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Noise pollution in intensive care units: a systematic review article

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ABSTRACT

Introduction: Noise pollution in hospital wards can arise from a wide range of sources including medical devices, air-conditioning systems and conversations among the staffs. Noise in intensive care units (ICUs) can disrupt patients' sleep pattern and may have a negative impact on cognitive performance.
Material and methods: In this review article, we searched through PubMed and Google Scholar, using [noise and (ICU or "intensive care unit")] as keyword to find studies related to noise pollution in ICUs. In total, 250 studies were found among which 35 articles were included.
Results: The majority of the reviewed studies showed that noise pollution levels were higher in ICUs than the level recommend by The United States Environmental Protection Agency and World Health Organization. Noise pollution was mostly caused by human activity and operating equipments in ICUs and other hospital wards.
Conclusion: As the results indicated, identifying, monitoring and controlling noise sources, as well as educating the hospital staffs about the negative effects of noise on patients' health, can be highly effective in reducing noise pollution.

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Introduction

Noise is described as unwanted sound, lacking harmony and rhythm. Noise pollution is defined as a level of environmental noise that is generally considered obtrusive and disturbing. According to World Health Organization (WHO), noise levels in hospital environments should not exceed 35 dB (decibel) at night and 40 dB during the day (1). Moreover, the American Conference of Governmental Industrial Hygienists (ACGIH) recommended that noise levels in work environments should not go beyond 85 dB (2).

Complex biomedical equipments in ICUs are essential for the monitoring of patients with serious physical conditions. These equipments are utilized to support patients' vital functions (3). Developments in medical technology and healthcare have resulted in increased noise levels in ICUs and other hospital wards (4). Various sources including medical devices, air-conditioning systems and conversations among the hospital staffs and others can result in noise pollution in hospital wards. Moreover, impulsive noises such as door slamming, metal-to-metal contact and alarms are often heard in hospitals (5).

Noise pollution may especially affect frail elderly patients with poor mental and physiological status (4). Noise level in ICUs ranges from 59 to 83 dB and can affect cardiovascular and endocrine systems. Noise-induced stress can disrupt patients' sleeping patterns in ICUs. In some cases, high noise levels in ICUs might lead to delirium, characterized by delusion and paranoia. Moreover, prolonged exposure to high noise levels in ICUs has a negative impact on the cognitive performance and altruistic behaviors of ICU staffs (3). Negative physiological consequences,

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cognitive deficits and limited personal privacy are among the other harmful effects (5).

The current article aimed to review studies related to noise pollution in ICUs to identify sources of noise pollution and determine its effects on patients and ICU staffs. We also tried to describe the best options for reducing noise levels.

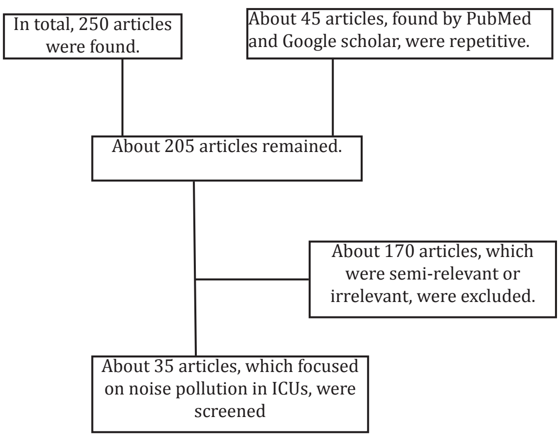
Methods

Search strategy

We reviewed the literature to find articles related to noise pollution in ICUs. We searched PubMed and Google Scholar, using [noise and (ICU or "intensive care unit")] as keyword. All the reviewed articles were evaluated for inclusion in our study. In total, 250 articles were found, and 35 articles, which mainly focused on noise pollution in ICUs, were included in our review. We summarized the results of different articles in various sub-sections. The majority of related studies, published in English, were included in this review; however, editorials and letters were excluded.

In our study, all repetitive and irrelevant studies were removed. According to the predetermined exclusion criteria, the remaining articles were assessed to find the common causes and effects of noise pollution in ICUs. After completing the full-text screening, the references of involved articles were manually assessed. The screening processes are shown in Figure 1.

Figure 1.The screening process of articles



Review

Noise sources in ICUs and strategies for noise elimination

Many studies have assessed the impact of noise pollution on patients and care providers in ICUs, neonatal intensive care units (NICUs) and other critical care units. In general, noise pollution increases the probability of error in ICUs and emergency departments (EDs). Therefore, it might result in occupational burnout and negative outcomes for patients. According to United States Environmental Protection Agency (EPA) and WHO, average background noise should not exceed 30 dBA in hospitals and the peak at night should be less than 40 dBA (6).

The majority of studies showed that noise levels are normally higher than the recommend levels in ICUs, EDs and other hospital wards (7-10). A study by Qutub et al. assessed environmental noise in the ICU of King Fahd University Hospital in Saudi Arabia. Noise pollution was measured using calibrated sound level meter during weekdays and weekends. The noise level was not significantly different in the morning from that reported in the evening or night shifts on weekdays and weekends. In addition, there was no significant difference between workdays and weekends in terms of overall exposure to noise. In total, the level of noise was higher than the stipulated international standards (3).

Similarly, Khademi et al. evaluated noise levels at nursing stations of 10 wards at Imam Reza University Hospital of Mashhad, Iran. Maximum level (Lmax) and the equalizing level (Leq) of noise were tested during morning shifts (10 times with 30-minute intervals). In total, the average level of noise in ICUs and emergency wards was higher than the standard level (9). Similarly, another study in Iran measured sound pollution in various departments of Imam Reza and Ghaem hospitals. According to the mentioned study, noise levels in ICUs, coronary care units (CCUs), emergency rooms (ERs) and libraries of Imam Reza and Ghaem hospitals were higher than the permissible limit (11).

According to a study by Christensen, morning shifts were significantly different from afternoon and night shifts combined in terms of noise level; however, there was no statistical difference between afternoon and night shifts. The mentioned study also showed that prolonged exposure to high levels of noise had harmful effects on the health and well-being of patients and hospital staffs (12).

In addition, findings of Bharathan's study showed that noise levels in ERs, medical-surgical floors and ICUs ranged between 55 and 70 dBA. Moreover, the noise level on weekdays was higher than that of weekends in ERs and ICUs. Additionally, the noise level was higher during midday, compared to the morning or evening hours. In total, human activity led to the maximum noise level in ERs, ICUs and medical-surgical floors (4).

According to a study by Tsara et al., noise levels in the pulmonary ward were significantly lower than those reported in the ICU. Noise levels significantly decreased during the day and reached the lowest level at night in the pulmonary ward; however, these findings were not observed in the ICU. According to the mentioned study, the measured noise levels in the pulmonary ward and ICU were higher than the permitted limits for hospital wards and ICUs (13).

According to a study by Kam et al., conversations among the hospital staffs and complex medical equipments were the major sources of noise pollution in operating rooms, recovery rooms and ICUs. Therefore, educating the staffs about the harmful effects of noise pollution on patients' health and modifying nursing care procedures and equipment design could be effective in reducing noise pollution in hospital wards (14). Similarly, Allaouchiche et al. showed that staff conversations were the most common cause of excessive noise in ICUs (15).

As Tsiou et al. indicated, human activity, conversations among the staffs and patients' relatives, operating equipment and hospital construction projects were the main noise sources at hospitals. According to the mentioned study, raising the awareness and sensitivity of the staffs is essential for counteracting noise pollution in ICUs (16).

Moreover, Tijunelis and colleagues put an emphasis on the identification and modification of noise sources for decreasing stress in hospital wards (17). Similarly, Parente and Loureiro showed that continuous quality improvement (CQI) was required for controlling noise pollution in ICUs. As they stated, noise sources should be identified, monitored and controlled. In addition, it was necessary to reduce the frequency and duration of sound peaks > 80 dBA, decrease the background noise and improve the ICU environment (18).

According to a study by Nakamura et al. in 1994, noise level was quite high in the ICU. Six years later, they started behavior modification and anti-noise programs in the ICU. Afterwards, they evaluated the effects of these programs on noise level. Noise level was measured using a sound level meter, placed close to the patient's head. Hospital architecture, equipment maintenance and patient care activities had changed over two years. In addition, an educational program had been implemented for the ICU staff (nurses, physicians and respiratory therapists) over four years. According to the results, an intensive anti-noise program, combined with behavior modification and minor architectural changes, could decrease noise pollution in ICUs (about a 30 % reduction) (19).

Moreover, Meyer et al. showed a significant relationship between noise pollution and patients' sleep cycle, recovery from critical diseases and respiratory weaning (20). Noise intensity had a negative effect on patients and ICU staffs. Furthermore, sleep deprivation in patients was associated with delirium in the ICU. Anand et al. recommended strategies to reduce noise pollution from recognized sources and increased awareness among the staffs. They suggested reducing the noise of ventilators, monitor alarms, phones and door bells and keeping the doors lubricated (21).

According to a study by Gorges et al., alarms were a major source of noise in the ICU. They showed that alarms went off 6.07 times per hour and were active for 3.28 min per hour. About 23%, 36% and 41% of the alarms were effective, ineffective and ignored, respectively. This study showed that more reliable alarms could reduce the staff workload and noise pollution in ICUs (22). Sources of noise pollution in the ICUs and strategies for noise elimination in some studies are shown in Table 1. In addition, the used measurement tools and noise pollution levels are indicated in Table 2.

Disorders caused by noise pollution in ICUs

Noise pollution in the ICU setting disrupts patients' sleep pattern, results in occupational burnout among the critical care staffs and causes psychosis and hearing loss. Therefore, identifying and controlling noise pollution in the ICU are very important for patients' health and the status of ICU staffs (14).

Sleep deprivation and fragmentation have negative impacts on the respiratory system. In addition, sleep deprivation in a patient with respiratory failure may lead to impaired recovery and weaning from mechanical ventilation. Therefore, evaluation of factors contributing to sleep abnormalities is essential. Inappropriate lighting, noise pollution and interruptions in the weaning unit are major factors for sleep disorders and possibly circadian rhythm disorders (20).

In a study by Freedman et al., all patients suffered from sleep cycle abnormalities such as awakening from sleep. According to the results of this study, noise pollution affected the quality of sleep; however, it did not necessarily reduce the amount of patients' sleep (30).

Peak sound levels in a study by Meyer et al. were extremely higher than the level recommended for a hospital environment. Their study showed that sleep disruption was frequent in all hospital wards, especially in ICU and respiratory care sections, where consequences may be extremely negative (20). Similarly, according to a study by Cordova et al., increased noise levels were significantly correlated with higher levels of sleep deprivation and patients' stress at hospitals and ICUs (29).

Christensen's study showed that noise exposure could have a negative effect on the cognitive performance of nurses and might lead to decreased wound healing, sleep deprivation and cardiovascular stimulation in patients (12). Moreover, a study by Hsu et al. showed a relationship between noise pollution and increased heart rate, blood pressure and perceived psychological and physiological responses in post-cardiac surgery patients in ICUs (31). These results were consistent with the findings of studies by Cureton-Lane and Fontaine and Schwab (32,33).

Table 1. Noise sources in ICUs and strategies for noise elimination

Authors Year Reference	Country	Source of noise	Strategies for noise elimination
Tsiou 1998 (16)	Greece	Human activity, operating equipments and hospital construction projects	Reduction of noise pollution in ICUs and increasing staff awareness
Tijunelis 2005 (17)	USA		Identification and modification of noise sources
Parente 2001 (18)	Portugal	Equipments, human activity and conversations among the staffs and visitors	CQI: identifying, monitoring, and controlling noise sources (e.g. equipments, human activity and conversations among the staffs), reducing the frequency and duration of sound peaks > 80 dBA, reducing the level of background noise and improving the ICU environment
Anand 2009 (21)	UK	Medical equipments and general activities	Noise reduction from recognized sources, increasing awareness among the staffs, reducing ventilator noise, monitor alarms, phone rings and door bells and keeping the doors well lubricated
Nakamura 2002 (19)	France	Human activity and medical equipments	A behavior modification program for the ICU staff (nurses, physicians and respiratory therapists) anti-noise programs and minor architectural changes
Allaouchiche 2002 (15)	France	Conversations among the staff (almost 56% of noise pollution), alarms and telephone rings	
Kam 1994 (14)	Australia	Equipments and conversations among the staff	Educating the staffs about the harmful effects of noise pollution on patients' health, modification of nursing care procedures and changes in equipment design
Bharathan 2007 (4)	USA	Human activity	
Balogh 1993 (23)	Austria	Technical ICU devices and alarms (the most irritating noise)	
Poursadegh 2001 (11)	Iran	Human activity	
Qutub 2009 (3)	Saudi Arabia	Environmental noises caused by using oxygen, suction equipments and respirators	
Kahn 1998 (24)	USA	Television and conversations (49%)	A behavior modification program
Stephens 1995 (25)	Australia		Installation of sound-absorbing ceilings, removal of rubbish bin lids, revising phone ringing policies, changing the use of mobile x-ray machines, prioritization of audible machine alarms and raising the staffs awareness about noise levels
Pai 2007 (26)	Taiwan		Design changes in hospitals to reduce noise-making factors, use of low-noise machines, turning off ambulance sirens between 10 p.m. and 7 a.m. and modifying employee behaviors and care procedures

Table 2. The used measurement tools and noise pollution levels

Author Year Reference	Country	Research tools	Noise pollution levels
Tsiou 1998 (16)	Greece	Bruel and Kjaer 2231 sound meter	27 dBA higher than the recommended level for hospitals Leq=60.3–67.4 dBA
Tijunelis 2005 (17)	USA	A 3-channel dosimeter Quest Q300	First measurement: average of 43 dBA Peak level: 94-117 dBA Second measurement: average of 52.9 dBA
Parente 2001 (18)	Portugal	Bruel and Kjaer 2232 sound meter	Maximum: 81.9 dBA Mean: 70.9 dBA Minimum: 55.5 dBA
Anand 2009 (21)	UK	Tecpel DSL-330 sound meter	Range: 54.4-52.5 dBA
Nakamura 2002 (19)	France		Mean (in the nursing station): 67.8±2.4 dBA Leq: 60.9 ± 0.6
Allaouchiche 2002 (15)	France	Visual analogue scale and structured and unstructured questionnaires	Leq: 67.1(sd 5.0) dBA LeqMax: 75.7 (4.8) dBA LeqMin: 48.6 (4.1) dBA
Bharathan 2007 (4)	USA		Range: 55-70 dBA
Balogh 1993 (23)	Austria		Leq: 60–65 dBA Sound pressure level (in most alarms): 60–70 dBA, with some exceeding 80 dBA
Poursadegh 2001 (11)	Iran		Mean values in different wards of Imam Reza and Ghaem hospitals: 52.7-68.0 dB and 56.2-66.2 dB, respectively Mean values in operating rooms: 64.4-70.0 dB and 54.7-58.8 dB, respectively
McLaughlin 1996 (10)	UK	CEL environmental noise meter	Maximum: 100.9-61.3 dBA Leq: 77.3 dBA
Tsara 2008 (13)	Greece	Cirrus CR: 245/R2 Environmental Noise Analyzer	Mean: 59±2.2 dBA
Short 2011 (27)	Australia		Range: 64.0-55.8 dBA
Elliott 2011 (28)	Australia		The mean equivalent sound level (LAeq): 56.22 ± 1.65 dBA LA90: 46.8±2.46 dBA
Khademi 2011 (9)	Iran	EXTECH 407727	
Cordova 2013 (29)	USA		Mean dBA Leq values in shift changes, days, and nights: 65.9±2.8, 65.7±2.6, and 60.9±5.2 dBA, respectively
Christensen 2007 (12)	UK	Norsonic 116	Mean: 56.42 dBA Minimum: 50 dBA
Meyer 1994 (20)	USA		> 80 dBA

Table3. Disorders resulting from noise pollution

Authors Year Reference	Country	Disruptions resulting from noise pollution	Major results
Freedman 2001 (30)	USA	Sleep/wake abnormalities: arousals and awakenings from sleep	Negative effects of noise pollution on the quality of sleep (not necessarily affecting the amount of sleep) and sleep cycle abnormalities
Meyer 1994 (20)	USA	Sleep deprivation and fragmentation	Frequent sleep disruptions in the ICU and respiratory care sections (with extremely negative consequences)
Christensen 2002 (12)	UK	Sleep deprivation, cardiovascular stimulation and reduced wound healing	Negative effects of noise pollution on the cognitive performance of nursing staffs and decreased wound healing, sleep deprivation and cardiovascular stimulation in patients
Hsu 2010 (31)	Taiwan	Disturbed sleep	Effect of noise pollution on prolonged stays in the ICU
Ryherd 2012 (5)	Sweden	Irritation, fatigue, tension headaches, personal hardiness and noise sensitivity	Lack of a significant relationship between noise pollution and salivary amylase or self-reported stress, increased annoyance with higher noise levels and associations between higher noise levels and increased heart rate, high caffeine intake, less nursing experience and work shifts

Chloé et al. aimed to determine whether a sound-activated light-alarm device could reduce noise pollution in the ICU. They showed that this device did not directly decrease the noise level when turned on, although it improved staff awareness of noise levels over time (34). In this regard, Cabrera and Lee designed a program to reduce stress and anxiety in hospital settings. Management of noise level in a hospital and providing a music therapy center for all individuals in the hospital were recommended in their program (35).

Some disorders resulting from noise pollution are shown in table 3.

A study by Ryherd et al. showed that increased noise levels caused stress, irritation, fatigue and tension headaches in nurses. They showed that self-reported health outcomes were associated with noise-induced stress and noise sensitivity. Moreover, noise was not associated with salivary amylase or self-reported stress. It was clear that higher noise levels were associated with elevated heart rate, increased caffeine intake, less nursing experience and work shifts (5). If stress-reducing elements are incorporated in ICU settings, we can reduce noise pollution.

In total, the majority of reviewed studies showed that the rate of noise pollution in ICU is higher than the levels recommend by EPA and WHO (35 dBA at night and 40 dBA during the day). Approximately, in the majority of reviewed articles, the rate of noise pollution in ICU was 10-50 dBA higher than the global standards. For instance, in the study by Tsiou et al., the rate of noise pollution was 27 dBA higher than the recommended level for hospitals; (16) in addition, in a study by Tijunelis et al., the peak level of noise pollution was 94-117 dBA (17).

In the reviewed studies, there was no considerable difference between developing and developed countries. Our study showed that different measuring tools for noise pollution were applied in various articles. However, not all the reviewed articles used different tools. For instance, in two studies in Greece and Portugal, Bruel and Kjaer 2231-2 sound meter was used to measure noise levels (16,18).

Furthermore, according to the obtained results, the majority of reviewed studies showed that noise pollution was mostly caused by human activity and operating equipments in ICU and other hospital wards. This may be due to non-compliance with international standards or lack of training programs for the hospital staffs. For instance, a study by Allaouchiche et al. showed that conversation among the staffs was the most important cause of noise pollution (almost 56% of noise pollution) (15).

Conclusion

In total, the majority of reviewed studies showed that the rate of noise pollution in ICU was higher than the levels recommend by EPA and WHO. Human activity and operating equipments is the most cpmmon cause of Noise pollution in ICUs and other hospital wards. Moreover, according to the obtained results, identifying, monitoring and controlling noise sources, as well as educating the staffs about the harmful effects of noise on patients' health, can be highly effective in reducing noise pollution.

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Conflict of Interest

The authors declare no conflict of interest.

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