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Review

Cutting Edge Technologies in Otology Field

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The development of science and technology leads to the development of medicine. With the development of information technologies, artificial intelligence and wearable devices, the future medical environment will change greatly. Various sciences and technology are applied in medical practice. The development of optical technology has enabled less invasive ear surgery with an endoscope, and virtual reality technology can be used for surgical training and education. Otology research tries to adapt artificial intelligence, which have rapidly developed a remarkable topic. Herein, cutting edge technologies and their appliance in the otology field were reviewed.

Key words: otology; endoscope; artificial intelligence

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INTRODUCTION

With the recent breakthrough of science and technology, revolutionary changes are taking place in the medical environment. There has been much progress in the field of otology. Recently, endoscopic ear surgery technique has expanded the application and scope of the technique [1,2]. The development of information technology (IT) also affects medical education systems. Surgical training and medical education adapt virtual reality simulation to increase education outcome over the traditional teaching methods [3]. Recently, hearing aids have adapted the emerging technology of "internet of things" to create an environment where the hearing loss patients can hear more [4]. In addition, artificial intelligence technology is gradually applied in the otology field. Machine learning, one of the artificial intelligence techniques, could help to explore the unknown areas of otology. The authors try to introduce the cutting-edge techniques used in the otology field and discuss about the future direction of medical science.

ENDOSCOPIC EAR SURGERY

Endoscopic surgery has developed dramatically over the past decades in the area of otolaryngology. Endoscopic sinus surgery has become the first-choice treatment modality in the treatment of nasal cavity diseases and it is expanding its coverage in the areas including skull base, head & neck region and temporal bone. Although endoscopic middle ear examination was firstly introduced in the 1960s, there has been much controversy about the use of endoscopy in the otology practice [1,2].

Most ear surgeries are done under a microscope, which provides excellent views of the surgical field with binocular

Fig. 1. Endoscopic view through transcanal endoscopic approach; A case of congenital ossicular anomaly, right ear

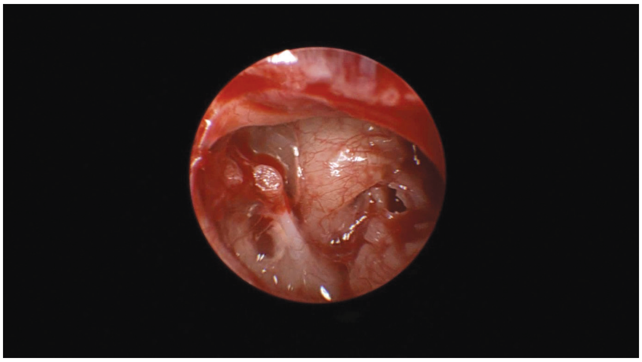
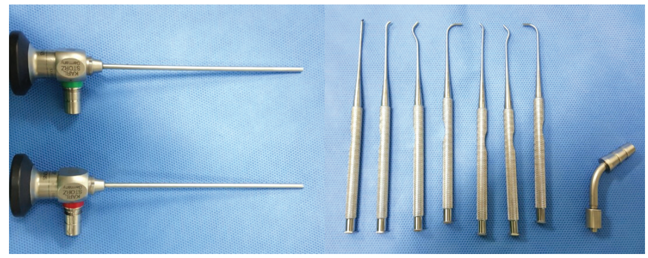


Fig. 2. Surgical endoscopes and suction incorporated micro-instruments for endoscopic ear surgery



vision. The ability to perform two-handed surgery is a great advantage when using a microscope. And most ear surgeons are trained under microscopic views and they are accustomed to perform a surgical procedure under the microscope. However, the microscope has the disadvantage of limited visualization of deeper anatomic sites where, an adequate amount of light does not reach. Thus, microscope based ear surgery needs skin incision, soft tissue dissection and drilling of the temporal bone to adequately visualize the targeted pathology.

In contrast, endoscopes can provide better images of hidden structures with wide angle view and diverse directions of the endoscope lens (Figure 1). The improved image of endoscope facilitates transcanal ear surgery without classical skin incisions.

Endoscopic ear surgery categorized into Transcanal Endoscopic Ear Surgery (TEES) and endoscopic assisted ear surgery, according to whether the operation was performed totally under endoscopy or not. Initially, endoscopic ear surgery was mainly used to access a blind spot which cannot be observed with a microscope. Thus, most of the endoscopic ear surgeries were applied as a diagnostic tool to confirm remnant or recurrence of cholesteatoma to assist in the limited microscopic view. Nowadays, TEES without an operative microscope extends its indication of chronic otitis media to retrocochlear lesions of vestibular schwannoma.

Transcanal operative endoscopy provides a wider view of the surgical field (around the corner) regardless of narrowing of the external auditory canal. Especially in cholesteatoma removal, transcanal endoscopic access can provide better understanding of anatomy, function and disease. Under endoscopic view, surgeons can intuitively trace the path of cholesteatoma extension and wider endoscopic view makes it easier to identify hypotympanic air cells and sinus tympani, where the microscope offers minimal to no accessibility despite mastoidectomy. However, there are several issues about the feasibility of TEES. The biggest disadvantage of endoscopic ear surgery is that the image through the monocular telescopic lens lacks depth perception. Impaired depth perception during surgery might cause eye-hand coordination problems. In addition, because the surgeon must hold the telescope during surgery, one-handed surgical technique is inevitable. Thus, bleeding control might be difficult compared to microscopic ear surgery. Likewise, surgical procedures under endoscopy are more likely to have a gradual learning curve [2]. In addition, there are two major issues of safety concerns in TEES. With Xenon light sources, the tip of the telescope can heat up quickly causing thermal damage to the inner ear structure.[5,6]. Frequent saline irrigation could prevent thermal injury during surgery. The other major safety concern was direct inner ear or ossicular damage caused by unintended movement of the telescope or patients.

TEES requires special endoscopic equipment and micro-instruments (Figure 2). The advancement of surgical instruments contributes to the increasing application of endoscopy in ear surgery. High definition digital cameras attached to the endoscope produce excellent quality of image.

Fig. 3. Operation room setup for endoscopic ear surgery

Table 1. Indications of Endoscopic ear surgery

Indications
• Myringoplasty / Tympanoplasty
• Cholesteatoma removal (attic cholesteatoma, congenital cholesteatoma)
• Exploration tympanotomy for perilymph fistula or ossicular anomaly
• Otosclerosis
• Cochlear implantation
• Middle ear tumor (paraganglioma, carotid tumor)
• Vestibular schwannoma

Special instruments for TEES are designed for one-hand surgery. To ensue efficient surgical performance with the angled 30° or 45° endoscope, instruments should be fashioned to have single / double bent shaft or significantly curved shaft with various angle tips. Those instruments facilitate the management of disease in a hidden area of the middle ear without drilling or curettage of temporal bone. For the preparation of TEES, the surgical microscope must be prepared even though exclusively endoscopic ear surgery is intended (Figure 3).

An increasing number of articles have been published demonstrating indication and outcome of endoscopic ear surgery. Primary indications for endoscopic ear surgery include cholesteatoma removal and myringoplasty [7,8]. And application of endoscopic ear surgery gradually expands to stapes surgery, middle ear tumors or retrocochlear lesions [9,10] (Table 1).

Feasibility of endoscopic ear surgery has been widely investigated. Endoscopic assisted middle ear surgery or observational endoscopic ear surgery might benefit from the localization of residual or recurrent cholesteatoma in hidden areas of the sinus tympani and facial recess. Recently, feasibility of TEES as a microscope replacement has been proposed by demonstrating the safety of TEES without significant complications in both adult and pediatric patients [11]. In addition, TEES does not have the morbidity associated with a post auricular incision and TEES has a short recovery time [2]. It is expected that endoscopic ear surgery will be applied to various otologic disease in the future, because surgical instruments and techniques are continuously being developed and the number of otologists who are gradually familiar with endoscopic surgery is increasing.

VIRTUAL REALITY

Virtual reality refers to computer technologies which presents an artificial environment with specialized display by enabling the users to interact with created space and objects [12]. In the current residency training program, resident doctors learn surgical skill through apprenticeship education by observing senior doctors and practicing under supervision. For the safety of the patients, it is necessary to practice, beginners prior to the surgery. Many training courses have been developed to improve surgical skills. Especially in the otology field, a cadaveric temporal bone dissection course is an essential step in preparing for middle ear or mastoid surgery. However, cadaveric temporal bone is hard to obtain and very expensive. And temporal bone cannot be reused after drilling [13]. In addition, diseases might be transmitted through cadaveric tissue or body fluids during the dissection course. To overcome these limitations, virtual reality technology has been adapted in ear surgery such as the VOXEL-MAN Tempo Surgery Simulator, Mediseus Surgical Simulator, Virtual Surgical Training System for the middle ear, etc (Figure 4).

Fig. 4. Virtual reality temporal bone dissection system; Voxel-Man Tempo surgery simulator®, http://voxel-man.com

Several studies confirmed the efficacy of the virtual reality temporal bone simulator by showing improvement of objective parameters for technical skills. And the virtual reality temporal bone dissection training is more effective than the traditional text book based training and as effective as cadaveric temporal bones [14].

Besides the temporal bone dissection simulators, the middle ear surgery simulator for myringotomy, virtual surgery for cochlear implantation and virtual reality based treatment education program for benign paroxysmal positional vertigo has been developed [3]. The recent advance of wearable devices including head mounted display technology will lead to breakthrough of medical / surgery educational system with virtual reality.

ARTIFICIAL INTELLIGENCE (AI)

Intelligence is the computational part of the ability to achieve goals and artificial intelligence refers to computer-implemented intelligence. Artificial intelligence (AI) technology is beginning to be applied to Medicine and building of AI programs which perform diagnosis and determine a treatment plan is the primary concern of medical AI appliance [15]. The medical AI system can be used as 1) generating alerts and reminders 2) diagnostic assistance, 3) therapy critiquing and planning 4) image recognition and interpretation [16]. When an AI system can receive and analyze medical information from an electronic medical record system, the AI system can review the current treatment plan and alert doctors when they are about to undergo treatment which is contraindicated or there is an error or defect in the plan. When treating complicated cases, the AI system might be helpful for diagnosis and decide a treatment plan. Now, AI systems can also automatically interpret various types of medical imaging including plain x-rays, EKG, CT, MRI, audiograms, etc.

The AI system has created a new era in medical science research. In particular, the AI system can learn by itself in the so called "machine learning or deep learning", thus the AI system learns through discovering new phenomena and new medical knowledge, by analyzing large amounts of medical data.

In the otology field, attempts are being made to develop a novel algorithm to diagnose or classify various otoneurological diseases such as dizziness and tinnitus [17,18]. A machine learning system (Galactica) has been developed for discovering a new diagnostic rule from a patient database and the diagnostic accuracy of developed rules were over 80% [17,19]. One of the machines learning model, the support vector machine, had successfully recognized the differences between normal subjects and dizziness patients by assessing a sensor based vestibular measuring system [20]. Recently, a technique for objectively confirming subjective symptoms of tinnitus using the machine learning system has been developed by assessing the resting-state cortical oscillation pattern on an EEG [21].

INTERNET TECHNOLOGY

With the application of internet devices and wireless connectivity, hearing rehabilitation technology has been greatly developed. The connection of a hearing aid and a smart phone can facilitate the hearing rehabilitation [22]. Bluetooth-implemented hearing aids has improved the subjective and objective speech recognition in both quiet and noisy environments during the use of smart phone, TV or other electronic audio devices [23]. In addition, the concept of the "Internet of Things" has been adapted to hearing aid technology, a hearing aid can communicate directly with a full range of connected devices including smoke sensors, baby alarms and door bells. These attempts make lives of hearing impaired patients more safe and comfortable.

CONCLUSIONS

With the development of science, medicine will continue to evolve. In this article, the authors briefly review the latest technologies adapted in the otoneurology field. By actively using new technologies, otologists will be able to provide medical services more effectively.

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