Non-microscopic Middle Ear Cholesteatoma Surgery: A Case Report of a Novel Head-Up Approach

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Clinical Capsule Report

Objective: To assess the feasibility of a postauricular transcortical mastoidectomy utilizing an exoscope, which offers 3D stereoscopic visualization.

Study Design: Clinical capsule report.

Patients: Two consecutive patients with cholesteatoma involvement in the mastoid cavity were included in the study.

Intervention: After transcanal endoscopic surgery, postauricular mastoidectomy utilizing a surgical 3D exoscope was performed. Then, the cholesteatoma in the mastoid cavity was removed through the mastoidectomy opening with endoscopes.

Results: The postauricular transcortical mastoidectomy utilizing a 3D exoscope was not only feasible, but importantly, the exoscope took little time to switch to and resulted in a smooth workflow. There was no cholesteatoma recurrence at 9 months.

Conclusion: During endoscope-based surgery, in patients with cholesteatoma mastoid involvement, we can continue to perform the surgical procedure in a heads-up position utilizing a surgical 3D exoscope. The combination of transcanal endoscopic ear surgery and the postauricular transcortical mastoidectomy utilizing a surgical 3D exoscope is a very novel treatment strategy for cholesteatoma, and it gives us a comfortable and consistent working environment in endoscope-based ear surgery. Key Words: Cholesteatoma—Exoscope—Non-microscopic surgery and head-up surgery—Transcanal endoscopic ear surgery—Transcortical mastoidectomy.

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INTRODUCTION

Traditional microscopic ear surgery is performed while watching the images through the microscopic eyepieces, namely in a heads-down position. This heads-down surgery increases the risk of musculoskeletal fatigue and injuries of the neck and back because surgeons are bound to the eyepieces during the surgery (1–4). Heads-up surgery, which is performed watching a monitor, is considered to be ergonomically better (1–5), because surgeons can work in a physiologically comfortable position (6). In detail, Yu et al. (1) reported that a biomechanical analysis found that the differences in angles can result in loads on the neck joint that are twice as high in the microscope than with the heads-up displays. This means that the angle of the neck joint during heads-up surgery is close to the natural angle of the neck joint (1). Capone et al. (4) reported that musculoskeletal symptoms were observed in 81.5% of surveyed plastic surgeons. Microscope usage of 3 h or more per week was associated with cervical and thoracic pain of those plastic surgeons (4).

Heads-up surgery also has several other advantages. Eckardt et al. (7) previously reported on comparison data between 3D heads-up surgery and microscopic surgery: 3D heads-up surgeries were performed utilizing a LeicaM822 surgical microscope (Leica Microsystems), and the TrueVision Visualization 3D System (TrueVision Visualization System). Microscopic surgeries were performed utilizing the surgical microscope. They compared the working techniques at 3 times magnification under microscopes with that of 3D heads-up surgery on 20 volunteers who lacked experience with a microscope. They found that significantly fewer mistakes were made with the heads-up method than with the microscope method. The 2 methods were also judged to be similar
regarding speed and ease of microscopic manipulations and sharpness of image (7). The other advantages of heads-up surgery include that the surgeons can perform while watching digitally modified images, and we can share the same 3D surgical views on a monitor with all people in the operation room (7).

Transcanal endoscopic ear surgery (TEES), which is a heads-up surgery, is considered to be a less invasive surgical procedure because we can treat ear diseases with small skin incisions and less dissection of the bone and mucosal tissue. Indeed, during cholesteatoma surgery, if the cholesteatoma is confined to the tympanic cavity, we can complete the surgery utilizing only TEES. When the middle ear disease involves the mastoid cavity, there are currently 2 surgical options to treat the diseased tissue in the mastoid cavity: transcanal mastoidectomy via the external auditory canal and postauricular transcortical mastoidectomy (PTM). We can achieve transcanal mastoidectomy with TEES, but there are several drawbacks. One is the requirement to remove a large portion of the posterior bony wall to reach the mastoid cavity. Subsequent reconstruction of the larger bony defect of the posterior wall is more difficult and time-consuming. The transcanal mastoidectomy via the external auditory canal is, thus, more invasive surgery than PTM mastoidectomy. In contrast, if we utilize PTM, which has been performed under surgical microscopes, we can preserve the bony external canal. When considering endoscope-based ear surgery, there are several significant drawbacks with microscopic PTM. One is that we have to change the way in which surgeons interact with the surgical fields during the transition between endoscope and surgical microscope; endoscopic surgery is heads-up surgery and microscopic surgery is heads-down surgery. Additionally, the surgical microscope occupies a large space and is heavy. Transition between endoscope and surgical microscope and setting up are both time-consuming. Considering the above, an ideal surgical modality for treating the mastoid cavity for endoscope-based ear surgery is heads-up PTM.

Recently, it has been reported that a new surgical visualization system called the 3D exoscope system can be a viable alternative to surgical microscopes in both ophthalmology (8,9) and neurosurgery (6,10). The 3D exoscope is meant to be exterior to the body surface like a microscope (vs. an endoscope which is interior to the body cavity) and to have dual image sensors for 3D visualization. The images obtained from the 3D exoscope are visualized on a monitor, and a surgeon observes 3D stereoscopic images wearing 3D glasses. A 3D exoscope enables us to perform the surgery in a heads-up position. Additionally, it gives us a similar surgical environment to a microscope: both exoscope and microscope are exterior to the body surface, and surgical images of both are 3D. Consequently, if we utilize a 3D exoscope for PTM in middle-ear diseases with mastoid involvement, we may be able to complete treating those diseases surgically in a heads-up position.

Herein, we report on our experience of PTM utilizing the surgical 3D exoscope. To the best of our knowledge, this is a novel report describing ear surgery utilizing a 3D exoscope.

MATERIALS AND METHODS

This is a case review of the first 2 sequential patients on whom R.M. performed heads-up surgery utilizing both 4 mm diameter, 18 cm length, 0° and 30° rigid endoscopes (HOP-KINS® II Telescopes, KARL STORZ, Tuttlingen, Germany) and a surgical 3D exoscope system (VITOM® 3D system,
KARL STORZ) (Figs. 1 and 2). The surgical 3D exoscope system consists of a 3D exoscope (Vitom® 3D, KARL STORZ), a holding arm (Versacrane™, KARL STORZ), a separate controller (Image1 Pilot, KARL STORZ), a tower containing a light source (Power Led 300, KARL STORZ), a camera controller (Image1 S Connect, KARL STORZ), a link module (Image1 S D3, KARL STORZ) and a 32-in full high definition (full HD) passive 3D monitor (KARL STORZ). In this system, surgical images are obtained via the two 4K (3840 × 2160 pixels) Complementary metal-oxide-semiconductor image sensors of the camera head, which is located outside the body surface and over the surgical field. These images are displayed on the full HD (1920 × 1080 pixels) 3D monitor screen. 3D exoscope surgery is performed while watching the images on the 3D monitor. The surgeon is wearing 3D glasses and the surgery is performed while watching the images on the 3D monitor.

These 2 cases are pars flaccida-type middle-ear cholesteatoma involving the mastoid cavity (Table 1).

In patient 1, we removed cholesteatoma tissue via TEES. After the endaural skin incision, the tympanomeatal flap was elevated, and the retracted tympanic membrane was cut at the entrance of the retracted cholesteatoma epithelium to the epi-tympanum. Then, the scutum bone was dissected utilizing curettes, chisels, and an otologic drill (Visao™ High-Speed Otologic Drill, Medtronic Xomed Inc. Jacksonville, USA). This was done to visualize the outer border of the cholesteatoma of the protympanum and the epitympanum, but not of the aditus ad antrum, the antrum, or the mastoid cavity. Then, the cholesteatoma epithelium which invaded into the protympanum and the epitympanum was removed via TEES. After the TEES removal, we performed a smaller PTM under 3D exoscope.

TABLE 1. Patient characteristics

| Patient Number | Age (yr) | Sex | Cholesteatoma Extension |
|----------------|---------|-----|------------------------|
| 1              | 50      | Male| T, P, A, M              |
| 2              | 64      | Male| T, P, A, M with defects of the skull base bone of the middle fossa and bony outer wall of the lateral semicircular canal |

A indicates Attic; M, mastoid cavity; T, tympanic cavity; P, protympanum.
during which we intentionally removed the cortical mastoid bone less than is usual with microscopic PTM (Figs. 2C and 3A and B). During the smaller PTM, we exposed the antrum, but not the aditus ad antrum, the epitympanum, or the major part of the mastoid air cells. The only mastoid air cells that were removed were lateral to the antrum. The debris of the cholesteatoma in the mastoid cavity was debulked under the surgical 3D exoscope. Then, under endoscope, via the opening of the PTM, the remaining cholesteatoma tissue in the mastoid cavity was cut around the anterior part of the antrum, and then, it was removed. Subsequently, the remaining cholesteatoma tissue between the epitympanum and the antrum was pushed anteriorly to the epitympanum under 30° endoscope. Subsequently, the cholesteatoma tissue was removed and the tensor tympani fold was opened via TEES.

In patient 2, the cholesteatoma destroyed the skull base bone of the middle fossa and bony outer wall of the lateral semicircular canal (LSC) (Fig. 3A). In this patient, initially the cholesteatoma epithelium, which invaded into the tympanum, protympanum, and the epitympanum, was similarly removed via TEES. Then, PTM was similarly performed via a retroauricular skin incision, and the cholesteatoma debris was debulked, utilizing the surgical 3D exoscope system (Fig. 3B). The cholesteatoma tissue at the mastoid cavity, excluding the area of the LSC, was then removed under endoscope via the mastoidectomy. The cholesteatoma tissue, which adhered to the endosteum of the LSC, was removed endoscopically utilizing Yamauchi et al.’s (10) underwater technique; water was delivered via a lens-cleaning system (Endoscrub® lens-cleaning system, Medtronic Xomed Inc.) (Fig. 4B). The remaining cholesteatoma tissue between the antrum and the epitympanum was pushed forward to the epitympanum under 30° endoscope, and then, it was removed via TEES. The tensor tympani fold was opened also via TEES.

RESULTS

All cholesteatoma tissues in both patients were successfully removed either through the external auditory canal or by a smaller PTM which was performed utilizing the surgical 3D exoscope system. The transition between endoscope and the surgical 3D exoscope system was very quick; it takes approximately 6 s for the transition from endoscopic surgery to the surgical 3D exoscope surgery (see Video, Supplemental Digital Content 1, http://links.lww.com/MAO/A786, which demonstrates this quick transition). There were no harmful side-effects, including
no deterioration of their bone conduction levels postoperatively. We could not find any residual cholesteatoma utilizing TEES during their second-stage surgery which was performed 9 months postoperatively.

**DISCUSSION**

We showed the feasibility of PTM via the surgical 3D exoscope system. We also showed that the combination of TEES and PTM utilizing the surgical 3D exoscope gives us an optimal surgical environment. The most significant advantage of this combination is that the transition between the surgical 3D exoscope system and endoscope was seamless; it was quick and smooth unlike the transition between microscope and endoscope. Two reasons for this seamless transition follow. First, the surgical 3D exoscope camera and its holding arm are lighter and more compact than surgical microscopes. Second, both surgeries utilizing the surgical 3D exoscope system and endoscopes are performed in a heads-up position, allowing us to share the same monitor during the whole surgery. In addition, when considering the heads-up surgery, it is considered to be ergonomically better (1–5); moreover, the combination of TEES and PTM utilizing the surgical 3D exoscope gives us a comfortable surgical environment.

Through our experience with the surgical 3D exoscope system, we found some drawbacks. One is that refocusing the surgical 3D exoscope system, which is performed using a separate controller (Image1 Pilot, KARL STORZ), is uncomfortable; an autofocus system or refocusing using a foot controller might help. Because the surgical 3D exoscope system has a digital zooming system, the higher magnification utilizing the system caused a deterioration of the surgical images, although the image quality of the exoscope was equal to the microscopic view at lower magnification. This needs to be ameliorated by incorporating some type of an optical zooming system. There are several other surgical 3D exoscope systems which are currently commercially available. Some of the surgical 3D exoscope systems have an optical zooming system, though, those exoscopes are bigger and more expensive, and those do not have an autofocus system. We expect that a compact surgical 3D exoscope system for endoscope-based ear surgery, which has higher image quality at higher magnification and an autofocus system, will be developed in the near future.

The significant difference between exoscopic surgical manipulation and microscopic manipulation is the relationship between visual line and surgical site: in microscopic manipulation, the visual line is directed at the surgical site, whereas in exoscopic manipulation, the visual line is directed at the monitor in front of the surgeon, not at the surgical site. The relationship between visual line and surgical site in exoscopic manipulation is the same as in normal endoscopic surgery. But exoscopic surgical manipulations are performed using both hands, whereas endoscopic surgical manipulation is performed using a single hand. Because of the difference of single hand and both hands, we felt uncomfortable when we perform exoscopic surgery for the first time, but we can easily get accustomed to this difference. Through our experience of exoscopic PTM in 2 cases, there is no doubt that we think that we can perform surgical procedures in which we manipulate the lateral part of the temporal bone, such as with a PTM, without any difficulty. Furthermore, we think we can also utilize it for other surgical procedures such as complete mastoidectomy, canal wall down tympanoplasty, and preparation for ossicular prostheses. Through future clarification of the feasibility to perform the surgical procedures at deeper sites using exoscope, we might be able to utilize it for facial nerve decompression and cochlear implant surgery. 3D surgical exoscopes with higher quality images at higher magnification may be a realistic alternative to surgical microscopes in the near future.

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