Research Article

Comprehensive Evaluation of Post-Operative Balance Function Following Mastoidectomy in Patients with Chronic Otitis Media

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Short running title: Comprehensive Evaluation of Post-Operative…

Highlights:
- Mastoidectomy does not impact balance in chronic otitis media patients
- Comprehensive tests show no major post-surgical imbalance after mastoidectomy
- Study confirms minimal effect of mastoidectomy on balance system function

ABSTRACT
Background and Aim: Patients with Chronic Otitis Media (COM) who undergo mastoidectomy sometimes experience imbalance, dizziness, and vertigo after the surgery. This study aimed to investigate the effects of mastoidectomy on the balance of patients with COM using standard and advanced balance tests.
Methods: The study was conducted in 2024 in Imam Reza and Ghaem Hospital affiliated with Mashhad University of Medical Sciences, Mashhad, Iran. Forty patients scheduled for mastoidectomy were enrolled over a 12-month period using a census method. Patients underwent balance tests before and after surgery. These tests included the video Head Impulse Test (vHIT), Subjective Visual Vertical (SVV), and posturography.

Results: Statistical analysis of the performance parameter under linear or sinusoidal plate movement conditions showed no significant difference before and after the surgery ($p>0.05$). Statistical analysis of the gain in the six semicircular canals in the vHIT test also showed no significant difference before and after the surgery ($p>0.05$). Similarly, statistical analysis of the deviation from the norm in the neutral position, –30° head tilt to the right, and –30° head tilt to the left showed no significant difference before and after the surgery ($p>0.05$).
Conclusion: The results of this study showed that mastoidectomy does not have a significant effect on balance tests, so performing it may not lead to severe balance disorders in patients with chronic otitis media who are candidates for mastoidectomy surgery.
Keywords: Mastoidectomy; balance; video head impulse test; subjective visual vertical; posturography

Introduction

Mastoidectomy is a standard surgical procedure in treating chronic middle ear diseases, including Chronic Otitis Media (COM), in which the mastoid bone air cells are removed to eliminate infection and prevent its spread [1, 2]. This surgery has numerous applications in Ear, Nose, and Throat (ENT) medicine and is important in controlling chronic middle ear diseases resistant to drug treatments [3]. Despite the many benefits of mastoidectomy in treating chronic middle ear diseases, its possible effects on the function of the vestibular system and balance have received less attention [4, 5]. Many patients complain of symptoms such as dizziness, a sense of imbalance, and even vertigo after mastoidectomy, which can affect their quality of life [6].

The inner ear, including the semicircular canals, saccule, and utricle, plays a major role in the sense of balance, and any damage or irritation to this area can lead to vestibular dysfunction [7]. During mastoidectomy, the proximity of vestibular structures to the surgical site may predispose to direct or indirect damage to these components [8]. Also, tissue manipulation, vibrations during bone resection, and possible contact with the posterior or horizontal semicircular canals can irritate or destroy vestibular sensory cells. For this reason, it is important to carefully examine the effects of mastoidectomy on the balance system and the patient's postoperative function [9].

Although some patients may only experience symptoms of imbalance for a short time after mastoidectomy, in several cases, these symptoms could become chronic [10]. On the other hand, some patients may not experience any symptoms at all, indicating that there are individual differences in response to mastoidectomy and that other factors, such as initial vestibular function, type of mastoidectomy, and technical conditions, may also play a role [11, 12]. These differences and uncertainties in clinical outcomes after mastoidectomy underscore the need for more rigorous and systematic studies [13].

Several tests examine balance and vestibular function, including the video Head Impulse Test (vHIT), caloric test, Subjective Visual Vertical (SVV), Vestibular Evoked Myogenic Potential (VEMP) test, computerized postural tests, and dynamic balance test [14-16]. These tests allow for the examination of the function of various components of the vestibular system with high accuracy. They can be beneficial in diagnosing balance disorders after ear surgeries [17, 18]. Using these methods in the design of future studies can help clarify the effect of mastoidectomy on the balance system and create an appropriate treatment path for symptomatic patients.

Very few studies have been conducted to date on the effects of mastoidectomy on balance in patients, and most of these studies have had small sample sizes and limited assessment tools. Many of these studies have used nonstandardized balance tests or only one assessment tool (such as the Romberg test or simple clinical tests), which cannot provide a comprehensive picture of the vestibular system's function after surgery. Hence, the present study aimed to comprehensively and objectively investigate the effects of mastoidectomy surgery on the balance of patients with COM using standard and advanced balance tests.

Methods

Study design

The present study was conducted in 2024 in Imam Reza and Ghaem hospitals affiliated with Mashhad University of Medical Sciences, Mashhad, Iran. It was designed as a quasi-experimental study on humans and aimed to investigate the effect of mastoidectomy surgery on patients' balance system function.

A total of 40 patients (40 ears) diagnosed with COM who were candidates for mastoidectomy with the canal wall-up technique were enrolled and followed for twelve months. Inclusion criteria were adult patients referred to the participating hospitals who met surgical candidacy and agreed to participate. Exclusion criteria were inability to complete balance testing, unwillingness to cooperate during different stages of the study, history of cholesteatoma, previous ear or balance-related surgery, traumatic ear injury, underlying systemic conditions affecting balance (such as diabetes), or the use of ototoxic drugs.

Surgical procedure

The surgical technique was identical in all patients. Initially, a cutting burr was used at high speed to open the antrum. Subsequently, a diamond burr was employed to fully widen the antrum. The average drilling time across all patients was approximately 15 to 20 minutes. These techniques were performed uniformly in all studied patients.

Procedure

After obtaining informed consent, all patients underwent a standardized battery of balance tests both preoperatively and on the first postoperative day at the Echo Audiometry Center. The assessments included the video Head Impulse Test (vHIT), Subjective Visual Vertical (SVV), and static posturography.

The vHIT was performed using an Interacoustics system (Interacoustics, Denmark). The test assessed the Vestibulo-Ocular Reflex (VOR) by recording the gain parameter for each semicircular canal. Each canal was tested with a minimum of seven valid head impulses. The test was conducted with the patient seated at a fixed distance of one meter from the visual fixation target. To ensure accuracy, patients were first given a demonstration of the procedure followed by a trial run, which was not included in the final data.

SVV testing was conducted using the Interacoustics virtual SVV system (Denmark). The test was performed in three head positions: neutral (head upright), 30° tilt to the left, and 30° tilt to the right. This sequence was strictly followed for all patients. In each position, two valid trials were recorded, and the mean deviation angle was calculated. A deviation beyond ±3° from vertical was considered abnormal. Patients received instructions and a practice trial prior to the actual testing to ensure understanding. Practice results were not included in the study analysis.

Postural stability was evaluated using a static posturography device (EasyTech, Italy). The test was performed in two movement patterns: line (linear) and sinusoidal trajectories, at difficulty levels 3 and 5. According to the device's internal algorithm, level 3 represents an easier task due to a wider displacement range, whereas level 5 is more difficult due to a narrower range of required posture correction. Each posturography condition was conducted for a duration of 1 minute, in line with the device's standard protocol. A rest period of 5 minutes was observed between test conditions. Prior to the actual measurement, patients were instructed and underwent a familiarization trial for each condition. The performance index, calculated automatically by the software, was used as the primary outcome measure to quantify balance performance. Only results from the formal (non-practice) trials were included in the final analysis.

A 5-minute rest period was observed between each test for all patients. Only the operated ear was considered for analysis.

Statistical analysis

For data analysis, qualitative descriptive information was presented using frequency tables and quantitative data using central and dispersion indices. A paired t-test was used to examine the changes in balance function before and after surgery, and in the case of a non-normal distribution of data, a non-parametric Wilcoxon test was used. Also, the McNemar test was used to compare qualitative data before and after surgery. To control the family-wise error rate associated with multiple comparisons, we applied the Holm-Bonferroni method within each test category. Statistical significance was set at $p<0.05$ after adjustment. SPSS version 17 was used for statistical analysis.

Results

A total of 40 people were included in the study, of which 72.5% (29/40) were female and 27.5% (11/40) were male. The mean age of the survey participants was 15.97±40.23 (Figure 1).

Video head impulse test

The mean preoperative gain for the right semicircular canals (right anterior, right lateral, and right posterior semicircular canals, respectively) was 1.00±0.17, 0.92±0.16, and 0.95±0.14. The mean preoperative gain for the

left semicircular canals (left anterior, left lateral, and left posterior semicircular canals, respectively) was 1.02±0.20, 0.95±0.14, and 0.96±0.14 (Figure 2).
The mean postoperative gain for the right semicircular canals (right anterior, right lateral, and right posterior semicircular canals, respectively) was 0.98±0.21, 0.94±0.18, and 0.91±0.15. The mean postoperative gain for the left semicircular canals (left anterior, left lateral, and left posterior semicircular canals, respectively) was 0.99±0.20, 0.93±0.18, and 0.96±0.19 (Figure 2).
The mean deviation from the normal limit before mastoidectomy in the no-head tilt position was –0.03±1.82. The deviation from the normal limit in the -30° head tilt to the right and left was 0.05 (–0.8–1.25) and –1.1 (–2.65–0.3) before mastoidectomy, respectively (Table 1).

Subjective visual vertical
The mean and standard deviation from the normal limit after mastoidectomy in the no-head tilt state was –0.18±2.12. The standard deviation from the normal limit in the 30-degree head tilt to the right and left was 0.7 (–1.18–2.26) and 0.22 (–1.5–1.38) after mastoidectomy, respectively (Table 1).
In the right-head tilt and neutral states, surgery had no significant effect on the individual's perception of uprightness ($p>0.05$). The unadjusted p-value for the left-head tilt SVV condition was 0.017, but after Holm-Bonferroni correction for multiple comparisons (adjusted $p=0.051$), this finding was no longer statistically significant (Table 1).

Posturography
Before surgery, the median performance score in the linear motion of the plane with a degree of difficulty of three and five was 7.3 (5.35–9.47) and 4.15 (2.95–6.07), respectively, and in the sinusoidal motion of the plane with a degree of difficulty of three and five was 9.85 (7.87–12.7) and 6.9 (5.35–9.52), respectively (Table 2).
After surgery, the median performance score in the linear motion of the plane with a degree of difficulty of three and five was 6 (3.6–9.3) and 4.6 (2.5–6.4), respectively, and in the sinusoidal motion of the plane with a degree of difficulty of three and five was 8.8 (6.5–12) and 5.9 (4.6–8.7), respectively (Table 2). There was no significant difference between performance levels (in different test formats and with different difficulties) before and after mastoidectomy ($p>0.05$) (Table 2).

Discussion
Mastoidectomy, as a standard treatment for COM, although it plays an essential role in controlling resistant infections, can lead to symptoms such as dizziness, imbalance, and vertigo due to the proximity of the surgical site to the vestibular structures of the inner ear; symptoms that are transient in some patients and chronic and persistent in others [19, 20]. Despite the clinical importance of COM, limited studies have examined the effect of mastoidectomy on patients' balance function in detail, and most of them have been conducted using non-standard instruments, small sample sizes, and limited clinical assessments. However, accurate and advanced tools such as vHIT, VEMP, caloric test, and computerized postural imaging to measure vestibular function can provide a deeper insight into balance changes after mastoidectomy. On the other hand, balance disorders can have consequences beyond the physiological aspect and lead to reduced quality of life, social functioning, and psychological disorders [21, 22]. The present study investigated balance disorders in patients who underwent mastoidectomy in 2024 at Imam Reza and Ghaem Hospital in Mashhad. vHIT, SVV, and posturography balance tests were performed on the included patients. The gain was evaluated separately in the vHIT test for each semicircular canal. Before and after the operation, mastoidectomy had no significant effect on the gain rate in any of the semicircular canals.
The SVV test examines the individual's perception of the vertical position [23, 24]. In SVV, the individual is asked to draw a vertical line in three tilt positions of 30° to the right, left, and neutral positions, and then the deviation from the normal limit is measured for each individual in each position [25, 26]. The deviation from the normal limit before and after the mastoidectomy did not differ significantly. In the –30° head tilt to the left, the deviation from the normal limit after the operation was reduced significantly. To address the concern of inflated Type I error due to multiple comparisons, we applied the Holm-Bonferroni correction to all comparisons within each test domain. The result did not remain significant after correction, suggesting that these findings should be interpreted with caution. This highlights the importance of adjusting for multiple testing, especially in exploratory studies.

Similar study investigating mastoidectomy's effect on balance parameters are very limited. A previous study was conducted between 2021 and 2023 by Karakuzu et al. to determine the impact of mastoidectomy on the SVV test in 45 COM patients who underwent mastoidectomy with a drill for more than one hour during the operation [27]. Researchers examined the deviation from the normal limit by the SVV test before the operation, 1 day, 3 days, 5 days, 7 days, and one month after. Unlike our study, the number of men included in this study was higher, at about 57.8%. Moreover, unlike our study, the deviation from the normal limit increased significantly on days 1, 3, 5, and 7 after the operation, while our study did not show a significant difference in the deviation from the normal limit in the neutral head position before and after the operation. The results of this study also showed that this balance test did not differ significantly from preoperatively 30 days after the operation. Additionally, unlike our study, which only examined the SVV test once after mastoidectomy. The SVV test was performed on days 1, 3, 5, 7, and one month after the operation. However, in our study, this test was also examined in –30° head tilts to the right and left, and the deviation from the normal limit in –30° head tilt to the left was significantly lower after the operation than before the operation.
In another study conducted by Gupta and Prasad, the posturography balance test was performed on 50 patients who had undergone mastoidectomy before, one month, three months, and six months after the operation [28]. Similar to our study, the mean age of the subjects was about 38 years, and unlike our study, the subjects were divided according to the type of procedure they performed (canal wall up or canal wall down) and the effect of the kind of procedure on the results of the posturography test was also examined. Unlike our study, which did not show a significant change in the posturography test, this study showed that mastoidectomy causes a significant change in the results of the posturography test one and three months after the operation compared to before the operation. The results of the posturography test six months after the operation did not differ significantly from before. In this study, unlike our study, the tests were performed at intervals of one, three, and six months after the operation. In contrast, in our study, the posturography test was performed only once after the operation. Similar to our study, the posturography test in this study was also performed dynamically. Notably, as all patients underwent canal wall up mastoidectomy in our study, our findings indicate this technique has less impact on posturography results compared to canal wall down procedures.
Our study focused on the short-term, immediate effects of canal wall-up mastoidectomy on balance function. This immediate postoperative evaluation captures a phase of vestibular compensation that might precede the onset of delayed imbalance or may miss transient dysfunctions altogether. Therefore, the time window of balance evaluation appears to significantly influence the observed outcomes. While long-term follow-up remains essential to fully understand the dynamics of vestibular compensation and balance recovery, our short-term findings provide a valuable early perspective. Importantly, the selection of precise, objective tests in our study was guided by their feasibility and sensitivity in the immediate postoperative setting, ensuring patient safety and data reliability.
From a clinical standpoint, the absence of significant short-term changes in vHIT, SVV, and posturography parameters following canal wall-up mastoidectomy suggests that this surgical technique may preserve vestibular stability in the immediate postoperative period. This finding is relevant for both surgeons and patients, as postoperative dizziness and imbalance are common concerns that may affect recovery and quality of life. Our results indicate that canal wall-up mastoidectomy may have a more favorable vestibular profile in the acute setting, while existing evidence suggests that transient balance disturbances may become more evident in the subacute period before recovery occurs through central compensation. This underscores the importance of providing patients with appropriate counseling: although most are unlikely to experience major balance dysfunction immediately after canal wall-up mastoidectomy, some degree of imbalance may emerge in the following weeks.
This study has several limitations that should be considered when interpreting the results. Performing repeated tests at specific intervals after the operation could have allowed the researchers to examine the balance changes that occurred at particular intervals after the mastoidectomy. Moreover; This study evaluates utricular function with SVV but does not assess saccule function. But notably, evaluation of the saccule has been more conventional, while assessment of the utricle is often overlooked. Given the distinct roles of otolithic organs —with the utricle primarily involved in horizontal movements and head tilts, and the saccule in perceiving vertical linear acceleration— this study aimed to implement newer evaluation techniques specifically for the utricle. Among other limitations of this study was omission of caloric testing. Undoubtedly, the caloric test holds significant diagnostic value in evaluating the lateral semicircular canal. However, since our study population consisted of

individuals undergoing evaluation before and after mastoidectomy surgery, the caloric test —which fundamentally relies on comparing both ears in terms of stimulation response— could not provide an accurate bilateral comparison when performed immediately post-operatively on a single ear. Therefore, the video head impulse test was employed due to its high precision, rapid execution, and minimal patient discomfort (e.g., absence of vertigo or nausea). This study did not include subjective balance assessment tools such as the Dizziness Handicap Inventory or the Activities-specific Balance Confidence scale. While objective tests were prioritized to minimize bias and ensure feasibility in the immediate postoperative setting, this limits the ability to capture patients' subjective perception of balance. The study was mainly descriptive, and inferential statistical analyses such as intra-subject comparisons (e.g., operated vs. non-operated ear) were not performed. This limits the strength of conclusions. Future research with larger samples and more robust statistical analysis is warranted to confirm and extend our findings. The strengths of this study include the number of balance tests performed. Suggestions for future studies include increasing the number of patients and the study time. In addition, performing repeated tests at specific intervals after the operation could more accurately determine the mastoidectomy's effect on balance tests.

Conclusion
The results of the present study showed that mastoidectomy does not have a significant effect on balance tests, so performing it does not cause severe balance disorders in patients with chronic otitis media who are candidates for mastoidectomy surgery.

Ethical Considerations

Compliance with ethical guidelines
According to the Helsinki Declaration, the research was conducted using ethical principles. Additionally, the Ethics Committee of the Mashhad University of Medical Sciences reviewed and approved the study design, procedures, and ethical considerations, ensuring that the research adhered to established ethical guidelines. IR.MUMS.MEDICAL.REC.1403.013.

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Authors' contributions
NN: Study design and interpretation of the results; MF: Acquisition of data and drafting the manuscript; HB: Acquisition of data and interpretation of the results; SK: Acquisition of data; HMM: Statistical analysis.

Conflict of interest
The authors declare no conflict of interest.

Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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This article is extracted from the second author's Ph.D.dissertation.

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Table 1. Mean and median deviation from the norm boundary before and after surgery in –30° head tilt to the right, left, and neutral positions

Head Position	Before surgery(median [IQR] or mean±SD)	After surgery(median [IQR] or mean±SD)	Unadjusted p-value	Adjusted p-value
Neutral	0.03±1.82	0.18±2.12	0.785*	0.785
30° tilt right	0.05(–1.25 to 0.8)	0.07(–1.18 to 2.26)	0.151**	0.302
30° tilt left	1.1(–2.65 to 0.3)	0.12(–1.5 to 1.38)	0.017**	0.051

IQR; interquartile range
* Paired sample t-test
** Wilcoxon test

Table 2. Median performance scores in different plate movements and difficulty levels

Test type	Before surgery(median [IQR])	After surgery(median [IQR])	Unadjusted p-value	Adjusted p-value
Linear movement (difficulty 3)	7.3(5.35 to 9.47)	6(3.6 to 9.3)	0.318*	0.954
Linear movement (difficulty 5)	4.15(2.95 to 6.07)	4.6(2.5 to 6.4)	0.977*	0.977
Sinusoidal movement (difficulty 3)	9.85(7.87 to 12.7)	8.8(6.5 to 12)	0.717*	0.999<
Sinusoidal movement (difficulty 5)	6.9(5.35 to 9.52)	5.9(4.6 to 8.7)	0.267*	0.999<

IQR; interquartile range
* Wilcoxon test

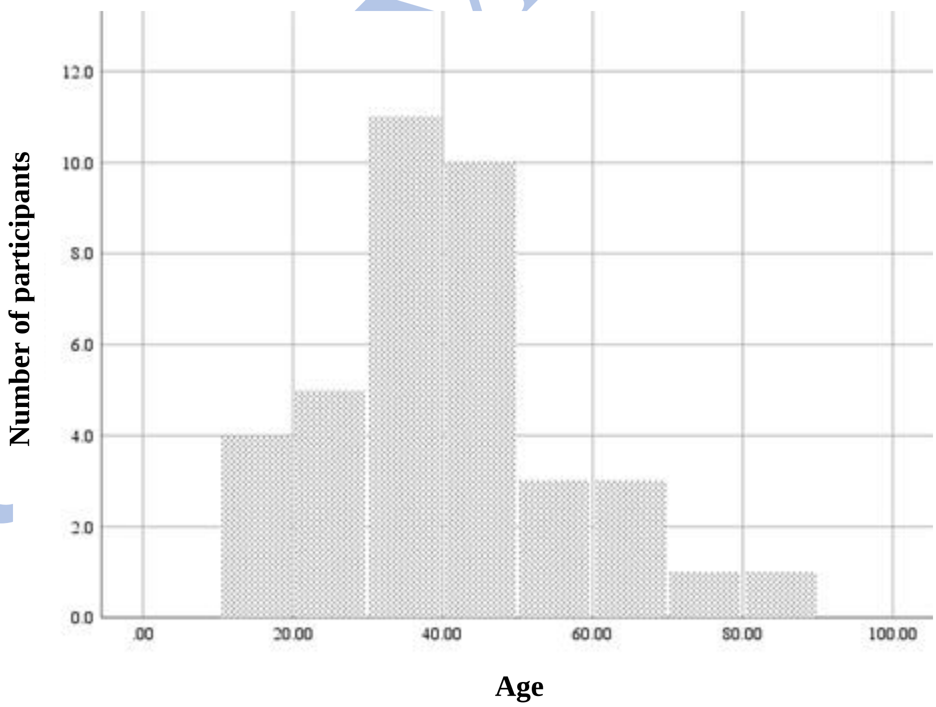

Figure 1. Number of participants under study in each age decade

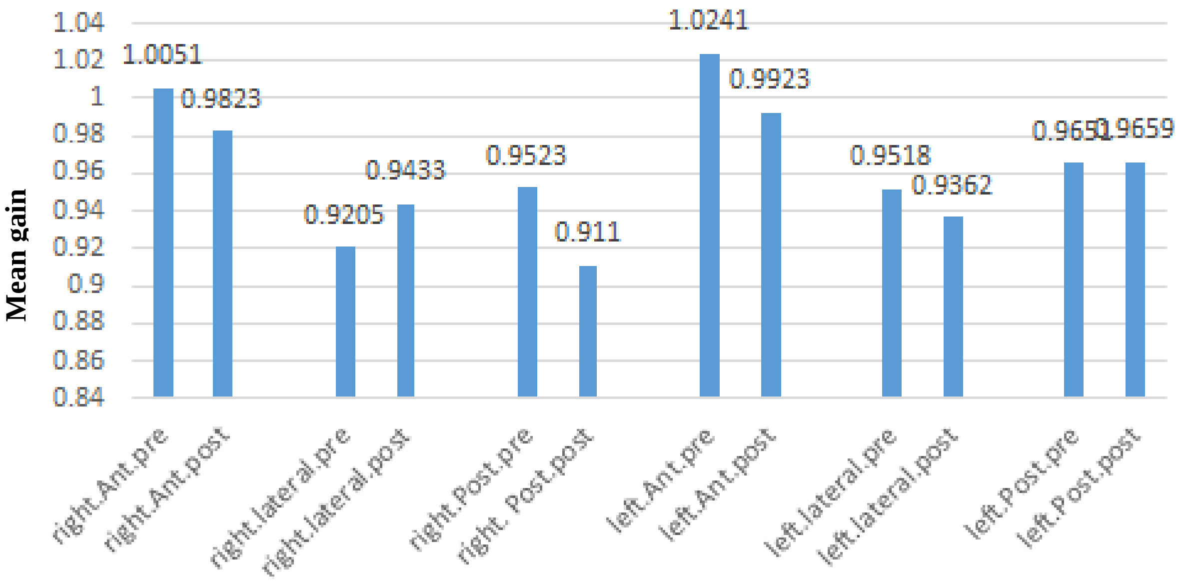

Figure 2. Mean gain in video head impulse test for each semicircular canal; Post: posterior, Ant: anterior, pre: before surgery; post: after surgery