

Effects of noise on the hearing of intensive care unit nurses

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ABSTRACT

This study aims to investigate the hearing problems experienced by nurses working in the intensive care units (ICUs) and gastroenterology departments of a hospital in China. A total of 93 participants who are currently employed in these settings were recruited for the study. The research methodology involved several components. Firstly, the pure tone audiometry (PTA) hearing threshold measurements were conducted in a closed audiometry room. The air conduction hearing and bone conduction hearing thresholds were recorded using calibrated equipment. Secondly, the participants underwent the Digits In Noise (DIN) test to assess their speech reception threshold in a noisy environment. They were instructed to wear headphones and adjust the volume to be a comfortable level while Chinese digit triplets were presented with a background masking noise. Thirdly, a questionnaire with previously validated and subjective components was also administered after the PTA and DIN tests. The survey aimed to assess self-reported auditory dysesthesia, including symptoms such as tinnitus, aural fullness, and otalgia. It was observed that ICU nurses exhibited more hearing loss at high frequencies above 4 kHz compared to non-ICU nurses. Additionally, nurses who worked more hours per week demonstrated worse hearing thresholds. Furthermore, ICU nurses reported more severe self-reported hearing problems compared with non-ICU nurses.

1. INTRODUCTION

It is well known that the noise levels in intensive care units (ICUs) commonly exceed the recommended levels set by the World Health Organisation (WHO) guidelines. Previous studies have demonstrated that noise probably has numerous negative effects on patients in ICUs, including sleep disorders, increased risk of delirium, and increased blood pressure[1-3]. Similarly, prolonged exposure to the noisy environment in ICUs may have adverse effects on the ICU staff such as nurses.

Several studies have highlighted the hearing loss experienced by healthcare workers as a result of exposure to noise. For instance, Daud, Noh [4] conducted a pure tone hearing threshold test and identified dental nurses as being at risk of hearing loss. Spencer [5] discussed the significance of hearing in nursing practice and the responsibility of nurses in maintaining their hearing health. However, there is limited reporting on noise-induced auditory dysesthesia among medical practitioners working in ICUs.

Therefore, the objective of this study is to assess the hearing loss among nurses currently working in the ICU. Additionally, a comparison group of nurses not working in the ICU was also included. The study employed several methods to gather data. Firstly, audiometric measurements were conducted to determine the hearing thresholds using both air conduction and bone conduction from 250 Hz to 8 kHz. Secondly, the digits-in-noise (DIN) test was administered. Lastly, a simple questionnaire survey was utilised to explore the hearing difficulties experienced by nurses in the ICU and non-ICU settings.

2. METHODOLOGY

2.1 Participants

This study was conducted at Nanchuan Hospital in China from January 2023 to March 2023. A total of 93 nurses (45 from the ICU and 48 from non-ICU) were recruited for the PTA measurement, DIN test, and questionnaire. Table 1 presents the socio-demographic and professional characteristics of the participants. Among all participants, females accounted for 89% and males for 11%. The participants' ages ranged from 20 to 58 (mean 33.1, SD 6.8), with the majority having worked in hospitals for more than 5 years (58.1%). Nurses with previous hearing loss and those with pathological findings related to the external auditory canal and eardrum in their otoscopic examination were excluded from the study.

Table 1: Socio-demographic and professional characteristics of the participants

Personal characteristics	ICU (N=45)	Non-ICU (N=48)	Total (N=93)
Gender			
Male	2	8	10
Female	43	40	83
Age (years old)			
20-30	15	21	36
30-40	27	20	47
>40	3	7	10
Years of working			
<1	0	2	2
1-2 years	0	9	9
2-5 years	8	13	21
5-10 years	31	23	54
>10	6	1	7
Hours of working per week			
<40	0	0	0
40-50	35	33	68
51-60	7	11	18
>60	8	4	12

2.2 Pure Tone Audiometry (PTA) measurements

The pure tone hearing threshold measurement consists of two parts: 1) the air conduction hearing threshold, and 2) the bone conduction hearing threshold. Participants wore a headphone in a closed audiometry room (indoor noise level does not exceed 30 dBA) and listened to pure tones generated by the doctor in the control room (refer to Figure 1). Hearing threshold levels were obtained at six frequencies (0.25, 0.5, 1, 2, 4, and 8 kHz) using calibrated equipment (GSI AudioStar Pro).



Figure 1: Closed audiometry room at Nanchuan Hospital

2.3 Digits-In-Noise (DIN) measurements

A digital mhealth app ‘HearWHO’ in Chinese (published in 2021) was used in this research. Participants were instructed to connect headphones and select a comfortable volume while digit triplets were presented without masking noise. Subsequently, 23 digit triplets (e.g. 6-7-3) were randomly selected and presented using an antiphase paradigm, where the digits had a 180° phase shift between the ears while keeping stationary masking noise in phase [6]. The Speech Reception Threshold (SRT) was categorised into three groups, namely ‘Good’, ‘OK’, or ‘Needs Help’, based on specific cut-offs values. Similar to the English language set, the cut-points for ‘Good’ was SRTs ≤ -15.2 dB Signal-to-Noise Ratio (SNR), between -15.1 and -12.5 dB SNR for ‘OK’ hearing and > -12.5 dB SNR for ‘Needs Help’. These cut-offs were based on the normative dataset presented in the previous study [7].

2.4 Questionnaire survey

The questionnaire consists of two major sections: 1) basic information such as age and gender, and 2) hearing problems in hospitals. The participants were asked to rate their experience of the hearing symptoms using a 5-point Likert scale (‘0’: never and ‘4’: always). The validated Hearing Handicap Inventory (HHIA-S) [8, 9] was also utilised to measure the self-perception of hearing handicaps. Additionally, participants were asked about communication after the pandemic, and they rated the changes in the quality of verbal communication using a 5-point scale (‘1’: much worsen and ‘5’: much improved).

3. RESULTS

3.1 PTA measurements

The hearing thresholds for both ears (left and right ear) of ICU and non-ICU nurses are presented in Figure 2. There were no statistically significant differences between the left and right ear ($p>0.05$,

paired sample t-test) for both groups. Therefore, the hearing thresholds were averaged, and the mean thresholds of both ears were used in the subsequent analyses.

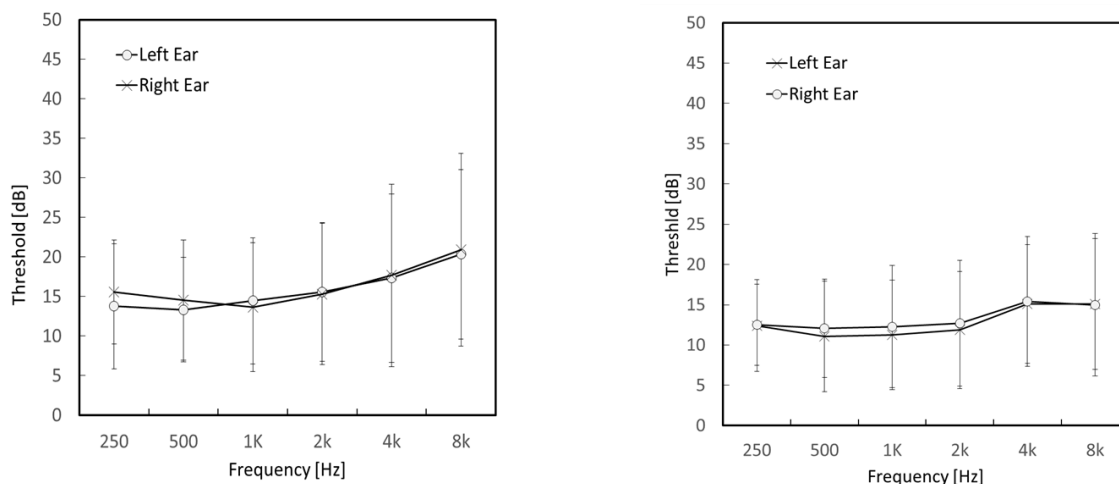


Figure 2: Pure Tone Audiometry results for ICU nurses (left) and non-ICU nurses (right). Error bars represent standard deviations.

Figure 3 shows the mean hearing threshold at different frequencies, along with the number of nurses with hearing loss. Generally, both ICU nurses and non-ICU nurses exhibited normal hearing (<25dB) in low frequencies (i.e. 0.25, 0.5, and 1 kHz). However, 19.6% of the ICU nurses and 10.4% of the non-ICU nurses showed hearing loss at high frequencies (i.e. 4 kHz and 8 kHz). ICU nurses reported a worse hearing threshold than non-ICU at high frequencies, and the difference between ICU and non-ICU were statistically significant.

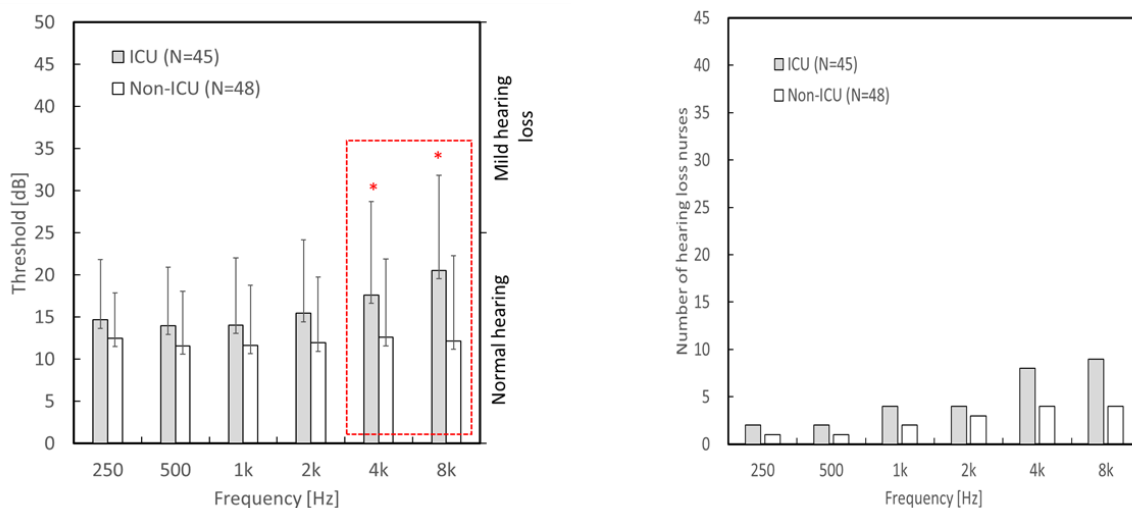


Figure 3: Comparison of Pure Tone Audiometry between ICU nurses and non-ICU nurses (left) and numbers of nurses with hearing loss at each frequency (right). (* $p < 0.05$)

Figure 4 shows the difference between air and bone conduction thresholds (known as the ‘air-bone gap’) for both ICU nurses and non-ICU nurses. The air-bone gap was below 10 dB for all nurses, indicating that the PTA at high frequencies was unlikely to be attributable to conductive hearing loss (e.g. issues with the ear drum or external auditory canal, or middle ear, like otitis media). ICU nurses exhibited slightly higher air-bone gap values than non-ICU nurses, and the differences between the two groups were statistically significant (* $p < 0.05$, ** $p < 0.01$).

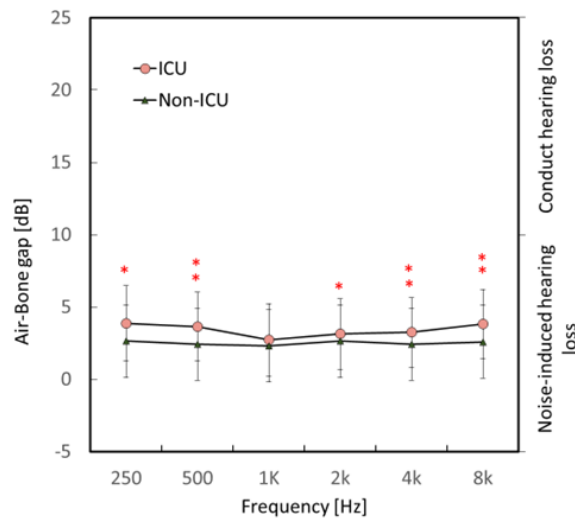


Figure 4: Comparison of air-bone gap between ICU nurses and non-ICU nurses. Error bars represent standard deviations. (* $p < 0.05$ and ** $p < 0.01$)

Figures 5(a) and 5(b) present the PTA results across different ages. The vertical axes represent the thresholds averaged from 0.25 to 8 kHz. As shown in Figure 5(a), the associations between ages and hearing threshold were not found to be significant ($p > 0.05$) for both groups. However, as illustrated in Figure 5(b), among nurses working less than 50 hours per week, there were significant relationships between age and the PTA results for both ICU nurses ($r = 0.129$, $p < 0.05$) and non-ICU nurses ($r = 0.171$, $p < 0.05$), indicating that the hearing thresholds slightly worsened as the age increased.

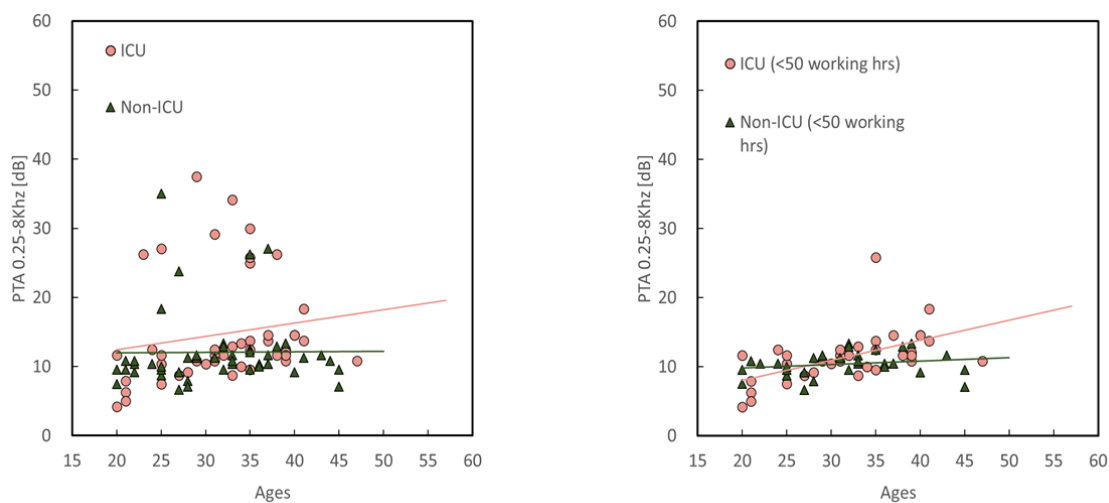


Figure 5: Relationships between hearing thresholds and ages: a) comparison between ICU and non-ICU nurses, and b) comparison between ICU and non-ICU nurses who worked less than 50 hours per week.

The PTA for all age groups (20-30 yrs, 30-40 yrs, and 40-50 yrs) is shown in Figure 6. The hearing thresholds were compared with the International Organization for Standardization standard (ISO 7029). The results revealed that both ICU and non-ICU nurses had worse hearing thresholds compared to the ISO 7029 equation applied to the same age band. However, it is important to note that the ISO 7029 was based on data for European and North American populations between the 1950s and the 1970s. Additionally, the PTA for different age groups was compared with a previous study by Sunghee Kim [10] conducted in Korea with 3470 participants in 2010. As shown in Figure 7, ICU nurses showed similar hearing thresholds at low frequencies but worse hearing thresholds at high frequencies compared to those reported in the Korean study.

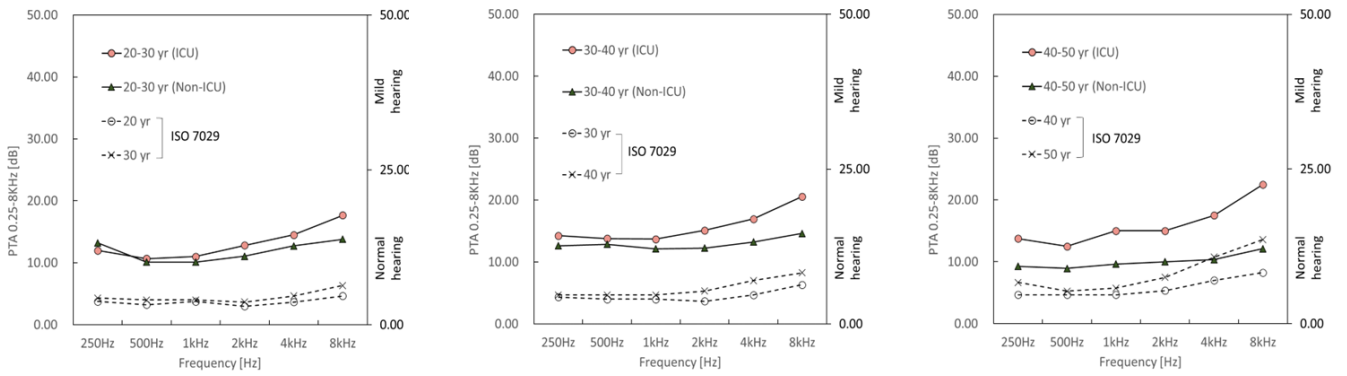


Figure 6: Comparisons of hearing thresholds between the current study and the ISO standard for different age bands (left: 20-30 yrs, middle: 30-40 yrs, and right: 40-50 yrs).

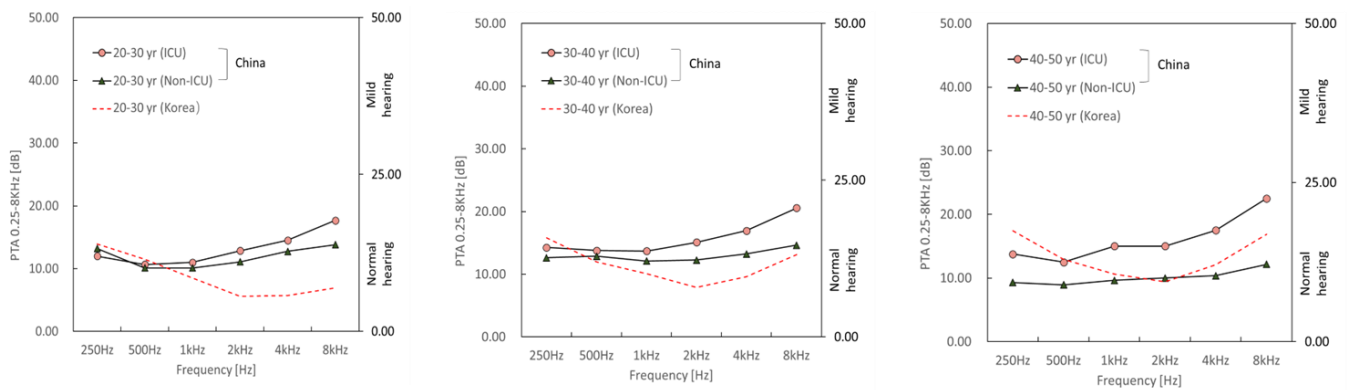


Figure 7: Comparisons of hearing thresholds between the current study and the Korean study [10] for different age bands (left: 20-30 yrs, middle: 30-40 yrs, and right: 40-50 yrs).

3.2 DIN measurements

Figure 8 shows the mean SRT across different ages. The association between ages and SRT were not significant in both ICU and non-ICU nurses ($p > 0.05$). However, among nurses working less than 50 hours, there was a significant relationship between age bands and SRT for both ICU ($r = 0.322, p < 0.05$) and non-ICU nurses ($r = 0.082, p < 0.05$).

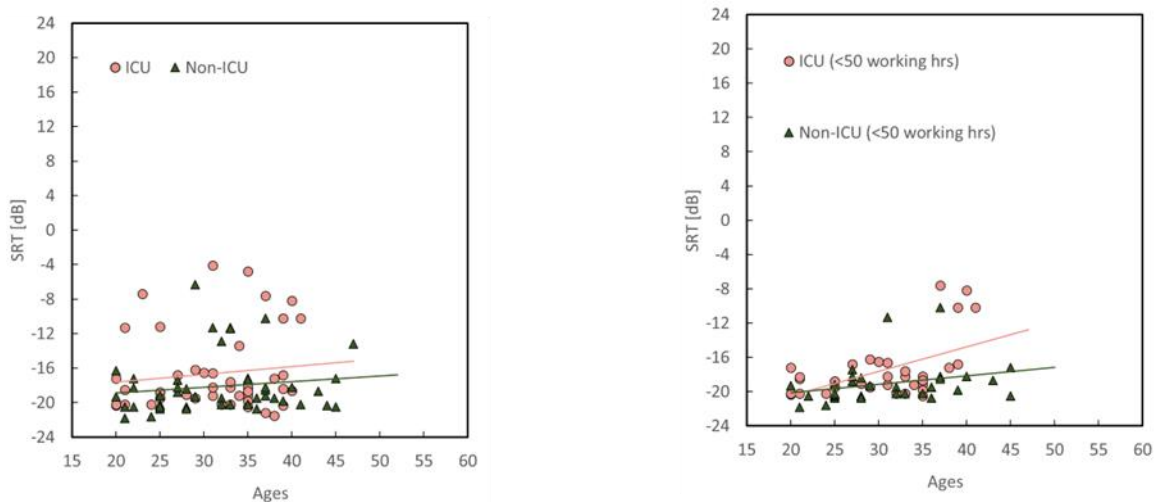


Figure 8: Relationships between SRT and ages for ages: a) comparison between ICU and non-ICU nurses, and b) comparison between ICU and non-ICU nurses who worked less than 50 hours per week.

Figure 9 shows relationships between the averaged PTA and SRT results for both ICU and non-ICU nurses. A strong and significant positive correlation of $r=0.824$ ($p<0.001$) was found between PTA and SRT for all the nurses. The relationship between them was significant for non-ICU nurses ($r=0.751$ and $p<0.001$), where it was also statistically significant for ICU nurses ($r=0.875$ and $p<0.001$).

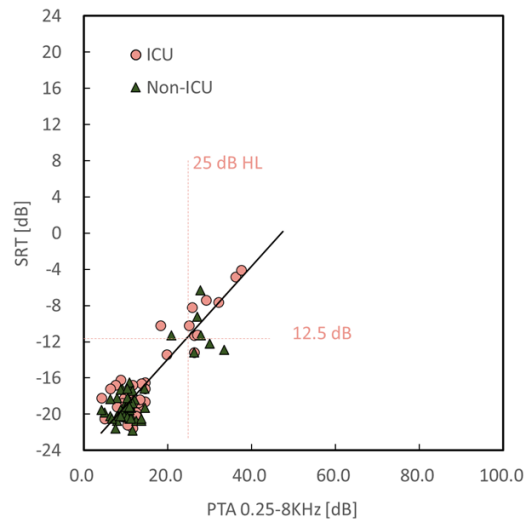


Figure 9: Relationship between PTA hearing threshold and SRT results.

3.3 Relationships between hearing thresholds and working hours

Figure 10 shows the PTA (left) and SRT (right) across varying working hours per week. The PTA measurements indicate that thresholds rise with increased working hours. Notably, nurses working over 60 hours per week exhibited significantly higher thresholds, regardless of whether they worked in the ICU or non-ICU setting. Likewise, SRT increased as working hours increased for both groups, with ICU nurses displaying more pronounced increases compared to non-ICU nurses.

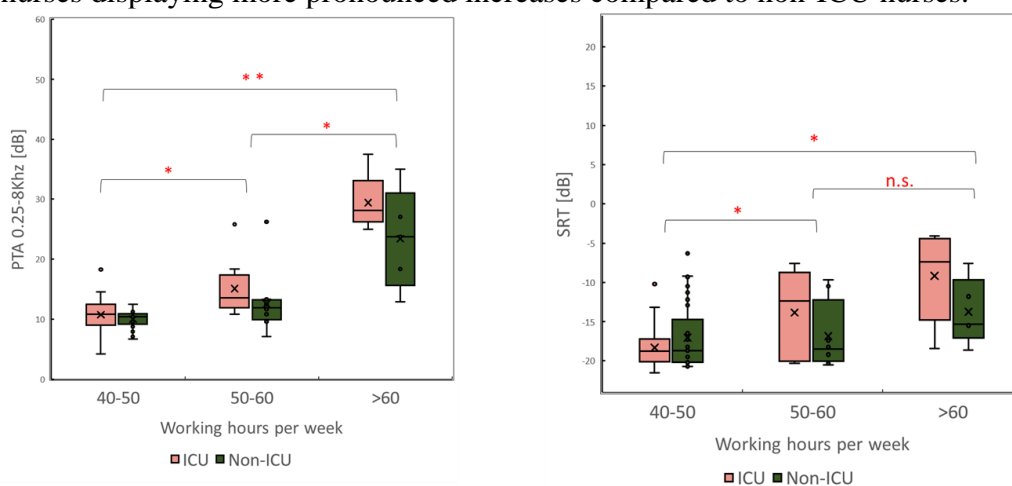


Figure 10: Pure hearing threshold for different working hours (left) and SRT for different working hours (right). (* $p<0.05$ and ** $p<0.01$)

3.4 Questionnaire survey

Figure 11 shows the average symptoms scores for both ICU and non-ICU nurses. ICU nurses reported experiencing ‘ringing in the ears’ and ‘difficulty determining the source of sounds’ more frequently compared to other symptoms. However, the mean scores for these symptoms were also less than 2 out of 5, suggesting that ICU nurses had minimal hearing symptoms. On the other hand, the average scores for non-ICU nurses were less than 1, suggesting that they had fewer hearing symptoms than ICU nurses.

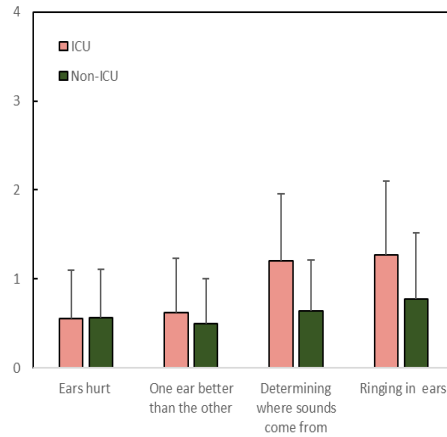


Figure 11: Experiences of hearing symptoms for ICU and non-ICU nurses assessed through a five-point scale (‘0’: never and ‘4’: always).

3.5 Hearing handicap inventory (HHIA-S)

Table 2 presented the hearing handicap inventory (HHIA-S) assessed through a five-point scale (‘0’: never and ‘4’: always). Overall, 35.6% of ICU nurses and 20.8% of non-ICU nurses reported hearing problems in verbal communication. The most common hearing issues were related to difficulties understanding people who mumble and challenges hearing conversations in noisy environments such as crowded rooms or restaurants.

Table 2: Hearing handicap inventory (HHIA-S) results for ICU and non-ICU nurses.

Hearing handicap inventory score	Number of nurses		
	ICU nurses	Non-ICU nurses	Total
0-8 (no handicap)	30	37	67
10-24 (mild to moderate handicap)	9	6	14
24-40 (severe handicap)	7	4	11

4. SUMMARY

This study aimed to investigate the hearing loss among nurses in both ICU and non-ICU settings in a single Chinese hospital. The results of PTA measurements revealed that ICU nurses reported poorer hearing thresholds than non-ICU, particularly at high frequencies. Additionally, the hearing thresholds for both ICU and non-ICU nurses were worse than those expected for their age and sex in the ISO standard (ISO 7029). Furthermore, there was a positive correlation between hearing thresholds and age as well as working hours for both groups. The DIN tests exhibited a strong and significant positive correlation between speech reception thresholds (SRT) and hearing thresholds for both ICU and non-ICU nurses. Moreover, as working hours increased, SRT also increased, with ICU nurses showing more pronounced increases compared to non-ICU nurses. In terms of self-reported hearing issues, the HHIA-S score was higher among ICU nurses compared to non-ICU nurses. The most common hearing difficulties reported by both groups were related to understanding people who mumble and challenges in hearing conversations in noisy environments. This study suggests that

nurses, particularly those working for longer hours, in an ICU setting are more likely to experience disabling hearing loss than peers working in non-ICU settings or for shorter hours. This suggests a dose dependent relationship and implications are that increased exposure to noise levels in ICU could have serious occupational health impacts for healthcare staff which needs greater exploration and investment internationally.

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