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Comparison of Endoscopic and Microscopic Ear Surgery in Pediatric Patients: A Meta-analysis

Sang-Yoon Han, MD; Doh Young Lee, MD, PhD; Juyong Chung, MD; Young Ho Kim, MD, PhD

OBJECTIVES: Recently, the endoscope has been increasingly introduced for middle-ear surgery. To evaluate the postoperative outcomes of endoscopic ear surgery (EES) in pediatric patients, we did a qualitative analysis with a systematic review and quantitative analysis with meta-analysis of available literature.

METHODS: Studies reporting the comparative surgical outcomes of EES in pediatric patients were systematically reviewed by searching the MEDLINE, PubMed, and Embase databases from database inception through 2017. The selected articles included clinical studies conducted with at least 30 subjects and at least one postoperative parameter, including residual or recurrent cholesteatoma and graft success in tympanoplasty. Two investigators independently reviewed all studies and extracted the data using a standardized form. A meta-analysis was performed using a random-effects model and qualitative review was performed on the smaller studies.

RESULTS: Ten studies were identified as appropriate for quantitative meta-analysis and 19 studies for qualitative analysis. In the meta-analysis, residual or recurrence rate of cholesteatoma was significantly lower in the EES group than in the microscopic ear surgery (MES) group (odds ratio [OR]: 0.56, 95% confidence interval [CI]: 0.38-0.84, \( P = .005 \)). The graft success rate of tympanoplasty was not statistically different between EES and MES groups (OR: 0.72, 95% CI: 0.41-1.26, \( P = .249 \)). In the qualitative analysis, most of the studies reported similar audiological outcomes after tympanoplasty and success rate of cholesteatoma removal between the two groups.

CONCLUSIONS: It appears that EES reduces the risk of residual cholesteatoma in children and that the success of perforation closure is equivalent to MES.

INTRODUCTION

Endoscopic ear surgery (EES) is a recently introduced technique to evaluate the degree of disease and eradicate residual disease via endoscopy or as a combined tool in microscopic ear surgery (MES). This technique has several advantages over conventional MES: 1) effective access to the middle ear with a smaller incision, and 2) a wider operative view with an increased angle of vision. With the increased application of EES to middle-ear diseases, EES is emerging as an option in tympanoplasty or myringoplasty. Moreover, the indications with this technique have widened to pediatric middle-ear disease.

Despite the advantages of endoscopic surgery in middle-ear diseases, EES has several limitations, especially in pediatric application, because the external auditory canal is small. The main limitation is having to perform a single-handed technique, with the other hand holding the endoscope, which is disadvantageous during fine dissection. Second, EES is not an appropriate approach in middle-ear diseases extending to the mastoid or further. Therefore, EES may be used in diseases limited to middle ears, such as early-stage pediatric cholesteatoma, simple tympanoplasty, or conductive hearing loss. Last, EES has its own learning curve, and the operation time is known to be longer than that of conventional MES. The appropriate application of EES in pediatric patients with middle-ear diseases is important, although there is no quantitative analysis of surgical outcomes of EES compared with those of MES, to the best of our knowledge.

The aim of this study was to evaluate the postoperative outcomes of EES in pediatric patients with chronic middle-ear diseases by means of a systematic review and a meta-analysis of the available literature. These will reveal advantages and limitations of EES in comparison with classical MES in children.

MATERIALS AND METHODS

This systematic review and meta-analysis was developed and performed according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-
Analyses (PRISMA). The PRISMA Flow Diagram was used to outline the various phases of the systematic review. This study used quantitative methods to examine reasons for differences in postoperative outcomes.

**Selection Criteria**

On January 1, 2018, two of the authors (J.C. and Y.H.K.) independently searched the MEDLINE, PubMed, and EMBASE databases for articles published between database inception and 2017 for all available studies reporting postoperative outcomes of pediatric EES. We independently screened the titles and abstracts of all nonduplicated articles and excluded irrelevant titles and abstracts. A final list was agreed upon, with discrepancies on the eligibility of studies resolved by consensus. The following terms were used for the literature search: (“ear” OR “otitis” OR “cholesteatoma” OR “stapes” OR “stapedial” OR “mastoid” OR “tympan” OR “otosclerosis” OR “osotic”) AND (“endoscope” OR “endoscopic”). We identified additional relevant manuscripts from the references of included studies.

**Inclusion and Exclusion Criteria**

The inclusion criteria for our meta-analysis of pediatric EES studies were as follows: 1) report of at least one postoperative outcome (residual disease or recurrence in pediatric cholesteatoma and graft success in tympanoplasty), 2) original articles from peer-reviewed scientific journals published in English, and 3) studies with children and youth aged 18 years or younger. The following types of publications were excluded: 1) animal studies, in vitro studies, review articles, case reports, and abstracts; 2) studies without access to original articles (e.g., only abstracts) and/or with incomplete data; and 3) duplicate publications.

We did not contact study authors to identify additional information and further studies. In addition, we assessed the risk of bias of the studies included in the qualitative review based on Newcastle-Ottawa Scale criteria, and all of the studies showed good or fair quality (see Supporting Information, Table I, in the online version of this article). The EES group included both totally endoscopic ear surgery and endoscope-assisted microscope-guided surgery.

**Data Extraction**

We reviewed all studies and independently performed data extraction; any discrepancies were resolved by consensus. For each article that reported postoperative outcomes of pediatric EES, the following information was noted: author, year of publication, number of patients, and postoperative outcomes. The analysis of pooled proportions was performed, and cases with missing or incomplete information were excluded. Weighted proportions and their 95% confidence intervals (CIs) for the percentage of residual/recurrence disease of cholesteatoma and graft success were calculated. Studies without any comparison (e.g., case series) were subjected to qualitative analysis.

**Statistical Analysis**

Both a fixed-effect model and a random-effects model were used. A random-effects model was adopted when the heterogeneity study revealed that the involved studies had inconsistent Cochran Q test results and $I^2$ statistics (for the percentage of overall variation). A $P$ value < .01 for the Cochran Q test indicated significant heterogeneity between studies. The $I^2$ statistic describes the percentage of total variation across studies due to heterogeneity rather than chance; thus, $I^2 < 25\%$, $I^2 = 25\%$ to 50\%, and $I^2 > 50\%$ represented low, moderate, and high degrees of inconsistency, respectively.

**RESULTS**

**Characteristics of the Studies**

A flow diagram of the initial identification, reasons for exclusion, and final selection of studies is shown in Figure 1. The search strategy identified 4,288 unique abstracts, including 211 that met the initial screening criteria. After reviewing the full-length articles, 182 studies were excluded because they contained a mixture of different patient populations (e.g., mixture of adult and pediatric patients) in the total cohort (n = 163), lacked postoperative outcomes (n = 14), or were review articles (n = 5). Ten studies met all the inclusion criteria for the meta-analysis; two were prospective and eight were retrospective cohort studies (Table I). The number of subjects collected for meta-analysis was 1004, including 513 patients belonging to EES and 491 patients under MES, and the included studies were published between 2015 and 2017. Nineteen studies were analyzed qualitatively, which were all case series studies, except for one retrospective cohort study (Table II). The included studies were published between 1995 and 2017, and a total of 406 patients were evaluated.

**Residual Cholesteatoma or Its Recurrence After EES in Pediatric Cholesteatoma**

Among the 10 studies enrolled in the quantitative meta-analysis, postoperative residual cholesteatoma or its recurrence was investigated in six studies. Residual cholesteatoma or its recurrence rate was significantly lower in EES than in MES (odds ratio: 0.56, 95% CI: 0.38–0.84, $P = .005$; Fig. 2A). Among the 19 studies enrolled in qualitative analysis, 10 investigated the recurrence rate of cholesteatoma after surgery (Table II). The recurrence rate of cholesteatoma after EES ranged from zero to 50%.

In these qualitative studies, the stage of cholesteatoma was a factor for successful postoperative outcomes. Congenital cholesteatoma (CC) in the Potsic stage III, II, III, and selective IV was considered as an appropriate indication for EES (Table III). A rate of residual lesion or recurrence of stage I CC was equivalent to that of stage II CC. However, residual lesions in stage III CC were higher than in stage I or stage II CC. The most frequent sites of residual or recurrence cholesteatoma and intraoperative detection of cholesteatoma were epitympanum, around stapes, and around the facial nerve (including sinus tympani) (Table III).
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Diagnosis</th>
<th>No. of Subjects (EES/MES)</th>
<th>Age, yr (Range)</th>
<th>Treatment in Control Group</th>
<th>F/U Period, mo (Range)</th>
<th>Parameters</th>
<th>Postoperative Outcomes, % (EES/MES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghadersohi et al. (2017)</td>
<td>Retrospective cohort</td>
<td>Cholesteatoma</td>
<td>47/18</td>
<td>10.9</td>
<td>MES</td>
<td>31.2 (9–55.2)</td>
<td>Residual cholesteatoma</td>
<td>29.8/50.0</td>
</tr>
<tr>
<td>James et al. (2016)</td>
<td>Prospective cohort</td>
<td>Cholesteatoma</td>
<td>127/108</td>
<td>10.9 (1–17.9)</td>
<td>MES</td>
<td>&gt;38</td>
<td>Residual cholesteatoma</td>
<td>15.0/24.1</td>
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<tr>
<td>Basonbul et al. (2016)</td>
<td>Retrospective cohort</td>
<td>Cholesteatoma</td>
<td>56/33</td>
<td>—</td>
<td>MES</td>
<td>—</td>
<td>Residual cholesteatoma</td>
<td>32.1/48.5</td>
</tr>
<tr>
<td>Marchioni et al. (2015)</td>
<td>Retrospective cohort</td>
<td>Cholesteatoma</td>
<td>31/28</td>
<td>8.7 (1.2–17.8)</td>
<td>MES</td>
<td>31.2 (9–55.2)</td>
<td>Residual cholesteatoma, hearing gain</td>
<td>32.3/53.6</td>
</tr>
<tr>
<td>James et al. (2017)</td>
<td>Prospective cohort</td>
<td>COM</td>
<td>111/167</td>
<td>12.7</td>
<td>MES</td>
<td>12</td>
<td>Graft success</td>
<td>82.0/87.4</td>
</tr>
<tr>
<td>Dündar et al. (2014)</td>
<td>Retrospective cohort</td>
<td>COM</td>
<td>32/29</td>
<td>12.4 (7–16)</td>
<td>MES</td>
<td>10</td>
<td>Graft success, hearing gain</td>
<td>87.5/93.1</td>
</tr>
<tr>
<td>Cohen et al. (2016)</td>
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<td>COM</td>
<td>19/13</td>
<td>9.8</td>
<td>MES</td>
<td>6–12</td>
<td>Graft success, hearing gain</td>
<td>79.0/84.6</td>
</tr>
<tr>
<td>Nassif et al. (2015)</td>
<td>Retrospective cohort</td>
<td>COM</td>
<td>22/23</td>
<td>10.0 (5–16)</td>
<td>MES</td>
<td>&gt;12</td>
<td>Graft success, hearing gain</td>
<td>90.9/82.6</td>
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<td>Cholesteatoma (6 studies)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>COM (4 studies)</td>
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</tr>
</tbody>
</table>

COM = chronic otitis media; EES = endoscopic ear surgery; F/U = follow up; MES = microscopic ear surgery.
**Graft Success in Tympanoplasty**

Four studies enrolled in the quantitative meta-analysis investigated postoperative graft success rate. In tympanoplasty, the graft success rate showed no significant difference between the EES and MES groups (odds ratio: 0.72, 95% CI: 0.41-1.26, \( P = .249 \); Fig. 2B). Among the 19 studies enrolled in the qualitative analysis, seven studies investigated graft-failure rate after tympanoplasty, which ranged from zero to 13.6% (Table II). In these studies, the size and location of tympanic membrane perforation affected the graft-failure rate. One study considered perforation diameter >3 mm as a cutoff point for tympanic membrane perforation.21 Another study considered a perforation >50% of tympanic membrane as the cutoff.22 Other studies investigated the relevance of perforation size and re-perforation. Larger perforation was related to higher graft-failure rate in these studies. Furthermore, the location of tympanic membrane perforation affected graft-failure rate (Table IV). When dividing the location of tympanic membrane perforation into anterior and posterior, one study reported no difference between the two perforation locations.35 On the other hand, another study showed that the marginal and posterior tympanic membrane perforation was a risk factor for graft failure.22 Furthermore, there was no obvious relevance between age, canal diameter, and recurrence rate in these studies. In general, younger patients’ canal diameter was shorter than that of older ones; that is, the EES technique could be very complicated in younger patients with narrower canal diameter, compared with adult patients. However, in these studies, age and canal diameter in patients with normal external auditory canal did not have a critical effect on EES results.22,29,31

**DISCUSSION**

Endoscopy in the otologic field was first introduced in the 1960s; however, it was not applied widely because of poor resolution and imaging quality. With the invention of high-resolution endoscopes and charge-coupled device cameras, endoscopes were actively introduced for sinus surgery in the 1990s. Subsequently, the performance of endoscopes improved significantly, and wide-angled surgical view was secured by using angled endoscopes. In the otologic field, operators obtained benefits similar to MES by using endoscopes, and the application of EES increased gradually.40

The indications for EES have extended. The early period of EES involved myringoplasty or simple tympanoplasty. Early-stage cholesteatoma was removed successfully. Kojima et al. and Hunter et al. have reported the application of endoscopes in stapes surgery40,41 and found that ear endoscopes could be used for stapes surgery by experienced surgeons. Dia et al. and Marchioni et al. suggested the utility of endoscopes in cochlear implantations.42,43 Furthermore, endoscopes were used in the management of middle-ear benign tumors, such as paraganglioma, carcinoid tumors, and osteoma.44,45

EES has various advantages and disadvantages. Transcanal EES was associated with minimal surgical scar. However, the cosmetic advantage of EES was not emphasized in all otologic ear diseases, especially in pediatric cholesteatoma cases, because EES was performed to remove pathological lesions as completely as possible. EES facilitates the identification and removal of cholesteatoma or inflammatory tissue in the blind spot beyond the reach of MES. In addition, surgical time is reduced with EES.
However, we cannot overlook the following limitations. First, it is basically a one-handed technique, because the other hand is used to grip the endoscope. Therefore, it may be very difficult in special conditions, such as massive bleeding. Preyer suggested that EES cannot fully substitute for the use of a microscope because of the limitation associated with the single-hand technique.46 Second, EES is associated with a potential risk of damage to the surrounding structures not included in the visual field, such as ossicles, nerves (including facial nerves and the chorda tympani nerve), and other surrounding tissues.9 EES in pediatric patients with a narrow ear canal requires great care. Third, the heat of the endoscope light may induce thermal damage to inner-ear structures. Therefore, the brightness of the light source should be adjusted during the surgical preparation.40,47

A few techniques to overcome the limitations of EES were developed. The double-handed technique supported by the endoscope-holding system was introduced in preliminary studies.8,48–50 This technique increased the effectiveness of the surgery over that of the one-handed EES if the stability of the holding system was guaranteed. Furthermore, ear endoscopy may be used for total EES or observation of the middle ear before and after MES. Observational practices of ear endoscopy in the conventional MES before the start of full-scale total EES will assist beginners in learning the surgical skills of EES.

This study demonstrated that the control rate of residual cholesteatoma after EES was higher than that of MES and the graft success rate after EES was similar to that of MES in qualitative studies. The graft-failure rate ranged from zero to 13.6%, which was similar to that of

### Table II

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Diagnosis</th>
<th>No. of Subjects</th>
<th>Age, yr (Range)</th>
<th>F/U Period, mo</th>
<th>Parameters</th>
<th>Postoperative Outcomes, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marchioni et al. (2017)</td>
<td>Retrospective cohort</td>
<td>Cholesteatoma</td>
<td>12 (6/6)</td>
<td>4 (2–7)</td>
<td>54.5</td>
<td>RCR</td>
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<td>D’Eredita et al. (2017)</td>
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<td>Cholesteatoma</td>
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<td>RCR/hearing gain</td>
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<td>Case series</td>
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<td>5 (6–12)</td>
<td>6</td>
<td>RCR</td>
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<td>Huang and Sun (2016)</td>
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<td>6</td>
<td>RCR</td>
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<td>Case series</td>
<td>Cholesteatoma/COM</td>
<td>13</td>
<td>6.9 ± 4.3</td>
<td>6–24</td>
<td>RCR/graft failure</td>
<td>0.0/0.0</td>
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<td>Ito et al. (2015)</td>
<td>Case series</td>
<td>Cholesteatoma/COM/CHL</td>
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<td>7.6 (2–13)</td>
<td>—</td>
<td>RCR/graft failure/hearing gain</td>
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<tr>
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<td>Cholesteatoma</td>
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<td>3 (1–16)</td>
<td>48</td>
<td>RCR</td>
<td>8.3</td>
</tr>
<tr>
<td>Kanotra and James (2012)</td>
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<td>Cholesteatoma</td>
<td>27</td>
<td>6.9 (3–15)</td>
<td>0</td>
<td>IDRC</td>
<td>18.5</td>
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<tr>
<td>Good and Isaacson (1999)</td>
<td>Case series</td>
<td>Cholesteatoma</td>
<td>29</td>
<td></td>
<td></td>
<td>IDRC</td>
<td>24.0</td>
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<tr>
<td>Rosenblatt et al. (1995)</td>
<td>Case series</td>
<td>Cholesteatoma</td>
<td>10</td>
<td>11.1</td>
<td>25.4</td>
<td>RCR</td>
<td>50.0</td>
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<tr>
<td>De Zinus et al. (2017)</td>
<td>Case series</td>
<td>COM</td>
<td>10</td>
<td>10 (6–14)</td>
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<td>Graft failure/hearing gain</td>
<td>0.0/6 dB</td>
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<tr>
<td>Akyigit et al. (2017)</td>
<td>Case series</td>
<td>COM</td>
<td>32</td>
<td>13.9 (8–17)</td>
<td>23.3</td>
<td>Graft failure/hearing gain</td>
<td>6.3/10.5 dB</td>
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<tr>
<td>Isaacson and Harounian (2017)</td>
<td>Case series</td>
<td>COM</td>
<td>31</td>
<td>6 (3.5–17)</td>
<td></td>
<td>Graft failure</td>
<td>12.9</td>
</tr>
<tr>
<td>Carter et al. (2017)</td>
<td>Case series</td>
<td>CHL</td>
<td>21</td>
<td>8.0 (4–15.8)</td>
<td>25.2</td>
<td>Graft failure/hearing gain</td>
<td>0.0/12.4 dB</td>
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<tr>
<td>Zhu et al. (2016)</td>
<td>Case series</td>
<td>CHL</td>
<td>8</td>
<td>10.1 (6–12)</td>
<td>6</td>
<td>Hearing gain</td>
<td>18.9 dB</td>
</tr>
<tr>
<td>Isaacson et al. (2015)</td>
<td>Case series</td>
<td>CHL</td>
<td>8</td>
<td>6–18</td>
<td></td>
<td>Hearing gain</td>
<td>Improved</td>
</tr>
</tbody>
</table>

CHL = conductive hearing loss; COM = chronic otitis media; EES = endoscopic ear surgery; F/U = follow up; IDRC = intraoperative detection of residual cholesteatoma; RCR = residual cholesteatoma or recurrence.
The recurrence rate of cholesteatoma after EES in this study was similar to that of MES (4%–15%).53 A few studies evaluated the efficacy of EES for intraoperative detection of residual cholesteatoma.25,30 In these studies, 18.5% to 24.0% of residual cholesteatoma cases were detected with endoscopes during MES. Although EES showed results similar to or better than those of MES in a few situations, no large cohort studies were available to date. Therefore, a significant publication bias may be present, suggesting that the worst outcomes of EES were not reported. Interestingly, there was no report of significant complications after EES in this review. Further studies are needed to investigate the surgical problems or complications in patients who underwent EES, especially in pediatric EES cases. Additional studies with larger cohorts are needed for clarification.

Compared with previously published systemic reviews of EES, this study was designed for only pediatric patients. Presutti et al. and Kozin et al. performed systematic reviews targeting all ages for EES.54,55 Therefore, their results may have heterogeneity for age in EES. In the present study, we selected only pediatric patients to investigate the efficacy of EES in children with a narrow surgical field.

This study has a few limitations. First, only a few published articles reported the quantitative analysis of EES compared with other techniques; this precluded sensitivity or subgroup analysis in the present study. Although residual and recurrent cholesteatoma should be analyzed separately, having so few studies made it difficult to perform subgroup analysis. Moreover, because of the lack of information about follow-up periods and timing of recurrences, a survival analysis using a time variable was not possible. Second, the stage of cholesteatoma or size of the perforated tympanic membrane was not reported in most studies, complicating the analysis of factors affecting the extent of diseases. The residual or recurrence rate according to the stage of cholesteatoma and graft-success rate based on the size of the perforated tympanic membrane need to be further investigated. Third, a publication bias was observed in most of the risk-factor analyses. Among the studies included in this meta-analysis, an epidemiologic analysis may compromise the consistency of the included articles and results. Fourth, studies in languages other than English were excluded; they might have reported different results. Last, demographic factors such as age were not adjusted, although age may contribute to the success of EES. Despite limitation of possible heterogeneity and bias in this study, its results may facilitate decision-making and outcome prediction for EES. Further clinical and basic studies are needed to elucidate the factors related to successful treatment outcomes of EES in pediatric patients.
<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Cholesteatoma</th>
<th>Potsic Stage (Surgery Type/Case/Recurrence Case)</th>
<th>Site of Cholesteatoma</th>
<th>RCR Site</th>
<th>IDRC Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marchioni et al. (2017)</td>
<td>Congenital (all)</td>
<td>TEES/3/0, TEES/1/0, TEES with ossiculoplasty/5/0, EES with CWU/2/0</td>
<td>CWU with EES/2/0</td>
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<td>D'Eredita et al. (2017)</td>
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<td>—</td>
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<td>Congenital (7), acquired (35)</td>
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<td>Congenital (13), acquired (3)</td>
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<td>Congenital closed (7), congenital open (5), open type recur (1)</td>
<td>TEES T/3/1/1</td>
<td>ASQ (7), PSQ+PIQ (2), ASQ+AIQ (1), ASQ+PSQ (1), ASQ=difficult to endoscopic surgery</td>
<td>Horizontal portion of FN and facial recess</td>
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<tr>
<td>Kanota (2012)</td>
<td>—</td>
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<td>Rosenberg et al. (1995)</td>
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</tbody>
</table>

AIQ = anterior inferior quadrant; ASQ = anterior superior quadrant; CWU = canal wall up mastoidectomy; EES, endoscopic ear surgery; FN = facial nerve; IDRC = intraoperative detection of residual cholesteatoma; N = number; PIQ = posterior inferior quadrant; PSQ = posterior superior quadrant; RCR = residual cholesteatoma or recurrence; TEES = transcanal endoscopic ear surgery.
CONCLUSION

EES appears to outscore or be comparable with conventional MES in patient outcome. In addition, the possibility of residual cholesteatoma or its recurrence in pediatric cholesteatoma was reduced by the removal of cholesteatoma using EES. However, further evidence-based studies about safety and postoperative outcomes of EES in pediatric patients are needed.

BIBLIOGRAPHY


