

Effectiveness of a visual noise warning system on noise levels in a surgical ICU A quality improvement programme

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BACKGROUND The effects of noise are harmful to patients in the ICU environment, and the latter are particularly noisy places. High noise levels seem to be a factor in sleep disturbance, which can, in turn, result in increased morbidity.

LOCAL PROBLEM High noise levels are a recognised problem in ICUs worldwide.

OBJECTIVE(S) The goal was to estimate the effect of a visual noise-warning system on noise levels in a surgical ICU before and after its implementation.

DESIGN A quality improvement initiative.

SETTING A 12-bedded surgical ICU in a tertiary care university hospital.

PATIENTS A total of 148 adult nonintubated and nonsedated patients completed the study, during a 6-week period.

INTERVENTION Noise levels were continuously recorded using a Type II sound level meter for 6 weeks. The study was divided into three phases. The first 2 weeks, baseline noise levels were measured (phase I). In week 3 of the study, a visual noise warning system (SoundEar //) that changed colour depending on noise levels within the ICU was installed and implemented (phase II). The alarm system was set to light up green at levels below 55 dBA, orange at levels between 55 and 60 dBA and red at levels above 60 dBA. The device was switched off at the beginning of week 5 and the sound level meter continued recording noise levels for another 2 weeks (phase III).

RESULTS Mean night-time noise level was 55.98 dBA in the preintervention phase, 54.14 dB during the intervention, and 54.98 dBA in the postintervention phase. Mean noise level was reduced statistically significantly by 1.35 dBA, and there was a sustained reduction of 0.86 dBA from the baseline noise level 2 weeks after SoundEar // was switched off.

CONCLUSION Visual noise warning systems can be effective in achieving a reduction in noise levels in critical care units.

Introduction

High noise levels in hospitals, and particularly in ICUs, are a long-recognised problem thought to be associated with sleep disruption and increased morbidity.^{1–3} ICUs are noisy environments: mean sound level has been reported at 45 to 65 decibels (dB), with peaks above 85 dB.⁴ According to the WHO guidelines, sound level should not exceed 35 dB in hospital areas where patients are treated or observed, with a maximum at night below 40 dB to ensure proper sleep.⁵

There is increasing concern about the impact of ICU noise levels on both patients and staff.^{6,7} Although there is some discrepancy in the literature regarding the importance of noise in sleep, high noise levels can affect sleep quality even if the individual does not actually wake up. Instead, sleep may enter a more superficial stage, often stage 1.^{8,9} Environmental noise is responsible for 11.5 and 17% of overall arousals and awakenings from sleep, respectively.⁹ In polysomnography studies, noise levels contribute to 15 to 20% of sleep disturbances.^{10–13}

In contrast to many other disturbing factors in a surgical ICU, excessive noise can be significantly reduced.^{14,15} In addition to ICU equipment, one unexpected source of high-level noise is conversations among the staff.^{16–18} Recent data suggest that over 50% of ICU noise may result from human speech and other activities.^{19,20} Patient-specific devices such as earplugs and earphones have been tested to mitigate this problem,^{1,21–24} but their clinical benefit is limited. Certain interventions to reduce noise levels have shown transient reductions in ambient noise, with limited reductions in peak levels.¹⁰ The old classic standard for improvement of noise reduction in this setting has been education of staff through posters and guidelines, which showed some effect on noise reduction but no evidence of maintaining lower noise levels in the long term.¹⁵

Noise control devices may be useful, but there is currently little data on their ability to reduce noise levels in these environments. Recently, a sound-activated visual noise display meter proved effective for providing a sustained reduction in night-time ambient sound, appearing to work through behavioural changes.¹⁴ SoundEar II is a noise monitoring and visual warning device which continuously measures sound levels and visually alerts staff when noise levels go over a preset threshold so that they are constantly aware whether excessive noise is being made. When the system flashes orange or red, it is expected the staff will instinctively quieten down, with no need for other interventions such as teaching or guidelines, which would need to be repeated every time a new member of staff is incorporated and which are easier to ignore. Visual noise-warning systems offer continuous feedback which helps staff to recognise and control excessive levels of noise. It displays objective information on noise, indicating when staff would need to reduce noise levels.

The goal of this study was to evaluate whether implementation of a visual noise-warning system in a surgical ICU had an effect on noise levels and whether it could be maintained when the SoundEar II was switched off.

Methods

After local ethical approval by the ethical committee of clinical investigation and commission of research projects of Vall d'Hebrón University Hospital, [head: Mrs Mireia Navarro Sebastián, in Barcelona, on 21 August 2017 (PR(AG)258/2017)], a prospective

single-centre study was conducted over a 6 -week period in the 12 -bed surgical ICU of a tertiary university hospital. We adhered to the revised standards for quality improvement reporting excellence (SQUIRE 2.0).

Context

Our 12 bed ICU admits 2400 patients per year with a mean stay of 30.16 h. The ICU works in three shifts: morning (8.00 to 15.00), afternoon (15.00 to 22.00) and night (22.00 to 8.00). The postoperative patients we receive are varied: general surgery (34.2%), neurosurgery (14.6%), urologic surgery (14.4%), vascular surgery (12.7%), thoracic surgery (7.7%), ear, nose and throat/ maxillofacial (2.3%), among others. 79% of surgical procedures are elective, with 21% being emergency. Some 20.6% of patients are sedated and intubated. One nurse is assigned to two patients and there are two consultant anaesthesiologists as well as three or four junior doctors on the unit every day. It is an open plan ICU with six beds (three pairs of beds) on either side including two isolation rooms and the nurses' station is located in the middle of the unit. The pairs of beds are separated only by a curtain, one bed is nearer by the window and the other is closer to the nurses' station with no walls in between (except for the isolation rooms).

Study population

Between 8 November 2017 and 21 December 2017, 154 consecutive patients admitted to ICU were included in the study. Exclusion criteria: mechanical ventilation and/or sedation, cranial neurosurgery or Glasgow Coma Scale score less than 14, inability to read or understand a questionnaire, and previous ICU admission and enrolment in the study.

Study design and interventions

The current study was a quality improvement programme, involving three phases of 2 weeks each. In the first 2-week period (phase I), baseline noise levels were measured, in the second 2-week period (phase II), a visual noise alarm system was implemented, and in the last 2-week period (phase III) the system was turned off. At the beginning of phase II (week 3), two SoundEar II visual alarm systems (SoundEar A/S, Madrid, Spain) were installed in the unit. SoundEar II is a visual warning system that records noise levels and can be set to flash different colours depending on the sound level recorded. After analysing the baseline noise levels, the alarm system was set to light up green at levels below 55 A-weighted decibels (dBA), orange at levels between 55 and 60 dBA, and red at levels above 60 dBA. Both systems were placed in clear view of all working staff, but were not visible to patients. Systems were switched off at the beginning of phase III (week 5).

Noise recording

Over the entire 6-week study period, noise levels were continuously recorded using a type II sound level meter (SC420, CESVA Instruments, Barcelona, Spain). The following data were recorded every 1 s with the filter frequency in A-weighting and Fast mode: noise equivalent level (LAFeq) to establish the noise level, maximum level (LAFmax) to establish the maximum value, and minimum level (LAFmin) to analyse temporary variations in noise in the unit. In addition, the 90th percentile (LAF90) and peak noise levels (LApeak) were recorded to establish the background noise level and the dynamic

of peak times or random noises, respectively.^{25,26} The sound level meter was positioned following the recommendations of Fortes-Garrido,²⁷ attempting to achieve the most representative noise level samples. Placement was in the centre of the surgical unit, 55 cm from the ceiling and 110 cm from the wall. Internal ICU dynamics were also considered, so that the daily clinical activity would be affected as little as possible. Each of the three sampling periods lasted for 2 weeks (total of 6 weeks) to ensure representative averages, to offset the Hawthorne effect of attention bias, and to avoid unexpected variables that could interfere with noise levels.

Statistical analysis

A descriptive analysis of the demographic variables was performed. Continuous variables were expressed as mean $\pm$ SD, and categorical variables were expressed as absolute values and (percentages). For statistical comparison, we used the Kruskal-Wallis for categorical variables and analysis of variance comparisons for continuous variables.

For interpretation purposes, noise measurement data (LAFeq, LApeak, LAFmin, LAFmax and LAF90) were aggregated and summarised from seconds to hours and day periods (morning, afternoon and night). In addition, to compare changes in noise measurements between the three study periods (preintervention, intervention, postintervention), a linear regression model was used after adjustment by noise variation during day hours. A subgroup analysis was performed to study noise measurements during night-time.

Data analyses were carried out using the R version 3.4.1 statistical software package (R Foundation for Statistical computing, Vienna, Austria).

Results

Patient characteristics in the three phases were similar and a similar number of patients were included in each phase (Table 1). Male patients represented 60.1% of the total and the mean age of all patients was of 63 ± 15 years. About a quarter of the patients underwent urgent surgical procedures. Patients in phase II received fewer hypnotic drugs than patients in the other two phases. The visual analogue score for pain was the same in all phases. Mean duration of ICU stay was 26.2 ± 2.3 h.

Mean preintervention noise levels, represented by LAFeq values, were 57.3 ± 5.2 dBA. Noise levels rapidly decreased during the night shift up to 05.00 or 06.00 the next morning, and this dynamic was maintained throughout the three study phases (Table 2). Background noise, obtained by comparing LAFmin and LAF90 (which were practically equal) showed that the lowest levels were 52.1 ± 5 and 52.7 ± 5 dBA, respectively. Finally, peak noise levels (LApeak) were considerably higher than LAFmax (75.6 ± 5.6 and 61.6 ± 5.3 dBA, respectively).

Noise levels before the intervention (phase I), when the visual noise warning system was in place (phase II), and after the warning system was switched off (phase III) are shown in Table 2. Overall, and after adjustment for noise variation during day hours, noise LAFeq levels decreased by 1.35 dBA [confidence interval (CI) 95% 0.63 to 2.08, $P < 0.001$] after SoundEar II was implemented (Table 3). Comparison between the preintervention (phase I) and postintervention (phase III) levels showed a noise

reduction of 0.86 dBA (CI 95%0.16 to 1.56, $P=0.02$). No statistically significant differences were found between phases II and III (when SoundEar II was activated and when it was switched off), although levels tended to increase by 0.5 dBA (CI 95%-0.13 to 1.13, $P=0.12$).

Equivalent A-weighted noise level (LAFeq), and maximum (LAFmax), minimum (LAFmin), 90th percentile (LAF90) and peak (LApeak) noise level per hour before, during, and after implementation of the visual warning system are shown in Fig. 1. Noise patterns were similar regardless of the measure used. The preintervention phase registered the highest noise levels (the only exception being peak morning noise levels), which decreased during SoundEar II implementation (except for LAF max and LApeak). Noise values showed few differences once the system was turned off, but a significant decrease in LAF90 and LAFmin was observed when comparing phase I with phase III.

Discussion

In this study, implementation of a visual noise warning system (SoundEar II) in a surgical ICU reduced noise to an extent that achieved clinical significance. The noise reduction was maintained after the system was turned off, which suggests that the staff had adopted behavioural changes that were maintained even when SoundEar II was not activated. However, there was a trend towards higher noise levels from phase II to phase III, suggesting that the effect of the presence of the SoundEar II on lowering noise levels is partially lost once it is switched off.

The acoustic status of our ICU, indicated by the preintervention LAFeq values, was similar to the situation described in other studies.⁴ After SoundEar II was implemented, the reduction achieved was mainly in the ambient noise level (LAFeq), but not in other parameters, such as the peak noise level (LApeak). LAFeq likely accounts for modifiable noise factors, such as staff conversations, whereas LApeak responds to nonmodifiable factors such as ventilators or monitoring alarms, as this parameter measures the maximum reached instantaneous sound pressure value. In an ICU environment, this type of noise is very difficult to modify. Background noise (LAF90) showed only a slight reduction, indicating that this was the lowest attainable level and that further reductions would probably require changes in the architecture of the building. A recent multicentre study reported that background noise is negatively associated with sleep, and emphasised the importance of taking building properties into account when designing an ICU.²⁵

Although noise remained above the recommended level⁵ in our ICU, a small reduction may still improve ICU conditions. Objective and subjective studies have shown that even small increases have an adverse impact on sleep.^{10,16,28,29} Of note, a 10-dB increase in noise is perceived as a doubling of noise level, whereas sound intensity is doubled for each 3 dB increase.³⁰ It is difficult to establish a clinically relevant threshold on noise reduction and more studies would be necessary to determine it. It was suspected that a reduction in noise of 2.7 dBA could improve sleep quality by 16.1%.¹⁰

The only intervention in this study was the SoundEar II placement; no other interventions, such as staff behavioural modification strategies were used. It may be speculated that multimodal approaches could further improve efficiency on noise reduction. Although implementation of a visual noise warning system reduced noise

levels in our surgical ICU, this noise reduction was small with the result that noise levels still remained above the WHO recommended levels.

A major limitation was that we did not evaluate the staff response to the visual noise-warning system. Another important limitation was the floorplan of our ICU. The sound level meter was not placed directly by the bedside but in the centre of the ICU, very close to the nurses' station, which allows for closer recordings of staff conversations and activities rather than monitor and ventilator-related noises. The difference in patient mix over the three periods (intubated and/or sedated patients) could potentially account for the difference in noise levels. Our ICU is usually very busy, with a high occupancy rate and a high turnover of patients, however, occupancy rate was not considered as a potential confounding factor and was not calculated for each period. Another limitation is the fact that the sound level meter and the two SoundEar II were not placed in the same place in our ICU, so the recording of noise levels will not have been exactly the same for both systems.

In conclusion, the implementation of a visual noise warning system achieved a sustained reduction in mean noise levels in our surgical ICU. This was probably accomplished by decreasing modifiable factors, such as staff conversations, and these behavioural changes were maintained once the system was switched off. Based on our results, we suggest that visual noise warning systems may be helpful in ICUs for noise reduction.

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Table 1 Patient characteristics on inclusion in the three different phases ($n = 148$)

Characteristic	Phase I	Phase II	Phase III	All phases
Patient characteristics (patients included)	$n = 49$	$n = 50$	$n = 49$	$n = 148$
Male sex, n (%)	32 (65%)	28 (56%)	29 (59%)	89 (60.1%)
Age (mean $\pm$ SD) (years)	64 ± 16	64 ± 15	62 ± 14	63 ± 15
Weight (mean $\pm$ SD) (kg)	73 ± 14	77 ± 20	71 ± 16	73 ± 17
Height (mean $\pm$ SD) (cm)	169 ± 8	169 ± 10	168 ± 9	170 ± 9
Type of surgery				
Abdominal (%)	44.8	46.9	42.8	44.6
Urologic (%)	8.1	14.2	22.4	14.9
Vascular: extremities/carotid (%)	20.4	12.2	8.1	13.5
Other (%)	16.3	8.1	8.1	10.8
Thoracic (%)	8.1	12.2	8.1	9.5
Spinal (%)	2.0	4.0	10.2	5.4
ENT or maxillofacial (%)	0	4.0	0	1.4
Surgery characteristics				
Urgent surgery, yes (%)	22.4	28.5	20.4	23.7
Nasogastric tube, yes (%)	22.4	30.6	14.2	22.3
Urinary catheter, yes (%)	87.7	89.7	89.7	88.6
Medical care				
Drain changes, yes (%)	20.4	54.0	42.8	39.2
Hypnotic drug administration, yes (%)	42.8	24.0	42.8	36.5
Initiate drinking water, yes (%)	44.8	48.0	67.3	53.4
Night hygiene, yes (%)	73.4	70.0	69.3	71.0
Postural changes, yes (%)	38.7	42.0	20.4	33.4
VAS score				
Maximum (mean $\pm$ SD)	2.5 ± 2.8	2.5 ± 2.8	2.5 ± 2.8	2.5 ± 2.8
Minimum (mean $\pm$ SD)	0.2 ± 0.6	0.2 ± 0.6	0.2 ± 0.6	0.2 ± 0.6
No. of hours VAS was > 3 (mean $\pm$ SD)	0.9 ± 1.5	0.9 ± 1.5	0.9 ± 1.5	0.9 ± 1.5

Table 2 Noise levels per shift before (phase I), during (phase II) and after (phase III) implementation of the visual noise warning system

Acoustic parameters (dBA)	Shift	I	Phase II	III
Equivalent noise level (LAFeq)	Morning	61.58	61.09	60.53
	Afternoon	60.39	58.66	59.33
	Night	55.98	54.14	54.98
	Total	59.31	57.96	58.32
Maximum noise level (LAFmax)	Morning	65.63	65.44	64.74
	Afternoon	64.70	63.04	63.69
	Night	60.16	58.56	59.41
	Total	63.5	62.35	62.65
Minimum noise level (LAFmin)	Morning	56.55	55.73	55.14
	Afternoon	55.06	53.23	53.75
	Night	51.17	48.99	49.66
	Total	54.26	52.65	52.89
Background noise level (LAF90)	Morning	57.22	56.43	55.85
	Afternoon	55.71	53.91	54.46
	Night	51.71	49.55	50.27
	Total	54.88	53.29	53.57
Peak noise level (Lapeak)	Morning	79.26	81.02	78.57
	Afternoon	78.60	78.06	77.51
	Night	74.31	73.20	73.49
	Total	77.39	77.42	76.56

Table 3 LAFeq changes in 24 h and at night

LAFeq: linear model regression (0 to 24h)

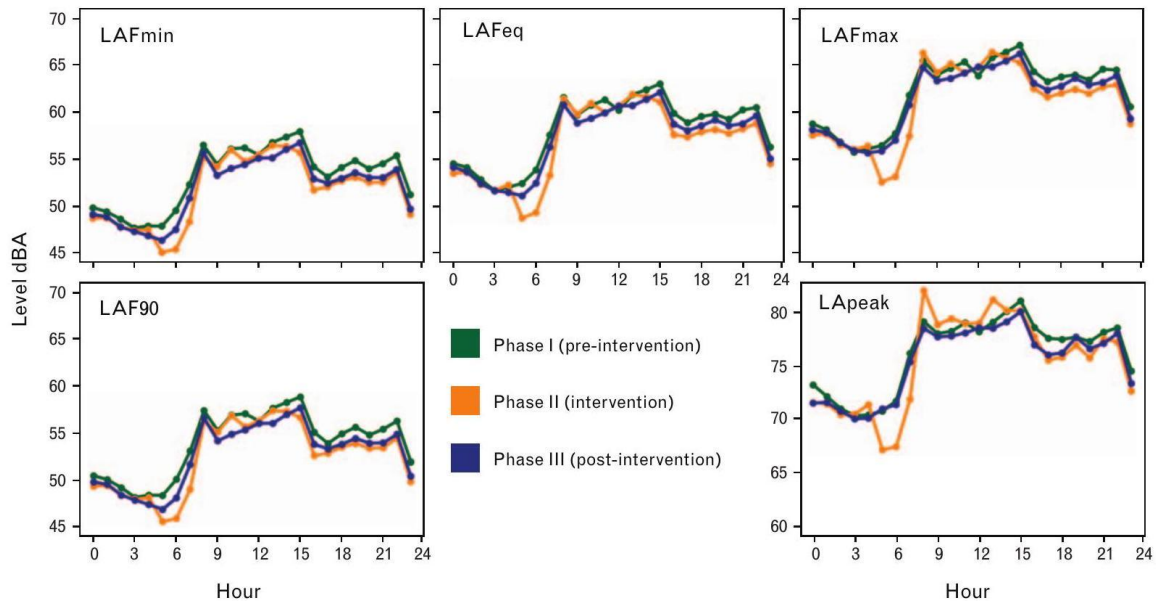
Comparison	Coefficient	95% CI	P value
Intervention (vs. preintervention)	-1.35	(−0.63, −2.08)	< 0.001
Postintervention (vs. preintervention)	-0.86	(−0.16, −1.56)	0.02
Postintervention (vs. intervention)	0.5	(−0.13, 1.13)	0.12

Subgroup analysis: LAFeq at night-time (22 to 08 h)

Comparison	Coefficient	95%CI	P value
Intervention (vs. preintervention)	-1.67	(−0.45, −2.89)	< 0.01
Postintervention (vs. preintervention)	-0.79	(0.39, −1.97)	0.19
Postintervention (vs. intervention)	0.88	(−0.17, 1.92)	0.1

CI , confidence interval.

Fig. 1



Mean noise levels per hour before, during and after the implementation of the visual noise warning system.