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Updates in Robotic Head and Neck Reconstructive Surgery

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Abstract

The use of robotics in head and neck surgery has drastically increased over the past two decades. Transoral robotic surgery has revolutionized the surgical approach to the upper aerodigestive tract including the oropharynx and supraglottic larynx. The expanded use and improving technology of robotics have allowed for new approaches in both the ablative and reconstructive aspects of head and neck surgery. Here, we discuss the recent updates in robotics in head and neck surgery and future directions the field may turn.

Keywords
- transoral robotic surgery
- head and neck neoplasms
- robotic-assisted reconstruction

The use of robotics in head and neck surgery has blossomed over the last nearly 20 years. Initially described by O'Malley et al in 2006, transoral robotic surgery (TORS) has greatly changed the approach to tumors of the oropharynx, posterior oral cavity, and supraglottic larynx.[1] TORS offers the surgeon unprecedented access and visualization of difficult-to-access anatomy while obviating the need for more invasive approaches. At the same time, surgical robotic systems mimic and augment the degree of freedom and stability of surgical instrumentation, allowing for precise and delicate dissection and reconstruction in otherwise difficult-to-access locations. In this article, we will review the implementation of robotics in surgery for the head and neck, and future advances in the field.

Robotics in Head and Neck Ablative Surgery

Oropharyngeal tumors have traditionally required a lip split with the mandibulotomy approach, which carries significant morbidity, including risk of malunion, fistula, and osteoradionecrosis if adjuvant radiotherapy is needed,[2] and worse yet, increased risk of functional deficits including lip paresthesia and sialorrhea. Given these risks, along with the increased sensitivity of human papilloma virus–associated oropharyngeal squamous cell carcinomas (which encompass most oropharyngeal cancers) to chemoradiation, these tumors have been increasingly managed nonsurgically.[3–5] However, along with this shift in treatment paradigm, the long-term toxicities of primary radiation and chemoradiotherapy have become readily apparent, with some patients enduring significant challenges to their quality of life with xerostomia, mucositis, dysphagia requiring gastrostomy tube dependence, osteoradionecrosis, and neck fibrosis.[6] To avoid these toxicities, the treatment paradigm has once again started to change, with select tumors now being accessed surgically through TORS without the need for mandibulotomy. Carefully selected patients have minimal impact on their quality of life once they recover from surgery, although it does expose patients to risk of hemorrhage in the initial recovery period.[7] Although an in-depth discussion on patient selection for TORS ablation is out of the scope of this article, contraindications include micrognathia, trismus, severe obesity, and advanced tumors involving the deep extrinsic tongue musculature, mandible, or carotid. Additionally, the presence of severe nodal disease with extranodal extension should also sway the surgeon away from TORS, as the patient will be subject to trimodality therapy, requiring adjuvant chemoradiation.

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TORS has since expanded beyond oropharyngeal cancer resections. The visualization and degrees of freedom with the instrumentation have allowed for its use in hypopharyngeal cancer resections as well as partial laryngectomies.[8,9] In fact, robotic surgery has also been applied to neck dissection and thyroidectomy, which may have similar outcomes to traditional open approaches, but a neck scar may potentially be avoided in patients prone to hypertrophic scarring or averse to neck scars due to cultural reasons.[10] Neck dissections completed robotically can allow the surgeon to place the incision more posteriorly in a facelift incision. TORS is also now approved for benign tongue base resections in patients with obstructive sleep apnea, based on Hoff et al's feasibility study in 2015.[11] The most used system for both benign and malignant disease is the da Vinci robotic system (Intuitive Surgical, Sunnyvale, CA). Other robotic systems used in head and neck surgery include but are not limited to the Flex Robotic System (Medrobotics Corp, Raynham, MA) and the Hugo RAS system (Medtronic, Minneapolis, MN). In recent years, some experienced surgeons have begun to use robotics in the recurrent and salvage setting.[12,13]

Robotics in Head and Neck Reconstructive Surgery

TORS defects have traditionally been left to heal by secondary intention. As surgeon experience and indications have expanded, TORS resections have gotten larger, often necessitating more complex reconstructions. The primary goals of reconstruction are to provide soft-tissue coverage of major vasculature (thus reducing the risk of major postoperative hemorrhage), to reduce the risk of velopharyngeal insufficiency, and to ultimately improve swallow outcomes. For post-TORS oropharyngeal defects, de Almeida et al created a classification system to help standardize the approach to reconstruction.[14] They defined defect adverse features as exposure of the carotid artery, communication of the oropharynx to the neck, and greater than 50% of soft palate resected. In short, the authors classified four classes of defects, with class I encompassing one oropharyngeal subsite with no adverse features, class II involving multiple subsites with no adverse features, class III involving one subsite and at least one adverse feature, and class IV involving more than one subsite and containing at least one adverse feature. While class I and II defects could generally be left to heal by secondary intention, primary closure, or local flaps, class III and IV defects generally require more advanced reconstruction, often involving free tissue reconstruction. Radial forearm free flaps are the most commonly used donor site, followed by anterolateral thigh (ALT) free flaps, and medial sural artery perforator (MSAP) flaps, although any thin, pliable donor tissue would provide the optimal tissue to resurface a dynamic swallowing apparatus such as the oropharynx.[15]

Large oropharyngeal defects requiring reconstruction can be particularly difficult to inset without the access granted by a traditional mandibulotomy approach. To assist in the inset, robotic-assisted reconstruction (RAR) has been described. Selber was the first to publish a case series detailing five patients who underwent head and neck RAR.[16] Three patients had free flaps in which the inset was assisted with the robotic system, one underwent primary closure of a vallecular defect, and one had a Facial Artery MusculoMucosal (FAMM) flap in which the inset was assisted with the da Vinci robot. An important note is that the robotic system was used only for the difficult-to-reach portions of the inset; the majority of sutures were placed by hand. Of note, one microvascular anastomosis was completed with the robotic system; however, he does note that in some areas of the anastomosis, the suture was placed robotically but tied down by hand. None of the patients developed fistulas following the procedures. Interestingly, the patient with the FAMM flap to the retromolar trigone and oropharynx did bite the pedicle, requiring control of bleeding and flap debridement with the robot. He notes the advantages of improved access, tremor elimination, and motion scaling. He also notes the disadvantages of the lack of haptic feedback and worse optics of the endoscope as compared with the operative microscope. A common thread among RAR studies is the improved visualization, which may assist in this complex three-dimensional (3D) reconstruction.

Hans et al then expanded the use of RAR to the hypopharynx with a case series of two patients with T3N0 hypopharyngeal tumors that were resected via TORS and reconstructed with radial forearm free flaps.[17] The high-resolution, 3D view afforded by the robotic approach allowed for safe, oncologic resection of the pyriform sinus in both cases. While the microvascular anastomosis was completed under the operative microscope in the standard fashion, the inset was performed transorally with the robot with circumferential suturing around the flap. The insets took 30 and 40 minutes, which is in line with standard inset techniques.

Chan et al describe total laryngopharyngectomy with jejunal free flap reconstruction using a TORS approach with the da Vinci system.[18] In this case, the inferior dissection was completed through a limited cervical incision, including the terminal tracheostomy, dissection of the thyroid lobes, division of the tracheoesophageal wall, and distal esophageal incision. The remainder of the dissection was completed transorally, with robotic dissection through the vallecula down to the thyroid cartilage, and a posterior oropharyngeal incision taken down to the level of prevertebral fascia where the cervical dissection was encountered. The specimen was then removed transorally, and the jejunal free flap was introduced transorally, where the distal esophageal–jejunal anastomosis was completed through cervical incision. The microvascular anastomosis was completed to the transverse cervical or superior thyroid arteries using the operative microscope. Finally, the proximal inset was completed with TORS.

At this time, the main added value of RAR in the head and neck is the superior visualization. While this enhances the reconstructive surgeons' ability to optimize their visual senses and see around corners, knowledge of the anatomy and good surgical technique and principles remain paramount to a successful reconstructive surgery in the head and neck.

Future Directions

The utility of robotics in head and neck surgery will continue to expand with surgeon experience and continued improvement of technology. A major advancement in the robotic systems has been the single-port (SP) system, in which reticulating arms and a 3D high-definition endoscope all pass through an SP. As with traditional systems, appropriate retraction is still of utmost importance; however, the SP system is no longer reliant on a straight line of view. This allows for access to areas not readily available through minimally invasive techniques, as well as significantly more degrees of freedom of the instrumentation that is less hindered by the cheek, teeth, and tongue as in traditional TORS. The feasibility and safety of the da Vinci SP system in TORS was demonstrated recently by Holsinger et al in a phase II clinical trial and proved to be a promising advancement in head and neck robotic surgery.[19]

One of the limitations in robotic access is the diameter of the actual instrument arms. A 3-mm-diameter arm that functions without a pulley system was recently described by Wu et al for use in cleft palate repairs.[20] It retains 4 degrees of freedom and can be used with the da Vinci system. This advancement may become crucial in pediatric cases, where a traditional 8-mm (or 5-mm) arm is too bulky to retain the visualization and degrees of freedom in such a limited working space. It is not hard to imagine how functional, smaller-diameter instruments will allow for robotic access and improved line of sight to more difficult-to-reach areas of the head and neck, such as the anterior skull base.

Finally, there is growing research in applying computer vision (CV) in surgery, where visual data (such as the endoscopic view) are run through artificial intelligence algorithms and machine learning is applied. CV can be applied to robotic systems to provide intraoperative feedback, recognizing anatomic structures and areas at risk of injury, and learn the steps of an operation.[21] Furthermore, when combined with advanced haptic feedback, artificial intelligent surgeon systems have the potential for revolutionizing the training of surgeons with real-time intraoperative feedback. One major disadvantage of current robotic systems in surgery is the lack of haptic feedback, although this may change when more advanced analytics are applied to robotic systems.

Conclusion

Several studies have shown the feasibility and utility of transoral robot approaches to both ablative and reconstructive head and neck surgery. As the field expands, surgeon experience grows, and the technology improves, RAR of the head and neck will become more prevalent. Chalmers et al note the ability to avoid more invasive approaches, improved and magnified 3D endoscopic visualization, reduction in tremor, improved access to certain anatomic areas, and the potential for complex instrument manipulation in tight spaces among the great advantages of TORS and reconstruction.[22]

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Conflict of Interest
None declared.

References

1 O'Malley BW Jr, Weinstein GS, Snyder W, Hockstein NG. Transoral robotic surgery (TORS) for base of tongue neoplasms. Laryngoscope 2006;116(08):1465–1472
2 Hedayat F, Jerry Htwe KK, Vassiliou LV, Kyzas P. Morbidity related to the lip-split mandibulotomy approach: a systematic and narrative review. Br J Oral Maxillofac Surg 2022;60(04):430–436
3 Liu C, Mann D, Sinha UK, Kokot NC. The molecular mechanisms of increased radiosensitivity of HPV-positive oropharyngeal squamous cell carcinoma (OPSCC): an extensive review. J Otolaryngol Head Neck Surg 2018;47(01):59
4 Caudell JJ, Gillison ML, Maghami E, et al. NCCN Guidelines® Insights: Head and Neck Cancers, Version 1.2022. J Natl Compr Canc Netw 2022;20(03):224–234
5 Chen AY, Schrag N, Hao Y, Stewart A, Ward E. Changes in treatment of advanced oropharyngeal cancer, 1985-2001. Laryngoscope 2007;117(01):16–21
6 Yeh DH, Tam S, Fung K, et al. Transoral robotic surgery vs. radiotherapy for management of oropharyngeal squamous cell carcinoma: a systematic review of the literature. Eur J Surg Oncol 2015;41(12):1603–1614
7 Yao CMKL, Hutcheson KA. Quality of life implications after transoral robotic surgery for oropharyngeal cancers. Otolaryngol Clin North Am 2020;53(06):1117–1129
8 Park YM, Kim WS, De Virgilio A, Lee SY, Seol JH, Kim SH. Transoral robotic surgery for hypopharyngeal squamous cell carcinoma: 3-year oncologic and functional analysis. Oral Oncol 2012;48(06): 560–566
9 Weinstein GS, O'Malley BW Jr, Snyder W, Hockstein NG. Transoral robotic surgery: supraglottic partial laryngectomy. Ann Otol Rhinol Laryngol 2007;116(01):19–23
10 Lee HS, Kim WS, Hong HJ, et al. Robot-assisted supraomohyoid neck dissection via a modified face-lift or retroauricular approach in early-stage cN0 squamous cell carcinoma of the oral cavity: a comparative study with conventional technique. Ann Surg Oncol 2012;19(12):3871–3878
11 Hoff PT, D'Agostino MA, Thaler ER. Transoral robotic surgery in benign diseases including obstructive sleep apnea: safety and feasibility. Laryngoscope 2015;125(05):1249–1253
12 White H, Ford S, Bush B, et al. Salvage surgery for recurrent cancers of the oropharynx: comparing TORS with standard open surgical approaches. JAMA Otolaryngol Head Neck Surg 2013;139 (08):773–778
13 Paleri V, Fox H, Coward S, et al. Transoral robotic surgery for residual and recurrent oropharyngeal cancers: exploratory study of surgical innovation using the IDEAL framework for early-phase surgical studies. Head Neck 2018;40(03):512–525
14 de Almeida JR, Park RC, Villanueva NL, Miles BA, Teng MS, Genden EM. Reconstructive algorithm and classification system for transoral oropharyngeal defects. Head Neck 2014;36(07): 934–941
15 Barrette LX, De Ravin E, Carey RM, Mady LJ, Cannady SB, Brody RM. Reconstruction following transoral robotic surgery for head and neck cancer: systematic review. Head Neck 2022;44(05): 1246–1254
16 Selber JC. Transoral robotic reconstruction of oropharyngeal defects: a case series. Plast Reconstr Surg 2010;126(06): 1978–1987
17 Hans S, Jouffroy T, Veivers D, et al. Transoral robotic-assisted free flap reconstruction after radiation therapy in hypopharyngeal

carcinoma: report of two cases. Eur Arch Otorhinolaryngol 2013; 270(08):2359–2364
18 Chan JYW, Chan RCL, Chow VLY, Tsang RKY, Wong STS, Wei WI. Transoral robotic total laryngopharyngectomy and free jejunal flap reconstruction for hypopharyngeal cancer. Oral Oncol 2017; 72:194–196
19 Holsinger FC, Magnuson JS, Weinstein GS, et al. A next-generation single-port robotic surgical system for transoral robotic surgery: results from prospective nonrandomized clinical trials. JAMA Otolaryngol Head Neck Surg 2019;145(11):1027–1034
20 Wu GCY, Podolsky DJ, Looi T, Kahrs LA, Drake JM, Forrest CR. A 3 mm wristed instrument for the da Vinci Robot: setup, characterization, and phantom tests for cleft palate repair. IEEE Trans Med Robot Bionics 2020;2(02):130–139
21 Mascagni P, Alapatt D, Sestini L, et al. Computer vision in surgery: from potential to clinical value. NPJ Digit Med 2022;5(01):163
22 Chalmers R, Schlabe J, Yeung E, Kerawala C, Cascarini L, Paleri V. Robot-assisted reconstruction in head and neck surgical oncology: the evolving role of the reconstructive microsurgeon. ORL J Otorhinolaryngol Relat Spec 2018;80(3–4):178–185

