

The Effectiveness of the Interventions to Reduce Sound Levels in the ICU: A Systematic Review

OBJECTIVES: Excessive noise is ubiquitous in the ICU, and there is growing evidence of the negative impact on work performance of caregivers. This study aims to determine the effectiveness of interventions to reduce noise in the ICU.

DATA SOURCES: Databases of PubMed, EMBASE, PsychINFO, CINAHL, and Web of Science were systematically searched from inception to September 14, 2022.

STUDY SELECTION: Two independent reviewers assessed titles and abstracts against study eligibility criteria. Noise mitigating ICU studies were included when having at least one quantitative acoustic outcome measure expressed in A-weighted sound pressure level with an experimental, quasi-experimental, or observational design. Discrepancies were resolved by consensus, and a third independent reviewer adjudicated as necessary.

DATA EXTRACTION: After title, abstract, and full-text selection, two reviewers independently assessed the quality of each study using the Cochrane's Risk Of Bias In Nonrandomized Studies of Interventions tool. Data were synthesized according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines, and interventions were summarized.

DATA SYNTHESIS: After screening 12,652 articles, 25 articles were included, comprising either a mixed group of healthcare professionals ($n = 17$) or only nurses ($n = 8$) from adult or PICU settings. Overall, the methodological quality of the studies was low. Noise reduction interventions were categorized into education ($n = 4$), warning devices ($n = 3$), multicomponent programs ($n = 15$), and architectural redesign ($n = 3$). Education, a noise warning device, and an architectural redesign significantly decreased the sound pressure levels.

CONCLUSIONS: Staff education and visual alert systems seem promising interventions to reduce noise with a short-term effect. The evidence of the studied multicomponent intervention studies, which may lead to the best results, is still low. Therefore, high-quality studies with a low risk of bias and a long-term follow-up are warranted. Embedding noise shielding within the ICU-redesign is supportive to reduce sound pressure levels.

KEY WORDS: acoustics; critical care; intensive care; interventions; noise

ICUs have become sophisticated and complex workplaces due to advanced medical technology and concomitant devices. However, the accompanying excessive noise production and required activities make the ICU a stressful environment for patients, family members, and caregivers (1). The World Health Organization (WHO) guidelines recommend that equivalent continuous sound pressure levels (LAeq) in hospitals should not exceed 35 decibels during daytime hours and 30 decibels during nighttime hours (2). Daily

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KEY POINTS

Question: This systematic review aims to evaluate the effectiveness of interventions to reduce sound levels in the ICU.

Findings: In total, 12,652 articles were screened, and 25 nonrandomized controlled trials were included, showing that education, a noise warning device, and architectural redesigning significantly decreased the sound pressure levels.

Meanings: Staff education and visual alert systems seem promising interventions to achieve some noise reduction with a short-term effect. The evidence of the multicomponent intervention studies, which may lead to the best results, remains uncertain for which high-quality studies are warranted.

practice, however, shows that the ICU is one of the noisiest environments in the hospital, exceeding these WHO recommended noise thresholds considerably (3–6), with average noise levels up to 55 to 70 decibels, comparable to heavy traffic (3, 5, 7–10) accompanied by peak noise levels of more than 80 A-weighted decibels (dBA) produced by monitor alarms, IV infusion pumps, and ventilators (10, 11).

Excessive ICU noise causes negative physiologic and psychological stress responses in patients resulting in, for example, a significant increase in heart rate, blood pressure, and disturbed sleep (12). This, in turn, has a detrimental impact on physical health and recovery (13–19) inducing secondary problems like delirium (20).

Nowadays, the negative influence on caregivers, such as annoyance, fatigue, and perceived stress, has gained attention (18, 19, 21, 22). In addition to these direct effects on staff's wellbeing, studies also raised patient safety concerns since excessive noise leads to miscommunication and difficulties in concentration and attention during high-risk task performance (1, 3, 13, 18, 19, 21, 23–27). There is growing evidence of the negative impact of noise on proper work performance (28) as an increased potential for medical errors (18, 19, 21, 22, 25). Especially human-induced noise threatened healthcare providers' cognitive task functions (29) and negatively affected patient safety (27). Increased noise can lead to medical errors due to distraction and decreased the ability to focus on patient

care tasks (30). Given that, there is a potential for growth in work carried out in the ICU area (31). Self-assessment by ICU staff revealed significantly higher stress levels, increased annoyance and distraction ratings, as well as decreases confidence in performance after ICU-noise exposure (32).

Sound pressure levels are objectively measured and expressed in decibels (26, 33). Undesired and disturbing sound is collectively referred to as noise, a subjective concept affected by various cultural and social factors, individual personalities and attitudes (34).

Most of the disruptive noises in the ICU are caused by conversation, care activities, and telephone calls, and therefore almost exclusively caused by behavior of staff and visitors (1, 35–37) and consequently susceptible to modification (37, 38).

Despite the fact that many studies focused on lowering the noise burden using different interventions, a concise overview of the effectiveness of these interventions on sound pressure levels is lacking. Therefore, the present study aimed to systematically review the literature to evaluate the effectiveness of interventions aiming to reduce sound levels in the ICU to optimize a safe working environment for caregivers in which the chance of making mistakes is reduced.

MATERIALS AND METHODS

A systematic review was performed in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines statement (39) (**Appendix 1, Supplemental Digital Content 1**, <http://links.lww.com/CCX/B158>). The criteria for article inclusion and data analysis were prespecified, and the initial protocol is registered in the International Prospective Register of Systematic Reviews (CRD42018087931) (40).

Data Sources and Searches

Databases of PubMed (including MEDLINE), EMBASE, PsycINFO, CINAHL, and Web of Science were searched from inception to March 9, 2022. Reference lists of included studies and relevant systematic reviews were also scanned to identify additional relevant studies.

The systematic search strategy was set up in close cooperation with a librarian and included a combination of medical subject headings and abstract title

terms consisting of two parts: “population and setting” (e.g., “intensive care,” “critical care,” “ICU”) and “auditory stimulus” (e.g., “sound,” “loudness,” “noise,” “alarms”) as well as relevant synonyms. The detailed search strategy per database is described in **Appendix 2 (Supplemental Digital Content 2, <http://links.lww.com/CCX/B158>)**.

Study Selection

Studies were selected according to the eligibility criteria:

- ICU setting for adult or pediatric patients.
- Interventions aimed to mitigate environmental sound levels (including alarm reduction studies) and optimize the acoustic (work-) environment to a lower noise level.
- Studies with at least one quantitative acoustic outcome measure in decibel (dBA).
- The study design was experimental including randomized controlled trial (RCT) and non-RCT or observational, for example, (un) controlled before-after studies and (non-) controlled cohort studies.
- There were no language restrictions, but an English abstract had to be available.

Non-ICU settings, like coronary care units and recovery units, and studies performed in neonatal ICUs were excluded. The latter due to the differences in the work environment with specific equipment, for example, incubators, compared with the other ICU settings.

Data Extraction and Quality Assessment

Titles, abstracts, and full-text articles were independently screened by two researchers (J.V., M.v.d.B.). When the abstract contained insufficient information to determine eligibility, the full text of the article was screened. Disagreements were resolved by discussion, and a third researcher arbitrated when no consensus was reached (J.L.). Data were extracted into a standardized form and independently cross-checked (**Appendix 3, Supplemental Digital Content 3, <http://links.lww.com/CCX/B158>**).

Quality assessment was performed independently by the researchers (J.V., M.v.d.B.), using the Cochrane’s Risk of Bias In Nonrandomized Studies of Interventions tool (41).

Each domain of bias was assessed from low to critical risk of bias. Any disagreement was resolved by discussion or involving a third author (J.L.).

Data Synthesis and Analysis

Environmental A-weighted sound pressure levels are reported in decibels (dBA). Most studies reported outcomes in LAeq, the A-weighted equivalent continuous sound level over a given time period (e.g., 24-hr, day, or night), which represents the (single value) total sound exposure for the period of interest (26). A minority of studies reported their outcomes in mean decibel (simple linear averaging) per time period. Both outcome measures were tabulated and discussed for proper comparisons.

In detail, the interventions were structured in “behavioral change interventions” and “architectural interventions.” Studies that focus on behavioral change interventions were classified into three categories: 1) education/training programs aimed to increase the knowledge and awareness of the noise problem; 2) noise warning devices as reminders for exceeding the noise threshold; or 3) multicomponent intervention programs or bundles, mostly with education and a noise warning device incorporated amplified with practical, low-cost instructions for noise reduction. Some studies introduced a “quiet time” period, a specific time frame of reduced controllable noise bundle interventions during day or night times (42–44).

In addition to behavioral change interventions, a fourth category was added, reflecting the implemented architectural interventions or design choices.

RESULTS

The search yielded 12,652 citations. After removing 3,600 duplicates, 9,052 citations remained and were screened for title and abstract, resulting in 50 full-text articles. Of these, 25 studies met the inclusion criteria (**Fig. 1**).

Study Characteristics and Outcome

A total of 20 studies had an uncontrolled before-after design, and five were controlled before-after studies (**Table 1**). The study populations were a mixed group of healthcare professionals, including physicians, nurses, and others ($n = 17$), or a specific group of only nursing staff ($n = 8$) from various ICUs including mixed, medical, neurology, surgical, thoracic/cardiovascular, cardiac, and PICUs.

The primary acoustic parameters were LAeq values ($n = 11$) and mean dBA ($n = 8$), with varying time blocks

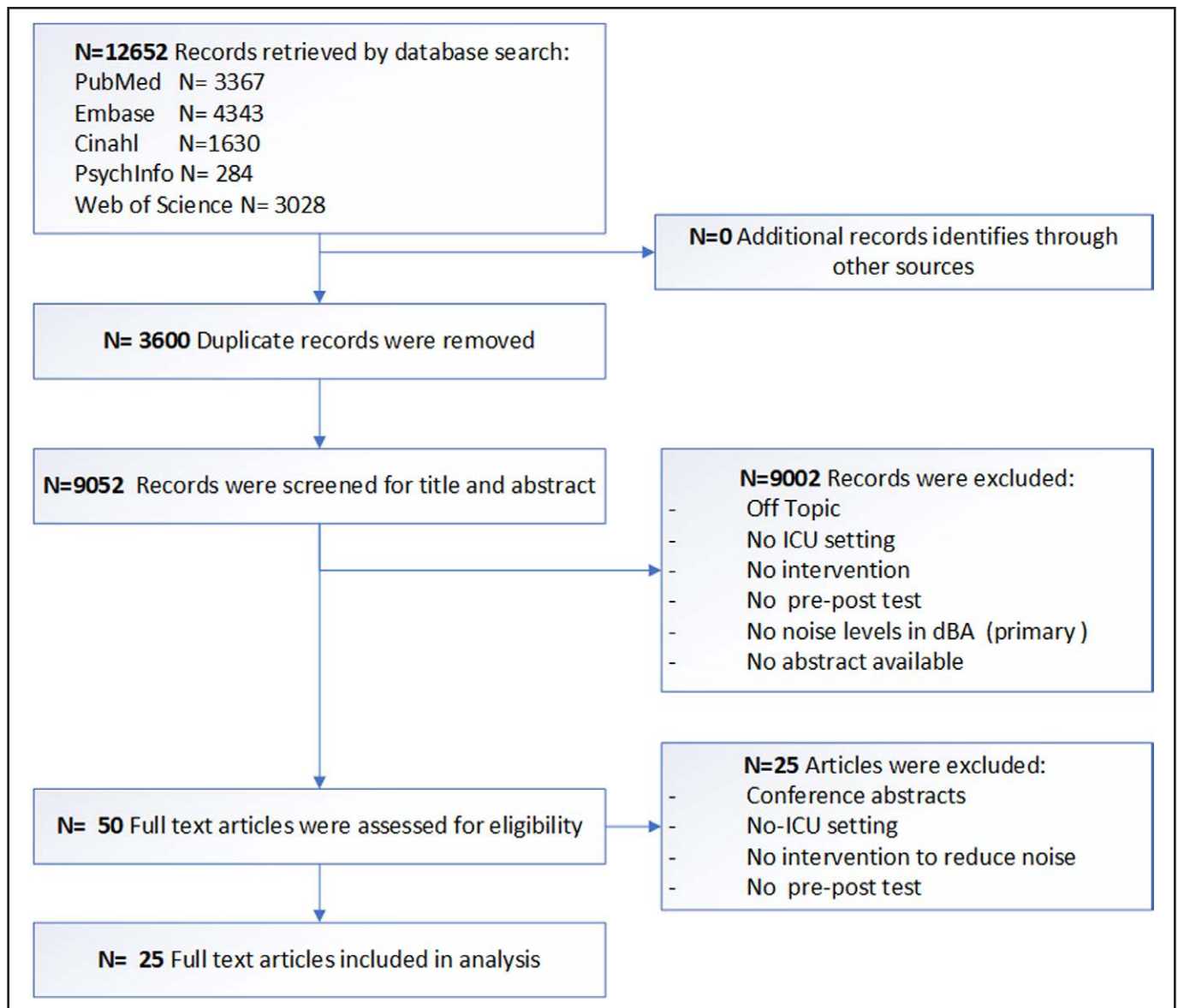


Figure 1. Flow chart showing inclusion of articles.

where day-and-night shifts were most used. Four studies reported only Lminimum, Lmaximum, and Lpeak decibels. Sound levels were measured in multiple locations, for example, patient rooms ($n = 17$) and central areas or corridors ($n = 14$) (**Appendix 4, Supplemental Digital Content 4**, <http://links.lww.com/CCX/B158>).

Methodological Quality

The included studies had a relatively high overall risk of bias (**Appendix 5, Supplemental Digital Content 5**, <http://links.lww.com/CCX/B158>; and **Appendix 6, Supplemental Digital Content 6**, <http://links.lww.com/CCX/B158>, respectively). In 15 studies, no adjustments

were made for confounders, for example, bed occupancy or the number of care providers. Most studies lacked appropriate clarity for comparing the before-after study population and compliance with the interventions. This may result in “bias due to selection of the population,” “bias due to deviations of intended interventions,” and “bias due to missing data.” Due to the high risk of bias, the heterogeneity of interventions, and the variety of outcome measures, no meta-analysis was performed.

Noise Reduction Interventions

A statistically significant reduction ($p < 0.05$) of mean sound levels after intervention was reported in 14 out

TABLE 1.
Characteristics of Included Articles

Author, Country, Year, References	Design	ICU Type	HCP Included	Interventions to Reduce Noise	Control	Outcome Parameters
Ar et al (45), Turkey, 2018	UBA	Mixed	HCP	A consciousness and awareness training ^a	Standard care	Sound levels, examination scores
Crawford et al (9), United States, 2018	UBA	Medical	Nurses	A noise reduction bundle	Standard care	Sound levels
Delaney and Nur (46), Australia, 2014	UBA	Mixed (adult), pediatric	Nurses	A behavior modification program	Standard care	Sound levels, sleep, staff education
Dennis et al (42), United States, 2010	UBA	Neuro	Not reported	Quiet time: day/night	Standard care	Sound levels, light levels, sleep
Duarte et al (47), Brazil, 2012	UBA	Mixed (adult), pediatric	HCP	Education ^a /lectures, posters	Standard care	Sound levels
Guisasola-Rabes et al (48), Spain, 2019	UBA	Surgical	HCP	Visual noise warning system	Standard care	Sound levels
Jousselman et al (49), France, 2011	Quasi-experimental	Pediatric, neonatal	HCP	A sound-activated light device	No device is present	Sound levels
Kahn et al (36), United States, 1998	UBA	Medical, respiratory	HCP	Behavior modification program	Standard care	Sound levels
Kawai et al (50), United States, 2017	Quasi-experimental	Pediatric	Nurses	Delirium bundle (8 PM and 11 PM)	Standard care	Sound levels
Kol et al (51), Turkey, 2015	UBA	Pediatric	HCP	Single-patient ICU rooms	Standard four-bed room	Sound levels
Konkani et al (37), United States, 2014	UBA	Pediatric	Nurses	A behavior modification program	Standard care	Sound levels
Li et al (52), Taiwan, 2011	Quasi-experimental	Surgical	Nurses	Guidelines (night-time noise and sleep)	Standard care	Sound levels, sleep
Luetz et al (53), Germany, 2016	CBA	Mixed	HCP	Architectural change: two modified rooms	Standard care	Sound levels
Monsén and Edéll-Gustafsson (54), Sweden, 2005	UBA	Neuro	HCP	A behavior modification program	Standard care	Sound levels
Moore et al (55), United States, 1998	UBA	Thoracic/cardiovascular	HCP	Education ^a and closing doors	Standard care	Sound levels

(Continued)

TABLE 1. (Continued).
Characteristics of Included Articles

Author, Country, Year, References	Design	ICU Type	HCP Included	Interventions to Reduce Noise	Control	Outcome Parameters
Nannapaneni et al (56), United States, 2015	UBA	Medical	HCP	Education ^a , environmental changes, visual noise indicator	Standard care	Sound levels
Patel et al (57), United Kingdom, 2014	UBA	Mixed	HCP	Bundle of non-pharmacologic interventions (nighttime)	Standard care	Sound levels, light levels, sleep
Philbin and Gray (58), United States, 2002	UBA	Pediatric	HCP	Education ^a and renovation	Standard care	Sound levels
Plummer et al (59), United Kingdom, 2019	UBA	Mixed	HCP	Visual noise warning device (SoundEar)	Standard care	Sound levels
Riemer et al (44), United States, 2015	UBA	Mixed	Nurses	Quiet time: 2 PM to 4 PM	Standard care	Sound levels, light level, stress scores
da Silva Souza et al (60), Brazil, 2022	UBA	Mixed	Nurses	Education/training ^a , visual noise warning device	Standard care	Sound levels, sleep, seven audit criteria
Tainter et al (61), United States, 2014	CBA	Surgical	HCP	Quiet time: 11 PM to 5 AM	Standard care	Sound levels
Walder et al (62), Switzerland, 2000	UBA	Surgical	HCP	Overnight: guidelines on noise and light levels	Standard care	Sound levels, light levels, sleep parameters
Wang et al (63), United States, 2013	UBA	Cardiac	Nurses	New ICU with a service corridor	Standard care	Sound levels, stress, light levels, temperature, satisfaction work
Zamani et al (64), Iran, 2018	UBA	Mixed	HCP	Education ^a	Standard care	Sound levels

CBA = controlled before after design, HCP = healthcare professionals (physicians, nurses, others), UBA = uncontrolled before after study design.

^aTraining and education programs are aimed at increasing awareness of the noise problem and behavior modification of the staff.

of 25 studies (56%) (42, 45, 47–53, 57, 59, 62, 63, 65) ranging from 1 or 2 dBA (48, 49, 53, 60) up to 16 dBA (51). This reduction was accomplished in almost all included studies in which education or a noise warning device was used as a single intervention (5/6), studies

with a renewed architectural environment (3/3), and multicomponent programs (5/15) studies. In 11 studies (11/25), this significant noise reduction was at least 3 dBA and thus discernible for the human ear (34, 42, 45, 47, 50, 52, 57, 59, 62, 63, 65, 66). Additionally, 14

TABLE 2.

The Effect Range, Number of Significant Studies, and Follow-Up Split by Category or Subcategory of Sound-Reducing Interventions in the ICU

Intervention Category	Subcategory	Effect Range, Mean dBA or Equivalent Continuous Sound Pressure Levels	No. of Studies With Significant Effects	Statistically Significant Long-Term Effects
Education		0.9–9 dBA	3/4	–0.9 dBA ^a (1 mo; 1/3 education studies)
Warning devices		1.0–3.9 dBA	3/3	–3.6 dBA (4 mo; 1/3 warning devices studies)
Multicomponent program	Complete program	Daytime 9–11 dBA; nighttime 3–7 dBA	5/15	–7 dBA nighttime (1 mo; 1/5 bundle studies)
	Quiet time	11 dBA	1/2	No follow-up
ICU redesign		1.0–16 dBA	3/3	–16 dBA (1 mo; 1/3 design studies)

dBA = A-weighted decibel.

^aThese numbers are numerical averages based on the original noise levels in the articles.

studies reported a reduction in a wide range of other often-used parameters describing the soundscape as Lminimum, Lmaximum (36, 37, 43, 44, 47, 50–54, 56, 58, 59, 62, 63). A detailed description of the interventions is provided in **Appendix 7 (Supplemental Digital Content 7, <http://links.lww.com/CCX/B158>)**.

Education/Training Programs

In three studies, education and training, group education, as well as individual instruction, aiming to increase knowledge and awareness, was used (3/25) as a single intervention strategy (45, 47, 64), which resulted in a significant noise decrease of 0.9 dBA (45) to 5–9 dBA (47, 64). A fourth study focused on training and staff awareness and measured noise using a noise warning device, but no noise level reduction was achieved (60). A sustained statistically significant noise reduction was reported for only 1 month after the intervention (**Table 2**).

Warning Device

Three studies (3/24) focused on the visual noise alert device as a single intervention strategy and showed a significant reduction in sound levels of 1–2 to 3.9 dBA

(48, 49, 59). There was no difference in noise level with the system turned on versus turned off (48, 49). The follow-up ranges from 2 weeks to 4 months. Only one study showed a sustained reduction of 3.6 dBA over 4 months (59) (**Table 2**).

Multicomponent Behavioral Program

A noise mitigating program or bundle was identified in 15 studies (9, 36, 37, 42, 44, 46, 50, 52, 54–58, 61, 62). These included a combination of relatively simple instructions to bundle care activities, rearrange time for diagnostic tests (9, 42, 46, 52, 54–56, 62), reduce noise from equipment (alarms), telephone, television (9, 36, 37, 42–44, 46, 50, 52, 55–58, 62), reduce noise from staff conversation and visitors (9, 36, 37, 43, 52, 55–58, 62), and posters, handouts, etc (9, 36, 42, 43, 46, 56, 58). Almost every program started with education or instruction on the guidelines as part of the implementation strategy, and three programs incorporated a noise warning device as part of the bundle (37, 46, 56). Three studies also included patient-related interventions to promote sleep, for example, sleep masks or earplugs (50, 56, 57). The interventions were applied to all shifts or explicitly introduced for a timeframe, for example, during day or nighttime. A significant

reduction of sound levels was seen in five out of the 15 studies (42, 50, 52, 57, 62) in a range from 9 to 11 dBA during daytime (42) and 3 to 7 dBA during nighttime (50, 52, 57) with a maximum follow-up of 1 month (Table 2). Two studies introduced a “quiet time-period” during daytime hours (42, 44) of which one study showed a significant mean sound level reduction of 11 dBA (42) and the other study, in which the focus was solely on turning down the lights for a designated timeframe, showed a reduction of 1.3 dBA, not significant (44). Overnight “quiet-time,” in contrast, resulted in a significant reduction of 6.4 dBA in maximum sound level (43).

Design

An architectural approach was the single focus in three studies (51, 53, 63), and part of a two-component-intervention study in a fourth study (63). In two studies, a technical corridor was created in a redesigned ICU, aimed at noise shielding in patient rooms (53) or staff services (63) and led to an overall noise reduction of 1 dBA (53) to 2.1 dBA (63). In the third study, new single-patient rooms were created with only essential equipment and a separate nurses' station. Sound levels reduced significantly with 16 dBA (from 72 to 56) (51) 1 month after renovation (Table 2). In a fourth study, a partial renovation (ventilation ductwork, a carpet, and acoustic ceiling) followed a staff behavioral change intervention (58) resulted into lower sound levels in L_{minimum-hour} and L_{maximum-hour} both in a range of 10 to 15 dBA.

DISCUSSION

This systematic review evaluated the effect of noise-reducing interventions in the ICU. Education and noise warning devices were potential effective interventions aimed at behavior modification to lower sound levels in the ICU with a short-term effect. An architectural redesign contributes to the reduction of sound levels, although the WHO recommendations are consistently not achieved. A multicomponent intervention program significantly reduced sound levels in one-third of the studies where measurements have been taken up to a maximum of only 1 month after the interventions. Overall, the risk of bias in all included studies was relatively high, mainly due to the uncontrolled before-after study design.

The included studies significantly reduced mean sound levels, ranging from 1 to 16 decibels. Importantly, since a reduction of less than 3 dBA is not meaningful because it is not detectable by human hearing (34), the clinical relevance poses a lower limit for the difference to be minimally 3 dBA.

ICU areas are dominated by many intermittent, unexpected, short-term loud noise events such as alarms, closing doors, and conversation. However, the contribution of these short-term sounds to the mean sound levels is relatively limited (67). Nevertheless, these noises were perceived by caregivers, as intrusive and annoying and affecting the cognitive performance (1, 34, 68, 69). So, from a safety point of view, to address these specific noises, additional noise parameters may be more appropriate, such as L_{maximum} (2, 31) for loud sounds, and the statistical indices L₅, L₁₀, L₅₀, and L₉₀ (31) to further describe the soundscape. Despite these statistical indices, other noise characteristics, such as duration and frequency, should also be considered (2). To calculate the psychologic impact of sound, the “loudness” calculation is recommended as a quantifiable value describing the human experience to sound (34).

Studies with interventions for behavioral change, for example, education, visual alarm systems, and multicomponent programs, are mainly aimed to mitigate intermittent and unpredictable (loud) high-frequency sound sources such as speech, activities, and equipment alarms. Architectural modifications aimed at shielding equipment noise and speech away from the bedside, effectively lowered the background noise level (4, 37, 57, 58) and therefore should support sound-reducing behavior in an ergonomic context of the ICU (35, 68).

Education and noise warning devices can be effective single-intervention strategies in reducing sound levels (35, 46, 48, 49, 59, 70–72) in the short term. As we know that most of the disruptive noises in the ICU are caused by conversation, care activities, and telephone calls, and therefore almost exclusively caused by behavior of staff and visitors. So the underlying aim is a structural change in staff's behavior which requires complex interventions which is characterized by different interacting components in the attempt to lower the sound levels step by step. However, there is growing evidence in implementation science that multicomponent strategies are more effective in changing professional

behavior on the long term (60, 72). Yet, these multi-component strategies require thorough implementation strategies, in which the interventions are focused on the primary noise sources, tailored to the setting, and based on an assessment of barriers and facilitators for change. Because human-induced noise is one of the primary sources, healthcare workers should be closely involved (60, 72). There is a positive association between high compliance rates to care bundles and positive effects outcomes (73). We found that two-thirds of the multicomponent intervention studies were ineffective, but limited information was available about the extent to which these essential elements of good implementation were present. Interestingly, although the quiet time intervention programs were only moderately successful in lowering sound levels, they were positively experienced by healthcare workers, causing a decrease in their stress levels (43, 44).

Implementation of a multicomponent program aimed at a noise-reducing culture change in the ICU is only feasible at a unit level since randomization at a patient level would result in contamination between intervention and control group patients, which could result in a diluted effect of the program, including risk for a false-negative outcome (74).

Noise in the work environment is linked to impaired quality of communication and an increased number of distractions during the task performance of healthcare professionals, thereby posing a risk to patient safety (27, 75–77). Education, aimed to increase the knowledge and awareness of the noise problem, should be an indispensable part of a noise reduction strategy. We also notice that a visual noise alert device showed significant noise reduction regardless it was on or off. So, when starting to creating awareness at the noise problem, these low cost, practical tools may have value to support medical staff in their effort to change noise behavior. Sustainable long-term change in staffs' noise behavior needs further high quality research. Furthermore, analysis of medical errors showed that noise, alarms, and interpersonal dynamics such as miscommunication are contributing factors (78, 79). So, in the ICU, environmental sound protection may also focus on reducing noise-related disturbances besides lowering overall sound pressure levels. An intelligent integrated alarming device for precise patient monitoring instead of each medical device alarming separately could efficiently reduce noise (80). So, in

addition to the psychological impact of noise on patients and healthcare providers, excessive noise levels are a real safety hazard.

Several limitations need to be addressed. First, no meta-analysis could be performed due to the heterogeneity and the high risk of bias in the included studies. Noise-level assessments showed substantial variability, with some studies conducting continuous noise recording, while others only employed point prevalence measurements using single measurements. Second, for evaluation of the sound environment, only a simple LAeq, as clearly defined and recommended by the WHO as an acoustic indicator for evaluation of continuous environmental noise (2) was studied. There may be differences due to the measured outcomes in LAeq or mean decibel (Appendix 4, Supplemental Digital Content 4, <http://links.lww.com/CCX/B158>). However, this difference did likely influenced our findings or conclusions for this systematic review. Third, most studies only reported short-term effects, and therefore no statement regarding the sustainability of the interventions can be drawn. However, ongoing education seems promising to empower staff to enact sustainable noise reduction (70), especially when this is part of a multifaceted approach and may lead to the best results (6, 19, 60). To determine the effectiveness of interventions to reduce noise levels, it is advised to perform high-quality studies with a low risk of bias, such as a RCT, in which the long-term effects are considered. Because of a wide range of costs in the different interventions, a cost analysis may be valuable.

CONCLUSIONS

Staff education and visual alert systems as noise warning devices seem promising interventions to achieve short-term noise reduction. The evidence for the effectiveness of multicomponent interventions, which may lead to the best results, remains uncertain. Therefore, high-quality studies with a low risk of bias and a long-term follow-up are warranted. Embedding noise shielding within the ICU-redesign is supportive to reduce sound pressure levels.

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