Published in final edited form as:

Ann Otol Rhinol Laryngol. 2016 January ; 125(1): 37–42. doi:10.1177/0003489415596754.

Intraoperative Ultrasonography During Transoral Robotic Surgery

Daniel R. Clayburgh, MD, PhD¹, J. Kenneth Byrd, MD², Jennifer Bonfili, BSN, RN⁴, and Umamaheswar Duvvuri, MD, PhD³

¹The Department of Otolaryngology-Head and Neck Surgery, Oregon Health and Science University and the Portland VA Medical Center, Portland, Oregon, USA

²Department of Otolaryngology-Head and Neck Surgery, Georgia Regents University, Augusta, Georgia, USA

³Department of Otolaryngology-Head and Neck Surgery, University of Pittsburgh, and Veterans Affairs Pittsburgh Health System Pennsylvania, USA

⁴Division of Perioperative Nursing, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA

Abstract

Objective—This study describes the potential application of intraoperative ultrasound imaging during transoral robotic surgery (TORS).

Methods—Ultrasound imaging was performed during transoral robotic resection of oropharyngeal tumors in 10 patients at a tertiary academic center. Ultrasound imaging was utilized to identify large-caliber vessels adjacent to the surgical site. Measurements were also taken on the ultrasound of tumor thickness to determine the deep margin. Following resection, the tumor was sectioned, and a gross measurement of the tumor thickness was obtained.

Results—Intraoperative ultrasound use led to the identification of larger-caliber blood vessels within the operative field prior to encountering them visually. Ultrasound could also aid in defining deep tumor margins; the tumor thickness measured via ultrasound was found to be accurate within 1 to 2 mm of the grossly measured tumor thickness. This allowed for focused, careful dissection to protect and avoid blood vessels during dissection as well as improved tumor resection.

Conclusions—The use of intraoperative ultrasound provides additional information to the head and neck surgeon during TORS. This may be used to identify blood vessels and assess tumor margins, thereby improving the safety and efficacy of TORS.

Corresponding Author: Umamaheswar Duvvuri, MD, University of Pittsburgh Medical Center, Eye and Ear Institute, Suite 500, 200 Lothrop St., Pittsburgh, PA 15213, USA. duvvuri@upmc.edu.

This manuscript was presented at the Triological Society Combined Sections Meeting, January 10–12, 2014, Miami Beach, Florida, USA.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr Duvvuri serves as a proctor for Intuitive Surgical, Inc. This work does not reflect the views of the US Government or the Department of Veterans Affairs.

Keywords

transoral robotic surgery; oropharynx; ultrasound

Introduction

Transoral robotic surgery (TORS) is a relatively new tool in the treatment of patients with malignancies and benign tumors of the oropharynx. The technique was initially described by O'Malley and coworkers at the University of Pennsylvania¹; FDA approval occurred in 2009,² and since that time, TORS has become an increasingly utilized method of managing selected oropharyngeal lesions. Transoral robotic surgery provides enhanced ability to work in the tight confines of the oropharynx due to the 3D visualization and wristed instrumentation of the robotic surgical system. This allows the surgeon to resect oropharyngeal tumors that previously would have required highly morbid open procedures such as lateral pharyngotomy or mandibulotomy.

Despite the many advantages of TORS, such as enhanced visualization, current robotic surgical systems do not provide haptic feedback to the surgeon. Haptic feedback allows the surgeon to distinguish the boundary between healthy tissue and malignancy and also allows for palpation of vascular structures within the tumor bed. One of the most devastating complications that may occur during TORS is massive hemorrhage from inadvertent injury to the vasculature of the head and neck.^{3,4} Although the excellent 3D visualization provided by the robotic system is helpful in locating these vessels, the absence of haptic feedback does place the surgeon at a disadvantage.

We sought to address this issue by using intraoperative imaging with real-time ultrasound to augment the 3D visualization of the robotic system. Ultrasound imaging may allow for identification of the tumor boundary and the neurovascular structure within the tongue base and laryngopharyngeal wall, thereby improving the oncologic resection and reducing morbidity. Herein we report a series of patients in which intraoperative ultrasound was used to facilitate TORS, with particular attention to 2 demonstrative cases. In 1, additional imaging allowed for identification of the vasculature at risk adjacent to the operative bed, thereby allowing the surgeon to perform a dissection in this area without inadvertent injury to these critical vascular structures. In the other, the ultrasound clearly showed the deep margin of the tumor, improving the ability of the surgeon to confidently perform a wide resection of this tumor with clear margins.

Materials and Methods

Intraoperative ultrasound was utilized during transoral robotic resection of oropharyngeal tumors in a series of patients. In each case, the Aloka Alpha 7 ultrasound system (Hitachi Aloka Medical, Ltd, Wallingford, Connecticut, USA) with a neuro spine ultrasound probe was used. Surgical resection was performed with the DaVinci Si robotic system (Intuitive Surgical, Inc, Sunnyvale, California, USA). For applications in the posterior and lateral oropharynx (eg, tonsillar fossa, parapharyngeal space), a neuro spine straight ultrasound probe was used. In order to use this ultrasound probe during TORS, the robotic arms were

removed from the patient's mouth while the camera was left in position, and the ultrasound probe was inserted alongside the camera. This provided ultrasound access to the lateral and posterior pharyngeal walls. For base of tongue imaging, a liver ultrasound probe was used. This probe is aligned at a 90° angle to better image the tongue base and has a small tab on its backside that could be grasped with the Maryland dissector on the robotic arm. Thus, with this probe, at least 1 and potentially both robotic arms could remain in the patient's mouth along with the camera. Intraoperatively, the ultrasound images were displayed within the robotic console using the TilePro multi-input display (Intuitive Surgical, Inc). All ultrasound imaging was performed by the surgeon. Intraoperative video was recorded, then edited using iMovie (Apple Inc, Cupertino, California, USA).

Results

Case No. 1

A 78-year-old female presented with a history of right-sided oropharynx carcinoma, initially staged T3N1. This tumor was treated 3 years previously with chemotherapy and radiation therapy and followed by a durable response in the right pharyngeal wall and neck. Prior to presentation, the patient was noted to have a lesion on the left tonsil and lateral pharyngeal wall with extension to the tongue base. The disease was biopsied and found to be at least carcinoma in situ. However, because of the patient's history of radiation therapy, which encompassed both sides of the oropharynx, surgical excision of this lesion was recommended.

Due to the patient's prior history of radiation therapy, it was noted that the tissues in the left lateral pharyngeal wall were somewhat atrophic, and pulsation transmitted from the carotid system could be seen intraorally. For this reason, we sought to augment the robotic assisted methodology with intraoperative imaging in order to more clearly define the vascular anatomy in this area and avoid inadvertent injury to the great vessels in the parapharyngeal space.

The patient was brought to the operating room for TORS left lateral pharyngectomy. The patient's tumor was clearly visualized involving the anterior and posterior tonsillar pillars and extending inferiorly to the left tongue base. Additionally, pulsation of the carotid system could be seen along the left pharyngeal wall in the area of this lesion, and vessels could be seen deep to this tumor using the ultrasound probe (Figure 1A). While vessels in the area of dissection were seen on preoperative computed tomography (CT) scans (Figure 1B), these scans do not provide the same correlation to the intraoperative view as the real-time ultrasound imaging. Surgical dissection was performed using monopolar cautery to initially define the superior, lateral, and inferior boundaries of dissection until the constrictor muscle was encountered (Figure 1C). Given the risk of vascular injury in this area, a hockey stick ultrasound probe was then placed into the tumor bed, allowing for visualization of a large artery just deep to the plane of dissection (Figure 2A). Further measurement with the ultrasound showed this vessel to be 1.46 cm deep to current level of dissection. With this information, dissection proceeded, and the vessel was safely identified without injury in the area predicted by the ultrasound (Figure 2B). Two small vascular branches from this vessel were also identified penetrating the constrictor muscle and were controlled with surgical

clips. The remainder of the tumor dissection could be safely performed without vascular injury. At the conclusion of the dissection, large-caliber vessels in the parapharyngeal space, including the carotid artery, could be clearly seen using the ultrasound within the wound bed (Figure 3). The procedure was completed uneventfully, and the patient was discharged home on postoperative day 1 tolerating oral intake. A video of this procedure demonstrating the use of the ultrasound may be seen in the supplemental materials.

Case No. 2

A 66-year-old male presented with a T2N2a, HPV+ squamous cell carcinoma (SCC) of the left tongue base. The patient elected to undergo TORS resection of the tongue base tumor, followed by a staged neck dissection. The patient was brought to the operating room for TORS resection of the tongue base, and a firm tumor of the left tongue base was readily palpable. Prior to beginning the TORS resection, the ultrasound was used to examine the tumor (Figure 4A). This clearly demonstrated the interface between the tumor and the surrounding normal tissue as an echogenic line, which was measured to be approximately 1.36 cm from the mucosal surface. The TORS tongue base resection was then performed. Once the tumor was removed, the specimen was examined, and the tumor margin was clearly seen as demonstrated previously by the ultrasound, and the tumor thickness was noted to be similar to that measured by ultrasound (Figure 4B). The resection margins were found to be free of tumor pathologically. The patient recovered well from this surgery, was discharged home 3 days after surgery tolerating oral intake, and subsequently underwent a staged neck dissection 2 weeks later.

Case Series

Intraoperative ultrasound was utilized in 10 patients undergoing TORS (Table 1). In most cases, this was primarily used for identification of vascular anatomy prior to and during resection; in all cases, nearby vessels were seen, and no vascular injuries or excessive intraoperative hemorrhage occurred. This was particularly helpful in 2 cases. Case No. 4 consisted of a transoral resection of a parapharyngeal space mass, where dissection was performed close to the great vessels in the parapharyngeal space; the ultrasound was useful to identify these vessels before they could be visualized. Case No. 8 involved a relatively large tonsillar tumor that had exhibited growth between the acquisition of CT imaging and the day of surgery, and in this case, ultrasound revealed a large vessel intimately involved by the deep aspect of the tumor, making further resection of this unnecessarily risky. These data from the intraoperative ultrasound led to the procedure being aborted.

The ultrasound was also used to identify tumor margins in 4 of the cases. Comparison of the ultrasound measurement with the measured depth of the tumor on gross pathologic sectioning showed that the ultrasound was generally accurate within 1 to 2 mm. In all cases, the final pathologic margins were found to be free of tumor. In 1 case of a patient undergoing a tongue base resection for an unknown primary tumor, the ultrasound was unable to identify the primary tumor in the lingual tonsil. A 0.7 cm primary tumor was later found on pathologic analysis of the resection specimen. In all cases, the use of ultrasound imaging added only 5 to 10 minutes onto the total operating time, despite frequently

requiring the removal of the robotic arms from the oral cavity in order to accommodate the ultrasound probe.

Discussion

Despite the advantage of enhanced visualization provided by the DaVinci robotic system, the loss of haptic feedback can create difficulties during TORS; thus, other modalities of augmenting the surgeon's vision may improve the safety and efficacy of this procedure. Ultrasound is widely available, easy to use, and can provide excellent visualization of blood vessels within tissue. Intraoperative ultrasound is widely employed in other surgical specialties, including thyroid surgery,⁵ hepatobiliary surgery,⁶ and neurosurgery.⁷ With this in mind, we utilized ultrasound imaging during TORS resection of oropharyngeal lesions in several patients, demonstrating the identification of nearby blood vessels and tumor margins with accurate calculation of tumor depth. Furthermore, intraoperative ultrasound appeared comparable or better to preoperative CT scans at revealing nearby vasculature. Thus, while CT is certainly a better imaging modality for overall tumor staging and preoperative anatomical assessment, it cannot provide real-time feedback to the surgeon during the procedure; only ultrasound can feasibly be repeated multiple times during the procedure to accurately "see" beyond the currently exposed tissue plane to assess deeper structures. This has the potential to reduce blood loss, operative time, and risk of postoperative hemorrhage as well as aid the surgeon in obtaining clear surgical margins. Indeed, in urologic surgery, the use of ultrasound has been shown to decrease the rate of positive surgical margins and improve the dissection of neurovascular bundles during prostatectomy,⁸ suggesting similar improvements may be possible with TORS.

In several cases, we were easily able to define the deep margin of a tongue base tumor, thereby providing a guide for tumor resection. The ultrasound provided an accurate measurement of the tumor thickness when compared to the pathologic specimen. We were less successful in locating an unknown primary tumor within the tongue base using the ultrasound probe. This may in part be due to lack of experience with intraoperative ultrasound, the small size of the unknown primary tumor, or the relative similarity of small amounts of tumor to normal tissue on ultrasound imaging. Further experimentation and experience with the use of ultrasound in this situation may yield more promising results.

Despite the potential advantages to using ultrasound as described previously, there remain some drawbacks to its use. There is a learning curve associated with the use of ultrasound; this may require repeated experimentation and correlation between ultrasound imaging and intraoperative visualization on the part of the surgeon. The currently available ultrasound probes, while compact, are still large and cumbersome to use transorally while the robot is docked. In patients with smaller mouths or tighter exposures, we found that the robotic arms need to be removed in order to place the ultrasound probe in the correct position. Ideally, more compact ultrasound probes may become available to circumvent this issue, or probes may be developed that are incorporated into the robotic instrumentation.

This initial case series was not designed to systemically prove the superiority of ultrasound use during TORS but rather to demonstrate a novel application of ultrasound during TORS.

Further studies will be required to define the utility of ultrasound to the TORS surgeon. Ideally, a larger-scale, prospective study of this technique will assess the impact of ultrasound use during TORS on a variety of factors, including surgical time, blood loss, surgical margins, complications, and cost. Furthermore, a systematic comparison between ultrasound imaging and preoperative CT scans on a larger scale would more clearly define the added benefit of ultrasound use. Nevertheless, the data presented here demonstrate that ultrasound use during TORS is feasible and has the potential to improve the safety and efficacy of TORS.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was funded in part by a Career Development Award from the Department of Veterans Affairs BLR&D, and the PNC Foundation (U.D.).

References

1. O'Malley BW Jr, Weinstein GS, Snyder W, Hockstein NG. Transoral robotic surgery (TORS) for base of tongue neoplasms. *Laryngoscope*. 2006; 116:1465–1472. [PubMed: 16885755]
2. Maan ZN, Gibbins N, Al-Jabri T, D'Souza AR. The use of robotics in otolaryngology-head and neck surgery: a systematic review. *Am J Otolaryngol*. 2012; 33:137–146. [PubMed: 21658808]
3. Chia SH, Gross ND, Richmon JD. Surgeon experience and complications with transoral robotic surgery (TORS). *Otolaryngol Head Neck Surg*. 2013; 149(6):885–892. [PubMed: 24013139]
4. Asher SA, White HN, Kejner AE, Rosenthal EL, Carroll WR, Magnuson JS. Hemorrhage after transoral robotic-assisted surgery. *Otolaryngol Head Neck Surg*. 2013; 149:112–117. [PubMed: 23585156]
5. Lew JI, Rodgers SE, Solorzano CC. Developments in the use of ultrasound for thyroid cancer. *Curr Opin Oncol*. 2010; 22:11–16. [PubMed: 19864951]
6. Marcal LP, Patnana M, Bhosale P, Bedi DG. Intraoperative abdominal ultrasound in oncologic imaging. *World J Radiol*. 2013; 5:51–60. [PubMed: 23671741]
7. van Leyen K, Klotzsch C, Harrer JU. Brain tumor imaging with transcranial sonography: state of the art and review of the literature. *Ultraschall Med*. 2011; 32:572–581. [PubMed: 22033868]
8. Ukimura O, Magi-Galluzzi C, Gill IS. Real-time transrectal ultrasound guidance during laparoscopic radical prostatectomy: impact on surgical margins. *J Urol*. 2006; 175:1304–1310. [PubMed: 16515987]

Figure 1.

(A) Tilepro image of ultrasound use prior to starting dissection. A large blood vessel is seen in the deep lateral portion of the planned dissection (arrow). (B) Preoperative computed tomography scan of this patient shows vasculature in the area of dissection (arrows). (C) Following vessel identification, initial dissection proceeds as planned to excise the tumor.

Figure 2.

(A) After initial dissection, the ultrasound is used to visualize the large blood vessel near the plane of resection (arrow). (B) Careful dissection in the area identified on ultrasound leads to identification and preservation of the artery (arrow).

Figure 3.

(A) After resection of the tumor, the ultrasound again identifies several large blood vessels within the parapharyngeal space just lateral and deep to the surgical bed. (B) Final surgical defect.

Figure 4.

(A) Intraoperative ultrasound still from patient No. 2 demonstrating the tongue base squamous cell carcinoma, with an echogenic line (white arrow) indicating the interface between tumor and adjacent normal tissue. Tumor thickness was measured to be 1.36 cm. (B) After removal from the patient, the tumor specimen was sectioned and measured. The tumor margin is marked with a black arrowhead; the overall tumor thickness was found to be approximately 1.3 to 1.4 cm.

Table 1

Case Series of Intraoperative Ultrasound Use During Transoral Robotic Surgery.

Patient	Age/Sex	Pathology	Procedure	Ultrasound Function
1	78 F	SCC of oropharynx, T2	Partial pharyngectomy	Vessel identification
2	66 M	SCC of base of tongue, T2	Base of tongue resection	Tumor margin assessment (US measurement, 1.36 cm; gross measurement, 1.3 cm)
3	60 M	SCC of tonsil, T2	Partial pharyngectomy	Vessel identification
4	83 M	Parapharyngeal space Warthin's tumor	Transoral resection of parapharyngeal space tumor	Vessel identification
5	71 M	Unknown primary SCC	Tongue base resection	Search for unknown primary unsuccessful (primary tumor later identified histologically in resection specimen)
6	70 F	SCC of tonsil, T2	Partial pharyngectomy	Vessel identification
7	51 M	Liposarcoma of pharyngeal wall	Partial pharyngectomy	Vessel identification, tumor depth assessment (US measurement, 0.68 cm; gross measurement, 0.75 cm)
8	57 M	SCC of tonsil, T3	Attempted radical tonsillectomy	Vessel identification—large caliber vessel seen running immediately adjacent to tumor edge, aborted procedure
9	73 F	SCC of tongue base, T1	Tongue base resection	Tumor depth assessment (US measurement, 0.66 cm; gross measurement, 0.6 cm)
10	49	SCC of tonsil, T2	Radical tonsillectomy	Tumor depth assessment (US measurement, 0.79 cm; gross measurement, 0.9 cm)

Abbreviations: SCC, squamous cell carcinoma; US, ultrasound.