauterize the bleeding vessel. Alternatively, figure of eight suturing may be performed with the robot suturing instruments. It is our impression that TORS offers a wider variety of technical options for hemostasis compared with transoral laser microsurgery. The ease of controlling hemostasis coupled with the lack of adverse events noted in both the preclinical and human clinical components of this study in conjunction with our recent publication on general technical safety issues for TORS support the overall safety of this novel procedure.

CONCLUSIONS

Our preclinical experiments in cadavers and live dogs and our subsequent study in three human patients demonstrate the technical feasibility of accessing and performing tongue base resections without requiring transcervical or transmandibular approaches. The exceptional high-magnification and three-dimensional optics allowed careful dissection with en bloc resection with identification of nerves and vessels before transaction or inadvertent injury. Hemostasis was easily managed in the live surgeries with either monopolar or bipolar cautery robotic instrumentation and the use of small-sized hemoclips. The robotic instrumentation furthermore offered at least 360 degrees of freedom of movement, varied levels of scaled movement, and hand tremor buffering that greatly enhanced the precision by which base of tongue procedures can be performed. TORS holds promise for human clinical application and may prove valuable as a minimally invasive and low morbidity primary therapy for base of tongue neoplasia. TORS may also shift the paradigm back to primary surgery with or without radiation for the management of base of tongue and pharyngeal cancers.

BIBLIOGRAPHY