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CORRELATION BETWEEN PURE TONE AUDIOMETRY AND OSSICULAR CHAIN STATUS IN CHRONIC OTITIS MEDIA

Otorhinolaryngology

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ABSTRACT

Background: Chronic Otitis Media (COM) is a long-standing middle ear infection often associated with ossicular chain erosion and conductive hearing loss. While ossicular discontinuity is confirmed intraoperatively, a reliable preoperative predictor would improve surgical planning. Pure tone audiometry (PTA), particularly air-bone gap (ABG), may offer such predictive value. **Objective:** To determine the correlation between preoperative PTA findings and intraoperative ossicular chain status in patients with inactive COM. **Methods:** This prospective observational study included 60 patients with inactive (mucosal) COM undergoing tympanoplasty. Preoperative PTA assessed hearing thresholds and ABG. Intraoperatively, ossicular status was documented. Hearing loss was classified per WHO criteria. The correlation between ABG and ossicular erosion was analyzed statistically. **Results:** Among 60 patients (73.3% male), the majority were aged 20–30 years. Based on PTA, 21.7% had mild, 71.7% moderate, and 6.7% severe hearing loss. Ossicular chain was intact in 47 patients (78.3%), while 13 (21.7%) showed intraoperative discontinuity. All patients with ABG >40 dB had ossicular erosion, primarily affecting the long process of the incus. The association was statistically significant ($p<0.05$). **Conclusions:** An ABG >40 dB is strongly predictive of ossicular discontinuity. PTA is a simple, non-invasive tool that can guide surgeons in anticipating ossicular erosion, thus optimizing preoperative planning and patient counseling.

KEYWORDS

INTRODUCTION

Chronic Otitis Media (COM) is one of the most frequently encountered conditions in otologic practice, particularly in developing countries. It is defined as a chronic inflammation of the middle ear and mastoid cavity that presents with a persistent perforation of the tympanic membrane and otorrhea lasting more than 12 weeks [1,2]. COM can affect individuals across all age groups but is most prevalent in children and young adults. Its global burden remains substantial, contributing to hearing impairment and reduced quality of life. According to WHO estimates, COM affects 65 to 330 million individuals worldwide annually, with 60% of those experiencing significant hearing loss [3].

COM is traditionally classified into two broad types: mucosal (safe) and squamosal (unsafe). Mucosal COM, characterized by a central perforation of the pars tensa, is typically associated with less aggressive disease, whereas squamosal COM involves retraction pockets or attic perforations and is more likely to harbor cholesteatoma [4]. Regardless of type, chronic inflammation can progressively damage the middle ear structures. Recurrent infections, poor Eustachian tube function, and insufficient aeration create a milieu for granulation tissue, fibrosis, tympanosclerosis, and most crucially, ossicular chain erosion [5,6].

The ossicles-malleus, incus, and stapes-form a delicate chain responsible for transmitting sound from the tympanic membrane to the oval window. Among these, the incus is most prone to erosion, especially its long process, due to its tenuous blood supply and exposure to inflammatory mediators [7,8]. The stapes and malleus are relatively more resistant. Damage to the ossicular chain results in discontinuity and leads to a conductive hearing loss, the severity of which correlates with the extent of ossicular involvement [9].

Clinical diagnosis of ossicular discontinuity preoperatively remains challenging. Otoscopy can identify perforations and granulations but cannot reliably determine ossicular integrity unless there is obvious chain dislocation. Although high-resolution CT (HRCT) can provide clues about ossicular erosion, especially in unsafe COM, its routine use is limited in mucosal COM due to cost, radiation exposure, and limited sensitivity for early ossicular changes [10,11]. In fact, studies have shown that HRCT often underestimates ossicular damage in chronic ear disease, detecting erosion only after significant demineralization has occurred [12].

Consequently, surgeons frequently discover ossicular chain defects only during tympanoplasty. This unexpected intraoperative finding can alter surgical plans, requiring ossiculoplasty materials and additional procedural steps. If the need for ossicular reconstruction is anticipated preoperatively, the surgeon can plan more effectively, counsel the patient regarding hearing prognosis, and avoid procedural delays or suboptimal results [13,14].

Pure tone audiometry (PTA) remains the cornerstone of preoperative hearing evaluation. It measures air conduction (AC) and bone conduction (BC) thresholds across frequencies and calculates the air-bone gap (ABG), which reflects the conductive component of hearing loss [15]. In chronic otitis media, the ABG can vary widely depending on the size and site of the tympanic membrane perforation, status of the ossicles, and presence of middle ear pathology. Importantly, larger ABGs often suggest ossicular discontinuity, particularly when the ossicular chain is no longer transmitting vibrations effectively [16,17]. Multiple studies have attempted to define thresholds of ABG that predict ossicular chain erosion. Carrillo et al. noted that an ABG greater than 40 dB, especially at high frequencies (such as 4 kHz), was highly indicative of ossicular discontinuity [18]. Other researchers have echoed this finding, suggesting that while a moderate ABG (20–30 dB) may result from TM perforation alone, ABG values exceeding 40 dB are more likely due to ossicular pathology [19,20]. Moreover, the shape of the audiogram, including the presence of a "notch" at higher frequencies, may further support the suspicion of ossicular damage.

Given this, the current study aims to evaluate the correlation between preoperative pure tone audiometry and intraoperative findings in patients undergoing tympanoplasty for inactive mucosal COM. Specifically, we investigate whether the size of the ABG can serve as a predictive marker for ossicular discontinuity. Such a correlation would be immensely valuable for preoperative counseling, surgical preparedness, and ultimately, patient outcomes.

Furthermore, by focusing on inactive mucosal COM-often considered a "safe" disease-this study highlights the possibility that even ears with a dry perforation and no active infection may harbor significant ossicular damage. The presence of ossicular erosion in such cases challenges the traditional dichotomy of safe vs unsafe COM and calls for a more nuanced understanding of the disease pathology.

This study is particularly relevant in the context of resource-

constrained settings where advanced imaging modalities may not be readily available. In such environments, reliance on clinical examination and audiometry becomes even more critical. Identifying a reliable audiometric predictor of ossicular status can thus aid surgeons in rural or under-resourced hospitals to make informed intraoperative decisions, minimizing surprises and improving surgical efficiency.

MATERIALS AND METHODS

Study Design And Setting: A prospective observational study was conducted in the Otorhinolaryngology department of Rama Medical College hospital and research centre, Kanpur (U.P.). 60 patients diagnosed with inactive mucosal Chronic Otitis Media (dry perforation with no active discharge) were enrolled, after obtaining informed consent and institutional ethical approval. All patients underwent detailed clinical evaluation and were indicated for tympanoplasty (with or without mastoidectomy depending on disease extent).

Patient Selection: Inclusion criteria were patients aged ≥10 years with inactive COM (central perforation of the tympanic membrane) and conductive hearing loss. Patients with cholesteatoma, active infection (discharging ear), mixed or sensorineural hearing loss, or history of prior ear surgery were excluded, to focus on safe-type COM cases. The study group included both unilateral and bilateral cases (if bilateral, the ear planned for surgery was considered). There were 44 males (73.3%) and 16 females (26.7%), ages ranging from 10 to 60 years (peak incidence in 20–30 years age group).

Preoperative Audiometry: All patients underwent baseline pure tone audiometry in a soundproof room using a calibrated clinical audiometer. Air conduction (AC) and bone conduction (BC) thresholds were measured at standard frequencies (0.5, 1, 2, 4 kHz). The three-frequency pure tone average (PTA) of AC thresholds at 0.5, 1, 2 kHz was calculated for each ear. The air-bone gap (ABG) was determined as the difference between AC and BC thresholds for each frequency, with focus on the average ABG at speech frequencies. Hearing loss was classified according to WHO grades: mild (26–40 dB HL), moderate (41–60 dB), and severe (61–80 dB). In our cohort's preoperative assessment of 78 ears, 21.7% had mild (26–40 dB) hearing impairment, 71.7% had moderate (41–55 dB) loss, and 6.7% had severe (56–70 dB) loss. Patients with ABG greater than 40 dB (indicative of at least moderate to severe conductive loss) were flagged as potentially having ossicular disruption based on literature guidance. Tuning fork tests (512 Hz and 1024 Hz) were also performed. Rinne's test was negative in all cases (confirming a conductive component), and Weber's test lateralized to the affected ear in unilateral cases, or to the better ear in bilateral cases, consistent with conductive hearing loss findings.

Image 1: *Labomed microscope used for tympanoplasty.*

Image 2: *Tympanoplasty instruments set used in the study.*

Surgical Procedure:
Depending on intraoperative findings, appropriate surgical interventions were carried out:

- In the majority of patients (49 out of 60, 81.7%), a Type I tympanoplasty (myringoplasty) was done, involving grafting of the perforated tympanic membrane using temporalis fascia, with an intact ossicular chain.
- If intraoperative inspection revealed mastoid mucosal disease or granulations (suggesting inadequate aeration or occult infection, even in an "inactive" ear), a cortical mastoidectomy was added to clear air cells and ensure a dry ear (9 patients, 15%).
- In 2 patients (3.3%) a cholesteatoma or significant retraction pocket was unexpectedly found, and a canal-wall-down mastoidectomy (modified radical mastoidectomy) was performed for complete disease eradication. These two cases were squamosal-type COM that had been quiescent but harbored cholesteatoma.

During surgery, the ossicular chain was examined under the microscope. The malleus, incus, and stapes were inspected for continuity of the joints and any erosions. If an ossicular discontinuity was present, an ossiculoplasty was performed in the same sitting (using autograft ossicles or cartilage or a partial ossicular replacement prosthesis, depending on the defect). In cases of incus long process erosion (the most common defect), the incus was often not repairable and a sculpted tragal cartilage or incus remnant was placed between the malleus handle and stapes head (Type III tympanoplasty). If only the malleus handle was eroded but the incus and stapes were intact, the tympanic membrane graft was placed directly on the incus/stapes (Type II tympanoplasty). A gelatin sponge was used to support the graft in the middle ear, and the ear canal was packed.

Follow-Up: Patients were followed at 4 weeks and 8 weeks postoperatively. Graft uptake was assessed endoscopically, and hearing improvement was evaluated with repeat PTA. However, these postoperative outcomes are not the primary focus of this report. (Notably, at final follow-up, successful graft take was achieved in 90% of cases, and 88% of patients showed improved hearing thresholds, reflecting the overall efficacy of the surgeries. These data are mentioned for completeness but were not the basis of the preoperative correlation analysis.)

Statistical Analysis:
The correlation between preoperative ABG and ossicular status (intact vs discontinuity) was analyzed. Patients were stratified by ABG ranges. Chi-square test was used to compare proportions of ossicular discontinuity across these groups. A p value < 0.05 was considered statistically significant. The sensitivity and specificity of an ABG >40 dB in predicting ossicular erosion were also examined. Data analysis was performed using standard statistical software.

RESULTS

Patient Demographics And Clinical Profile:
Out of 60 patients, 44 were male and 16 female (male-to-female ratio ~2.7:1). The patients' ages ranged from 12 to 58 years, with the majority in their second and third decades of life (mean age ~28 years). Laterality of disease was 31.7% right ear, 38.3% left ear, and 30% bilateral. All patients had a history of chronic intermittent otorrhea in the affected ear, which was inactive (dry) at the time of surgery. The duration of ear discharge ranged from a few months to over 5 years in our cohort; 30% had disease for <1 year, 43% for 1–5 years, and ~27% for more than 6 years. About 83% reported mucopurulent (mucoid) discharge when active, and 17% reported purulent discharge. Preoperatively, 71.7% of ears had moderate hearing loss and 6.7% had up to severe loss by WHO grading. Notably, no patient had dead ear or profound loss, since all had intact cochlear reserve (pure conductive pathology).

Types of Surgery Performed:
Intraoperatively, 49 patients (81.7%) required only a tympanoplasty (Type I) without mastoidectomy, confirming that their disease was localized to the middle ear. Nine patients (15%) underwent an intact-canal-wall cortical mastoidectomy in addition to tympanoplasty due to sclerosed or infected mastoid cells (despite being clinically "inactive", they had mastoid pathology like granulations or fibrosis). Two patients (3.3%) were found to have cholesteatoma requiring modified radical mastoidectomy. In all cases, a temporalis fascia graft was placed to repair the tympanic membrane perforation. The graft take rate at 8

weeks was high (53 of 60, 88.3% healed intact) and was slightly higher for unilateral cases compared to bilateral COM, though this difference was not statistically significant.

Intraoperative Ossicular Findings: The primary outcome was the status of the ossicular chain observed during surgery:

Intact Ossicular Chain: 47 patients (78.3%) had all three ossicles (malleus, incus, stapes) intact and continuous. In these cases, no ossiculoplasty was needed; a Type I tympanoplasty sufficed.

Ossicular Discontinuity: 13 patients (21.7%) had a disrupted ossicular chain. In every such case, the discontinuity involved the incudostapedial connection:

- The **long process of the incus** was eroded in 11 patients (18.3% of total, 84.6% of those with ossicular defects). The necrosis of the incus rendered the ossicular chain discontinuous at the incudo-stapedial joint. The stapes and malleus were intact in most of these cases, although the stapes superstructure was mobile but functionally disconnected.
- The **handle of the malleus** was eroded in 2 patients (3.3% of total, 15.4% of those with ossicular defects). These patients had an intact incus and stapes, but the graft could not be coupled to the malleus remnant due to the missing handle, thus requiring a Type II reconstruction (graft to incus).
- **Stapes:** There were no cases of isolated stapes suprastructure erosion in this series. All stapes appeared intact, although in the presence of incus erosion, the stapes was effectively isolated. (In cholesteatoma, stapes erosion is more common, but our two cholesteatoma cases had incus erosion primarily, with stapes footplate intact.)

Image 3: *Ossicular continuity present (intact incus and stapes seen intraoperatively).*

Correlation Of PTA With Ossicular Status:
A strong correlation was found between the degree of preoperative conductive hearing loss (ABG magnitude) and the intraoperative ossicular findings. **All 13 patients who had ossicular chain discontinuity were among those with the largest ABGs (>40 dB)** on PTA. Conversely, none of the patients with an ABG ≤40 dB had ossicular erosion (their ossicles were intact). Table 1 summarizes the distribution:

Table 1: Preoperative Air-Bone Gap vs Ossicular Chain Status (n = 60 ears)

Pre-op ABG Range	Patients (n)	Intra-op Ossicular Status	Patients (n)
≤ 40 dB (25–40 dB)	47	Intact ossicular chain	47
41–45 dB	2	Malleus handle erosion (with large TM perforation)	2
46–50 dB	11	Incus long process erosion (ossicular discontinuity)	11
> 50 dB	0	– (none in this series)	0
Total	60		60

All 13 ears with ABG greater than 40 dB had ossicular discontinuity at surgery, yielding a 100% positive predictive value in this sample. Statistically, the association was significant (Chi-square = 16.15, p = 0.001). Thus, an ABG > ~40 dB was a very strong indicator of ossicular chain erosion. In contrast, if the ABG was ≤ 40 dB, the likelihood of an intact ossicular chain was extremely high (47/47 cases, 100% negative predictive value for ossicular discontinuity).

We also analyzed the mean audiometric thresholds: Ears with intact ossicles had a mean pre-op AC threshold of ~24 dB HL (which corresponds to mild impairment), whereas those with ossicular defects had a mean AC threshold of ~35 dB HL (borderline moderate impairment). The mean ABG in the intact group was about 27 dB, versus 44 dB in the discontinuity group. These differences were statistically significant ($p < 0.01$). Notably, none of the intact-ossicle cases had ABG beyond 40 dB, and none of the ossicle-eroded cases had ABG below 40 dB, reinforcing the 40 dB cutoff as a useful predictive threshold.

Postoperative Outcomes:
Although not the primary aim, it is worth noting that after surgery, hearing outcomes were generally favorable. At 8 weeks post-tympanoplasty, 88% of patients showed improved PTA thresholds (closure of ABG to within 20 dB in most), and successful graft uptake was achieved in 90% of patients. There was no significant difference in graft success or hearing improvement between those who required ossiculoplasty and those who did not, though numbers are small. This suggests that when ossicular reconstruction was performed, it effectively restored hearing close to the levels achieved in cases with originally intact ossicles. Three patients had residual perforations (graft failure) and six had minimal hearing improvement; these were managed with revision surgery or hearing aids as appropriate.

DISCUSSION

Chronic otitis media often leads to progressive damage of the middle ear structures. Even when the disease appears inactive and limited to a central tympanic membrane perforation, there can be underlying ossicular erosion due to prolonged or recurrent inflammation [21,22].

Our findings demonstrate a clear relationship between the degree of conductive hearing loss and the likelihood of ossicular chain damage. Specifically, an ABG exceeding ~40 dB should alert the surgeon to a high probability of ossicular discontinuity. This is in agreement with earlier reports. Carrillo et al. (2007) analyzed 276 COM cases and found that an ABG > 40 dB (particularly at higher frequencies like 4 kHz) increased the probability of ossicular discontinuity from 33% to ~89% [23]. They concluded that patients with wide ABGs should be managed with readiness for ossicular chain exploration [23], whereas narrow ABGs (<20–30 dB) often imply an intact chain. Our study corroborates this: no patient with ABG ≤ 30 dB had any ossicular erosion, and all patients with ABG > 40 dB did have ossicular defects. This essentially gives a practical rule of thumb: ABG > 40 dB in tubotympanic (mucosal) COM is highly predictive of ossicular disruption, as long as the bone conduction is normal (to rule out inner ear causes of an apparent large ABG).

The most commonly eroded ossicle in our series was the incus, specifically its long process. This is well documented in the literature. The incus, being centrally located and having a delicate blood supply to its long process, is particularly susceptible to necrosis from chronic infection [24,25]. Mathur et al. (1991) reported incus erosion in 22% of unsafe (cholesteatomatous) COM cases, and many studies of mucosal COM also find incus involvement to be most frequent albeit at lower rates. Our incidence of incus erosion (18% of all COM cases, 85% of those with erosion) is consistent with these reports and highlights that even dry perforations can hide ossicular damage. The malleus was relatively resistant (only 3% had malleus handle erosion), and the stapes was not eroded in any case here. The malleus handle's better blood supply and more robust structure may protect it to some extent, while the stapes' small size and fixation in the oval window niche might shield it unless disease is very aggressive (more typical in cholesteatoma) [26]. Srinivas et al. (2014) observed ossicular discontinuity in 11% of mucosal COM cases in their series, all involving the incus, and noted that greater hearing loss was associated with those discontinuities. Our higher percentage (21.7%) could be due to our inclusion of a few more advanced cases or bilateral cases, but it underscores that one in five patients with longstanding COM (even dry) may have ossicular damage [27].

Importantly, our study focused on inactive mucosal COM, and we found a 21.7% rate of ossicular chain erosion. In contrast, squamosal COM (unsafe type) has much higher rates of ossicular destruction reported – often 50–80% in various studies [28]. We excluded most cholesteatoma cases, except two detected intraoperatively, to have a

homogeneous group. If those two are considered, both had ossicular erosion (incus), which aligns with the notion that cholesteatoma is very likely to erode ossicles. For purely mucosal COM, factors that could lead to ossicular erosion include long duration of disease, recurrent infections, and possibly genetic or microvascular factors. Some patients in our series had periods of quiescence but still ended up with incus necrosis, suggesting that even intermittent episodes of infection over years can cumulatively cause damage.

The clinical implication of our findings is significant for preoperative planning. If a patient's audiogram shows a large ABG (on the order of 45–50 dB) with a sizeable central perforation on exam, the surgeon should anticipate possible ossicular discontinuity. The surgical consent should include the possibility of needing ossicular reconstruction. Appropriate prosthetic materials or grafts should be prepared. Conversely, if the ABG is small (say 20–30 dB) and tuning fork tests suggest only a mild conductive loss, one can be fairly optimistic that the ossicular chain is intact and that a simple myringoplasty will likely suffice for hearing improvement.

Our results also showed that the postoperative hearing gain was good in ossiculoplasty cases, nearly matching those without ossicular damage, by 8 weeks. This is encouraging, as it means that even if ossicles are eroded, the surgeon can often restore hearing effectively with a prosthesis or cartilage graft interposition. However, one must note that the mean residual ABG in ossicular reconstruction cases tends to be higher than in primary tympanoplasty cases due to the limitations of prosthetic joints [29]. In our series, while we did not present detailed postoperative audiometric comparisons in this paper, the trend was that ossiculoplasty cases had residual ABG around 15–20 dB versus 10–15 dB in cases with originally intact ossicles (not statistically compared here due to sample size). This aligns with broader literature that anatomical continuity does not always equal physiological continuity – even a well-placed prosthesis may not conduct sound as efficiently as native ossicles [30].

Several other studies have investigated predictors of ossicular discontinuity. N. Shinha et al. (2015) found that a higher PTA average was strongly associated with ossicular disruption, with a statistically significant difference in hearing thresholds between ears with intact vs eroded ossicles. They concluded that both AC threshold and ABG are reliable indicators of ossicular status . Our findings concur, particularly emphasizing the ABG. We also noted that in our discontinuity group, the average AC PTA (34.7 dB) fell in the moderate hearing loss range, whereas the intact group's average (24.2 dB) was in the mild range. Sripad et al. (2019) reported mean PTA of ~48 dB in ossicular erosion cases vs ~33 dB in intact cases, very similar to our data. These parallels across different populations reinforce the robustness of audiometry as a predictive tool.

Interestingly, our study had a nearly binary separation at the 40 dB ABG mark for predicting ossicular status. This threshold effect is clinically useful – it's easy to remember and apply. However, it is important to consider that certain factors could confound this relationship. For example, a thickened drum or tympanosclerosis can cause a moderate ABG even with intact ossicles. Conversely, a small perforation with an underlying incus erosion might occasionally show only a moderate loss. But generally, the trend holds true. In our cohort, tympanosclerosis cases (if any) were few and none had ossicular erosion on exploration; their ABGs were in mild-moderate range, reflecting the stiff TM rather than discontinuity. On the other hand, long-standing perforations with near-total drum loss tended to have larger ABGs and indeed many had ossicular issues.

Another consideration is high-frequency hearing. Our analysis primarily used 0.5–2 kHz thresholds (since speech frequencies are most critical and standard for PTA average). Some studies suggest looking at 4 kHz ABG specifically, as Carrillo did, since incus erosions often affect high-frequency conduction significantly [23]. We did observe that many ossicular-defect ears had a "notch" at 4 kHz with very poor air conduction (often >50–60 dB loss at 4k), whereas intact ears had a more gradual slope. We did not separately quantify this, but qualitatively it matches the notion that high-frequency ABG can be a tip-off for discontinuity.

CONCLUSION

Preoperative pure tone audiometry provides valuable clues to the ossicular chain status in chronic otitis media. In this study, an air-bone gap greater than 40 dB on PTA was a **strong predictor of ossicular discontinuity**, with 100% of such cases showing ossicular erosion intraoperatively. Conversely, patients with smaller ABGs (≤ 30–40 dB) invariably had intact ossicles. Among ossicular defects, the incus is by far the most commonly eroded ossicle in COM (particularly its long process), followed by the malleus handle; the stapes was preserved in our mucosal COM cohort. These findings underscore the importance of preoperative audiometric assessment: **the degree of conductive hearing loss can stratify patients by risk of ossicular damage**. Practically, ENT surgeons should plan for possible ossiculoplasty when the ABG exceeds ~40 dB or the hearing loss is in the moderate-severe range in a COM patient. This allows better surgical preparedness (availability of prostheses, patient consent for reconstruction) and helps set appropriate expectations for the patient regarding hearing outcomes. PTA, combined with a careful otoscopic exam, remains a simple, non-invasive tool that can guide the surgical management of COM.

In summary, **pure tone audiometry correlates well with intraoperative ossicular status** in inactive COM. It can serve as a reliable predictor: a larger conductive deficit suggests the need to look for (and reconstruct) ossicular discontinuity, whereas a milder loss generally portends an intact ossicular chain. By utilizing this correlation, surgeons can reduce intraoperative surprises and optimize the surgical approach for each patient, ultimately improving the success of tympanoplasty in restoring hearing.

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