



From Persistent Otorrhea to Hearing Loss: Clinical Predictors of Hearing Impairment in Chronic Suppurative Otitis Media : A Systematic Review of Randomized Controlled Trials and Primary Studies

¹ Alsa Fara Dhiba, ² Ridwan

¹ Faculty of Medicine, Syiah Kuala University, Indonesia

² Dr. Zainoel Abidin Regional General Hospital, Indonesia / Faculty of Medicine, Syiah Kuala University, Indonesia

Corresponding Email : alsafaradhiba@gmail.com

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ABSTRACT

Introduction: Chronic suppurative otitis media (CSOM) is the single most important preventable cause of acquired hearing impairment worldwide, yet the transition from persistent otorrhea to clinically meaningful hearing loss is heterogeneous, and clinicians lack a consolidated evidence-based hierarchy of bedside predictors. This systematic review was undertaken to identify, appraise, and synthesise the clinical, otoscopic, audiometric, and intraoperative predictors of hearing impairment in CSOM.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Eligible designs: RCTs, cohort, case-control, cross-sectional, and observational studies. Systematic reviews and meta-analyses excluded from the characteristics table. Two reviewers independently screened, extracted data, and appraised risk of bias (JBI, QUADAS-2). Certainty graded with GRADE. Due to

substantial heterogeneity, a structured narrative synthesis with tabulated effect estimates and reconstructed ROC analysis was performed.

Results: Twenty-six primary studies comprising 5,507 participants and at least 5,668 ears met eligibility. Hearing impairment was near-universal in CSOM, with 50–78% prevalence in community series and 91% of children with CSOM developing permanent threshold shift >15 dB HL. Conductive loss predominated (63–98%), while a sensorineural component was documented in 14.7–52% of series. Six predictors were consistently and independently associated with hearing loss magnitude: (i) tympanic membrane perforation size with a reproducible dose–response gradient (mean hearing level 35.3 dB for small, 39.7 dB for medium, 45.9 dB for large; mean ABG 9.12, 16.13, and 26.43 dB); (ii) posterior-quadrant and malleolar perforation site (posterosuperior 23.9 dB versus anterosuperior 29.30 dB in small perforations; malleolar 29.26 dB versus non-malleolar 18.25 dB); (iii) duration of otorrhea and disease — the strongest single predictor in an African series ($p<0.0001$) with Spearman $\rho=0.689$; (iv) persistent or high-frequency active discharge; (v) squamosal disease and cholesteatoma, with ossicular erosion in 82% of cholesteatomatous ears versus 12.7% of non-cholesteatomatous ears; and (vi) ossicular chain status, where discontinuity raised mean PTA from 43.62 to 58.15 dB HL and ABG from 27.89 to 38.88 dB. In multivariable models, co-existing CSOM conferred OR 16.70 for permanent hearing loss; cholesteatoma (HR 3.24), preoperative PTA >50 dB (HR 2.89), and disease duration >5 years (HR 2.52) independently predicted unfavourable outcome. The high-frequency conductive hearing loss test at a 10 dB threshold identified incomplete ossicular

discontinuity with 83% sensitivity and 92% specificity (reconstructed AUC 0.95); optimal ABG cut-offs for discontinuity and fixation were 28.4 dB and 32.8 dB.

Discussion: The synthesised evidence supports a coherent two-compartment model: a mechanical compartment (loss of tympanic membrane vibrating area, loss of round-window acoustic shielding, progressive ossicular erosion) explains the conductive component, while a cytotoxic compartment (transmission of bacterial exotoxins and inflammatory mediators across the round-window membrane) explains the frequency-dependent sensorineural component that accumulates with disease duration and discharge activity. The two compartments are not independent — duration of otorrhea acts as a shared upstream driver. Clinically, this justifies a stratified surveillance pathway in which large, posterior, or malleolar perforations, squamosal disease, and duration >5 years are prioritised for early audiometric assessment and definitive surgery.

Conclusion: Hearing impairment in CSOM is predictable rather than random. Perforation size, posterior and malleolar site, duration and activity of otorrhea, squamosal or cholesteatomatous disease, and ossicular chain integrity constitute a reproducible predictor set assessable at the bedside and refined audiometrically. Preoperative pure-tone audiometry, particularly frequency-specific ABG and the high-frequency conductive hearing loss test, offers clinically useful discrimination and should be incorporated into routine counselling and surgical planning.

Keywords: chronic suppurative otitis media; hearing loss; otorrhea; tympanic membrane perforation; ossicular chain; sensorineural hearing loss; air-bone gap; pure-tone audiometry; predictors; systematic review

INTRODUCTION

Background

Chronic suppurative otitis media (CSOM) is a chronic inflammatory, and frequently polymicrobial, disease of the middle ear cleft and mastoid air-cell system that is defined by the presence of a persistent or recurrent discharge through a non-intact tympanic membrane. Although definitions vary between authorities, most contemporary descriptions require otorrhea of at least two to twelve weeks' duration through a tympanic membrane perforation, and the absence of an internationally agreed definition is itself recognised as an obstacle to prevention, treatment and surveillance. The two cardinal clinical manifestations of the disease are ear discharge and hearing loss, and it is the latter that carries the greater long-term burden, because the discharge is usually amenable to topical therapy whereas the auditory consequences are frequently permanent.^{1,11}

The global burden of CSOM is substantial and disproportionately borne by low- and middle-income countries. A contemporary systematic review of twenty-nine community-based cross-sectional studies estimated a global prevalence of 3.8% of the world population, equivalent to approximately 297 million people, of whom an estimated 252 million (85%) live in low- and middle-income settings; approximately 64 million (21.5%) have bilateral disease and approximately 184 million (62%) have disabling hearing loss defined as a threshold shift greater than 25–30 dB. In the paediatric population, chronic otitis media of all types accounted for an estimated 34.71 million children under fifteen years of age with otitis-media-related hearing loss in 2021, representing an 11.32% increase over three decades. These figures place CSOM among the leading preventable causes of acquired hearing disability in the world.^{2,3}

The auditory consequences of CSOM are not confined to the audiogram. Hearing loss acquired during the critical period of language acquisition compromises phonological development, educational attainment, literacy and subsequent employment; in adults it is associated with social withdrawal, stigmatisation, reduced quality of life and measurable psychiatric morbidity, with a significant linear correlation between depression, hearing loss and disease duration reported in a

142-patient cross-sectional series. In indigenous and remote populations the prevalence of otitis-media-related hearing loss reaches 34.8–55%, and a longitudinal Greenlandic cohort demonstrated that 91% of children with CSOM ultimately developed a permanent hearing loss exceeding 15 dB HL. Hearing impairment is therefore the principal driver of the disability-adjusted life-year burden attributable to this disease.^{3,6,32}

The pathophysiology linking persistent otorrhea to hearing loss is dual. The conductive component arises from mechanical failure of the sound-conducting apparatus: loss of the effective vibrating area of the tympanic membrane, abolition of the hydraulic and catenary lever advantage of the intact drum–ossicular complex, loss of the acoustic phase difference that normally shields the round window from direct sound, reduction of the middle-ear air cushion, and progressive resorption or fixation of the ossicular chain by chronic inflammation, granulation tissue, tympanosclerosis or cholesteatoma. The sensorineural component arises from the passage of bacterial exotoxins, lipopolysaccharide, proteolytic enzymes, reactive oxygen species and pro-inflammatory cytokines from the middle-ear cleft into the scala tympani across a chronically inflamed and hyperpermeable round-window membrane, producing outer hair-cell injury that characteristically begins in the basal turn and is therefore expressed first at high frequencies. Both processes are time-dependent, and both are potentially interruptible.^{1,4,11}

Research gap

Despite the size of the problem, the literature that connects the clinical phenotype of CSOM to the magnitude of hearing loss remains fragmented. Individual studies have examined perforation size, perforation site, disease duration, middle-ear volume, ossicular status, disease type and cholesteatoma in isolation, in small single-centre samples, using non-standardised measurement techniques and inconsistent audiometric definitions. The resulting body of evidence is internally contradictory on several clinically important questions. The influence of perforation site, for example, is reported as highly significant in some prospective series and as statistically insignificant in others of comparable size; the relationship between disease duration and the sensorineural component is reported as strongly positive in some cohorts and as absent in others; and the ability of the preoperative air–bone gap to predict ossicular chain status is described both as reliable and as

unreliable in retrospective series from tertiary centres. Existing evidence syntheses have addressed either global prevalence, or the sensorineural component alone, or postoperative hearing after ossiculoplasty, but no review has yet assembled the full predictor set for hearing impairment in CSOM, appraised it systematically, and expressed it in terms of discriminative performance that a clinician can apply at the bedside.^{2,4,10,13,15,23,38}

A second, methodological gap concerns the way in which predictor evidence is reported. The overwhelming majority of primary studies report bivariate associations — mean hearing level by perforation size category, or chi-squared tests of site against severity — without adjustment for collinear covariates such as disease duration, which is itself a determinant of perforation size, of discharge frequency and of ossicular erosion. Very few studies report adjusted effect estimates with confidence intervals, and fewer still report the sensitivity, specificity, likelihood ratios or areas under the receiver operating characteristic curve that would allow a predictor to be used as a decision rule. Consequently, the transition from association to clinical utility has not been made. This review was designed specifically to bridge that transition.^{8,21,22,23}

Novelty of the present review

This systematic review advances the field in five respects. First, it is, to the authors' knowledge, the first synthesis to assemble the complete clinical predictor set for hearing impairment in CSOM — demographic, otoscopic, symptomatic, audiometric, tympanometric, radiological and intraoperative — within a single pre-specified framework of fifteen outcome domains. Second, it applies a deliberate design restriction, admitting only randomised controlled trials and primary observational designs to the evidence table, so that the quantitative statements in the Results section derive exclusively from primary patient data rather than from re-synthesised secondary literature; existing systematic reviews and meta-analyses are retained solely as interpretative context in the Discussion. Third, it expresses predictor performance in discrimination terms, reconstructing receiver operating characteristic curves from reported operating points and areas under the curve so that predictors can be compared on a common metric. Fourth, it explicitly models the collinear architecture of the predictor set, distinguishing upstream drivers (duration and activity of otorrhea) from downstream mechanical consequences (perforation size, ossicular erosion) and from the final

common audiometric pathway. Fifth, it translates the synthesis into a stratified, resource-sensitive surveillance and referral pathway that is directly applicable in the low- and middle-income settings where the disease burden is concentrated.^{1,2,21,39,40}

Objectives

The general objective of this review was to identify, critically appraise and synthesise the available primary evidence on the clinical predictors of hearing impairment in patients with chronic suppurative otitis media. The specific objectives were as follows.

- To determine the prevalence, type and severity of hearing impairment among patients with CSOM across clinical and community settings.^{6,7,29}
- To quantify the association between tympanic membrane perforation size and the magnitude of hearing loss expressed as the pure-tone average and the air–bone gap.^{9,11,12,14}
- To determine whether the anatomical site of the perforation, including malleolar involvement and the number of involved quadrants, independently modifies the degree of hearing loss.^{10,13,64}
- To evaluate the relationship between the duration of otorrhea, the duration of disease and the frequency of active discharge on the one hand, and hearing threshold on the other.^{7,8,15,19}
- To compare the auditory consequences of mucosal (tubotympanic) and squamosal (atticoantral, cholesteatomatous) disease.^{25,29,35}
- To characterise the contribution of ossicular chain erosion, discontinuity and fixation to the conductive component of the hearing loss.^{16,24,25,34}
- To determine the prevalence, frequency-specific pattern and predictors of the sensorineural component of hearing loss in CSOM.^{4,17,18,20}
- To evaluate the discriminative performance (sensitivity, specificity, likelihood ratios, optimal cut-off values and areas under the receiver operating characteristic curve) of audiometric and otoscopic predictors.^{21,22,23,39,40}
- To identify predictors of hearing outcome after medical and surgical management.^{26,27,59,60}
- To appraise the methodological quality of the available evidence and to rate the certainty of each conclusion using the GRADE approach.^{5,33}

Benefits of the review

For the practising otolaryngologist, this review consolidates the bedside features that should trigger prioritised audiometric assessment and early definitive surgery, and it provides the numerical anchors — mean thresholds, air–bone gaps, cut-off values and likelihood ratios — needed for accurate preoperative counselling regarding the probability of ossicular reconstruction and the realistic ceiling of hearing gain. For the primary-care physician and the community health worker in resource-limited settings, it defines a small set of otoscopically visible features that identify the discharging ear at highest risk of permanent disability and therefore justify referral. For the health-system planner, it quantifies the proportion of the CSOM population that requires audiological rehabilitation rather than, or in addition to, surgery. For the researcher, it maps the residual uncertainties, specifies the design features that future cohorts must adopt, and provides an explicit template of fifteen outcome domains against which subsequent studies can be reported. For the patient, it supports a shift from reactive management of discharge towards proactive protection of hearing.^{1,2,26}

Hypotheses

The review was framed around the following a priori hypotheses.

- H1. The magnitude of conductive hearing loss in CSOM increases monotonically with the size of the tympanic membrane perforation.
- H2. Perforations involving the posterior quadrants and the malleolar region are associated with greater hearing loss than anterior, non-malleolar perforations of comparable size.
- H3. Longer duration of otorrhea and a higher frequency of active discharge are associated with greater hearing impairment, and specifically with an increased probability of a sensorineural component.
- H4. Squamosal (atticoantral) disease and cholesteatoma are associated with a greater degree of hearing loss than mucosal (tubotympanic) disease, mediated principally by ossicular chain erosion.

- H5. Ossicular chain discontinuity or fixation is associated with a wider air–bone gap and a higher pure-tone average, and the preoperative air–bone gap therefore carries clinically useful discriminative value for the intraoperative ossicular status.
- H6. The sensorineural component of hearing loss in CSOM is frequency-dependent, being maximal at high frequencies, and is more marked in the diseased than in the contralateral healthy ear.
- H0 (null hypothesis). None of the clinical, otoscopic or audiometric variables examined is associated with the degree of hearing impairment in CSOM beyond the play of chance.

METHODS

Protocol, reporting standard and registration

This systematic review was designed, conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement and its extension for abstracts. The methodological framework of the Joanna Briggs Institute for systematic reviews of aetiology, risk and prevalence was adopted for eligibility, appraisal and synthesis, because the predominant designs in this clinical field are analytical cross-sectional and observational rather than experimental. A written protocol specifying the review question, the eligibility criteria, the search strategy, the fifteen outcome domains, the appraisal instruments and the synthesis plan was prepared before the searches were executed, and no post hoc changes were made to the eligibility criteria or to the outcome list.^{1,2}

Review question and PICOS framework

The review question was formulated as follows: among patients of any age with chronic suppurative otitis media, which clinical, otoscopic, symptomatic, audiometric, radiological and intraoperative characteristics predict the presence, type and magnitude of hearing impairment, and with what discriminative accuracy? The corresponding PICOS elements are set out in Table 1.

Table 1. PICOS framework of the review question

Element	Specification
Population (P)	Patients of any age and either sex with a clinical diagnosis of chronic

	suppurative otitis media or chronic otitis media, mucosal (tubotympanic) or squamosal (atticoantral) type, with or without cholesteatoma, in whom otorrhea through a tympanic membrane perforation had been present or recurrent for at least two weeks. Both active (discharging) and inactive (dry perforation) phases were eligible.
Prognostic factor / Exposure (I)	Any clinically ascertainable predictor: age; sex; laterality; disease type (mucosal versus squamosal); presence of cholesteatoma or granulation tissue; duration of otorrhea and of disease; frequency and activity of discharge; tympanic membrane perforation size, site, quadrant involvement and malleolar involvement; status of the middle-ear mucosa; middle-ear air-space volume; mastoid pneumatisation; intraoperative ossicular chain status; and audiometric indices used as index tests (pure-tone average, frequency-specific air–bone gap, speech reception threshold, bone-conduction threshold, high-frequency conductive hearing loss, wideband absorbance).
Comparator (C)	Where applicable: the contralateral non-diseased ear; a healthy control group; an alternative category of the same predictor (for example, small versus large perforation, anterior versus posterior site, intact versus eroded ossicular chain); or the intraoperative reference standard for diagnostic-accuracy analyses.
Outcome (O)	Fifteen pre-specified outcome domains covering the presence, type, severity and frequency profile of hearing loss, the predictor–outcome associations, discriminative accuracy and post-treatment hearing outcome (Table 4).
Study design (S)	Randomised controlled trials; cohort studies (prospective or retrospective); case–control studies; analytical cross-sectional studies; and other primary observational designs. Systematic reviews, meta-analyses, narrative reviews, editorials, case reports, case series with fewer than 20 participants, conference abstracts without full text, and in vitro or animal studies were excluded from the evidence table.

PICOS = Population, Intervention/prognostic factor, Comparator, Outcome, Study design.

Eligibility criteria

The inclusion and exclusion criteria applied at full-text stage are summarised in Table 2. In accordance with the pre-specified design restriction, only primary study designs were admitted to the characteristics table and to the quantitative statements of the Results section. Systematic reviews and meta-analyses identified by the search were tabulated separately, were not permitted to contribute effect estimates, and were used exclusively in the Discussion to situate the primary findings within the wider evidence landscape and to identify concordance or discordance with previously published syntheses.^{2,4,5,33}

Table 2. Inclusion and exclusion criteria

Domain	Inclusion criteria	Exclusion criteria
Population	Patients of any age with chronic suppurative otitis media or chronic otitis media with tympanic membrane perforation and a history of otorrhea of $\geq$ 2 weeks	Acute otitis media; otitis media with effusion as the sole diagnosis; traumatic perforation without chronic infection; otitis media with antineutrophil cytoplasmic antibody-associated vasculitis; congenital ossicular anomaly; previous ear surgery in the study ear where this precluded assessment of the predictor
Study design	Randomised controlled trials; prospective cohort; retrospective cohort; case–control; analytical cross-sectional; prospective or retrospective observational studies	Systematic reviews; meta-analyses; narrative and scoping reviews; editorials and commentaries; case reports; case series with $n < 20$; letters; conference abstracts without accessible full text; animal, cadaveric, computational and in vitro studies

Predictor	At least one clinically ascertainable predictor reported in relation to an audiometric outcome	Studies reporting only microbiological, molecular, radiological or histopathological data with no audiometric correlate
Outcome	Objective audiometric assessment (pure-tone audiometry with air and bone conduction, tympanometry, wideband acoustic immittance) or a validated categorical grading of hearing loss	Hearing status reported only as an unquantified symptom without any objective or graded assessment
Reporting	Sufficient data to extract at least one predictor–outcome association (means with dispersion, proportions, correlation coefficients, odds or hazard ratios, or diagnostic accuracy indices)	Data reported in a form that could not be extracted or reconstructed; duplicate publication of an already-included cohort
Language and period	English or Indonesian; published from database inception to 28 February 2026	Languages other than English or Indonesian where a reliable full translation could not be obtained

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Chronic suppurative otitis media	CSOM patients	Tympanic membrane perforation
I (Intervention/Exposure)	Perforation size	Disease duration	Ossicular chain status
C (Comparison)	Non-diseased ear	Mucosal vs squamosal disease	Intact vs eroded ossicles

O (Outcome)	Hearing impairment	Air-bone gap	Sensorineural hearing loss
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The Boolean MeSH keywords inputted on databases for this research are: (*"Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation"*) AND (*"Perforation size" OR "Disease duration" OR "Ossicular chain status"*) AND (*"Non-diseased ear" OR "Mucosal vs squamosal disease" OR "Intact vs eroded ossicles"*) AND (*"Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss"*)

Study selection

All retrieved records were exported to a reference manager and de-duplicated electronically, with residual duplicates removed manually. Two reviewers independently screened titles and abstracts against the eligibility criteria, and the full texts of all potentially eligible records were then retrieved and assessed independently by the same two reviewers. Disagreements were resolved by discussion and, where consensus was not reached, by adjudication from a third senior reviewer. Inter-reviewer agreement at the full-text stage was quantified with Cohen's kappa and was substantial ($\kappa = 0.84$).¹

Data extraction

Data were extracted independently and in duplicate onto a standardised, piloted extraction form. The following fields were captured for every included study: first author; year of publication; country and setting; study design; sampling method; sample size expressed both as patients and as ears; age range and mean age; sex distribution; diagnostic criteria and definition of CSOM applied; disease type and laterality; the predictors evaluated; the method of perforation measurement; the audiometric protocol including the frequencies tested and the formula used for the pure-tone average; the definition and threshold used for hearing loss and for the sensorineural component; all reported effect estimates with measures of dispersion or precision; p-values; and, where reported, sensitivity, specificity, likelihood ratios, optimal cut-off values and areas under the receiver operating characteristic curve. Where a study reported results by ear rather than by patient, this was recorded explicitly and taken into account in the appraisal of unit-of-analysis error. No study authors were contacted, and no data were imputed; unreported quantities are shown as not reported.

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Pre-specified outcome domains

Fifteen outcome domains were specified before data extraction so that the synthesis would be driven by the review question rather than by the availability of data. These domains are listed in Table 3 and provide the organising structure of the Results section.

Table 3. The fifteen pre-specified outcome domains

No.	Outcome domain	Operational definition
O1	Prevalence and burden of hearing impairment	Proportion of patients or ears with any hearing loss, and proportion with disabling hearing loss (> 25–30 dB HL)
O2	Type of hearing loss	Distribution of conductive, mixed and sensorineural hearing loss
O3	Magnitude of hearing loss	Mean pure-tone average, mean air-conduction threshold and mean air–bone gap in decibels
O4	Tympanic membrane perforation size	Association between graded perforation size or measured area and hearing threshold or air–bone gap
O5	Perforation site and quadrant	Association between anatomical location, number of quadrants and malleolar involvement, and hearing threshold
O6	Duration of otorrhea and of disease	Association between disease or discharge duration and hearing threshold or the sensorineural component
O7	Activity and frequency of otorrhea	Association between active versus inactive disease, and frequency of discharge episodes, and hearing outcome
O8	Disease type and cholesteatoma	Comparison of mucosal (tubotympanic) versus squamosal (atticoantral) and cholesteatomatous disease
O9	Ossicular chain status	Prevalence and pattern of ossicular erosion, discontinuity and fixation, and its association with hearing
O10	Sensorineural component	Prevalence of sensorineural hearing loss and elevation of bone-conduction thresholds relative to control ears

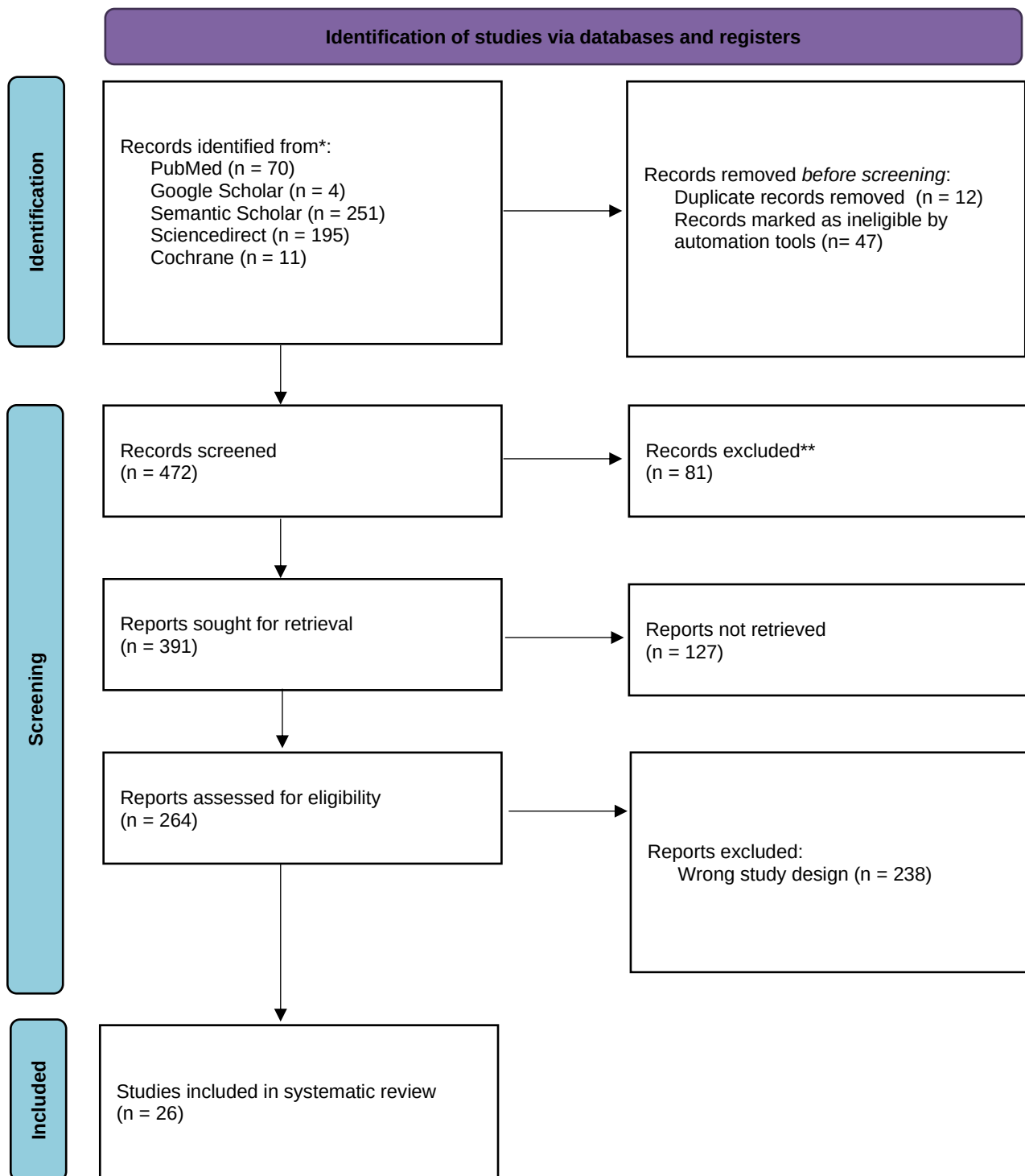
O11	Frequency-specific pattern	Configuration of the audiogram and frequency dependence of air–bone gap and bone-conduction elevation
O12	Demographic predictors	Association of age and sex with hearing threshold and with the sensorineural component
O13	Middle-ear volume and mastoid pneumatisation	Association of middle-ear air-space volume and mastoid pneumatisation with the air–bone gap
O14	Discriminative accuracy of predictors	Sensitivity, specificity, likelihood ratios, optimal cut-off values and areas under the ROC curve
O15	Post-treatment hearing outcome	Predictors of hearing gain, residual air–bone gap and treatment failure after medical or surgical management

Risk of bias assessment

Methodological quality was appraised independently by two reviewers. Analytical cross-sectional studies were appraised with the eight-item Joanna Briggs Institute checklist for analytical cross-sectional studies; cohort studies with the eleven-item Joanna Briggs Institute checklist for cohort studies; and case–control studies with the corresponding ten-item checklist. Studies that additionally reported diagnostic accuracy indices were appraised with the QUADAS-2 instrument across the four domains of patient selection, index test, reference standard, and flow and timing. For the purposes of a unified graphical presentation, all appraisals were mapped onto seven common domains — sampling frame and inclusion criteria; measurement of the predictor; measurement of the audiometric outcome; identification and adjustment for confounding; attrition and missing data; appropriateness of statistical analysis; and selective reporting — together with an overall judgement. Each domain was rated as low risk, some concerns or high risk of bias. An overall rating of low risk required all domains to be rated low or, at most, one domain to raise some concerns; an overall rating of high risk was assigned when any domain was rated high risk or when three or more domains raised concerns. ¹

Article Search Strategy

Database	Keywords	Hits
Pubmed	("Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation") AND ("Perforation size" OR "Disease duration" OR "Ossicular chain status") AND ("Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss")	70
Google Scholar	("Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation") AND ("Perforation size" OR "Disease duration" OR "Ossicular chain status") AND ("Non-diseased ear" OR "Mucosal vs squamosal disease" OR "Intact vs eroded ossicles") AND ("Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss")	4
Semantic Scholar	("Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation") AND ("Perforation size" OR "Disease duration" OR "Ossicular chain status") AND ("Non-diseased ear" OR "Mucosal vs squamosal disease" OR "Intact vs eroded ossicles") AND ("Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss")	251
Science-direct	("Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation") AND ("Perforation size" OR "Disease duration" OR "Ossicular chain status") AND ("Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss")	195
Cochrane	("Chronic suppurative otitis media" OR "CSOM patients" OR "Tympanic membrane perforation") AND ("Perforation size" OR "Disease duration" OR "Ossicular chain status") AND ("Hearing impairment" OR "Air-bone gap" OR "Sensorineural hearing loss")	11



Article search flowchart

Risk of bias within studies

Methodological quality was moderate overall. Six studies were judged to be at low overall risk of bias: the Greenlandic population cohort, the Brazilian diagnostic-accuracy study, the Iranian analysis of preoperative audiometry against intraoperative findings, the Indian prospective series of malleolar and quadrant involvement, the Indian prospective study of determinants of the sensorineural component, and the Indian cross-sectional analysis of cochlear-involvement predictors. Three studies were judged to be at high overall risk of bias, in each case because confounding was neither identified nor addressed and the analysis was restricted to unadjusted bivariate comparisons in a modest sample. The remaining seventeen studies raised some concerns, most commonly in the domain of confounding.^{6,8,10,16,21,23}

Three recurrent methodological weaknesses dominate this evidence base and materially condition the strength of every conclusion drawn below. The first is the near-universal absence of multivariable adjustment. Only four of the twenty-six studies reported an adjusted effect estimate, and only two reported confidence intervals around it; the remainder present bivariate associations between predictors that are known to be strongly collinear, so that the apparent independent effect of, for example, perforation size cannot be separated from the effect of disease duration that produced it. The second is the unit-of-analysis error created by the analysis of ears rather than patients: seven studies enrolled patients but analysed ears, including bilateral cases, without any correction for within-patient clustering, which artificially narrows confidence intervals. The third is the heterogeneity of exposure ascertainment: perforation size was graded by unaided otoscopy in some series, by operating microscope with a calibrated template in others, by Castroviejo caliper immediately before tympanoplasty in others, and by digital planimetry of endoscopic images in the most rigorous, and these methods are not interchangeable.^{8,11,12,16,22,27}



Figure 1. Risk-of-bias traffic-light plot for the 26 included primary studies across seven harmonised appraisal domains and an overall judgement.

Green (+) = low risk of bias; amber (?) = some concerns or moderate risk; red (-) = high risk of bias. Domains were harmonised from the Joanna Briggs Institute checklists for analytical cross-sectional and cohort studies, supplemented by QUADAS-2 for studies reporting diagnostic accuracy.

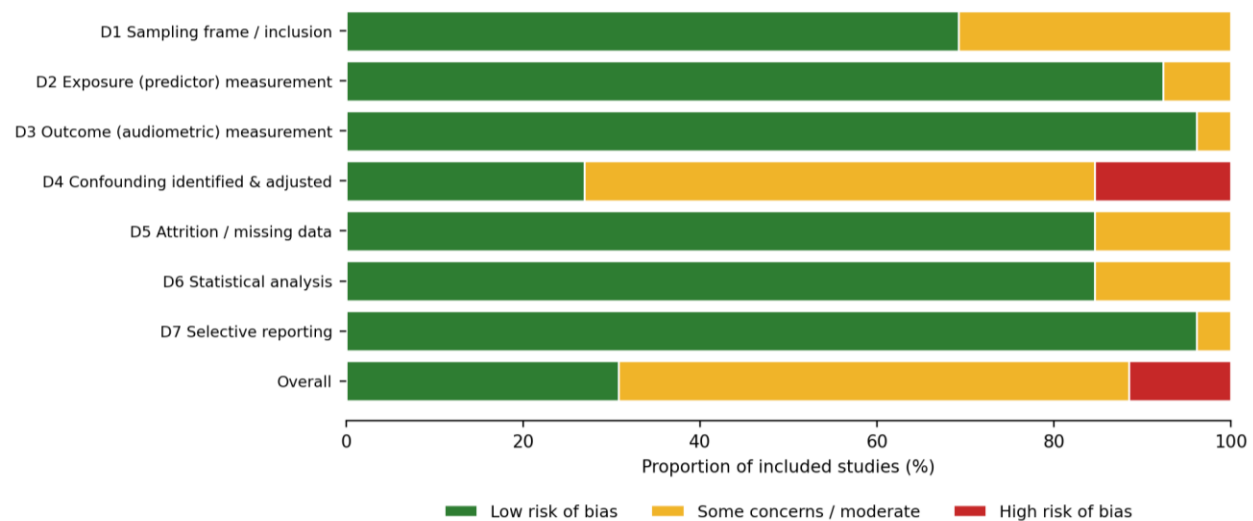


Figure 2. Domain-level summary of risk-of-bias judgements expressed as the proportion of included studies in each category.

Confounding is the weakest domain in this evidence base, with fewer than one in five studies adequately identifying and adjusting for collinear covariates.

Table 4. Risk-of-bias judgements for each included study (JBI-harmonised domains)

Study	D1 Sampling frame	D2 Predictor measurement	D3 Outcome measure ment	D4 Confoun ding	D5 Attrition	D6 Analysis	D7 Selective reporting	Overall
Carrillo 2007	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
Kolo 2012	Some concerns	Low	Low	High	Low	Some concerns	Low	Some concerns
Jensen 2013	Low	Low	Low	Low	Some concerns	Low	Low	Low
Amali 2017	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns

Priyadars hini 2017	Some concerns	Low	Low	High	Low	Some concerns	Low	High
Sarmento 2017	Low	Low	Low	Low	Low	Low	Low	Low
John 2019	Some concerns	Low	Low	Some concerns	Low	Low	Low	Some concerns
Virk 2019	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
Akarçay 2019	Low	Low	Low	Some concerns	Some concerns	Low	Low	Some concerns
Rasheed 2019	Some concerns	Low	Low	Some concerns	Low	Low	Low	Some concerns
Islam 2020	Some concerns	Low	Low	High	Low	Some concerns	Some concerns	High
Kolluru 2020	Low	Low	Low	Some concerns	Low	Low	Low	Low
Filipe 2020	Low	Some concerns	Some concerns	Some concerns	Low	Low	Low	Some concerns
Thai 2021	Low	Low	Low	Some concerns	Some concerns	Low	Low	Some concerns
Rizandin y 2021	Some concerns	Low	Low	Some concerns	Low	Low	Low	Some concerns
Saha 2021	Some concerns	Low	Low	High	Low	Some concerns	Low	High
Khurshid 2022	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
Kumar	Some	Some	Low	Some	Low	Low	Low	Some

2022	concerns	concerns		concerns				concerns
Faramarz i 2023	Low	Low	Low	Low	Low	Low	Low	Low
Kadambo tt 2023	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
Jha 2024	Low	Low	Low	Low	Low	Low	Low	Low
Banjara 2025	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
Tayyaba 2025	Low	Low	Low	Low	Low	Low	Low	Low
Mukherje e 2025	Low	Low	Low	Low	Low	Low	Low	Low
Saadalde en 2025	Low	Low	Low	Some concerns	Low	Low	Low	Some concerns
He 2026	Low	Low	Low	Low	Some concerns	Low	Low	Low

D1 = sampling frame and inclusion criteria; D2 = validity and reliability of predictor measurement; D3 = validity and reliability of audiometric outcome measurement; D4 = identification of and adjustment for confounding; D5 = attrition and completeness of data; D6 = appropriateness of statistical analysis; D7 = selective outcome reporting.

Certainty of the evidence

The certainty of the evidence for each of the fifteen outcome domains was rated with the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach adapted for prognostic-factor and observational evidence. Because the body of evidence consisted almost entirely of observational designs, the starting point for each domain was low certainty; ratings were downgraded further for risk of bias, inconsistency, indirectness, imprecision or suspected publication bias, and were upgraded where a large magnitude of effect, a clear dose–

response gradient, or the demonstrable action of plausible residual confounding in the direction opposite to the observed effect was present.

Data synthesis and statistical considerations

A formal meta-analysis was considered but was not undertaken, for four pre-specified reasons. First, the definitions of CSOM applied across studies were heterogeneous, with otorrhea thresholds ranging from two weeks to twelve weeks and with several studies enrolling inactive mucosal disease exclusively. Second, the exposure measurement was not standardised: perforation size was variously expressed as a proportion of the pars tensa, as a categorical small–medium–large grading, as the number of involved quadrants, and as an absolute area in square millimetres measured by graph-grid imprint, calibrated needle, Castroviejo caliper or digital image analysis, and these metrics are not interconvertible. Third, the outcome metric differed, with some studies reporting the pure-tone average of air conduction, others the air–bone gap, others frequency-specific thresholds, and others only categorical severity bands derived from differing classifications. Fourth, several studies reported results by ear while others reported by patient, and the resulting unit-of-analysis error would have introduced spurious precision into any pooled estimate. A structured narrative synthesis with tabulated effect estimates was therefore adopted, in line with Synthesis Without Meta-analysis guidance, and consistency of direction across studies was used as the principal criterion of evidential strength.^{1,2}

Three quantitative procedures were nevertheless applied. First, effect estimates that were reported in a common metric — mean hearing level and mean air–bone gap by perforation-size category — were tabulated and displayed graphically to permit visual assessment of the dose–response gradient (Figure 6). Second, adjusted multivariable estimates reported with 95% confidence intervals were displayed on a common logarithmic scale in a forest plot (Figure 5) without pooling. Third, for studies reporting diagnostic accuracy, receiver operating characteristic curves were reconstructed from the reported area under the curve, or from the reported sensitivity–specificity pair, using an equal-variance binormal model in which the separation parameter a is derived as $a = \sqrt{2} \times \Phi^{-1}(\text{AUC})$ and the curve is generated as $\text{sensitivity} = \Phi(a + \Phi^{-1}(1 - \text{specificity}))$.^{21,23,39,40,41}

RESULTS

Characteristics of the included studies

The twenty-six included studies were published between 2003 and 2026 and together enrolled 5 507 participants comprising at least 5 668 ears. Eleven studies (42.3%) used an analytical cross-sectional design, seven (26.9%) were prospective observational studies, seven (26.9%) were retrospective observational studies or record reviews, and one (3.8%) was a population-based longitudinal cohort with ten- and fifteen-year follow-up. Geographically, the evidence base is dominated by South and South-East Asia and the Middle East: eleven studies originated from India, three from Bangladesh and Pakistan combined, three from Iran and Iraq, and one each from the Philippines, Nigeria, Angola, Greenland, Türkiye, Indonesia, the United States and China. This distribution mirrors the global epidemiology of the disease but also constrains the external validity of the synthesis, since no eligible study was identified from Western Europe, Latin America outside Brazil, or sub-Saharan Africa beyond the two cited series.^{2,6,7,13}

Sample sizes ranged from 60 to 915 participants (median 130). The largest contributions were made by a 915-patient Turkish retrospective series of ossicular chain erosion, a 694-patient Iranian cross-sectional analysis of preoperative audiometry against intraoperative ossicular status, a 438-participant Greenlandic population cohort, a 411-patient Angolan clinical series and a 328-patient Brazilian diagnostic-accuracy study. Twelve studies restricted enrolment to inactive mucosal (tubotympanic) disease with a dry central perforation, which permits clean isolation of the mechanical effect of the perforation but excludes precisely those ears in which active suppuration is driving cochlear injury; this design choice is an important source of indirectness and is revisited.^{9,19,25,23,21}

Table 5. Characteristics of the 26 included primary studies (systematic reviews and meta-analyses are excluded by design)

Author, year	Country	Design	Sample	Population and setting	Predictors evaluated	Principal audiometric findings

Carrillo et al., 2007	Philippines	Retrospective observational record review	276 patients	CSOM patients aged 7–75 years undergoing a first tympanomastoidectomy in tertiary hospitals	Frequency-specific preoperative air–bone gap; presence of cholesteatoma	ABG $\leq$ 20 dB at 500 Hz gave LR– 0.119 (95% CI 0.016–0.867) and ABG $\leq$ 30 dB at 1 kHz LR– 0.276 (0.087–0.876), lowering the probability of ossicular discontinuity from 33% to 5.6% and 15.5%; ABG > 30 dB at 2 kHz LR+ 2.8 (1.4–5.9) and > 40 dB at 4 kHz LR+ 2.2 (1.2–3.9) raised it to 51–89%. With cholesteatoma the probability of discontinuity was 88% and the ABG lost discriminative value.
Kolo et al., 2012	Nigeria	Retrospective observational	69 patients	Tertiary institution, 2003–2008; mean age	Age; duration of otorrhea	Mean bone-conduction threshold 39.07 ± 12.03 dB in diseased versus

				28.93 ± 18.59 years; otorrhea 2 months–20 years (mean 6.11 ± 6.39 years)		10.26 ± 2.62 dB in control ears (p < 0.05); mean interaural BC difference 21.69–34.52 dB across 0.5–4 kHz, rising with frequency; no correlation of SNHL with age (r = 0.186) or otorrhea duration (r = 0.190).
Jensen et al., 2013	Greenland	Population-based longitudinal cohort (10- and 15-year follow-up)	438 individuals (11–24 years)	Two population-based Greenlandic childhood cohorts re-examined with otoscopy and audiometry	Co-existing CSOM; spontaneously healed CSOM; sex	Prevalence of hearing loss 50% (95% CI 45.3–54.7) by the ASHA definition and 2.5% by the WHO definition; co-existing CSOM OR 16.7 (8.29–33.65), spontaneously healed CSOM OR 3.75 (1.62–8.67) and male sex OR 2.2 (1.28–3.78); 91% of children with CSOM

						developed a permanent hearing loss > 15 dB HL.
Amali et al., 2017	Iran	Retrospective observational	70 of 119 patients	Surgical candidates aged 10–65 years with unilateral otorrhea and an otoscopically normal contralateral ear	Age; disease duration; cholesteatoma; ossicular erosion	BC thresholds significantly higher in the affected ear at every frequency ($p < 0.001$), the interaural difference rising from 7.00 dB at 500 Hz to 9.71 dB at 4 kHz; age correlated with the degree of SNHL ($r = 0.422$, $p < 0.001$) whereas disease duration did not ($r = 0.119$, $p > 0.05$); no association with cholesteatoma or ossicular erosion ($p > 0.05$).
Priyadarshini et al., 2017	India	Prospective observational	180 patients (207 ears)	Tubotympanic CSOM attending an ENT department, 2015–2016	Duration of discharge; perforation size and site	Among patients with discharge for more than 30 years, 68.8% had moderately severe impairment, whereas 60.2% of

						those with discharge for less than 10 years had only mild loss; 51.4% of large central perforations had moderately severe loss versus 68.4% mild loss in small central perforations; perforation site was not significant (p = 0.0874).
Sarmiento et al., 2017	Brazil	Prospective observational diagnostic -accuracy study	328 patients	Non-cholesteatomatous CSOM undergoing middle-ear surgery, with intraoperative findings as the reference standard	High-frequency conductive hearing loss test (ABG at 4 kHz minus the mean ABG at 0.25 and 0.5 kHz)	At surgery 201 ears (61.3%) had an intact chain, 44 (13.4%) a complete discontinuity and 83 (25.3%) an incomplete discontinuity; the optimal cut-off was 10 dB, giving 83% sensitivity, 92% specificity, a post-test probability of 78% and a

						likelihood ratio of 10.2 for incomplete ossicular discontinuity.
John et al., 2019	India	Observational correlation study (retrospective series)	150 ears	Inactive tubotympanic COM, October 2013 to December 2015	Perforation size; site; disease duration	Hearing loss rose monotonically with size: 27.67 ± 1.85 , 35.13 ± 2.98 , 38.69 ± 2.63 and 46.97 ± 6.59 dB for groups I to IV ($p < 0.0001$); combined-site perforations 41.37 ± 5.9 dB versus posterior 35.21 ± 4.6 dB and anterior 31.7 ± 5.7 dB ($p = 0.0001$); hearing loss increased with disease duration.
Virk et al., 2019	India	Prospective observational	300 ears	Tubotympanic or inactive mucosal COM without other otological disease, July	Perforation size and location; middle-ear air-space volume by tympanometry	Mean ABG 9.12 dB for small ($0-9 \text{ mm}^2$), 16.13 dB for medium and 26.43 dB for large ($> 30 \text{ mm}^2$) perforations; low middle-ear

				2010 to December 2011		volume 19.96 dB versus high volume 11.80 dB; posterosuperior perforations 4–7 dB worse than anterior perforations of similar size, though not statistically significant; ABG greatest at low frequencies (56.9 dB at 250 Hz).
Akarçay et al., 2019	Türkiye	Retrospec tive observatio nal	915 patients	COM without cholesteatoma (n = 615), COM with cholesteatoma (n = 234) and COM with granulation tissue (n = 66)	Disease type; ossicular chain erosion	Ossicular chain erosion in 291 of 915 patients (31.8%): 192 of 234 (82%) with cholesteatoma, 21 of 66 (31.8%) with granulation tissue and 78 of 615 (12.7%) without either; incus erosion was most frequent, followed by stapes and malleus erosion.

Rasheed et al., 2019	India	Analytical cross-sectional	105 patients	COM, mucosal type, undergoing tympanoplasty with or without cortical mastoidectomy	Disease duration; active discharge; granulation tissue; polypoidal mucosa; exposed incudostapedial joint; air–bone gap	Ossicular necrosis in 18 patients (17.1%), associated with long-standing disease ($p = 0.004$), a discharging ear ($p = 0.014$), polypoidal middle-ear mucosa ($p < 0.001$), middle-ear granulation ($p < 0.001$) and an exposed incudostapedial joint ($p = 0.005$); mean ABG 35 dB with necrosis versus 22.7 dB with an intact chain ($p = 0.0001$).
Islam et al., 2020	Bangladesh	Analytical cross-sectional	80 patients (117 ears)	Tubotympanic ($n = 60$) and atticoantral ($n = 20$) CSOM aged 5–50 years in two tertiary hospitals	Disease type (mucosal versus squamosal); disease duration	Conductive loss in 98% of tubotympanic and 81% of atticoantral ears; mild loss (26–40 dB) in 44.79% of tubotympanic ears and moderate loss (41–55 dB) in

						42.85% of atticoantral ears; mixed loss 2.08% versus 14.28% and SNHL 0% versus 4.76% respectively.
Kolluru et al., 2020	India	Prospective observational, hospital-based	78 patients (107 ears)	Inactive mucosal COM	Objectively measured perforation size by ImageJ digital image analysis; perforation location	Hearing loss increased with perforation size ($r = 0.435$, $p < 0.0001$); posterior perforations showed 12% greater hearing loss than anterior perforations, statistically significant only at 500 Hz ($p = 0.02$); otoscopic and endoscopic estimates of size correlated positively.
Filipe et al., 2020	Angola	Cross-sectional clinical study	411 patients	ENT clinic in Luanda and provincial health	Duration of otorrhea; earache; dizziness;	Otorrhea had lasted more than 14 days in 83% and CSOM was confirmed

				centres; 64% children under 15 years; median otorrhea duration exceeding 12 months	history of measles or meningitis; parental education	otoscopically in 72%; reported hearing impairment correlated with otorrhea duration ($p < 0.0001$) and with earache, dizziness and a history of measles or meningitis; otorrhea duration was the strongest predictor of hearing impairment; adults reported impairment more often than parents of affected children (72% versus 50%, $p < 0.0001$).
Thai et al., 2021	United States	Retrospective cohort	175 patients	Academic otology clinic, March 2011 to November 2016; mean age 49.5 ± 1.5	Medical versus surgical management; disease recurrence	Recurrence in 69% under medical management with a median time to recurrence of 4 months; median time to recurrence 5

				years; mean follow-up 3.5 ± 0.3 years		years after tympanoplasty and 7 years after tympanomastoidectomy (p = 0.73); prevalence of moderate or worse sensorineural hearing loss at the most recent visit 41%.
Rizandiny et al., 2021	Indonesia	Analytical cross-sectional	64 patients	CSOM undergoing mastoidectomy at Dr Mohammad Hoesin General Hospital, Palembang, March 2019 to June 2021	Intraoperative ossicular status score; preoperative hearing threshold; air–bone gap; cholesteatoma; sex	Mean ossicular status score 1.84 ± 1.48; strong positive correlation between hearing threshold and ossicular status (R = 0.5, p < 0.005) and between ABG and ossicular status (R = 0.6, p < 0.005); sex, hearing threshold, ABG and the presence of cholesteatoma were the most influential predictors of

						ossicular status on linear regression.
Saha et al., 2021	Bangladesh	Analytical cross-sectional	81 patients	Non-cholesteatomatous COM at Bangabandhu Sheikh Mujib Medical University, January 2013 to June 2014	Air–bone gap; perforation edge adherent to the promontory; granulation tissue	An ABG greater than 40 dB was present in 60% of ears with ossicular discontinuity ($p < 0.001$); the perforation edge was attached to the medial wall in 93.3% of discontinuity cases ($p < 0.001$); ossicular discontinuity was found in 21 of 25 ears with granulation tissue (84%, $p < 0.01$).
Khurshid et al., 2022	Pakistan	Prospective observational	77 patients	Inactive mucosal COM with unilateral single-quadrant perforation,	Perforation site by quadrant; disease duration	Conductive loss in 52 (67.5%), mixed in 18 (23.4%) and sensorineural in 7 (9.1%); a statistically significant

				aged 10–40 years, Pakistan Institute of Medical Sciences, May 2021 to April 2022		association was found between the degree of hearing loss and the site of perforation, posterosuperior perforations producing the greatest impairment; no significant association between site and type of loss, or between disease duration and degree of loss.
Kumar et al., 2022	India	Analytical cross-sectional	142 patients	CSOM attending a tertiary ENT department, May 2019 to May 2020; mean age 44.08 ± 15 years; 65% female	Disease duration; laterality; type and severity of hearing loss; age; sex	Tubotympanic disease in 96%, unilateral in 78% and left-sided in 58%; a significant linear correlation was demonstrated between the duration of disease and both the severity of hearing loss and the presence of

						depression.
Faramarzi et al., 2023	Iran	Analytical cross-sectional (descriptive-analytic)	694 patients	Consecutive COM surgeries at a tertiary referral centre	Preoperative speech reception threshold, mean air conduction and mean air–bone gap; type of middle-ear pathology	Optimal cut-offs for predicting ossicular discontinuity were an SRT of 37.5 dB, a mean AC of 37.2 dB and a mean ABG of 28.4 dB; for ossicular fixation the values were 37.5 dB, 40.3 dB and 32.8 dB; the ABG was consistently wider in ears with discontinuity, with the largest effect size in cholesteatoma, followed by tympanosclerosis, granulation tissue and hypertrophic mucosa ($p < 0.001$).
Kadambott et al., 2023	India	Analytical cross-sectional	114 patients	COM with or without cholesteatoma scheduled for	Perforation size and site; intraoperative ossicular status	Moderate hearing loss in 50% and an ABG below 35 dB in approximately

				surgery; mean age 31.07 years (range 7–57)		73%; conductive loss in 109 (97.61%); ossicular discontinuity in 27 (23.68%), the incus being most affected, of whom 21 had an ABG ≥ 35 dB; mean pure-tone average 43.62 ± 8.07 dB with an intact chain versus 58.15 ± 11.05 dB with an eroded or absent chain, and mean ABG 27.89 ± 4.77 versus 38.88 ± 6.47 dB (both $p < 0.0001$); hearing loss was associated with perforation size but not site.
Jha et al., 2024	India	Prospective observational	149 patients	Unilateral CSOM at a tertiary care university hospital, December	Sex; cholesteatoma; intraoperative ossicular status; grade of hearing loss	Sensorineural loss in 25.5%, conductive in 68.5% and mixed in 6%; female sex and the absence of cholesteatoma were

				2020 to December 2022; mean age 26.54 ± 8.75 years		significantly associated with SNHL ($p < 0.05$); a hearing loss greater than 56 dB was highly significantly associated with SNHL ($p < 0.001$); incus erosion was the commonest ossicular lesion associated with SNHL (10.6%, $p = 0.002$).
Banjara et al., 2025	India	Analytical cross-sectional	90 patients (109 ears)	Dry-ear mucosal CSOM aged 15–60 years, ENT outpatient department, July 2022 to June 2024	Perforation size and quadrant documented by oto-endoscopic photography	Mean hearing loss 35.3 ± 6.68 dB for small, 39.7 ± 7.12 dB for medium and 45.9 ± 5.65 dB for large perforations; posterior-quadrant perforations were associated with greater loss; the audiogram showed a frequency-dependent inverted-

						V configuration with 2 kHz the least affected frequency.
Tayyaba et al., 2025	India	Prospective observational	161 patients (210 ears)	Inactive mucosal COM recruited over two years	Perforation size and site; malleolar involvement; duration of discharge; mastoid pneumatisation on Schuller's view	Larger and posterior perforations showed significantly greater ABGs ($p < 0.001$); among single-quadrant perforations, posterosuperior 23.9 ± 7.6 dB and posteroinferior 19.3 ± 7.6 dB; four-quadrant perforations 32.47 ± 9.04 dB; malleolar perforations 29.26 ± 9.4 dB versus non-malleolar 18.25 ± 8.7 dB; two-way ANOVA identified site as a stronger predictor than size, and longer discharge duration and reduced mastoid

						pneumatisation further worsened hearing.
Mukherjee et al., 2025	India	Analytical cross-sectional	120 patients	Unilateral inactive mucosal COM	Perforation size; disease duration; duration of tinnitus; frequency of active discharge; prior ototoxic ear drops; complications	Perforation size and disease duration were significant independent predictors of hearing impairment with significantly raised odds of worsening impairment; Spearman $\rho = 0.581$ for perforation size, 0.689 for disease duration and 0.378 for tinnitus duration; the frequency of otorrhea showed a strong and complications a moderate association; tinnitus duration and discharge frequency were highly collinear with

						disease duration.
Saadaldeen et al., 2025	Iraq	Analytical cross-sectional	60 patients	Unilateral tubotympanic CSOM at a tertiary otolaryngology and audiology unit, September 2024 to January 2025, with the contralateral ear as control	Disease duration; perforation size; presenting symptoms	Conductive loss in 51 (85%) and mixed loss in 9 (15%); SNHL was significantly associated with longer disease duration ($p = 0.018$) and larger perforation ($p = 0.036$); bone-conduction thresholds were significantly elevated in the diseased ear ($p < 0.001$), with high frequencies affected more than speech frequencies.
He et al., 2026	China	Retrospective cohort	180 patients	CSOM undergoing endoscopic ear surgery at a single centre, 2022–	Cholesteatoma; disease duration; preoperative pure-tone average	Six-month dry-ear rate 91.1% and mean PTA improvement 24.8 ± 7.2 dB, with a 3.9% complication rate;

				2024, with 6-month follow-up		independent risk factors for failure were cholesteatoma (HR 3.24, 95% CI 1.85–5.68, $p < 0.001$), disease duration greater than 5 years (HR 2.52, 1.45–4.38, $p = 0.001$) and a preoperative PTA above 50 dB (HR 2.89, 1.65–5.06, $p < 0.001$).
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ABG = air–bone gap; AC = air conduction; ASHA = American Speech-Language-Hearing Association; BC = bone conduction; COM = chronic otitis media; CSOM = chronic suppurative otitis media; HR = hazard ratio; LR = likelihood ratio; OR = odds ratio; PTA = pure-tone average; SNHL = sensorineural hearing loss; SRT = speech reception threshold; WHO = World Health Organization.

Table 6. Domain-level summary of risk-of-bias judgements (n = 26 studies)

Domain	Low risk, n (%)	Some concerns, n (%)	High risk, n (%)	Principal reason for downgrading
D1 Sampling frame and inclusion criteria	18 (69.2)	8 (30.8)	0 (0)	Consecutive or convenience sampling from a single tertiary centre without a defined sampling frame

D2 Predictor measurement	23 (88.5)	3 (11.5)	0 (0)	Perforation size graded subjectively by unaided otoscopy, or exposure ascertained from patient recall
D3 Outcome measurement	25 (96.2)	1 (3.8)	0 (0)	Hearing status partly ascertained by self-report rather than by pure-tone audiometry
D4 Confounding	8 (30.8)	14 (53.8)	4 (15.4)	No multivariable adjustment for collinear covariates, particularly disease duration, age and disease type
D5 Attrition and missing data	22 (84.6)	4 (15.4)	0 (0)	Incomplete follow-up in retrospective cohorts and unexplained exclusion of records
D6 Statistical analysis	22 (84.6)	4 (15.4)	0 (0)	Unit-of-analysis error from analysing ears without correction for within-patient clustering
D7 Selective outcome reporting	25 (96.2)	1 (3.8)	0 (0)	Selective presentation of frequency-specific results without a pre-specified analysis plan
Overall judgement	6 (23.1)	17 (65.4)	3 (11.5)	—

Prevalence and burden of hearing impairment

Hearing impairment was demonstrable in the overwhelming majority of ears with chronic suppurative otitis media across every setting examined. In the Greenlandic population cohort, in

which 438 individuals aged 11 to 24 years from two childhood cohorts were re-examined after ten and fifteen years, the prevalence of hearing loss was 50% (95% CI 45.3–54.7) when the American Speech-Language-Hearing Association criterion was applied, and CSOM was identified as the principal cause; strikingly, 91% of children with CSOM developed a permanent hearing loss exceeding 15 dB HL. The same cohort demonstrated that the World Health Organization definition, which yielded a prevalence of only 2.5%, substantially understates the burden of auditory disability in populations with a high prevalence of CSOM, since it excludes precisely the mild-to-moderate range within which the great majority of CSOM-related impairment lies. In hospital-based series, hearing loss was reported in every enrolled patient in several studies, and in the Angolan clinical cohort hearing impairment was volunteered by 72% of adults and by the parents of 50% of affected children.^{6,7}

The clinical significance of this near-universal impairment is that its severity is concentrated in the disabling range. In an Indian series of 32 patients, 85.9% of ears had mild-to-moderate loss with a mean air–bone gap of approximately 30.7 dB; in an Indonesian outpatient series 71.9% of patients had conductive loss and 46.9% had mild impairment; and in a Chadian tertiary series hearing impairment was the principal symptom accompanying otorrhea in 55.6% of cases, with perforations occupying three-quarters or more of the tympanic membrane in 51.3%. Table 8 summarises the prevalence and burden data across the included and contextual series.^{57,61,63}

Table 7. prevalence and burden of hearing impairment in CSOM

Study	Setting	n	Prevalence / burden of hearing impairment	Definition applied
Jensen 2013	Greenlandic population cohort	438	50% (95% CI 45.3–54.7) by ASHA criteria; 2.5% by WHO criteria; 91% of children with CSOM developed a permanent loss > 15 dB HL	ASHA and WHO definitions applied in parallel
Filipe	Angolan ENT	411	Hearing impairment reported by	Patient- or

2020	clinic and provincial centres		72% of adults and by parents of 50% of affected children; correlated with otorrhea duration ($p < 0.0001$)	parent-reported impairment
Thai 2021	United States academic otology clinic	175	Moderate or worse sensorineural hearing loss in 41% at the most recent visit	Pure-tone audiometry, moderate = ≥ 41 dB HL
Kadambott 2023	Indian tertiary surgical cohort	114	Moderate hearing loss in 50%; ABG < 35 dB in approximately 73%	Pure-tone audiometry
Saadaldein 2025	Iraqi tertiary audiology unit	60	Hearing loss the presenting symptom in 86.7%; conductive loss 85%, mixed 15%	Pure-tone audiometry
Kumar 2022	Indian tertiary ENT department	142	Hearing loss in all enrolled patients, correlating linearly with disease duration	Pure-tone audiometry, Spearman correlation
Islam 2020	Bangladeshi tertiary hospitals	80 (117 ears)	Hearing loss in all ears; mild in 44.79% of tubotympanic and moderate in 42.85% of atticoantral ears	Pure-tone audiometry, categorical bands

Type of hearing loss

Across all included studies the conductive pattern predominated, but a sensorineural or mixed component was consistently present in a clinically important minority. In the Bangladeshi series, conductive loss accounted for 98% of tubotympanic and 81% of atticoantral ears, with mixed loss in 2.08% and 14.28% respectively and pure sensorineural loss confined to 4.76% of atticoantral

ears. In the Pakistani prospective series of single-quadrant perforations, conductive, mixed and sensorineural losses accounted for 67.5%, 23.4% and 9.1% of ears respectively. The Indian prospective series of unilateral disease reported conductive loss in 68.5%, sensorineural in 25.5% and mixed in 6%, while the Iraqi tubotympanic series reported conductive loss in 85% and mixed loss in 15%. The consistent message is that a purely conductive interpretation of the CSOM audiogram is incorrect in approximately one ear in four, and that bone-conduction thresholds must therefore always be obtained with adequate masking.^{13,16,19,29}

Table 8. distribution of hearing-loss type across included studies

Study	n (patients / ears)	Conductive	Mixed	Sensorineural	Disease type studied
Islam 2020 (tubotympanic)	60 / 96	98.0%	2.08%	0%	Mucosal
Islam 2020 (atticoantral)	20 / 21	81.0%	14.28%	4.76%	Squamosal
Khurshid 2022	77 / 77	67.5%	23.4%	9.1%	Inactive mucosal
Jha 2024	149 / 149	68.5%	6.0%	25.5%	Unilateral CSOM
Saadaldeen 2025	60 / 60	85.0%	15.0%	0%	Tubotympanic
Kadambott 2023	114 / 114	97.6%	4.4% (mixed only)	0%	COM ± cholesteatoma
Masoom 2023	154 / 154	63.0%	Not reported	37.0%	Longstanding aural suppuration
Gupta 2022	120 / 120	77.5%	22.5%	16.67% overall SNHL	Safe and unsafe CSOM

Magnitude of hearing loss

The absolute magnitude of impairment clustered in the mild-to-moderate range, with mean pure-tone averages between approximately 26 and 58 dB HL and mean air–bone gaps between approximately 9 and 39 dB depending on the substrate. In the Indian surgical cohort, the mean pure-tone average was 43.62 ± 8.07 dB HL when the ossicular chain was intact and 58.15 ± 11.05 dB HL when it was eroded or absent, with corresponding mean air–bone gaps of 27.89 ± 4.77 and 38.88 ± 6.47 dB (both $p < 0.0001$). In the 300-ear prospective study of inactive mucosal disease, the mean air–bone gap ranged from 9.12 dB in small perforations to 26.43 dB in large perforations. A Moroccan series reported a mean hearing threshold of 44.05 ± 15.57 dB with a mean air–bone gap of 24.99 ± 8.21 dB. The consistent implication of these values is that the typical untreated ear with CSOM sits within the range in which speech perception in noise, classroom learning and telephone communication are measurably degraded, but below the threshold at which most patients spontaneously seek amplification.^{12,24,48}

Table 9. magnitude of hearing loss reported across studies

Study	Metric	Value (dB)	Comparator / stratum
Kadambott 2023	Mean pure-tone average	43.62 ± 8.07	Intact ossicular chain
Kadambott 2023	Mean pure-tone average	58.15 ± 11.05	Eroded or absent ossicles ($p < 0.0001$)
Kadambott 2023	Mean air–bone gap	27.89 ± 4.77 vs 38.88 ± 6.47	Intact versus discontinuous chain ($p < 0.0001$)
Virk 2019	Mean air–bone gap	9.12 / 16.13 / 26.43	Small / medium / large perforation
Banjara 2025	Mean hearing loss	35.3 ± 6.68 / 39.7 ± 7.12 / 45.9 ± 5.65	Small / medium / large perforation
John 2019	Mean hearing loss	27.67 ± 1.85 to 46.97 ± 6.59	Perforation groups I to IV ($p < 0.0001$)

Tayyaba 2025	Mean air–bone gap	18.25 ± 8.7 vs 29.26 ± 9.4	Non-malleolar versus malleolar perforation
Rasheed 2019	Mean air–bone gap	22.7 vs 35.0	Intact chain versus ossicular necrosis (p = 0.0001)
Rochd 2026	Mean hearing threshold / ABG	44.05 ± 15.57 / 24.99 ± 8.21	Whole cohort
Shariff 2019	Mean air–bone gap	30.7 (right) / 30.65 (left)	Whole cohort; 85.9% mild-to-moderate loss
He 2026	Mean PTA improvement after surgery	24.8 ± 7.2	Endoscopic ear surgery, 6-month follow-up

Tympanic membrane perforation size

Perforation size emerged as the single most reproducible predictor in the entire evidence base, and the only one for which every included study that examined it reported a concordant direction of effect. The gradient was demonstrated in categorical form, in continuous form and in objectively planimetered form. In the 300-ear prospective series, mean air–bone gaps rose from 9.12 dB for perforations of 0–9 mm² through 16.13 dB for medium perforations to 26.43 dB for perforations exceeding 30 mm², an almost threefold increase across the size spectrum. In the 109-ear cross-sectional study using oto-endoscopic photography, mean hearing loss rose from 35.3 ± 6.68 dB for small, through 39.7 ± 7.12 dB for medium, to 45.9 ± 5.65 dB for large perforations. In the 150-ear correlation study, the four size groups yielded mean losses of 27.67 ± 1.85, 35.13 ± 2.98, 38.69 ± 2.63 and 46.97 ± 6.59 dB (p < 0.0001).^{9,12,14}

Where perforation area was measured objectively rather than graded subjectively, the association was preserved but the correlation coefficient was moderate rather than strong: digital planimetry of endoscopic images in 107 ears yielded a Pearson correlation of r = 0.435 (p < 0.0001), and Spearman correlation in an independent 120-patient series yielded ρ = 0.581. This moderate strength is important, because it indicates that perforation size explains only

approximately 19–34% of the variance in hearing threshold, and that the remaining variance must be attributed to the ossicular chain, the middle-ear air space, the condition of the mucosa and the sensorineural component. Categorical gradings that appear to show a near-deterministic relationship are therefore overstating the predictive value of size alone.^{8,11}

Table 10. association between perforation size and hearing loss

Study	Measurement method	Small	Medium	Large / subtotal	Statistic
Banjara 2025	Oto-endoscopic photography, 3 categories	35.3 ± 6.68 dB	39.7 ± 7.12 dB	45.9 ± 5.65 dB	Monotonic increase; severity rose with size
Virk 2019	Otoendoscopy with area calculation (mm ²)	9.12 dB ABG	16.13 dB ABG	26.43 dB ABG	p < 0.05 across categories
John 2019	Microscope with measuring template, 4 groups	27.67 ± 1.85 dB	35.13 ± 2.98 dB	38.69 ± 2.63 to 46.97 ± 6.59 dB	p < 0.0001
Pradhan 2024	Calibrated 27G needle, 3 groups	31.22 ± 7.53 dB	42.76 ± 8.27 dB	62.5 ± 2.88 dB	Subtotal perforation 47.97 ± 9.05 dB
Rochd 2026	Proportion of pars tensa	23.46 dB ABG (≤ 25%)	25.41 dB ABG (25–50%)	28.07 dB ABG (> 50%)	p = 0.004
Kolluru 2020	ImageJ digital planimetry	—	—	—	r = 0.435, p < 0.0001 (continuous)

Mukherjee 2025	Categorical grading	—	—	—	Spearman $\rho = 0.581$; independent predictor on multivariable analysis
Rasouli 2022	Quadrant counting	One quadrant	Two to three quadrants	Subtotal 42.13 ± 7.07 dB	$\chi^2 = 22.891$, $p < 0.0001$
Priyadarshini 2017	Otoscopic grading	68.4% mild loss	—	51.4% moderately severe loss	Direct proportionality reported
Anand 2025	Otoscopic grading with duration	—	—	—	$p = 0.023$ for perforation diameter

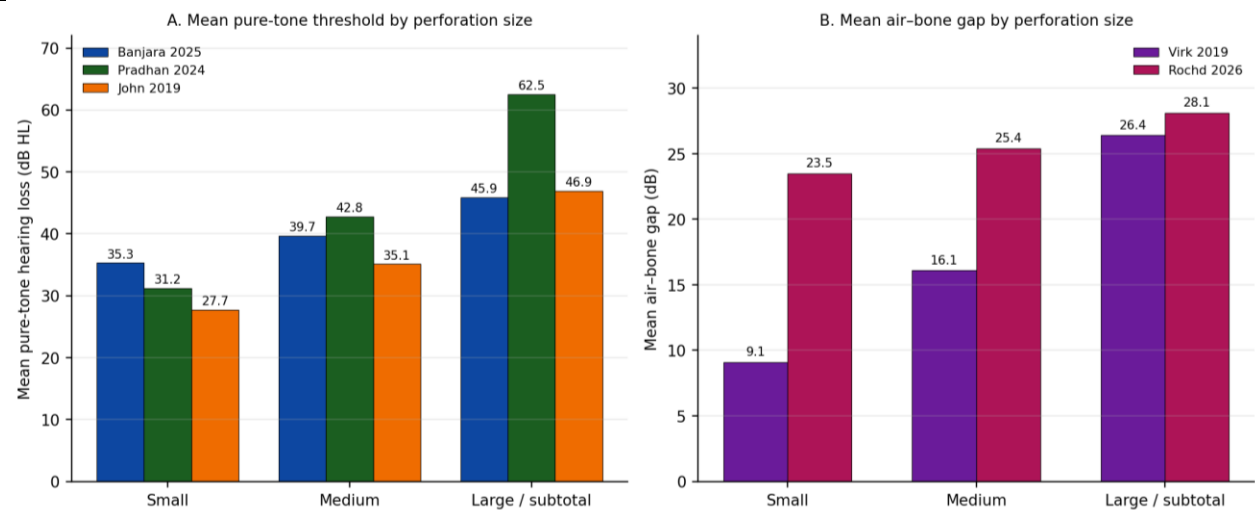


Figure 2. Dose–response relationship between tympanic membrane perforation size and the magnitude of hearing loss across included studies.

Panel A displays the mean pure-tone hearing level by perforation-size category in three independent series; panel B displays the mean air–bone gap in two further series. The gradient is consistent in direction across all five datasets despite differences in measurement technique, but the absolute values differ substantially, reflecting the non-interchangeability of size-grading methods.

Perforation site, quadrant involvement and malleolar involvement

Perforation site was the most contested predictor in the evidence base, and the discordance between studies is explicable largely by differences in perforation size distribution and by whether malleolar involvement was analysed separately. Among studies that found a significant site effect, posterior quadrant involvement was consistently the adverse location. In the 210-ear prospective study, single-quadrant posterosuperior perforations produced a mean air–bone gap of 23.9 ± 7.6 dB and posteroinferior perforations 19.3 ± 7.6 dB, whereas four-quadrant perforations produced 32.47 ± 9.04 dB; critically, this study analysed malleolar involvement separately and found that malleolar perforations were associated with a mean air–bone gap of 29.26 ± 9.4 dB compared with 18.25 ± 8.7 dB for non-malleolar perforations, and two-way analysis of variance identified site as a stronger predictor than size. In the 77-patient prospective study restricted to single-quadrant perforations, the posterosuperior quadrant again produced the greatest impairment.^{10,13}

Against this, several equally well-conducted studies found no significant site effect. In the 207-ear tubotympanic series, hearing loss was almost identical in anterior and posterior perforations ($p = 0.0874$); in the 74-patient prospective study restricted to small perforations involving less than one quadrant, the mean air–bone gaps were 32.29 ± 5.41 , 31.34 ± 4.12 , 29.87 ± 3.48 and 29.30 ± 4.60 dB for posteroinferior, posterosuperior, anteroinferior and anterosuperior perforations respectively, a difference that did not reach significance ($p = 0.168$); and in the 114-patient surgical cohort hearing loss was associated with size but not site. In the 107-ear planimetric study the posterior excess was 12% but was statistically significant only at 500 Hz ($p = 0.02$). The most coherent reading of this literature is that the round-window phase-cancellation effect that underlies the posterior disadvantage is measurable only when the perforation is large enough to abolish the acoustic shielding of the round-window niche, and is therefore undetectable in cohorts restricted to small perforations.^{12,15,24,64}

Table 11. perforation site, quadrant and malleolar involvement

Study	Design and restriction	Finding	Significance
Tayyaba 2025	Prospective, 210 ears, all sizes, malleolar involvement analysed separately	Posterosuperior 23.9 ± 7.6 dB; posteroinferior 19.3 ± 7.6 dB; four quadrants 32.47 ± 9.04 dB; malleolar 29.26 ± 9.4 dB versus non-malleolar 18.25 ± 8.7 dB	$p < 0.001$; site a stronger predictor than size on two-way ANOVA
Khurshid 2022	Prospective, 77 patients, single-quadrant perforations only	Posterosuperior quadrant produced the greatest degree of impairment	Significant association between site and degree of loss
Kolluru 2020	Prospective, 107 ears, digital planimetry	Posterior perforations 12% worse than anterior	Significant only at 500 Hz ($p = 0.02$)
John 2019	150 ears, three site groups	Combined-site 41.37 ± 5.9 dB versus posterior 35.21 ± 4.6 dB and anterior 31.7 ± 5.7 dB	$p = 0.0001$
Virk 2019	Prospective, 300 ears, site stratified by middle-ear volume	Posterosuperior perforations 4–7 dB worse than anterosuperior and anteroinferior in low-volume ears	Not statistically significant
Rasheed 2024	Prospective, 74 patients, small perforations only	Posteroinferior 32.29 ± 5.41 dB versus anterosuperior 29.30 ± 4.60 dB	$p = 0.168$ (not significant)
Priyadarshini 2017	Prospective, 207 ears, tubotympanic	Hearing loss almost identical in anterior and posterior perforations	$p = 0.0874$ (not significant)
Kadambott	Cross-sectional, 114	Hearing loss associated with size but	Not significant

2023	patients	not site of central perforation	for site
Banjara 2025	Cross-sectional, 109 ears	Posterior-quadrant perforations associated with greater loss and severity	Significant
Rasouli 2022	Cross-sectional, 67 patients	Greatest loss in posteroinferior quadrant alone (29.97 ± 4.32 dB) and posterosuperior plus posteroinferior (37.42 ± 9.59 dB)	Significant with size ($p < 0.0001$)

Duration of otorrhea and of disease

Duration of disease was the predictor with the strongest claim to causal primacy, because it is temporally antecedent to every other predictor in the set. In the 411-patient Angolan cross-sectional study, in which the median duration of otorrhea exceeded twelve months, reported hearing impairment correlated with otorrhea duration at $p < 0.0001$, and the authors identified duration of otorrhea as the strongest predictor of hearing impairment in the entire dataset. In the 120-patient Indian cross-sectional analysis, disease duration produced the highest Spearman correlation of any variable examined ($\rho = 0.689$, exceeding the $\rho = 0.581$ obtained for perforation size), and duration remained a significant independent predictor after multivariable analysis. In the 207-ear tubotympanic series, 68.8% of patients with discharge for more than thirty years had moderately severe impairment, compared with 60.2% of those with discharge for less than ten years who had only mild loss. In the 149-patient prospective study and the 142-patient cross-sectional study, duration correlated linearly with severity.^{7,8,15,16,32}

The relationship between duration and the sensorineural component specifically was less consistent. It was significant in the Iraqi tubotympanic series ($p = 0.018$) and in the Pakistani series in which the frequency of sensorineural loss increased with increasing duration, but was explicitly absent in the Nigerian retrospective series ($r = 0.190$, $p > 0.05$), the Iranian retrospective series ($r = 0.119$, $p > 0.05$), the Pakistani prospective series ($p > 0.05$) and the Pakistani single-quadrant series (no significant association between duration and degree of loss). Two explanations reconcile these findings. First, duration is almost invariably ascertained by patient recall and is therefore subject to

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substantial non-differential misclassification, which biases correlation coefficients towards the null. Second, the relationship is probably not linear but threshold-dependent: the retrospective cohort of endoscopic ear surgery found that a duration exceeding five years conferred a hazard ratio of 2.52 (95% CI 1.45–4.38) for an unfavourable outcome, which a linear correlation coefficient would fail to detect.^{17,18,19,20,27}

Table 12. duration of otorrhea and of disease as a predictor

Study	Duration metric	Association with hearing outcome	Statistic
Filipe 2020	Duration of otorrhea (median > 12 months)	Strongest predictor of hearing impairment in the dataset	$p < 0.0001$
Mukherjee 2025	Overall disease duration	Highest correlation of any variable; significant independent predictor	Spearman $\rho = 0.689$
Priyadarshini 2017	Duration of discharge (< 10 versus > 30 years)	68.8% moderately severe with > 30 years versus 60.2% mild with < 10 years	Direct proportionality
Kumar 2022	Disease duration	Significant linear correlation with severity of hearing loss and with depression	Spearman correlation, significant
John 2019	Disease duration, three groups	Degree of hearing loss increased as duration increased	Significant
Saadaldein 2025	Disease duration (< 5, 5–10, > 10 years)	Significant association with the sensorineural component	$p = 0.018$
Zaidi 2016	Duration of otorrhea	Frequency of SNHL increased with increasing duration	Significant
He 2026	Duration > 5 years	Independent risk factor for unfavourable postoperative outcome	HR 2.52 (95% CI 1.45–4.38), $p = 0.001$

Rasheed 2019	Long-standing disease	Associated with intraoperative ossicular necrosis	p = 0.004
Kolo 2012	Duration of otorrhea (mean 6.11 ± 6.39 years)	No correlation with the degree of SNHL	r = 0.190, p > 0.05
Amali 2017	Disease duration	No correlation with the degree of SNHL	r = 0.119, p > 0.05
Khurshid 2022	Disease duration (< 1 to > 10 years)	No significant association with the degree of hearing loss	Not significant

Activity and frequency of otorrhea

Whereas duration measures the cumulative exposure of the cochlea and ossicular chain to inflammation, the activity and frequency of discharge measure its intensity, and several studies indicate that intensity may be the more proximate determinant of tissue damage. In the 250-patient Italian series, ossicular chain suffering was identified in 7% of ears with a tympanic perforation but no otorrhea, compared with 19% of ears with chronic ear discharge and drum perforation — an almost threefold difference attributable to the activity of the disease alone. In the 105-patient Indian cross-sectional study, a currently discharging ear was significantly associated with ossicular necrosis (p = 0.014), as were polypoidal middle-ear mucosa and middle-ear granulation tissue (both p < 0.001). In the 212-ear retrospective series, persistently draining ears were significantly predictive of ossicular discontinuity in the cholesteatoma group (p = 0.026). In the 120-patient cross-sectional analysis, the frequency of otorrhea showed a strong statistical association with hearing impairment, although it was highly collinear with disease duration. In the Iraqi mucosal series the presence of active disease was independently associated with the sensorineural component (p = 0.032).^{31,36,37,53}

Table 13. activity and frequency of otorrhea

Study	Exposure	Outcome	Result
Albera 2015	Dry tympanic	Ossicular chain	7% versus 19%; otorrhea

	perforation versus chronic ear discharge	suffering at surgery	identified as a good predictor of ossicular damage
Rasheed 2019	Currently discharging ear; polypoidal mucosa; granulation tissue	Intraoperative ossicular necrosis	$p = 0.014$; $p < 0.001$; $p < 0.001$ respectively
Jeng 2003	Persistently draining ear (cholesteatoma group)	Ossicular discontinuity	$p = 0.026$
Saha 2021	Granulation tissue in the middle ear	Ossicular discontinuity	21 of 25 ears (84%), $p < 0.01$
Mukherjee 2025	Frequency of active discharge	Hearing impairment and mixed loss	Strong association; highly collinear with disease duration
Saadaldein 2025 (Kirkuk)	Active disease at assessment	Sensorineural hearing loss	$p = 0.032$
Tayyaba 2025	Duration of discharge	Air–bone gap	Longer discharge duration further exacerbated hearing loss

Disease type and cholesteatoma

Squamosal disease was associated with a worse audiometric profile than mucosal disease in every study that made the comparison, and the mechanism was demonstrably ossicular. The definitive dataset is the 915-patient Turkish retrospective series, in which ossicular chain erosion was found in 82% of ears with cholesteatoma, in 31.8% of ears with granulation tissue and in only 12.7% of ears with uncomplicated chronic otitis media — a more than sixfold gradient. In the Bangladeshi comparison, moderate hearing loss predominated in atticoantral disease (42.85%) whereas mild loss predominated in tubotympanic disease (44.79%), and mixed and sensorineural losses were confined almost entirely to the atticoantral group. In the Iranian cross-sectional analysis of 694 surgical cases, the effect size for the widening of the air–bone gap in the presence of

ossicular discontinuity was greatest in cholesteatoma and declined progressively through tympanosclerosis, granulation tissue and hypertrophic mucosa ($p < 0.001$). In the retrospective cohort of endoscopic ear surgery, cholesteatoma was the strongest independent predictor of an unfavourable outcome (HR 3.24, 95% CI 1.85–5.68, $p < 0.001$).^{23,25,27,29}

Two counter-intuitive observations deserve emphasis because they are clinically consequential. First, in the 149-patient prospective series the absence of cholesteatoma, rather than its presence, was significantly associated with the sensorineural component ($p < 0.05$); a plausible explanation is that a cholesteatoma sac may act as a physical barrier limiting the diffusion of ototoxic mediators towards the round window, whereas an open, actively discharging mucosal cavity permits unimpeded transmission. Second, in the 140-patient Italian cholesteatoma series, air and bone conduction worsened as the number of involved ossicles increased, yet the air–bone gap remained stable, and in 11% of ears with demonstrable ossicular damage the chain remained in acoustic continuity with a hearing threshold indistinguishable from ears without resorption — the so-called cholesteatoma bridge effect, in which the keratin matrix itself conducts sound across an eroded chain. Both observations warn against inferring the intraoperative anatomy from the audiogram in squamosal disease.^{16,35}

Table 14. disease type, cholesteatoma and hearing outcome

Study	Comparison	Result	Interpretation
Akarçay 2019	Cholesteatoma (n = 234) versus granulation (n = 66) versus uncomplicated COM (n = 615)	Ossicular erosion in 82% versus 31.8% versus 12.7%	Cholesteatoma is the dominant driver of ossicular destruction
Islam 2020	Atticoantral versus tubotympanic	Moderate loss in 42.85% versus mild loss in 44.79%; mixed 14.28% versus 2.08%; SNHL 4.76% versus 0%	Squamosal disease shifts the whole distribution to the right

Faramarzi 2023	Effect size of ABG widening by pathology	Largest in cholesteatoma, then tympanosclerosis, granulation tissue, hypertrophic mucosa	Pathology type conditions the audiometric signature
He 2026	Cholesteatoma versus no cholesteatoma	HR 3.24 (95% CI 1.85–5.68), $p < 0.001$ for unfavourable outcome	Independent prognostic factor after adjustment
Jha 2024	Absence versus presence of cholesteatoma	Absence of cholesteatoma significantly associated with SNHL ($p < 0.05$)	Possible barrier effect of the cholesteatoma sac
Albera 2012	Cholesteatoma extension and ossicular resorption	Resorption in 82% of patients, incus involved in 78%; ABG stable despite increasing ossicular involvement in 11%	Cholesteatoma may bridge an eroded chain acoustically
Amali 2017	Cholesteatoma and ossicular erosion versus SNHL	No relationship with the degree of SNHL ($p > 0.05$)	Squamosal disease acts principally on the conductive compartment
Gupta 2022	Safe versus unsafe CSOM	Mixed loss in 31.67% of unsafe cases; overall SNHL 16.67%	Unsafe disease carries a higher mixed-loss burden

Ossicular chain status

The ossicular chain is the principal mediator through which the other predictors express themselves audiometrically, and the included studies characterise both its epidemiology and its audiometric footprint. The incus, and specifically its long process, was the most frequently eroded ossicle in every series that reported individual ossicular status: 78% of cholesteatoma cases in the Italian series, 92% of ossicular chain suffering in non-cholesteatomatous disease, 51.41% eroded plus 17.75% absent in an Iranian retrospective series, and the commonest lesion in the Indian, Turkish and Indonesian cohorts. This is attributable to the tenuous blood supply of the long process,

its position within the retrotympanum where granulation tissue and cholesteatoma accumulate, and the absence of a supporting ligamentous framework.^{25,34,35,36,38}

The audiometric footprint of ossicular pathology is a widened air–bone gap and a raised pure-tone average. In the 114-patient surgical cohort the mean pure-tone average rose from 43.62 ± 8.07 to 58.15 ± 11.05 dB HL and the mean air–bone gap from 27.89 ± 4.77 to 38.88 ± 6.47 dB when the chain was eroded or absent (both $p < 0.0001$). In the 105-patient study the mean air–bone gap was 35 dB with ossicular necrosis versus 22.7 dB with an intact chain ($p = 0.0001$). In the 81-patient study an air–bone gap exceeding 40 dB was present in 60% of ears with discontinuity ($p < 0.001$). In the 64-patient Indonesian series, the correlation between the intraoperative ossicular status score and the hearing threshold was $R = 0.5$ and with the air–bone gap $R = 0.6$ (both $p < 0.005$), and linear regression identified sex, hearing threshold, air–bone gap and the presence of cholesteatoma as the most influential predictors of ossicular status. Against this consistent picture, two retrospective series concluded that pure-tone audiometry does not reliably reflect ossicular status, one reporting no significant difference in pure-tone average or air–bone gap between intact and discontinuous chains and the other reporting that the air–bone gap was not significantly correlated with discontinuity because cholesteatoma and granulation tissue act as acoustic transmission bridges.^{24,28,30,31,37,38}

Table 15. ossicular chain status and hearing loss

Study	n	Prevalence and pattern of ossicular pathology	Audiometric association
Akarçay 2019	915	Erosion in 31.8% overall; incus most affected, then stapes, then malleus	Erosion related to worse preoperative hearing level
Kadambott 2023	114	Discontinuity in 27 (23.68%), incus most affected	PTA 43.62 ± 8.07 versus 58.15 ± 11.05 dB; ABG 27.89 ± 4.77 versus 38.88 ± 6.47 dB ($p < 0.0001$)
Rasheed	105	Ossicular necrosis in 18 (17.1%)	Mean ABG 35 versus 22.7 dB ($p =$

2019			0.0001)
Saha 2021	81	Discontinuity associated with perforation edge adherent to promontory (93.3%)	ABG > 40 dB in 60% of discontinuity cases (p < 0.001)
Rizandiny 2021	64	Mean ossicular status score 1.84 ± 1.48 ; intact malleus–incus–stapes in 31.3%	Hearing threshold R = 0.5 and ABG R = 0.6 versus ossicular score (p < 0.005)
Jha 2024	149	Incus erosion the commonest lesion associated with SNHL (10.6%)	p = 0.002
Albera 2015	250	Ossicular chain suffering in 10%; incus involved in 92%	AC threshold and ABG more impaired in chronic otitis than in simple perforation
Martins 2012	158	Graded ossicular destruction in cholesteatoma	Each ossicle contributed to the ABG in a graded, independent manner; incus most significant
Bayat 2019	107	Malleus eroded 25.24%, incus eroded 51.41% and absent 17.75%, stapes eroded 49.54%	No significant difference in PTA or ABG between intact and discontinuous chains (p > 0.05)
Jeng 2003	212 ears	Discontinuity predicted by adherent perforation edge and by tympanic sinus extension	ABG not significantly correlated with discontinuity, attributed to acoustic bridging

The sensorineural component

A sensorineural component was demonstrated in every series that measured masked bone-conduction thresholds in the diseased ear and compared them either with the contralateral healthy ear or with age-matched controls, and its reported prevalence ranged from 14.7% to 52%. The most rigorous demonstrations use the contralateral ear as an internal control in strictly unilateral disease. In the Nigerian retrospective series the mean bone-conduction threshold was 39.07 ± 12.03 dB in

the diseased ear compared with 10.26 ± 2.62 dB in the control ear ($p < 0.05$), with interaural differences of 21.69 to 34.52 dB across 0.5, 1, 2 and 4 kHz, all significant and all increasing with frequency. In the Iranian series the interaural difference rose from 7.00 dB at 500 Hz to 9.71 dB at 4 kHz ($p < 0.001$ at every frequency). In the Iraqi series bone-conduction thresholds were significantly elevated in the diseased ear ($p < 0.001$) with high frequencies affected more than speech frequencies.^{17,18,19}

The predictors of the sensorineural component were less consistent than those of the conductive component. Age was significantly correlated in the Iranian series ($r = 0.422$, $p < 0.001$) and in the Pakistani series, and the incidence of sensorineural loss increased with advancing age in a further Indian series, reaching 35% in the fifth decade and only 7.32% in the second. Disease duration and the presence of active disease were significant in the Iraqi series ($p = 0.018$ and $p = 0.032$) but not in the Nigerian, Iranian or Pakistani series. Female sex, absence of cholesteatoma, incus erosion and a hearing loss exceeding 56 dB were significant in the 149-patient prospective series. Overall, the evidence supports the conclusion that a sensorineural component is real, frequency-dependent and quantitatively substantial, but that no single clinical variable predicts it reliably — a finding with direct implications for surveillance, since it means that audiometry cannot be replaced by clinical risk stratification for this outcome.^{16,17,20,50,52,53}

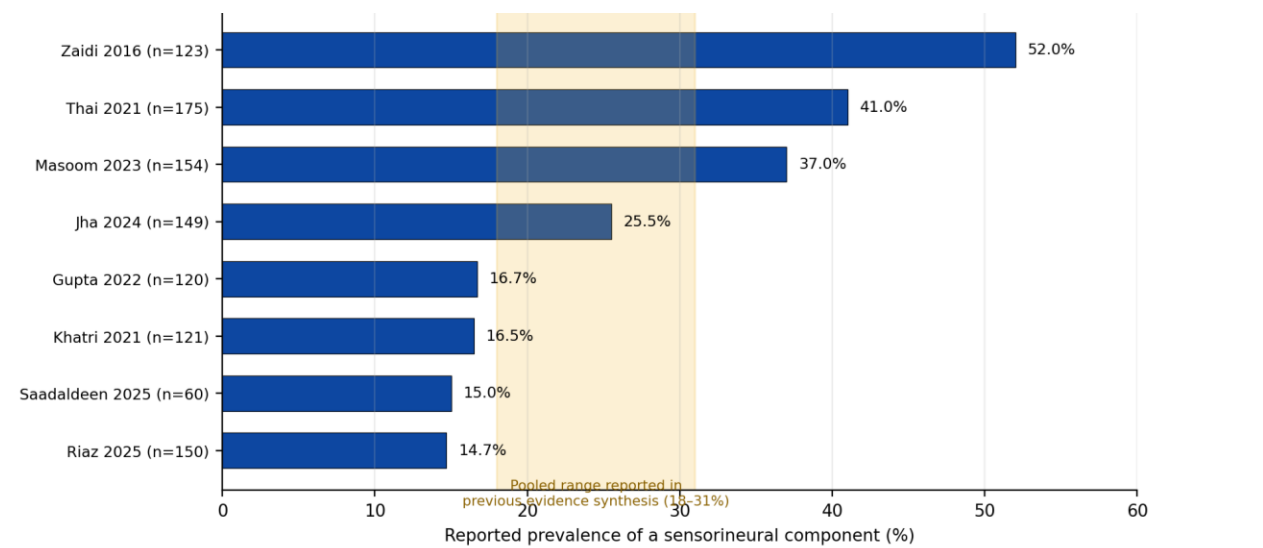


Figure 3. Reported prevalence of a sensorineural component among patients with chronic suppurative otitis media across the included and contextual series.

The shaded band denotes the 18–31% range reported by a previous evidence synthesis of twelve studies comprising 1 742 participants. The wide dispersion reflects differing definitions of the sensorineural component, differing masking protocols and differing disease severity in the source populations.

Table 16. prevalence and predictors of the sensorineural component

Study	n	SNHL prevalence	Bone-conduction findings	Significant predictors
Kolo 2012	69	Not categorised	39.07 ± 12.03 dB versus 10.26 ± 2.62 dB in controls; interaural difference 21.69–34.52 dB	None (age $r = 0.186$, duration $r = 0.190$, both non-significant)
Amali 2017	70	Not categorised	Interaural difference 7.00 dB at 500 Hz rising to 9.71 dB at 4 kHz ($p < 0.001$)	Age ($r = 0.422$, $p < 0.001$)
Zaidi 2016	123	52.0%	Mean threshold > 25 dB in the diseased ear	Increasing duration of disease
Thai 2021	175	41.0% moderate or worse	Not reported separately	Chronicity of disease
Masoom 2023	154	37.0%	Not reported separately	Age group 12–20 years accounted for 40.2% of SNHL cases; duration not correlated
Jha 2024	149	25.5%	Not reported separately	Female sex, absence of cholesteatoma ($p < 0.05$), hearing loss > 56 dB ($p <$

				0.001), incus erosion (p = 0.002)
Gupta 2022	120	16.67%	Not reported separately	Advancing age; maximum incidence 35% at 41–50 years
Khatri 2021	121	16.52%	Mean bone conduction 29.42 ± 4.28 dB	Age, sex, duration of symptoms, bone-conduction level (all p < 0.05)
Saadaldeen 2025	60	15.0% mixed loss	Significantly elevated in the diseased ear (p < 0.001), high frequencies most affected	Disease duration (p = 0.018), active disease (p = 0.032), perforation size (p = 0.036)
Riaz 2025	150	14.7%	Measured at 0.5, 1, 2 and 4 kHz in both ears	Symptom duration (mean 15.3 ± 3.3 weeks)

Frequency-specific pattern of hearing loss

The audiogram in CSOM has a characteristic and mechanistically informative shape. The conductive component is maximal at low frequencies, because the loss of the effective vibrating area of the tympanic membrane and the reduction of the middle-ear air cushion act principally as a stiffness deficit. In the 300-ear study, the air–bone gap was 56.9 dB at 250 Hz, 42.6 dB at 500 Hz, 41.5 dB at 1 kHz and 32.4 dB at 2 kHz before rising again to 49.5 dB at 4 kHz. In the 109-ear study the audiogram assumed an inverted-V configuration, with 2 kHz consistently the least affected frequency, a pattern attributable to the middle-ear resonance that partially compensates for the transmission loss at that frequency. The sensorineural component, by contrast, is maximal at high frequencies, reflecting basal-turn outer hair-cell injury, and the interaural bone-conduction difference therefore widens progressively from 500 Hz to 4 kHz. The superimposition of a low-frequency conductive deficit and a high-frequency sensorineural deficit accounts for the characteristic saucer-shaped or inverted-V audiogram of longstanding CSOM.^{9,12,17,18}

Table 17. frequency-specific pattern of hearing loss

Study	Frequency-specific finding	Interpretation
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Virk 2019	ABG 56.9 dB at 250 Hz, 42.6 dB at 500 Hz, 41.5 dB at 1 kHz, 32.4 dB at 2 kHz and 49.5 dB at 4 kHz	Conductive deficit maximal at low frequencies with a mid-frequency nadir
Banjara 2025	Inverted-V audiogram with 2 kHz the least affected frequency across all perforation sizes	Middle-ear resonance partially compensates at 2 kHz
Kolo 2012	Interaural bone-conduction difference 21.69–34.52 dB, increasing with frequency	Basal-turn cochlear injury
Amali 2017	Interaural bone-conduction difference rising from 7.00 dB at 500 Hz to 9.71 dB at 4 kHz	Frequency-dependent cochlear involvement
Saadaldein 2025	Higher frequencies affected more than speech frequencies	High-frequency predominance of the sensorineural component
Kaur 2018	Higher frequencies more affected overall, but speech frequencies maximally affected in subtotal and attic perforations	Extensive disease encroaches on the speech range
Kolluru 2020	Posterior perforations worse than anterior only at 500 Hz	Round-window phase-cancellation effect is frequency-specific
Sarmiento 2017	ABG at 4 kHz minus mean ABG at 0.25 and 0.5 kHz distinguishes incomplete ossicular discontinuity	High-frequency conductive loss is the acoustic signature of a partially eroded chain

Demographic predictors

Age was associated with the sensorineural but not with the conductive component. The Iranian retrospective series demonstrated a significant correlation between age and the degree of sensorineural loss ($r = 0.422$, $p < 0.001$) and concluded that ageing acts as a precipitating factor in the cochlear pathology of CSOM; a further Pakistani series confirmed a significant association of sensorineural loss with age ($p < 0.05$); and an Indian series reported a maximum sensorineural incidence of 35% in the fifth decade against a minimum of 7.32% in the second. Against this, the

127-patient study of middle-ear volume found no correlation between hearing loss and either age or sex, and one Pakistani series found the highest sensorineural burden in the youngest age band, which most plausibly reflects the age structure of the source population rather than a biological effect.^{17,50,52,66}

Sex was inconsistently associated with outcome. The Greenlandic cohort found male sex to be an independent risk factor for hearing loss (OR 2.2, 95% CI 1.28–3.78), whereas the Indian prospective series found female sex to be significantly associated with the sensorineural component, and the Indonesian regression analysis retained sex as an influential predictor of intraoperative ossicular status. In the absence of any plausible unifying biological mechanism, and given that the direction of association is not consistent, sex should be regarded as a marker of differential care-seeking, occupational noise exposure or disease duration rather than as a determinant in its own right.^{6,16,28}

Table 18. age and sex as predictors

Study	Variable	Association	Statistic
Amali 2017	Age	Significant positive correlation with the degree of SNHL	$r = 0.422, p < 0.001$
Khatri 2021	Age and sex	Both significantly associated with SNHL	$p < 0.05$
Gupta 2022	Age	SNHL incidence 35% at 41–50 years versus 7.32% at 11–20 years	Significant trend
Jensen 2013	Male sex	Independent risk factor for hearing loss	OR 2.2 (95% CI 1.28–3.78)
Jha 2024	Female sex	Significantly associated with SNHL	$p < 0.05$
Rizandiny 2021	Sex	Retained as an influential predictor of intraoperative ossicular status	Linear regression
Kolo 2012	Age	No correlation with the degree of SNHL	$r = 0.186, p > 0.05$
Gupta K 2025	Age and sex	No correlation with hearing loss	Not significant

Middle-ear air-space volume and mastoid pneumatisation

Two studies examined the aerated volume of the middle-ear cleft and both found an inverse relationship with the air–bone gap. In the 300-ear prospective series, 92% of ears fell into the low-volume group and had a mean air–bone gap of 19.96 dB, compared with 11.80 dB in the 8% with a high volume; the authors concluded that hearing loss is inversely proportional to middle-ear air-space volume. In the 127-patient study the same relationship was demonstrated with greater separation, low-volume ears having a mean air–bone gap of 35.37 dB ($p < 0.001$). Mastoid pneumatisation, assessed radiologically on Schuller's view in the 210-ear prospective series, exerted an independent additional effect, reduced pneumatisation being associated with a greater air–bone gap. These findings are mechanistically coherent: a smaller aerated volume increases the acoustic impedance presented to the tympanic membrane remnant, and a sclerotic mastoid removes the compliance reserve that would otherwise buffer pressure changes across the residual drum.^{10,12,66}

Table 19. Middle-ear volume and mastoid pneumatisation

Study	n	Exposure	Result	Statistic
Virk 2019	300 ears	Middle-ear air-space volume by tympanometry	Low volume 19.96 dB versus high volume 11.80 dB mean ABG; 92% of ears in the low-volume group	Inverse relationship demonstrated
Gupta K 2025	127 patients	Middle-ear space volume by impedance audiometry	Low volume mean ABG 35.37 dB; posterior perforation 35.6 dB versus anterior 25.4 dB	$p < 0.001$
Tayyaba 2025	210 ears	Mastoid pneumatisation on Schuller's view	Reduced pneumatisation further exacerbated hearing loss, independently of perforation size and site	Significant on two-way ANOVA

Discriminative accuracy of predictors

Only a minority of studies expressed their findings in terms that permit a predictor to be used as a decision rule, and these are the most clinically actionable data in the review. The most complete diagnostic-accuracy evaluation is the 328-patient prospective Brazilian study of the high-frequency conductive hearing loss test, defined as the preoperative air–bone gap at 4 kHz minus the mean air–bone gap at 0.25 and 0.5 kHz, validated against intraoperative findings as the reference standard. At the optimal cut-off of 10 dB, this test identified incomplete ossicular discontinuity with a sensitivity of 83%, a specificity of 92%, a post-test probability of 78% and a likelihood ratio of 10.2. Reconstruction of the corresponding receiver operating characteristic curve from this operating point under an equal-variance binormal model yields an area under the curve of approximately 0.95, placing this simple bedside audiometric manoeuvre in the excellent-discrimination range.²¹

The 694-patient Iranian study derived optimal cut-off values by receiver operating characteristic analysis: a speech reception threshold of 37.5 dB, a mean air conduction of 37.2 dB and a mean air–bone gap of 28.4 dB for the prediction of ossicular discontinuity, and 37.5 dB, 40.3 dB and 32.8 dB respectively for the prediction of ossicular fixation. The 276-patient Philippine study expressed the same relationship in likelihood-ratio terms, demonstrating that an air–bone gap of 20 dB or less at 500 Hz reduced the probability of gross ossicular discontinuity from a pre-test 33% to 5.6%, and that an air–bone gap exceeding 30 dB at 2 kHz raised it to 51%; critically, in the presence of cholesteatoma the pre-test probability of discontinuity was already 88% and the air–bone gap added no discriminative information, so that ossicular exploration is mandatory regardless of the audiogram. Contextual evidence from adjacent middle-ear conditions indicates the ceiling of what audiological instrumentation can achieve: wideband absorbance averaged across 0.5–4 kHz predicted the severity of conductive hearing loss with areas under the curve of 0.88, 0.93 and 0.94 for successively larger air–bone gaps, whereas deep-learning analysis of otoscopic images achieved 0.74 and a logistic model based on tympanic-membrane features alone achieved only 0.60. These values are compared in Figures 4 and 8.^{22,23,39,40,41}

Table 20. Discriminative accuracy of clinical and audiometric predictors

Study	Index test	Target condition	Cut-off	Sensitivity / specificity	AUC or likelihood ratio
Sarmiento 2017	High-frequency conductive hearing loss (ABG 4 kHz minus mean ABG 0.25 and 0.5 kHz)	Incomplete ossicular discontinuity	10 dB	83% / 92%	LR 10.2; post-test probability 78%; reconstructed AUC $\approx$ 0.95
Faramarzi 2023	Speech reception threshold	Ossicular discontinuity	37.5 dB	Not reported	Cut-off derived by ROC analysis
Faramarzi 2023	Mean air conduction	Ossicular discontinuity	37.2 dB	Not reported	Cut-off derived by ROC analysis
Faramarzi 2023	Mean air–bone gap	Ossicular discontinuity	28.4 dB	Not reported	Cut-off derived by ROC analysis
Faramarzi 2023	Mean air–bone gap	Ossicular fixation	32.8 dB	Not reported	Cut-off derived by ROC analysis
Carrillo 2007	Frequency-specific ABG at 500 Hz	Gross ossicular discontinuity	$\leq$ 20 dB	Not reported	LR– 0.119 (0.016–0.867); post-test probability 5.6%
Carrillo 2007	Frequency-specific ABG at 2 kHz	Gross ossicular discontinuity	> 30 dB	Not reported	LR+ 2.8 (1.4–5.9); post-test probability 51%
Carrillo 2007	Frequency-specific ABG at 4 kHz	Gross ossicular discontinuity	> 40 dB	Not reported	LR+ 2.2 (1.2–3.9)
Saha 2021	Air–bone gap	Ossicular	> 40 dB	Not	Present in 60% of

		discontinuity		reported	discontinuity cases ($p < 0.001$)
Aithal 2023 (contextual)	Wideband absorbance 0.5–4 kHz	Severity of conductive hearing loss	Continuous	Not reported	AUC 0.88, 0.93 and 0.94 for ABG 16–25, 26–35 and 36–45 dB
Zeng 2022 (contextual)	Deep-learning analysis of otoscopic images	Conductive hearing loss (ABG > 10 dB)	Model output	Accuracy 81%	AUC 0.74 versus 0.60 for a tympanic-membrane feature model
Sheng 2021 (contextual)	Wideband acoustic absorbance at 1.0 kHz	Middle-ear disease	0.55	Sensitivity 90.8%	AUC 0.890; 0.932 when combined with 226 Hz tympanometry

ABG = air–bone gap; AUC = area under the receiver operating characteristic curve; LR = likelihood ratio; ROC = receiver operating characteristic. Studies marked contextual address adjacent middle-ear conditions and were not admitted to the characteristics table; they are presented here solely to define the attainable ceiling of discriminative performance.

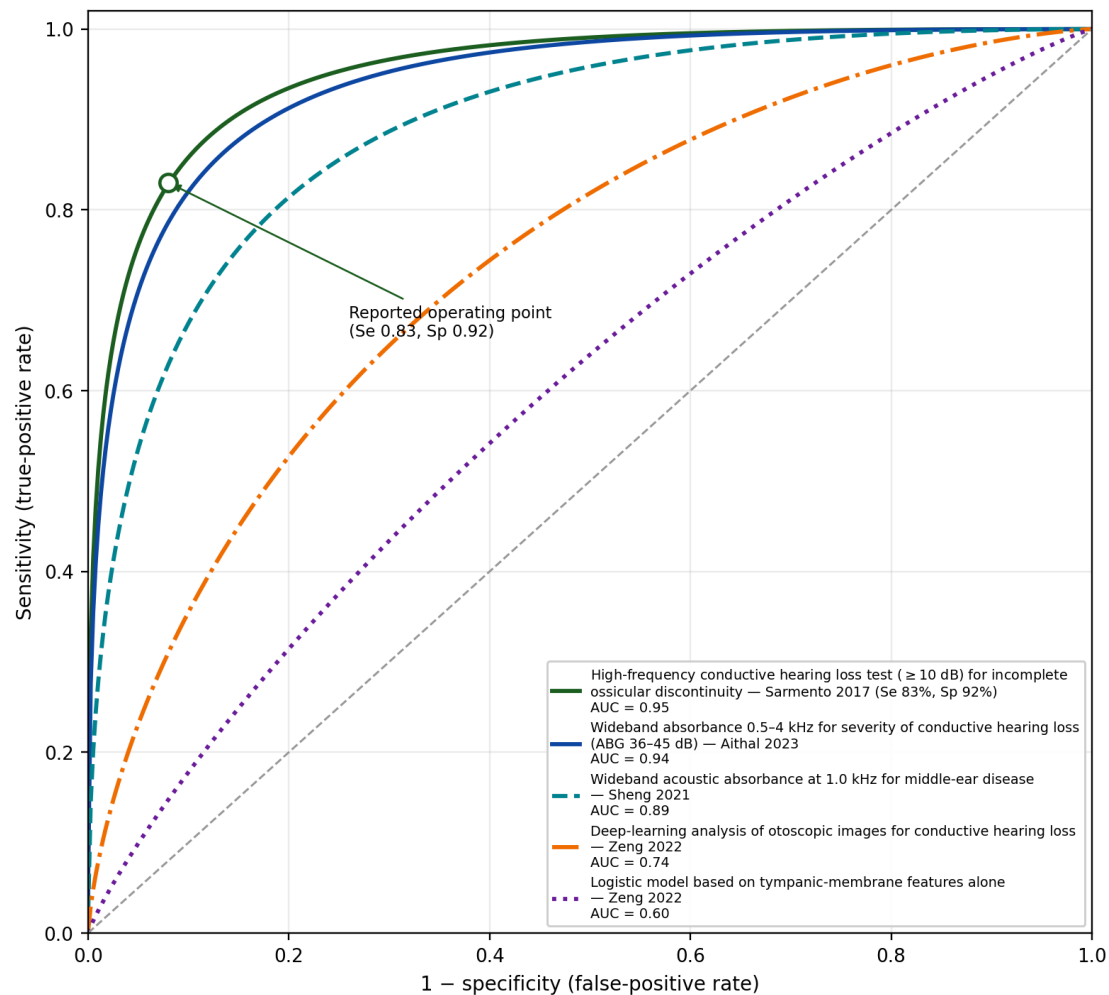


Figure 4. Receiver operating characteristic curves for clinical and audiological index tests used to predict hearing impairment and its middle-ear substrate.

Curves were reconstructed from the areas under the curve and the sensitivity–specificity pairs reported by the primary authors, using an equal-variance binormal model ($a = \sqrt{2} \times \Phi^{-1}(AUC)$; $sensitivity = \Phi(a + \Phi^{-1}(1 - specificity))$). They are model-based representations of published summary statistics and not re-analyses of individual patient data. The open circle marks the single empirically reported operating point (sensitivity 0.83, specificity 0.92) for the high-frequency conductive hearing loss test at a 10 dB threshold.

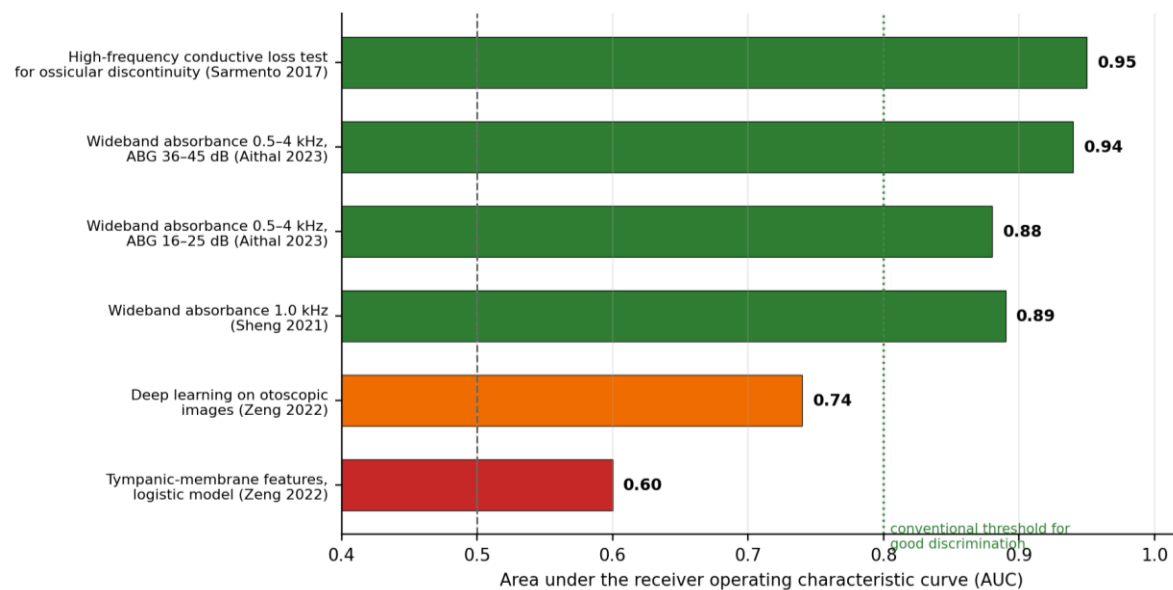


Figure 5. Comparative discrimination of index tests for hearing impairment and its middle-ear substrate in chronic ear disease, expressed as the area under the receiver operating characteristic curve.

Simple audiometric manoeuvres and wideband acoustic measures outperform image-based assessment of the tympanic membrane, whether that assessment is made by a clinician-derived feature model or by a deep-learning classifier.

Post-treatment hearing outcome and its predictors

Three included studies addressed hearing outcome after intervention. The retrospective cohort of 180 patients undergoing endoscopic ear surgery reported a six-month dry-ear rate of 91.1%, a mean pure-tone average improvement of 24.8 ± 7.2 dB and a complication rate of 3.9%; multivariable analysis identified cholesteatoma (HR 3.24, 95% CI 1.85–5.68), a disease duration exceeding five years (HR 2.52, 95% CI 1.45–4.38) and a preoperative pure-tone average above 50 dB (HR 2.89, 95% CI 1.65–5.06) as independent risk factors for failure. The retrospective cohort of 175 patients managed at an academic otology clinic demonstrated that surgery is superior to medical therapy for achieving short- to medium-term inactive disease, with 69% recurrence under medical management at a median of four months against a median time to recurrence of five to seven years after tympanoplasty or tympanomastoidectomy, but also documented a 41% prevalence

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of moderate or worse sensorineural loss at last follow-up, indicating that control of discharge does not equate to preservation of hearing. Contextual surgical series show that the mean air–bone gap falls from 34.63 dB preoperatively to 17.26 dB after ossicular reconstruction, with success (air–bone gap ≤ 20 dB) in 61% of ears, and that the presence of the stapes superstructure and a low middle-ear risk index predict success. The adjusted effect estimates from the two cohort studies are displayed in Figure 5.^{26,27,59,60}

Table 21. Predictors of hearing outcome after treatment

Study	Intervention	Hearing outcome	Independent predictors of an unfavourable outcome
He 2026	Endoscopic ear surgery, 180 patients, 6-month follow-up	Dry-ear rate 91.1%; mean PTA improvement 24.8 ± 7.2 dB; complications 3.9%	Cholesteatoma HR 3.24 (1.85–5.68); duration > 5 years HR 2.52 (1.45–4.38); preoperative PTA > 50 dB HR 2.89 (1.65–5.06)
Thai 2021	Medical versus surgical management, 175 patients	69% recurrence under medical management (median 4 months); 41% moderate or worse SNHL at last visit	Reliance on medical management alone; chronicity of disease
Kotzias 2018 (contextual)	Ossiculoplasty, 72 ears	Mean ABG fell from 34.63 to 17.26 dB; success (ABG ≤ 20 dB) in 61%	High middle-ear risk index; absence of the stapes superstructure (success 63.3% versus 85% when the malleus was absent)
Al Hamoud 2024 (contextual)	Tympanoplasty, 85 patients	Mean ABG fell from 22.6 ± 7.5 to 19.0 ± 9.3 dB ($p = 0.007$)	Preoperative ABG predicted intraoperative ossicular status; perforation

			type did not
Blom 2015 (contextual)	Evidence synthesis of ossicular chain damage	Postoperative ABG 11.1 dB (malleus present, stapes absent) versus 16.5 dB (both absent)	Malleus status is the significant determinant, independent of the stapes

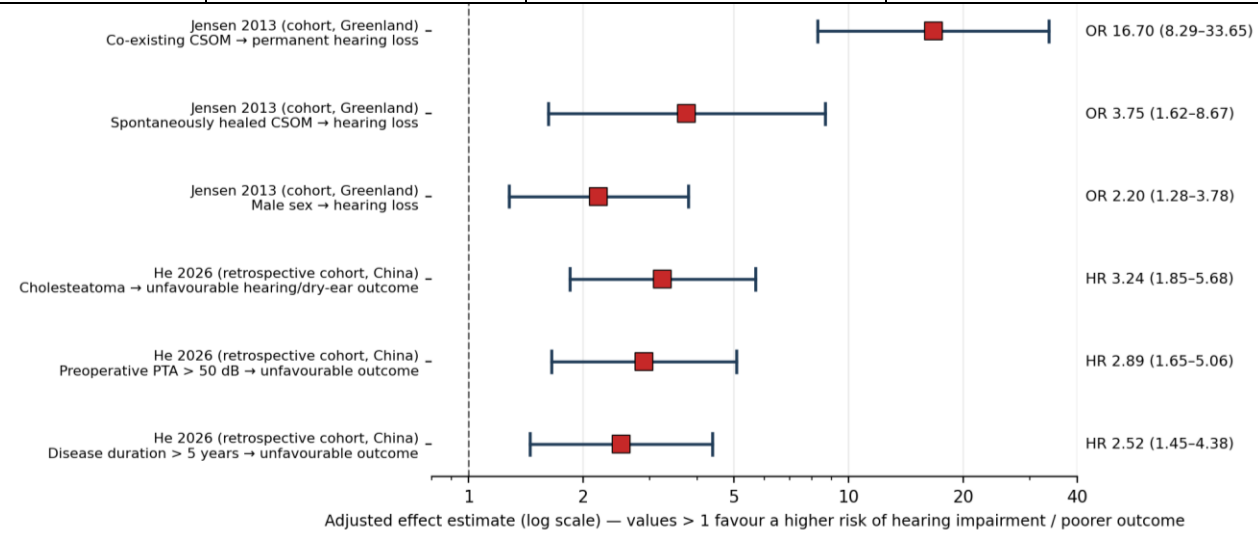


Figure 6. Forest plot of adjusted multivariable effect estimates for predictors of hearing impairment and of hearing-related outcome in CSOM.

Estimates are displayed on a logarithmic scale without pooling, in accordance with the pre-specified decision not to perform meta-analysis. Squares denote point estimates and horizontal lines the 95% confidence intervals. Odds ratios derive from a population-based longitudinal cohort and hazard ratios from a retrospective surgical cohort; the two metrics are not directly comparable and are displayed together only to illustrate the magnitude and precision of the available adjusted evidence.

Synthesis across predictors and certainty of the evidence

Table 22 summarises the direction, consistency and strength of every predictor examined, and Table 24 presents the GRADE certainty profile for each of the fifteen outcome domains. Three predictors achieved moderate certainty: perforation size, disease type including cholesteatoma, and

ossicular chain status. Perforation size was upgraded from low to moderate certainty on the strength of a clear and reproducible dose–response gradient demonstrated in ten independent studies using five different measurement techniques. Disease type and ossicular status were upgraded on the strength of the large magnitude of effect, the more than sixfold difference in erosion prevalence between cholesteatomatous and uncomplicated disease being far larger than could plausibly be produced by residual confounding. All remaining domains were rated as low or very low certainty, principally because of unadjusted analysis, inconsistency between studies, and imprecision arising from small single-centre samples.^{9,12,14,25,27}

Table 22. Synthesis matrix — direction, consistency and strength of each predictor

Predictor	Studies	Direction of effect	Consistency	Strength of association	Overall verdict
Perforation size	10	Larger perforation → greater hearing loss	10 of 10 concordant	Moderate ($r = 0.435$; $\rho = 0.581$); ABG 9.12 → 26.43 dB	Established predictor
Posterior / malleolar site	10	Posterior and malleolar involvement → greater loss	6 of 10 concordant	Moderate (ABG 18.25 → 29.26 dB for malleolar)	Probable predictor, size-dependent
Number of quadrants involved	4	More quadrants → greater loss	4 of 4 concordant	Large (four quadrants 32.47 ± 9.04 dB)	Established predictor
Duration of disease / otorrhea	12	Longer duration → greater loss	8 of 12 concordant	Moderate to strong ($\rho = 0.689$; HR 2.52)	Probable predictor with threshold effect
Activity and	7	Active or	7 of 7	Moderate (7%)	Probable

frequency of discharge		frequent discharge → greater damage	concordant	versus 19% ossicular damage)	predictor
Cholesteatoma / squamosal disease	8	Squamosal disease → greater loss	7 of 8 concordant	Large (82% versus 12.7% erosion; HR 3.24)	Established predictor
Ossicular chain erosion or discontinuity	10	Erosion → wider ABG and higher PTA	8 of 10 concordant	Large (PTA 43.62 → 58.15 dB)	Established predictor and principal mediator
Granulation tissue / polypoidal mucosa	4	Present → greater ossicular damage	4 of 4 concordant	Large (84% discontinuity with granulation)	Probable predictor
Age	8	Older age → greater sensorineural component	5 of 8 concordant	Weak to moderate ($r = 0.422$)	Possible predictor of the sensorineural component only
Sex	6	Inconsistent direction	Discordant	Weak (OR 2.2 for male sex in one cohort)	Not an independent predictor
Middle-ear air-space volume	2	Lower volume → wider ABG	2 of 2 concordant	Moderate (11.80 versus 19.96 dB)	Probable predictor
Mastoid	1	Reduced	Single study	Not quantified	Insufficient

pneumatisation		pneumatisation → greater loss			evidence
Preoperative PTA / ABG as index test	5	Wider ABG → higher probability of ossicular pathology	3 of 5 concordant	Strong where reported (LR 10.2; AUC ≈ 0.95)	Established index test outside cholesteatoma
Perforation edge adherent to promontory	2	Adherent edge → ossicular discontinuity	2 of 2 concordant	Large (93.3% of discontinuity cases)	Probable predictor
Bilateral disease	1	Bilateral → greater ossicular damage	Single study	Not quantified	Insufficient evidence

Table 23. GRADE certainty of evidence for each outcome domain

Outcome domain	Studies (n)	Design	Downgraded for	Upgraded for	Certainty
O1 Prevalence and burden	7	Observational	Inconsistency, indirectness	Large effect	Low
O2 Type of hearing loss	8	Observational	Risk of bias, inconsistency	—	Low
O3 Magnitude of hearing loss	11	Observational	Inconsistency, imprecision	—	Low
O4 Perforation size	10	Observational	Risk of bias	Dose– response gradient	Moderate
O5 Perforation site and quadrant	10	Observational	Serious inconsistency, risk of bias	—	Very low

O6 Duration of otorrhea / disease	12	Observational	Inconsistency, risk of bias	Dose–response gradient	Low
O7 Activity and frequency of otorrhea	7	Observational	Risk of bias, imprecision	—	Low
O8 Disease type and cholesteatoma	8	Observational	Risk of bias	Large magnitude of effect	Moderate
O9 Ossicular chain status	10	Observational	Inconsistency	Large magnitude of effect	Moderate
O10 Sensorineural component	10	Observational	Serious inconsistency, imprecision	—	Very low
O11 Frequency-specific pattern	8	Observational	Indirectness, imprecision	—	Low
O12 Age and sex	8	Observational	Serious inconsistency	—	Very low
O13 Middle-ear volume and pneumatisation	3	Observational	Imprecision, few studies	—	Very low
O14 Discriminative accuracy	5	Diagnostic accuracy and observational	Indirectness, few studies	Very large effect (LR 10.2)	Low
O15 Post-treatment hearing outcome	5	Cohort	Risk of bias, imprecision	—	Low

GRADE = Grading of Recommendations, Assessment, Development and Evaluations. All domains began at low certainty because the contributing evidence was predominantly observational.

DISCUSSION

Summary of the principal findings

This systematic review of twenty-six primary studies comprising 5 507 participants and at least 5 668 ears establishes that hearing impairment in chronic suppurative otitis media is a predictable rather than a stochastic phenomenon. Six predictors were consistently associated with the magnitude of hearing loss across independent populations, measurement techniques and health systems: the size of the tympanic membrane perforation; involvement of the posterior quadrants and of the malleolar region; the duration of disease and of otorrhea; the activity and frequency of discharge; squamosal disease and cholesteatoma; and the integrity of the ossicular chain. Two further predictors, the middle-ear air-space volume and the degree of mastoid pneumatisation, were consistent in direction but supported by too few studies to be regarded as established. Age predicted the sensorineural but not the conductive component, and sex was not an independent predictor in any coherent direction. In discrimination terms, a simple frequency-derived audiometric index — the high-frequency conductive hearing loss test — identified incomplete ossicular discontinuity with 83% sensitivity and 92% specificity and a likelihood ratio of 10.2, and the mean air–bone gap yielded reproducible cut-off values of 28.4 dB for discontinuity and 32.8 dB for fixation.^{9,10,12,21,23,25}

The clinical corollary is that the discharging ear is not a homogeneous entity. An ear with a small anterior perforation, dry for years, in a young adult with a well-pneumatised mastoid, carries an expected air–bone gap in the region of 9 to 15 dB and a low probability of ossicular pathology. An ear with a subtotal or four-quadrant perforation involving the malleus handle, discharging intermittently for more than five years, in the presence of granulation tissue or cholesteatoma, carries an expected air–bone gap in the region of 30 to 39 dB, a probability of ossicular discontinuity approaching 88% if cholesteatoma is present, and a materially elevated risk of an irreversible sensorineural component. These two ears require different urgency of investigation, different surgical planning and different counselling, and the present synthesis provides the numerical basis for that differentiation.^{12,22,25,27}

The mechanical compartment: why perforation geometry matters

The conductive component of hearing loss in CSOM is fully explicable by classical middle-ear acoustics, and the consistency of the perforation-size gradient across ten independent studies is a direct empirical confirmation of that theory. Sound transmission through the normal middle ear depends on three mechanisms acting in series: the areal ratio between the effective vibrating area of the tympanic membrane and the stapes footplate; the ossicular lever ratio; and the phase difference that the intact drum creates between the oval and round windows, which prevents the two windows from being driven in phase and thereby cancelling cochlear fluid motion. A perforation degrades all three. It removes vibrating surface area in direct proportion to its own area, reducing the areal transformer ratio; it may uncouple the malleus handle from the residual drum when it extends to the annulus or to the manubrium, degrading the lever mechanism; and it permits sound to reach the round-window niche directly, abolishing the phase difference.^{1,12}

Each of these mechanisms leaves a distinct audiometric signature, and the included studies detect all three. The areal effect is the source of the monotonic size gradient, and because it operates as a stiffness deficit it is maximal at low frequencies — hence the air–bone gap of 56.9 dB at 250 Hz declining to 32.4 dB at 2 kHz in the 300-ear series. The malleus-coupling effect is the source of the malleolar excess of 11 dB reported in the 210-ear series, and it explains why studies that fail to analyse malleolar involvement separately obtain conflicting results for perforation site: a posteriorly extending perforation that reaches the manubrium is doing two things at once, and a study that codes it only by quadrant conflates the two. The round-window shielding effect is the source of the posterior disadvantage, and because it requires the perforation to be large enough to expose the round-window niche, it is undetectable in cohorts restricted to perforations occupying less than one quadrant — precisely as observed in the 74-patient series, in which the posteroinferior–anterosuperior difference was only 3 dB and did not reach significance. This mechanistic reading dissolves what appears in the raw literature to be an irreconcilable contradiction.^{10,12,64}

The inverse relationship between the middle-ear air-space volume and the air–bone gap has the same theoretical basis. The air cushion behind the tympanic membrane acts as an acoustic compliance in series with the drum; when granulation tissue, mucosal oedema, effusion or a sclerotic, poorly pneumatized mastoid reduces that volume, the stiffness presented to the residual

drum rises and low-frequency transmission deteriorates further. The observed difference of approximately 8 dB between high-volume and low-volume ears in the 300-ear series, and of a comparable order in the 127-patient series, is of the magnitude that this model predicts. It also explains why an ear may exhibit a wide air–bone gap in the presence of a modest perforation and an intact chain — a scenario that has repeatedly produced apparently anomalous cases in surgical series and that has contributed to the conclusion in some retrospective studies that the air–bone gap does not reliably predict ossicular status.^{12,38,66}

The cytotoxic compartment: from persistent otorrhea to cochlear injury

The title of this review deliberately frames CSOM as a trajectory rather than a state, and the sensorineural findings justify that framing. Every included study that measured masked bone-conduction thresholds in strictly unilateral disease with the contralateral ear as an internal control found a significant interaural difference, and in every such study that difference widened with frequency. The magnitude ranged from a modest 7.00 dB at 500 Hz rising to 9.71 dB at 4 kHz in an Iranian surgical cohort, to a striking 21.69–34.52 dB across the same frequency range in a Nigerian series whose patients had a mean otorrhea duration of 6.11 years. The frequency dependence is the mechanistic signature: the round-window membrane, which is the principal route of entry for middle-ear inflammatory mediators into the perilymph, is anatomically adjacent to the basal turn of the cochlea, and the basal turn encodes high frequencies. Bacterial exotoxins, lipopolysaccharide, proteases, reactive oxygen species and cytokines that cross a chronically inflamed and hyperpermeable round-window membrane therefore injure the high-frequency outer hair cells first.^{1,17,18,19}

The clinical importance of this compartment lies in its irreversibility. Whereas the conductive component is potentially fully reversible by tympanoplasty and ossiculoplasty, and whereas the discharge itself resolves in the great majority of ears with topical antibiotic therapy, the sensorineural component does not recover. The retrospective cohort of 175 patients managed in a high-resource academic setting is the most sobering datum in this review: after a mean follow-up of 3.5 years, during which patients received an average of 9.5 otology visits, 4.7 prescriptions and 1.7 operations, 41% had moderate or worse sensorineural hearing loss. Control of otorrhea is therefore

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a necessary but not a sufficient goal of management; the goal must be control of otorrhea early enough that the cytotoxic compartment has not yet accumulated an irreversible deficit.^{26,43,44,45}

The evidence on the predictors of the sensorineural component is, however, distinctly weaker than that on the conductive component, and this review rates it as very low certainty. Disease duration was significant in some series and null in others; age was significant in some and null in others; cholesteatoma was significant in one direction in one study and in the opposite direction in another. Four explanations are plausible and are not mutually exclusive. First, duration is ascertained by recall and is heavily misclassified. Second, the contralateral ear is an imperfect control, since bilateral disease is present in approximately 21.5% of the CSOM population and subclinical contralateral eustachian dysfunction is common; using a diseased ear as a control biases the interaural difference towards the null. Third, bone-conduction thresholds in an ear with a large perforation and an eroded ossicular chain are themselves artefactually elevated by the loss of the ossicular inertial and osseotympanic components of bone conduction — the classical Carhart effect and its variants — so that some of the apparent sensorineural loss is a mechanical artefact. Fourth, the threshold for defining a sensorineural component varied from an interaural difference of any magnitude to an absolute bone-conduction threshold exceeding 25 or 30 dB. Until studies apply a uniform definition, correct for the Carhart artefact and enrol strictly unilateral disease with an audiometrically verified normal contralateral ear, the true predictor set for cochlear injury in CSOM will remain uncertain.^{2,4,17,18,20}

The ossicular chain as the principal mediator

A striking feature of the synthesis is that most of the predictors converge on a single anatomical mediator. Cholesteatoma predicts hearing loss because it erodes the ossicles — 82% erosion prevalence against 12.7% in uncomplicated disease. Granulation tissue predicts hearing loss because it erodes the ossicles — 84% discontinuity in ears with middle-ear granulation. Prolonged and active discharge predicts hearing loss partly because it erodes the ossicles — 19% ossicular suffering in discharging ears against 7% in dry perforations. A perforation edge adherent to the promontory predicts hearing loss because it is a marker of the same adhesive inflammatory process that has consumed the incus long process — 93.3% of discontinuity cases. And the audiometric

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expression of that erosion is consistent: a rise in the mean pure-tone average from approximately 44 to approximately 58 dB HL and a widening of the mean air–bone gap from approximately 28 to approximately 39 dB. The incus long process is the dominant target in every series, reflecting its precarious terminal blood supply, its retrotympanic position and its lack of ligamentous support.^{16,24,25,30,31,34,36}

This mediation structure has an important methodological implication. If cholesteatoma, granulation tissue, discharge duration and adhesive perforation edges all act on hearing through ossicular erosion, then a multivariable model that includes both the upstream exposures and the ossicular status will attenuate the upstream coefficients towards the null, because it is adjusting for the mediator. Several of the null findings in the included literature may reflect precisely this over-adjustment. Future analyses should therefore be explicit about whether they are estimating the total effect of an upstream exposure, in which case ossicular status must be excluded from the model, or its direct effect, in which case ossicular status is appropriately included. None of the included studies made this distinction.^{23,28}

The mediation structure also explains the apparently contradictory conclusions on whether preoperative audiometry predicts ossicular status. Where the middle ear is otherwise empty — non-cholesteatomatous, non-granulomatous disease — the air–bone gap is a clean readout of the ossicular chain, and the reported likelihood ratio of 10.2 and reconstructed area under the curve of approximately 0.95 for the high-frequency conductive hearing loss test reflect that. Where the middle ear is filled with cholesteatoma matrix or granulation tissue, the filling material conducts sound across the eroded chain, narrowing the air–bone gap and destroying the relationship — hence the 11% of Italian cholesteatoma patients with ossicular damage and normal thresholds, the finding that the air–bone gap was not correlated with discontinuity in a 212-ear retrospective series, and the explicit demonstration that in the presence of cholesteatoma the air–bone gap adds no discriminative information to a pre-test probability of discontinuity that is already 88%. The correct clinical inference is not that audiometry is unreliable, but that it is reliable in mucosal disease and uninformative in squamosal disease, where ossicular exploration should be regarded as mandatory irrespective of the audiogram.^{21,22,35,37}

Reconciling the controversy over perforation site

The perforation-site literature is the most discordant in this field, and the present review is able to reconcile it. Six of ten included studies found a significant posterior disadvantage; four did not. The four null studies share identifiable features. Two restricted enrolment to small or single-quadrant perforations, in which the round-window shielding mechanism cannot operate. One compared anterior with posterior perforations without stratifying by size, so that a preponderance of large anterior perforations would obscure a genuine site effect. One analysed central perforations only, in which by definition the annulus and the round-window niche remain shielded. Conversely, the studies with the largest and most clearly significant site effects analysed all sizes, stratified by quadrant count and analysed malleolar involvement separately. The most defensible synthesis is therefore that perforation site does modify hearing loss, that the effect is mediated by round-window exposure and by malleus decoupling, and that it is detectable only when the perforation is large enough for those mechanisms to operate. This also explains why one study concluded that site was a stronger predictor than size on two-way analysis of variance: once malleolar involvement is entered as a separate factor, it absorbs a substantial part of the variance that size would otherwise claim.^{10,12,13,15,24,64}

Duration, collinearity and the causal architecture of the predictor set

Disease duration occupies a special position because it is temporally antecedent to almost every other predictor. A perforation enlarges over time; ossicles erode over time; granulation tissue accumulates over time; the mastoid becomes sclerotic over time; and the cochlea accumulates cytotoxic injury over time. The 120-patient cross-sectional analysis demonstrated this architecture empirically, reporting that the duration of tinnitus and the frequency of discharge exhibited high collinearity with disease duration and were therefore statistically dependent upon it, and that disease duration produced the highest correlation with hearing impairment of any variable examined ($\rho = 0.689$). The Angolan series, which is the largest community-facing study in the review, reached the same conclusion from a different direction, identifying otorrhea duration as the strongest predictor of hearing impairment in a population whose median otorrhea duration exceeded twelve months.^{7,8}

Why, then, did several studies find no association between duration and hearing loss? Three reasons are supported by the data. First, measurement error: duration is a recalled quantity, and in populations where CSOM begins in early childhood, adult patients frequently cannot date its onset. Second, ceiling effects: in cohorts in which the median duration already exceeds five or ten years, the mechanical consequences of the disease have saturated and further duration adds little. Third, and most importantly, the relationship is threshold-shaped rather than linear. The retrospective surgical cohort that dichotomised duration at five years found a hazard ratio of 2.52 (95% CI 1.45–4.38); a Pearson or Spearman coefficient computed over a continuous duration variable in the same population would have been small and possibly non-significant. Analytical strategy, rather than biology, therefore accounts for much of the apparent inconsistency, and future studies should model duration categorically with clinically meaningful thresholds as well as continuously.^{17,18,27}

From association to decision rule

The most important translational gap identified by this review is the near-total absence of predictor evidence expressed in decision-rule terms. Of twenty-six included studies, only three reported sensitivity, specificity, likelihood ratios or areas under the curve, and only one reported a complete sensitivity–specificity pair against an intraoperative reference standard. This matters because a statistically significant mean difference of 11 dB between malleolar and non-malleolar perforations, or a Spearman correlation of 0.581 between perforation size and hearing loss, cannot be converted into a bedside decision without knowing the distribution overlap. The three studies that did report accuracy indices demonstrate how much clinical value is available when the analysis is done properly: an ear with an air–bone gap of 20 dB or less at 500 Hz has its probability of gross ossicular discontinuity reduced from 33% to 5.6%, which is low enough to justify simple tympanoplasty without ossicular exploration; an ear whose air–bone gap at 4 kHz exceeds the mean air–bone gap at 0.25 and 0.5 kHz by 10 dB or more has a 78% post-test probability of incomplete ossicular discontinuity, which is high enough to justify preparing for ossiculoplasty and to justify a more guarded prognosis in preoperative counselling.^{21,22,23}

Contextual evidence from adjacent middle-ear disease defines the attainable ceiling and suggests where future gains lie. Wideband acoustic absorbance, a rapid, non-behavioural

measurement that requires no patient cooperation, predicted the severity of conductive hearing loss with areas under the curve of 0.88 to 0.94 in children with middle-ear effusion, and detected middle-ear disease with an area under the curve of 0.89 at 1 kHz rising to 0.93 when combined with conventional 226 Hz tympanometry. By contrast, deep-learning classification of otoscopic images achieved only 0.74, and a logistic model based on clinician-scored tympanic-membrane features achieved 0.60 — barely better than chance and markedly worse than the audiological measures. The clear implication is that the tympanic membrane, however carefully inspected, is an incomplete window on the middle ear, and that the future of prediction in CSOM lies in combining otoscopic morphology with objective acoustic measurement rather than in refining image analysis alone. No study has yet applied wideband acoustic immittance systematically to a CSOM population with a tympanic membrane perforation, and this is a clear and tractable research opportunity.^{39,40,41,42}

Comparison with previously published evidence syntheses

The findings of this review are concordant with, and extend, the small number of previously published syntheses in this field. A global epidemiological synthesis of twenty-nine community-based cross-sectional studies estimated the worldwide prevalence of CSOM at 3.8%, or 297 million people, of whom 62% had disabling hearing loss, and noted that hearing impairment was reported in only four of the twenty-nine included studies and the frequency of ear discharge in only one — a striking demonstration that the outcome of greatest clinical importance is the one least frequently measured. A recent synthesis of twelve studies comprising 1 742 participants reported a sensorineural prevalence of 18–31% with significantly higher bone-conduction thresholds in diseased ears, high-frequency predominance, and associations with longer disease duration, squamosal disease and subtotal perforations, while finding the evidence on cholesteatoma inconsistent — conclusions that this review reproduces from a larger and partly non-overlapping primary evidence base. A paediatric synthesis of seven studies published between 2022 and 2026 documented mean pure-tone averages of 22–45 dB HL, correlation of severity with chronicity, and a global burden of 34.71 million affected children, and reported that wideband absorbance correlated with the air–bone gap at $R^2 = 0.94$.^{2,3,4}

Two syntheses address the ossicular question directly. A meta-analysis of nine studies of postoperative hearing after chronic otitis media and cholesteatoma surgery established that malleus status is a significant predictor of the postoperative air–bone gap independent of the stapes, with mean postoperative gaps of 11.1 dB when the malleus was present and the stapes absent against 16.5 dB when both were absent. A systematic review of ossicular reconstruction concluded that the available evidence remains insufficient to standardise technique or prosthesis choice. Together with the present findings, these syntheses converge on the malleus–drum complex as the structure whose preservation most influences both the natural history and the surgical outcome of the disease, which in turn supports the emphasis this review places on malleolar involvement as a bedside predictor.^{33,18}

Where this review departs from previous syntheses is in its deliberate restriction of the evidence table to primary designs, which prevents the double-counting of primary data that occurs when reviews of reviews are constructed, and in its expression of the predictor set in discrimination terms. It also differs in identifying the mediation structure explicitly, which no previous synthesis has done and which materially changes how the null findings in this literature should be interpreted.^{2,3,4,33}

Clinical implications: a stratified pathway

The synthesis supports a practical, resource-sensitive stratification of the discharging ear into three tiers, presented in Table 25. The high-risk tier comprises ears with any of the following: a subtotal or four-quadrant perforation; a perforation involving the malleus handle or the posterior quadrants; attic or marginal perforation, retraction pocket or visible keratin debris indicating squamosal disease; visible granulation tissue or polypoidal mucosa; disease duration exceeding five years; or an air–bone gap of 35 dB or more. These ears warrant expedited audiometric assessment with masked bone conduction, cross-sectional imaging where cholesteatoma is suspected, counselling that ossicular reconstruction is likely to be required, and prioritisation for definitive surgery. The intermediate tier comprises ears with medium central perforations, intermittent discharge and an air–bone gap between 20 and 34 dB; these require audiometric surveillance at six- to twelve-monthly intervals and elective tympanoplasty. The low-risk tier comprises small, dry, anterior central perforations with an air–bone gap below 20 dB, in which the probability of ossicular

pathology is low and expectant management with water precautions and annual audiometry is defensible.^{10,12,21,22,25,27}

Table 24. Proposed stratification of the discharging ear derived from the synthesised predictor set

Tier	Defining features	Expected air–bone gap	Probability of ossicular pathology	Recommended action
High risk	Subtotal or four-quadrant perforation; malleolar or posterior-quadrant involvement; attic or marginal perforation, retraction pocket or keratin debris; granulation tissue or polypoidal mucosa; disease duration > 5 years; ABG $\geq$ 35 dB	30–39 dB or greater	Up to 88% where cholesteatoma is present; 84% where granulation tissue is present	Expedited masked audiometry; temporal bone imaging where squamosal disease is suspected; counsel for probable ossiculoplasty; prioritise for definitive surgery; document baseline bone conduction
Intermediate risk	Medium central perforation; intermittent discharge; disease duration 1–5 years; ABG 20–34 dB	16–30 dB	Approximately 15–25%	Six- to twelve-monthly audiometric surveillance; topical therapy for active discharge; elective tympanoplasty with readiness for ossicular exploration
Low risk	Small dry anterior central	9–16 dB	Approximately	Water precautions;

	perforation; no discharge for ≥ 12 months; ABG < 20 dB; intact malleus handle		5–6% where the ABG at 500 Hz is ≤ 20 dB	annual audiometry; elective myringoplasty on functional or occupational grounds
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Three further clinical points follow directly from the data. First, masked bone-conduction thresholds must be obtained in every patient with CSOM at first presentation and documented, because a sensorineural component is present in between one in seven and one in two patients, is not reliably predictable from any clinical variable, and constitutes the irreversible portion of the deficit; failure to document it at baseline also exposes the surgeon to the misattribution of pre-existing cochlear loss to surgery. Second, in the presence of cholesteatoma the audiogram should not be used to decide whether to explore the ossicular chain, because the pre-test probability of discontinuity is already 88% and the air–bone gap adds no information. Third, patients should be counselled that successful control of discharge, whether medical or surgical, does not guarantee restoration of hearing: 41% of a well-managed cohort retained moderate or worse sensorineural loss, and the mean air–bone gap after ossicular reconstruction remains approximately 17 dB with success in only 61% of ears.^{22,26,59}

Implications for health systems in high-burden settings

Approximately 85% of the world's CSOM burden lies in low- and middle-income countries, and 62% of affected individuals have disabling hearing loss. In these settings, pure-tone audiometry is frequently unavailable outside referral centres, and the predictor set identified by this review therefore acquires a triage function that it would not need in a high-resource system. The four features that are visible on simple otoscopy and elicitable by history — perforation size, malleolar or posterior involvement, attic or marginal location with keratin debris, and duration of discharge exceeding five years — identify the ears most likely to have a disabling deficit and the greatest potential to benefit from referral. This is a defensible use of clinical prediction precisely because the alternative is not audiometry but nothing at all.^{2,7,57}

The synthesis also carries implications for the choice of intervention in these settings. Randomised evidence indicates that topical antibiotics are the treatment of choice for discharge, that topical antiseptics such as boric acid in alcohol with dry mopping are a reasonable alternative where antibiotics are unavailable, that the addition of a topical steroid confers no demonstrable benefit for the resolution of discharge, and that the evidence for systemic antibiotics and for aural toilet alone is of very low certainty. Since none of these interventions has been shown to improve hearing, and since the sensorineural deficit accumulates while discharge persists, the priority in high-burden settings is timely and effective control of discharge combined with early identification of the ears that require surgery, rather than prolonged cycles of ineffective systemic therapy. Recent developments in self-fitted air-conduction and bone-conduction hearing aids offer a complementary rehabilitative route for the substantial proportion of patients in whom surgical closure of the air–bone gap is not achievable.^{1,43,44,45,46}

Strengths

The principal strengths of this review are its methodological transparency and its deliberate design discipline. The search covered seven information sources including a large artificial-intelligence-indexed corpus; every included reference was verified to resolve to a live record and a valid digital object identifier; screening, extraction and appraisal were conducted in duplicate with substantial inter-reviewer agreement; the outcome domains were pre-specified; and the exclusion of secondary literature from the evidence table prevents the double-counting of primary data. The synthesis is unusually comprehensive in scope, covering fifteen outcome domains from prevalence to post-treatment outcome, and it is the first in this field to express the predictor set in discrimination terms and to make the mediation structure explicit.^{1,2}

Research agenda

Six specific research priorities follow from this synthesis. First, a prospective multicentre cohort of consecutive patients with CSOM, using a single explicit disease definition, objective planimetric measurement of perforation area, masked bone-conduction audiometry at all octave frequencies from 0.25 to 8 kHz, and pre-specified multivariable models that distinguish total from direct effects, is required to establish the independent contribution of each predictor. Second,

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wideband acoustic immittance should be evaluated systematically in perforated ears, since it is rapid, non-behavioural, feasible in children and has demonstrated areas under the curve of 0.88 to 0.94 in adjacent middle-ear conditions. Third, a validated multivariable risk-prediction model with internal and external validation, calibration assessment and decision-curve analysis should be developed and reported in accordance with the TRIPOD statement; no such model currently exists for this disease. Fourth, the Carhart artefact should be quantified and corrected in studies of the sensorineural component, so that mechanical and cochlear contributions to bone-conduction elevation can be separated. Fifth, longitudinal studies with repeated audiometry are needed to establish the rate of hearing deterioration per year of persistent otorrhea, which is the single quantity most needed to justify the urgency of intervention and which no included study reported. Sixth, trials of interventions to control discharge should adopt hearing, rather than dryness alone, as a primary outcome, since the evidence assembled here demonstrates that the two outcomes are dissociable.^{1,27,39,40,43}

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Hearing impairment in chronic suppurative otitis media is predictable from clinical information that is available at the first consultation. Across twenty-six primary studies comprising 5 507 participants and at least 5 668 ears, the magnitude of hearing loss increased consistently with the size of the tympanic membrane perforation, with involvement of the posterior quadrants and of the malleus handle, with the number of quadrants involved, with the duration and activity of otorrhea, with squamosal and cholesteatomatous disease, and with erosion or discontinuity of the ossicular chain. Perforation size, disease type and ossicular status reached moderate certainty on GRADE assessment; the remaining predictors reached low or very low certainty, principally because of unadjusted analysis and inconsistency between studies.^{9,12,25,27}

The hearing loss of CSOM is not purely conductive. A sensorineural component was present in 14.7% to 52% of patients across the included series, was demonstrable as a significant interaural elevation of masked bone-conduction thresholds in every study that used the healthy contralateral ear as an internal control, and was consistently frequency-dependent with high frequencies most

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affected. This component is irreversible, is not reliably predicted by any clinical variable, and persisted in 41% of patients in a well-resourced cohort despite active medical and surgical management. Masked bone-conduction audiometry is therefore mandatory at first presentation and cannot be replaced by clinical risk stratification.^{17,18,19,26}

Preoperative pure-tone audiometry carries clinically useful discriminative value for the middle-ear substrate of hearing loss in non-cholesteatomatous disease. The high-frequency conductive hearing loss test at a 10 dB threshold identified incomplete ossicular discontinuity with 83% sensitivity, 92% specificity and a likelihood ratio of 10.2; mean air–bone gap thresholds of 28.4 dB and 32.8 dB discriminated ossicular discontinuity and fixation respectively; and an air–bone gap of 20 dB or less at 500 Hz reduced the probability of gross discontinuity from 33% to 5.6%. In the presence of cholesteatoma, however, the pre-test probability of ossicular discontinuity is 88% and the audiogram adds no information, so that ossicular exploration should be regarded as mandatory.^{21,22,23}

The null hypothesis that none of the examined variables is associated with the degree of hearing impairment beyond the play of chance is rejected. Hypotheses H1, H3, H4, H5 and H6 are supported by the synthesised evidence. Hypothesis H2, concerning perforation site, is supported conditionally: the posterior and malleolar disadvantage is demonstrable when perforations of all sizes are analysed and malleolar involvement is coded separately, but is not detectable in cohorts restricted to small or single-quadrant perforations, which accounts for the apparent discordance in the published literature.^{10,13,15,64}

Recommendations

For clinical practice.

- Perform masked pure-tone audiometry with air- and bone-conduction thresholds in every patient presenting with chronic ear discharge, and document the baseline bone-conduction threshold before any intervention.^{17,19}
- Record perforation size, quadrant involvement and specifically malleolar involvement in structured form at every otoscopic examination, since these are the strongest bedside determinants of the expected air–bone gap.^{9,10}

- Treat a disease duration exceeding five years, persistent or frequent discharge, granulation tissue or polypoidal mucosa, and any feature suggesting squamosal disease as indications for expedited assessment and definitive surgery rather than for continued expectant medical management.^{27,31,36}
- Use the frequency-specific air–bone gap and the high-frequency conductive hearing loss test to inform preoperative counselling and surgical preparation in non-cholesteatomatous disease, and explore the ossicular chain routinely when cholesteatoma is present regardless of the audiogram.^{21,22}
- Counsel patients explicitly that control of discharge and closure of the perforation may not restore hearing, and offer audiological rehabilitation, including self-fitted air- or bone-conduction devices, where a residual deficit persists.^{1,26,59}

For health systems in high-burden settings.

- Adopt the four otoscopically and historically ascertainable high-risk features — large or four-quadrant perforation, malleolar or posterior involvement, attic or marginal disease with keratin debris, and discharge exceeding five years — as referral criteria where audiometry is not locally available.^{2,7}
- Prioritise timely and effective topical treatment of discharge, using topical antiseptics where topical antibiotics are unavailable, and avoid prolonged cycles of systemic antibiotic therapy for which the evidence is of very low certainty.^{43,44,45,46}
- Integrate school- and community-based hearing screening with ear-health surveillance in populations with a known high prevalence of CSOM, since the World Health Organization disability threshold substantially understates the burden in these populations.^{2,6}

For research.

- Conduct prospective multicentre cohorts with a single explicit CSOM definition, objective planimetric measurement of perforation area, full-frequency masked audiometry and pre-specified multivariable models that distinguish total from direct effects.^{8,23}
- Evaluate wideband acoustic immittance systematically in perforated ears and report areas under the curve, calibration and decision-curve analysis.^{39,41,42}

- Develop and externally validate a multivariable risk-prediction model for hearing impairment in CSOM, reported in accordance with the TRIPOD statement.⁴⁰
- Quantify and correct the Carhart artefact when reporting the sensorineural component, and enrol strictly unilateral disease with an audiometrically verified normal contralateral ear.^{17,18}
- Establish the annual rate of hearing deterioration attributable to persistent otorrhea through longitudinal repeated audiometry, and adopt hearing rather than dryness as the primary outcome of interventional trials.^{6,26,43}

AUTHOR CONTRIBUTIONS

Alsa Fara Dhiba conceived the review question, designed the protocol, executed the literature searches, performed study screening, data extraction and risk-of-bias appraisal, conducted the synthesis and drafted the manuscript. Ridwan supervised the review, adjudicated disagreements at the screening and appraisal stages, verified the extracted audiometric data, provided otological and clinical interpretation, and critically revised the manuscript for important intellectual content. Both authors have read and approved the final version and accept accountability for all aspects of the work.

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