18 Complications and Postoperative Care

Eugene L. Son and Neil D. Gross

18.1 Introduction

No matter what measures are taken, doctors will sometimes falter, and it isn't reasonable to ask that we achieve perfection. What is reasonable is to ask that we never cease to aim for it [1]. The da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) was approved by the US Food and Drug Administration (USFDA) in 2009 for transoral robotic surgery (TORS) of the upper aerodigestive tract. Since approval, TORS has been described for the treatment of benign and malignant neoplasms of the upper aerodigestive tract. Interest in TORS has increased because of its minimally invasive nature when compared to traditional open approaches that require mandibulotomy for access to the oropharynx. This technology has also been applied to surgical procedures for benign indications such as obstructive sleep apnea (OSA) including lingual tonsillectomy [2]. TORS using the da Vinci Surgical System provides high-resolution three-dimensional visualization and increased magnification with angled scopes [3]. Another system, the Flex Robotic System (Medrobotics Corp., Raynham, MA), has been developed and was approved for transoral surgery by the USFDA in July 2015.

Although TORS has proven to be a less morbid approach compared to traditional open surgery, it has predictable sequelae and risks of complications. Sequela can be defined as an expected event following surgery. TORS produces the well-recognized sequelae of throat pain, odynophagia, and dysphagia. When these sequelae are poorly managed, complications can develop including dehydration, weight loss, and aspiration pneumonia. Life-threatening complications can result as well. In addition, there is a very serious risk of bleeding after TORS with the possibility of airway compromise and death. Self-reported complication rates following TORS have been relatively low. Proper training, careful technique, and appropriate management of the sequelae of TORS can lead to a decreased rate of complications. In this chapter, the incidence and management of sequela and complications will be explored.

18.2 Sequelae

Swallowing is a complex function with multiple coordinated voluntary and involuntary actions of the surrounding muscles. There are four stages which include the oral preparatory stage, the oral stage, the pharyngeal stage, and the esophageal

E.L. Son
Department of Otolaryngology – Head and Neck Surgery, The University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77555-0521, USA
e-mail: elson@utmb.edu

N.D. Gross (✉)
Department of Head and Neck Surgery, Unit 1445, Division of Surgery, The University of MD Anderson Cancer Center, 1400 Pressler Street, Houston, TX 77030, USA
e-mail: ngross@mdanderson.org

Z. Gil et al. (eds.), *Atlas of Head and Neck Robotic Surgery*, DOI 10.1007/978-3-319-49578-1_18

stage [4]. TORS can affect one or multiple sites of the upper aerodigestive tract (UADT) causing dysfunctional swallowing. When mucosa and muscle are violated in the pharynx, the result is pain and dysfunction of specific muscles. After TORS in the oropharynx, all patients are expected to experience odynophagia and dysphagia.

18.2.1 Odynophagia

Odynophagia is derived from the Greek roots odyno meaning pain and phagia meaning to eat. The UADT from the oral cavity to the larynx is innervated by branches of cranial nerves V, VII, IX, and X. Postoperative pain is expected after surgery in the upper aerodigestive tract. There are no guidelines nor studies performed regarding optimal postoperative pain management following TORS. Opioids are commonly administered intravenously in the immediate postoperative period. Patient-controlled anesthesia (PCA) can be employed for the acute demands expected immediately postoperatively, but is not commonly used at our institution. The cumulative amount of opioid administered within a 24 h period can be collected and then converted to a scheduled per os (PO) dose with allowance of breakthrough doses for outpatient pain management. Other classes of pain medication including acetaminophen, nonsteroidal anti-inflammatory drugs (NSAID), and neurotransmitter modulators such as gabapentin may aid as an adjunct but have not been well studied for pain control in this population. A Cochrane review found perioperative local anesthesia such as lidocaine injection in the oropharynx does not reduce postoperative pain and does not decrease the need for analgesics following routine tonsillectomy [5].

Patients have different thresholds of pain which merit individualized titration of medication. In general, we start postoperative pain management with 5–10 milligrams (mg) of oxycodone oral solution every 3–4 h. The liquid form provides an easy transition from enteral to oral administration. Hydrocodone and codeine elixirs contain acetaminophen, which limits the ceiling dose of these opioids. Oxycodone is available as a single drug, preventing potential toxicity with acetaminophen. Intravenous (IV) opioids including morphine (2.5–5 mg every 3–4 h) and fentanyl (25–30 micrograms (mcg) every 1–3 h) are placed as standing orders as needed for breakthrough pain. In addition to this, acetaminophen and tramadol are provided as a third line for breakthrough pain. All of these medicines are available in liquid form making an easy transition for outpatients after discharge from the hospital. At about 1 week when patients have been discharged, patients are called to monitor pain control and can be instructed to start ibuprofen if the current regiment is not adequate. Currently, there is no evidence on the effect of NSAID use on postoperative bleeding. Consultation with a pain specialist may be beneficial in patients with a history of chronic pain and opioid dependence. It must be stressed that pain regiments should be tailored to individual patients.

Administration of steroids after tonsillectomy has been shown to decrease throat pain, decrease time to resume oral intake, and decrease postoperative nausea and vomiting [5]. Until recently, there has not been any studies on the effect of steroids in the perioperative period specifically for patients following TORS. However, the results of an important randomized, double-blinded, placebo-controlled trial of extended (up to 4 days after surgery) administration of dexamethasone versus placebo after TORS for oropharyngeal squamous cell carcinoma (OPSCC) are expected imminently (unpublished data). In the meantime, the best available evidence would support a single intraoperative dose of steroids such as 8–10 mg of dexamethasone.

18.2.2 Dysphagia

Dysphagia can lead to aspiration or inefficient swallowing causing pneumonia, malnutrition, dehydration, and weight loss [4]. Any significant surgical intervention in the oropharynx will result in dysphagia. Less extensive procedures (e.g., resection of lingual tonsil tissue versus resection of tongue musculature) are generally expected to result in less dysphagia. Many patients undergoing TORS tolerate early initiation of an oral diet and have a short hospital length of stay. Vicini et al. reviewed complications after 243 TORS proce-

dures for sleep-related disorders and reported patients returning to mechanical soft diets on an average of 1.15 days, ranging from 1 to 4 days [6]. Hoff et al. reviewed complications after TORS for benign disease in 293 procedures with the average hospital stay of 1.8 days [7]. Easa et al. evaluated swallowing outcomes for 78 patients that underwent TORS for OSA [8]. Although they performed tracheostomy in 82% of patients, who were all decannulated on postoperative day 4, the average timing to start PO feeding was 1.05 ± 0.25 days, and no patients required feeding tubes. Richmon et al. reviewed outcomes after TORS in 91 patients treated mostly for OPSCC (86.8%) [9]. The mean time to initiation of oral diet was 1.26 days with the average length of hospital stay of 1.5 days. Early initiation of oral intake was not associated with an increase in postoperative complications.

Patients with malignancy undergoing larger resections may have longer average hospital stays due to the expected increase in severity of dysphagia. Moore et al. reported 45 patients undergoing TORS for OPSCC with an average hospital stay of 3.8 days (range 1–10 days) [10]. Weinstein et al. reported the result of TORS for malignancy in 177 patients, who had average hospital stays of 4.2 ± 2.7 days [11]. The presence of tracheostomy, free flap transfers, and previous therapies for malignancy can impact length of stay.

The use of a temporary feeding tube after TORS varies depending upon the extent of resection. We place nasogastric feeding tubes intraoperatively in all patients undergoing TORS for malignancy. These are removed when the patient demonstrates adequate oral intake which is usually around postoperative day 3–5. Glazer et al. reviewed 166 patients following TORS for OSA and reported only 1 patient who required a gastrostomy tube, which was removed after 4 months [12]. Hoff et al. reviewed complications after TORS for benign disease in 293 procedures and only placed feeding tubes in 2 patients intraoperatively, both of which were removed on postoperative day 1 [7]. In the setting of resections for malignancy, studies show an increased use of feeding tubes. Moore et al. reviewed 45 patients who underwent TORS for OPSCC with 48.9% of these patients having a nasogastric feeding tube for an average of 12.5 days (range 2–41 days) [10]. Weinstein et al. reviewed 177 patients who underwent TORS for malignancy and had 6.7% of patients relying on a gastrostomy tube for nutrition at 12-month follow-up [11]. Twenty-five percent of these patients had previous radiation therapy. Patients without previous radiation had a 5.0% gastrostomy tube dependency rate. Although feeding tube placement is not routine after TORS for benign indications, temporary feeding tubes are often required after TORS for malignancy with a low rate of long-term dependence depending upon baseline swallowing function and the extent of adjuvant therapies applied.

Chia et al. performed a voluntary survey study of TORS surgeons in the United States. Their results provided normative data after TORS for malignancy (88.8%) [13]. 62.2% of the respondents initiated oral diet on postoperative day 0–1 with a minority of 6.7% respondents delaying oral intake until 1 week after surgery. In that study, the majority of respondents (71.1%) routinely placed a nasogastric feeding tube at the time of TORS. Patients with a history of prior radiation therapy had a higher rate of prolonged gastrostomy tube dependency at 6.5% compared to those without one at 0.3% ($p < 0.0001$). The presence of previous radiation therapy should merit consideration of prophylactic placement of a gastrostomy tube.

Preoperative swallow studies are predictive of posttreatment swallow function in the setting of head and neck cancer. All patients undergoing TORS should have a preoperative swallow assessment to stratify those patients who may potentially have severe dysphagia postoperatively [9]. Thus, consultation with a speech and language pathologist should be completed routinely prior to TORS. A modified barium swallow study is beneficial prior to TORS in patients with substantial baseline dysphagia. The speech and language pathologist is also critical for advising the safer resumption of oral intake after surgery.

The tumor (T) classification OPSCC has been shown to correlate with swallowing outcomes following TORS for malignancy. Hutcheson et al. performed a systemic review of functional outcomes after TORS for oropharyngeal cancer [14]. Time to oral intake varied by group of T classification studied. Studies excluding T4 tumors had earlier time to oral diet than ones that included T4 tumors.

A study that included only T1 and T2 OPSCC had 96% of patients beginning oral intake by postoperative day 1. Studies that included all T classes of OPSCC had only 51% of patients beginning oral intake by postoperative day 1. Therefore, a prophylactic gastrostomy tube should be considered in patients undergoing TORS with bulky (T3, T4), endophytic cancers.

18.3 Complications

Avoidable and unavoidable complications can occur after TORS. Exploring the factors that contribute to complications can minimize the frequency and severity of injury. There are a number of complications that can be expected after TORS with postoperative bleeding being the most deadly. Chia et al. conducted a multi-institutional survey with TORS-trained surgeons (45 surgeons responded) performing a combined 2015 procedures [13]. There was an overall major complication rate of 10.1%. Postoperative bleeding was the most common complication at 3.1% (Table 18.1).

An increased risk of complications may be seen in OSA patients. Richmon et al. reported 43% of OSA patients undergoing TORS experienced at least one complication compared to 10% of non-OSA patients ($p = 0.04$). The authors attributed the increased risk of complications in the OSA patient population to an increased number of comorbidities including obesity [9]. Glazer et al. reviewed postoperative complications in 166 patients following TORS for OSA and concluded that the number of specific OSA procedures performed and preoperative ASA (American Society of Anesthesiologists) score were both independent predictors of having a complication [12].

Table 18.1 Postoperative complications [15]

Complication	% cases
Hemorrhage	3.10
Tooth injury	1.40
Dehydration requiring admission	1.30
Aspiration pneumonia	1.10
Temporary (<2 months) hypoglossal nerve injury	0.90

18.3.1 Postoperative Bleeding

Richmon et al. assessed the factors that contributed to length of stay after TORS in 91 patients [9]. Twelve percent of patients in their cohort experienced a complication. Postoperative bleeding occurred in 7% of patients with two patients having recurrent postoperative bleeding. Nearly all (94%) of the complications occurred in the first postoperative week with 38% of the complications occurring within 24 h of surgery. Asher et al. examined factors that contributed to bleeding after TORS in 147 patients [16]. They reported 11 (7.5%) patients with postoperative bleeding at a mean occurrence of 11.1 ± 9.2 days after surgery. The majority (82%) of these bleeds required management in the operating room. Another large study of 293 TORS procedures reported an average time to onset of bleeding being 7.3 days postoperatively (range 0–18 days) [7]. Glazer et al. reported all major postoperative bleeding occurred within 10 days [12]. Pollei et al. concluded that the greatest bleeding risk is present from postoperative day 7 to 14 [17]. The mean postoperative day for bleeding was day 10 with 83.6% of those bleeds occurring within 2 weeks of surgery. Thus, there seems to be a bimodal distribution of bleeding similar to what is observed in patients after tonsillectomy (Fig. 18.1). Patients should be educated about the risk of bleeding with TORS as well as the most likely times for bleeding.

Although there is a wide range of complication rates between studies, the rate of postoperative bleeding appears greater in patients undergoing TORS for malignancy compared to patients undergoing TORS for benign indications (Tables 18.2 and 18.3).

In the USFDA indication trial for TORS with the da Vinci Surgical System, the postoperative bleeding rate was 7.3% (2.8% requiring return to operating room) among 177 patient treated at 3 institutions [11]. Vergez et al. reviewed 130 patients undergoing TORS with 93% having a diagnosis of malignancy. The postoperative bleeding rate was 11.5% with 93% of patients treated in the operating room [20]. In comparison, a cohort of 243 patients undergoing TORS for sleep-related breathing disorders experienced a postoperative

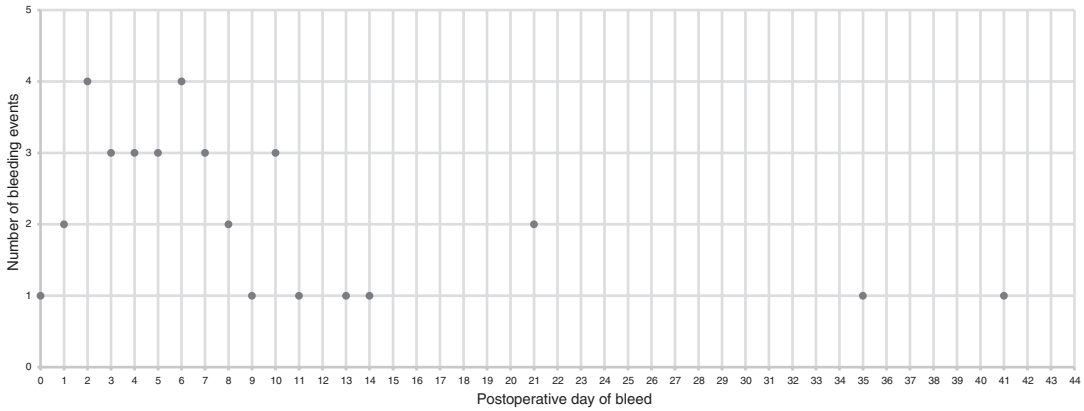

Fig. 18.1 Timing to postoperative bleed (33 events). Combined data from Asher et al. [16] and Mandel et al. [18]

Table 18.2 Incidence of complications after TORS for malignancy

Authors	Institution(s)	# patients	# malignancy (%)	# OP cases (%)	# complications (%)	# POB (%)	# OP bleeds (%)
Aubry et al. [15]	TORS's French Group (9 centers)	178	178 (100%)	51 (28.7%)	73 (41%)	33 (18.5%)	10 (30.3%)
Asher et al. [16]	University of Alabama at Birmingham (UAB)	147	136 (92.5%)[a]	102 (69.4%)[a]	N/A	11 (7.5%)	10 (90.9%)
Cognetti et al. [19]	Thomas Jefferson University	61	53 (87%)	46 (82%)	5 (8.2%)	2 (3.3%)	2 (100%)
Mandal et al. [18]	University of Pittsburgh Medical Center	224	185 (82.6%)	N/A	N/A	22 (9.8%)	11 (50%)
Pollei et al. [17]	Mayo Clinic (3 centers)	269	269 (100%)	269 (100%)	N/A	16 (5.9%)	16 (5.9%)
Richmon et al. [9]	Johns Hopkins University	91	79 (91%)	91 (100%)	11 (12.1%)	8 (8.8%)	8 (8.8%)
Weinstein et al. [11]	Multi-institutional (Univ. of Pennsylvania, UAB, Mayo Clinic)	177	177 (100%)	139 (78.5%)	29 (16%)	13 (7.3%)	N/A

Abbreviations: *OP* oropharyngeal, *POB* postoperative bleeds
[a]At least this number; more may be present but not specified

bleeding rate of 5% with only 34% managed in the operating room [6]. A study of 293 TORS procedures performed for benign disease experienced a postoperative bleeding rate of 4.1% [7]. A cohort of 166 patients who underwent TORS for OSA had a postoperative bleeding rate of 7.2% with 58% going to the operating room for cauterization; all but one patient had bleeding that originated from the tonsillar fossa [12]. Aubry et al. reported the highest rate of postoperative bleeding at 18.5% in 178 patients [15]. Interestingly, this group had a very high proportion of laryngeal and hypopharyngeal tumors (71%) suggesting that the decreased working space and more limited expo-

Table 18.3 Incidence of complications after TORS for benign indications

Authors	Institution(s)	# patients	# OP cases (%)	# complications (%)	# POB (%)	# OP bleeds (%)
Hoff et al. [7]	Multi-institutional (University of Michigan, University of Pennsylvania, Middlesex Hospital)	285	285 (100%)	59 (20.7%)	12 (4.1%)	N/A
Vicini et al. [6]	Multi-institutional (Morgagni-Pierantoni Hospital, University of Michigan, University of Pennsylvania, Columbia University, Clinica Universidad de Navarra, Louvain University Hospital of Mont Godinne, University of Pavia)	243	243 (100%)	50 (20.5%)	11 (4.6%)	N/A

Abbreviations: *OP* oropharyngeal, *POB* postoperative bleeds

sure of the larynx and hypopharynx can contribute to poorer hemostatic control.

Anticoagulation and antiplatelet therapy can affect postoperative bleeding rates and are usually withheld and/or bridged during the perioperative period. A review of 147 patients undergoing TORS revealed that 72% of the patients who had postoperative bleeding were on an antithrombotic medication for other comorbidities [16]. The postoperative bleeding rate in patients taking antithrombotic medication was significantly higher at 17% versus 3% ($p = 0.02$). They also noted that postoperative bleeding risk was greatest on postoperative days 7–14. A French review found that anticoagulation and/or antiplatelet therapy was a significant risk factor for postoperative bleeding ($p < 0.05$) [15]. Richmon et al. reported similar trends stating 50% of the patients who had postoperative bleeding were found to be on anticoagulation therapy [9]. Hoff et al. reported a postoperative bleeding rate of 4.1% and contributed two late postoperative bleeding episodes after re-initiation of clopidogrel or warfarin [7]. Patients who had anticoagulation at the time of surgery had higher rates of postoperative bleeding compared to patients not anticoagulated (13.5% vs. 8.1%) although this did not reach statistical significance ($p = 0.2785$) [7]. The authors in this study were so convinced of the association between bleeding after TORS and perioperative anticoagulation that they recommended withholding anticoagulation for 4 weeks postoperatively. However, at this time it remains unclear the optimal duration of time to withhold or bridge anticoagulation in patients treated using TORS.

18.3.2 Transcervical Ligation

The majority of bleeding after TORS is venous and self-limiting. However, potentially catastrophic arterial bleeding can occur after TORS. The incidence of life-threatening bleeding after TORS is unknown. No deaths from bleeding after TORS were reported in the USFDA indication trial [11]. However, by 2013, there were seven deaths from bleeding after TORS self-reported in a voluntary survey of TORS surgeons in the USA [13]. This is likely a gross underestimation, underscored by the fact that the response rate for the study was low and that the respondents were heavily weighted to high volume TORS surgeons. A variety of surgical techniques have been developed to minimize the risk of catastrophic bleeding after TORS, and some authors have advocated for routine transcervical ligation of feeding vessels to minimize or eliminate the risk of arterial bleeding after TORS.

Pollei et al. reviewed factors affecting bleeding rates in patients undergoing transoral oropharyngectomy by different approaches which included TORS, transoral laser microsurgery (TLM) and handheld cautery in 906 patients [17]. Of the 5.4% of patients with postoperative bleeding, 67% required operative intervention. In that retrospective study, prophylactic transcervical ligation of the external carotid system was performed during the primary surgery in 15.6% of patients. They reported no overall difference in bleeding rate after ligation compared to those patients who were not ligated ($p = 0.21$). Severe postoperative bleeding, defined as bleeding resulting in hypoxia/airway compromise requiring tracheostomy, cardiopulmonary arrest, or hemodynamic instability requiring of a blood transfusion, occurred less frequently in patients who had concurrent transcervical vessel ligation at 11.1% versus 25.8%. The difference was clinically meaningful but not statistically significant ($p = 0.66$). Vessel ligation was performed more frequently in patients with higher T classification ($p = 0.002$) since these patients were most likely to develop bleeding after TORS. So the authors recommended that patients with higher T classification should be considered for prophylactic transcervical ligation to decrease the rate and severity of bleeding after TORS.

More recently, Mandal et al. reviewed factors for postoperative bleeding after TORS in 224 patients with 185 cases performed for malignancy and 39 performed for benign indications [18]. 9.82% of these patients had varying degrees of bleeding after TORS. Prophylactic transcervical arterial ligation (9.1%) did not decrease overall postoperative bleeding rates when compared to the non-prophylactically ligated group (9.9%) ($p = 1.00$). There was a decreasing trend in frequency of severe bleeding after TORS, but this did not reach statistical significance ($p = 0.70$). Prior radiation therapy or chemoradiation therapy increased postoperative bleeding rates but not significantly ($p = 0.09$). Many experienced TORS surgeons routinely ligate branches of the ipsilateral external carotid system despite the paucity of data to date to support the effectiveness of the procedure. This is likely because the consequences of arterial bleeding after TORS can be dire and, although rare, may be preventable with a simple maneuver. A better understanding of the incidence and pathogenesis of catastrophic bleeding after TORS is needed to more clearly define the optimal strategies for prevention.

18.3.3 Neurologic Injury

There are multiple cranial nerves that can be encountered performing TORS, especially for malignancy. The severity of injury can include neuropraxia, axonotmesis, and neurotmesis. In cases that involve malignancy, important nerves may be intentionally sacrificed for adequate resection. The glossopharyngeal, hypoglossal, and lingual nerves are all at risk during TORS. Every effort should be made to preserve these nerves as they are collectively instrumental in the function of swallowing. It is also important to remember that neurologic injuries can be either direct or indirect. Direct nerve injury (e.g., cutting the nerve) is far less common than indirect injury (e.g., nerve compression).

The glossopharyngeal nerve serves as the main afferent innervation for the tonsillar fossa and oropharynx. It descends from the jugular foramen and courses with the stylopharyngeus through the superior and middle constrictor muscles. The nerve can be visualized anterior and medial to these muscles [21]. A branch of this nerve is frequently encountered during TORS for tonsillar malignancy as it courses between the stylopharyngeus and styloglossus muscles (Fig. 18.2). Sacrifice of this branch is often necessary to ensure an oncologic resection of cancers involving the inferior tonsil and or glossopharyngeal sulcus. The functional impact of sacrifice of a branch of the glossopharyngeal nerve during TORS has not been formally described but appears inconsequential in the context of soft tissue and mucosa loss.

In contrast, injury to the hypoglossal nerve during TORS can be functionally devastating. In well-selected TORS cases, the hypoglossal nerve is typically not at risk. However, an increased risk of injury is observed in patients with recurrent disease, a history of radiation treatment, and/or bulky primary tumors. Muscle movement of the ipsilateral tongue during electrocautery dissection can be an important, albeit traumatizing, signal of proximity to the nerve. It is also important to recognize that hypoglossal nerve injury can occur during placement of surgical clips to control or prevent bleeding. The lingual nerve is also at risk during TORS. Risk of direct injury to the lingual nerve is particularly relevant for cancers that extend anteriorly toward the floor of the mouth.

A critical understanding of the anatomy of the submandibular triangle from an "inside-out" perspective is paramount to avoiding injury to the hypoglossal and lingual nerves. Early recognition of the submandibular gland and posterior belly of the digastric muscle during TORS for cancers involving the glossopharyngeal sulcus can help avoid direct nerve injury. The hypoglossal nerve is at most risk during TORS as it passes over the hyoglossus and runs along the superior border of the hyoid bone, deep to the digastric and mylohyoid muscles [21]. The lingual nerve which gives afferent and taste sensation to the anterior two-thirds of the tongue can be found on the lateral surface of the styloglossus muscle [22].

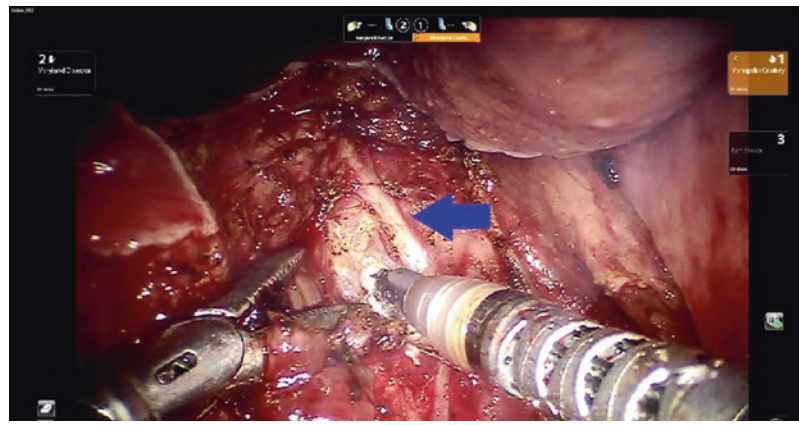

Fig. 18.2 Right glossopharyngeal nerve (*blue arrow*) exposed and preserved during TORS for tonsil cancer

Finally, the internal branch of the superior laryngeal nerve is at risk during TORS for supraglottic cancers. After piercing the thyrohyoid membrane, the internal branch of the superior laryngeal nerve provides afferent innervation for the supraglottic laryngeal mucosa [23]. It is involved with the cough reflex and aspiration prevention. This nerve travels in close proximity to the superior laryngeal artery which requires deliberate ligation during TORS of the larynx.

The incidence of significant neurologic injury after TORS is reportedly low. In a large survey study, temporary (<2 month) hypoglossal nerve injury occurred in 0.9% out of 2015 patients undergoing TORS, prolonged (>2 month) hypoglossal nerve injury occurred in 0.1%, and inadvertent lingual nerve injury occurred in 0.6% of cases [13]. Richmon et al. reported there were no hypoglossal nor lingual nerve palsies in 91 consecutive patients [9]. Weinstein et al. reported only 1 patient with tongue numbness out of 192 patients undergoing TORS for malignancy [11]. Many large retrospective studies have not reported nerve injuries. In contrast, Vicini et al. reported a hypogeusia rate of 14.2% in 243 TORS procedures for sleep-related disorders with all resolving within 8 months [6]. This likely represents indirect compression injury to the lingual nerve which may be underreported in other TORS series for malignancy. The risk of compression injury to the lingual nerve would seem proportional to the size of the tongue, duration and extent of retraction, as well as the surgical defect. Anecdotally, many patients undergoing TORS will have some extent of temporary sensation or taste change of their tongue. As with all risks, this should be communicated with patients preoperatively.

18.3.4 Aspiration and Pneumonia

With swallowing being compromised from odynophagia and dysphagia, the risk of aspiration and subsequent pneumonia is increased after TORS. Easa et al. evaluated swallowing outcomes for 78 patients that underwent TORS for OSA [8]. Gastrografin fluoroscopy was performed in the first postoperative week with only 6% having signs of significant aspiration. These patients all were without any swallowing complaints within 3 months and had no resulting significant weight loss. There was also no significant correlation between the volumes of tissue removed and the incidence of aspiration. A large review of TORS for benign indications reported pneumonia occurring six times in a cohort of 285 patients [7].

The risk of aspiration and pneumonia is likely greatest after TORS for malignancy, although there is a wide range in the incidence reported. In the USFDA indication trial for TORS, there was a 2.8% rate of pneumonia with two out of these five patients developing life-threatening complications of acute respiratory distress syndrome and pneumothorax [11]. Chia et al. noted 1.1% rate of aspiration pneumonia out of survey study of 2015 patients [13]. In a systemic review, Hutcheson et al. reported an incidence of postoperative pneumonia ranging from 0% to 7% in patients following TORS for oropharyngeal malignancy [14]. Recently, Aubry et al. reported an aspiration pneumonia rate of 15.5% and found that higher T-stage (T3, T4) and laryngeal location of the primary tumor were significant risk factors ($p < 0.05$) [15]. These authors attributed the high rate of aspiration pneumonia to the high percentage of patients with laryngeal tumors (47.2%). The reporting of aspiration after TORS is likely linked to the extent and timing of investigation as some degree of laryngeal penetration is common on early swallowing studies after TORS. Aggressive management of pain with early and frequent speech and language pathology coaching are critical to preventing aspiration and pneumonia.

18.3.5 Dehydration

Dehydration is a well-known complication from inadequate oral intake when odynophagia is not well controlled. Decreased urine output, tachycardia, and hypotension are some of the signs and symptoms of dehydration that will need to be treated with intravenous fluid hydration. Reported rates of dehydration following TORS ranges from 1.3% to 9.6% [7, 9, 11–13]. Dehydration is also relatively uncommon after TORS for benign indications. Richmon et al. reported dehydration to occur more frequently in OSA patients ($p < 0.001$) [9]. Educating patients on the importance of adequate oral intake and signs of dehydration can reduce emergency room visits and readmissions. Many TORS surgeons will place a nasogastric feeding tube during surgery. Some patients will require continued use of the feeding tube at home to avoid dehydration. Careful assessment of realistic oral intake prior to removal of the feeding tube and discharge is important to minimize the risk of dehydration.

18.3.6 Airway Compromise

Surgery in the upper airway always carries the risk of obstructive postoperative edema. Extended (e.g., overnight) intubation or prophylactic tracheostomy should always be considered when there are concerns of potential airway obstruction. The use of prophylactic tracheostomy was increased in early TORS series, likely reflecting the learning curve of TORS surgeons. In 130 patients treated with TORS primarily for malignancy (95%), Vergez et al. reported planned tracheostomy in 17 patients and emergent tracheostomy in 2 patients for postoperative edema [20]. In contrast, Hoff et al. reviewed complications after TORS for benign disease in 293 procedures with only 1 patient undergoing planned tracheostomy and 2 patients undergoing reintubation [7]. Oral tongue edema secondary to compression from the retractor and reperfusion is the most common cause of obstruction. For resections of oropharyngeal neoplasms, the amount of tissue excised can help offset resulting airway edema allowing for immediate postoperative extubation. Sleep apnea patients often have known difficult airways and could be at risk for obstructive postoperative edema. Perioperative steroids should be given routinely to decrease expected oropharyngeal edema after TORS. Extended intubation may be prudent in TORS cases where significant tongue swelling is observed during surgery.

Differing philosophies exist regarding concomitant tracheostomy with TORS as some surgeons perform tracheostomies routinely. Vicini et al. reported 110 tracheostomies performed after 243 TORS procedures for sleep-related disorders [6]. Two of seven institutions in this study routinely performed tracheostomy concomitantly with TORS. Patients with tracheostomy were capped after 3.85 ± 1.57 days and decannulated after 5.83 ± 1.96 days. Easa et al. performed tracheostomy in 82% of patients, which were all removed by postoperative day 4 [8].

In general, the need for tracheostomy after TORS is low. In a review involving 11 studies, Hutcheson et al. reported tracheostomy rates ranging from 0% to 31% [14]. A total of 411 patients were included, and only two had permanent tracheostomy dependence with a mean tracheostomy dependence ranging from 7 to 8 days. Chia et al. reported 2.8% of 2015 patients undergoing TORS required tracheostomy [13]. Patients undergoing salvage surgery for recurrent disease, with a history of radiation, or having bulky primary tumors are at greatest risk of needing a tracheostomy. Therefore, the indication for tracheostomy with TORS is essentially no different than that for open procedures of the oral tongue. In the setting of transoral bleeding, the airway may need to be secured with emergent tracheostomy. In a large survey study including 2015 patients, five patients had emergent tracheostomy performed in the setting of acute bleeding [13]. Prophylactic tracheostomy should be considered in any TORS procedure where the risk of postoperative bleeding is increased [18].

Postoperative airway management is similar as in traditional head and neck surgery. For example, placement of an oral airway or nasal trumpet will be based on factors such as short thyromental distance or an enlarged tongue. Anesthesiologists can also make decisions about placement of these airway tools at the time of extubation. Routine tracheostomy is not performed at our institution. Patients are also not routinely kept intubated unless intraoperative findings reveal significant tongue edema. Properly selected patients such as those with non-bulky primary tumors will not need to be intubated for an extended period. Intensive care unit (ICU) placement is usually needed only when extended (>4 hrs) intubation will be needed.

18.3.7 Death

Reported mortality rates following TORS are low with most cases attributed to postoperative bleeding. Chia et al. reported an overall 0.3% mortality rate with four reported causes of death due to hemorrhage [13]. Seven of the 62 patients (11.3%) who experienced a postoperative bleeding died. Vergez et al. reported 3 of 130 patients died from complications including one due to pulmonary embolism and two due to postoperative bleeding [20]. Mandal et al. reported a mortality rate of 0.9% with two patients who experienced severe bleeding [18]. Pollei et al. had an overall postoperative bleeding rate of 5.4% with a 1.1% severe or life-threatening postoperative bleeding rate [17]. One patient who developed anoxic brain injury and died 8 months postoperatively. Multiple large retrospective studies reported no TORS-related mortalities [6, 7, 11, 12, 19, 24]. Of course, given that most patients considered for TORS have an excellent prognosis, any mortality after TORS is tragic. Every effort should be made to minimize the risk of death after TORS. This is best achieved by minimizing the risk of severe bleeding after TORS.

18.3.8 Other Complications

Additional minor complications have been reported inconsistently after TORS. Dental complications occur at 1.4% [13]. Lip burns can occur up to 1.2% [12]. Local bacterial infections are very uncommon in the immediate postoperative course. Best evidence would suggest a single dose of IV antibiotics given preoperatively. Oral thrush has been known to occur with a reported incidence of 2% [9]. This can be treated with swish and spit nystatin solution. Better reporting these types of complications in the future may increase the rate of total complications but can help surgeons and patient understand the frequency of these risks.

18.4 Avoiding Complications

18.4.1 Training

The learning curve for surgeons performing TORS is now well known. Chia et al. studied the effects of case numbers and complications in TORS surgeons. Complication rates significantly decreased when surgeons performed more than 50 cases at 6.1% compared to those performing less than 50% ($p < 0.0001$) [13]. Surgeons performing fewer than 25 cases had a postoperative bleeding rate of 4.5%, those performing 26–50 cases had a rate of 2.5%, and those performing more than 50 cases had a rate of 2.8%. Vergez et al. had six cases where TORS was converted to an open procedure due to lack of exposure and noted that all of these came in the first half of their review hinting that experience increased ability for exposure [20]. White et al. reviewed a 4-year period of 168 patients undergoing TORS divided into 4 groups of 42 patients by time and compared outcomes [25]. There was a significant decrease in total operative time ($p < 0.001$), decrease in total intubation time ($p < 0.001$), and decrease in length of hospital stay ($p < 0.001$). There was a 47% decrease in operative time and 87% decrease

in total intubation time from the first to the last group. There was a decrease in complications including postoperative bleeding and airway edema, but these were not significant. The first group had seven patients with postoperative bleeding and six patients with airway edema, whereas group 4 had 1 and 1, respectively. Although outcomes of operative time and intubation time may not reflect the surgeon's skill level independently, experience of a hospital and its staff may also contribute to better outcomes when performing TORS.

Training is paramount to summiting the learning curve with TORS. In other specialties, there are established guidelines for surgeons to become trained and credentialed robotic surgery. Requirements typically include formal training through a residency and/or fellowship program or an independent structured training curriculum [26]. Consensus guidelines were recently established for TORS as well [27]. These guidelines are meant to provide guidance to aspiring TORS surgeons and to hospitals charged with credentialing. Historically, most TORS surgeons were trained after residency or fellowship. A survey of 45 TORS surgeons showed 86.7% of respondents were trained through industry-sponsored training and 15.6% were trained through fellowship experience [13]. Yet, there is a clear difference in the quality of training afforded during residency or fellowship (graduate) compared to postgraduate training. Residency programs have reported development of curriculums to increase safety and efficiency [28]. During periods of inactivity, biweekly practice of 1 h has been shown to retain robotic surgical skills [29]. There are increasing efforts to provide TORS training free from industry influence. However, to date, no national organization has taken the lead in the oversight of training and credentialing of TORS.

18.4.2 Tumor Selection

Proper patient selection is paramount to successful outcomes with TORS. Patient and tumor factors impact patient selection; experience is needed to recognize these factors which can be subtle. Exposure of the target tissue is imperative to precise surgery and avoidance of complications. A good clinical exam in the office and under anesthesia can help determine the likelihood of good exposure intraoperatively (Fig. 18.3). Trismus and obstructive dentition can be rate-limiting factors as is the opportunity for neck extension. Medical conditions including kyphosis and previous cervical spine surgery can negatively impact the exposure for TORS. For malignancy, tumor factors will also heavily influence the decision for TORS. TORS is best suited for small primary (T1–T2) OPSCC. For larger primary tumors, the value of TORS may be diminished by the larger expected surgical defect and incumbent increased morbidity. One exception is bulky, pedunculated primary tumors where the surgical defect would be expected to be no larger than that for a smaller primary (Fig. 18.4). In these cases, a primary surgical approach using TORS may be most beneficial in allowing for a more focused delivery of adjuvant radiation (e.g., unilateral versus bilateral).

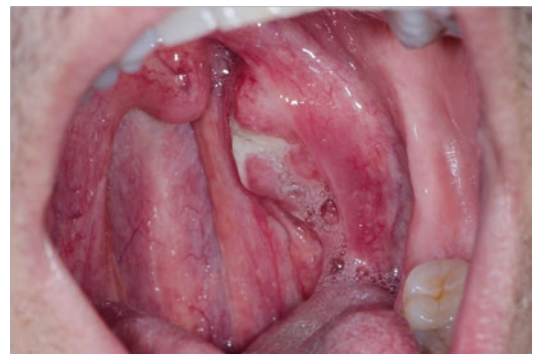

Fig. 18.3 Good exposure of a T2 tonsil cancer

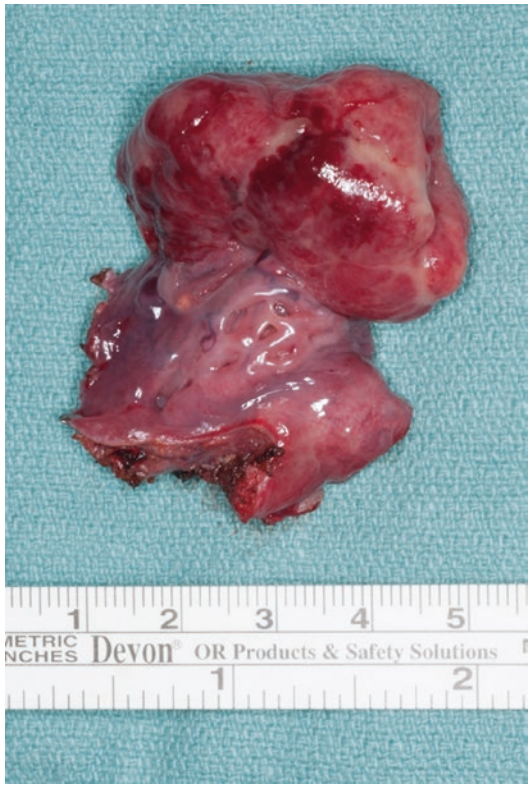

Fig. 18.4 Specimen after TORS of a pedunculated T3 tonsil cancer

18.4.3 Tools

The correct use of available tools can minimize complications. The oral cavity, eyes, and face are vulnerable to collateral damage during TORS. Application of eye protection (e.g., eye shields) is important for TORS cases. Tooth guards can be helpful in protecting the maxillary dentition from damage as well as protecting the tongue from being lacerated by the lower incisor teeth during suspension laryngoscopy (Fig. 18.5). Keeping the lips moist and protected can prevent from desiccation and trauma during TORS as well.

There are many retractors that can be used during TORS including a Crow-Davis mouth gag and a Dingman mouth gag. The only retractors specifically designed for TORS are the Feyh-Kastenbauer (F-K) retractor (Olympus, Barlett, TN) and the Flex retractor (Medrobotics, Raynham, MA). Multiple blades have been developed for use with the TORS retractor to access specific parts of the upper aerodigestive tract.

When encountering vessels, especially named vessels, application of surgical clips are necessary to prevent postoperative bleeding. In a survey taken by 45 surgeons, exposed arterial vessels in the oropharynx are most commonly managed intraoperatively with surgical clips (93.3%) and electrocautery (55.6%) [13].

The use of different forms of energy for cutting and ablating tissue is usually dependent on the surgeon and institution. Hoffman et al. studied the use of four different resection methods on porcine tongues including CO_2 laser, Tm:YAG laser, monopolar blade, and radiofrequency needle [30]. The radiofrequency needle had the most favorable cutting width and smaller coagulation defects in that study. Still, the monopolar blade is the most widely used tools for dissection during TORS.

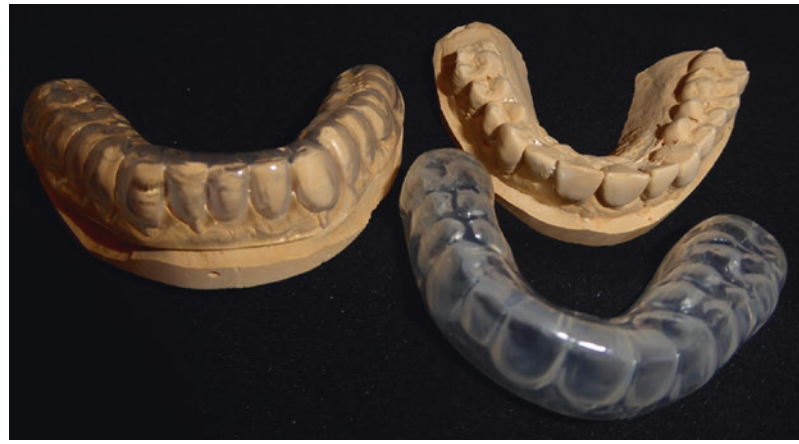

Fig. 18.5 Teeth guards

18.4.4 Technique

18.4.4.1 General

Meticulous surgical technique is crucial for all head and neck surgery. For TORS, this may be more difficult to achieve given the lack of haptic feedback with current technology. Most importantly, with TORS there is an increased reliance of visual cues, and any bleeding during TORS can obscure visualization of the anatomy. So the importance of careful, layer-by-layer dissection with careful hemostasis during TORS cannot be overstated. Coordination between the console surgeon and bedside assistant is very important in this regard.

18.4.4.2 Management of Blood Vessels and Intraoperative Bleeding

During TORS, there are named arteries that may need to be identified and ligated, especially for malignancy. Branches of the facial, lingual, and ascending pharyngeal artery supply the pharynx. Cautery can control mucosal and muscle bleeding as well as small unnamed vessels. However, larger vessels such as the dorsal lingual artery require vascular clip application. During TORS of the supraglottis, the superior laryngeal artery should always be identified and ligated [23]. Pollei et al. recommends using hemoclips on all arteries 2 mm or larger and suture ligation on arteries larger than 4 mm [17]. Brickman et al. recommended that any vessel larger than 1 mm should be meticulously clipped and divided [31]. Regardless of vessel size, the liberal use of surgical clips is advised by more experienced TORS surgeons (Fig. 18.6). Any exposed artery should be clipped and/or covered with adjacent soft tissue when possible. This is particularly important in the setting of previous radiation therapy.

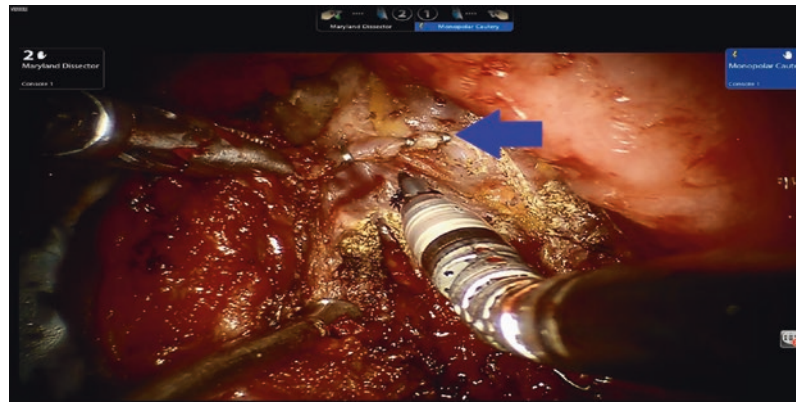

Fig. 18.6 Multiple surgical clips applied to ascending pharyngeal artery (*blue arrow*) during TORS for right tonsil cancer

18.4.4.3 Management of the Neck

Currently, there is no consensus on the ideal timing of neck dissection in patients with malignancy undergoing TORS. Benefits from concomitant TORS and neck dissection include a single anesthetic exposure, convenience, decreased length of treatment, concurrent vessel ligation, and decreased cost. Staged neck dissections have the benefit of potentially decreasing postoperative fistula formation and decreasing postoperative upper aerodigestive tract edema since ipsilateral lymphatics are undisturbed. Additionally, if margins were positive on initial tumor resection, then re-resection can be performed concurrently with a staged neck dissection. Staged neck dissection before TORS has the advantage of ligating named arteries to decrease bleeding risk during and after TORS.

The extent of neck dissection influences the risk of pharyngocutaneous fistula after TORS. Resection of the submandibular gland significantly increases the risk of fistula. Moore et al. reviewed 148 patients who underwent concurrent TORS and neck dissection for oropharyngeal cancer [32]. Twenty-nine percent of these patients were identified to have a communication between the oropharynx and neck during surgery. All patients had level I–IV neck dissections with removal of the submandibular gland. All had a combination of primary closure, local advancement flap, fibrin glue application (Tisseel), and cervical drain placement. 14.3% of these patients developed postoperative pharyngocutaneous fistulae which required incision and drainage with daily packing. All other fistulae resolved with clinical therapy and without return to the operating room. All patients with fistula formation had tonsillar fossa or lateral pharyngeal involvement; no patients with purely base of tongue involvement developed fistulae. None of the patients without intraoperative communication developed fistulae.

In contrast, Kucur et al. reviewed the safety of concurrent neck dissection with TORS in 113 patients with OPSCC where the submandibular gland was persevered in all cases except 2. Six intraoperative communications were found and repaired with either primary repair or muscle advancement flap reconstruction resulting in no postoperative fistulae [33]. The techniques included primary closure, primary closure with acellular dermal matrix reinforcement, submandibular gland transposition, anterior belly of digastric muscle rotational flap, posterior belly of digastric muscle rotational flap, and omohyoid muscular pedicled rotational flap.

Mockelmann et al. compared 21 patients who underwent concurrent TORS and neck dissection and 20 patients who underwent staged neck dissection on average 8.4 days (3–28 days) after TORS [34]. The group with concurrent surgery had a 9.5% rate of intraoperative communication that developed no postoperative fistulae after primary repair. These were repaired with primary closure and a pedicled muscle flap. However, there was no significant difference observed between the two groups for rates of fistula formation, postoperative bleeding, hematoma, and seroma. The group with concurrent surgery had a median hospital stay of 8 days (5–9 days), and the staged group had a median stay of 15 days (11–35 days). The average delay in surgery accounted for the difference in length of stay. Howard et al. compared 96 patients who underwent ipsilateral submandibular gland (SMG) preservation and 157 who underwent SMG resection during concomitant TORS and neck dissection [35]. The incidence of intraoperative communication was significantly lower in cases with SMG preservation compared to those with SMG removal, 2.1% vs. 14.1% ($p = 0.0017$). All postoperative fistulae occurred in those patients who underwent SMG removal (7.6%) compared to 0% in the SMG preservation group. Tonsil location of the primary tumor had a significant effect on fistula formation ($p = 0.0039$). T-stage was associated with intraoperative communication formation ($p = 0.0048$) but not for postoperative fistula formation ($p = 0.3410$). There was no significant difference in disease-free survival, disease-specific survival, disease-specific survival, nor overall survival at 5 years.

Overall, preservation of the submandibular gland has been reported to decrease the rate of postoperative pharyngocutaneous fistula formation after concurrent TORS and neck dissection.

Preservation of the submandibular gland has also shown to be oncologically safe [36]. Rotational muscle flaps can decrease the frequency of fistula formation by increased vascularized bulk and allowing for a robust partition between the oropharynx and neck. These techniques may be utilized to decrease the rate of postoperative pharyngocutaneous fistula formation after concurrent TORS and neck dissection.

Conclusion

TORS has proven to be a safe procedure with a low overall complication rate. As the volume of TORS increases, further analysis can be performed to identify factors that contribute to the frequency and severity of complications. Swallowing function is impacted by TORS and, in most cases, the sequelae of dysphagia and odynophagia is short-lived. Judicial use of prophylactic feeding tubes and tracheostomy placement may further decrease complication rates. Postoperative bleeding continues to be an infrequent but potentially lethal complication. Transcervical ligation does not affect overall postoperative bleeding rates but may decrease the risk of catastrophic arterial bleeding after TORS. Neck dissection concomitant with TORS is safe with an acceptably low pharyngocutaneous fistula rate.

References

1. Gawande A. Complications: a surgeon's notes on an imperfect science. New York: Picador; 2002.
2. Crawford JA, Montevecchi F, Vicini C, Magnuson JS. Transoral robotic sleep surgery: the obstructive sleep apnea-hypopnea syndrome. Otolaryngol Clin North Am. 2014;47(3):397–406. doi:10.1016/j.otc.2014.03.004.
3. O'Mallet Jr BW, Weinstein GS. Robotic skull base surgery: preclinical investigations to human clinical application. Arch Otolaryngol Head Neck Surg. 2007;133(12):1215–9.
4. Logemann JA. Mechanisms of normal and abnormal swallowing. In: Cummings CW, Flint PW, editors. Cummings otolaryngology head & neck surgery. 5th ed. Philadelphia: Mosby/Elsevier; 2010. p. 1215–21.
5. Baugh RF, Archer SM, Mitchell RB, et al. Clinical practice guideline: tonsillectomy in children. Otolaryngol Head Neck Surg. 2011;144(1 Supple): S1–30. doi:10.1177/0194599810389949.
6. Vicini C, Montevecchi F, Campanini A, et al. Clinical outcomes and complications associated with TORS and OSAHS: a benchmark for evaluating an emerging surgical technology in a targeted application for benign disease. ORL J Otorhinolaryngol Relat Spec. 2014;76(2):63–9. doi:10.1159/000360768.
7. Hoff PT, D'Agnostino MA, Thaler ER. Transoral robotic surgery in benign diseases including obstructive sleep apnea: safety and feasibility. Laryngoscope. 2015;125(5):1249–53. doi:10.1002/lary.25026.
8. Eesa M, Montevecchi F, Hendawy E, et al. Swallowing outcome after TORS for sleep apnea: short- and long-term evaluation. Eur Arch Otorhinolaryngol. 2015;272(6):1537–41. doi:10.1007/s00405-014-3480-x.
9. Richmon JD, Feng AL, Yang W, et al. Feasibility of rapid discharge after transoral robotic surgery of the oropharynx. Laryngoscope. 2014;124(11):2518–25. doi:10.1002/lary.24748.
10. Moore EJ, Olsen KD, Kasperbauer JL. Transoral robotic surgery for oropharyngeal squamous cell carcinoma: a prospective study of feasibility and functional outcomes. Laryngoscope. 2009;119(11):2156–64. doi:10.1002/lary.20647.
11. Weinstein GS, O'Malley Jr BW, Magnuson JS, et al. Transoral robotic surgery: a multicenter study to assess feasibility, safety, and surgical margins. Laryngoscope. 2012;122(8):1701–7. doi:10.1002/lary.23294.
12. Glazer TA, Hoff PT, Spector ME. Transoral robotic surgery for obstructive sleep apnea: perioperative management and postoperative complications. JAMA Otolaryngol Head Neck Surg. 2014;140(12):1207–12. doi:10.1001/jamaoto.2014.2299.
13. Chia SH, Gross ND, Richmon JD. Surgeon experience and complications with Transoral Robotic Surgery (TORS). Otolaryngol Head Neck Surg. 2013;149(6):885–92. doi:10.1177/0194599813503446.
14. Hutcheson KA, Holsinger FC, Kupferman ME, Lewin JS. Functional outcomes after TORS for oropharyngeal cancer: a systemic review. Eur Arch Otorhinolaryngol. 2015;272(2):463–71. doi:10.1007/s00405-014-2985-7.
15. Aubry K, Vergez S, de Mones E, et al. Morbidity and mortality revue of the French group of transoral robotic surgery: a multicentric study. J Robot Surg. 2015;11 [Epub ahead of print]
16. Asher SA, White HN, Kejner AE, et al. Hemorrhage after transoral robotic-assisted surgery. Otolaryngol Head Neck Surg. 2013;149(1):112–7. doi:10.1177/0194599813486254.
17. Pollei TR, Hinni ML, Moore EJ, et al. Analysis of postoperative bleeding and risk factors in transoral surgery of the oropharynx. JAMA Otolaryngol Head Neck Surg. 2013;139(11):1212–8. doi:10.1001/jamaoto.2013.5097.
18. Mandal R, Duvvuri U, Ferris RL, et al. Analysis of post-transoral robotic-assisted surgery hemorrhage: frequency, outcomes, and prevention. Head Neck. 2015; doi:10.1002/hed.24101.

19. Cognetti DM, Luginbuhl AJ, Nguyen AL, Curry JM. Early adoption of transoral robotic surgical program: preliminary outcomes. Otolaryngol Head Neck Surg. 2012;147(3):482–8. doi:10.1177/0194599812443353.
20. Vergez S, Lallemant B, Ceruse P, et al. Initial multi-institutional experience with transoral robotic surgery. Otolaryngol Head Neck Surg. 2012;147(3):475–81. doi:10.1177/0194599812443221.
21. Moore EJ, Janus J, Kasperbauer J. Transoral robotic surgery of the oropharynx: clinical and anatomic considerations. Clin Anat. 2012;25(1):135–41. doi:10.1002/ca.22008.
22. Dallan I, Seccia V, Faggiono L, et al. Anatomical landmarks for transoral robotic tongue base surgery: comparison between endoscopic, external and radiological perspectives. Surg Radiol Anat. 2013;35(1):3–10. doi:10.1007/s00276-012-0983-2.
23. Gun R, Ozer E. Surgical anatomy of oropharynx and supraglottic larynx for transoral robotic surgery. J Surg Oncol. 2015;112:690–6. doi:10.1002/jso.24020.
24. Blanco RG, Fakhry C, Ha PK, et al. Transoral robotic surgery experience in 44 cases. J Laparoendosc Adv Surg Tech A. 2013;23(11):900–7. doi:10.1089/lap.2013.0261.
25. White HN, Frederick J, Zimmerman T, et al. Learning curve for transoral robotic surgery: a 4-year analysis. JAMA Otolaryngol Head Neck Surg. 2013;139(6):564–7. doi:10.1001/jamaoto.2013.3007.
26. Herron DM, Marohn M, SAGES-MIRA Robotic Surgery Consensus Group. A consensus document on robotic surgery: prepared by the SAGES-MIRA robotic surgery consensus group. Surg Endosc. 2008;22(2):313–25. discussion 311-2
27. Gross ND, Holsinger FC, Magnuson JS, et al. Robotics in otolaryngology and head and neck surgery: recommendations for training and credentialing. Head Neck. 2016; doi:10.1002/hed.24207. [Epub ahead of print]
28. Curry M, Malpani A, Li R, et al. Objective assessment in residency-based training for transoral robotic surgery. Laryngoscope. 2012;122(10):2184–92. doi:10.1002/lary.23369.
29. Guseila LM, Saranathan A, Jenison EL, et al. Training to maintain surgical skills during periods of robotic surgery inactivity. Int J Med Robot. 2014;10(2):237–43. doi:10.1002/rcs.1562.
30. Hoffman TK, Schuler PJ, Bankfalvi A, et al. Comparative analysis of resection tools suited for transoral robot-assisted surgery. Eur Arch Otorhinolaryngol. 2014;271(5):1207–13. doi:10.1007/s00405-013-2615-9.
31. Brickman D, Gross ND. Robotic approaches to the pharynx: tonsil cancer. Otolaryngol Clin North Am. 2014;47(3):359–72. doi:10.1016/j.otc.2014.03.002.
32. Moore EJ, Olsen KD, Martin EJ. Concurrent neck dissection and transoral robotic surgery. Laryngoscope. 2011;121(3):541–4. doi:10.1002/lary.21435.
33. Kucur C, Durmus K, Gun R, et al. Safety and efficacy of concurrent neck dissection and transoral robotic surgery. Head Neck. 2015; doi:10.1002/hed.24033.
34. Mockelmann N, Busch CJ, Münscher A, et al. Timing of neck dissection in patients undergoing transoral robotic surgery for head and neck cancer. Eur J Surg Oncol. 2015;41(6):773–8. doi:10.1016/j.ejso.2015.02.002.
35. Howard BE, Hinni ML, Nagel TH, et al. Submandibular gland preservation during concurrent neck dissection and transoral surgery for oropharyngeal squamous cell carcinoma. Otolaryngol Head Neck Surg. 2014;150(4):587–93. doi:10.1177/0194599813519041.
36. Takes RP, Robbins KT, Woolgar JA, et al. Questionable necessity to remove the submandibular gland in neck dissection. Head Neck. 2011;33(5):743–5. doi:10.1002/hed.21451.