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CLINICAL REVIEW

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Transoral robotic surgery for head and neck malignancies: Imaging features in presurgical workup

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Abstract

The objective of this article was to review the indications for transoral robotic surgery (TORS) in head and neck malignancies. The role of imaging in patient selection will be specifically reviewed. TORS is a recently developed technique that allows minimally invasive surgeries to be performed in the head and neck. TORS has a role in the de-escalation of oropharyngeal cancers, which allows for lower doses of chemoradiation therapy (this is a technique currently in clinical trials). Additionally, this technique allows for less invasive surgery and decreases associated complications. TORS can also be performed at other subsites. Cross-sectional imaging has a prominent role to help identify suitable candidates for this type of surgery. This article will review important anatomy and staging related to TORS. Additionally, the key imaging features for patient selection (indications and contraindications) will be presented along with case illustrations.

KEYWORDS

head and neck, oncology, oropharynx, radiology, TORS

1 | INTRODUCTION

The treatment of early stage oropharyngeal carcinomas has historically been radiotherapy with or without chemotherapy or surgery with adjuvant therapy.[1,2] Historically, nonsurgical modalities of treatment gained favor due to the morbidity associated with open surgical approaches.[1,3] Chemoradiotherapy, however, may also be associated with morbidity and side effects such as mucositis, xerostomia, and dysphagia and in some cases necessitating the placement of a gastrostomy tube.[4-6] In order to ameliorate the toxicity associated with this treatment, many have looked back to surgical approaches. In addition, with the improved prognosis in patients with human papillomavirus (HPV)-related oropharyngeal carcinomas, efforts are being made to decrease treatment intensity and decrease patient moribidity.[1,2,6,7]

Transoral robotic surgical techniques allows for minimally invasive methods to resect tumors in the oropharynx.[1-12] This technology allows for multiple degrees of freedom of movement and wristed instrumentation that can safely access difficult locations in the upper aerodigestive tract.[1]

Presurgical imaging workup is critical in the identification of proper candidates for transoral robotic surgery (TORS).[13-15] Several imaging features of both the primary tumor and associated nodal disease will help the surgeon identify patients who are candidates for surgery and who may also need adjuvant therapies. This article will review the key radiologic imaging features that need to be assessed

Abbreviations: TORS, transoral robotic surgery; HPV, human papillomavirus.

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in order to determine the feasibility for resectability by TORS in the head and neck.

2 | KEY ANATOMICAL CONSIDERATIONS

TORS has a focus on treatment within the oropharynx. Key anatomical features for tonsillar and tongue base carcinomas will be reviewed. The oropharynx consists of the posterior one-third of the tongue, palatine tonsils, and soft palate. The anterior border is demarcated by the circumvallate papillae of the tongue, anterior tonsillar pillars, and soft palate. The posterior pharyngeal wall demarcates the posterior border, and the lateral border consists of the palatine tonsils. The superior border is bounded by the soft palate and inferiorly by the valleculae.[16] The tonsillar fossa is bounded by the anterior and posterior tonsillar pillars, which consists of the palatoglossal and palatopharyngeal muscles, respectively.[17] Within the tonsillar fossa lies the palatine tonsil. Inferiorly, the valleculae are present and beneath this is the pre-epiglottic fat space, a key landmark to note for oropharyngeal tumor involvement due to its implication on TORS candidacy. Lateral to the oropharynx runs the pre-styloid parapharyngeal space which consists primarily of fat. Surgically, the post-styloid parapharyngeal space is analogous to what some refer to as the "carotid space" which contains the internal carotid artery, internal jugular vein, and cranial nerves 9 to 11. Tumor involvement of the post-styloid parapharyngeal space is important to note due to implications on TORS candidacy. The tongue base, particularly the posterior tongue base, is of importance in TORS. The circumvallate papillae delineate separation between the oral tongue and the base of tongue. The tongue base consists of intrinsic and extrinsic muscles. Inferiorly, the lingual arteries run in the sublingual space, another important landmark. Lingual tonsillar tissue is noted in the mucosal space of the tongue base.

3 | PHILOSOPHY OF TREATMENT

Our general approach (from both the literature and opinion of the authors) for selecting patients for surgery is to avoid triple modality therapy (surgery, radiation, and chemotherapy). Although this is not always possible, several radiographic features may suggest the need for adjuvant therapies based both on the primary tumor and nodal disease features. For instance, in cases where there is extensive nodal disease, there will be a higher risk of extranodal extension or of positive surgical margins, both of which would require subsequent adjuvant therapy. Other examples may include extensive tumor invasion of the pre-styloid parapharyngeal space by a tonsillar carcinoma or extensive invasion of the tongue base in a tongue base carcinoma. In these cases, careful review of imaging and counseling patients on the likelihood of needing adjuvant therapies is important in helping make treatment decisions. Conversely, patients with limited nodal disease (eg, no lymphadenopathy or one involved node) and localized primary site tumors may be well served with an upfront surgical approach because of the possibility of avoiding adjuvant therapy altogether.[18]

4 | TONSILLAR CARCINOMAS

In the evaluation of patients with tonsillar carcinomas for TORS, there are several imaging features that may help identify suitable candidates or exclude nonoperative patients. For example, tumors which are localized to the tonsillar fossa as seen in Figure 1 without any further tumor spread

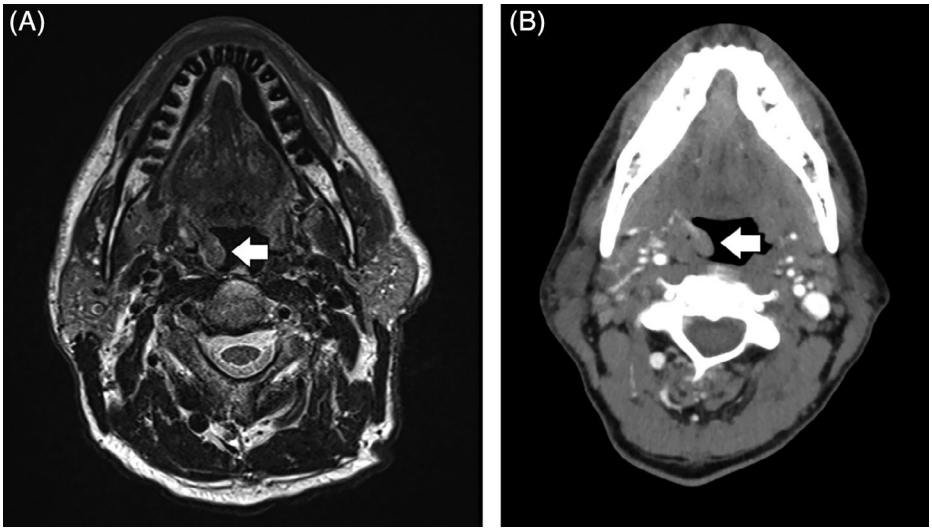

FIGURE 1 Axial T2-weighted MR (A) and contrast-enhanced CT (B) images demonstrate an example of a good transoral robotic surgery candidate. There is a right tonsillar carcinoma which is localized to the tonsillar fossa (white arrow) with no or limited nodal disease. It is important to note the relationship of the deep tumor margin to the nearby ICA, ECA, and lingual arteries. This allows the surgeon to mitigate bleeding risk during surgery as any adjacent arteries can be surgically clipped during surgery

into adjacent structures would be a very good candidate for TORS.

Absolute contraindications for TORS of tonsillar carcinomas (examples shown in Figure 2) include complete internal carotid artery encasement, which would render the disease unresectable (note this would also be a contraindication for an open surgical approach). Identification of tumor encasement of the carotid vessels can be performed on MRI and CT, and there is a higher likelihood of tumor being adherent to the carotid artery when there is a greater degree of circumferential involvement.[19,20] A study by Yousem et al noted that the involvement of 270 degrees or more of the circumference of the carotid was accurate in predicting the surgeon's inability to peel tumor away from the carotid in 100% of the cases.[21] Tumor that has extended to involve the periosteum of the mandible would also not be amenable to a transoral resection as there are currently no available transoral bone cutting instruments (note this would also be a contraindication in laser microsurgery). Prevertebral involvement is important to note as this would again represent unresectable disease (Figure 2C, D). Radiographically visible effacement of the prevertebral soft tissues with loss of fat planes is suggestive of prevertebral involvement.[22] Invasion into the prevertebral musculature or the presence of bony vertebral destructive changes on CT or bony signal changes on MRI would be compatible with vertebral bony involvement. Another contraindication would be extensive tumor involvement of the masticator space, pterygoid muscles, or temporalis muscle as clear margins would be difficult to achieve from the transoral approach and ultimately require adjuvant therapy. Excessive stranding, nonseparation of the tumor from the musculature, and frank invasion are imaging findings to note.

Relative contraindications to TORS for tonsillar carcinoma are also important to note in presurgical imaging workup and gives the surgeon an advanced warning of potential risks which can be weighed in the treatment decision-making process. Prestyloid parapharyngeal space (Figure 3A) involvement is a relative contraindication due to the difficulty in achieving clear margins from a transoral approach.[23] Extension of tumor into the nasopharynx (Figure 3B) may make TORS unsuitable due to difficulty in surgically accessing the nasopharyngeal component of disease for resection. Medialization of the carotids is another relative contraindication and is a known anatomic variant. During a pharyngeal resection, a patient with a medialized internal carotid artery would have a higher risk of vascular injury during resection. However, recent publications suggest TORS can still be feasible for this subset of patients.[14,15,24] Finally, assessment of soft palate involvement (Figure 3C) is important as extensive involvement would be a relative

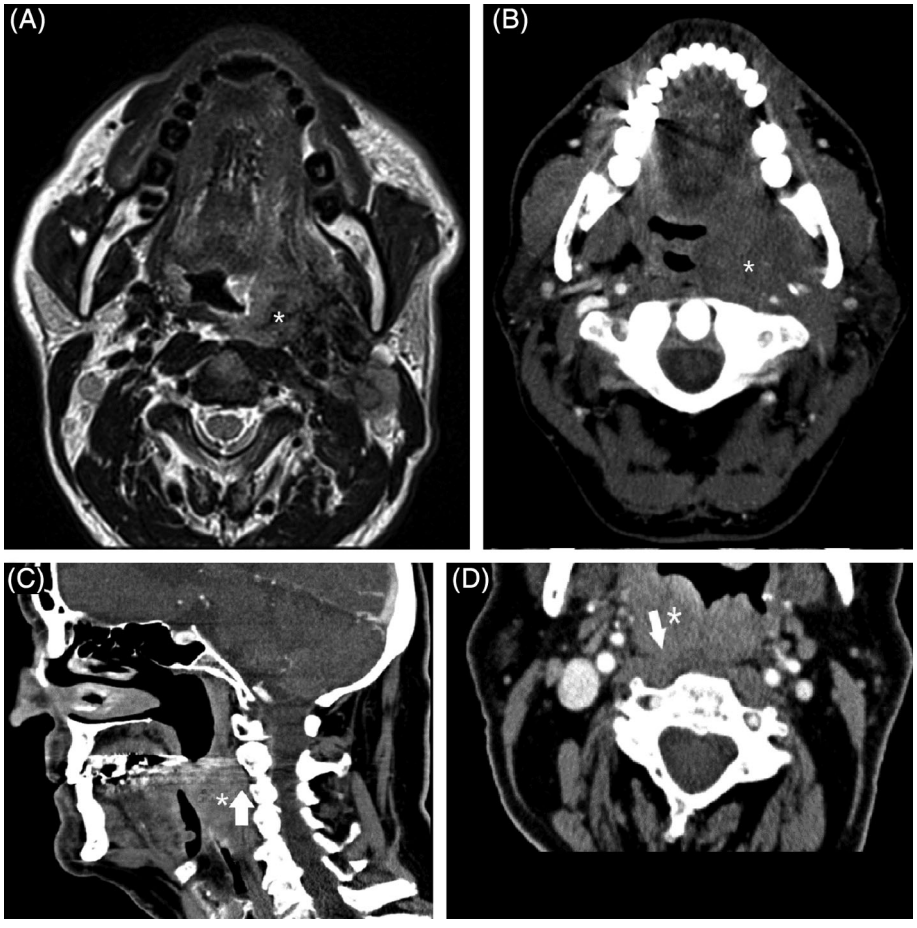

FIGURE 2 MR and CT images demonstrate absolute contraindications for transoral robotic surgery in tonsillar carcinoma. A and B, Axial T2-weighted MR and axial contrast-enhanced CT images show a left oropharyngeal tumor (*) that extends posterolaterally to encase the left carotid artery and also infiltrates the left masticator space. C and D, Sagittal and axial contrast-enhanced CT images show a lobulated oropharyngeal tumor extending posteriorly to involve the prevertebral space (*), as evidenced by focal loss of the prevertebral fat plane (white arrow)

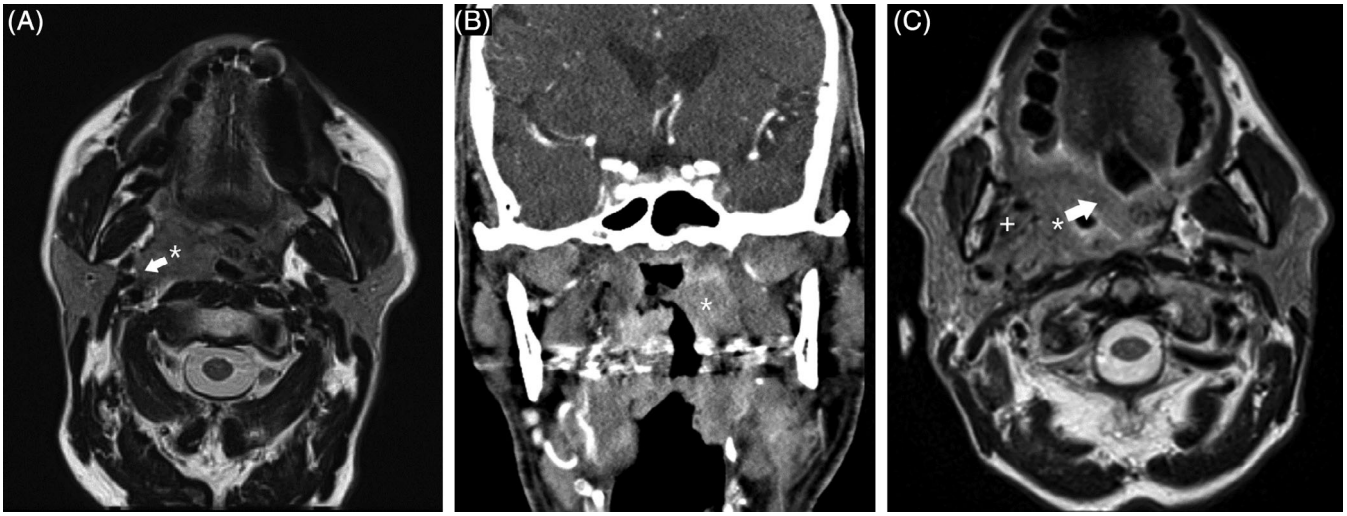

FIGURE 3 MR and CT images demonstrate examples of relative contraindications for tonsillar carcinoma in transoral robotic surgery (TORS). A, Axial T2-weighted MR image shows a right tonsillar carcinoma (*) with pre-styloid parapharyngeal fat involvement and extension laterally to abut the vascular structures (white arrow). B, Coronal contrast-enhanced CT shows a left-sided tonsillar carcinoma which extends superiorly to involve the nasopharynx (*). C, Axial T2-weighted MR image shows a right tonsillar mass (*) that has extended onto the right soft palate (white arrow). This is itself a relative contraindication but ultimately in this case, there is also right masticator space invasion (+) that was an absolute contraindication for TORS

contraindication as a large soft palate resection may result in a significant functional deficit with associated velopharyngeal insufficiency that would obviate the potential functional benefits of an upfront surgical approach and may also require more complex microvascular reconstructive methods to mitigate the risk of downstream functional deficit.

5 | TORS FOR THE TONGUE BASE

When considering TORS for tongue base carcinomas, there are several important imaging features that need to be assessed (examples shown in Figure 4). Absolute contraindications for TORS in the tongue base include invasion of the hyoglossus muscle or extension beyond the boundary of the hyoglossus muscle into the neck. The rationale for this is that an open approach is better suited to identifying and preserving the continuity of the hypoglossal nerve that runs on the lateral aspect of the muscle. A hypoglossal palsy in the setting of a large tongue base resection can lead to a poor functional outcome. Extensive invasion of the genioglossus is a relative contraindication due to its close proximity to the lingual artery at the lateral aspect.[25] Additionally, this type of invasion would require a near total or total glossectomy causing postoperative dysphagia/aspiration risk and hence would be contraindicated.[3,15,26] Bilateral encasement of the lingual arteries is a contraindication as resection would lead to devascularization of the tongue (Figure 5A). Finally, extensive involvement of a tongue base tumor that is crossing the midline may lead to poor long-term functional outcomes and predispose patients to aspiration pneumonia (Figure 5B).[27] These case imaging features need to be considered carefully.

Another important scenario to note is the tumor which invades and undercuts the tongue as this would not be resectable by TORS due to the risk of tongue devascularization post-resection. This type of invasion is best appreciated on a sagittal MRI (Figure 5C).

Extensive pre-epiglottic fat involvement (Figure 6) is also a relative contraindication as it would be difficult to achieve clear margins (as involvement of the hyoid would preclude TORS eligibility)[17] and thus increases the likelihood of requiring adjuvant chemoradiation therapy.

6 | TORS IN RECURRENT DISEASE

In the setting of local recurrent cancer which has been treated previously with radiation/chemotherapy, nonsurgical options do not exist. Thus, the relative contraindications for primary TORS are often eschewed. For instance, bilateral tongue base invasion or extension into the pre-styloid parapharyngeal space is often encountered and a resection will be considered in these instances. Advantages of a TORS approach in the recurrent cancer setting include the avoidance of a mandibulotomy (reducing the risk of osteoradionecrosis); there will be less extensive disruption of the floor of mouth musculature when performing the resection (thereby allowing better function) and also still allowing reconstruction if needed.[28]

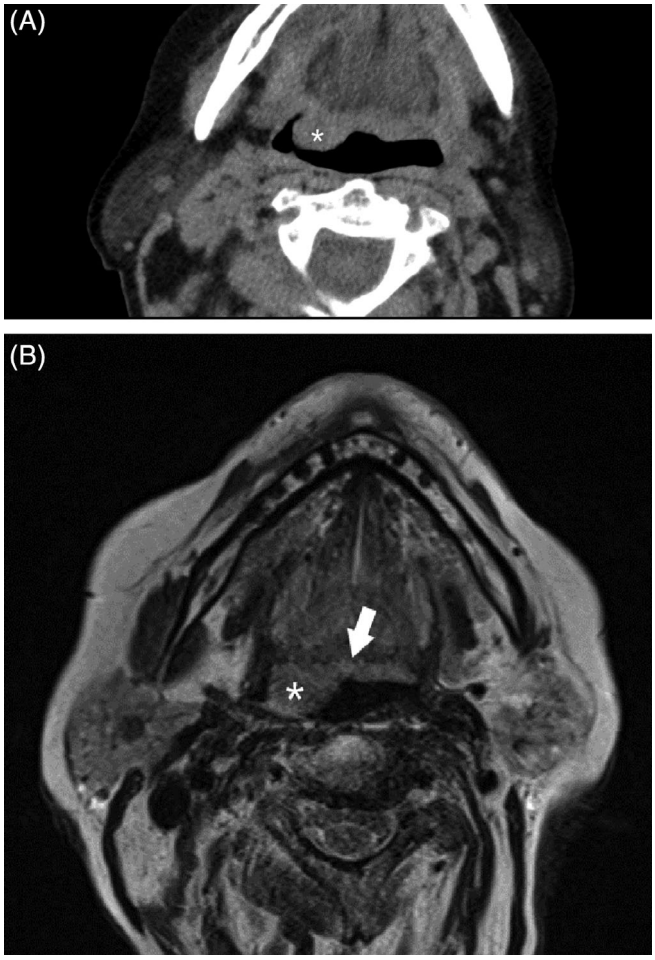

FIGURE 4 CT and MR images demonstrate candidates for transoral robotic surgery in patients with tongue base primary carcinoma. A, Axial contrast-enhanced CT image demonstrates right-sided exophytic tongue base mass (*) with no signs of deep invasion. B, Axial T2-weighted MR image demonstrates right tongue base mass (*) which extends towards the midline (white arrow) of the tongue. Limited bilateral tongue base lesions are still candidates for resection

Radiological support is invaluable in the assessment of recurrent tongue base cancers. It should be noted, however, that preoperative imaging, although valuable in defining the extent of the disease and defining resectability, will not correlate with the on-table findings of tumor depth and invasion. This is because during surgery, the tongue will be pulled out and a retractor placed to obtain exposure vs the neutral state of the tongue on cross-sectional imaging where the tissues are in their resting position in the mouth. In these instances, intraoperative ultrasound, in conjunction with a radiologist, can be of value in defining the depth of resection.[29] Another use of ultrasound is in predicting the anatomy of nearby vasculature, for instance, in the removal of pre-styloid parapharyngeal or retropharyngeal nodal deposits.

7 | NODAL DISEASE IN TORS

Selective neck dissections are used in conjunction with TORS and the extent of neck adenopathy is an important consideration. Two absolute contraindications for TORS (as well as conventional surgery) are vascular space/carotid involvement by nodal disease (Figure 7A) and deeply fixated lymph nodes.[15]

Other important considerations to note for the surgeon include any retropharyngeal nodal disease and extranodal extension. Retropharyngeal nodal disease is difficult to access by surgical techniques and often requires radiotherapy treatment (Figure 7B) (making these less ideal TORS candidates).[30] Extranodal extension (Figure 7C) has been shown to have negative implications for recurrence-free survival.[31]

Patients with no radiographically suspicious adenopathy and those with a single node under 3 cm would be good candidates for a TORS treatment approach. In the latter situation, surgery alone would be amenable for treatment of the neck disease in the absence of any other adverse pathologic features. Patients with multiple metastatic nodes almost always require adjuvant therapy and being cognizant of these imaging findings would be valuable when counseling patients and determining treatment approach. Patients with extranodal extension or a significant number of involved nodes also require adjuvant chemotherapy and must be counseled as such.

8 | HYPOPHARYNGEAL DISEASE

Tumors of the hypopharynx can undergo TORS in certain cases but is limited due to the difficult access in this area. Ideal cases are superficial disease without involvement of the apex or lateral wall of the pyriform sinus with no cartilage and/or bone involvement and no carotid involvement. Ongoing research is being conducted on this subject with promising results.[32]

9 | LARYNGEAL DISEASE

Ideal TORS candidates have no cartilage/bone involvement, pre-epiglottic and/or paraglottic fat involvement. Clear margins are difficult to attain in these situations. There is currently limited data on this subsite for TORS.[33]

10 | OTHER RADIOGRAPHIC OBSERVATIONS TO PREDICT TORS ACCESS

There are certain radiographic predictors of difficult access such as a bulky tongue, large neck circumference, and the presence of an obtuse thyromental angle which can be an adjunct to the physical examination.[34] Edentulous patients,

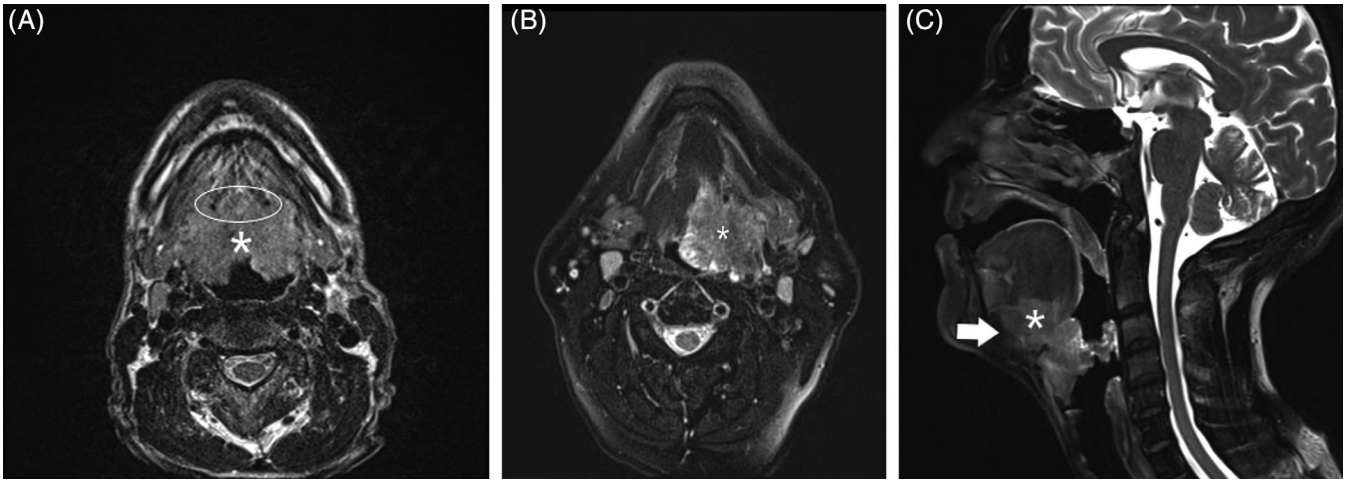

FIGURE 5 MR images demonstrate absolute contraindications for transoral robotic surgery of the tongue base. A, Axial T2-weighted MR image demonstrates an extensive tongue base mass (*) which encases the bilateral lingual arteries (circled). B, Axial T2-weighted MR image demonstrates a left tongue base carcinoma which extends anteriorly and left laterally with involvement of the left genioglossus and hyoglossus musculature. Tumors with such a degree of extension carry a high risk for aspiration post-resection. C, Sagittal T2-weighted MR image demonstrates a tongue base carcinoma (*) which undercuts the tongue parenchyma (arrow), leaving the tongue tissues at risk for devascularization following a surgical resection

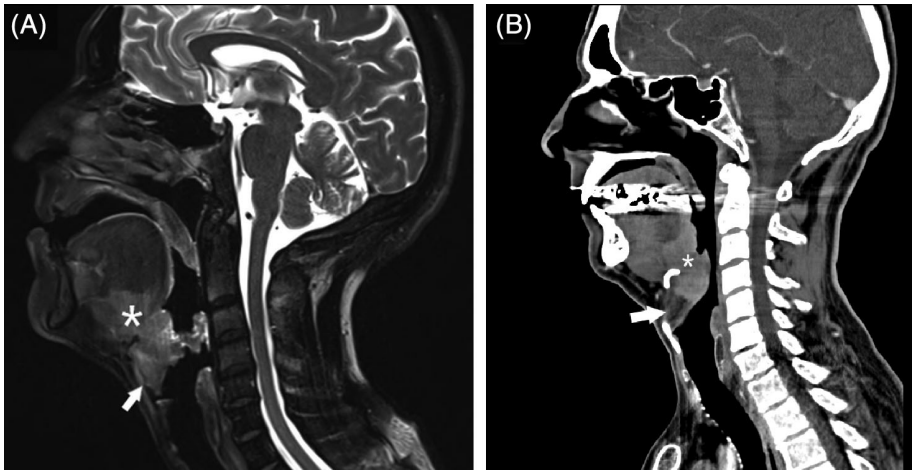

FIGURE 6 MR and CT image demonstrates a relative contraindication for transoral robotic surgery of the tongue base. A, Sagittal T2-weighted MR image. B, Sagittal contrast-enhanced CT images demonstrates a large tongue base mass (*) which extends inferiorly with pre-epiglottic fat involvement (white arrow)

however, have easier access. Correlation of these factors with clinical parameters such as mouth opening and Mallampati scores (which classifies the airway according to visibility of airway landmarks into various grades) has also been noted to be helpful.[35]

11 | EXTERNAL CAROTID ARTERY LIGATION

One last area to mention is the management of the neck with external carotid artery branch ligation. Hemorrhage remains a major potential risk when performing any form of transoral surgery. The risk of hemorrhage is between 5% and 20%, but this complication is more commonly seen in patients who are being salvaged after previous radiation therapy or in surgical candidates who are anticoagulated. Existing studies suggest no statistically significant difference in the bleeding rate when comparing patients who have undergone transcervical ligation of vessels to those who have not. However, the frequency of "severe" bleeding (defined as bleeding resulting in hypoxia/airway compromise requiring tracheostomy, cardiopulmonary arrest, or hemodynamic instability requiring of a blood transfusion) occur less in patients who have undergone vessel ligation.[36-38] One study[39] examining the risk of bleeding in a cohort of 122 patients identified no severe bleeding in among the 36 patients who underwent TORS and external carotid ligation; the odds of presenting with a bleed was 6.67 times greater in patients who did not have arterial ligation ($P = .09$).

The vast majority of patients need a neck dissection. Based on the above evidence, the general consensus is for vessel ligation during the neck dissection. It is the authors' policy to identify and target the vessels for ligation, rather

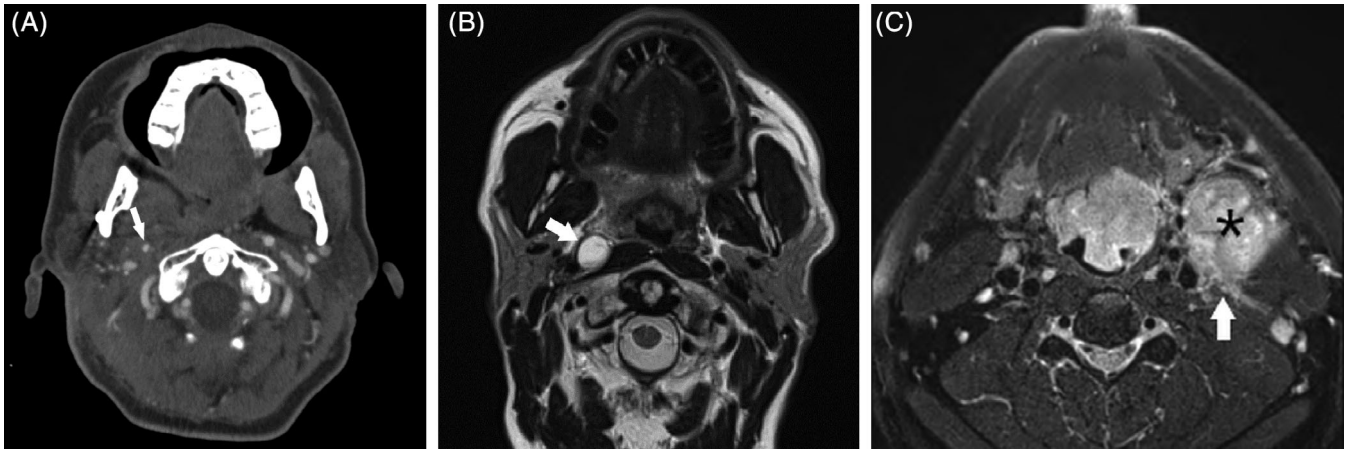

FIGURE 7 Axial CT and MR images demonstrate nodal considerations in transoral robotic surgery. A, Axial contrast-enhanced CT image demonstrates right-sided nodal disease encasing and narrowing the carotid artery (white arrow). B, Axial T2-weighted MR image demonstrates an enlarged right-sided retropharyngeal node. C, Axial T1-weighted post-gadolinium MR image demonstrates conglomerate nodal mass on the left (*) with extranodal extension (white arrow)

than ligate the external carotid main trunk: the facial, lingual, and ascending pharyngeal arteries for oropharyngeal primaries and the superior laryngeal for supraglottic cancer.

12 | CONCLUSION

With the rising incidence of HPV-related oropharyngeal malignancies, there has been a recent movement towards greater consideration of surgical therapy for these patients. TORS provides the surgeon the ability to resect tumors with good visualization without exposing the patient to the morbidity and possible complications associated with traditional approaches, such as mandibulotomy. However, appropriate patient selection plays a pivotal role in safely achieving the outcome of wide resection with disease-free margins and avoiding triple modality therapy. Radiologic evaluation to define the extent of disease, nodal involvement, and involvement of critical structures is a key component of this evaluation.

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