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Review Article

Surgical management of petrous apex cholesteatomas in the pediatric population: A systematic review

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ABSTRACT

Background: Cholesteatomas are growths of squamous epithelium that can form inside the middle ear and mastoid cavity and damage nearby structures causing hearing loss when located at the petrous apex. The primary goal of petrous apex cholesteatoma resection is gross total removal with tympanoplasty and canal-wall up or canal-wall down tympanomastoidectomy. At present, there is no definitive surgical approach supported by greater than level 4 evidence in the literature to date.

Methods: A systematic review was conducted utilizing PubMed, Embase, and Scopus databases. Articles were screened and selected to be reviewed in full text. The articles that met inclusion criteria were reviewed for relevant data. Data analysis, means, and standard deviations were calculated using Microsoft Excel.

Results: After screening, five articles were included in the systematic review. There were a total of eight pediatric patients with nine total cholesteatomas removed. Conductive hearing loss was the most common (77%) presenting symptom. Perforations were noted in seven ears (86%). Recurrence was noted in 50% of patients with an average recurrence rate of 3.5 years (SD = 1.73). Average length of follow-up was 32.6 months (SD = 21.7). Canal-wall up was the most utilized technique (60%) and there were zero noted surgical complications. Five of the seven (71%) patients that experienced hearing loss from perforation noted improved hearing.

Conclusion: Due to its rarity, diagnostic evaluation and treatment can vary. Further, multi-institutional investigation is necessary to develop population-level management protocols for pediatric patients affected by petrous apex cholesteatomas.

Keywords: Cholesteatoma, Petrous apex, Skull base, Pediatric neurosurgery

INTRODUCTION

Cholesteatomas are abnormal growths of keratinizing squamous epithelium arising within the middle ear and mastoid cavity.[11,18,29] Cholesteatomas are typically benign, but if untreated, they may expand and erode the ossicles of the middle ear and other infratemporal structures, potentially leading to conductive hearing loss, otomastoiditis, facial nerve palsy, abscesses, and

rarely death.[18] Cholesteatomas remain a rare but serious cause of death, especially in children who lack access to proper medical care, with an incidence of 3–6/100,000 in the pediatric population.[18,28] Children have a higher rate of incidence than adults for developing cholesteatomas and are more susceptible to disease recurrence.[28] Pediatric populations are thought to be at a higher risk of developing these lesions due to immature eustachian tube function, higher rates of otitis media infections, and immature temporal bones.[34] Cholesteatomas can be congenital or acquired, with acquired cholesteatomas comprising most of these lesions.[13,23,24] Congenital cholesteatomas are less common and responsible for approximately 28% of pediatric cholesteatomas.[24] The petrous apex, located at the medial aspect of the temporal bone between the greater wing of the sphenoid bone anteriorly and occipital bone posteriorly, is an especially rare location for cholesteatoma formation.[4,39] Cholesteatomas of the petrous bone account for 4–9% of all petrous bone lesions and are commonly found incidentally on imaging of the head and neck.[16,23] When symptomatic, patients commonly present with hearing loss and/or facial palsy, affecting their quality of life.[16] If asymptomatic, small, or demonstrating minor growth, petrous apex cholesteatomas may be monitored with serial imaging. Surgery is often required for definitive treatment, however, with the goal of gross total resection and to minimize recurrence.[3] There are several possible operative approaches including transsphenoidal, transpalatinal-transclival, and middle cranial fossa.[30] Dedicated postoperative surveillance is vital to monitor surgical morbidity and lesion recurrence. While information regarding pediatric cholesteatomas is well defined in the literature, the management of pediatric petrous apex cholesteatomas is poorly discussed. This systematic review aims to cover the demographics, genetics, pathogenesis, clinical presentation, radiology, surgical management, and postoperative management of pediatric cholesteatomas at the petrous apex.

MATERIALS AND METHODS

A systematic search for eligible literature describing pediatric cholesteatoma at the petrous apex was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analysis 2020 guidelines.[27] PubMed MEDLINE (National Library of Medicine), Embase (Elsevier), and Scopus (Elsevier) databases were extensively queried using the specific keywords, including *pediatric cholesteatoma, petrous apex, cholesteatoma, children, neurosurgical, and skull base*. Every database was searched from its beginning and without any language or date restrictions. All search results were exported into a spreadsheet and duplicate articles were removed. The remaining articles were manually screened based on title and abstract for relevance. Unique full-text publications were then reviewed for inclusion and exclusion criteria. Inclusion criteria included pediatric cholesteatomas at the petrous apex (18 years of age or younger), surgical management of cholesteatomas, and outcomes of intervention specific to children and adolescents, with these published in the English language. Exclusion criteria included cholesteatomas in nonpediatric patients, cholesteatomas that were not located at the petrous apex, articles that did not mention surgical management or techniques, and any of the following article types: abstracts for conferences, reviews, meta-analyses, letters to the editor, and commentaries. Article inclusion discrepancies were discussed and resolved by consensus [Figure 1]. Once the final papers were selected, the studies were reviewed for designated a priori characteristics such as aim, design, participants, operative and postoperative details, outcomes, and length of follow-up. The primary outcomes of interest were presenting symptoms, initial imaging ordered, major complications (including reoperations), mean age of patient at diagnosis and surgical intervention, type of surgical intervention used, extent of resection, and average length of follow-up. Data analysis, including mean and standard deviations, was calculated using Microsoft Excel (Microsoft Co., Redmond, WA,

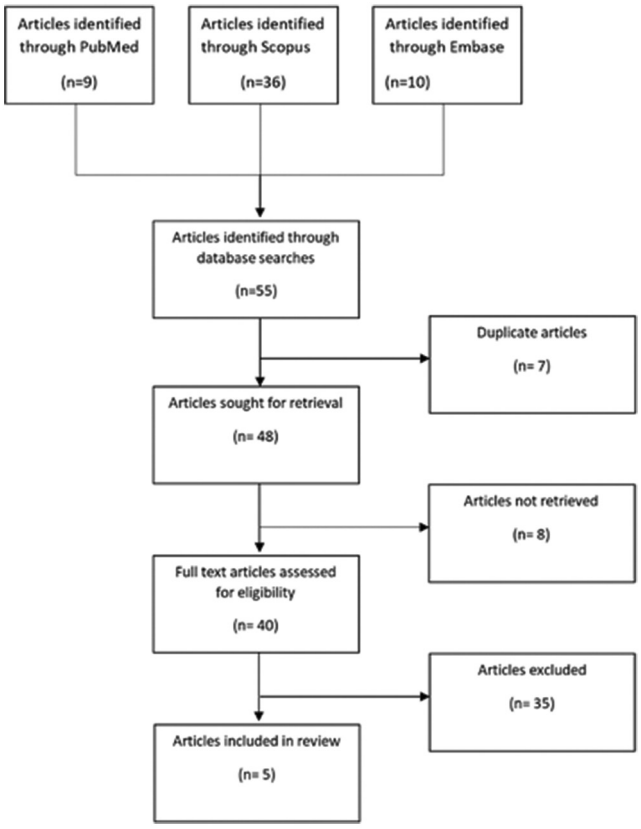

Figure 1: PRISMA flowchart highlighting inclusion and exclusion process for systematic review.

USA). The quality of each study was evaluated through the grading of recommendations, assessment, development, and evaluations framework.[14] The risk of bias was assessed through the risk of bias in nonrandomized studies of interventions tool.[35] A judgment of the risk of bias for the entire study was determined by the aggregate data of the bias of the individual studies.

RESULTS

A review of the literature yielded five articles that met inclusion criteria,[12,22,26,37,38] four of which were case reports and one a retrospective cohort study. There were eight pediatric patients (63% males) with cholesteatomas of the petrous apex that was surgically removed in nine total ears within this systematic review. Conductive hearing loss was a presenting symptom in seven (88%) of the children with one patient having a mixed conductive and sensorineural hearing loss. All patients underwent a CT or MRI scan to image the cholesteatomas, while 25% had a non-echo-planar DWI. One case report specifically mentioned wanting to get a confirmatory DWI scan, but could not due to dental hardware. Only one patient had bilateral cholesteatomas, while the rest had unilateral ones with 86% being on the left side. There was involvement of the internal carotid artery and facial nerve in only two of the children (25%). Perforations were noted in seven ears (78%) with the most common being in the attic and posterosuperior portions of the tympanic membrane. Mean age of diagnosis and surgical intervention was 10.25 years (SD = 4.63). Recurrence was reported in 50% of the patients. The average rate of recurrence was 3.5 years (SD = 1.73). Average length of follow-up was 32.6 months (SD = 21.7) with one article not reporting this data. The most utilized surgical techniques were the canal-wall up (CWU) and tympanostomy (60%) with other articles utilizing translabyrinthine-transcochlear (transotic), retrosigmoid, and transmastoid approach. All four patients in the case reports had a complete resection. Extent of resection was not specified in the retrospective cohort review. No technical complications were reported in any of the studies included. Adjuvant therapy was not required for any patients in the follow-up period aside from surgical resection following recurrence. Following surgical intervention, five out of the seven (71%) patients that experienced perforations had improvement in their hearing loss. The overall risk of bias in this study was high [Table 1].

DISCUSSION

We present a systematic and narrative review on the surgical management and outcomes of cholesteatomas of the petrous apex in the pediatric population. Outcomes investigated include presenting symptoms, initial imaging ordered, major complications (including reoperations), mean age of patient at diagnosis and surgical intervention, type of surgical intervention used, extent of resection, and average length of follow-up. In addition, we include a case of a 17-year-old patient presenting with a cholesteatoma of the external auditory canal with mastoid involvement [Figure 2]. Due to the paucity of the literature of cholesteatomas at this anatomic location in pediatric patients, the goal of this study is to increase awareness of this pathology and improve overall care.

Etiology

Cholesteatomas represent one of the most common pathologies of the petrous apex.[25] Sanna *et al*. have previously classified petrous bone cholesteatomas into five main groups, including apical, massive, infralabyrinthine-apical, supralabyrinthine, and infralabyrinthine, with the majority being supralabyrinthine.[33] Congenital cholesteatomas belong to the larger class of CNS epidermoid cysts, which are inclusion bodies of epidermal material that remains and becomes included within the neuroaxis during embryogenesis, and which represent approximately 1% of CNS tumors.[22] An important factor differentiating congenital and acquired cholesteatomas is involvement of the tympanic membrane. While acquired cholesteatomas are typified by their association with the tympanic membrane, congenital cholesteatomas arise independent of the tympanic membrane. Altogether, cholesteatomas form as cystic collections – whether congenitally or in the acquired manner – that expand as they accumulate keratin, cholesterol, and fatty debris. Precipitating factors for acquired cholesteatomas explain their close association with the tympanic membrane: these lesions usually form due to tympanic membrane trauma (resulting in perforation, retraction, or invagination), tympanic membrane disease, or tympanic cavity mucosal pathology.[21]

Symptomatology

As epidermoid cysts of the petrous portion of the temporal bone, congenital petrous bone cholesteatomas may initially be asymptomatic if they extend in the direction of the nonpetrous portion of the temporal bone, leaving the tympanic membrane unscathed.[26] Alternatively, physical examination may reveal purulent otorrhea in the affected ear. Due to their proximity to and potential involvement of the cochleovestibular labyrinth, otic capsule, facial nerve, and dura mater of the meninges, cholesteatomas often manifest with hearing loss, headache, dizziness, otorrhea, and facial paralysis.[26] Deteriorations in conductive hearing and facial nerve function will generally occur gradually.[22] Interestingly, in the case described by MacKeith *et al*., the patient presented with recurrent aseptic meningitis as a result of a congenital petrous apex cholesteatoma.[22]

Table 1: Articles that met inclusion criteria from systematic review performed.

Paper	Authors	DOI	Country	Study Design	Risk of Bias	Number of pediatric cholesteatomas diagnosed	Mean age at diagnosis (years)	Gender	Unilateral or bilateral	Imaging	Perforation areas	Involvement of other areas	Mean size of cholesteatoma at diagnosis	Mean age at surgery (years)	Type of operation	Extent of resection	Recurrence	Mean blood loss	Adjuvant therapy	Complication percentage	Presentation hearing loss	Post op hearing loss	Mean length of follow up
Subarcuate supralabyrinthine approach for supralabyrinthine petrosal cholesteatoma[38]	Van Dinther *et al.*	10.1 177/0003489411900108	Belgium	Case report	High	1	18 years	Female	Unilateral- left	CT, MRI (T1, T2), non–echo-planar DWI	Posterosuperior portion of TM	Filled mastoidectomy cavity extended laterally, superiorly, and medially to the SSC via supralabyrinthine extension eroded the tegmen tympani destroyed the bony layer covering the geniculate ganglion and the labyrinthine segment of the facial nerve, reached the internal auditory canal	Not recorded	20 and 18	Initial: resection Recurrence: Surgical revision comprised a conventional canal-wall up technique with wide posterior tympanotomy	Complete	Yes	Not recorded	None	Not recorded	Left-sided conductive hearing loss with an air-bone gap of 48.3 dB hearing level (HL) on pure-tone average (PTA) frequencies (500, 1,000, and 2,000 Hz).	Improved	24 months, no recurrence
Endoscope-Assisted Surgery for Petrous Bone Cholesteatoma with Hearing Preservation[26]	Orhan *et al.*	10.5152/iao. 2019.7212	Turkey	Retrospective chart review	High	Total 8 patients, with 4 being children	10.8 avg age among children	Male: 4 (100%)	Unilateral: 3 (2 left, 1 right) Bilateral: 1	MRI, CT	4 ears: Attic perforation 1 ear: posterosuperior portion of TM	Epithelium was filling mastoid cavity and the epitympanum perilabyrinthine space where between labyrinth, internal acoustic canal and middle fossa dura, was invaded by the cholesteatoma	Not recorded	10.8 avg age among children	Transmastoid, perilabyrinthine endoscope-assisted for all children Peds: Canal-wall down mastoidectomy with tympanoplasty	Not specified	1/4 (25%) with recurrence	Not recorded	None	Not recorded	4/4 with conductive hearing loss	Improved	1.6 years amongst children
Patient-specific 3D-printed Model-assisted Supracochlear Approach to the Petrous Apex[37]	Takahashi *et al.*	10.1097/ MAO.0000000000002720	Japan	Case report	High	1	5	Male	Unilateral- left	CT	Not recorded	Entire middle ear cavity, which had invaded the PA anterior to the SSCC and superior to the internal auditory canal	Not recorded	5	Initial: canal-wall up (CWU) mastoidectomy secondary: mastoidectomy, supratrochlear approach	Complete	not recorded	Not recorded	None	Not recorded	Could not assess	Not available	Not recorded
Piezosurgery-, neuroendoscopy-, and neuronavigation-assisted intracranial approach for removal of a recurrent petrous apex cholesteatoma: Technical note[12]	Grauvogel *et al.*	10.3 171/2017.8.PEDS17327	Germany	Case report Technical note	High	1	Inital diagnosis – 4-years-old; recurrences: 6, 10 (suspected), 14-years-old	Female	Unilateral- left	MRI, CT	Not recorded	On current presentation: around the facial nerve in its intrapetrous course and the internal carotid artery	Not recorded	Mastoidectomy: 4-years-old; resection: 6 years old surgery at 10-years-old, but no macroscopic sign of cholesteatoma; retrosignmoid craniotomy: 14-years-old	Mastoidectomy, resection (not specified), retrosigmoid crani with implementation of piezoelectric surgery, neuronavigation, neuroendoscopy, and neuromonitoring	1- Complete 2- Complete 3-Suspected, but no actually one 4- Complete	Yes (2- definitive)	Not recorded	None	Uneventful, no complications	Conductive hearing loss	Stable	6 years
Recurrent aseptic meningitis as a rare but important presentation of congenital petrous apex cholesteatoma: The value of appropriate imaging[22]	MacKeith *et al.*	10.1136/bcr-2013-010390	UK	Case report	High	1	18-years-old	Female	Unilateral- left	CT, MRI (T1, T2), non–echo-planar DWI	Dry perforation of the left tympanic membran	Contact with horizontal portion of ICA lateral portion in the infralabyrinthine area and the more medial portion also eroded through the posterior wall of the pyramid to be in contact with the posterior cranial fossa	Not recorded	18 y/o recurrence at 23 y/o	Transotic surgical excision, repeated procedure at recurrence	Complete	Yes	Not recorded	None	Not recorded	Conductive/ sensorineural hearing loss	Not specified	5 years

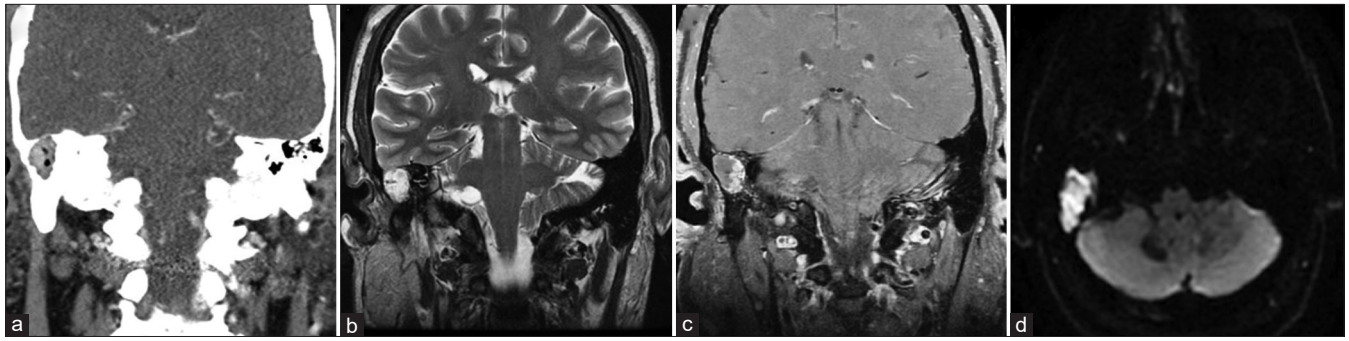

Figure 2: A case of a 17-year-old patient with a delayed presentation of a cholesteatoma after initially presenting as a trauma from a motor vehicle accident and right sided otorrhea. (a) Computed tomography scan demonstrated 2 cm mass in the right medial aspect of the external auditory canal involving the right mastoid consistent with a cholesteatoma. (b-d) Magnetic resonance imaging of the lesion demonstrating, (b) T2 signal hyperintensity, and (c) mild irregular peripheral enhancement on T1 sequences with contrast. (d) DWI sequences demonstrating avid diffusion restriction, a characteristic feature of cholesteatomas.

To categorize facial nerve deficits, clinicians can use the House–Brackmann grading system for facial nerve function. Furthermore, pure-tone audiogram (PTA) can be performed to assess for hearing loss, and speech discrimination testing can screen for changes in speech recognition thresholds at specific decibels (dB) of sound. Interestingly, although most patients with petrous bone cholesteatomas will present with at least one of the aforementioned symptoms, hearing will not always be affected. For example, in their retrospective case series of eight patients, Orhan *et al.* reported that of eight patients who underwent endoscope-assisted surgery for petrous bone cholesteatoma, four exhibited normal-range hearing on preoperative PTA.[26] This is not surprising, because children with petrous bone cholesteatomas normally present with fewer symptoms than adults who develop the lesion.[37] In fact, the literature indicates that pediatric congenital cholesteatomas can spare auditory and facial nerve function even when they invade the petrous bone. Nonetheless, a systematic approach to assessing preoperative hearing loss and facial nerve function, such as through performance of PTA and use of the House-Brackmann grading system, is essential in that it can enable clinicians to monitor for deficits and potential recurrence in the postoperative setting.

Diagnosis

In patients presenting with suspicion for cholesteatoma, choice of imaging can be critical for accurate and timely diagnosis. The standard approach for detection involves MRI non-echo-planar DWI as well as high-resolution CT scan.[7-10,12,19,38] In fact, MRI non-echo-planar DWI allows for extremely sensitive and specific detection of cholesteatomas >2 mm in size (with a sensitivity and specificity both approaching 100%).[38] Furthermore, DWI MRI comes with the added advantage of enabling clinicians to differentiate between varying lesions of the petrous bone, allowing cholesteatoma to be efficiently ruled in or out.[22] Aside from DWI, T2-weighted MRI, in combination with CT, represents an additional bread-and-butter imaging approach for diagnosing petrous bone cholesteatomas.[12] With respect to CT imaging, bone window CT is particularly useful and will often reveal bony erosion of the petrous bone.

In their case illustration, MacKeith *et al.* highlight the importance of choice of imaging in diagnosing and planning surgery for cholesteatoma.[22] Notably, the patient they describe experienced recurrent aseptic meningitis, with CT of the head appearing normal in each of the patient's first two episodes. Specifically, there were no pathological radiographic findings in either the middle ear, mastoid air cells, or sinuses. However, during the patient's third episode of aseptic meningitis, an ear, nose, and throat physician was consulted, and PTA was recommended. Physical examination was significant for the left tympanic membrane perforation but no otorrhea or other signs of infection, and the patient's PTA ultimately revealed a mixed conductive and sensorineural hearing loss averaging 65 dB in the left ear. Subsequently, the patient was sent for CT of the temporal bone with fine cuts and bony windows, as well as MRI of the skull base and cerebellopontine angle which revealed an erosive, expansile lesion of the left petrous apex medial to the cochlear that was hypointense on T1, noncontrast enhancing, and hyperintense on T2. Non-echo-planar imaging DWI MRI was employed to allow for differentiation between cholesteatomas and other typical lesions of the petrous apex. Although cholesteatomas, cholesterol granulomas, arachnoid cysts, and mucoceles are each cystic lesions of the petrous apex that appears hyperintense on T2, cholesteatoma is unique in that it is the only one of the four lesions that will appear bright due to diffusion restriction on DWI. In the case reported by MacKeith *et al*., the lesion appeared bright on DWI and confirmed the diagnosis of petrous apex cholesteatoma. Overall, due to its sensitivity

in detecting cholesteatomas >2 mm in size, specificity, and ability to differentiate between cholesteatomas and other common lesions of the petrous apex, non-echo-planar DWI should be the diagnostic choice of imaging – when coupled with CT scans – that clinicians use when cholesteatoma is suspected.[22]

In the case of recurrent aseptic meningitis reported by MacKeith *et al*., lumbar puncture for CSF analysis before initiation of antibiotics was instrumental in directing subsequent choice of imaging.[22] Notably, during the patient's second recurrence of aseptic meningitis, elevated levels of triglyceride and cholesterol were identified in the CSF. This finding is the likely result of rupture of the cystic cholesteatoma (epidermoid cyst) and release of keratin, cholesterol, and lipids into the subarachnoid space. Subsequent irritation of the meninges explains the presentation of recurrent aseptic meningitis in this patient.

Surgical approaches

Surgical approaches for petrous apex cholesteatomas that have been previously described include subtotal petrosectomy, translabyrinthine, infralabyrinthine, supralabyrinthine, and middle cranial fossa techniques. In general, the most important aspect of the surgical approach is that it is optimized to the specific location of the cholesteatoma and overall patient at hand, including their anatomical variation.

Each of the surgical approaches offers a unique set of benefits, and some can predispose to complications more than others [Table 2].[1,2,5,6,15,20,31,32,36] In certain instances, mastoidectomy is indicated in order to achieve maximal resection. For example, the canal-wall down (CWD) open mastoidectomy approach involves removal of the posterior semicircular canal which can afford superior visualization of the diseased middle ear anatomy.[12] This approach is associated with water entry and complications with hearing aid mold fitting making it generally unpopular in the pediatric population. However, CWD surgery can be justified in patients with a small mastoid and narrow ear canal.[16,17] On the other hand, in the CWU closed approach to mastoidectomy, middle ear anatomy is preserved, an advantage that can be especially important for pediatric and young adult patients [Figure 3]. Collectively, the CWU and CWD procedures have been previously associated with recurrence rates varying between 17% and 70% and, unfortunately, can involve postoperative complications such as hearing loss and facial nerve dysfunction. In an alternative approach to CWU and CWD, Grauvogel *et al*. described an alternative intracranial approach to resection of PBC which combined neuroendoscopy, piezoelectric surgery, and neuronavigation to enable safe, targeted removal of recurrent petrous bone cholesteatoma in a 14-year-old patient.[12] A retrosigmoid approach provided safe access to the petrous apex and allowed for total resection as well as facial nerve and internal carotid artery decompression. Throughout the procedure, continuous neurophysiological monitoring through acoustic evoked potentials and electromyography for cranial nerves IV, VI, VII, IX, X, and XI was used, and neuroendoscopy allowed for superior visualization of the lateral portions of the cholesteatoma inside the petrous apex. In addition, the most novel component of the procedure was the piezoelectric technique, which utilizes ultrasonic microvibrations to enable targeted bone-cutting in a low-risk manner that spares adjacent soft tissues. In this case, piezoelectric surgical removal of the petrous bone was performed using the Mectron Piezosurgery II device and hearing was preserved. Furthermore, although the retrosigmoid and other surgical approaches involving the

Table 2: Advantages and disadvantages of common surgical approaches for petrous apex lesions.

Surgical Approach	Advantages	Disadvantages
Translabyrinthine-transcochlear	Most direct route to petrous apex,[15,36] approach of choice in patients with a high jugular bulb or anterior sigmoid sinus, wider exposure of anterior, medial, and median cerebellopontine angle[6,20]	Unsuited for hearing preservation in most cases, high risk of damage to vestibular and cochlear organs[6]
Infralabyrinthine	Approach of choice in patients with severe hearing loss or deafness[2]	May result in conductive hearing loss[2]
Infracochlear (meatal)	Preserves hearing function in most cases, may be accessed via endoscopic techniques[20]	May result in conductive hearing loss[20]
Middle cranial fossa	Recommended approach for isolated congenital petrous apex cholesteatomas and hearing preservation[1,5]	CSF leak (in up to 13% of patients), facial nerve palsy, meningitis, hydrocephalus, ataxia, more limited access, limited exposure to petrous apex and may lead to a secondary surgery[1]
Retrosigmoid	Lower risk of facial nerve palsy, hearing loss, and damage to labyrinth, good visualization of petrous apex[32]	Increased difficulty accessing anterior cerebellopontine angle[32]
Medial transsphenoidal	Lower risk of neurovascular injury[20]	Limited visualization[20]
Transpalatinal-transclival	Applicable to midline clival lesions[31]	Limited visualization, increased risk of infection[20,31]

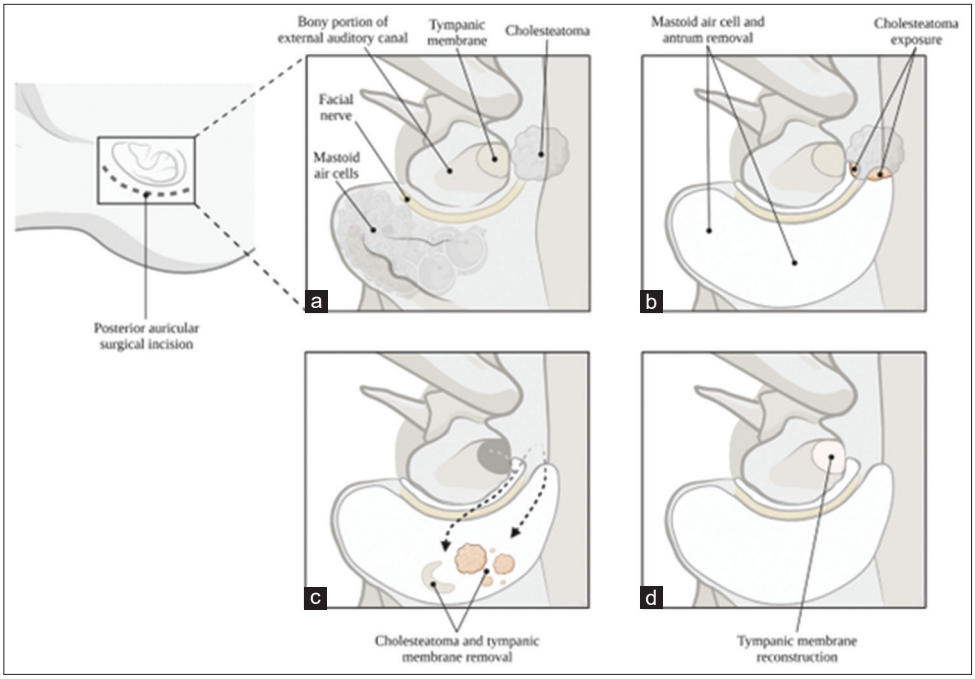

Figure 3: Illustration of the canal-wall up procedure for removal of cholesteatomas of the petrous apex. (a) Orientation of anatomical landmarks relative to the cholesteatoma. (b) Removal of mastoid air cell and antrum for exposure of cholesteatoma. (c) Removal of cholesteatoma and tympanic membrane. (d) After removal, reconstruction of tympanic membrane.

posterior cranial fossa can predispose to complications such as CSF leak, headaches, infection, and postoperative homonymous dysdiadochokinesia (resulting from cerebellar retraction), the use of neuroendoscopy and intraoperative neuronavigation enabled only slight cerebellar retraction, and no dysdiadochokinesia or other complications occurred.

Limitations and future perspectives

In this study, there were several limitations. Due to the exclusion of articles that were not published in English and did not include full texts, a publication bias could be present. Our results could over-suggest the utilization of the CWU approach to resection and underemphasize the utilization of the other surgical approaches mentioned. A low level of evidence is present due to the paucity of the literature available regarding this pathology in the pediatric population at this anatomical location. Future directions aim to establish a gold-standard approach to cholesteatoma resection at the petrous apex in pediatric patients and investigate risk factors for recurrence.

CONCLUSION

Cholesteatomas of the petrous apex are rare middle ear tumors that can appear in pediatric patients and, when untreated, can lead to facial nerve palsy and conductive hearing loss, along with higher susceptibility to recurrence in comparison to adults. Close follow-up after resection with MRI surveillance, in addition to a strong physical exam, is necessary to ensure proper management postoperatively. A comprehensive and tailored plan must be ensured for each patient to achieve desirable outcomes in pediatric patients with cholesteatomas of the petrous apex.

Declaration of patient consent

Patient's consent not required as patient's identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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