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Hearing loss among otolaryngologist and healthcare workers: Case control study

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ABSTRACT

Background: Noise-induced hearing loss is a prevalent occupational hazard characterized by gradual, sensorineural hearing impairment, primarily affecting higher frequencies (3–6 kHz) due to prolonged exposure to excessive noise. The severity of hearing impairment is directly linked to sound pressure intensity, frequency, exposure duration, and pattern. Otolaryngologists, among other healthcare specialists, frequently use instruments that surpass safety limits, rendering them more susceptible to noise-induced hearing loss. This condition detrimentally impacts communication, performance, healthcare personnel well-being, and patient safety.
Objectives: This study aims to assess whether otolaryngologists and other operating room staff face a higher risk of hearing loss compared to their peers in non-surgical fields, particularly considering advances in surgical instrumentation.
Methods: A case-control study conducted at King Saud University Medical City in Riyadh, Saudi Arabia, in collaboration with the Otolaryngology and Audiology departments from June 2021 to December 2023. Comprehensive medical histories, physical measurements, and various audiological tests, including tympanometry, standard pure-tone audiometry, extended high-frequency pure-tone audiometry, and distortion-product otoacoustic emission (DPOM), were administered to ensure precise results. The study included 20 otolaryngologists of varying ages and experience levels ($n = 20$) and a comparison group of 20 apparently healthy non-otolaryngologist medical professionals. Both groups were drawn from the same population and matched for age, socioeconomic factors, and environments. All subjects underwent extensive audiological testing for result accuracy.
Results: The mean age of otolaryngologists was 31 ± 11 years with a balanced gender distribution. In contrast, the mean age of the non-otolaryngologist group was 32 ± 10 years, with a male predominance. Otolaryngologists exhibited higher odds of low-frequency hearing loss. Additionally, most otolaryngologists displayed the absence of DPOM at 8 kHz, 9 kHz, and 10 kHz, whereas in non-otolaryngologists, DPOM was predominantly present.
Conclusions: This study provides objective evidence of varying hearing levels among otolaryngologists and their peers in different specialties. Preventive measures should be implemented to mitigate communication challenges and enhance patient safety.

1. Introduction

Noise-induced hearing loss (NIHL) is one of the most prevalent occupational hazards across various industries, particularly in environments with chronic exposure to loud sounds [1]. It is a type of sensorineural hearing loss, which typically progresses over time, and is most commonly observed at higher sound frequencies, usually between 3 and 6 kHz [2]. This gradual decline in hearing ability can be traced to prolonged exposure to excessive noise levels. The Occupational Safety and Health Administration (OSHA) has established noise exposure limits to safeguard workers, beginning at 90 A-weighted decibels (dBA) for an 8-h workday, with a 5-dBA exchange rate [3]. This exchange rate recognizes that in most work environments, noise exposure varies, with periods of interruption throughout the day. Despite these regulations, certain workplace environments, such as operating rooms, consistently exhibit noise levels that far exceed recommended limits, posing a

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significant risk to the hearing of both medical professionals and patients [4]. Operating rooms, by their very nature, are environments where noise is present even when they are not actively in use. One contributing factor is the presence of high-capacity air conditioning systems, which are necessary for maintaining optimal conditions for surgical procedures [5]. However, once the operating room becomes occupied with medical staff and patients, the noise levels increase substantially. This noise originates from two primary sources: the equipment used during surgeries and the staff themselves. In particular, surgical equipment can produce noise levels as high as 115 dBA, while the staff-generated noise often reaches up to 78 dBA [6]. These levels are alarmingly high and well above the safe exposure limits set by OSHA. The highest levels of noise in operating rooms typically occur at the beginning and end of surgeries, especially during critical anesthetic periods, such as anesthetic induction and emergence [7]. Studies have shown that these periods are significantly noisier compared to other phases of surgery, with sound levels exceeding safe limits. This heightened noise not only poses a danger to the hearing of the medical staff but also to patients who are exposed to these hazardous levels during their procedures [7]. Furthermore, surgical instruments across various specialties have been identified as major contributors to the elevated noise levels in operating rooms [8]. Many instruments, when used routinely, generate sound levels that are hazardous, surpassing the recommendations set forth by the National Institute for Occupational Safety and Health (NIOSH). For example, orthopedic and neurological surgeries are notorious for their elevated noise levels, with peak sound levels frequently surpassing 100 dBA for >40 % of the time during procedures [9]. Such noise exposure over the course of multiple surgeries, which can last several hours, has a cumulative effect on the hearing of both the surgeons and other healthcare personnel in the room [9]. Despite awareness of the dangers of noise-induced hearing loss, there has been insufficient action taken to mitigate the risks associated with high noise levels in operating rooms. The cumulative nature of noise exposure, combined with the excessive levels found in surgical settings, underscores the urgent need for effective noise control strategies [10]. Implementing measures to reduce noise in operating rooms is essential not only for protecting the hearing health of medical professionals but also for ensuring a safer and more comfortable environment for patients undergoing surgery. As noise-induced hearing loss is preventable, raising awareness and taking steps to address this issue in medical settings is crucial to safeguarding the well-being of those who work in or undergo treatment in noisy environments. The primary aim of this study was to investigate the impact of occupational noise exposure on the hearing function of healthcare professionals, particularly focusing on otolaryngologists who are frequently exposed to high levels of noise in operating rooms. By comparing this group to non-otolaryngologist healthcare workers, who experience minimal noise exposure, the study sought to identify differences in auditory health outcomes attributable to chronic noise exposure. Understanding these effects is crucial for developing effective strategies to mitigate noise exposure and protect the auditory health of medical professionals, ultimately enhancing patient safety and care quality within healthcare settings.

2. Methods

This case-control study was conducted in full compliance with the ethical standards outlined in Good Clinical Practice (GCP), the Declaration of Helsinki, and the local regulations of Saudi Arabia. The study took place at King Saud University Medical City in Riyadh, Saudi Arabia, in collaboration with the Otolaryngology and Audiology Departments at King Abdul-Aziz University Hospital. The research was conducted over a six-month period, from June 2021 to December 2021.

2.1. Study design

This case-control study aimed to investigate the impact of occupational noise exposure on the hearing function of healthcare professionals, with a specific focus on otolaryngologists frequently exposed to high levels of noise in operating rooms. The study compared this group to non-otolaryngologist healthcare workers who were exposed to minimal noise. The participants were divided into two groups: the case group, which included 20 otolaryngologists and operating room nurses working at King Abdul-Aziz University Hospital, and the control group, consisting of 20 non-otolaryngologist healthcare workers from King Saud University Medical City who were not routinely exposed to operating room noise. Both groups were carefully matched for age, gender, socioeconomic status, and work environment to minimize potential confounding factors and ensure a more accurate comparison of the effects of noise exposure on hearing function.

2.2. Inclusion and exclusion criteria

The inclusion criteria for the case group consisted of otolaryngologists and otolaryngology operating room nurses who were actively working in the operating theaters of King Abdul-Aziz University Hospital. Participants were required to have a minimum of one year of work experience in operating rooms, where exposure to noise from surgical equipment and the environment is a routine occupational hazard. For the control group, the inclusion criteria involved non-otolaryngologist healthcare workers, including physicians and nurses, employed at King Saud University Medical City. These participants were selected from various medical departments to ensure a comparable demographic profile to the case group but without the same level of noise exposure as found in operating rooms.

Participants from both groups were excluded from the study if they had any of the following: a history of chronic suppurative otitis media, a history of ear trauma, a diagnosis of sudden-onset hearing loss, a family history of hereditary or congenital hearing loss, or any comorbidities associated with hearing loss, such as diabetes mellitus, hypertension, or a history of stroke. Additionally, participants currently using ototoxic medications were excluded to prevent confounding effects on hearing outcomes.

2.3. Data collection and assessments

All participants underwent a thorough medical evaluation, followed by a series of audiological tests designed to comprehensively assess hearing function. The assessments included several key components. First, a comprehensive medical and hearing history was taken from each participant, focusing on any pre-existing ear-related conditions. Participants were asked specific questions about symptoms such as hearing loss, tinnitus, vertigo, ear discharge, ototoxic medication use, history of ear trauma, and any systemic diseases that might impact hearing function, such as diabetes or hypertension. Next, otoscopy and tuning fork tests were conducted. Otoscopic examination was used to inspect the ear canal and tympanic membrane for abnormalities, including earwax buildup or signs of infection. The Rinne and Weber tuning fork tests were performed to differentiate between conductive and sensorineural hearing loss.

Tympanometry was then utilized to assess middle ear function by measuring the movement of the eardrum in response to changes in air pressure. This test was critical in ruling out any middle ear pathology that could interfere with the accuracy of hearing test results.

Participants also underwent standard pure tone audiometry (PTA) in a soundproof booth. PTA was used to evaluate hearing thresholds across standard frequencies ranging from 0.5 to 8 kHz. The audiometric testing was conducted by a certified audiologist, and hearing loss was classified based on World Health Organization (WHO) criteria. The results were plotted on an audiogram for each participant. To detect early signs of noise-induced hearing loss, extended high-frequency (EHF) audiometry was performed. This test expanded the range of frequencies assessed beyond standard PTA, covering up to 16 kHz. EHF audiometry is particularly effective for identifying early-stage hearing damage that may not yet be noticeable at standard frequencies. Finally, distortion product otoacoustic emissions (DPOAE) testing was conducted to evaluate cochlear function, specifically the activity of the outer hair cells in the cochlea. DPOAE testing is sensitive to early cochlear damage and provides objective data on cochlear health, even in participants who have normal audiometric thresholds.

2.4. Statistical analysis

Data analysis was performed using IBM SPSS Statistics (Version 27.0, IBM Corp., New York). Categorical variables were summarized as frequencies and percentages, while continuous variables were presented as mean values with standard deviations or medians with interquartile ranges, depending on the normality of the data distribution. The chi-square (χ^2) test was employed to assess statistically significant differences between categorical variables. For continuous variables with normal distributions, grouped by a categorical variable, an independent samples *t*-test was used to compare mean values. For non-normally distributed continuous variables, the Mann-Whitney *U* test was applied to compare medians. A *p*-value of <0.05 was considered statistically significant for all analyses.

2.5. Ethical considerations

Prior to the commencement of the study, the research protocol was reviewed and approved by the Research Ethics Committee at King Saud University Medical City. Informed consent was obtained from all participants before their inclusion in the study. Participants were provided with comprehensive information regarding the study's objectives, the procedures involved, and any potential risks and benefits. They were also informed of their right to withdraw from the study at any time, without any consequences, ensuring their autonomy and comfort throughout the study.

3. Results

A total of 40 participants were enrolled in the study, with an equal distribution between the otorhinolaryngology (OR) group and the non-otorhinolaryngology (NOR) group ($n = 20$ in each). The NOR group comprised family medicine physicians and plastic surgeons. Gender distribution was roughly equal between the groups, with no statistically significant difference in gender ($p = .752$). The majority of the OR group were from King Abdul-Aziz University Hospital (KAUH), while most participants in the NOR group were from King Khalid University Hospital (KKUH), with this difference being statistically significant ($p < .001$). There was no significant difference in the median years of experience between the two groups ($p = .235$). The baseline characteristics of the participants, including ear-related symptoms and systemic conditions, were comparable across both groups, with no reported instances of ear trauma, vertigo, tinnitus, aural fullness, hearing loss, diabetes mellitus, hypertension, or head trauma in either group (Table 1).

Table 1
Participants characteristics.

Characteristic	Otorhinolaryngology (n = 20)	Non-otorhinolaryngology (n = 20)	p-value
Gender			0.752
	11 (55.0)	10 (50.0)	
- Males	9 (45.0)	10 (50.0)	
- Females			
Center			<0.001*
	3 (15.0)	14 (70.0)	
- KKUH	17 (85.0)	6 (30.0)	
- KAUH			
Median years of experience	1.5 (1.0–3.0)	2.0 (2.0–2.8)	0.235
Ear discharge	0	0	–
Ear trauma	0	0	–
Vertigo	0	0	–
Tinnitus	0	0	–
Aural fullness	0	0	–
Hearing loss	0	0	–
DM	0	0	–
Hypertension	0	0	–
Head trauma	0	0	–
Smoking	1 (5.0)	3 (15.0)	0.292
Medication use	0	0	–
Stroke	0	0	–
Earphone use			0.528
	2 (10.0)	0	
- None	5 (25.0)	5 (25.0)	
- Rarely	8 (40.0)	10 (50.0)	
- 30 mins/day	5 (25.0)	5 (25.0)	
- 1–3 h/day	0	0	
- >3 h/day			
Tympanogram			0.311
right ear	19 (95.0)	20 (100)	
	0	0	
- Type A	0	0	
- Type B	1 (5.0)	0	
- Type C	0	0	
- Type Ad			
- Type As			
Tympanogram			0.311
left ear	19 (95.0)	20 (100)	
	0	0	
- Type A	0	0	
- Type B	1 (5.0)	0	
- Type C	0	0	
- Type Ad			
- Type As			

3.1. Distortion Product Otoacoustic Emissions (DPOAE) audiological findings

3.1.1. Tympanometry results

Comparison of hearing loss based on audiological tests between OR and NOR groups revealed a few statistically significant differences. OR group detected absent at 500 Hz for 5 (12.5 %) patients as compared to 0 patients detected by the NOR group ($p = .039$). Mean SNR was noted to be lower at 4 k Hz as recorded by the OR group (24.1 ± 6.6) versus the NOR group (26.9 ± 5.2) ($p = .041$). Similarly, Mean SNR was also noted to be lower at 6 k Hz as recorded by the OR group versus the NOR group ($p = .024$). Percentage of absent DPOE detected at 8 k Hz, 9 k Hz, and 10 k Hz was higher among the OR group as compared to the NOR group, with statistical significance (Table 2).

DPOAE analysis revealed some key differences between the groups. A statistically significant difference was noted at 500 Hz, where 12.5 % of participants in the OR group had absent emissions compared to 0 % in the NOR group ($p = .039$). Additionally, the OR group showed significantly lower signal-to-noise ratios (SNR) at 4 k Hz ($p = .041$) and 6 k Hz ($p = .024$) compared to the NOR group. The results of the DPOAE testing are illustrated in Fig. 1.

3.1.2. Hearing loss based on pure tone audiometry (PTA)

Table 3 shows the comparison of hearing loss based on right vs left ear. No difference was noted on tympanogram characteristics. On the other hand, absent DPOE was more common at 500 Hz, 8 k Hz, 9 k Hz, and 10 k Hz for right ear vs left ear, with statistical significance. At the same time, mean SNR was noted to be higher for left ear as compared to the right ear at 6 k Hz, with statistical significance ($p = .039$). No differences were noted between the ears in terms of standard high frequency testing. Meanwhile, for extended high frequency audiometry testing at 9 k Hz, lower mean value was observed for left ear as compared to right ear, with statistical significance ($p = .030$) (Table 3).

Table 2
Comparison of hearing loss based on audiological tests.

Variable	Parameters	Otorhinolaryngology	Non-otorhinolaryngology	p-value
Tympanogram characteristics	ME pressure	−8.7 ± 20.0	−5.8 ± 15.8	0.474
	Volume	1.3 ± 0.3	1.2 ± 0.2	0.470
	Compliance	1.1 ± 1.3	0.9 ± 0.4	0.245
	Gradient	69.6 ± 22.8	62.5 ± 15.7	0.107
Distortion product otoacoustic emission	SNR 500 Hz	8.6 ± 5.4	10.3 ± 2.2	0.067
	Detected 500 Hz			0.039*
		34 (85.0)	40 (100)	
	- Present, normal	1 (2.5)	0	
	- Present, abnormal	5 (12.5)	0	
	- Absent			
	SNR 1 k Hz	17.8 ± 6.2	16.5 ± 4.6	0.295
	Detected 1 k Hz			–
		40 (100)	40 (100)	
	- Present, normal	0	0	
	- Present, abnormal	0	0	
	- Absent			
	SNR 1.5 k Hz	22.7 ± 6.8	21.5 ± 4.7	0.129
	Detected 1.5 k Hz			–
		40 (100)	40 (100)	
	- Present, normal	0	0	
	- Present, abnormal	0	0	
	- Absent			
	SNR 2 k Hz	22.7 ± 7.4	21.5 ± 4.2	0.415
	Detected 2 k Hz			0.314
		39 (97.5)	40 (100)	
	- Present, normal	0	0	
	- Present, abnormal	1 (2.5)	0	
	- Absent			
	SNR 3 k Hz	22.5 ± 4.2	22.1 ± 3.5	0.607
	Detected 3 k Hz			–
	- Present, normal	40 (100)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	0	0	
	SNR 4 k Hz	24.1 ± 6.6	26.9 ± 5.2	0.041*
	Detected 4 k Hz			–
		40 (100)	40 (100)	
	- Present, normal	0	0	
	- Present, abnormal	0	0	
	- Absent			
	SNR 5 k Hz	28.5 ± 6.9	29.0 ± 5.0	0.711
	Detected 5 k Hz			0.484
		36 (90.0)	39 (97.5)	
	- Present, normal	3 (7.5)	1 (2.5)	
	- Present, abnormal	1 (2.5)	0	
	- Absent			
	SNR 6 k Hz	26.1 ± 6.7	29.1 ± 5.0	0.024*
	Detected 6 k Hz			0.136
		34 (85.0)	38 (95.0)	
	- Present, normal	6 (15.0)	2 (5.0)	
	- Present, abnormal	0	0	
	- Absent			
	SNR 7 k Hz	26.4 ± 6.6	27.2 ± 6.0	0.567
	Detected 7 k Hz			0.077
		33 (82.5)	38 (95.0)	
	- Present, normal	7 (17.5)	2 (5.0)	
	- Present, abnormal	0	0	
	- Absent			
	SNR 8 k Hz	17.3 ± 8.0	19.6 ± 8.8	0.208
	Detected 8 k Hz			0.039*
		19 (47.5)	30 (75.0)	
	- Present, normal	13 (32.5)	6 (15.0)	
	- Present, abnormal	8 (20.0)	4 (10.0)	
	- Absent			
	SNR 9 k Hz	18.7 ± 8.8	17.9 ± 10.5	0.708
	Detected 9 k Hz			0.012*
		15 (37.5)	28 (70.0)	
	- Present, normal	16 (40.0)	9 (22.5)	
	- Present, abnormal	9 (22.5)	3 (7.5)	
	- Absent			
	SNR 10 k Hz	14.6 ± 8.3	15.6 ± 8.0	0.599
	Detected 10 k Hz			0.002*
		21 (52.5)	35 (87.5)	
	- Present, normal			

(*continued on next page*)

Table 2 (*continued*)

Variable	Parameters	Otorhinolaryngology	Non-otorhinolaryngology	p-value
	- Present, abnormal	8 (20.0)	1 (2.5)	
	- Absent	11 (27.5)	4 (10.0)	
Standard high frequency audiometry	250 Hz	0.5 ± 5.6	0.8 ± 3.4	0.798
	500 Hz	6.0 ± 6.0	6.3 ± 2.7	0.811
	1 k Hz	7.3 ± 4.9	6.5 ± 3.0	0.415
	2 k Hz	8.1 ± 5.4	8.4 ± 3.3	0.803
	3 k Hz	8.6 ± 4.1	7.6 ± 2.8	0.204
	4 k Hz	8.3 ± 7.3	6.3 ± 4.2	0.137
	6 k Hz	7.5 ± 7.1	5.9 ± 4.8	0.232
	8 k Hz	1.8 ± 8.1	−0.6 ± 4.4	0.106
Extended high frequency audiometry	9 k Hz	−6.0 ± 9.5	−9.4 ± 7.0	0.074
	10 k Hz	1.5 ± 11.3	1.8 ± 11.0	0.920
	11.2 k Hz	−7.3 ± 10.1	−4.6 ± 11.4	0.278
	12.5 k Hz	−6.4 ± 13.1	−6.6 ± 12.4	0.930
	14 k Hz	3.1 ± 18.7	−1.0 ± 15.0	0.256
	16 k Hz	19.0 ± 15.0	21.8 ± 13.9	0.398
	18 k Hz	14.6 ± 5.7	14.4 ± 2.6	0.801
	20 k Hz	−3.8 ± 4.6	−5.0 ± 0.0	0.092

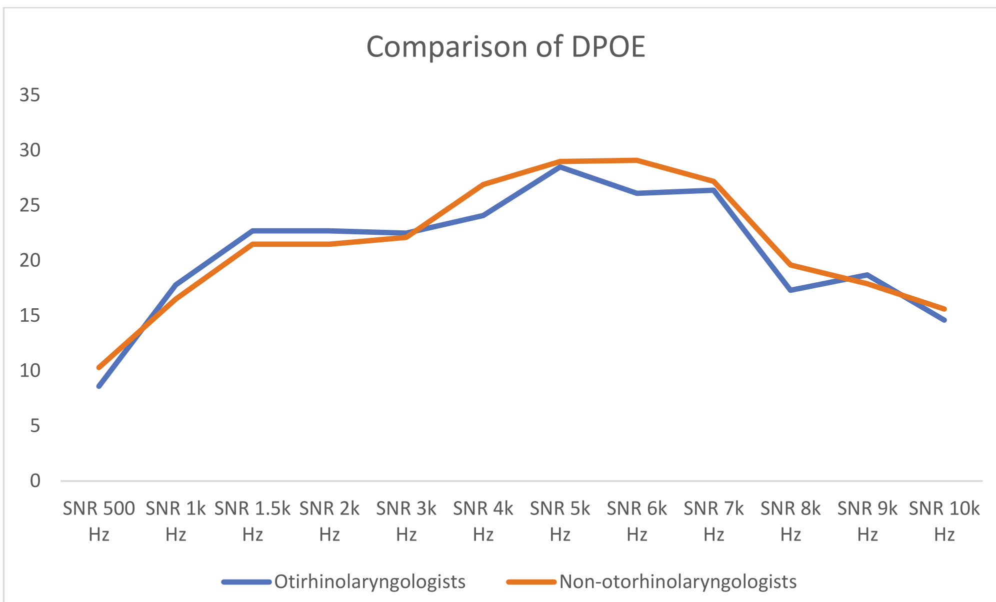

Fig. 1. Comparison of DPOE for OR vs NOR.

3.1.3. *Comparison between right and left ears*

When comparing hearing loss between the otorhinolaryngologists and non-otorhinolaryngologists, the results indicated no significant difference in tympanogram characteristics or standard high-frequency audiometry (Fig. 2).

In terms of comparison of hearing loss based on headphone use, no differences were noted between frequency of headphone use and distortion product otoacoustic emission, and extended high frequency audiometry testing. Meanwhile for standard high frequency audiometry testing, highest mean value at 500 Hz was observed for those with no headphone use, with statistical significance (p = .008). Similarly, for testing at 1 k Hz, highest mean value was noted for those with no headphone use (p = .027) (Table 4).

4. Discussion

Noise in the healthcare environment has long been recognized as a significant concern, impacting not only the well-being of medical staff but also patient safety [11]. The operating room, a critical area for patient care, often exposes healthcare professionals to elevated noise levels due to various factors, including surgical instruments, equipment, and the operational activities of the healthcare team [11]. Chronic exposure to high noise levels can lead to several adverse consequences, including communication barriers, reduced performance, and health issues among the healthcare team, ultimately compromising patient safety [12]. The relationship between noise exposure and hearing impairment is well-documented, with tinnitus and NIHL being the most common consequences of prolonged exposure to elevated sound levels [13]. NIHL is a significant concern for healthcare professionals such as nurses and surgeons, who routinely work in noisy operating rooms. Studies have shown that these professionals are at a higher risk of developing NIHL compared to their peers in quieter environments [14]. The constant din of the operating room, often exceeding safe noise levels, puts surgical staff at significant risk of auditory damage, further exacerbated by the high-frequency sounds generated by surgical instruments [5]. It is crucial to note that even relatively moderate noise levels, when experienced over extended periods, can result in significant auditory damage [15]. The risks are compounded in operating rooms where noise levels frequently exceed established safety limits, making it imperative for healthcare institutions to recognize and address the potential for hearing loss among their staff [16]. In addition to auditory effects, chronic noise exposure triggers the body's nervous and endocrine systems' fight-or-

Table 3
Comparison of hearing loss based on ear.

Variable	Parameters	Right ear	Left ear	p-value
Tympanogram characteristics	ME pressure	−7.6 ± 21.7	−6.8 ± 13.5	0.856
	Volume	1.3 ± 0.2	1.3 ± 0.2	0.557
	Compliance	1.0 ± 1.0	1.0 ± 0.9	0.870
	Gradient	65.7 ± 20.4	66.4 ± 19.4	0.876
Distortion product otoacoustic emission	SNR 500 Hz	8.8 ± 5.2	10.3 ± 2.1	0.103
	Detected 500 Hz			,039*
	- Present, normal	34 (85.0)	40 (100)	
	- Present, abnormal	1 (2.5	0	
	- Absent	5 (12.5)	0	
	SNR 1 k Hz	17.6 ± 6.0	16.6 ± 4.6	0.443
	Detected 1 k Hz			–
	- Present, normal	40 (100)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	0	0	
	SNR 1.5 k Hz	22.0 ± 6.9	21.2 ± 5.5	0.314
	Detected 1.5 k Hz			–
	- Present, normal	40 (100)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	0	0	
	SNR 2 k Hz	22.3 ± 7.2	21.8 ± 4.7	0.542
	Detected 2 k Hz			0.314
	- Present, normal	39 (97.5)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	1 (2.5)	0	
	SNR 3 k Hz	22.6 ± 4.1	22.6 ± 4.1	0.733
	Detected 3 k Hz			–
	- Present, normal	40 (100)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	0	0	
	SNR 4 k Hz	24.7 ± 6.5	26.5 ± 5.4	0.523
	Detected 4 k Hz			–
	- Present, normal	40 (100)	40 (100)	
	- Present, abnormal	0	0	
	- Absent	0	0	
	SNR 5 k Hz	28.5 ± 6.8	29.2 ± 4.8	0.184
	Detected 5 k Hz			0.484
	- Present, normal	36 (90.0)	39 (97.5)	
	- Present, abnormal	3 (7.5)	1 (2.5)	
	- Absent	1 (2.5)	0	
	SNR 6 k Hz	26.4 ± 6.6	29.2 ± 4.9	0.039*
	Detected 6 k Hz			0.136
	- Present, normal	34 (85.0)	38 (95.0)	
	- Present, abnormal	6 (15.0)	2 (5.0)	
	- Absent	0	0	
	SNR 7 k Hz	26.5 ± 6.6	27.3 ± 5.8	0.564
	Detected 7 k Hz			0.077
	- Present, normal	33 (82.5)	38 (95.0)	
	- Present, abnormal	7 (17.5)	2 (5.0)	
	- Absent	0	0	
	SNR 8 k Hz	17.4 ± 8.0	19.7 ± 7.9	0.200
	Detected 8 k Hz			0.039*
	- Present, normal	19 (47.5)	30 (75.0)	
	- Present, abnormal	13 (32.5)	6 (15.0)	
	- Absent	8 (20.0)	4 (10.0)	
	SNR 9 k Hz	17.5 ± 8.0	19.3 ± 9.0	0.428
	Detected 9 k Hz			0.012*
	- Present, normal	15 (37.5)	28 (70.0)	
	- Present, abnormal	16 (40.0)	9 (22.5)	
	- Absent	9 (22.5)	3 (7.5)	
	SNR 10 k Hz	14.3 ± 8.5	16.1 ± 7.5	0.326
	Detected 10 k Hz			0.002*
	- Present, normal	21 (52.5)	35 (87.5)	
	- Present, abnormal	8 (20.0)	1 (2.5)	
	- Absent	11 (27.5)	4 (10.0)	
Standard high frequency audiometry	250 Hz	0.7 ± 5.5	0.6 ± 3.2	0.941
	500 Hz	6.0 ± 5.7	6.3 ± 2.8	0.787
	1 k Hz	6.9 ± 4.8	6.9 ± 3.0	0.973
	2 k Hz	8.0 ± 5.1	8.6 ± 3.3	0.571
	3 k Hz	8.6 ± 3.9	7.6 ± 2.8	0.215
	4 k Hz	8.3 ± 7.2	6.3 ± 3.9	0.207
	6 k Hz	7.4 ± 6.8	5.7 ± 4.9	0.207
	8 k Hz	1.3 ± 7.9	−0.4 ± 4.3	0.236
Extended high frequency audiometry	9 k Hz	−5.9 ± 9.0	−10.0 ± 7.2	0.030*
	10 k Hz	2.2 ± 11.8	0.9 ± 10.3	0.588
	11.2 k Hz	−6.3 ± 10.1	−5.4 ± 11.7	0.712
	12.5 k Hz	−6.3 ± 12.9	−6.7 ± 12.5	0.895

(continued on next page)

Table 3 (*continued*)

Variable	Parameters	Right ear	Left ear	p-value
	14 k Hz	2.7 ± 18.1	−1.0 ± 13.2	0.317
	16 k Hz	19.7 ± 14.6	21.3 ± 14.5	0.622
	18 k Hz	14.7 ± 5.4	14.3 ± 2.8	0.703
	20 k Hz	−3.9 ± 4.4	−5.0 ± 0.0	0.138

flight response, leading to increased cardiovascular workload [16]. This physiological response to noise can result in serious health implications, including cardiovascular diseases such as hypertension, angina pectoris, myocardial infarction, and even premature death. The interplay between stress induced by noise and the physiological strain on the cardiovascular system emphasizes the need for interventions to mitigate noise exposure in healthcare settings [17]. Another critical aspect of noise in the operating room is its disruptive effect on verbal communication, which is vital for effective teamwork and patient safety [18]. Effective communication among healthcare team members is essential to ensure patient safety, especially during complex surgical procedures [18]. However, excessive noise levels can lead to misunderstandings and errors, as staff may struggle to hear one another clearly. This often

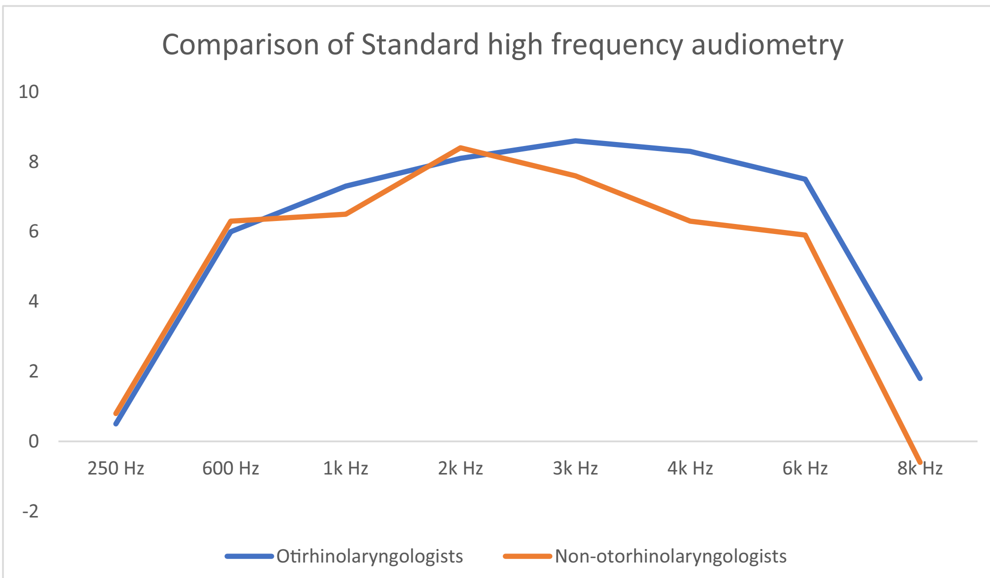

Fig. 2.

Table 4
Comparison of hearing loss based on headphone use.

Variable	Parameter	No use	Rare use	30 mins	1–3 h	p-value
Distortion product otoacoustic emission	SNR 500 Hz	3.3 ± 9.3	9.7 ± 2.5	9.7 ± 2.9	8.1 ± 6.7	0.233
	SNR 1 k Hz	14.6 ± 1.5	18.7 ± 6.2	17.0 ± 5.1	15.8 ± 4.8	0.603
	SNR 1.5 k Hz	22.4 ± 7.1	23.7 ± 6.7	21.1 ± 6.3	19.3 ± 7.0	0.525
	SNR 2 k Hz	22.4 ± 1.0	23.6 ± 7.5	23.3 ± 5.6	21.1 ± 6.1	0.782
	SNR 3 k Hz	23.9 ± 6.8	23.0 ± 3.9	23.2 ± 3.2	22.4 ± 3.1	0.919
	SNR 4 k Hz	23.6 ± 5.4	26.3 ± 5.8	28.0 ± 4.7	25.4 ± 8.6	0.617
	SNR 5 k Hz	23.9 ± 6.9	30.0 ± 6.0	28.5 ± 5.9	28.7 ± 6.8	0.644
	SNR 6 k Hz	24.3 ± 5.0	27.5 ± 5.9	29.6 ± 4.8	27.5 ± 5.0	0.442
	SNR 7 k Hz	20.9 ± 1.0	26.8 ± 6.6	29.0 ± 5.2	26.5 ± 7.0	0.279
	SNR 8 k Hz	16.5 ± 1.3	18.9 ± 6.6	21.4 ± 7.2	18.0 ± 7.5	0.567
	SNR 9 k Hz	21.6 ± 5.5	18.2 ± 16.4	16.9 ± 11.4	20.6 ± 9.8	0.871
	SNR 10 k Hz	13.4 ± 0.8	13.8 ± 8.7	16.9 ± 10.0	15.0 ± 5.5	0.801
Standard high frequency audiometry	250 Hz	7.5 ± 10.6	−0.5 ± 2.8	0.0 ± 4.2	1.5 ± 3.4	0.076
	500 Hz	12.5 ± 10.6	3.5 ± 3.4	5.0 ± 1.7	7.5 ± 4.9	0.008*
	1 k Hz	10.0 ± 7.1	4.0 ± 3.2	5.3 ± 2.7	8.0 ± 4.2	0.027*
	2 k Hz	15.0 ± 21.2	8.5 ± 3.4	9.4 ± 3.4	9.5 ± 2.8	0.389
	3 k Hz	5.0 ± 7.1	9.5 ± 4.4	8.3 ± 3.4	7.5 ± 2.6	0.382
	4 k Hz	7.5 ± 10.6	8.5 ± 6.3	7.2 ± 4.9	6.0 ± 6.1	0.818
	6 k Hz	10.0 ± 0.0	6.5 ± 5.7	5.0 ± 5.7	4.5 ± 5.5	0.596
	8 k Hz	5.5 ± 14.1	−2.0 ± 7.1	−0.8 ± 6.0	−1.0 ± 4.6	0.574
Extended high frequency audiometry	9 k Hz	0.0 ± 7.1	−4.5 ± 8.6	−6.7 ± 9.4	−9.5 ± 4.4	0.371
	10 k Hz	0.0 ± 7.1	−1.0 ± 10.5	−0.3 ± 11.8	0.0 ± 8.5	0.997
	11.2 k Hz	−15.0 ± 0.0	−3.5 ± 7.8	−6.9 ± 8.6	−5.5 ± 9.9	0.368
	12.5 k Hz	10.0 ± 0.0	−2.0 ± 11.4	−8.6 ± 9.4	−8.5 ± 7.1	0.288
	14 k Hz	5.0 ± 14.1	10.0 ± 14.9	−3.3 ± 15.7	2.0 ± 11.8	0.159
	16 k Hz	15.0 ± 7.1	25.5 ± 10.4	21.4 ± 13.3	25.5 ± 9.8	0.538
	18 k Hz	15.0 ± 0.0	17.0 ± 6.3	15.8 ± 5.2	14.5 ± 1.6	0.711
	20 k Hz	−5.0 ± 0.0	−3.0 ± 6.3	−3.3 ± 5.1	−5.0 ± 0.0	0.749

results in personnel raising their voices to communicate effectively, inadvertently amplifying the overall noise level in the operating room. Such a cycle of increased noise and strained communication can hinder the performance of the healthcare team, posing risks to patient outcomes [19]. Otolaryngology is among the specialties that regularly use instruments exceeding safety limits. Reports indicate that noise levels can reach as high as 125.5 dBA during simulated otolaryngological surgeries [8]. This increased vulnerability may be attributed to advancements in surgical instrumentation that produce higher noise levels, along with the unique demands of the specialty itself. As surgical techniques and tools evolve, the auditory risks for those working in this field may escalate, underscoring the urgent need for protective measures. Our results reveal that otolaryngologists, who are routinely exposed to elevated noise levels, are at a significantly higher risk of experiencing hearing loss, particularly at higher frequencies. Notably, this study identified a higher incidence of absent DPOE at key frequencies (8 kHz, 9 kHz, and 10 kHz) in the otolaryngology group compared to the non-otolaryngology group, which suggests early signs of cochlear damage [14]. This aligns with previous research that found noise exposure in the operating room can cause high-frequency sensorineural hearing loss, particularly among surgeons using high-speed drills and other equipment that produce hazardous noise levels [20]. In contrast, the non-otolaryngology group, comprising healthcare workers with minimal noise exposure, showed significantly better hearing thresholds and fewer abnormalities across these high frequencies [21]. Moreover, the study observed statistically significant differences in signal-to-noise ratios (SNR) between the two groups. The otolaryngology group exhibited lower SNR values at 4 kHz and 6 kHz compared to their non-otolaryngology counterparts. These findings are in line with the literature, which indicates that SNR decreases as noise-induced hearing damage progresses, and higher frequencies are often the first to be affected [22]. This further underscores the vulnerability of otolaryngologists to NIHL due to their occupational environment, where they are exposed to intense noise during surgical procedures. Interestingly, the present study also highlighted the cumulative nature of noise-induced auditory damage. Despite the relatively short-term noise exposure experienced during surgical procedures, the prolonged and repetitive nature of this exposure over years contributes to the gradual deterioration of auditory function. Studies have shown that exposure to noise levels exceeding 85 dBA, even for short durations, can lead to significant hearing impairment over time [23]. In our study, the otolaryngologists were regularly exposed to noise levels exceeding the National Institute for Occupational Safety and Health (NIOSH) recommendations for safe noise levels, supporting the assertion that operating room noise presents a serious occupational hazard [24]. While the study corroborates existing literature on the risks of noise exposure in healthcare settings, particularly in surgical environments, it also raises questions about the effectiveness of current preventive measures. Although regulations exist to protect workers from excessive noise exposure, the unique challenges posed by the operating room, where communication and precision are critical, make it difficult to implement certain noise reduction strategies [25]. For instance, while noise-cancelling devices and ear protection are standard in other noisy workplaces, their use in surgical settings can hinder communication between team members and potentially compromise patient safety. Another important aspect of this study is the potential impact of noise on cardiovascular health. Although our study primarily focused on auditory outcomes, the literature indicates that chronic noise exposure is also associated with an increased risk of cardiovascular diseases, such as hypertension and myocardial infarction, due to the activation of the body's stress response [26]. Future studies could explore the broader health implications of noise exposure in the operating room, including cardiovascular effects, to provide a more comprehensive understanding of the risks faced by healthcare workers.

To mitigate the adverse effects of noise in operating rooms, several strategies can be implemented. First, the adoption of sound-reducing technologies, such as quieter surgical instruments and effective soundproofing materials in operating rooms, can help lower exposure levels. Additionally, regular maintenance of existing equipment can help minimize unnecessary noise, further enhancing the acoustic environment in operating rooms.

Regular auditory assessments for healthcare professionals who frequently work in high-noise environments should be instituted as a preventive measure. Educational programs aimed at raising awareness about the risks associated with noise exposure and promoting safe practices in the operating room can also be beneficial. [27] The study's limitations should also be noted. The sample size was relatively small, with only 20 participants in each group, which may limit the generalizability of the findings. Additionally, the cross-sectional design of the study precludes any conclusions about the long-term effects of noise exposure on hearing function. Longitudinal studies with larger sample sizes are needed to confirm these findings and further investigate the cumulative impact of noise exposure on hearing over time.

5. Conclusion

In summary, noise exposure in healthcare settings, particularly in operating rooms, presents significant risks to the auditory health of medical professionals and compromises patient safety. This study highlights the prevalence of NIHL among otolaryngologists and the adverse effects of chronic noise exposure, including tinnitus and increased cardiovascular stress. The findings underscore the urgent need for effective noise mitigation strategies, including the use of quieter surgical instruments, soundproofing measures, and comprehensive training for healthcare staff on communication practices in noisy environments. Moreover, regular auditory assessments should be established to identify early signs of hearing impairment, ensuring timely interventions to protect the health of medical professionals. Creating a culture of safety that prioritizes both staff well-being and patient care is essential for fostering a more conducive working environment.

CRediT authorship contribution statement

Dana A. Obeid: Formal analysis, Writing – original draft, Writing – review & editing. **Hassan Assiri:** Conceptualization, Formal analysis. **Jawaher AlShalawi:** Investigation. **Abdullah AlKhaldi:** Formal analysis, Methodology. **Farid AlZhrani:** Supervision.

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