NARRATIVE REVIEW

Big surgeons don't need big incisions: Minimally invasive surgery and use of robotics in Otolaryngology: A Narrative Review

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Abstract

Minimally invasive surgery (MIS) and robotics have revolutionized the field of Otolaryngology. MIS and robotics have reshaped traditional otolaryngological practices, offering patients a multitude of benefits. Reduced incision sizes and tissue manipulation minimize postoperative pain and discomfort, while also improving cosmetic outcomes. MIS has facilitated enhanced visualization and access to intricate anatomical structures, enabling the treatment of previously inaccessible lesions. MIS procedures also offer shorter hospital stays, reduced blood loss, and faster healing times whilst enhancing patient satisfaction and overall quality of life The ongoing progress in minimally invasive approaches solidifies their role as a cornerstone in modern Otolaryngology, and surgeons navigating this transformative landscape must embrace the learning curve associated with these advanced techniques, recognizing the potential for improved patient outcomes. This article explores the transformative impact of MIS and robotics on the diverse branches of Otolaryngology, highlighting the technological advancements that have enabled these techniques to flourish.

Keywords: Invasive Surgical Procedures, Pain, Postoperative, Otolaryngology, Surgeons, invasive surgery, Robotics, Endoscopic, Robotic Surgical Procedures, Three-dimensional imaging, Otolaryngology

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Introduction

"Big surgeons make big incisions." A notion that has been believed and followed since decades in general surgery and in the head and neck surgery. It is less of a notion and more of an idea that large problems require large incisions, and it has deeply dominated surgical thinking in the past.[1] The unconventional anatomical terrains in Otolaryngology have urged much technological advances to help in better visualization and approach to narrow spaces. This has steered the Otolaryngologist to adapt to endoscopes and robots in their field introducing new avenues and learning curves. In Otolaryngology the adoption of minimally invasive surgery started with functional endoscopic sinus surgery (FESS) and since then the use of endoscopes has found its way in all branches of otolaryngology. The surgical limitation in trans-orally addressing oropharyngeal and pharyngeal space pathologies gladly welcomed robots in the operating room for better manipulation and access of the disease. Not only access but cosmesis also pushed forward for transoral endoscopic and robotic thyroidectomies in lieu avoiding grave scars across the neck.

In the ever-evolving landscape of modern medicine the integration of robotics in otolaryngology introduces a level of precision and dexterity that was once unimaginable. In the delicate procedures involving the intricate structures robotic technology is proving to be a transformative force, offering surgeons unprecedented control and a three-dimensional view of the surgical field. This article delves into the multifaceted applications of robotics in otolaryngology. From exploring the current state of the field to recent technological advancements we discuss the potential impact it has on patient outcomes. From robot-assisted surgeries to the development of innovative diagnostic tools, these tool in the armamentarium of otolaryngologists–head and neck surgeons increase proficiency in the appropriate clinical setting and allow for the best possible outcomes for patients and provide a tailored management to cater to the unique needs of each patient. Today we discuss the recent technological advances which have helped develop the minimal invasive surgical domain of otolaryngology in its main branches.

Otology

The otological surgeries went through a revolutionary change with the introduction of microscope and high-speed drills. It brought better vision, better clearance of disease and safer approach towards patients. But it still required giving an incision behind the ear and digging up a lot of bone before reaching the disease. The incorporation of minimally invasive or endoscopic ear

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surgery upgraded otological surgeries in all the above 3 aspects, without having to give an external incision. The concept of endoscope-assisted ear surgery begun in mid 1990s with Dennis Poe introducing this concept in 1995.[2] Since then the interest in endoscopic ear surgery (EES) has increased exponentially which can be witnessed with the comparison in number of publications which publications increased from 6 in 1990 to an accumulated total of 451 in 2018, and an additional 132 articles on this subject published between January of 2019 and September of 2020.[1,3].With the advent of International Working Group On Endoscopic Ear Surgery (IWGEES), which includes membership representing almost all countries, the standardizing, teaching, and spreading of the technique has become much easier and widely available. From diagnostic and documentation to being an ancillary instrument to microscope to complete transcanal surgery the endoscopic technique has come far and wide. The existing microscopic approach allows narrow field of view through ear canal as permitted by the narrowest segment of the canal forcing surgeons to perform post auricular mastoidectomy drilling out much of healthy bone to get access, whereas transcanal endoscopic access aligns surgical access with anatomic reality and allows wide access to the sinus tympani, facial recess, attic, eustachian tube isthmus, protympanum, anterior mesotympanum, the tympanic isthmus and tympanic cavity, ultimately helping in better clearance of disease and restoring of ventilation pathways preventing further disease.[4]

The external auditory canal is also a natural access point for addressing temporal bone pathology during lateral skull base surgeries. Marchioni and colleagues have described 3 transcanal approaches to the inner ear and petrous apex, transcanal suprageniculate corridor, transcanal infracochlear corridor and transcanal transpromontorial corridor.[5] Through them temporal bone pathologies such as Cholesteatoma of the superior petrous apex, distal labyrinthine facial nerve decompression, facial nerve haemangiomas, suprageniculate fossa, intralabyrinthine and intracanalicular schwannomas, Internal auditory canal and CPA neoplasms with limited CPA expansion can be addressed without a retro-auricular incision or via a per-meatal approach. These approaches help in hearing preservation as well, which was not possible with previous open approaches.[6]

The recent advancements in the field like introduction high-definition camera systems, three dimensional high-definition imaging system and three dimensional exoscopes has spiked the interests of seasoned surgeons to switch away from traditional microscopic approaches. High-definition camera systems have helped develop new anatomical atlas by landscaping the minute anatomical details which were veiled to previous imaging systems and the addition of depth perception to these high-quality images has further enhanced the surgical access and removal of disease from delicate areas. The new surgical visualization system called the 3D exoscope system is a viable alternative to surgical microscopes. It is a scope exterior to the body surface and has dual image sensors for 3D visualization. The images obtained are visualized on a monitor, and a surgeon and assistant observe 3D stereoscopic images wearing 3D glasses.[7] Both the above advances have helped in ergonomics between the surgical team with better communication between team members including residents, anaesthesiologists, and nurses, better instrument exchange and allowing an active participation in procedures for trainees and medical students.[8]

EES has transformed many aspects of otology and neurotology. The utilization of endoscope is not only limited to operating rooms as otoendoscopic examinations in clinics allow better visualization. It helps in pictorial documentation of the disease, surgical planning, and counselling of the patient and in post-operative cases helps to overcome the anatomic barriers limiting the view. Understanding the challenges that come with EES is crucial in developing the skills necessary to be successful with the technique. But with sufficient knowledge, training, and experience, otolaryngologists around the world can incorporate EES into their practice.[9] One of the greatest advantages is the ability to better match surgical access with the disease process in these times. An experienced otolaryngologist can now develop a tailored approach using both the microscope and endoscope to facilitate specific clinical situations.

Another frontier in ear surgery is inclusion of robots in the field. Inclusion of Robots can be defined in 3 classes based upon surgeon-device-patient interaction. 1. Collaborative Robot/Guide: where the surgeon's hands directly actuate the end effector. In collaborative guide the robot can aligns a tool or an implant to a patient-specific trajectory and the surgeon can then carry out the remaining task and it can also help establish a boundary to avoid surgeon entering a no-go area preventing damage to healthy tissues. 2. Teleoperated Robot: where the surgeon remotely controls the end effector during the surgery. Clinical example of this class is RobOtol, developed at Pierre and Marie Curie University in Paris, France and now available throughout Europe, acts like an assistant with platform and arms used to hold endoscopes and instruments and the motion are scaled to accomplish gross versus microscopic motions. This ensures precise movement in narrow tunneled areas in middle ear such as in stapes surgery. Another application of the RobOtol is to pair it with a force feedback control drill allowing drilling of a stapedotomy or cochleostomy with minimal trauma to internal endosteum. 3. Autonomous Robot: where the end effector interacts with the patient independently, under the surgeon's supervision. Clinical application of this class is HEARO robot from Bern, Switzerland. This robot has custom-built multi articulated arm robot which uses image guidance to drill from the surface of the mastoid through the facial recess where the drill also functions as a facial nerve stimulator to avoid facial nerve damage creating a facial recess approach with minimal mastoid drilling. Autonomous robots may have their greatest affect in insertion of Cochlear implants where compared to humans the placement of implant with a robot has a consistent insertion trajectory with low insertion forces avoiding frequently occurring complications like tip fold-over and translocation from scala tympani to scala vestibuli. The important aspect with robots is that the high accuracy and low-tension insertion is repeatable. Although these integration of robotics in surgical field is quite enticing but much of these ideas are still under development and trials and clinical implantation may take time.[10]

Rhinology

The field that has been the most beneficiary from the advent of the endoscope is rhinology. Endoscopic sinus approach has now become a gold standard for most of the rhinological procedures especially for CRS with polyposis. Alfred Hirschman in 1901 is credited with the first attempt at nasal endoscopy but the term "sinuscopy" was introduced by Maxwell Maltz in 1925. The creation of the Hopkins rod system in the 1960s with a design markedly enhancing light delivery and providing superior optical quality provided the major turning point in the field of sino-nasal endoscopy. Walter Messerklinger's landmark book on diagnostic endoscopy of the nose in 1978, provided a new endoscopic anatomical landscape of the nasal cavities.[1]

Endoscopic Sinus Surgery, a cornerstone of minimally invasive rhinologic procedures, addresses a wide range of pathologies from chronic rhinosinusitis with nasal polyposis up to nasal and skull base malignancies with reduced morbidity and improved patient recovery. The treatment of chronic rhinosinusitis with nasal polyposis via endoscope is well established. Over the past few decades, the use of endoscopic approaches for surgical resection of sinonasal and skull base cancers has gained popularity. The advantages of endoscopic approaches are avoidance of scarring and facial incisions, avoidance of maxillofacial skeletal dissection and translocation and better cosmetic outcome. Ahmed S. in his recent study demonstrated results with 239 undergoing sinonasal and skull base carcinoma resection. The tumour pathology popularly included olfactory neuroblastoma, melanoma, neuroendocrine carcinoma, and squamous cell carcinoma. Negative surgical resection margins were achieved in 87.4% of the patients with surgical complications among 28.8% patients. The 5-year overall survival rate was 73.9% while the 5 years disease free survival rate was 79.7% and the progression-free survival was 65.9% at 5 years. The main criticism of the endoscopic approaches is the inability to perform enbloc resection of the tumour.[11]

Expanded endoscopic skull-base surgery (EESBS) was developed by Castelnuovo and Locatelli in 1997 with the introduction of the 4-hand, 2-surgeon technique. With EESBS resection of extradural and intradural lesions is possible by accessing the skull base from the frontal sinus posterior table to the C-2 vertebra.[12] Advantages with EESBS are it provides direct midline exposure, improves visualisation, less manipulation of neurovascular structures is required, avoids brain retraction, and provides the ability to follow the patient postoperatively with similar or superior oncologic results.[13, 14] This approach also provides reduced operating time, morbidity, local recurrence, length of stay and improved quality of life.[15, 16] Downside to this technique are, for 2 surgeons this is ergonomically an inefficient method to operate and the bony confines of the transnasal corridor, namely the nasal bones, hard palate, and pterygoid plates, restricts triangulation of instruments for tissue traction and counter-traction. This narrow corridor also proves difficult in managing vascular injuries and cerebrospinal fluid (CSF) leaks.[17]

Balloon sinuplasty is another minimally invasive technique gaining popularity in rhinology. It utilizes a small, inflatable balloon catheter to open up narrowed sinus openings and ostiomeatal complex, restoring drainage and alleviating sinus symptoms. Balloon sinuplasty is particularly effective for patients with chronic rhinosinusitis who have not responded well to medical therapy. Advantages of balloon sinuplasty are, non-invasive, requires no incisions, short procedure time and fast recovery with minimal discomfort.[18] Consecutive series of 165 adults diagnosed with CRS (CRSsNP and CRSwNP) were recruited by Castro who were refractory to medical therapy that were submitted to Ballon Sinuplasty. The results also demonstrated that 92.68% of patients in the CRSsNP group and 92.86% patients of the CRSwNP group achieved the minimally clinical important difference (MCID) defined has improvement of 9 points of SNOT-22 from baseline score after balloon sinuplasty. Regarding changes in Modified Lund Kennedy score and Lund Mackay scores, significant improvements from baseline were observed in both groups. The results suggest that balloon sinus dilation can be a safe alternative to conventional FESS with the added advantage of being performed as an in-office procedure with local anaesthesia. This allows a faster recovery, decreased postprocedural pain, and less requirement for debridement thus preserving the nasal mucosa and bony structures.[19]

Minimally invasive techniques have also found utility in functional rhinoplasty, addressing issues such as nasal obstruction and septal deviations. Endoscopic approaches allow for precise correction of anatomical deformities while minimizing external scarring, resulting in improved functional and aesthetic outcomes.

The possibility of Transoral robotic surgery (TORS) for resection of skull-base tumours was introduced by O'Malley and Weinstein in 2007. They used a combined cervical-transoral approach in a cadaver to access the nasopharynx, clivus, sphenoid, sella, and anterior suprasellar fossa.[20] Yin Tsang et al. in 2012 were the first to report the clinical use of robots in anterior skull-base surgery by combining EESBS and TORS to remove a recurrent nasopharyngeal carcinoma. The resection was complete, uneventful, and no complications were reported.[21] Similarly combined use of EESBS and TORS was used to complete a nasopharyngectomy for a chordoma, and an adenoid cystic carcinoma by Carrau et al in 2013.[22] In 2015, Tsang et al. performed robotic salvage nasopharyngectomy of 12 patients using da Vinci surgical robot for recurrent nasopharyngeal carcinoma.[23] Two years later Chauvet et al resected 4 cystic pituitary lesions and Henry et al. reported the use of TORS to resect 3 clival chordomas extending into the nasopharynx using TORS.[24,25] But in all these studies the surgeons had to perform soft palate or hard palate splitting resulting in complications such as soft/hard palate junction fistulas, velopharyngeal insufficiency, transient hypernasal speech and CSF leak. But Harichane et al. in 2018 in cadaveric study using the da Vinci S and Si robots accessed the entire nasopharynx, sphenoid sinus to the sella turcica, the pituitary gland, and the optic chiasm via an inferosuperior approach without splitting the palate.[26]

Currently, only approved clinical use robots are multi-arm robotic systems. However, the development of next-generation flexible robotic systems such as the da Vinci Sp system which uses a single port, 4 channels pass through system allowing a flexible 0-degree camera and 3 serpentine 6-mm instruments delivery into the surgical field via a 25-mm port. The instrument arm can rotate 360 degrees and can be docked on either side of the patient or at the head of the bed, improving ergonomics by permitting navigation systems to be used in conjunction with the robot and hence the Sp instruments can operate within a very narrow surgical space up to the size of a tennis ball.[27] Other developers such as Cambridge Medical Robotics Surgical, Titan Medical and TransEnterix also have their prototypes under development with goal to improve visualization, maneuverability, and haptic feedback in the narrow bony confined space of sinonasal cavity.[17]

While minimally invasive surgery and robotics have transformed the field of rhinology, challenges exist, including a steep learning curve for surgeons, limitations in the treatment of extensive pathologies, and the potential for complications. Minimally invasive surgery has revolutionized the field of rhinology, offering effective and less traumatic alternatives to traditional open procedures. The continuous evolution in this field holds promise for further advancements, ultimately benefiting patients through improved outcomes and quality of life.

Laryngology

Since the time of Banjamin Babington-1800s the possibility of viewing larynx in action has been explored in many ways. The development through the past two centuries has brought us in an era where awake office based laryngeal procedures are possible. It began with development of flexible fiberoptic transnasal endoscope, aiding in assessment of supraglottic and glottic diseases and helping in better staging the neoplastic lesions.

Paediatric Sub-glottic stenosis either acquired occurring commonly due to prolonged intubation or congenital caused by syndromic diagnosis, such as trisomy 21, CHARGE, and 22q11 deletion syndromes, remains both complex and challenging for paediatric otolaryngologists and required tracheostomies in such patients. With advent of balloon dilation technique, the decannulation rates have increased significantly in Cotton-Myer grade I and II. The study by Avelino and colleagues showed 100% success rate with acute subglottic stenosis of grade II or III in 48 patients mean age of 20.7 months, whereas in patients with chronic subglottic stenosis the success rate was only 39% ($P<.0001$).[28] A meta-analysis by Lang and Brietzke including 7 studies and 150 paediatric patients showed random effects model estimate of treatment success 65.3% (range 50%–100%) with 1.6 mean dilations per patient over an average follow-up period of 4.6

months.[29] Those with higher grade and more chronic stenosis Endoscopic posterior cricoid split with rib grafting can be done. This technique helps in expanding the subglottic diameter without open approach. Dahl and colleagues in there study included 32 patients over 15 years which included patients with subglottic stenosis (13 patients), posterior glottic stenosis (12 patients), and bilateral vocal fold immobility (7 patients) and among them they were able to decannulate 65.6% of the patients and 53.8% in subglottic stenosis group.[30]

For adult population sub glottic and glottic stenosis can be managed by balloon dilatation and radial incisions with carbon dioxide (CO^2) Laser. The development of the CO2 laser with the surgical microscope in the 1970s led to transoral laser surger. Cevizci[31] reported successful restoration with flexible CO2 laser treatment with 71% decannulation while Patel[32] showed 90% success in initial dilatation patients and 100% success in dilatation as second procedure. Only drawback is that sometimes patient may need a second procedure as Anne F.[33] demonstrated 55% the patients had to go for second procedure. Laser is also helpful in anterior and posterior glottic web releases.[34, 35] With advancements in equipment like flexible nasal endoscopes with ports and better local anaesthesia techniques, laser anterior glottic web release, subglottic and tracheal stenosis release and balloon tracheoplasty is being performed in office based setting without a trip to operation theater.[36]

Tamura used transoral laser surgery with the potassium-titanyl-phosphate (KTP) laser on early glottic carcinoma in 22 patients and his results were quite comparable to radiotherapy at the time for T1a glottic carcinoma.[37] A systematic review and meta-analysis conducted by M Suppah on outcomes of KTP Laser in early glottic neoplasms included 342 patients in 8 studies. The disease-free survival after KTP was 98.5% and overall survival was 90.7% with recurrence rate within1 year of 8.1%. They concluded that KTP laser is a safe and effective method for treatment of early glottic neoplasms and the results are similar to CO2 laser and radiotherapy treatments.[38]

Another trend shift is seen in tracheostomies is with introduction of percutaneous endoscopic tracheostomy providing convenience of bedside procedure. It is the preferred method in ICU patients as there is minimal patient mobilization required and rate complications is low as well.[39]

Robotic equipment has the potential to overcome many of the limitations in endo-laryngeal procedures by improving optics, modulating tremor, and increasing instrument degrees of freedom. McLeod and Melder were the first to report use of the da Vinci Surgical Robot in laryngeal surgery. The procedure was successful without complication and the patient was discharged the same day. The authors concluded that superb 3D visualisation allowed for accurate assessment and precise instrument control.[40] After success with cadaveric robotic surgery the da Vinci Surgical Robot was implemented for supraglottic partial laryngectomy and base of tongue neoplasm resection. These studies introduced the use of electrocautery robotic instruments and a flexible tracheal suction device manipulated by a robotic arm. The authors concluded that owing to good exposure a safe and complete tumor resection was possible in base of tongue neoplasm excision and supraglottic laryngectomy.[41, 42]

Oropharynx

The anatomy of oropharynx is quite constricted and provides very restricted access. The crucial structures passing through and surrounding this region makes approach furthermore difficult. In conjunction with it the first decade of this century showed dramatic increase in oropharyngeal squamous cell carcinoma (OPSCC) incidence owing to HPV oncogenicity. This became a catalyst for innovation in minimally invasive techniques in oropharyngeal tumours. In early years of this century the standardised method of dealing with such tumours was radical tonsillectomy using cold knife and electrocautery by Laccourreye and Holsinger.[43, 44] But this was limited by a lack of adequate visualisation of the tongue base and limited access to reliably obtain negative margins. Haughey and other investigators explored transoral laser microsurgery as an alternative surgical technique that provides improved visualisation and haemostasis with excellent oncologic outcomes, but this did not get widely popular.[45] The limitations of existing techniques paved the way for development of a novel application of robotics in oropharynx. As discussed in previous section after success in cadaveric and animal models da Vinci robot was utilized for base of tongue resections, by virtue of this technique's excellent visualisation and decreased line of sight issue using a 30← endoscope, and most early-stage oropharyngeal tumours could be reliably treated with primary surgery.[41, 42] Other robotic systems, including the Medrobotic Flex system (Medrobotics, Raynham, MA) have since been pioneered and tested successfully.[46]

FDA approval of Transoral robotic surgery (TORS) for benign and T1/T2 malignant otolaryngologic tumours was given in 2009, but it is mainly utilised in resection of early-stage OPSCC. Since its approval the percentage of patients undergoing primary surgery for T1/T2 OPSCC has increased to 82% from 56% in 2013.[47] Weinstein showed a 100% locoregional control for selected T1 to T3 tonsillar cancers and a 93% 2-year disease-specific survival rate in a subsequent study including all oropharyngeal sub-sites.[48, 49] Moore showed 3-year local control rates of 97% and regional disease control rates of 94% and 2- year disease-free and recurrence-free survival rates of 95% and 92%, respectively.[50, 51] A large multicentre study including 410 patients which included 89% OPSCC among which 84% were T1/T2 and 70% were HPV positive underwent TORS. The results showed 2-year disease-specific of 95% and overall survival rates of 91%. [51] These finding are consistent with review of 772 patients that showed 2-year survival estimates of 82% to 94% for early-stage OPSCC treated with upfront TORS.[52]

Functional outcomes following TORS are quite encouraging. Dziegielewski reviewed a series of 81 patients who underwent TORS and found that patients had high levels of aesthetic, social and overall quality of life at 12 months after surgery.[53] A recent randomised trial comparing primary TORS and primary radiotherapy showed comparable oncologic outcomes.[54] For TORS complication rates have been found to be low in early stage OPSCC. In a recent systematic review, patients having TORS for early OPSCC, rate of neck haematoma was 0.4%, and for postoperative haemorrhage and pharyngocutaneous fistula was 2.4% and 2.5%, respectively.[52]

Paediatric otolaryngology has been utilizing Transoral robotic surgery (TORS) since 2007 in laryngeal cleft repairs.[55] As the TORS technology improved its use also expanded from treating children with obstructive sleep apnoea to resection of base of tongue lesions, resection of supraglottic and hypopharyngeal lesions. A review of 16 patients undergoing lingual tonsillectomy via TORS for obstructive sleep apnoea, authors attributed their success to smaller instruments-5 mm instruments with 12 mm endoscope- wide exposure of the tongue base musculature, proper magnification of working area, and clear visualisation of cranial nerve IX.[56] In another study with 9 patients undergoing lingual tonsillectomy and base of tongue reduction via TORS for OSA reported that a three-dimensional view and more freedom of motion were clear advantage over endoscopic coblation or radiofrequency ablation.[57] Apart from OSA TORS have also been used in a variety of oropharyngeal and airway procedures in paediatric population. In 2017 Zdanski et al. in the first paediatric series of 16 patients including children from as young as 14 days to 15 years, described successful procedures via TORS. Procedures included resection of hamartoma, repair of laryngeal cleft, removal of saccular cyst, release of pharyngeal or oesophageal strictures, and excision of lymphatic malformations without any intraoperative complications or conversions to open or traditional endoscopic surgery.[58] The advantages he mentioned over previous methods included 3D visualization, precise control of the laser, ability to place more sutures in small spaces, and multilayer closure with greater exposure. Arnold used TORS in a 6-year-old girl with neurofibromatosis type I (NF1) for successful resection of supraglottic neurofibroma with parapharyngeal space extension.[59] These case series suggest that the known advantages of TORS in adults are also beneficial in paediatric populations for head and neck surgery despite the limitations of cumbersome setup, obtaining surgical access for robotic arms and high surgical cost. The adoption of TORS in paediatric otolaryngology still remains limited and it can be better integrated with advanced preoperative surgical planning.[60]

Endocrinology

Thyroid disease prevalent worldwide, more prevalent in females, requires thyroidectomy. Patients suffering from thyroid disease specially young women are much concerned with cosmesis and demand reducing or eliminating the neck scar.[61] Since the first report of endoscopic thyroidectomy by Huscher in 1997, various approaches via endoscope have been applied for thyroid surgery, which are the vestibular, the axillary, the areolar and the subclavian. Endoscopic approach provides better surgical view with magnification, less postoperative pain and most importantly better cosmetic appearance compared to open approach.[62] Wang compared Endoscopic versus Conventional Open Thyroidectomy in 442 patients. He used breast Endoscopic approach for thyroidectomy. Apart from longer operative time endoscopic approach provided lesser blood loss and drainage, lesser post-op complication of recurrent nerve damage and hypocalcaemia, lesser pain and better cosmetic results compared to open approach.[63] Jeong compared the same in Papillary Thyroid Microcarcinoma (PTMC) Patients via trans-axillary approach. The results showed no abnormal RAI uptake in both the groups. However, among open approach 7 patients had increased Thyroglobulin levels and 6 patients had recurrence whereas none in Endoscopic group. The complication rates were also better in endoscopic group.[64] A systemic review and meta-analysis conducted by de Vries including 31 articles and 25,373 participants and including all approaches for endoscopic thyroidectomy. They compared surgical complications and operative time and concluded that apart from operative time which was higher in endoscopic approaches the transient hypocalcaemia and recurrent nerve injury was lower in endoscopic group and permanent hypocalcaemia and recurrent nerve injury was lower but equal in both groups.[65] Hence it can be concluded that the newer endoscopic approach not only provides better cosmesis but is equivalently safe to convention open approach.

The introduction of the robotic thyroidectomy via a trans-axillary approach by Lobe and colleagues in 2005 opened new doors for surgeons. The robotic thyroidectomy implies 4 approaches 1.transaxillary, 2.retro auricular, 3.areolar and 4.transoral using the da Vinci robots.[66] Robot usage gives better manipulation with instruments in a restricted area and is very much comparable in results to conventional approach. It is evident in Jandee and colleagues published work where more than 6000 cases were performed using a gasless trans-axillary approach via da Vinci robot and has similar oncologic effectiveness as open surgery, but without additional complications.[67] Although inclusion of robots seems quite promising, but it does come with drawbacks that is it requires high degree of training before practice, it is a highly expensive surgery, and requires a highly integrated teamwork.[66]

Conclusion

In conclusion, the field of Otolaryngology has witnessed a transformative shift towards minimally invasive surgical techniques. This paradigm shift is particularly evident in the diverse branches of Otolaryngology, each benefiting from technological innovations and evolving surgical approaches. The adoption of minimally invasive surgery in Otolaryngology has reshaped traditional practices, offering patients improved outcomes, reduced morbidity, and enhanced cosmetic results. The ongoing evolution in technology and techniques promises to further refine and expand the domain of minimally invasive surgery and robotics, solidifying their role as a cornerstone in modern Otolaryngology. Surgeons navigating this transformative landscape must balance the learning curve with the promise of better patient outcomes, ultimately contributing to the ongoing success and progress of minimally invasive approaches in Otolaryngology.

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References

1. Chandrasekhar SS. Big Ear Surgeons Don't Need to Make Such Big Incisions. Otolaryngol Clin North Am 2021;54:xvii-xx. doi: 10.1016/j.otc.2020.10.002.
2. Bottrill ID, Poe DS. Endoscope-assisted ear surgery. Am J Otol 1995;16:158-63.
3. Kapadiya M, Tarabichi M. An overview of endoscopic ear surgery in 2018. Laryngoscope Investig Otolaryngol 2019;4:365-73. doi: 10.1002/lio2.276.
4. Tarabichi M, Arsiwala Z. History of Endoscopic Ear Surgery. Otolaryngol Clin North Am 2021;54:1-9. doi: 10.1016/j.otc.2020.09.002.
5. Marchioni D, Alicandri-Ciufelli M, Rubini A, Presutti L. Endoscopic transcanal corridors to the lateral skull base: Initial experiences. Laryngoscope 2015;(Suppl 5):s1-13. doi: 10.1002/lary.25203.
6. Isaacson B, Killeen DE, Bianconi L, Marchioni D. Endoscopic Assisted Lateral Skull Base Surgery. Otolaryngol Clin North Am 2021;54:163-7. doi: 10.1016/j.otc.2020.09.020.
7. Nogueira JF, de Sousa Lobo Ferreira Querido R, Gonçalves da Silva Leite J, Cabral da Costa T. Future of Endoscopic Ear Surgery. Otolaryngol Clin North Am 2021;54:221-3. doi: 10.1016/j.otc.2020.09.023.
8. Mamelak AN, Drazin D, Shirzadi A, Black KL, Berci G. Infratentorial supracerebellar resection of a pineal tumor using a high definition video exoscope (VITOM®). J Clin Neurosci 2012;19:306-9. doi: 10.1016/j.jocn.2011.07.014.
9. Stern Shavit S, Sharma RK, Chern A, Golub JS. Pearls and Pitfalls in Endoscopic Ear Surgery. Otolaryngol Clin North Am 2021;54:201-9. doi: 10.1016/j.otc.2020.09.016.
10. Riojas KE, Labadie RF. Robotic Ear Surgery. Otolaryngol Clin North Am 2020;53:1065-7. doi: 10.1016/j.otc.2020.07.014.
11. Abdelmeguid AS, Raza SM, Su SY, Kupferman M, Roberts D, DeMonte F, et al. Endoscopic resection of sinonasal malignancies. Head Neck 2020;42:645-52. doi: 10.1002/hed.26047.
12. Castelnuovo P, Pistochini A, Locatelli D. Different surgical approaches to the sellar region: focusing on the "two nostrils four hands technique". Rhinology 2006;44:2-7.
13. Saedi B, Aghili M, Motiee M, Valadkhani S, Niazi AB, Safavi A. Surgical outcomes of malignant sinonasal tumours: open versus endoscopic surgical approaches. J Laryngol Otol 2014;128:784-90. doi: 10.1017/S0022215114001583.
14. Carrabba G, Dehdashti AR, Gentili F. Surgery for clival lesions: open resection versus the expanded endoscopic endonasal approach. Neurosurg Focus 2008;25:E7. doi: 10.3171/FOC.2008.25.12.E7.
15. Eloy JA, Vivero RJ, Hoang K, Civantos FJ, Weed DT, Morcos JJ, et al. Comparison of transnasal endoscopic and open craniofacial resection for malignant tumors of the anterior skull base. Laryngoscope 2009;119:834-40. doi: 10.1002/lary.20186.
16. Wood JW, Eloy JA, Vivero RJ, Sargi Z, Civantos FJ, Weed DT, et al. Efficacy of transnasal endoscopic resection for malignant anterior skull-base tumors. Int Forum Allergy Rhinol 2012;2:487-95. doi: 10.1002/alr.21062.
17. Campbell RG. Robotic surgery of the anterior skull base. Int Forum Allergy Rhinol 2019;9:1508-14. doi: 10.1002/alr.22435.
18. Lofgren DH, Shermetaro C. Balloon Sinuplasty. Treasure Island, FL:

StatPearls Publishing; 2024.
19. Castro A, Furtado M, Rego Â, Serras D, Plácido M, Martins C. Long term outcomes of balloon sinuplasty for the treatment of chronic rhinosinusitis with and without nasal polyps. Am J Otolaryngol 2021;42:102825. doi: 10.1016/j.amjoto.2020.102825.
20. O'Malley BW Jr, Weinstein GS. Robotic anterior and midline skull base surgery: preclinical investigations. Int J Radiat Oncol Biol Phys 2007;69(Suppl 2):s125-8. doi: 10.1016/j.ijrobp.2007.06.028.
21. Yin Tsang RK, Ho WK, Wei WI. Combined transnasal endoscopic and transoral robotic resection of recurrent nasopharyngeal carcinoma. Head Neck 2012;34:1190-3. doi: 10.1002/hed.21731.
22. Carrau RL, Prevedello DM, de Lara D, Durmus K, Ozer E. Combined transoral robotic surgery and endoscopic endonasal approach for the resection of extensive malignancies of the skull base. Head Neck 2013;35:E351-8. doi: 10.1002/hed.23238.
23. Tsang RK, To VS, Ho AC, Ho WK, Chan JY, Wei WI.s Early results of robotic assisted nasopharyngectomy for recurrent nasopharyngeal carcinoma. Head Neck 2015;37:788-93. doi: 10.1002/hed.23672.
24. Chauvet D, Hans S, Missistrano A, Rebours C, Bakkouri WE, Lot G. Transoral robotic surgery for sellar tumors: first clinical study. J Neurosurg 2017;127:941-8. doi: 10.3171/2016.9.JNS161638.
25. Henry LE, Haugen TW, Rassekh CH, Adappa ND, Weinstein GS, O'Malley BW Jr. A novel transpalatal-transoral robotic surgery approach to clival chordomas extending into the nasopharynx. Head Neck 2019;41:E133-40. doi: 10.1002/hed.25747.
26. Harichane A, Chauvet D, Hans S. Nasopharynx access by minimally invasive transoral robotic surgery: anatomical study. J Robot Surg 2018;12:687-92. doi: 10.1007/s11701-018-0804-7.
27. Intuitive Surgical. Da Vinci SP: A versatile1 and high-performance single-port robotic surgical system. [Online] 2019 [Cited 2024 April 15]. Available from URL: https://www.intuitive.com/en-us/products-and-services/da-vinci/sp.
28. Avelino M, Maunsell R, Jubé Wastowski I. Predicting outcomes of balloon laryngoplasty in children with subglottic stenosis. Int J Pediatr Otorhinolaryngol 2015;79:532-6. doi: 10.1016/j.ijporl.2015.01.022.
29. Lang M, Brietzke SE. A systematic review and meta-analysis of endoscopic balloon dilation of pediatric subglottic stenosis. Otolaryngol Head Neck Surg 2014;150:174-9. doi: 10.1177/0194599813510867.
30. Dahl JP, Purcell PL, Parikh SR, Inglis AF Jr. Endoscopic posterior cricoid split with costal cartilage graft: A fifteen-year experience. Laryngoscope 2017;127:252-7. doi: 10.1002/lary.26200.
31. Cevizci R, Dilci A, Can IH, Kersin B, Bayazit Y. Flexible CO2 Laser Treatment for Subglottic Stenosis. J Craniofac Surg 2017;28:983-4. doi: 10.1097/SCS.0000000000003549.
32. Patel KB, Prajapati O, Chauhan VM, Joshi C, Darji D. Balloon dilation laryngoplasty for acquired subglottic stenosis at a tertiary center in India. Indian J Otolaryngol Head Neck Surg 2021;73:276-81. doi: 10.1007/s12070-020-02061-y.
33. Hseu AF, Benninger MS, Haffey TM, Lorenz R. Subglottic stenosis: a ten-year review of treatment outcomes. Laryngoscope 2014;124:736-41. doi: 10.1002/lary.24410.
34. Atallah I, Manjunath MK, Omari AA, Righini CA, Castellanos PF. Reconstructive transoral laser microsurgery for posterior glottic web with stenosis. Laryngoscope 2017;127:685-90. doi: 10.1002/lary.26212.
35. Su CY, Alswiahb JN, Hwang CF, Hsu CM, Wu PY, Huang HH. Endoscopic laser anterior commissurotomy for anterior glottic web: one-stage procedure. Ann Otol Rhinol Laryngol 2010;119:297-303. doi: 10.1177/000348941011900505.
36. Belafsky PC, Kuhn MA. Office airway surgery. Otolaryngol Clin North Am 2013;46:63-74. doi: 10.1016/j.otc.2012.08.018.
37. Tamura E, Kitahara S, Ogura M, Kohno N. Voice quality after laser surgery or radiotherapy for T1a glottic carcinoma. Laryngoscope 2003;113:910-4. doi: 10.1097/00005537-200305000-00025.
38. Suppah M, Kamal A, Karle WE, Saadoun R, Lott DG. Outcomes of KTP Laser Ablation in Glottic Neoplasms: A Systematic Review and Meta-Analysis. Laryngoscope 2023;133:1806-14. doi: 10.1002/lary.30547.
39. Jarosz K, Kubisa B, Andrzejewska A, Mrówczyńska K, Hamerlak Z, Bartkowska-Śniatkowska A. Adverse outcomes after percutaneous dilatational tracheostomy versus surgical tracheostomy in intensive care patients: case series and literature review. Ther Clin Risk Manag 2017;13:975-81. doi: 10.2147/TCRM.S135553.
40. McLeod IK, Melder PC. Da Vinci robot-assisted excision of a vallecular cyst: a case report. Ear Nose Throat J 2005;84:170-2.
41. O'Malley BW Jr, Weinstein GS, Snyder W, Hockstein NG. Transoral robotic surgery (TORS) for base of tongue neoplasms. Laryngoscope 2006;116:1465-72. doi: 10.1097/01.mlg.0000227184.90514.1a.
42. Weinstein GS, O'Malley BW Jr, Snyder W, Hockstein NG. Transoral robotic surgery: supraglottic partial laryngectomy. Ann Otol Rhinol Laryngol 2007;116:19-23. doi: 10.1177/000348940711600104.
43. Laccourreye O, Hans S, Ménard M, Garcia D, Brasnu D, Holsinger FC. Transoral lateral oropharyngectomy for squamous cell carcinoma of the tonsillar region: II. An analysis of the incidence, related variables, and consequences of local recurrence. Arch Otolaryngol Head Neck Surg 2005;131:592-9. doi: 10.1001/archotol.131.7.592.
44. Holsinger FC, McWhorter AJ, Ménard M, Garcia D, Laccourreye O. Transoral lateral oropharyngectomy for squamous cell carcinoma of the tonsillar region: I. Technique, complications, and functional results. Arch Otolaryngol Head Neck Surg 2005;131:583-91. doi: 10.1001/archotol.131.7.583.
45. Haughey BH, Hinni ML, Salassa JR, Hayden RE, Grant DG, Rich JT, et al. Transoral laser microsurgery as primary treatment for advanced-stage oropharyngeal cancer: a United States multicenter study. Head Neck 2011;33:1683-94. doi: 10.1002/hed.21669.
46. Mandapathil M, Duvvuri U, Güldner C, Teymoortash A, Lawson G, Werner JA. Transoral surgery for oropharyngeal tumors using the Medrobotics(®) Flex(®) System - a case report. Int J Surg Case Rep 2015;10:173-5. doi: 10.1016/j.ijscr.2015.03.030.
47. Cracchiolo JR, Roman BR, Kutler DI, Kuhel WI, Cohen MA. Adoption of transoral robotic surgery compared with other surgical modalities for treatment of oropharyngeal squamous cell carcinoma. J Surg Oncol 2016;114:405-11. doi: 10.1002/jso.24353.
48. Weinstein GS, O'Malley BW Jr, Snyder W, Sherman E, Quon H. Transoral robotic surgery: radical tonsillectomy. Arch Otolaryngol Head Neck Surg 2007;133:1220-6. doi: 10.1001/archotol.133.12.1220.
49. Cohen MA, Weinstein GS, O'Malley BW Jr, Feldman M, Quon H. Transoral robotic surgery and human papillomavirus status: Oncologic results. Head Neck 2011;33:573-80. doi: 10.1002/hed.21500.
50. Moore EJ, Olsen SM, Laborde RR, García JJ, Walsh FJ, Price DL, et al. Long-term functional and oncologic results of transoral robotic surgery for oropharyngeal squamous cell carcinoma. Mayo Clin Proc 2012;87:219-25. doi: 10.1016/j.mayocp.2011.10.007.
51. de Almeida JR, Li R, Magnuson JS, Smith RV, Moore E, Lawson G, et al. Oncologic Outcomes After Transoral Robotic Surgery: A Multi-institutional Study. JAMA Otolaryngol Head Neck Surg 2015;141:1043-51. doi: 10.1001/jamaoto.2015.1508.
52. de Almeida JR, Byrd JK, Wu R, Stucken CL, Duvvuri U, Goldstein DP, et al. A systematic review of transoral robotic surgery and radiotherapy for early oropharynx cancer: a systematic review.

Laryngoscope 2014;124:2096-102. doi: 10.1002/lary.24712.
53. Dziegielewski PT, Teknos TN, Durmus K, Old M, Agrawal A, Kakarala K, et al. Transoral robotic surgery for oropharyngeal cancer: long-term quality of life and functional outcomes. JAMA Otolaryngol Head Neck Surg 2013;139:1099-108. doi: 10.1001/jamaoto.2013.2747.
54. Nichols AC, Theurer J, Prisman E, Read N, Berthelet E, Tran E, et al. Radiotherapy versus transoral robotic surgery and neck dissection for oropharyngeal squamous cell carcinoma (ORATOR): an open-label, phase 2, randomised trial. Lancet Oncol 2019;20:1349-59. doi: 10.1016/S1470-2045(19)30410-3.
55. Rahbar R, Ferrari LR, Borer JG, Peters CA. Robotic surgery in the pediatric airway: application and safety. Arch Otolaryngol Head Neck Surg 2007;133:46-50. doi: 10.1001/archotol.133.1.46.
56. Leonardis RL, Duvvuri U, Mehta D. Transoral robotic-assisted lingual tonsillectomy in the pediatric population. JAMA Otolaryngol Head Neck Surg 2013;139:1032-6. doi: 10.1001/jamaoto.2013.4924.
57. Thottam PJ, Govil N, Duvvuri U, Mehta D. Transoral robotic surgery for sleep apnea in children: Is it effective? Int J Pediatr Otorhinolaryngol 2015;79:2234-7. doi: 10.1016/j.ijporl.2015.10.010.
58. Zdanski CJ, Austin GK, Walsh JM, Drake AF, Rose AS, Hackman TG, et al. Transoral robotic surgery for upper airway pathology in the pediatric population. Laryngoscope 2017;127:247-51. doi: 10.1002/lary.26101.
59. Arnold MA, Mortelliti AJ, Marzouk MF. Transoral resection of extensive pediatric supraglottic neurofibroma. Laryngoscope 2018;128:2525-8. doi: 10.1002/lary.27186.
60. Konuthula N, Parikh SR, Bly RA. Robotics in Pediatric Otolaryngology-Head and Neck Surgery and Advanced Surgical Planning. Otolaryngol Clin North Am 2020;53:1005-16. doi: 10.1016/j.otc.2020.07.011.
61. Duncan TD, Rashid Q, Speights F, Ejeh I. Transaxillary endoscopic thyroidectomy: an alternative to traditional open thyroidectomy. J Natl Med Assoc 2009;101:783-7. doi: 10.1016/s0027-9684(15)31006-3.
62. Yoon JH, Park CH, Chung WY. Gasless endoscopic thyroidectomy via an axillary approach: experience of 30 cases. Surg Laparosc Endosc Percutan Tech 2006;16:226-31. doi: 10.1097/00129689-200608000-00006.
63. Wang YC, Zhu JQ, Liu K, Xiong JJ, Xing TF, Han QQ, et al. Surgical Outcomes Comparison Between Endoscopic and Conventional Open Thyroidectomy for Benign Thyroid Nodules. J Craniofac Surg 2015;26:e714-8. doi: 10.1097/SCS.0000000000002223.
64. Jeong JJ, Kang SW, Yun JS, Sung TY, Lee SC, Lee YS, et al. Comparative study of endoscopic thyroidectomy versus conventional open thyroidectomy in papillary thyroid microcarcinoma (PTMC) patients. J Surg Oncol 2009;100:477-80. doi: 10.1002/jso.21367.
65. de Vries LH, Aykan D, Lodewijk L, Damen JAA, Borel Rinkes IHM, Vriens MR. Outcomes of Minimally Invasive Thyroid Surgery - A Systematic Review and Meta-Analysis. Front Endocrinol (Lausanne) 2021;12:719397. doi: 10.3389/fendo.2021.719397.
66. Kandil E, Attia AS, Hadedeya D, Shihabi A, Elnahla A. Robotic Thyroidectomy: Past, Future, and Current Perspectives. Otolaryngol Clin North Am 2020;53:1031-9. doi: 10.1016/j.otc.2020.09.001.
67. Lee J, Chung WY. Robotic Thyroidectomy and Neck Dissection: Past, Present, and Future. Cancer J 2013;19:151-61 doi: 10.1097/PPO.0b013e31828aab61.