The Laryngoscope

Endoscope or Microscope-Guided Pediatric Tympanoplasty? Comparison of Grafting Technique and Outcome

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Objectives/Hypothesis: To review experience from the introduction of totally endoscopic ear surgery (TEES) to a pediatric tympanoplasty practice to identify factors influencing technique selection and successful outcome.

Study Design: Prospective cohort study.

Methods: Analysis of prospectively acquired data from a consecutive series of 295 surgeries for tympanic membrane perforation over a 12-year period. Success of perforation closure was compared between microscope and TEES grafting techniques. Impact of the acquisition of endoscopic techniques and equipment were compared with annual proportion of cases completed by TEES.

Results: Of 267 tympanoplasties, 109 (41%) were completed with TEES and 158 by a postauricular approach. The proportion completed with TEES increased gradually to 97% of cases as equipment and expertise were acquired. Young age did not prevent TEES tympanoplasty. Two hundred nineteen of 250 (88%) perforations were closed successfully by tympanoplasty, with equivalent closure rates between TEES and postauricular approaches. Underlay of tragal perichondrium was less successful than lateral graft technique using TEES ($P = .04$, Fisher exact test). "Push-through" myringoplasty using a microscope or endoscope was least successful (19 of 28 (68%), $P = .005$). The median length of stay was 13 hours shorter for TEES than postauricular tympanoplasty ($P = .04$, Mann-Whitney rank sum test). Wound complications occurred in five (3%) postauricular cases and one TEES case.

Conclusions: TEES tympanoplasty is feasible in a large majority of children given appropriate equipment and surgical experience. Nonautogenous graft material is ideal for this minimally invasive approach. TEES is recommended as providing equivalent likelihood of perforation closure to the post-auricular approach but with less postoperative morbidity.

Key Words: Tympanic membrane perforation, tympanoplasty, myringoplasty, endoscopic ear surgery.

Level of Evidence: 2b.

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INTRODUCTION

The repair of tympanic membrane (TM) perforation in children, commonly referred to as tympanoplasty (type 1) or myringoplasty, may be accomplished by a wide variety of techniques with varying complexity and invasiveness. Until recently, all such surgeries were almost invariably completed with illumination and magnification from an operating microscope. Although easily accessible perforations can be repaired permeatally using variations of a "push-through" technique, when using a microscope the external auditory meatus is frequently too narrow or too curved to provide a clear enough view of the perforation, especially when surgical instruments are placed into the field. An external incision is then required for adequate access, placed either postauricular or end-aural according to the surgeon's preference. This requirement is of particular significance in children, where the meatus is likely to be narrower, and the morbidity of open surgery perhaps felt more keenly.

Recent years have seen growing enthusiasm for the use of endoscopes in middle ear surgery,[1] with an increasing number of reports showing a benefit in surgery for cholesteatoma.[2–4] By providing a wide angle of view and illumination close to the TM, endoscopes overcome the permeatal limitation of the operating microscope, in which the direct line of sight may be impeded by instruments and ear canal morphology. Although endoscopes were first recommended for tympanoplasty in the 1990s,[5] even fairly recent reports have revealed reservations about a totally endoscopic technique for tympanoplasty.[6,7] With the growing availability of instruction courses dedicated to endoscopic ear surgery,[8] surgical experiences have been shared internationally allowing endoscopic techniques to be developed to the point where totally endoscopic tympanoplasty has now become a very feasible option, reported even in children's ears.[9–12] Whereas these accounts demonstrate feasibility of the approach, they combine outcome data with cholesteatoma surgery for a fairly small number of tympanoplasty cases. The objective of this study was to specifically address totally endoscopic repair of TM perforation in children, comparing outcomes with microscope-guided techniques and describing lessons learned from experience with the technique that may be of value to others adopting endoscopic ear surgery into their practice.

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MATERIALS AND METHODS

Approval for this study was granted by the institution's research ethics board.

Study participants included children <18 years of age having surgical TM repair for perforation without cholesteatoma or atelectasis between 2005 and 2016 by a single surgeon. Demographic information, details of surgical technique, audiometric thresholds, and presence of TM closure were recorded prospectively on a consecutive series of such cases over the study period. For this study, clinical data were extracted on age of the patient at surgery, history of previous perforation repair, and source of the referral. Surgical data included year of surgery, surgical approach, choice of graft material, and method of graft stabilization. Length of hospital stay was obtained from hospital episode data. The primary outcome measure was success of TM closure, which was assessed with otoscopy after microdebridement and tympanometry at the clinic follow-up assessment closest to 12 months.

Surgical Approach

Surgical approach was characterized as postauricular with microscope or totally endoscopic ear surgery (TEES) through the ear canal. TEES was introduced in November 2008 and used increasingly through the study period. Ultimately, a 3-mm 0° endoscope was favored for TEES, though many cases were completed with a 4-mm 0° or 3-mm 30° endoscope. Infrequently used techniques were excluded (endaural [n = 1] or permeatal [n = 3] tympanoplasty with a microscope), albeit with successful closure. Surgery in which a tympanomeatal flap was elevated was defined as *tympanoplasty*, and the simpler approach of pushing a graft through the perforation without a meatal skin incision as *myringoplasty*. A hemicircumferential meatal skin incision was used on the posterior wall for postauricular tympanoplasty and more inferiorly placed for TEES. Myringoplasty was typically reserved for small readily accessible perforations, frequently at the time of contralateral tympanoplasty.

Graft Material

When performing postauricular tympanoplasty, temporalis fascia or areolar tissue was usually used because it was readily available. For TEES tympanoplasty, surgery was initially completed with tragal perichondrium on the basis that the posterior surface of the tragus provides a relatively hidden, minimally invasive donor site. Nonautogenous grafts were preferred when there was insufficient donor-site material, using porcine submucosal collagen graft (Biodesign; Cook Medical Inc., Bloomington, IN) or human cadaveric acellular dermal graft (Alloderm; LifeCell Corp., Bridgewater, NJ) according to parental or patient preference. With postauricular surgery, this situation occasionally arose during revision surgery. With TEES, nonautogenous grafts were used increasingly over the study period, but especially for larger perforations, as the pediatric tragus can be too small. A small number of myringoplasty cases were completed with other grafts during the study period but were excluded from analysis because of small sample size. These included cartilage butterfly myringoplasty,[13] 12 cases (10 successful closure); gelatin sponge graft, eight cases (seven successful); and fat graft, three cases (two successful). Cartilage tympanoplasty was excluded from this series, being utilized only for reconstruction of TMs with cholesteatoma or atelectasis.

Graft Stabilization

For postauricular tympanoplasty, grafts were placed by underlay technique, suspending the graft under the perforation from one side of the boney meatus to the other, so as not to require any packing material in the middle ear space. Gelatin sponge (Gelfoam; Pfizer Inc., New York, NY) was only used to support the graft with push-though myringoplasty surgery, or in rare cases of tympanoplasty where the graft could not be adequately suspended. Additional support was sometimes provided by pulling a "peg" of graft material through a tiny stab incision in the TM adjacent to the perforation (Fig. 1a, i).[14] For anteriorly placed perforations, a "tab" of graft was brought up through a small incision on the anterior canal wall (Fig. 1a, ii)[15]; for anterosuperior perforations, the tab was brought up over the anterior malleolar fold (Fig. 1a, iii); and for subtotal perorations, the entire annulus was elevated and the graft brought up to line the full circumference of the bony meatus (referred to as lateral graft technique [Fig. 1b]).[16,17] The meatal skin was back-elevated and left pedicled anteriorly for the postauricular lateral graft approach, and a boney canalplasty was drilled for access when necessary.

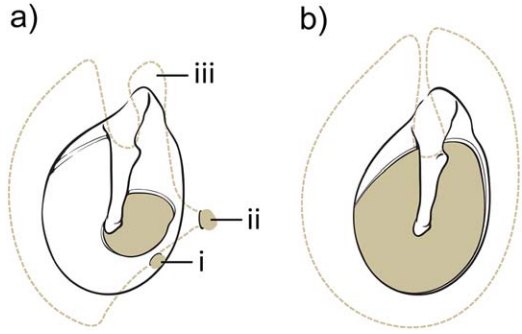

Fig. 1. Diagrammatic representation of graft stabilization techniques for underlay tympanoplasty, right ear. (a, i) A peg of graft pulled through a microincision in the ear drum; (a, ii) a tab of graft pulled up through a small meatal incision; (a, iii) a tab of graft wrapped over the neck of the malleus. (b) Position of graft for lateral graft tympanoplasty. (Modified from James and Papsin[17] with the publisher's permission.) [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

For TEES tympanoplasty, an interlay technique was preferred for smaller perforations, in which the graft was placed between the squamous and fibrous layers of the pars tensa.[18] When the layers of the tympanic membrane could not be separated, an underlay technique was used; an underlay lateral graft technique was used for larger perforations. For a TEES lateral graft, the meatal skin flap was pedicled superiorly, usually leaving the vascular strip attached to the malleus handle, and the graft was placed under the handle with tabs wrapped around the neck of the malleus and tucked between the skin flap and superior canal wall. A boney canalplasty was occasionally drilled for access using a 2-mm curved bur with protected shaft to avoid soft tissue injury (Medtronic, Minneapolis, MN).

Analysis

The primary outcome measure was the proportion of successful TM closures for TEES in comparison with non-TEES. Subgroup analysis of this outcome was completed for different graft types and methods of stabilization. Secondary outcome measures were annual proportion of cases completed with TEES versus non-TEES, which was interpreted according to availability of instrumentation and evolution of surgical technique; length of hospital stay; and surgical complications. SigmaPlot-11 (Systat Software Inc., San Jose, CA) was used for statistical analysis.

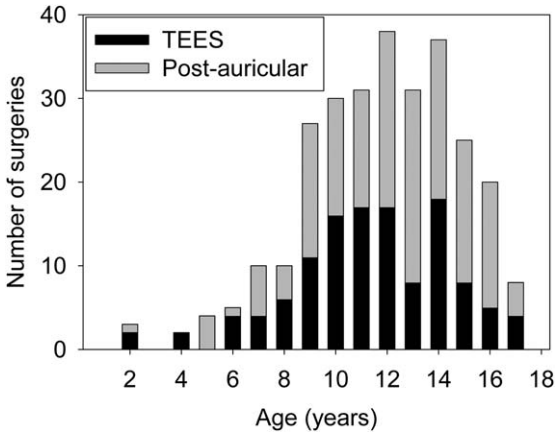

Fig. 2. Histogram showing number of tympanoplasty surgeries completed according to the age of the child. Number of postauricular microscope-guided tympanoplasties is indicated by pale shading and totally endoscopic ear surgery (TEES) by dark shading.

RESULTS

A total of 295 surgeries was completed on 284 ears in 248 children (36 bilateral). The median age at surgery was 12.7 years, with the distribution of ages illustrated in Figure 2. Fifty-eight (23%) children had a secondary diagnosis (cleft palate or 22q deletion = 11; Down syndrome = 3), and 86% were tertiary or quaternary referrals from otolaryngologists. Forty-eight (16%) were revision cases, of which 33 had their previous repair elsewhere. Follow-up data were available for 281 (95%) surgeries. Chart review was completed for cases for which follow-up data were unavailable in the database showing that five had been lost to follow-up before the integrity of the TM could be assessed, and 13 were completed too recently for follow-up assessment.

Proportion of TEES Cases

Regarding surgical approach, 123 were completed with TEES, 109 by tympanoplasty, and 14 by myringoplasty. Of the cases completed with a microscope, 158 were postauricular tympanoplasties, and 15 were myringoplasties. The proportion of cases completed each year according to surgical approach is shown in Figure 3. It can be seen that since the introduction of TEES 8 years ago, the proportion of endoscopic cases has steadily increased to the point where most recently, almost all cases have been completed with TEES. Over the last 5 years, reasons for choosing a postauricular approach instead of TEES were recorded in the database as ear canal too narrow or curved in 23 patients (32%), perforation too large for TEES in 23 patients (32%), anterior perforation in six patients (8%), surgeon preference for revision surgery in seven patients (10%) or active chronic suppurative otitis media in four patients (6%), family preference in three patients (4%), and no reason recorded in five patients (7%). These reasons for non-TEES tympanoplasty gradually became less influential with time as new equipment and techniques were introduced.

The time points of the introduction of new technologies are labeled in Figure 3. Of greatest significance, the introduction of the nonautogenous graft allowed TEES closure of subtotal perforation using the lateral graft technique, removing large perforation size as a deterrent to TEES. The availability of 3-mm 0° endoscopes has allowed TEES in narrower earl canals than was previously possible with 4-mm 0° or angled 3-mm endoscopes. Finally, the introduction of curved burs with a protected shaft allowed TEES canalplasty for access in the remaining cases, which previously would have been too narrow or curved to allow endoscopic access. Since 3-mm 0° endoscopes became available, the proportion of cases requiring canalplasty decreased from 18% to 4%. Before a large enough experience had been gathered to reliably determine efficacy, uncertainty regarding success of TEES versus postauricular repair influenced the preference of surgeons and families.

Young patient age did not prevent selection of a TEES approach. The median age at TEES tympanoplasty of 11.9 years is slightly younger than non-TEES cases (12.9 years) (P = .04, Mann-Whitney rank sum test). Of note, the youngest patients in the series had successful TEES tympanoplasty, showing that young age alone is not a barrier to the endoscopic approach. TEES canalplasty was completed in six patients aged between 10 and 15 years.

TM Closure and Technique

Overall, successful TM closure was achieved in 222 of 250 (88%) cases with tympanoplasty, being significantly more effective than myringoplasty at 19 of 28 (68%) (P = .005 Fisher exact test). The proportion of perforations closed successfully according to surgical approach is summarized in Table I. There was no statistically significant difference in tympanoplasty closure rate between TEES and microscope-guided surgery, nor between any of the different techniques for graft stabilization ($P > .05$, Fisher

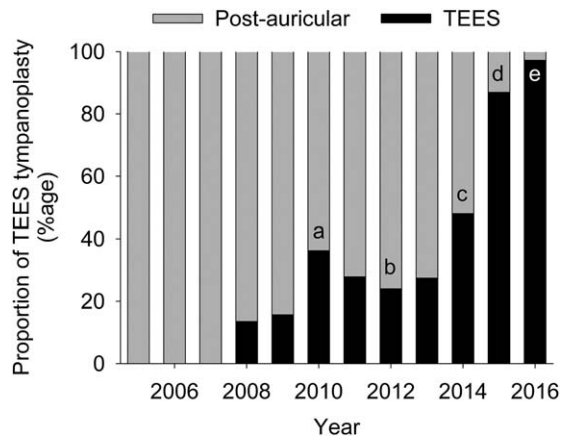

Fig. 3. Histogram showing proportion of tympanoplasties completed by either postauricular microscope-guided tympanoplasties (pale shading) or totally endoscopic ear surgery (TEES) (dark shading) according to the year the surgery was completed. The year of introduction of new technologies facilitating TEES is demonstrated by (a) high-definition camera, (b) 30° 3-mm endoscope, (c) porcine submucosal collagen graft, (d) 0° 3-mm endoscope, (e) curved burrs with protected shaft.

TABLE I.
Proportion of Cases With Successful Perforation Closure According to Surgical Approach and Method of Graft Stabilization

	TEES		Microscope		Total
Myringoplasty	9/13	69%	10/15	67%	68%
Tympanoplasty (all)	83/98	85%	136/152	89%	88%
Interlay	31/36	86%	—	—	—
Simple underlay	22/28	79%	21/24	88%	83%
Pegs	5/ 5	100%	18/21	86%	89%
Tabs	3 / 5	60%	62/67	93%	91%
Lateral graft	30/32	94%	48/53	91%	92%

Data are presented as number of intact tympanic membranes/ number of cases with follow-up and percentages.

Grafting techniques are as described in the Materials and Methods section.

TEES = totally endoscopic ear surgery.

exact test). It is of note that the lateral graft technique achieved successful closure in >90% of cases with TEES and postauricular surgery, even though this technique was only used for subtotal or anteriorly placed perforations. The five cases lost to follow-up were all completed by a microscopic postauricular approach using temporalis fascia and pegs or tabs for stabilization. Intention-to-treat analysis including these cases either as presumed failures or successes does not significantly change these findings.

TM Closure and Graft Material

Temporalis fascia and nonautogenous grafts were the preferred grafting materials for microscope and TEES tympanoplasties, respectively, and had equivalent closure rates (Table II). TEES underlay of tragal perichondrium was less successful than TEES lateral graft technique ($P = .04$ Fisher exact test).

Length of Stay

Hospital episode statistics available for a subset of 94 surgeries between January 2014 and June 2016 showed the median length of stay was 25 hours for postauricular and 12 hours for TEES tympanoplasty ($P < .001$ Mann-Whitney rank sum test). More recently, TEES cases have been discharged in <2 hours without inpatient admission.

Complications

Wound complications requiring treatment occurred in five (3%) patients following postauricular tympanoplasty (keloid requiring excision = 3, pain clinic for severe hyperesthesia = 1, intravenous antibiotics for wound infection = 1). One hematoma requiring drainage occurred from a tragal graft site in a TEES case. Superficial epithelial cysts or inclusion cholesteatoma were found in 12 (8%) postauricular cases and seven (6%) TEES cases. The majority dispersed without treatment or with simple excision.

DISCUSSION

Recent years have seen growing recognition that endoscopes can be used to increase the range of otologic procedures that can be completed through the ear canal without an external incision (TEES), but comparative data on efficacy remain limited.[19] This study shows that TEES tympanoplasty can be completed in a high proportion of children with equivalent success at perforation closure to microscope-guided surgery. The success rate over 85% matches that reported in a recent meta-analysis of published reports of pediatric tympanoplasty.[20]

A weakness of this study is that allocation to treatment was not randomized, and TEES cases were performed toward the end of the series when overall, the surgeon's experience was greater. This potential bias is offset by inclusion of outcomes from TEES surgeries completed during the learning curve of the new technique, whereas the postauricular techniques had been mastered prior to start of the study. The prospective recording of data in a consecutive series with negligible loss to follow-up reduces the risk of other bias in this study.

Data were recorded prospectively in this series, with the specific intention of monitoring surgical outcome with different techniques. Uncertainty about efficacy of outcome led to the careful and relatively slow adoption of TEES in this series, as shown in Figure 3, because of the desire to maintain standards of TM closure despite the potential pitfalls inherent with mastering a new technique. Poor success with underlay of perichondrium contributed to initial hesitation in adoption of TEES tympanoplasty in this series. Introduction of the interlay technique and availability of large nonautogenous grafts allowed progress with better success. The learning curve represents not just a personal learning curve but also reflects evolution of techniques shared through the International Working Group in Endoscopic Ear Surgery[8] and the contribution of technological advances and equipment. It can be argued that the widespread availability of better endoscopic equipment has allowed the field to advance recently since it was first advocated in the 1990s.[4,5]

Although the adult tragus is an ideal donor site for tympanoplasty,[21] it was appreciated early in this series that the pediatric tragus is not always large enough to repair larger perforations. This is particularly true for the underlay technique if Gelfoam is not used as a support in the middle ear. The TM is adult size at birth, but the ear canal and tragus grow during childhood.[22,23] Little

TABLE II.
Proportion of Cases With Successful Tympanoplasty Closure According to Graft Material.

	TEES		Microscope		Total
Fascia	—	—	133/149	89%	
Nonautogenous graft*	49/56	88%	3/3	100%	90%
Perichondrium	30/38	79%	—	—	
Simple underlay	12/17	71%	—	—	
Inlay	10/11	91%	—	—	

Data are presented as number of intact tympanic membranes/ number of cases with follow-up and percentages.

*Porcine submucosal collagen (Biodesign) = 53/56 TEES cases; human acellular dermis (Alloderm) = 6 cases.

TEES = totally endoscopic ear surgery.

anthropometric data seem to have been published on tragal growth, but from experience, the tragus is barely as large as the pars tensa in young children. Although tympanoplasty might not be commonly recommended at younger ages,[24,25] it is obviously preferable to have a larger graft available, especially for the underlay technique and subtotal perforations.

Nonautogenous graft material was used increasingly during this series, allowing even subtotal perforations to be repaired with TEES. Biodesign and Alloderm are relatively easy to manipulate with one hand in TEES. They are not as pliable as fascia so do not conform to shape so readily, but can be folded more easily allowing redundant material to be pleated up the ear canal. Level 1 evidence has shown equivalent closure rates between Biodesign and temporalis fascia in pediatric tympanoplasty,[26] with similar findings for Alloderm in retrospective comparative case series.[16,27] Other advantages include a saving in surgical time and elimination of all donor site morbidity as graft harvest is avoided, but these products are not licensed for ear surgery in all jurisdictions.

Alternatively, a larger autogenous graft can be harvested (eg with a small incision for temporalis fascia or perichondrium from the medial surface of the concha), but this is less consistent with the minimally invasive advantage of TEES. Many children would prefer to avoid the small increase in early postoperative morbidity and delayed participation in contact sports associated with the external incision. From the author's experience, parents are also very enthusiastic about the prospect of their child avoiding a wound; parental satisfaction has been one of the principle incentives and rewards for utilizing TEES tympanoplasty.

The lateral graft technique is certainly feasible endoscopically and has provided reliable closure of large perforations in this series. Although it has been the author's practice to avoid Gelfoam in the middle ear for tympanoplasty, primarily on the basis of animal models showing increased adhesion formation,[28–30] there seems to be little clinical evidence of adverse outcome from this practice. Conceivably, Gelfoam may facilitate graft support, though it did not contribute to good success with push-through myringoplasty in this series. Placement of grafts on, instead of under, the malleus handle (after TM elevation) and use of cartilage pieces to provide support are potentially easier TEES techniques that may provide clinically similar or even better outcomes.[31] The interlay technique, in which the fibrous layer of the pars tensa is left in situ, is also an effective method that provides excellent graft support for nonsubtotal perforation and straightforward graft placement for TEES tympanoplasty.

Although the narrow confines of the pediatric ear canal restricted use of TEES earlier in this series, the use of 3-mm-diameter endoscopes and occasional use of curved, sheathed burs alongside the endoscope now allows TEES access for tympanoplasty in virtually all cases. The small quantity of bone dust generated in canalplasty can easily be removed with intermittent suction. The skill-set and mind-set of otologists is expanding with regard to TEES, and no doubt further innovations will allow more to be achieved endoscopically for patient benefit in the future.

CONCLUSION

No complications were attributable to use of endoscopes in this series, though complications were seen from the postauricular incision in microscope-guided surgery. Although keloids and wound infections only occur in a small percentage of postauricular cases, there is no doubt that surgeons and patients would prefer to avoid these problems if possible. When considered alongside the equivalent perforation closure rate, the potential for reduction in pain, length of hospital stay, and time off sports, with parental and child preference for avoiding a surgical incision, the arguments for considering TEES tympanoplasty are compelling. Although the learning curve may be slow, evolution of surgical technique and widespread availability of instruction courses are facilitating wider application of endoscopic ear surgery. This series shows that even in the child's ear, it is a feasible and effective technique.

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