Development of a Temporal Bone Model for Transcanal Endoscopic Ear Surgery

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Abstract

Transcanal endoscopic ear surgery (TEES) is being increasingly used in chronic ear disease for cholesteatoma removal and middle ear reconstruction, reducing the need for a postauricular incision and mastoidectomy. However, TEES is a challenging technique even for the most experienced otologist, requiring one-handed dissection using angled instrumentation. We have therefore developed a high-fidelity dissection model incorporating key aspects of TEES and cholesteatoma removal to facilitate the acquisition of these skills. Artificial cholesteatoma was implanted into middle ear spaces of a human temporal bone via a facial recess approach. A pilot study was conducted whereby surgeons endoscopically elevated a tympanomeatal flap with artificial bleeding and removed artificial cholesteatoma with angled instrumentation. Surgeons were uniformly satisfied with the experience and felt it would translate into improved performance in the operating room. This study suggests that the TEES dissection model could become an integral tool in the training of emerging TEES techniques.

Keywords

endoscopic ear surgery, transcanal, dissection model, cholesteatoma

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Transcanal endoscopic ear surgery (TEES) is a relatively new technique that is being used predominately for chronic ear surgery and ossicular chain reconstruction. Endoscopic visualization enables a surgeon to look around corners to identify and dissect lesions, making TEES well suited for removal of cholesteatoma.¹,² However, improved exposure comes at the expense of difficult one-handed dissection under monocular vision, which could not only decrease adoption of the technique among the otolaryngology community but also potentially increase the risk of adverse patient outcomes for inexperienced operators. Indeed, the introduction of new surgical technologies has been shown to negatively affect complication rates, such as with the increase in complications after the introduction of laparoscopic techniques to gallbladder surgery.³ The introduction of endoscopic techniques to sinus surgery was also associated with significantly elevated complication rates,⁴ but these were decreased with improved protocols and dedicated practice.⁵

Surgical models and simulators provide a way to learn and practice technical skills in a safe environment and can improve performance in real operating scenarios.⁶–⁸ We have therefore designed a dissection model to facilitate the acquisition of the most challenging aspects of TEES, which include one-handed dissection with limited depth perception, the use of angled endoscopes and instruments, and controlling bleeding while elevating tympanomeatal flaps. The acquisition of these key TEES techniques may assist in reducing the procedural learning curve and ultimately improve patient outcomes.

Materials and Methods

Design of TEES Dissection Model

The main component of the model is a fixed cadaveric temporal bone secured in a standard temporal bone holder with lead weighting. To replicate cholesteatoma, multiple organic and synthetic materials were assessed to determine their similarity to cholesteatoma. Ultimately, fresh chicken skin was selected due to its texture, epithelial nature, and ability to replicate real tissue dissection. A mastoidectomy and facial recess approach were drilled to provide access for cholesteatoma placement. The chicken skin was sectioned into small pieces with a scalpel, and each piece was coated with cyanoacrylate (Super Glue) on one side and then fixed in the epitympanum, oval window niche, sinus tympani, and mastoid antrum using a Rosen needle under microscopic visualization (Figure 1). Five small pieces were placed in

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the middle ear for each procedure. The adhesive was stable to freeze-thaw cycles, allowing prepared temporal bones to be stored at –20°C and thawed prior to use.

Bleeding during flap elevation was replicated by drilling a hole in the posterior ear canal and passing a polyethylene tube (Intramedic 1.6-mm outer diameter; BD Diagnostic Systems, Sparks, Maryland) into the canal. Artificial blood was made by diluting red paint (ArtMinds Washable Paint; Michaels Stores, Irving, Texas) 2:1 with water. This mixture was dripped into the field during flap elevation via manual injection into the tubing using a 1-cc syringe and 18-gauge needle. The flow of artificial blood was optimized visually by an assistant to pool along the tympanomeatal flap incision in a realistic manner (Supplemental Video available at otojournal.org/supplemental).

**Testing of TEES Dissection Model**

A pilot study was approved by the Massachusetts Eye and Ear Infirmary Institutional Review Board. Each participant raised a tympanomeatal flap with bleeding. After participants elevated the flap to the annulus, the bleeding was turned off and the middle ear was entered. Participants then elevated the tympanic membrane off of the malleus, performed an atticotomy, and removed the malleus and incus. Cholesteatoma was then resected using 0-, 30-, and 45-degree endoscopes (4-mm diameter, 18-cm length; Karl Storz, Tuttlingen, Germany). Standard instruments were used, as well as angled 5 and 20 suctions and a Crabtree dissector. The procedure was considered complete once the middle ear was free of cholesteatoma and the tympanomeatal flap was replaced.

All participants completed the procedure in approximately 45 minutes. Participants completed an anonymous postprocedure survey using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The purpose of this study was the determination of face validity, and therefore no additional performance assessments were employed.

**Results**

Six surgeons with training levels ranging from third-year otolaryngology resident to attending otologist/neurotologist participated in the study. Prior TEES experience was reported as <10 cases in 33.3% of participants, 10 to 50 cases in 50%, and >50 cases in 16.7%. An equal number of left and right ear specimens were used, and all surgeons used their dominant hand for dissection.

Surgeons completed tasks designed to teach the key aspects of TEES (Figure 2 and Supplemental Video available at otojournal.org/supplemental). There was agreement that cholesteatoma dissection was realistic and that bleeding during flap elevation increased the realism of the procedure, with median responses of 4.5 to 5 (Table 1). Overall satisfaction with the experience was high, and 100% of participants strongly agreed that training on the model would improve real operating performance.

**Discussion**

We have designed a high-fidelity temporal bone model to teach key endoscopic dissection skills. The use of animal skin as cholesteatoma is novel and provides a realistic dissection experience. The use of artificial blood during flap elevation increases the difficulty of the procedure. More than half of participants in the study reported performing...
>10 real endoscopic ear cases, and their testaments to the high fidelity of the experience confirm the face validity of the model.

TEES approaches can also be used for other procedures, including tympanoplasty and stapedectomy. With TEES gaining popularity in the otolaryngology community, we aim to provide a readily reproducible model to teach these unique skills. Future experiments include validation studies for additional TEES techniques, as well as investigation of ideal endoscopic surgical approaches and development of expert techniques such as nondominant hand dissection.

**Conclusion**

We have designed a temporal bone model that captures the key technical components of TEES. This model will provide a versatile platform for ear surgeons of all skill levels to learn and refine TEES techniques in a safe environment.

**Author Contributions**

Matthew M. Dedmon, project design, conduct of study, analysis of data, drafting and revising of manuscript, approval of final version, accountability for all aspects of the work; Daniel J. Lee, project design, conduct of study, analysis of data, drafting and revising of manuscript, approval of final version, accountability for all aspects of the work.

**Disclosures**

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**Supplemental Material**

Additional supporting information may be found at http://otojournal.org-supplemental.

**References**