

SZEREJ, Krzysztof, BIALKOWSKA, Zuzanna, GÓRKA, Mateusz, STEC, Weronika, WOJTKIEWICZ, Anna, KUDAS, Zuzanna and PIEKARSKA, Magda. Medical and health benefits of noise reduction at Intensive Care Units. *Quality in Sport*. 2024;27:55450. eISSN 2450-3118.

<https://dx.doi.org/10.12775/QS.2024.27.55450>

<https://apcz.umk.pl/QS/article/view/55450>

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.

Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).

Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.

Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

© The Authors 2024;

This article is published with open access at Licensee Open Journal Systems of Nicolaus Copernicus University in Torun, Poland

Open Access. This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author (s) and source are credited. This is an open access article licensed under the terms of the Creative Commons Attribution Non commercial license Share alike. (<http://creativecommons.org/licenses/by-nc-sa/4.0/>) which permits unrestricted, non commercial use, distribution and reproduction in any medium, provided the work is properly cited.

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 30.09.2024. Revised: 18.10.2024. Accepted: 21.10.2024. Published: 22.10.2024.

Medical and health benefits of noise reduction at Intensive Care Units

¹**Krzysztof Szerej**

District Hospital in Sochaczew, Batalionów Chłopskich 3/7, Sochaczew, Poland,

<https://orcid.org/0009-0003-7581-4965>

krzychszerej@gmail.com

²**Zuzanna Białkowska**

1st Military Clinical Hospital with the Outpatient Clinic, Lublin, Poland

<https://orcid.org/0009-0002-5682-8360>

zuzanna.bialkowska@gmail.com

³**Weronika Stec**

Independent Public Complex of Health Care Facilities, Marshal Józef Piłsudski in Płońsk, Henryka Sienkiewicz 7, 09-100 Płońsk

<https://orcid.org/0009-0009-8495-3573>

weronikastec1234@gmail.com

¹ krzychszerej@gmail.com

² zuzanna.bialkowska@gmail.com

³ weronikastec1234@gmail.com

⁴ Mateusz Górka

Voivodeship Integrated Hospital of Stanisław Rybicki in Skierniewice 1 Rybickiego Street 96-100 Skierniewice, Poland

<https://orcid.org/0009-0004-6201-4691>

mateusz.a.gorka@gmail.com

⁵ Anna Wojtkiewicz

District Medical Centre in Grójec, 10 Piotra Skargi Street 05-600 Grójec, Poland;

<https://orcid.org/0009-0002-3451-124X>

anna.a.wojtkiewicz@gmail.com

⁶ Zuzanna Kudas

Independent Public Complex of Health Care Facilities, Marshal Józef Piłsudski in Płońsk, Henryka Sienkiewicza 7, 09-100 Płońsk

<https://orcid.org/0009-0009-6750-6886>

md.zuzannakudas@gmail.com

⁷ Magda Piekarska

Bielanski Hospital, Ceglowska 80, 01-809, Warsaw

<https://orcid.org/0000-0002-3583-8802>

madzia12792@gmail.com

Abstract

Introduction: The presence of excessive noise poses a significant risk to the overall well-being and health of individuals. The presence of elevated noise levels within Intensive Care Units (ICUs) has the potential to exert detrimental effects on both the well-being of patients and the healthcare personnel.

The aim of this study: This study aims to gather knowledge about the effects of noise pollution on patient's wellbeing within Intensive Care Units, analyze various investigations around the world and discuss the possible preventive methods of reducing noise and thus sleep disturbances.

Materials and methods: This review was based on available data collected in the PubMed database and Google Scholar web search engine using the key words Intensive Care Unit, sleep deprivation, noise pollution

⁴ mateusz.a.gorka@gmail.com

⁵ anna.a.wojtkiewicz@gmail.com

⁶ md.zuzannakudas@gmail.com

⁷ madzia12792@gmail.com

Conclusions: Intensive Care Unit noise disrupts patient's sleep, communication, and increases stress, potentially leading to medical errors and longer recovery times. Addressing this issue is vital, aligning with patient-centered care and holistic therapy trends. Solutions include architectural changes, quieter equipment, staff education, clinical guidelines, and providing earplugs and eye masks for patient comfort. Noise negatively impacts sleep, causing circadian disruptions, cognitive impairments, and health issues. Identifying and mitigating noise sources can significantly enhance patient well-being and treatment outcomes.

Keywords: Sleep deprivation, intensive care unit, noise pollution

Introduction

The intensive care unit (ICU) plays a significant role in contemporary healthcare by delivering specialized and crucial medical attention to individuals who are confronted with life-threatening ailments. This location serves as a nexus for the convergence of medical breakthroughs, steadfast commitment, and cutting-edge technologies in the battle against the brink of human mortality. In this meticulously regulated and highly specialized setting, the principal objective is to facilitate the recovery, mitigate distress, and reinstate individuals to a condition of well-being. [23]

Nevertheless, notwithstanding the notable advancements in the field of medical science and technology, there is a prevailing opponent that is frequently overlooked but significantly affects the welfare of both patients and healthcare professionals. The aforementioned enemy is characterized as noise, a persistent and apparently benign factor that pervades the confines of intensive care units. [24]

The issue of noise within the boundaries of an Intensive Care Unit is a complex and multidimensional matter. The origin of the sound can be attributed to a diverse range of factors, including the high-pitched alarms sent by monitoring equipment, the steady vibrations produced by ventilation systems, the conversations among healthcare personnel, the noise generated by carts and equipment, and even the ambient sounds permeating from the external environment around the unit. [10] The presence of this auditory background is not merely a nuisance; it presents a substantial challenge to the fundamental goals of acute care.

The ramifications of noise pollution within the Intensive Care Unit extend well beyond transient disruptions. The phenomenon under consideration has the potential to disturb the valuable period of rest for patients during their most susceptible state, impede effective communication among healthcare professionals, and impose subtle yet significant levels of stress on the persons responsible for providing patient care. In the middle of a noisy environment, the provision of treatment may be impaired, which can result in errors in medicine administration, prolonged recovery times, and bad clinical results.

The need to address the issue of noise in Intensive Care Units is becoming urgent, particularly within the framework of the continuing paradigm shift in healthcare. The significance of patient-centered care and holistic therapy is progressively acknowledged as essential elements within contemporary medicine. The presence or absence of silence significantly contributes to the attainment of these objectives. The importance of creating a setting that promotes healing and comfort should not be underestimated.

The Guidelines for Community Noise provided by the World Health Organization (WHO) offer recommendations regarding noise levels within hospital settings. It is suggested that in order to account for patients' reduced ability to manage heightened stress levels resulting from excessive environmental noise, the sound level in areas where patients are treated or observed should not surpass the level of 35 dBA. Additionally, a corresponding maximum level of 40 dBA is advised [1]

Consequences of sleep deprivation

Primarily, sleep disturbance in the intensive care unit hinders the inherent circadian rhythm, resulting in irregular sleep patterns and compromising the alignment of the body's internal clock with external temporal cues. The phenomenon of circadian misalignment not only gives rise to a state of confusion, but also impedes the process of memory consolidation and learning, so causing cognitive impairments that may endure beyond the period of intensive care unit confinement. Patients frequently demonstrate instances of memory deficits, diminished attention spans, and compromised cognitive capacities, hence impeding their ability to actively engage in their healthcare and make well-informed medical choices.

The chemosensitivity of the respiratory center in the brain is diminished in individuals who are experiencing sleep deprivation. Studies have indicated a decline in the innate ability of these patients to respond to low oxygen and high carbon dioxide levels, resulting in a reduced ventilatory response [2]. Moreover, numerous studies have consistently reaffirmed the diverse negative consequences of sleep deprivation on the functioning of respiratory muscles. [3] These studies have shown a notable decrease in forced expiratory volume in one second (FEV1) by an average of 6% and forced vital capacity (FVC) by an average of 5% in individuals with chronic obstructive pulmonary disease (COPD) who experienced sleep deprivation, in comparison to COPD patients who did not experience sleep deprivation.

The cardiovascular consequences of sleep deprivation arise from the activation of the sympathetic nervous system (SNS) and the subsequent release of the catecholamines adrenaline and noradrenaline. Consequently, alterations in baroreflex sensitivity have been observed to lead to elevated blood pressure and heart rate. [4,5] Specifically, it has been reported that a single night of sleep deprivation in healthy adults resulted in an increase of 12 mmHg in blood pressure.

In addition, it is crucial to acknowledge the significant impact of sleep on immunomodulation. Sufficient sleep is crucial for optimal immune system functioning, and intensive care unit patients who experience a lack of restful sleep frequently demonstrate reduced immunological function. [6] The increased susceptibility to infections not only adds complexity to the patients' clinical progression but also prolongs their duration of stay in the intensive care unit, so exacerbating their overall health difficulties.

Psychological anguish is a prominent characteristic associated with sleep deprivation in the intensive care unit. Patients who have persistent sleep disruption often exhibit symptoms of anxiety, despair, and post-traumatic stress disorder (PTSD) [25]. The presence of these psychological burdens not only has a negative impact on the general well-being of patients, but it can also impede their recovery process, potentially leading to a series of long-term mental health problems.

The sleep physiology of patients in the intensive care unit suggests that although their total sleep time (TST) typically falls within the normal range of 7 to 9 hours, their sleep is characterized by frequent interruptions, with an average of 6.2 awakenings per hour. [7] The quality of sleep is further diminished due to the predominant occurrence of sleep phases N1 and N2, commonly referred to as "light sleep," which is believed to provide limited restorative advantages. Consequently, the attributes of non-consolidated light sleep have led to a state of sleep deprivation among patients in the intensive care unit. A decrease in the duration of REM sleep and slow wave sleep has been associated with this phenomenon. [8] It is hypothesized that both phases play a role in facilitating restorative processes and are crucial for the process of recovery. Patients may have daytime somnolence as a result of inadequate sleep quality, leading to up to 50% of total sleep time (TST) occurring during daylight hours. [9,10]

Delirium, a syndrome marked by cognitive impairment, perceptual disturbances, and disorientation, is frequently underdiagnosed and is strongly linked to sleep deprivation in the intensive care unit.[11,12] Delirium not only extends the duration of intensive care unit stays, but also contributes significantly to the overall disease burden experienced by critically sick patients. Elevated levels of noise can additionally be a contributing factor to the development of sleep difficulties and a condition known as "intensive care unit psychosis." This particular kind of delirium is commonly observed in patients within critical care units and is partially attributed to the combined effects of sleep deprivation and excessive sensory stimulation.

In conclusion, sleep deprivation within the intensive care unit presents a multifaceted and intricate dilemma that encompasses more than just restlessness. The phenomenon under consideration has the potential to disturb the natural patterns of circadian cycles, affect the functioning of the immune system, degrade cognitive abilities, induce psychological anguish, heighten the likelihood of experiencing delirium, and intensify sensations of pain and suffering. The acknowledgement of the extensive and significant consequences of sleep deprivation emphasizes the imperative nature of prioritizing interventions aimed at promoting and protecting the sleep quality of patients in the intensive care unit. These endeavors are not solely imperative for their immediate welfare but also pivotal for long-term health consequences and the standard of living subsequent to discharge from the intensive care unit.

The noise levels in various studies around the world

Numerous investigations were undertaken in intensive care unit environments to assess noise levels across a 24-hour period, employing sound level monitors for continuous monitoring.

In one study the results consistently indicated that the mean sound levels surpassed 45 dBA, with half of the duration falling between 52 and 59 dBA within each unique Intensive Care Unit. Diurnal fluctuations were found, wherein the sound levels exhibited a decline during evening hours, reaching a minimum of 51 dBA at 4 AM. Throughout the day, there were frequent occurrences of sound levels surpassing 85 dBA. Achieving compliance with the sound level recommendations set forth by the World Health Organization necessitated the utilization of a secluded room with little ambient noise, along with the deactivation of all operational equipment.[13]

A separate investigation encompassing a cohort of 35 patients in the intensive care unit following coronary artery bypass graft surgery revealed a spectrum of noise levels spanning from 49 to 89 decibels with a mean value of 65 decibels and maximum levels peaking at 89 decibels. [14] The patients reported experiencing disturbances originating from multiple sources, including as noises generated by fellow patients, individuals admitted from the emergency room and operation room, monitor alarms, and talks among staff members

In a distinct cross-sectional study conducted within a prominent Australian hospital, patients exhibited a noteworthy decrease in the duration of their sleep while hospitalized in comparison to their sleep patterns at home. [15] The participants also reported diverse sleep quality, with a significant percentage indicating it as being of low or extremely low quality. The main determinants associated with inadequate sleep encompass clinical care interventions and ambient noise. The noise levels observed in different clinical settings frequently surpassed the levels recommended by the World Health Organization with the highest recorded peak noise level reaching 103.3 dB.

A separate investigation conducted within Dutch hospitals involved a sample of 2005 patients, ultimately uncovering that the duration of sleep experienced by individuals within the hospital setting was 83 minutes less compared to their sleep duration at home.[16] Furthermore, the study also observed a higher frequency of nocturnal awakenings during the hospital stay. The study findings indicate that patients experienced an average shift in their waking time, with an earlier awakening of 44 minutes compared to their typical routine. Furthermore, a significant proportion of patients, namely 70.4%, reported being disturbed by external factors, such as interactions with hospital staff. The quality of sleep experienced by individuals was found to be poorer during their period of hospitalization. Several variables commonly disrupt sleep in healthcare settings, such as noise generated by fellow patients, medical equipment, discomfort, and the need for bathroom visits.

Another study conducted in a nine-bed intensive care unit involved the continuous monitoring of noise levels over a period of three days. The findings revealed an average noise level of 56.42 dB, with intermittent instances of noise spikes reaching up to 80 dB. There was a considerable difference in noise levels between morning shifts and combined afternoon and night shifts. Nevertheless, there was no discernible disparity detected between afternoon and night shifts. The present study brings attention to the persistent issue of excessive noise within the intensive care unit. [17]

Sources of noise

The intensive care unit is a dynamic healthcare setting characterized by a variety of sources of noise that cumulatively contribute to increased levels of ambient noise. [26] The initial source of the cacophony frequently arises from the life-sustaining apparatus that is required for the provision of patient care, including ventilators, heart monitors, infusion pumps, and dialysis machines. These machines produce a range of auditory signals, including alarms, beeps, and constant humming sounds, each of which possesses a unique acoustic character that collectively contributes to the total level of noise. Furthermore, the dynamic actions of healthcare workers, encompassing dialogues between nurses and physicians pertaining to patient care, alongside the commotion generated by the relocation of medical equipment, contribute to the auditory landscape within the intensive care unit.

The entry and exit of healthcare personnel and guests can also serve as a significant source of noise, particularly when doors close with a mechanical impact. Furthermore, noise levels in the ICU might be increased by external sources, such as discussions in the hallway, deliveries of equipment, and ongoing building activities in the surrounding hospital environment. In addition, the acoustic properties of the intensive care unit itself, such as the presence of rigid surfaces that reflect sound, contribute to the phenomenon of sound reverberation and amplification. [26] This further exacerbates the issue of excessive noise within the ICU environment. Therefore, the intensive care unit encompasses a multifaceted auditory environment consisting of various origins, each possessing its distinctive acoustic characteristics. As a whole, this environment is characterized by heightened levels of noise, which can hinder patient rest, interrupt communication between healthcare professionals, and potentially jeopardize patient outcomes. Comprehending and effectively dealing with the many origins of noise are crucial measures in order to alleviate the negative consequences of excessive noise in the Intensive Care Unit and promote a healthcare environment that prioritizes recovery.

According to existing research literature, it has been found that conversations among staff members and alarms from medical equipment are identified as the primary causes of disruptive noise within the intensive care unit . [19] Noise can also be generated by various sources within a building, such as ventilation systems, the act of opening and closing doors and drawers, the use of telephones, mobile phones, and pagers, the operation of overhead speakers and televisions, the closing of metallic dust bins, the sound produced by the wheels of patient beds or wheelchairs, the use of vacuum cleaners, and the pneumatic tube systems employed for the transportation of drugs, documents, and specimens between laboratories and the intensive care unit.

Preventive methods

Various preventive measures are implemented in intensive care units to reduce noise levels and provide an environment conducive to healing. First and foremost, architectural and environmental adjustments are of paramount importance. This encompasses the utilization of materials that possess sound-absorbing properties for the construction of walls and ceilings, with the implementation of floor coverings that effectively mitigate the transmission of sounds. The installation of acoustic panels and drapes can effectively mitigate sound reflections and transmission. Furthermore, the arrangement of the intensive care unit can be modified in order to minimize noise levels. This can be achieved by strategically positioning loud equipment in areas that are distant from patient zones, as well as implementing buffer zones to provide a physical separation between regions with high activity and patient rooms. [27]

The implementation of clinical protocols and the provision of staff education are key elements in the endeavor to reduce noise levels. Raising awareness among healthcare staff regarding the influence of noise on patient outcomes and underscoring the need of speaking quietly and reducing superfluous talks can make a substantial contribution towards creating a more tranquil intensive care unit environment. [28] The implementation of scheduled periods of quietude throughout the day and night has demonstrated efficacy in mitigating noise levels.

In addition, providing personnel with training in communication techniques, such as the utilization of hand gestures and non-verbal cues, can effectively reduce the amount of noise produced during patient care tasks.

The use of personalized interventions, such as the provision of earplugs and eye masks, has the potential to improve individual comfort levels and positively impact the overall quality of sleep experienced by patients. [22] These straightforward strategies enable individuals to take an active role in managing their sleep surroundings. In conclusion, the provision of patient and family education regarding the significance of minimizing noise levels within the intensive care unit can facilitate the cultivation of a cooperative mindset towards noise management.

In summary, the implementation of a comprehensive strategy that incorporates architectural alterations, technological improvements, staff training, clinical guidelines, and individualized interventions is necessary in order to successfully mitigate noise levels within intensive care units. The aggregate implementation of these preventive techniques serves to create a quieter and more favorable healing environment, so eventually improving patient outcomes and general well-being.

The presence of high levels of noise within intensive care units has been found to significantly interfere with the overall well-being of patients. The objective of a project conducted at a coronary intensive care unit located in Doha, Qatar, was to mitigate noise levels through the implementation of several interventions. [18] These interventions included the establishment of designated quiet intervals, educational initiatives targeting the healthcare personnel, modifications to the physical environment, and the introduction of a noise alarm system. Over the course of several years, an investigation was conducted to monitor the levels of noise, which revealed a noteworthy decrease from an average of 64.6 decibels (dB) to a steady 24 dB during periods of tranquility. Importantly, this reduction in noise did not result in any adverse consequences on communication or medical treatment. Both the patients and the staff expressed satisfaction with the reduced levels of noise. The implemented environmental controls encompassed several actions such as equipment maintenance, door stopper installation, utilization of noise-reducing pads for sample transport, establishment of a designated mobile phone area, and promotion of timely answers to calls and patient warnings.

In a separate investigation, a team of neurosurgical intensive care unit practitioners implemented designated periods of reduced noise levels, referred to as "quiet times," between the hours of 3 am to 5 am and 3 pm to 5 pm. [20] This intervention was implemented in response to concerns raised over excessive noise levels. The objective was to achieve a reduction in noise levels of 10 decibels over a period of six months. Data on noise levels were gathered over a span of eight consecutive days using a decibel meter at four distinct locations. Following the completion of staff and patient education, the implementation of quiet hours was undertaken. Following a period of 60 days, it was observed that there was a notable reduction in noise levels at certain places, while other locations did not exhibit the same decline. During periods of less activity, the recorded noise levels regularly exhibited a decrease of 10 to 15 dB compared to the established baseline data.

Furthermore, a study was conducted in medical and surgical intensive care units to investigate the effects of employing eye masks and earplugs as a preventive measure against delirium in patients. Nurses had specialized training, and a three-day period was dedicated to the implementation of nonpharmacological therapies. [21]

The intervention group was provided with eye masks and earplugs for three consecutive nights. The research encompassed a sample size of 60 individuals and revealed a noteworthy decrease in the incidence of delirium among the participants assigned to the intervention group. Additionally, many documented an improvement in the quality of their sleep. Several factors, including the kind of ICU, age over 65, hearing impairment, admission source, and education level, were found to have an influence on the occurrence of delirium. Notably, internal medicine ICUs exhibited the greatest impact among these factors.

What is more The University of Texas Southwestern Medical Center Surgical ICU did another intriguing investigation. [22] Adult female breast free flap surgery patients from February 2018 to October 2019 who needed hourly postoperative assessments were assessed. Earplugs, eye masks, and routine treatment were given to two groups of patients. The study assessed sleep, patient satisfaction, and ICU delirium. The intervention group (earplugs and eye masks) had considerably higher sleep quality (average score 64.5) than the control group (average score 47.3) ($p = 0.0007$). The assessments showed no significant changes in ICU delirium rates or patient satisfaction between the two groups. After meeting significance requirements, the study ended early.

Conclusion

The ICU provides crucial medical care, but its noise pollution, often underestimated, impairs patient sleep, healthcare provider communication, and caregiver stress. This might cause medical blunders and slow recovery. As patient-centered care and holistic therapy become more common, ICU noise must be addressed. Patients with poorer stress tolerance should have 35 dBA in treatment rooms, according to the WHO. Architectural improvements, quieter medical equipment, staff training, clinical practices, and earplugs and eye masks are solutions. ICU noise impairs sleep, producing circadian rhythm disruptions, cognitive deficiencies, respiratory concerns, cardiovascular issues, decreased immunity, psychological anguish, and increased pain sensitivity. Poor sleep and delirium extend ICU stays and impair outcomes. To improve patient care, ICU noise must be reduced. Identifying and mitigating noise sources through architecture, technology, staff training, guidelines, and targeted treatments can improve patient recovery and health.

Disclosures:

No disclosures

Financial support:

No financial support was received.

Conflict of interest:

The authors declare no conflict of interest.

References

1 Darbyshire, J.L., Müller-Trapet, M., Cheer, J., Fazi, F.M. and Young, J.D. (2019), Mapping sources of noise in an intensive care unit. *Anaesthesia*, 74: 1018-1025. <https://doi.org/10.1111/anae.14690>

- 2 White, D. P., Douglas, N. J., Pickett, C. K., Zwillich, C. W., & Weil, J. V. (1983). Sleep deprivation and the control of ventilation. *The American review of respiratory disease*, 128(6), 984–986. <https://doi.org/10.1164/arrd.1983.128.6.984>
- 3 Phillips, B. A., Cooper, K. R., & Burke, T. V. (1987). The effect of sleep loss on breathing in chronic obstructive pulmonary disease. *Chest*, 91(1), 29–32. <https://doi.org/10.1378/chest.91.1.29>
- 4 Mullington, J., Haack, M., Tóth, M., Serrador, J. M., & Meier-Ewert, H. K. (2009). Cardiovascular, inflammatory, and metabolic consequences of sleep deprivation. *Progress in Cardiovascular Diseases*, 51(4), 294–302. <https://doi.org/10.1016/j.pcad.2008.10.003>
- 5 Ogawa, Y., Kanbayashi, T., Saitō, Y., Takahashi, Y., Kitajima, T., Takahashi, K., Hishikawa, Y., & Shimizu, T. (2003). Total Sleep Deprivation Elevates Blood Pressure Through Arterial Baroreflex Resetting: a Study with Microneurographic Technique. *Sleep*, 26(8), 986–989. <https://doi.org/10.1093/sleep/26.8.986>
- 6 Walder, B., Haase, U., & Rundshagen, I. (2007). Schlafstörungen bei kritisch kranken Patienten [Sleep disturbances in critically ill patients]. *Der Anaesthesist*, 56(1), 7–17. <https://doi.org/10.1007/s00101-006-1086-4>
- 7 Friese, R. S., Diaz-Arrastia, R., McBride, D., Frankel, H. L., & Gentilello, L. M. (2007). Quantity and quality of sleep in the surgical intensive care unit: Are our patients sleeping? *Journal of Trauma-injury Infection and Critical Care*, 63(6), 1210–1214. <https://doi.org/10.1097/ta.0b013e31815b83d7>
- 8 Freedman, N., Gazendam, J. a. C., Levan, L., Pack, A. I., & Schwab, R. J. (2001). Abnormal Sleep/Wake cycles and the effect of environmental noise on sleep disruption in the intensive care unit. *American Journal of Respiratory and Critical Care Medicine*, 163(2), 451–457. <https://doi.org/10.1164/ajrccm.163.2.9912128>
- 9 Aurell, J., & Elmqvist, D. (1985). Sleep in the surgical intensive care unit: continuous polygraphic recording of sleep in nine patients receiving postoperative care. *BMJ*, 290(6474), 1029–1032. <https://doi.org/10.1136/bmj.290.6474.1029>
- 10 Bihari, S., McEvoy, R. D., Matheson, E., Kim, S. W., Woodman, R., & Bersten, A. D. (2012). Factors affecting sleep quality of patients in intensive care unit. *Journal of Clinical Sleep Medicine*. <https://doi.org/10.5664/jcsm.1920>
- 11 Aaron, J. N., Carlisle, C. C., Carskadon, M. A., Meyer, T. J., Hill, N. S., & Millman, R. P. (1996). Environmental noise as a cause of sleep disruption in an intermediate respiratory care unit. *Sleep*, 19(9), 707–710. <https://doi.org/10.1093/sleep/19.9.707>
- 12 Van De Pol, I., Van Iterson, M., & Maaskant, J. (2017). Effect of nocturnal sound reduction on the incidence of delirium in intensive care unit patients: An interrupted time series analysis. *Intensive and Critical Care Nursing*, 41, 18–25. <https://doi.org/10.1016/j.iccn.2017.01.008>
- 13 Darbyshire, J., & Young, J. (2013). An investigation of sound levels on intensive care units with reference to the WHO guidelines. *Critical Care*, 17(5), R187. <https://doi.org/10.1186/cc12870>
- 14 Akansel, R. N., & Kaymakçi, R. Ş. (2008). Effects of intensive care unit noise on patients: a study on coronary artery bypass graft surgery patients. *Journal of Clinical Nursing*, 17(12), 1581–1590. <https://doi.org/10.1111/j.1365-2702.2007.02144.x>

- 15 Delaney, L., Currie, M. J., Hsu, C., Lopez, V., & Van Haren, F. (2018). "They can rest at home": an observational study of patients' quality of sleep in an Australian hospital. *BMC Health Services Research*, 18(1). <https://doi.org/10.1186/s12913-018-3201-z>
- 16 Wesselius, H. M., Van Den Ende, E. S., Alsmas, J., Ter Maaten, J. C., Schuit, S. C. E., Stassen, P. M., De Vries, O. J., Kaasjager, K., Haak, H. R., Van Doormaal, F. F., Hoogerwerf, J. J., Terwee, C. B., Van De Ven, P. M., Bosch, F. H., Van Someren, E. J., & Nanayakkara, P. W. (2018). Quality and quantity of sleep and factors associated with sleep disturbance in hospitalized patients. *JAMA Internal Medicine*, 178(9), 1201. <https://doi.org/10.1001/jamainternmed.2018.2669>
- 17 Christensen, M. (2007). Noise levels in a general intensive care unit: a descriptive study. *Nursing in Critical Care*, 12(4), 188–197. <https://doi.org/10.1111/j.1478-5153.2007.00229.x>
- 18 Gupta, P., Thomas, M., Amer, A., Joseph, S., Louis, I., George, J., Zubi, M. A., McDonald, I. G., & Hassan, M. E. (2023). Implementation of noise-reduction strategies and designated quiet time in an intensive care unit. *British Journal of Healthcare Management*, 29(2), 1–9. <https://doi.org/10.12968/bjhc.2022.0036>
- 19 Konkani, A., Oakley, B., & Penprase, B. (2014). Reducing hospital ICU noise: A Behavior-Based approach. *Journal of Healthcare Engineering*, 5(2), 229–246. <https://doi.org/10.1260/2040-2295.5.2.229>
- 20 Goeren, D., John, S., Meskill, K., Iacono, L., Wahl, S. E., & Scanlon, K. (2018). Quiet Time: a noise reduction initiative in a neurosurgical intensive care unit. *Critical Care Nurse*, 38(4), 38–44. <https://doi.org/10.4037/ccn2018219>
- 21 Kiliç, G., & Kav, S. (2023). Effect of using eye masks and earplugs in preventing delirium in intensive care patients: A single-blinded, randomized, controlled trial. *Nursing in Critical Care*, 28(5), 698–708. <https://doi.org/10.1111/nicc.12901>
- 22 Obanor, O. O., McBroom, M., Elia, J., Ahmed, F., Sasaki, J., Murphy, K. M., Chalk, S., Menard, G. A., Pratt, N. V., Venkatachalam, A. M., & Romito, B. T. (2021). The impact of earplugs and eye masks on sleep quality in surgical ICU patients at risk for frequent awakenings. *Critical Care Medicine*, 49(9), e822–e832. <https://doi.org/10.1097/ccm.0000000000005031>
- 23 Marshall, J. C., Bosco, L., Adhikari, N. K. J., Connolly, B., Díaz, J., Dorman, T., Fowler, R., Meyfroidt, G., Nakagawa, S., Pelosi, P., Vincent, J., Vollman, K. M., & Zimmerman, J. L. (2017). What is an intensive care unit? A report of the task force of the World Federation of Societies of Intensive and Critical Care Medicine. *Journal of Critical Care*, 37, 270–276. <https://doi.org/10.1016/j.jcrc.2016.07.015>
- 24 Althahab, A. Q. J., Vuksanović, B., Al-Mosawi, M., Machimbarrena, M., & Arias, R. (2022). Noise in ICUs: Review and detailed analysis of Long-Term SPL monitoring in ICUs in Northern Spain. *Sensors*, 22(23), 9038. <https://doi.org/10.3390/s22239038>
- 25 Koffel, E., Khawaja, I. S., & Germain, A. (2016). Sleep Disturbances in Posttraumatic Stress Disorder: Updated review and Implications for treatment. *Psychiatric Annals*, 46(3), 173–176. <https://doi.org/10.3928/00485713-20160125-01>

- 26 Simons, K. S., Verweij, E., Lemmens, P., Jelfs, S., Park, M., Spronk, P. E., Sonneveld, H., Feijen, H. M., Steen, M., Kohlrausch, A. A., Van Den Boogaard, M., & De Jager, C. P. (2018). Noise in the intensive care unit and its influence on sleep quality: a multicenter observational study in Dutch intensive care units. *Critical Care*, 22(1). <https://doi.org/10.1186/s13054-018-2182-y>
- 27 HealthManagement.org. (n.d.-b). Noise in the intensive care unit: where does it come from and what can you do about it? HealthManagement. <https://healthmanagement.org/c/icu/issuearticle/noise-in-the-intensive-care-unit-where-does-it-come-from-and-what-can-you-do-about-it>
- 28 Kol, E., Demircan, A., Erdoğan, A., Gencer, Z., & Erengin, H. (2015). The effectiveness of measures aimed at noise reduction in an intensive care unit. *AAOHN Journal*, 63(12), 539–545. <https://doi.org/10.1177/2165079915607494>