By Amy Stafford, MN, RN, CCRN,
Amy Haverland, BSN, RN, CCRN, and
Elizabeth Bridges, PhD, RN, CCNS

Editor's note: This is part of an ongoing series of columns from nurses at the University of Washington that will examine in depth the research related to critical care practices.

Noise in the ICU

What we know and what we can do about it.

> Unnecessary noise, then, is the most cruel absence of care which can be inflicted either on sick or well.
> —Florence Nightingale, *Notes on Nursing: What It Is, and What It Is Not*

Noise is unwanted sound. What is noise to one person may not be to another. Studies indicate that sound levels in hospitals have increased during the past 50 years[1-3] and exceed World Health Organization (WHO) recommendations for community noise.[4]

As part of the Centers for Medicare and Medicaid Services (CMS) Hospital Value-Based Purchasing Program, the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey has been used since 2006 to obtain patients' perspectives on hospital care. It specifically asks about noise: "During this hospital stay, how often was the area around your room quiet at night?" In 2013, patients' responses to this question were included in the calculation of a facility's value-based purchasing score, which is linked to CMS payment.

To effectively carry out noise-reducing interventions, it's important to understand what we know about noise in the hospital. This article focuses on noise in the ICU and describes basic sound-level measurement terminology, the effect of noise on critically ill patients, and evidence-based strategies to which nurses can actively contribute to decrease or protect patients from noise.

NOISE IN INTENSIVE CARE

Despite an increased emphasis on the need for noise reduction in intensive care, a number of studies published in the past six years have found that sound levels in the ICU continue to exceed WHO noise recommendations.[2, 5-9] To interpret research on noise in the hospital, it's important to have an understanding of the terminology used (see Table 1[4]).

Sound levels are reported in decibels (dB), with 0 dB being the threshold for human hearing. A 3-dB change in sound level is just discernible, a 5-dB change is discernible, and a 10-dB change is perceived as either a doubling or halving of the sound level. Researchers often report A-weighted sound

levels (abbreviated "dBA"), which reflect the normal range of human hearing, although some refer to sound in dB. C-weighted sound levels (abbreviated "dBC") are used to describe high intensity or peak sound levels.

Researchers may also describe A-weighted average (L_{Aeq}) and maximum (L_{Amax}) sound levels. The former is used to measure continuous sound and represents the average sound level during a period of time, whereas the latter is a calculated value reflecting the maximum variation of sound over time. L_{Amax} is used to measure varying sound levels and is not the same as peak sound (L_{peak}). Peak sound levels (often C-weighted and abbreviated L_{Cpeak}) reflect raw noise or minute-by-minute sound peaks. They are used to describe intermittent, high frequency noise (the sound of a door slamming, for example) that may not be detected when sound measurements are averaged over time.

> **Studies have found that sound levels in the ICU continue to exceed WHO noise recommendations.**

An appreciation of how quiet the ICU should be aids in the interpretation of noise research. The WHO guidelines state that the average sound level (L_{Aeq}) should not exceed 30 dBA in general hospital areas and 35 dBA in rooms where patients are treated or observed; the maximum sound level (L_{Amax}) indoors should not exceed 40 dBA during the night.[4] The Environmental Protection Agency (EPA) recommends that hospital noise levels not exceed an average of 45 dB during the day and 35 dB at night.[10]

To achieve these goals, nurses need to be as quiet as a whisper, 24 hours a day. A challenge in meeting these recommendations is that ambient sound often exceeds these levels, and noise from equipment, alarms, and conversations in the ICU further increase sound levels. In some cases, the ICU can be as noisy as the

Table 1. Sound Terminology Primer[4]

Sound level	Any variation in sound pressure the human ear can detect.
Noise	Unwanted sound.
dB	Decibel (1/10th of a bel, which is the value used to describe sound intensity and named for Alexander Graham Bell; bel is never reported).
dBA	Noise is usually measured as A-weighted sound, which approximates human hearing and deemphasizes lower frequencies (humans hear higher frequency sound better than lower frequency sound). A-weighted values are generally reported in hospital noise studies.
L_{Aeq}	Average sound level over a period of time. L_{Aeq} is used when sound is continuous.
L_{Amax}	Maximum noise level over a period of time. L_{Amax} is used when sound levels are not continuous (they vary over time). The L_{Amax} is the maximum variation (as indicated by the root mean square) over time.
L_{peak}	Raw noise—the minute-to-minute peak values reached by sound pressure levels; often measured as C-weighted sound (L_{Cpeak}), which is used for higher intensity sounds. **L_{peak} is not the same as L_{Amax}.**

community (see Table 2[2, 4, 11-13]). For example, the noise from a nebulizer is equivalent to the sound of traffic, an IV infusion pump alarm is equivalent to a vacuum cleaner, and staff conversation can be as loud as a lawn mower at 10 meters.

A systematic review of 29 studies related to ICU noise found that the major sources of noise in the ICU were conversations, equipment alarms, caregiver activities (such as handwashing and opening equipment), telephones, pagers, televisions, closing doors, and falling objects.[3] The noise from these sources is constant. In a study in five ICUs, all the units recorded an L_{Aeq} greater than 45 dBA at all times, and between 52 and 59 dBA more than 50% of the time.[7] Additionally, in more than 50% of minutes sampled, the peak sound level was between 79 and 84.6 dBA.

EFFECT ON THE PATIENT

Knowing that sound levels in the ICU exceed WHO recommendations is important because of the effects this increased level of noise can have on patients. Noise interrupts sleep and can be disruptive to hospitalized patients. In 2003, Gabor and colleagues used polysomnography to investigate the effects of noise and patient care activities on sleep in healthy subjects and ventilated patients.[14] In the ICU, sound peaks (an abrupt 10-dBA increase) occurred 36.5 ± 20.1 times per hour, and patient care activities, such as IV adjustment and medication administration, occurred 7.8 ± 4.2 times per hour. These abrupt sound peaks were the most common cause of arousals caused by noise.

However, the effect of sound on patients is equivocal. Elliott and colleagues found no relationship between sound peaks greater than 80 dBC and arousal in ICU patients,[15] and noise accounted for only 17% to 30% of arousals in two other studies.[14, 16] While noise has been identified as a factor that disrupts sleep,[17] patients have indicated other causes of sleep disruption to be pain[17, 18] and being kept immobile.[19]

To develop interventions to minimize the impact of noise on sleep, it's important to identify the effects of specific noises. Buxton and colleagues used polysomnography to study the effects of sounds typically found in a hospital (such as conversations, alarms, phones, and equipment) on 12 healthy subjects in a sleep laboratory.[20] The sound levels were increased until they caused a disruption in sleep. The subjects had different arousal responses to sounds based on their stage of sleep. For example, an IV pump alarm (70 dBA) caused arousal in 100% of subjects in non–rapid eye movement (NREM) stage N2 sleep, and conversational speech produced a 50% arousal rate at just 50 dBA in both N2 and REM sleep.[20] Across all stages of sleep, ringing phones, IV pump alarms, and staff conversations (regardless of topic) were found to cause the most arousals. These sources of noise have been identified by patients as being disruptive.[21]

Although Buxton and colleagues' study provides important information on the potential effects of noise on patients' sleep, it was conducted in healthy volunteers. As noted, the relationship between peak sound and arousal in critically ill patients is equivocal,[14, 15]

indicating that further research is needed on the effects of noise and other disruptive factors (such as pain and immobilization) on sleep in critically ill patients.

When evaluating the effects of sound and noise in the ICU, it's important to also consider the psychological effects. In a survey of ICU patients, 40% recalled ICU noise—85% of whom reported feeling disturbed by it.[17] Cardiac surgery patients have reported being most disturbed by noise from other patients, patients being admitted, monitor alarms, and staff conversations.[5]

Johansson and colleagues interviewed ICU patients about their experiences and memories of sounds and the ICU environment.[22, 23] In recalling noise in the ICU, patients mentioned hearing sounds related to the setting, staff, other patients in the same room, and technical equipment.[23] A majority of patients said they were not disturbed by staff presence and reported that hearing staff quietly completing tasks made them feel safe and secure.[23] However, one patient described her memories of staff conversations: "Then sometimes when you lie there, half asleep . . . the staff stand in the doorway and joking with each other, then I thought, are they talking about me?"[23]

generally include restricting or limiting visitors, staff movement, and treatments; closing doors or privacy curtains; and decreasing noise and light.

In a study conducted by Gardner and colleagues on a quiet time and a control unit, there was a 10.3-dB difference between the units during quiet time, and patients on the quiet time unit were twice as likely to be asleep.[27] In a study by Dennis and colleagues of quiet time in a neuro-ICU, during the designated daytime quiet period, sound levels decreased at the patient's door (74.1 ± 1.62 dB to 65.1 ± 1.29 dB, $P < 0.001$), at the head of the bed (71.2 ± 2.02 dB to 62.2 ± 1.75 dB, $P < 0.001$), and at the nurses' station (83.1 ± 2.09 dB to 71.9 ± 1.6 dB, $P < 0.001$).[28] Of note, at 30 minutes after quiet time, the sound levels returned to pre–quiet time levels, suggesting that the intervention does not carry over. The authors of both studies noted an increase in the percentage of patients assessed as asleep during quiet time.[27, 28]

Li and colleagues evaluated a night-time intervention that included noise and light reduction and the modification of nursing care activities, such as changing the times for chest radiographs and blood draws and checking the volume of IV and feeding tube bags

Quiet time may be beneficial to the patient as it creates a restorative period—that is, a period when sound is at a level that is less likely to cause arousal.

Although most patients lacked memories of equipment sounds, others were aware of these and interpreted them differently. One patient said, "I think [the sound of the ventilator] was some kind of signal that sounded regularly, saying 'I am working with this patient with no problem . . . '"[22] For another patient, the sound of the ventilator alarm caused her to be "scared to death that the machine is about to stop. I know that I can't breathe on my own so if the ventilator stops, I will die."[22] Patients also remembered being exposed to constant noise they were unable to escape. One stated, "[B]ut it was so annoying, this noise all the time, and I couldn't sleep to escape the noise, it was impossible, it was so loud it was impossible."[23]

STRATEGIES TO DECREASE NOISE
Quiet time. Although recommendations for quiet time have existed for more than 20 years,[24-26] until recently there has been limited evaluation of the effectiveness of this strategy. Quiet time interventions

at 11 PM.[29] There was a significant difference in peak (51.3 ± 3.9 dB versus 59.2 ± 4.5 dB, $P < 0.001$) and average (50.1 ± 4 dB versus 57.7 ± 4.5 dB, $P < 0.001$) sound levels at the head of the bed between the experimental and control groups. Moreover, the patients in the experimental group perceived the noise as being significantly less than those in the control group did. In general, quiet time interventions resulted in an approximate 10-dB decrease in sound levels (a perceived halving of the sound level), although it should be noted that none of the units studied achieved the WHO noise recommendations.[27-29]

The effect of quiet time interventions on sound levels, as reported in these studies, should also be considered in light of research showing that a decrease in recorded ICU maximal noise (L_{Amax}) from 64 to 56 dBA didn't improve sleep quality in healthy subjects,[30] as well as Buxton and colleagues' study, which showed that sound at levels similar to those maintained during quiet times still caused sleep disruptions.[20] In these

Table 2. Average Sound Levels in the ICU and the Community[2, 4, 11-13]

Sound Level (dBA)	In the ICU	In the Community
0		Threshold for normal human hearing
20	Sound of breathing at 1 meter	Grand Canyon at night, no birds, no wind
30	According to the WHO: L_{Aeq} should not exceed 30 dBA in general hospital areas and 35 dBA in rooms where patients are treated or observed	Quiet room or whisper Quiet bedroom at night
40	According to the WHO: L_{Amax} indoors should not exceed 40 dBA during the night	Noise of normal living, talking, or radio in the background
50	Endotracheal aspiration unit	Library
60	Ventilator Oximeter alarm Conversation at the nurses' station	Conversational speech at 1 meter Television Noisy lawn mower at 10 meters
70	IV infusion alarm Monitor alarm Ventilator alarm	Vacuum cleaner at 1 meter
80	Supply cart Nebulizer Pager Connection of gas supply Rattling side rails	Heavy traffic at 10 meters Door closure
90	Loud crying Items falling onto floor Portable X-ray machine	Circular saw at 1 meter Motorcycle
100		Jackhammer at 10 meters
110		Siren at 10 meters A club or disco

dbA = A-weighted decibels; WHO = World Health Organization.
Note: For information about other sounds, see www.sengpielaudio.com/TableOfSoundPressureLevels.htm and www.cdc.gov/niosh/topics/noise/noisemeter.html.

studies, a major outcome was sleep; however, each study used a different method to evaluate it. The use of a valid and reliable measure of sleep is important,[31] as a recent study on quiet time found that nurses tend to overestimate the quality of sleep.[32]

The variable effect of quiet time on patient, family, and staff satisfaction is also important. In the study by Gardner and colleagues, 94% of patients said they had enough time with visitors and 87% of patients liked the quiet time intervention.[27] Among visitors, 74% indicated that visiting hours were convenient and they didn't mind leaving the unit during quiet time; however, 55.9% believed visiting should be allowed throughout the day. Among staff, 96.2% of nurses said they had enough time to provide patient care, while the allied health providers believed quiet time interfered with their clinical work (44%) and limited access to patients (51.9%). The positive effects for nurses were also noted in the study by Dennis and colleagues, in which nurses reported that quiet time gave them the time to review patient charts, document their work, and "refocus and reprioritize," as one nurse put it.[28]

Quiet time may be beneficial to the patient as it creates a restorative period—that is, a period when sound is at a level that is less likely to cause arousal. A restorative period is defined as a minimum of five minutes with the L_{Amax} at less than 55 dB and the L_{Cpeak} at less than 75 dB.[33] Among the quiet time studies reviewed, only Li and colleagues documented that these goals were achieved.[29] In a study of the effect of room size on sound level by Tegnestedt and colleagues, restorative time was minimal in a single room with a bedside nursing station (in the day, 1.3%; in the evening, 11.6%; and at night, 30.8%), suggesting that, in general, quiet time alone is not achieving the desired goals, and further modifications may be needed.[33]

Sound-activated light alarms. One of the main sources of noise in the ICU is staff conversations.[3] Jousselme and colleagues studied whether a sound-activated light alarm device placed in the central area of a pediatric ICU would decrease staff noise, and, if so, whether this decrease in noise would be perceived in the patient rooms.[34] The researchers found that when the device was present, sound levels decreased in both the central area (by 2 dBA) and the patients' rooms (by 3 dBA). However, after the device was present for a period of time, there was no difference in sound levels when the device was on or off, suggesting that the light alarm did not affect staff behavior.

In a study by Chang and colleagues of the use of a noise sensor light alarm in a neonatal ICU, the red light on the alarm lit up when sound levels exceeded 65 dBA.[35] Sudden peak noise (abrupt noise levels greater than or equal to 65 dBA) was identified by direct observation, and common sources were staff conversations (51.3%) and nursing activities (9.7%). The mean sound level decreased from 58 ± 0.6 dBA during the control period to 56.4 ± 0.7 dBA when the light alarm was in use ($P < 0.001$). More interestingly, while the average decrease in noise with use of the alarm was minimal, the frequency of peak noise events decreased by 71.5%. Specifically, there was a decrease in the frequency of sudden peak noise associated with caregiving (362 to 98 events), monitor alarms (121 to 14 events), and staff conversation (65 to 17 events). These results suggest that the alarm contributed to behavior modifications; however, the effect of the intervention was not captured by the use of mean sound levels (L_{Aeq}). These results are similar to the outcomes of a behavior modification intervention aimed at decreasing peak noise greater than or equal to 80 dBA.[36] Although the intervention had little effect on noise (peak sound between 12 PM and 6 PM decreased from 80.3 ± 0.3 dBA to 77.5 ± 0.2 dBA, $P = 0.001$), it significantly decreased the number of sound peaks greater than 80 dBA.

While these studies demonstrate a statistically significant decrease in sound levels, the approximately 2-to-3-dBA decrease would be barely discernible. More importantly, these studies highlight the need to select the appropriate sound level measurements for a given intervention (average versus peak sound levels, for example).

Modification of alarms. There has been increased emphasis on medical device alarm safety in recent years.[37] One potential benefit of actions to improve alarm safety and decrease alarm fatigue is a decrease in alarm-related noise.[38] A large component of alarm management is programming the alarm sound level. In a study by Lawson and colleagues, the researchers focused on the noise from various alarms (ventilators, cardiac monitors, IV pumps) and evaluated

Figure 1. Peak sound pressure levels of the Alaris infusion pump alarm settings with the alarm setting varied. The effect on sound levels was evaluated in the patient room and in an adjacent room with the door open and closed. The term "dBA" is used to measure sounds that are most important to human hearing, whereas "dBC" is used to measure high intensity or peak sound levels.[39]
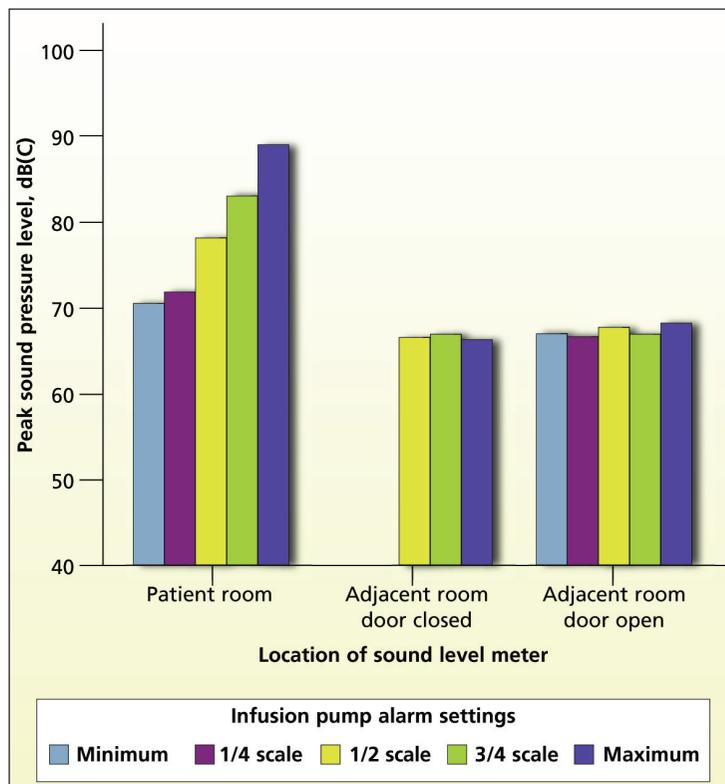
Reprinted from Lawson N, et al. *Am J Crit Care* 2010;19(6):e88-e98. Copyright © 2010 American Association of Critical-Care Nurses. Used with permission.

strategies that could decrease patient exposure to this noise.[39] Sound level measurements were taken in an unoccupied patient room with equipment alarms set at increasing volumes. Although louder output alarm settings increased the sound level in the room, they didn't increase the sound levels in an adjacent room (see Figure 1). Ambient noise was also measured in a patient room with the door open and closed. The mean sound level (L_{Aeq}) was 40 dBA on average when the door was closed and 45 dBA when open, suggesting that closing the door to a patient's room decreases mean noise levels.

and confusion among ICU patients.[44] Although there was no difference in the incidence of delirium based on the use of earplugs, the patients who wore them beginning on their first night in the ICU developed mild confusion less frequently than the control group (15% versus 40%, respectively). Additionally, there was a 53% decrease in the risk of delirium or confusion and a delayed onset of cognitive disturbances in patients wearing earplugs. The barriers to application of this intervention include patient acceptance and adherence to wearing earplugs. Of note, this study excluded patients with known hearing impairment,

> Evidence suggests that interventions such as quiet time and closing doors don't help ICU staff achieve WHO or EPA sound-level goals.

Nurses may increase alarm sound levels with the intent to better hear the alarms while in adjacent rooms. However, as Lawson and colleagues demonstrated, increasing the output level increases sound levels only in the patient's room.[39] Additionally, although the researchers found that closing the door decreased the average sound levels, it did not significantly decrease peak noise level. This study does not support turning up the alarms as a safety precaution and emphasizes the need for interventions that actively modify the sources of peak noise.

Earplugs. Efforts to decrease sound levels are essential, but evidence suggests that interventions such as quiet time and closing doors don't help ICU staff achieve WHO or EPA sound-level goals. Therefore, consideration should be given to "protecting" the patient from this noise.

Several studies have found that the use of earplugs (as well as eye masks to decrease light in one study[40]) by healthy subjects exposed to ICU sounds decreased REM latency and improved REM sleep.[40, 41] The use of earplugs has subsequently been studied in acute and critically ill patients. Nonintubated, alert, and oriented patients in the ICU who wore earplugs at night had significantly better sleep satisfaction scores in seven out of eight questions on the Verran and Snyder-Halpern Sleep Scale than control subjects.[42] Among patients in postanesthesia care units, the use of earplugs and eye masks was associated with improved sleep efficiency and decreased sleep disruptions and napping compared with a control group.[43]

Van Rompaey and colleagues sought to determine if using earplugs at night could help prevent delirium

dementia, confusion, or delirium on admission, and those with a Glasgow Coma Scale score of less than 10, making it difficult to generalize the results to broader ICU populations.

CONCLUSIONS

Despite interventions aimed at decreasing noise, sound levels continue to exceed WHO recommendations, and ICU sounds (such as alarms and conversations) may interfere with sleep. The psychological impact of noise in the ICU varies. For some patients, the sounds are comforting, but for others they cause distress.

To create a therapeutic environment, continued efforts are needed to decrease background noise and to modify behavior and factors that cause peak noise events. Interventions to protect patients from noise in the ICU, such as earplugs, may be beneficial in optimizing outcomes. However, further research is needed in a broader ICU population. Finally, to evaluate the effects of these interventions, valid and reliable methods for outcomes, such as sleep and sound levels, must be used. ▼

> **Keywords:** decibel, hospital, intensive care, noise, peak sound, quiet time, sound level

Amy Stafford is clinical nurse specialist in critical care and Amy Haverland is a critical care nurse educator, both at the University of Washington Medical Center in Seattle. Elizabeth Bridges is a clinical nurse researcher at the University of Washington Medical Center and an associate professor at the University of Washington School of Nursing in Seattle. Bridges also

REFERENCES

1. Busch-Vishniac IJ, et al. Noise levels in Johns Hopkins Hospital. *J Acoust Soc Am* 2005;118(6):3629-45.

2. Elliott RM, et al. A pilot study of sound levels in an Australian adult general intensive care unit. *Noise Health* 2010; 12(46):26-36.

3. Konkani A, Oakley B. Noise in hospital intensive care units—a critical review of a critical topic. *J Crit Care* 2012;27(5): 522.e1-522.e9.

4. Berglund B, et al. *Guidelines for community noise*. Geneva, Switzerland: World Health Organization; 1999. http://www. who.int/docstore/peh/noise/guidelines2.html.

5. Akansel N, Kaymakci S. Effects of intensive care unit noise on patients: a study on coronary artery bypass graft surgery patients. *J Clin Nurs* 2008;17(12):1581-90.

6. Cordova AC, et al. Noise levels in a burn intensive care unit. *Burns* 2013;39(1):44-8.

7. Darbyshire JL, Young JD. An investigation of sound levels on intensive care units with reference to the WHO guidelines. *Crit Care* 2013;17(5):R187.

8. Qutub HO, El-Said KF. Assessment of ambient noise levels in the intensive care unit of a university hospital. *J Family Community Med* 2009;16(2):53-7.

9. Ryherd EE, et al. Characterizing noise and perceived work environment in a neurological intensive care unit. *J Acoust Soc Am* 2008;123(2):747-56.

10. U.S. Environmental Protection Agency, Office of Noise Abatement and Control. *Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety*. Washington, DC; 1974 Mar. http://www.nonoise.org/library/levels74/levels74. htm.

11. Chepesiuk R. Decibel hell: the effects of living in a noisy world. *Environ Health Perspect* 2005;113(1):A34-A41.

12. Occupational Safety and Health Administration. *Occupational noise exposure*. n.d. https://www.osha.gov/SLTC/ noisehearingconservation.

13. Pugh R, et al. The impact of noise in the intensive care unit. *Intensive Care Medicine: Annual Update* 2007:942-49.

14. Gabor JY, et al. Contribution of the intensive care unit environment to sleep disruption in mechanically ventilated patients and healthy subjects. *Am J Respir Crit Care Med* 2003;167(5):708-15.

15. Elliott R, et al. Characterisation of sleep in intensive care using 24-hour polysomnography: an observational study. *Crit Care* 2013;17(2):R46.

16. Freedman NS, et al. Abnormal sleep/wake cycles and the effect of environmental noise on sleep disruption in the intensive care unit. *Am J Respir Crit Care Med* 2001;163(2): 451-7.

17. Hofhuis JG, et al. Experiences of critically ill patients in the ICU. *Intensive Crit Care Nurs* 2008;24(5):300-13.

18. Frisk U, Nordstrom G. Patients' sleep in an intensive care unit—patients' and nurses' perception. *Intensive Crit Care Nurs* 2003;19(6):342-9.

19. Uğraş G, Oztekin SD. Patient perception of environmental and nursing factors contributing to sleep disturbances in a neurosurgical intensive care unit. *Tohoku J Exp Med* 2007; 212(3):299-308.

20. Buxton OM, et al. Sleep disruption due to hospital noises: a prospective evaluation. *Ann Intern Med* 2012;157(3): 170-9.

21. Yoder JC, et al. Noise and sleep among adult medical inpatients: far from a quiet night. *Arch Intern Med* 2012;172(1): 68-70.

22. Johansson L, et al. Meaning of being critically ill in a sound-intensive ICU patient room—a phenomenological hermeneutical study. *Open J Nurs* 2012;6:108-16.

23. Johansson L, et al. The sound environment in an ICU patient room—a content analysis of sound levels and patient experiences. *Intensive Crit Care Nurs* 2012;28(5):269-79.

24. Edwards GB, Schuring LM. Pilot study: validating staff nurses' observations of sleep and wake states among critically ill patients, using polysomnography. *Am J Crit Care* 1993;2(2):125-31.

25. Lower JS, et al. Peace and quiet. *Nurs Manage* 2003;34(4): 40A-40D.

26. Olson DM, et al. Quiet time: a nursing intervention to promote sleep in neurocritical care units. *Am J Crit Care* 2001; 10(2):74-8.

27. Gardner G, et al. Creating a therapeutic environment: a non-randomised controlled trial of a quiet time intervention for patients in acute care. *Int J Nurs Stud* 2009;46(6):778-86.

28. Dennis CM, et al. Benefits of quiet time for neuro-intensive care patients. *J Neurosci Nurs* 2010;42(4):217-24.

29. Li SY, et al. Efficacy of controlling night-time noise and activities to improve patients' sleep quality in a surgical intensive care unit. *J Clin Nurs* 2011;20(3-4):396-407.

30. Persson Waye K, et al. Improvement of intensive care unit sound environment and analyses of consequences on sleep: an experimental study. *Sleep Med* 2013;14(12): 1334-40.

31. Kamdar BB, et al. Patient-nurse interrater reliability and agreement of the Richards-Campbell sleep questionnaire. *Am J Crit Care* 2012;21(4):261-9.

32. Maidl CA, et al. The Influence of "quiet time" for patients in critical care. *Clin Nurs Res* 2013 July 10 [Epub ahead of print].

33. Tegnestedt C, et al. Levels and sources of sound in the intensive care unit—an observational study of three room types. *Acta Anaesthesiol Scand* 2013;57(8):1041-50.

34. Jousselme C, et al. Efficacy and mode of action of a noise-sensor light alarm to decrease noise in the pediatric intensive care unit: a prospective, randomized study. *Pediatr Crit Care Med* 2011;12(2):e69-e72.

35. Chang YJ, et al. A noise-sensor light alarm reduces noise in the newborn intensive care unit. *Am J Perinatol* 2006;23(5): 265-71.

36. Kahn DM, et al. Identification and modification of environmental noise in an ICU setting. *Chest* 1998;114(2):535-40.

37. ECRI Institute. Top 10 health technology hazards for 2013. *Health Devices* 2012;41(11):342-65.

38. Konkani A, et al. Reducing hospital noise: a review of medical device alarm management. *Biomed Instrum Technol* 2012;46(6):478-87.

39. Lawson N, et al. Sound intensity and noise evaluation in a critical care unit. *Am J Crit Care* 2010;19(6):e88-e98.

40. Hu RF, et al. Effects of earplugs and eye masks on nocturnal sleep, melatonin and cortisol in a simulated intensive care unit environment. *Crit Care* 2010;14(2):R66.

41. Wallace CJ, et al. The effect of earplugs on sleep measures during exposure to simulated intensive care unit noise. *Am J Crit Care* 1999;8(4):210-9.

42. Scotto CJ, et al. Earplugs improve patients' subjective experience of sleep in critical care. *Nurs Crit Care* 2009;14(4): 180-4.

43. Le Guen M, et al. Earplugs and eye masks vs routine care prevent sleep impairment in post-anaesthesia care unit: a randomized study. *Br J Anaesth* 2014;112(1):89-95.

44. Van Rompaey B, et al. The effect of earplugs during the night on the onset of delirium and sleep perception: a randomized controlled trial in intensive care patients. *Crit Care* 2012;16(3):R73.