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Systematic Review of Endoscopic Middle Ear Surgery Outcomes

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Abstract

Objective—Middle ear surgery increasingly employs endoscopes as an adjunct to or replacement for the operative microscope. Superior visualization and transcanal access to disease normally managed with a transmastoid approach are touted as advantages with the endoscope. No study, however, has systemically reviewed the literature to evaluate outcomes of endoscopic ear surgery (EES). We provide a systematic review of endoscope applications in middle ear surgery with an emphasis on outcomes.

Data Sources—PubMed, Embase, and Cochrane

Methods—A literature review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis recommendations. Articles were categorized based on study design, indication, and use of an endoscope either as an adjunct to or as a replacement for a microscope. Quantitative and descriptive analyses were performed.

Results—Ninety-one articles published between 1967 and 2014 met inclusion and exclusion criteria. The main indication for the use of an endoscope was cholesteatoma or myringoplasty. Of the identified articles, 40 provided a discrete discussion of outcomes. In cholesteatoma surgery, the endoscope has been mainly employed as an adjunct to the microscope, and although outcomes assessments vary across studies, the endoscope identified residual cholesteatoma in up to 50% of cases.

Conclusion—Endoscopes have been predominately used as an observational adjunct to the microscope to improve visualization of the tympanic cavity. Recent reports utilize the endoscope exclusively during surgical dissection; however, data comparing patient outcomes following the use of an operative endoscope versus a microscope are lacking. Areas in need of additional research are highlighted.

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Keywords

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Introduction

Endoscopic ear surgery (EES) has remained controversial since its first description in the English literature in the late 1960s[1]. Advocates of endoscopic visualization of chronic ear disease espouse its wide-field view of the surgical field, high resolution, magnification, and the ability to "look around corners". Recognizing the potential advantage of this technology over standard operative microscopes, sinus and skull base surgeons incorporated the use of the endoscope in the 1980s and 1990s into sinus surgery.[2] Optimized and designed for sinus surgery, rigid zero degree and angled endoscopes are now the standard instrument for visualization of the paranasal sinuses.[3]

Paralleling the application of endoscopes in sinus surgery over the past two decades, the field of otology appears to be in a similar era of debate regarding the use of endoscopes for middle ear surgery. Contemporary middle ear surgery employs operative microscopes for visualization of the tympanic cavity. While modern microscopes provide excellent views of the surgical field and confer the ability for binocular vision and two-handed surgery, visualization of deeper recesses in the middle ear is limited. The optical properties of a microscope require an adequate amount of light to reach the surgical plane. As a result, current microscope-based operative approaches frequently necessitate soft tissue retraction and/or bony drilling to adequately visualize the targeted pathology.

In contrast, endoscopes allow for improved visualization as the light source is located at the distal tip of the instrument and angled lenses offer a wide perspective of the operative field. Further, transcanal endoscopic approaches transform the external auditory canal into a surgical portal. Due to the relative diameter of the endoscope to the ear canal, however, only one-handed surgery is feasible, thereby making dissection less efficient and more challenging, especially in the case of blood in the operative field. Although endoscope holders have been devised to enable two-handed procedures[4], there remains technical challenges of developing an endoscope holder with adequate precision for middle ear surgery. Further, questions remain as to the long-term safety of extended static application of endoscopes in the middle ear due to the heat generated by these instruments.[5,6]

Initially, rigid endoscopes were used in the ear predominately as an adjunct to microscopes for diagnostic purposes.[7,8] The improved image clarity, wide-angle view, and superior illumination of endoscopes afforded visualization of the middle ear cavity through transtympanic, transtubal or transmastoid approaches with relative ease. Consequently, early studies on endoscope application in middle ear surgery focused on the anatomy of the middle ear. In the 1990s, as an extension of these anatomic studies, investigators examined the application of endoscopes as observational tools in cholesteatoma second-look procedures to evaluate their ability to detect residual or recurrent disease.[9–13] Over the past 15 years, however, there has been increasing application of the endoscope as a tool not only for observation, but also as the sole instrument for visualization of the middle ear during operative dissection, which is similar to the way paranasal sinus surgery is currently performed. Given this dual application, it is important to make a semantic distinction between *observational EES* and *operative EES*.

To date, no study has systemically reviewed outcomes following EES. Herein, we aim to 1) provide a comprehensive review of observational and operative EES outcomes, 2) review the contemporary use of endoscopes for middle ear surgery, and 3) highlight critical areas in EES needed for future outcomes research.

Methods

Search Strategy

A review of the literature was conducted to comprehensively identify articles related to endoscopic middle ear surgery. We utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analysis checklist and statement recommendations to guide this qualitative systematic review.[14] In June 2014, we searched PubMed, Embase, and the Cochrane CENTRAL database for relevant publications for all available dates. A principle electronic search strategy was designed for use in PubMed and then tailored for the other electronic databases. The initial search combined key endoscope terms, such as endoscope, endoscopic, and endoscopy and the following Medical Subject Headings (MeSH) terms: "Ear Canal/surgery"[MeSH Terms], "Ear, Middle/surgery"[MeSH Terms], "Ear, Inner/surgery"[MeSH Terms], "Ear Ossicles/surgery"[MeSH Terms], and "Tympanic Membrane/surgery"[MeSH Terms]. Additional publications were identified by reviewing the reference lists of articles in the search described above.

Inclusion and Exclusion Criteria

Studies must have been written in the English-language with a title, abstract, and full manuscript available. All study types, including case reports and case series, were included. Articles were then reviewed to confirm use of an endoscope in middle ear surgery. Full publications were obtained following initial selection of titles and abstracts. Two investigators independently reviewed articles for inclusion and exclusion criteria.

Study Extraction, Categorization, and Analysis

Articles were assessed for study size, location, setting, main outcome measures, complications, and conclusions. Each article was also reviewed for study design and assigned a level of evidence based on published guidelines by the Oxford Centre for Evidence-based Medicine-Levels of Evidence. Articles were categorized based on study design: case review, safety study, instrument study, review paper, surgical technique paper, anatomic study, and outcomes. These categories were derived *a priori* based on standard topics of endoscopic middle ear surgery. Papers were subsequently subcategorized by their indication, inclusion of pediatric patients, and endoscope usage (simple observation versus visualization during dissection). Data were sorted and summarized by the major categories. A meta-analysis could not be performed due to the marked heterogeneity and quality disparities among the studies. As the information available was limited in nature, the data was analyzed using descriptive statistics alone.

Results

Search Results for Endoscopic Ear Surgery

The primary search strategy initially identified 234 articles. The study selection process is illustrated in Figure 1. A complete list of reviewed articles is available from the authors on request. The 234 articles identified in the primary search strategy comprised 910 references. Including the references contained in these 910 articles brought the total number of articles to 1144. Of these referenced articles, 1053 were excluded due to duplicates (n=523), non-English language (n=55), endoscopic ear surgery of the inner ear (n=45), and studies completely unrelated to endoscopic ear surgery (n=422). After the above screening, the total number of articles qualified for review was 91.

The first article identified on endoscopic middle ear surgery was published in 1967, and there has been a steady increase in the number of papers since, peaking in 2013 with 17. (Figure 2) Important to understanding the dissemination of the technique, papers on the topic of endoscopic ear surgery have a broad distribution in the country of origin. In contrast to observational endoscopic ear surgery, the majority of papers that investigate operative endoscopic ear surgery originated from countries other than the United States (Figure 3).

Use and Indications for Endoscopic Ear Surgery

There has been an increase in the number of publications on both observational and operative endoscopic ear surgery. Outcomes papers are most common, followed by anatomic and surgical technique papers. Other categories of papers have remained fairly constant over time (Figure 4). Major indications for the use of endoscopic middle ear surgery include cholesteatoma and myringoplasty, among others (Table 1).

Outcomes in Observational Endoscopic Ear Surgery for Cholesteatoma

Systematic review demonstrated two types of observational endoscopic surgery for cholesteatoma. While some authors simply used the endoscope during second-look procedures, others employed the endoscope during the primary resection. In terms of papers reporting endoscope use during second-look procedures, residual cholesteatoma was identified in up to 50% of cases that only used the microscope. (Table 2) Most common sites of residual cholesteatoma included sinus tympani, epitympanum, facial recess, attic, and mastoid cavity. A variety of operative approaches were employed with endoscopes, including canal wall up (CWU) and canal wall down (CWD) procedures. The articles ranged from 10 to 294 patients with a wide scope of follow-up time, spanning 3 months to 12 years. Greater than 50% of these cases described the application of endoscopes in the pediatric population. Complications include a minority of patients with sensorineural hearing loss (SNHL) after endoscopic ear surgery. The level of evidence for these cases was consistently 3 or 4.

Outcomes in Operative Endoscopic Ear Surgery for Cholesteatoma

Eleven publications describing cholesteatoma surgery performed exclusively with an endoscope were identified. (Table 3) The number of procedures in each article ranged from 14 to 146 procedures with a wide range of follow-up time, spanning 16 months to 43 months. The conversion from endoscope to a traditional microscope occurred in 4.3 to 23.8% of procedures. Many of these studies did not provide robust analysis of follow-up data. No publications report wound healing outcomes or quality of life measures. It is important to note that there were several studies by the same authors that may have included analysis of the same cohort of patients in more than one paper. The level of evidence for these cases was either 3 or 4.

Outcomes in Operative Endoscopic Ear Surgery for Other Middle Ear Procedures, including Cochlear Implantation

Thirteen publications describing operative endoscopic surgery in the middle ear for indications beyond cholesteatoma were identified. (Table 4, online supplement) These publications describe operative endoscopy for several indications such as myringoplasty, tympanoplasty, ossiculoplasty, and cochlear implantation. These articles vary greatly in terms of number of procedures (6 – 165), indications, follow-up length, and aims of studies. The follow-up range was between 8 weeks and 36 months. The majority of papers did not include use of microscope during surgery. A minority of papers reported complications, including iatrogenic cholesteatoma in TM and worsening of bone conduction. Similar to previous articles for cholesteatoma, the papers included pediatric patients and had a level of evidence of 3 or 4. Of note, more recent articles have described the use of endoscopes in placing a cochlear implant. In 18 of 19 described cases, electrode insertion via endoscopy was achieved. Few complications were noted, including chorda tympani injury (n=1).

Outcomes in Pediatric Endoscopic Ear Surgery

Many of the articles reviewed in Tables 2–4 demonstrate the use of endoscopes in the pediatric population. These articles, however, do not stratify outcomes based on age. We also identified three publications focused solely on pediatric outcomes in endoscopic ear surgery.[8,11,12] The indications for pediatric cases were cholesteatoma and anatomical description of middle ear structures during otitis media. Articles contained a range of procedures (10 to 44), as well as follow-up times (0 months to 9 years). Of the papers using the endoscope for observation, residual cholesteatoma was identified equally between endoscopes and microscopes. Other outcomes, including audiometric data and long term recurrence rates were not listed. The level of evidence for these cases was either 3 or 4.

Discussion

The use of the rigid endoscope for middle ear surgery should be thought of as either an observational adjunct or as an operative tool. Given current research it appears that otologists are experiencing a debate as to the relative merits of the endoscope in ear surgery, similar to the way endoscopes were introduced to paranasal sinus surgery in the 1990s. A review of published literature identified 91 articles that describe various aspects of both observational and operative endoscopic middle ear surgery. In recent years, there has been an increase in publications, likely reflecting a rise in surgeon acceptance and comfort with the endoscope. Primary indications for endoscopic ear surgery include cholesteatoma and myringoplasty; however, the literature reflects a breadth of other experimental uses for the endoscope in middle and inner ear surgery.

Observational endoscopic ear surgery has historically been the most common application, and this is reflected in the size and scope of publications. The recent description of operative endoscopic ear surgery is relegated to a few surgeons. The reason for this difference is unclear. Several possibilities exist: operative endoscopic ear surgery remains in its nascency and is not yet widely adopted; use of endoscopes is technically challenging due to a one-handed approach and the lack of optimized instruments; or bias exists in the literature with research containing negative findings remaining unpublished.

Observational endoscopic ear surgery has been subjected to outcomes review. Its role in the localization of residual cholesteatoma in both primary and secondary cases appears to be high yield. Consistently, authors noted utility of the endoscope for identifying “hidden” cholesteatoma not identified by the microscope. Authors frequently cite the sinus tympani, epitympanum, facial recess, attic and mastoid cavity as locations for residual disease. Unfortunately, given the heterogeneity of available data, it is difficult to provide compiled quantitative findings; that said, endoscopes consistently identify cholesteatoma in up to 50% of cases.

More recent articles have investigated the feasibility of an endoscope as a microscope replacement. These studies demonstrate the safety profile of endoscopes in pediatric and adult patients without significant evidence of complications. Papers detailing operative endoscopic middle ear surgery for cholesteatoma did not typically perform second look procedures, making assessment of residual cholesteatoma challenging. Long-term clinical follow up is similarly lacking and no reports on the success of reconstruction and recurrence of cholesteatoma have been published. Only a small number of cases report complications.

Research has demonstrated the ability to both observe and operate with an endoscope in the pediatric population. Transcanal visualization of the tympanic space has been demonstrated to be possible in the pediatric population. One might posit that endoscopic transcanal approaches for tympanoplasty or cholesteatoma would decrease morbidity associated with a post-auricular incision and mastoidectomy. Outcomes for pediatric cases, however, are not well described with published papers focusing on anatomy and surgical technique. No papers were identified with both adult and pediatric outcomes that stratify outcomes by age.

How does the available data on endoscopic ear surgery influence otologic practice? At the most basic level, the current literature demonstrates the adequate safety profile of the use of endoscopes in pediatric and adult patients without significant evidence of complications. There is also a clear advantage to the use of the endoscope for the identification of additional pathology. Given available evidence, it seems reasonable to recommend routine use of the endoscope for surveillance, both in the operating room and in the clinic.

Literature on operative endoscopic ear surgery is limited. The field is clearly still in its early stages and more data must be obtained before the endoscope could be recommended as a replacement for the microscope. Operative endoscopic ear surgery is currently practiced by a small set of individuals, likely with specialized training. Broader comfort with observational endoscopic ear surgery may lead to a richer adoption of operative endoscopic ear surgery and hopefully with it - a more mature literature base.

Few of the papers identified provide a direct microscope to endoscope comparison. Available data are further complicated by the variegated use of the endoscope during the primary and secondary procedures procedure, as well as variable follow-up and use of post-operative Computer Tomography scans (CT). Looking forward, audiometric analyses, case length, wound healing, post-operative pain, and patient and provider satisfaction surveys should be part of new outcomes-focused comparison studies. Prospective trials with surgeons skilled in both traditional and endoscope-based techniques are clearly needed to demonstrate the utility of operative endoscopic surgery. Trials are also needed to accurately document the risk profile of operative endoscopic ear surgery so that otolaryngologists can provide an informed consent to patients. Once the optimal technique for the carefully selected patient is determined, a balanced approach to the use of endoscopes may be better taught at temporal bone courses and incorporated into the otolaryngology community.

There are several weaknesses of the present study. First, our search criteria may have missed articles that describe endoscopic ear surgery. Our search criteria lead to the examination of papers over a 50-year period, during which time the evoluation in terms for endoscopic surgery, and in particular MeSH terms, evolved, making identification of all studies involving endoscopic ear surgery challenging. Our search, however, was broad, and we performed a comprehensive review of references of our primary article cohort. Consequently, we believe that we captured the majority of literature published on this subject matter. Second, there may have been bias introduced into our systematic review due to our exclusion criteria. Non-English articles may have yielded additional studies deserving review, especially on the topic of operative endoscopic ear surgery. Finally, many of the papers described herein have non-standardized approaches to describing outcomes data. Indeed, this systematic review largely analyzed a group of case series. As part of the data analysis, best attempts were made to fit disparate data into comparable and interpretable datasets. We acknowledge that some of data reorganization is subject to author interpretation. In order to address this limitation, three authors independently reviewed all papers for accuracy.

In summary, this study demonstrates that there is a growing body of literature, both in depth and breadth, on the use of endoscopic ear surgery. There is clear benefit of observational endoscopic ear surgery, enabling improved visualization of the tympanic cavity and discovery of hidden, residual disease. The aforementioned data signal the need for routine use of the endoscopes as an adjunct to operative microscopes in cholesteatoma surgery. Operative endoscopic ear surgery is still in its infancy and currently lacking high-quality outcomes data. Rigorous and standardized approaches to publication on operative endoscopic ear surgery are needed. Comparison cohorts, detailed audiometric and wound healing outcomes, operating room times, as well as and evaluation of quality of life measures should be included in reported outcomes going forward.

Conclusion

At present, endoscopes in middle ear surgery are predominately employed as an adjunct to the microscope and enable improved visualization of the tympanic cavity. More recent reports illustrate utilization of the endoscope during surgical dissection; however, patient outcomes comparing the operative endoscope versus the microscope are lacking. Further research is needed in the field of operative EES.

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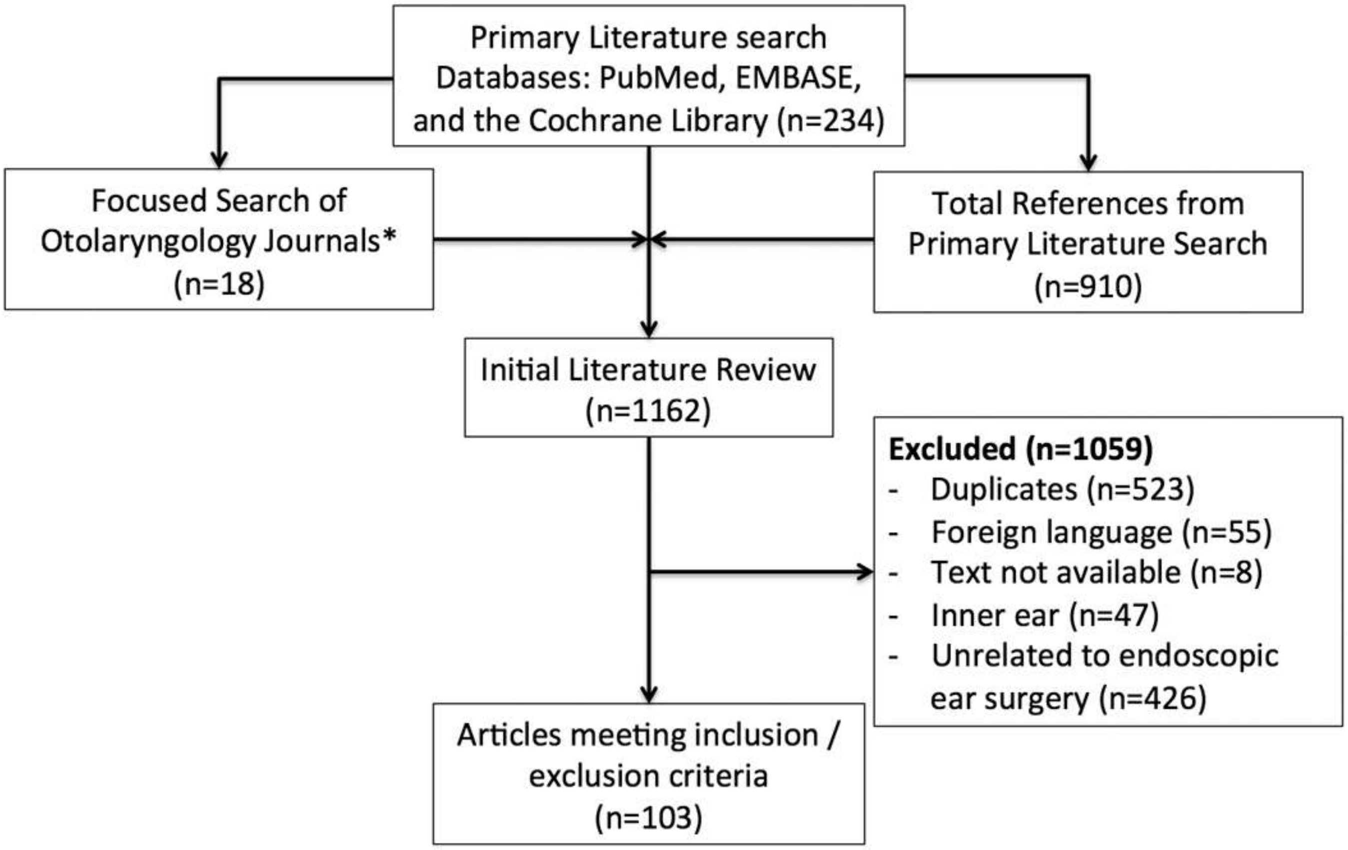

Figure 1. Search Strategy for Systematic Review

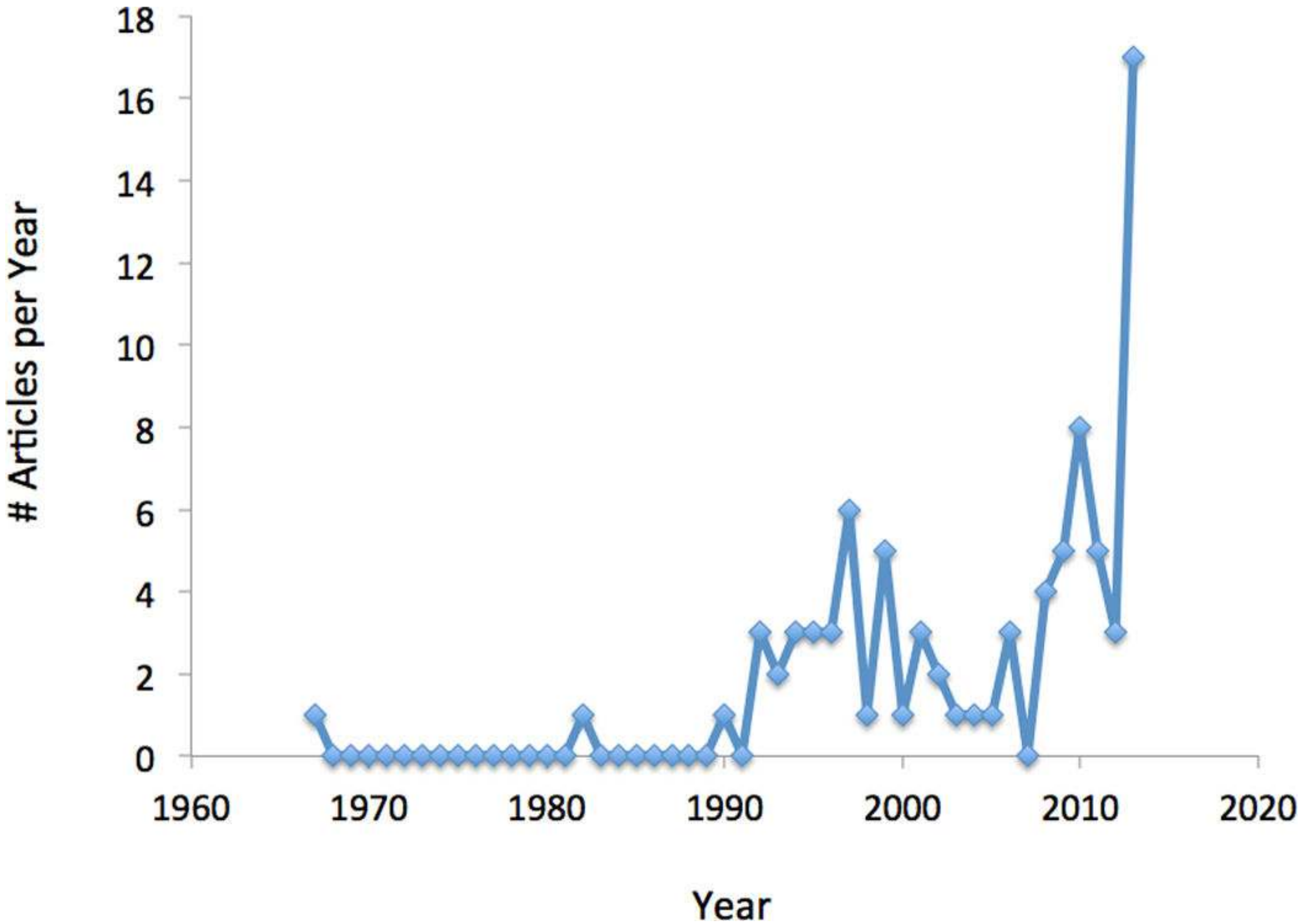

Figure 2. Number of Articles Related to Endoscopic Ear Surgery per Year

Figure 3. Geocoding Article Location Based on Corresponding Author Location

3A: Location of article publication on observational endoscopic ear surgery. 3B: Location of article publication on operative endoscopic ear surgery.

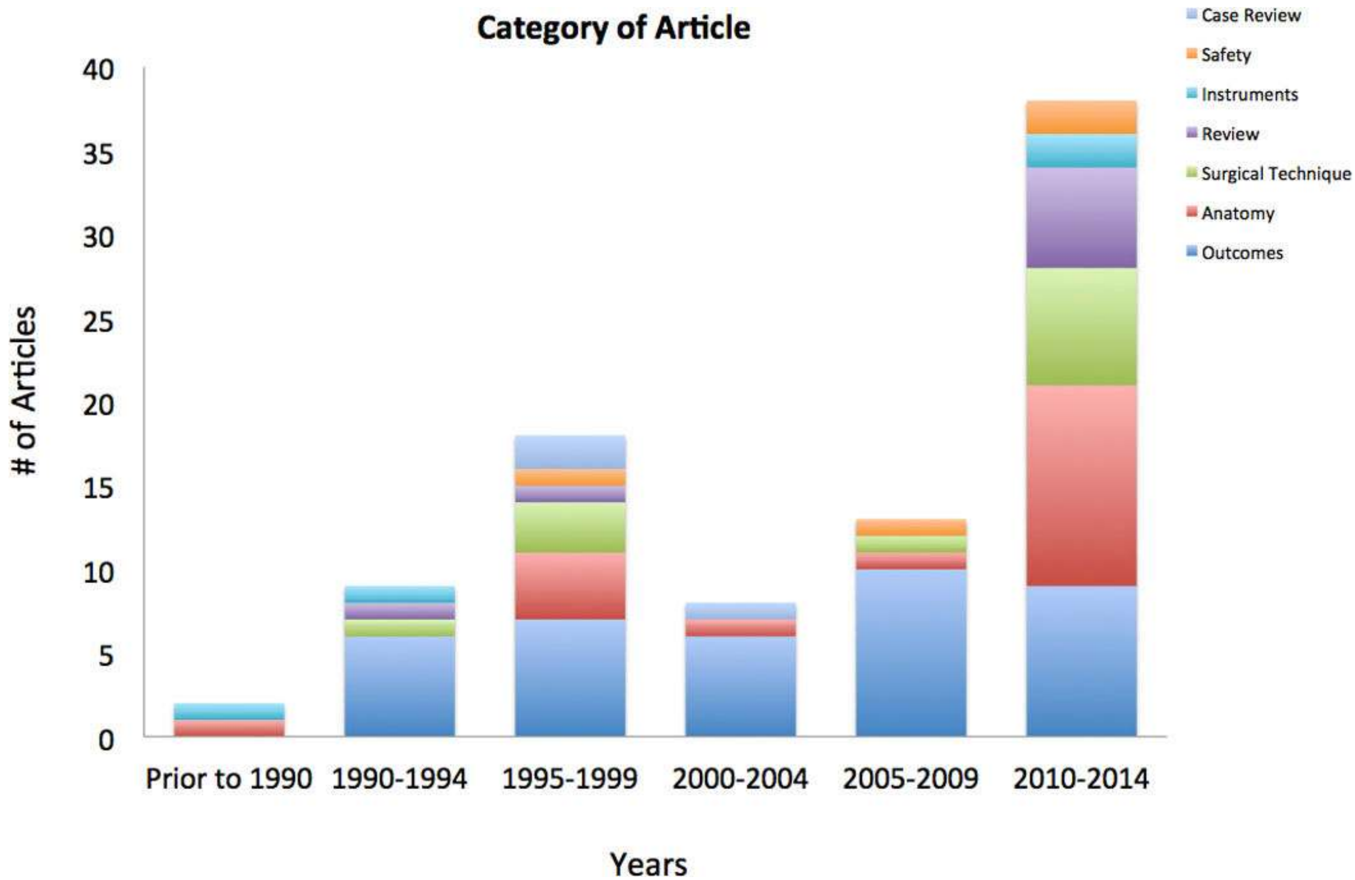

Figure 4. Breakdown of Category of Article on Endoscopic Ear Surgery

*This systematic review excluded publications unrelated to endoscopic middle ear surgery, such as endonasal approaches and unrelated surgical instruments.

Table 1

Indications for Endoscopic Ear Surgery

Indications
Cholesteatoma
Myringoplasty
Attic retraction pocket
Cochlear implant
Perilymph fistula
Chronic suppurative otitis media
Tympanoplasty
Paraganglioma
Carcinoid tumor
Osteoma
Stapedectomy
Ossiculoplasty
Granular myringitis
Evaluation of ossicular continuity

Table 2

Use of Endoscopes Predominately for Observation in Cholesteatoma Procedures

	Experimental Design	1° procedures	Residual at 1° procedure	Mean Follow-up (Range)	Cholesteotoma found during second-look	Pediatric patients?
Thomassin, 1993[10]	Group A: microscope alone. **Group B** microscope + endoscopy. Second-look with endoscope.	Group A= 36; **Group B**=44	N/A	N/A (12–18 months)	Group A=47.7% (n=21); Group B=5.5% (n=2)	Yes (n=20)
Rosenberg, 1995[11]	Endoscope for second-look, then microscopic confirmation.	10*	N/A	N/A (8 mos–9 yrs)	50.0% (n=5)	Yes (n=10)
Youssef, 1997[15]	Endoscope for second-look, then microscopic confirmation.	13*	N/A	N/A (6–12 mos)	23.1% (n=3)	Yes (n=5)
Haberkamp, 1999[13]	Endoscope for second-look, then microscopic confirmation.	15	N/A	N/A	Endoscope: 20.0% (n=1); microscope 50% (n=5)	Unk
Good, 1999[12]	Endoscope as microscope adjunct during 1° procedure. Second-look only performed in select patients.	29	24.1% (n=7)	6.4 mos (12–18 mos)	18.2% (n=2 of 11)	Yes (n=29)
Badr-El-Dine, 2002[16]	Endoscope as microscope adjunct during 1° procedure. Second-look with endoscope for both observation and dissection.	92	22.8% (n=21)	N/A (9–12 mos)	8.6% (n=3 of 35)	Unk
El-Meselaty, 2003[17]	Group A: endoscope used as microscope adjunct during 1° procedure for observation and dissection. Group B: 1° procedure performed with microscope alone. Second-look with endoscope for observation and dissection	**Group A**= 40 Group B= 42	Group A = 40.0% (n=16)	14.5 mos (12–18 mos)	Group A=0% (n=0 of 5); Group B=42.9% (n=3 of 7)	Yes
Ayache, 2008[18]	Group A: 1° procedure performed with microscope alone. **Group B** Endoscope as microscope adjunct during 1° procedure for observation and dissection	Group A= 157 **Group B**= 80	Group B = 44% (n=35)	N/A	37.5% (n=6 of 16)	Yes
Presutti, 2008[19]	Endoscope as microscope adjunct during 1° procedure for observation and dissection. Second-look performed in select patients.	32	37.5% (n= 12)	34 mos (N/A)	16.7% (2 of 12)	Unk
Badr-El-Dine, 2009[20]	Endoscope as microscope adjunct during 1° procedure for observation and dissection. Second-look performed in select patients.	294	16.7% (n=49)	28.2 mos (N/A)	8.6% (n=8 of 93)	Unk

*Note: 1 microscope only; 1° = primary; n = number of procedures; mos = months; yrs = years; unk = unknown.

Table 3

Operative Endoscopic Ear Surgery in Cholesteatoma Surgery

	n*	Mean Follow-Up (Range)	Second - Look/ Revisions	Evidence of Cholesteatoma	Conversion to Microscope?	Hearing outcomes?	Pediatric patients?	Complications	Level of Evidence
Yung, 1994[9]	92	N/A	N/A	N/A	Case started with microscope	N/A	Unknown	N/A	4
Bottrill, 1995[21]	14	7 (6–12) mos	Yes	3 of 9 (33.3%)	Yes (n=2 for 1° procedure; n=2 for second-look procedure)	N/A	Yes	No	4
Tarabichi, 1997[22]	36	N/A (0–2 yrs)	Yes	n=4 (unk %)	No	Yes	Yes	Tympanic membrane defect (n=9), 15dB worsened bone conduction at 3,000 Hz (n=1)	4
Tarabichi, 2000[23]	69	41 mos (N/A)	Yes (n=6)	Unk	Yes (4.3%, n=3)	Yes	Unknown	15dB worsened bone conduction at 3,000 Hz (n=1)	4
Yung, 2001[9]	231	N/A (1–12 yrs)	Yes	19 of 231 (8.2%)	Case started with microscope	N/A	Yes	N/A	4
Tarabichi, 2004[24]	73	43 mos (N/A)	Yes	n=6 (Unk %)	No	Yes	Yes	N/A	4
Barakate, 2008[25]	68	16 mos (N/A)	Yes	14 of 68 (20.6%)	Yes (5.9%, n=4)	N/A	Yes	N/A	4
Marchioni, 2009[26]	21	23 mos (N/A)	No	N/A	Yes (23.8%, n=5)	Yes	Unknown	No	4
Migirov, 2011[27]	30	N/A (0–1 year)	No	N/A	No	Yes	Yes	Worsening of sensorineural hearing loss (n=2)	4
Marchioni, 2011[28]	68	18 (6–48) mos	Yes	3 of 23 (13.0%)	No	No	Unknown	No	4
Marchioni, 2013[29]	146	31.2 mos (N/A)	Yes^	11 of 146 (7.5%)	Yes (17.8%, n=26)	No	Yes	N/A	4

* n = number of procedures; mos = months; yrs = years; unk = unknown.

^ = Follow-up consisted of in office exam and CT scans.

Table 4

Operative Endoscopic Ear Surgery for Other Middle Ear Procedures, including Cochlear Implantation (Online Supplement)

Publication	Indication	n*	Mean Follow-Up (Range)	Use of Microscope	Major Finding		Complication	Pediatric patients	Level of Evidence
El-Guindy, 1992[30]	Myringoplasty	36	N/A (1.5–6 mos)	No	Graft take rate was 91.7% (n=33) and the air-bone gap was closed to less than 10 dB in 83.3% (n=30)	N/A	N/A	No	4
Tarabichi, 1999[31]	Several	165	Varies by indication	No	Transcanal approach was used without conversion to postauricular open approach in all tympanoplasty procedures (n=96) and 50 of 53 procedures performed for acquired cholesteatoma.	Yes	Worsening bone conduction (15-dB at 3 kHz) (n=1), blunting of anterior sulcus (n=3), TM cholesteatoma pearl formation (n=1)	Yes	4
Usami, 2001[32]	Myringoplasty	22	24.5 (6–36) mos	No	Closure of the perforation was seen in 18 of 22 ears. Reduced air-bone gaps were seen in all ears.	N/A	N/A	Yes	4
Jang, 2006[33]	Granular myringitis	21	11 (3 –2.6 yrs) mos	No	18 of 21 patients were cured after a single treatment, 3 of 21 required multiple treatments. No recurrences observed during follow-up.	No	N/A	Unknown	4
Kakehata, 2006[34]	Ossiculoplasty	9	17 (7–24) mos	No	Average hearing level improved from 59 dB to 27 dB post-surgically, with an average air-bone gap of 11 dB.	Yes	Inserted cartilage bent (n=1)	Yes	4
Yadav, 2009[35]	Myringoplasty	50	8 wks (N/A)	No	Successful graft uptake in 80% of patients. Of these patients, air-bone gap showed a >20 dB improvement in 1 patient, 11 to 20 dB improvement in 30 patients, and 0 to 10 dB improvement in 9 patients.	N/A	N/A	No	4
Marchioni, 2010[36]	Several	27	20.1 mos (N/A)	Yes	5 patients received microscopic meatoplasty prior to transcanal approach. Mastoid bone was preserved in all 21 of 27 patients presented with no recurrence of disease at follow-up.	No	N/A	Unknown	4
Konstantinidis, 2012[37]	Myringoplasty	82	N/A (0–6 months)	No	Closure of the perforation was seen in 85.4% of patients. Closure rate decreased when size of the perforation was >30% of the pars tensa.	No	N/A	No	3
Ayache, 2013[38]	Myringoplasty	30	N/A (2–12 mos)	Yes	Preoperative microscope revealed total exposure in 27% of cases vs. 100% in endoscope cases. 96% of patients had a closed perforation at 1 year follow up.	Yes	Iatrogenic cholesteatoma in TM (n=2)	Yes	4
Marchioni, 2013[39]	Several	6	8.5 (5–18) mos	No	Exclusive endoscopic transcanal approach used in all patients. No pathology recurrence at follow-up.	No	N/A	No	4

Publication	Indication	n*	Mean Follow-Up (Range)	Use of Microscope	Major Finding		Complication	Pediatric patients	Level of Evidence
Furukawa, 2014[40]	Myringoplasty	25	9.8 (5–18) mos	Yes	Greater visualization of the tympanic membrane and perforation edges with the endoscope (25/25) compared to microscope (20/25).	N/A	N/A	Yes	4
Migirov, 2014[41]	Cochlear implant	13	N/A (0–4 yrs)	No	Complete electrode insertion via the round window was achieved and the chorda tympani nerve was preserved in all cases.	No	N/A	Yes	4
Marchioni, 2014[42]	Cochlear implant	6	7.3 (1–11) mos	No	In 5 of 6 patients, the endoscopic cochlear implant was placed without complications.	Yes	Chorda tympani injury (n=1)	No	4

*n = number of procedures; wks = weeks; mos = months; yrs = years; unk=unknown.