Section of Otolaryngology, Head & Neck Surgery

Department of Surgery

1-1-2021

Training in temporal bone surgery: A review of current practices

Muhammad Wasif

Abdul Basit Shah Vardag

Ainulakbar Mughal

Syed Akbar Abbas

Shayan Khalid

See next page for additional authors

Authors
Muhammad Wasif, Abdul Basit Shah Vardag, Ainulakbar Mughal, Syed Akbar Abbas, Shayan Khalid, and Hamdan Ahmed Pasha

REVIEW ARTICLE

Training in temporal bone surgery: A review of current practices

Muhammad Wasif,[1] Abdul Basit Shah Vardag,[2] Ainulakbar Mughal,[3] Sayed Akbar Abbas,[4] Shayan Khalid Ghaloo,[5] Hamdan Ahmed Pasha[6]

Abstract

The temporal bone consists of complex anatomy, and the presence of various vital structures in close proximity makes the surgery of temporal bone highly challenging. Such a surgery requires years of training under the direct observation of trainers. Over the course of history, different training models have been adopted by experts to help train the young surgeons in this complex procedure. Cadaveric dissections of the temporal bone remains the gold standard in training of residents as the cadavers present the actual anatomical details which the surgeons encounter while operating on patients. However, due to scarcity of available cadavers, their one-time-only usage and high cost of involved in such trainings, experts have developed newer techniques of training, including three-dimensional reconstruction models and virtual reality simulators. Most of the literature on simulation in training of residents focuses on anatomical understanding and development of the surgical technique. There has been significant improvement in these techniques over time. With the addition of haptic feedback in the newer virtual simulation models, simulation has edged closer to basic modules of temporal bone dissection. the current review article was planned to have an overview of the different techniques in detail that are currently being in used.

Keywords: Temporal bone surgery, Visual stimulation, Cadaveric dissection.

Introduction

Otolaryngology is a technical and highly demanding speciality. It challenges surgical trainees to acquire proficiency.[1] Ear surgery challenges residents in their course of training because they have to acquire sense of three-dimensional (3D) orientation of vital structures housed in a small space. Delicate anatomical dissection of the temporal bone is essential for middle-ear surgery. A wide variety of media is available in the form of textbooks, atlases, surgical diagrams, models, digital media and surgical videos. Cadaveric dissections have been used very effectively over the decades to teach temporal bone surgery.[2]

The precise but complicated anatomy and surgical relationships may give the surgeon a hard time if proper practice with dissections has not been done. With all favourable conditions in place, complications are reported in 2-6% of patients undergoing otology surgeries. These complications include facial nerve, sigmoid sinus, labyrinthine and dural damage. The complication rate is higher in countries where surgical training is not readily available. This specially holds true for Third World countries.[2,3] Although there is a bulk of literature, both digital and traditional, present on temporal bone dissection, understanding the intricacies of temporal bone anatomy needs time and effort.

High-fidelity ancillary methods, like tissue preservation and cadaveric dissection, play a leading role in otology curriculum.[4] It is a very useful tool in attaining thorough understanding of ear anatomy and the surgical landmarks. It also has limitations, like risk of infection transmission, exposure to formalin fumes, high maintenance cost, and ethical considerations.[3,4] An estimated cost to run a temporal bone wet-lab is $300,000 a year.[4] To overcome these limitations, a plastic model was introduced for otology teachings. Due to homogeneity of the plastic model, it provided limited correlation with actual human bone structure.[2,3] Recent advances in virtual reality (VR) simulations have added a whole new dimension to teaching and training of temporal bone dissection.

Cadaveric bone dissection

The process of temporal bone dissection has long been employed for resident training and has withstood the test of time. With new technological advances, innumerable virtual resources are available for residents' assistance, but cadaveric bone dissections impart a particular insight regarding the intricacies and variations of human anatomy.[5] Whether there is over-pneumatisation of the mastoids or there is a low-lying dura, variation in otology anatomy, and difference in its morphology with changes in

[1-5]Department of Otolaryngology, Head and Neck Surgery, Aga Khan University, Karachi, [6]Department of Otolaryngology, Head and neck Surgery, Liaquat National Hospital, Karachi, Pakistan.

Correspondence: Ainulakbar Mughal. Email: ainul.akbar@aku.edu

age, can only be understood with repeated dissections and exposure to its structures and their mutual relationship. It has long been stated that the need of cadaveric bone dissections for training is an essential part of the training as text and observation can never replace real experience.[6]

Cadaveric dissections offer the operator a certain haptic feedback and engages the faculties in a way that is comparable to actual temporal bone dissection. The employment of all physical and mental faculties required in an operating room (OR) experience on a patient is of paramount significance for the trainee. This also addresses patient-safety concerns.[7] As stated earlier, with the advent of technological advances, there have been numerous other alternatives to cadaveric dissections. Literature has shown a staggering ambivalence when defining the effectiveness of the modalities. Okada et al. showed great inclination towards cadaveric dissection and claimed that no VR model is similar in terms of practical experience to the cadaveric dissection.[8]

With growing concerns regarding the mutilation of corpses and the ethical consideration of harvesting temporal bones, a lack of temporal bone availability has been reported in certain otolaryngology centres. Several potential disadvantages of the use of human cadaveric temporal bones exist. These include the requirement of a specialised lab for cadaveric dissection along with the need of an infection control system. Moreover, cadaveric dissection labs require trained manpower as well.[5] Due to limited use and availability issues, otolaryngology residents are in need of an alternative resource for ear surgery training. Also, there remains a minor but significant risk of the spread of disease through temporal bone dissection even today. This holds true for diseases like Prion disease.[6]

3D reconstructed models

Three-dimensional printing has revolutionised the manufacturing process for a while now and its utilisation for medical training is becoming popular. The 3D printed models are not only being used for training simulations, but also for the preparatory phase of challenging cases. There are multiple materials that can be utilised as raw material for the manufacturing of synthetic temporal bones, such as polylactic acid (PLA), acrylo-nitrile-butadiene-styrene (ANBS), hydroxyapatite etc.[9] Computed tomography (CT) images are utilised for variation in the ear anatomy. The utilisation of these models in the planning and preparation of surgical plan has been deemed safe for drilling, and the synthetic polymers used pose no additional disadvantage compared to the conventional cadaveric dissections.[10] Moreover, this resource is a worthy alternative to harvested bones as it also takes care of ethical issues and the raw material for synthesis is mostly accessible with ease.[11]

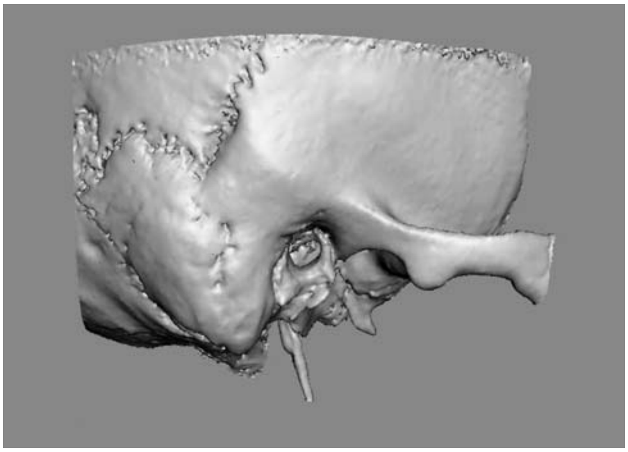

Figure-1: Three-dimensional reconstructed model of human temporal bone.

The variable paediatric mastoid morphology has a steep learning curve for otolaryngology. The increase in the mastoid surgery in paediatric age groups raises a concern for the need of training. Longfield et al. pointed out a novel use for the technology. Paediatric temporal bones for dissections are difficult to arrange, and, with the growing need of young patients requiring surgery, there is a growing need for an otologist to be well -versed with anatomical variations that exist. Therefore, CT-based renditions for paediatric patients can be utilised for the training of the residents.[12] As such, 3D printed models provide a non-infectious, anatomically accurate and cost-effective option for otology residents to learn the intricacies of mastoid surgery.[13]

Introduction of computer-based simulations

Simulation is considered an important adjunct along with cadaveric dissections in learning the art of temporal bone surgery.[1] The concept of using 3D volumetric reconstruction by using CT for exploration of human temporal bone surgically was first introduced by Harda et al. This method gained popularity quiet rapidly[2] even though specimen preparation and integration of photomicrographs was intensive and time-consuming. At the same time, the ability of 3D models in the demonstration of subtle morphologic relationships was very evident, accelerating the learning process.[2,14] A problem of real-time unavailability was faced initially, but soon isosurface approaches started being used for modelling structure to exploit hardware-accelerated techniques, as is the case with video games. For transpetrosal, retrosigmoid and middle-fossa approaches to the cerebropontine angle, stereo presentations of surface-based models acquired from the visible human project (VHP) have been presented.[14] Although the development of surface-based depiction of soft tissues and bone has been done, the system is able to provide only schematic evaluation of dissection and surgical technique. There have been multiple advancements in the field over time, including the development of Ray-casting techniques, to provide simulation of drilling and cutting. Augus put extensive efforts to present characteristics, such as haemorrhage, debris formation and fluid flow from cochlea.[2]

Current international techniques

Simulation has emerged as a cornerstone modality used for training of technical competency without actually compromising patient-care.[4] But it is still in its infancy in the realm of otolaryngology head and neck surgery. It is defined as an exercise that helps the participant to practice what is likely to occur in an actual patient setting under testing conditions.[4] Multiple temporal bone simulation systems are being used for training purposes.

At the Stanford University, CT scan data with hybrid volume and surface-based 3D rendering and a haptic interface is used. The haptic interface is networked which lets the trainee have the "feel" of the dissection.[4]

A team of European physicians and technologists run a project named 'The Integrated Environment for the Rehearsal and Planning of Surgical Intervention' which is being funded by the European Commission.[15] The simulator for temporal bone produced by this team uses stereotypically rendered 3D models of temporal bone. These models are derived from CT and haptic feedback device. The system has three highlights: availability of patient data for preoperative surgical planning; simulation; and training and education.[15]

A patient-specific high-resolution ear model is established at the University of Leipzig. A high-resolution micro magnetic resonance (MR) model is used and a replica of patient's ear is made using CT image. In this way, preoperative planning is carried out. The programme has an option of navigation control where the drill stops automatically when it approaches a pre-programmed risky structure during the actual surgery.[2]

Voxel-Man

The Voxel-Man TempoSurg simulator is an invention developed at the University Medical Centre, Hamburg-Eppendorf, Germany. It is a 3D reality simulator developed for teaching of temporal bone anatomy and surgical techniques.[3] Currently, it is the only commercial temporal bone simulator present. It is based on virtual 3D temporal bone models derived from high-resolution CT. It consists of a viewing station, a haptic feedback device, a foot control pedal and a central processing system.[4] The central processing system consists of an Intel Core Quad central processing unit (CPU) Q9650 processor which is operated by Linux operating system. It is the only otology simulator providing haptic feedback. Use of touch to communicate with the users is called haptic feedback, and it resembles a rumble which is felt in the controller during video games or vibration on the mobile screen. With the help of haptic feedback, tactile sensation is felt during drilling. This haptic feedback is believed to enhance the VR experience and learning process significantly.[16,17]

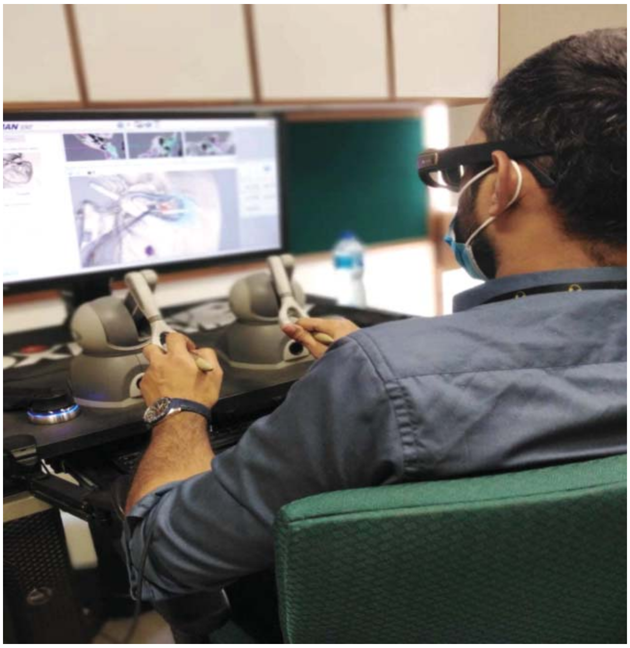

Figure-2: Resident operating on Voxel-Man visual stimulator.

The simulated procedure is very close to the reality with respect to a surgeon's view and anatomical orientation. The trainee can adjust the instruments and get a real view and feel close to the human temporal bone. Three orthogonal cross-sectional views are available for the trainee to see. During early training, organ at risk are painted, but later it disappears. Trainee can record the session and get an automatic feedback on technique. The software is designed to give hundred points when the complete removal of mastoid air cells is achieved. Points are deducted as penalty when a delicate structure is injured. The time of dissection is also calculated and point deduction is made when time exceeds and reward is given if procedure is done within time.[2,3] Prior procedural or technical knowledge is not measured objectively before the practice session. Improvement in simulation does not necessarily indicate improved operating capability.[18]

Voxel-Man is validated in multiple centres. In 2009, McDonald et al. conducted a study to validate the tool at their institute with 20 otologists. They completed self-evaluation of skill level followed by simulation. The video recordings of the otologists were assessed by two experts, and scores were given on the procedural steps and tissue handling. A significant positive correlation was observed between self-rating by participants and scores given by the experts.[19] At John Hopkins, postgraduates practised VR temporal bone simulation and their assessment was done. It was concluded that Voxel-Man simulator system improves surgical performance.[19] Combined approach of VR simulation and cadaveric dissection can provide the environment of surgical training, but VR plays an important role in shortening the learning curve for mastoid training.

In Pakistan, Aga Khan University Hospital (AKUH) is the first and till date the only institute providing training of otolaryngology residents on Voxel-Man visual stimulator. Residents are encouraged to use visual stimulator routinely before getting a hands-on experience on cadavers and then on the patients. However, no objective data has been published on the impact of use of Voxel-Man stimulator on surgical training. Studies focussing on anatomical understanding of the complex anatomy and subsequent development of surgical techniques are required from this centre to add to the existing knowledge.

Conclusion

Despite the recent advances in 3D models and VR simulators, cadaveric bone dissection still remains the gold standard for training in temporal bone surgery. However, recent advances in virtual simulation, especially the addition of haptic feedback mechanisms, have closed the gap between cadaveric and simulatory ear surgery learning experience. Due to limited availability of cadavers, regular sessions on virtual simulators should be incorporated in all otolaryngology residency programmes as mandatory. This will help to increase the knowledge of complex anatomy of this region and will shorten the learning curve for aspiring future otologists.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

References

1. Musbahi O, Aydin A, Al Omran Y, Skilbeck CJ, Ahmed K. Current Status of Simulation in Otolaryngology: A Systematic Review. J Surg Educ 2017;74:203-15. doi: 10.1016/j.jsurg.2016.09.007.
2. Wiet GJ, Stredney D, Wan D. Training and simulation in otolaryngology. Otolaryngol Clin North Am 2011;44:1333-50. doi: 10.1016/j.otc.2011.08.009.
3. Linke R, Leichtle A, Sheikh F, Schmidt C, Frenzel H, Graefe H, et al. Assessment of skills using a virtual reality temporal bone surgery simulator. Acta Otorhinolaryngol Ital 2013;33:273-81.
4. Francis HW, Malik MU, Diaz Voss Varela DA, Barffour MA, Chien WW, Carey JP, et al. Technical skills improve after practice on virtual-reality temporal bone simulator. Laryngoscope 2012;122:1385-91. doi: 10.1002/lary.22378.
5. Kashikar TS, Kerwin TF, Moberly AC, Wiet GJ. A review of simulation applications in temporal bone surgery. Laryngoscope Investig Otolaryngol 2019;4:420-24. doi: 10.1002/lio2.277.
6. Naik SM, Naik MS, Bains NK. Cadaveric temporal bone dissection: is it obsolete today? Int Arch Otorhinolaryngol 2014;18:63-7. doi: 10.10 55/s-0033-1351681.
7. Adoga SA, Maan ND, Umar BT, UGWU BT, Nwaorgu GO. Cadaver Temporal BoneDissection - The JOS Experience. Webmedcentral 2011;2:WMC001767. doi: 10.9754/journal.wmc.2011.001767
8. Okada DM, de Sousa AM, Huertas Rde A, Suzuki FA. Surgical simulator for temporal bone dissection training. Braz J Otorhinolaryngol 2010;76:575-8.
9. Prasannan A, Shrivastava A, Nandhan R, Kameswaran M. 3D Printed Temporal Bones - Current Status and Future Directions. Otolaryngol 2020;10:e1000399. doi: 10.4172211-119-1000399.
10. Mowry SE, Jammal H, Myer C, Solares CA, Weinberger P. A Novel Temporal Bone Simulation Model Using 3D Printing Techniques. Otol Neurotol 2015;36:1562-5. doi: 10.1097/MAO.0000000000000848.
11. Hsieh TY, Cervenka B, Dedhia R, Strong EB, Steele T. Assessment of a Patient-Specific, 3-Dimensionally Printed Endoscopic Sinus and Skull Base Surgical Model. JAMA Otolaryngol Head Neck Surg 2018;144:574-9. doi: 10.1001/jamaoto.2018.0473.
12. Longfield EA, Brickman TM, Jeyakumar A. 3D Printed Pediatric Temporal Bone: A Novel Training Model. Otol Neurotol 2015;36:793-5. doi: 10.1097/MAO.0000000000000750.
13. Freiser ME, Ghodadra A, Hart L, Griffith C, Jabbour N. Safety of Drilling 3-Dimensional-Printed Temporal Bones. JAMA Otolaryngol Head Neck Surg 2018;144:797-801. doi: 10.1001/jamaoto.2018.1516.
14. Volsky PG, Hughley BB, Peirce SM, Kesser BW. Construct validity of a simulator for myringotomy with ventilation tube insertion. Otolaryngol Head Neck Surg 2009;141:603-08.e1. doi: 10.1016/j.otohns.2009.07.015.
15. John NW, Thacker N, Pokric M, Jackson A, Zanetti G, Gobbetti E, et al. An integrated simulator for surgery of the petrous bone. Stud Health Technol Inform 2001;81:218-24.
16. Al-Sada M, Jiang K, Ranade S, Kalkattawi M, Nakajima T. HapticSnakes: multi-haptic feedback wearable robots for immersive virtual reality. Virtual Reality 2020;24:191-209. Doi: 10.1007/s10055-019-00404-x
17. Leung R, Samy RN, Leach JL, Murugappan S, Stredney D, Wiet G. Radiographic anatomy of the infracochlear approach to the petrous apex for computer-assisted surgery. Otol Neurotol 2010;31:419-23. doi: 10.1097/MAO.0b013e3181c99524.
18. Arora A, Hall A, Kotecha J, Burgess C, Khemani S, Darzi A, et al. Virtual reality simulation training in temporal bone surgery. Clin Otolaryngol 2015;40:153-9. doi: 10.1111/coa.12352.
19. McDonald S, Alderson D, Powles J. Assessment of ENT registrars using a virtual reality mastoid surgery simulator. J Laryngol Otol 2009;123:e14.