Evaluation of Vestibular Function in Chronic Otitis Media: Effects of Tympanoplasty and Tympanomastoidectomy via vHIT

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Abstract

Aim: This study aimed to investigate the effects of surgical treatment (tympanoplasty or tympanomastoidectomy) on semicircular canal function in patients with COM using the vHIT, VOR gains before and one month after surgery.

Methods: A prospective observational study was conducted with 45 patients (21 males, 24 females; mean age 34.47 ± 12.44 years) diagnosed with unilateral COM who were scheduled for surgical intervention. Only patients with normal preoperative vHIT results were included. Vestibular assessment was performed with vHIT preoperatively and one month postoperatively, measuring VOR gains in all six semicircular canals. Patients were divided into two groups based on the surgical procedure: tympanoplasty (n=26) and tympanomastoidectomy (n=19). Statistical comparisons of VOR gain changes were made within and between groups using paired and independent tests.

Results: Preoperative VOR gains in the affected ears were within normal limits across all canal planes (anterior: 0.91 ± 0.14, lateral: 0.96 ± 0.11, posterior: 0.93 ± 0.09), and remained stable postoperatively (anterior: 0.92 ± 0.11, lateral: 0.99 ± 0.10, posterior: 0.94 ± 0.10), with no statistically significant differences ($p>0.05$). No significant differences were found in VOR gain changes between surgical groups. All patients maintained normal VOR gain one month after surgery, consistent with the literature suggesting preserved vestibular function following COM surgery in patients with normal preoperative vHIT.

Conclusions: Surgical techniques for COM do not adversely affect high-frequency semicircular canal function when preoperative vHIT results are normal. Both tympanoplasty and tympanomastoidectomy are vestibular-safe procedures in this context. vHIT can be considered a valuable perioperative tool to assess vestibular integrity in COM, although additional testing is recommended in symptomatic cases.

Keywords: *Chronic otitis media; tympanomastoidectomy; tympanoplasty; vestibular system; video head impulse test*

1. Introduction

Chronic otitis media (COM) is a globally prevalent middle ear disease that affects both hearing and balance mechanisms characterized by persistent otorrhea lasting more than three months, conductive hearing loss, and tympanic membrane perforation due to chronic infection of the middle ear and mastoid air cells.

The pathophysiology of COM involves mechanical damage due to perforation or ossicular erosion and the potential for inner ear injury.[1] Inflammatory mediators and bacterial toxins may penetrate the round window membrane, reaching the inner ear structures, particularly the cochlea and vestibular apparatus, thus causing sensory dysfunction.[2] Consequently, several studies have reported vestibular symptoms such as vertigo and imbalance in over 40% of patients with COM.[3]

The vestibular system is crucial in maintaining spatial orientation and postural stability. It consists of peripheral components - namely the semicircular canals (SSCs), utricle, and saccule - and central connections to the brainstem and cerebellum.4 Among vestibular assessment tools, the video head impulse test (vHIT) has emerged as a valuable clinical method due to its ability to assess high-frequency vestibulo-ocular reflex (VOR) function in all six semicircular canals independently. [5] vHIT is advantageous over other vestibular tests because it is quick, non-invasive, and less affected by middle ear pathologies.

Although the literature has discussed the relationship between COM and vestibular dysfunction, few studies have explored the direct effects of COM and its surgical treatment on vestibular function using vHIT. [6] Furthermore, surgical approaches such as tympanoplasty or tympanomastoidectomy may also influence vestibular responses due to changes in middle ear mechanics and inner ear exposure during surgery.

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This study uses the video head impulse test to evaluate vestibular function in patients diagnosed with COM before and after surgery. We specifically investigate whether surgical treatment leads to any measurable change in VOR gain in affected and contralateral ears. By addressing this, we hope to contribute to the limited but growing body of literature regarding vestibular outcomes in chronic otitis media.

2. Materials and Methods

2.1. Study Design

This prospective observational study was conducted at the Department of Otorhinolaryngology, Çukurova University Medical Faculty, between November 2019 and December 2021. The study aimed to evaluate the effects of COM and surgical intervention on vestibular function using the vHIT.

2.2. Participants

A total of 45 patients (21 males and 24 females), aged between 17 and 63 years, who were diagnosed with unilateral COM and scheduled for surgical treatment, were enrolled in the study. Only patients who demonstrated normal vHIT results in the preoperative assessment were included in the study to evaluate the vestibular effects of COM surgery and the surgical techniques used in the study. Patients with a history of bilateral COM, known neurological or vestibular disorders, previous inner ear surgery, or contraindications to the vHIT were excluded. Based on clinical and radiological evaluations, including the extent of middle ear disease and ossicular chain involvement, participants were allocated into two groups according to the surgical procedure performed: 26 patients underwent tympanoplasty, and 19 underwent tympanomastoidectomy.

2.3. Clinical and Audiological Assessment

All participants underwent routine otorhinolaryngologic examination, pure tone audiometry, and preoperative temporal bone imaging. Each patient's affected ears were documented.

2.4. Vestibular Evaluation

Vestibular function was evaluated using the vHIT preoperatively and one month after surgery. The assessments were conducted with the ICS Impulse System (Otometrics, Denmark), which measures the VOR gains of all six semicircular canals: horizontal, anterior, and posterior. All tests were performed by a single experienced clinician in a controlled clinical environment to ensure consistency and minimize variability. During the procedure, head impulses were delivered in the plane of each semicircular canal while patients maintained visual fixation on a stationary target. A VOR gain of less than 0.8 for horizontal canals and less than 0.7 for vertical canals was considered indicative of vestibular dysfunction.

2.5. Statistical Analysis

All data were analyzed using SPSS v22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as mean ± standard deviation. The Shapiro-Wilk test was used to evaluate data normality. Paired comparisons (pre- and postoperative) were analyzed using paired t-tests or Wilcoxon signed-rank tests, depending on distribution. A p-value <0.05 was considered statistically significant.

3. Results

The study included 45 patients diagnosed with COM who underwent surgical intervention. Within the experimental group, each participant's affected ear was assessed using the vHIT. Of the participants, 26 underwent Type 1 tympanoplasty, and 19 underwent tympanomastoidectomy. All patients' preoperative and one-month postoperative vHIT results were analyzed.

The study population included 21 males (46.7%) and 24 females (53.3%), with a mean age of 34.47 ± 12.44 years. In the tympanoplasty group, 11 patients (42.3%) were male and 15 (57.7%) female, whereas in the tympanomastoidectomy group, 10 patients (52.6%) were male and 9 (47.4%) female. The operated side was the right ear in 14 (53.8%) tympanoplasty cases and 13 (68.4%) tympanomastoidectomy cases. No statistically significant difference was found between surgical groups concerning gender or operated ear (p>0.05). Similarly, age distribution did not differ significantly between the two surgical groups (p>0.05). (Table I)

Table 1

Comparison of Demographic Characteristics Between Groups

Variable	Tip 1 Tympanoplasty (n = 26)	Tympano-mastoidectomy (n = 19)	p
Sex, n (%)			
Male	11 (42.3%)	10 (52.6%)	0.702
Female	15 (57.7%)	9 (47.4%)	
Operated ear, n (%)			
Right	14 (53.8%)	13 (68.4%)	0.498
Left	12 (46.2%)	6 (31.6%)	
Age (mean ± SD)	36.12 ± 12.64 (17–63)	34.58 ± 12.44 (19–56)	0.874

Table 2

Comparison of Preoperative and Postoperative VOR Gains Between Surgical Groups

Variable	Tip 1 Tympanoplasty (n = 26)	Tympano-mastoidectomy (n = 19)	p
•Anterior Canal			
Preoperative VOR Gain	0.86 ± 0.13	0.97 ± 0.12	>0.05
Postoperative VOR Gain	0.91 ± 0.11	0.94 ± 0.08	
•Lateral Canal			
Preoperative VOR Gain	0.97 ± 0.12	0.95 ± 0.08	>0.05
Postoperative VOR Gain	0.99 ± 0.10	0.98 ± 0.08	
•Posterior Canal			
Preoperative VOR Gain	0.93 ± 0.08	0.92 ± 0.08	>0.05
Postoperative VOR Gain	0.93 ± 0.09	0.94 ± 0.10	

In the overall cohort, mean preoperative VOR gains for the affected ears were as follows: for the anterior semicircular canal (ASC), 0.91 ± 0.13; for the lateral canal, 0.96 ± 0.10; and for the posterior canal, 0.93 ± 0.08, respectively. No statistically significant differences were observed in any of the canal planes (p>0.05).

When comparing preoperative and postoperative VOR gain values across all participants, no significant changes were identified in any canal of the affected ear. Specifically, VOR gains for the anterior, lateral, and posterior canals before surgery were 0.91 ± 0.14,

0.96 ± 0.11, and 0.93 ± 0.09, respectively, while postoperative values were 0.92 ± 0.11, 0.99 ± 0.10, and 0.94 ± 0.10. Again, these differences were not statistically significant (p>0.05).

Subgroup analysis of surgical techniques revealed no significant changes in VOR gains in either group. In the tympanoplasty group, pre- and postoperative VOR gains for the anterior, lateral, and posterior canals were 0.86 ± 0.13 vs. 0.91 ± 0.11, 0.97 ± 0.12 vs. 0.99 ± 0.10, and 0.93 ± 0.08 vs. 0.93 ± 0.09, respectively. In the tympanomastoidectomy group, respective pre- and postoperative values were 0.97 ± 0.12 vs. 0.94 ± 0.08 (anterior), 0.95 ± 0.08 vs. 0.98 ± 0.08 (lateral), and 0.92 ± 0.08 vs. 0.94 ± 0.10 (posterior), with all changes remaining statistically insignificant (p>0.05). (Table II)

The mean differences in VOR gains before and after surgery were also compared between surgical groups. In the tympanoplasty group, the mean differences for anterior, lateral, and posterior canals were 0.046, 0.016, and 0.001, respectively, while in the tympanomastoidectomy group, they were 0.028, 0.031, and 0.021. No statistically significant intergroup differences were found (p>0.05). (Table III)

Table 3

Evaluation of Preoperative and Postoperative VOR Gain Differences in Patient Ears According to Surgical Groups

Variable	Tip 1 Tympanoplasty	Tympanomastoidectomy	p
Semicircular Canal			
Anterior Canal	0.046	0.028	0.071
Lateral Canal	0.016	0.031	0.625
Posterior Canal	0.001	0.021	0.578

4. Discussion

This prospective study evaluated the impact of surgical treatment for chronic otitis media-either tympanoplasty or tympanomastoidectomy- on vestibular function by assessing changes in VOR gain using the vHIT. Our findings demonstrated no statistically significant difference in VOR gains between the preoperative and postoperative conditions of the two surgical groups among the affected ears. These results suggest that high-frequency semicircular canal function, as assessed by vHIT, remains intact in patients with COM before and after surgery.

The vHIT offers numerous advantages in evaluating the vestibular function of patients with chronic otitis media, as it is a readily validated assessment that remains unaffected by the patient's age or the presence of conductive or mixed hearing loss. In our study, vHIT was preferred for evaluating the semicircular canals (SCCs) due to its advantages over the air caloric test. Unlike the caloric test, which assesses only the horizontal SCC and reflects low-frequency vestibular responses, vHIT allows for the independent assessment of the VOR in all six semicircular canals and captures high-frequency function.

The literature has widely discussed the relationship between COM and vestibular dysfunction, although objective evidence remains limited.[3] Paparella et al. and others have proposed that bacterial toxins and inflammatory mediators can cross the round window membrane, causing damage to the vestibular structures of the inner ear. Clinical symptoms such as dizziness and imbalance are reported in over 40% of patients with COM.[2] Monsanto et al., who evaluated VOR in COM, found no significant differences in VOR gain between the chronic suppurative otitis media subgroup and the control group.[7]

Abdelmotaleb et al. demonstrated that the vHIT is a reliable method for evaluating high-frequency VOR, particularly in detecting horizontal semicircular canal (SCC) deficits in patients with chronic suppurative otitis media (CSOM), and reported significantly reduced VOR gain in the lateral SCC compared to healthy controls. [8] They suggest that dysfunction in the otolithic organs (utricle and saccule) may precede or exceed that of the SCCs in patients with chronic otitis media. The aforementioned hypothesis is supported by Chang et al., who reported that vestibular dysfunction tends to be more pronounced in the saccule and utricle, whereas SCC deficits tend to manifest later in the disease process. [9] However, objective testing often fails to reveal definitive vestibular dysfunction in all symptomatic individuals.

Our study aimed to investigate whether surgical treatment resulted in any measurable changes in VOR gain in the operated ears by including only patients with normal preoperative vHIT results. Only a limited number of studies in the literature investigate the effects of surgical techniques on the vestibular system. Covelli et al. evaluated the lateral semicircular canal (LSCC) function using vHIT in eight patients with COM who had a labyrinthine fistula, both preoperatively and postoperatively. [10] They observed normal VOR gains in 62.5% of the cases during the preoperative assessment. Furthermore, they suggested that without additional factors such as toxic effects, simple labyrinthine exposure due to bony erosion may not result in functional impairment. Upon examining the patients with preoperatively reduced VOR gain, ıt was found to have type II and type III labyrinthine fistula. In contrast, all patients affected by type I labyrinthine fistulae demonstrated normal VOR gain before surgery. Notably, one month postoperatively, vHIT results remained within normal limits in all five patients who had shown normal VOR gain preoperatively. In line with the findings reported by Covelli et al., our study also demonstrated stable vestibular function postoperatively in patients with chronic otitis media. Specifically, we included only patients with normal vHIT values during the preoperative evaluation to isolate the effect of surgery on vestibular integrity. Consistent with Covelli et al.'s results, all of our patients maintained normal VOR gain at one month postoperatively, suggesting that tympanoplasty or tympanomastoidectomy procedures may not cause significant vestibular dysfunction when the baseline semicircular canal function is preserved.

Although tympanomastoidectomy involves the use of a high-speed drill, several factors suggest that drill-related vibration does not adversely affect semicircular canal integrity. The vHIT evaluates high-frequency VOR dynamics, which are relatively resistant to transient mechanical stimuli and perioperative vibratory artifacts.[5] Furthermore, contemporary surgical practice -employing continuous irrigation, intermittent drilling, and avoiding direct labyrinthine contact- minimizes mechanical and thermal energy transfer to the vestibular apparatus. Importantly, in our series, all postoperative vHIT gains remained within normal limits in the tympanomastoidectomy group, corroborating previous observations that even in cases with labyrinthine fistula, careful surgical handling does not necessarily impair high-frequency canal function.[10] Taken together, these findings indicate that routine drilling, when performed with standard precautions, is unlikely to compromise vestibular function, consistent with our clinical results.

The absence of significant changes in VOR gain after surgery suggests that surgical manipulation of the middle ear, including removal of diseased tissue and repair of ossicular or tympanic structures, does not adversely affect the vestibular end organs. Both tympanoplasty and tympanomastoidectomy are widely practiced pro-

cedures with a favorable safety profile, and our findings reinforce their vestibular safety.

Interestingly, the VOR gain values remained within normal limits in both ears across all measured planes (anterior, lateral, posterior) and both surgical groups. This uniformity in results reinforces the hypothesis that COM-related vestibular dysfunction, when present, may be functional or subclinical, rather than structural damage detectable by vHIT.

Our findings are reassuring from a clinical standpoint. They suggest that surgical intervention for COM does not exacerbate vestibular dysfunction, at least not as detectable by high-frequency VOR assessments. Surgeons can confidently proceed with tympanoplasty or tympanomastoidectomy without substantial concern for inducing vestibular deficits detectable by vHIT.

Additionally, the vHIT may be a valuable tool in the perioperative period to evaluate semicircular canal function, especially in patients with dizziness or vertigo. However, clinicians should remain cautious in interpreting normal vHIT findings in the presence of vestibular symptoms, as other components of the vestibular system (e.g., otolith organs) may still be impaired.

In symptomatic patients, vHIT should ideally be complemented by caloric testing and vestibular evoked myogenic potentials (VEMP), which assess different frequency ranges and vestibular end organs. This multimodal approach would provide a more comprehensive assessment and assist in tailoring appropriate rehabilitation strategies.

4.1. Strengths and Limitations

A key strength of our study lies in its prospective design, consistent testing methodology, and inclusion of two different surgical techniques. All vHIT assessments were performed by a single experienced clinician, reducing variability. Pre- and postoperative testing also allowed for intra-subject comparison, increasing the reliability of the findings.

Nonetheless, our study has several limitations. First, the sample size remains relatively small. This may limit the generalizability of our findings and restrict the ability to detect subtle differences. Second, the follow-up period was limited to one month postoperatively. While this duration is adequate for early postoperative evaluation, it does not capture longer-term changes or delayed-onset vestibular symptoms, which may arise from scarring, ossicular chain movement, or chronic inflammation.

Third, vHIT evaluates only high-frequency semicircular canal function. It does not assess the otolithic system or low-frequency VOR responses. As such, patients with isolated utricular or saccular dysfunction could have normal vHIT results despite having vestibular symptoms. Future studies incorporating caloric testing, cVEMP, oVEMP, and posturography would yield a more holistic understanding.

Lastly, subjective symptom assessment tools (such as the Dizziness Handicap Inventory or Vestibular Activities and Participation questionnaire) were not employed, as such measures provided a valuable correlation between objective findings and patient-perceived impact.

Future studies should include larger, multicenter cohorts and longer postoperative follow-up periods to detect delayed vestibular effects. Incorporating a wider range of vestibular tests—such as caloric testing, VEMP, and rotational chair assessments—will help capture low-frequency and otolithic dysfunctions potentially missed by vHIT.

5. Conclusion

In conclusion, our study demonstrates that VOR gains remain stable in patients with chronic otitis media, both before and after tympanoplasty or tympanomastoidectomy, as measured by vHIT. These findings suggest that semicircular canal function is preserved and not adversely affected by either the disease process or surgical intervention. vHIT may serve as a valuable and safe method for perioperative vestibular assessment, although complementary tests are necessary for comprehensive evaluation, especially in symptomatic patients.

Statement of ethics

The study protocol was approved by the Ethics Committee of Çukurova University Faculty of Medicine (IRB Number: 93, dated November 1, 2019). All participants were informed in detail about the study's purpose and procedures, and written informed consent was obtained from each participant in accordance with the Declaration of Helsinki.

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

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Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

Due to institutional privacy policies, the datasets generated and/or analyzed during the current study are not publicly available, but they are available from the corresponding author upon reasonable request.

Author contributions

Conception and design: EO, SK, OS. Analysis and interpretation of data: EO, SK, CE, MD, ITP, OS. Drafting the article: EO, SK, ITP OS. Revising the article: EO, OS, MD,CE. All authors read and approved the final manuscript.

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