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Noise in the ICU

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Abstract. *Objective:* The growing number of technical devices in ICUs makes noise exposure a major stressor. The purpose of this study was to assess noise levels during routine operation in our ICU.
Design: Our ICU is an open ward with four rooms, constructed in the 1960s. During the study period, 4 patients were in the controlled room and were treated by 4 nurses during the day and by 2 at night. A-weighted sound pressure levels (SPL) were measured continuously for 2 days and nights. Also measured were the alarms of various appliances. For gross overall evaluation it is customary to state the L_{eq}, i.e. the energy-averaged level during measurement. The annoyance caused by noise depends more on rare events of high intensity. Therefore, the distribution of SPL values (L_n) over time was also analysed.
Results: SPL was roughly the same during the day and at night, with L_{eq} between 60–65 dB(A) and peaks up to 96 dB(A). Most alarms reach an SPL of 60–70 dB(A), but some exceed 80 dB(A). During teaching rounds L_{eq} exceeds 65 dB(A).
Conclusion: During the day and at night SPL always surpasses the permissible noise exposure for 24 h of 45 db(A) recommended by the US Environmental Protection Agency. Alarms cause the most irritating noise. Hospital management should pay attention to internal noise, and SPL should be measured routinely.

Key words: Noise – Alarms – ICU

Although all intensive care units (ICUs) pay careful attention to hygiene problems and air pollution, the acoustic environment of an ICU is most frequently neglected. Noise levels at industrial plants are monitored regularly, and recommendations or even stringent laws govern allowable noise exposure.

The steadily growing number of technical devices increase the "acoustic pollution" of our ICUs, because every machine in use is monitored by acoustical alarms [1, 2].

Various monitors like ECG, pulse oximetry, balloon pump etc., emit a steady signal, while some respiratory equipment, like continuous positive airway pressure (CPAP) devices, create constant noise. Telephones and pagers call out day and night. Not to be overlooked is the conversation of the nursing staff, of doctors on their rounds etc. Wherever there are several patients in one room, noise exposure is most irritating disrupting the concentration of the staff and disturbing patients. Some reports assert that even anaesthetized patients are aware of noise, so we must expect all sedated patients to perceive noise [4]. The actual and definitive effect has never been clearly determined until now [2].

The purpose of this study was to assess the noise levels (SPL) at our ICU.

Methods

ICU characteristics

Our ICU is an open ward with 4 rooms for 4 patients each. All rooms open onto a central corridor with administration desk, 3 telephones and central monitoring.

The building was constructed in the mid 1960s and the ICU opened in 1969. Every room is 6×6 m square with a height of 3.50 m. Noise was measured in a room with 4 patients; initially all were mechanically ventilated. Two patients were extubated during the study period, and one patient was on intermittent haemodialysis. For every patient the following devices were in use: 1 ventilator, 1 bedside monitor with ECG, 3 pressure lines (AP, CVP, PAP), pulse oximetry, 2 infusion pumps and 3 motor syringes; the patient on haemodialysis required one additional infusion pump and 4 additional motor syringes. At least 18 alarms were set for each patient, although only mean pressure values and not systolic and diastolic pressure were controlled by alarms.

During the day 4 nurses, and at night 2 nurses, worked in this room; teaching rounds with 6–8 persons were made twice a day.

Method of measurement

Two types of measurement were carried out in this study. In the first type, the overall A-weighted sound pressure level (SPL) present in the ICU under normal operation was monitored for 48 h. The second type involved the noise produced by several typical instrument alarms, such as respirators, monitors and infusion pumps (Table 2).

Decibel (dB) measurements were made on the A scale, which approximates the greater sensitivity of the human ear to higher frequencies and is the scale most commonly used in noise surveys and legal recommendations

$$\text{db(A)SPL} = 2\log_{10}\frac{\text{A-weighted SP}}{0.0002\ \text{dynes/cm}^2}$$

dB(A) is a logarithmic expression of sound pressure with respect to a reference sound pressure of 0.0002 dynes/cm^2.

1. Measurement of overall noise. For this type of measurement the microphone was placed at one side of the opening from the ICU room to the central corridor at a height of 1 m above the floor, with the distance to the patients beds ranging from 3.0–6.5 m. Measurements were carried out using an SPL meter type 2209 equipped with a half-inch microphone type 4134, Brüel & Cjaer (B+K). The output of the SPL meter was recorded on a strip chart. A continuous recording over two 24-h periods was taken. A follow-up measurement of 20 min was performed under similar conditions using the same microphone in conjunction with a B+K preamplifier type 2819 and a sound analyzer type 110 (SA 110), Norwegian Electronics. Rapid registration allowed a more detailed evaluation of the distribution of SPL.

2. Noise measurement of instrument alarms. The measurements were recorded in one of the ICU rooms, unoccupied at the time. The room is identical in size and equipment to the other rooms of the ward.

To obtain a representative sample of a patient's noise exposure under typical conditions, the measuring microphone was placed at a distance of 1 m from the source and a height of 1 m above the floor.

3. Counting alarms. During two 4 h day and night periods alarms were registered by a nurse for every patient in this ICU room.

Analysis of SPL

For gross overall evaluation it is customary to state the L_{eq}, i.e. the energy-averaged level during the measurement period. The distribution of noise level over time L_n, expresses the fact that for n percent of time the acute SPL reaches or exceeds the value L_n. Thus, L_1 indicates rare events of high intensity, while L_{99} corresponds to the base level that is almost always surpassed by the instantaneous SPL.

Results

Measurement of overall noise

The limited resolution of the recording permits only semiquantitative conclusions:

- During daytime hours for intervals of 20 min or more the L_{eq} fluctuates between 60 and 65 dB(A).
- For intervals of a few minutes L_{eq} may climb to values between 70 and 80 dB(A) during periods of special activity (e.g. dialysis).
- During doctor's rounds (4–8 persons) L_{eq} exceeds 65 dB(A).
- During daytime hourse even the minimum SPL is slightly in excess of 50dB(A).
- Even at night the 20-min L_{eq} stays close to 60 dB(A) and events with levels exceeding 70 dB(A) frequently occur. (Elevated levels occurring within 1 min and spikes separated by more than 1 min were counted as separate events. During the first night between 10 pm and 4 am there were 53 events exceeding 70 dB(A) and 9 events exceeding 75 dB(A) and during the second night 50 and 6 such events, respectively.
- Elevated dB(A) level events occur at irregular intervals and the mean time between such events (approximately 7 min) is not very relevant. The longest intervals uninterrupted by events of 70 dB(A) or more were found to last 22, 18 and 15 min during the two nights of observation.

Table 1. Distribution of sound pressure levels in dB(A) during a 20-min period

L_{eq}	L_{min}	L_{max}	L_1	L_{99}
63	48.5	96	69.8	50.8

L_{eq}, Averaged SPL during the measurement period; L_1-L_{99}, SPL during 1 to 99 percent of time; L_1, indicates rare events of high intensity, while L_{99} corresponds to the constant base level, that is almost always surpassed by the instantanous SPL

Table 1 lists the dB(A) levels of a 20 min measurement period reaching a maximum of 96 dB(A).

The distribution of A-weighted SPL values is presented in Fig. 1. It shows the percentage of time during which the SPL was within a specific interval with a range of 2 dB(A). It must be noted that prominent bars between about 50 and 64 dB(A) represent the rather steady and relatively moderate background noise, while the innocuously looking low percentage values at higher noise levels are the actual disturbance.

Measurement of instrument alarms

Table 2 lists the measurement recorded for the different alarms. Some of the alarms show a pronounced directivity. Most alarms reach SPL of 60–70 dB(A), but some exceed 80 dB(A).

Counting alarms

On average 2.1 ± 0.8 alarms/patient/h were registered, but for one patient in very unstable condition 42 alarms/h were counted (patient on ventilator and haemodialysis + 24 possible alarms).

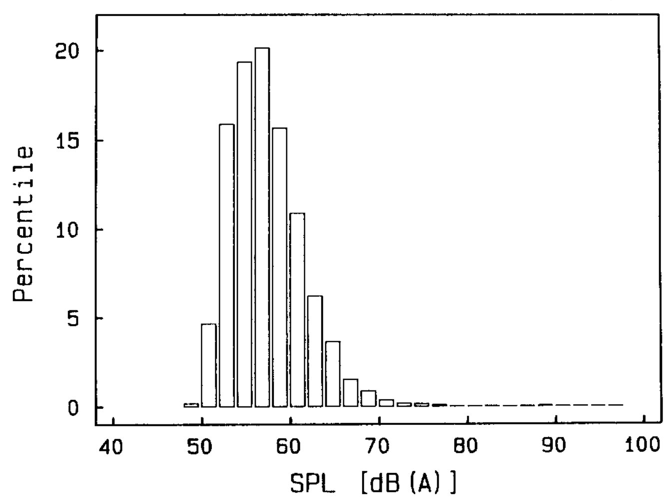

Fig. 1. Differential sound pressure level distribution for a level class width of 2 dB(A) measured in ICU at normal occupation

Table 2. Sound pressure levels in dB(A) for instrument alarms

Intrument	Alarm type	L_{eq}	L_1	L_{10}	L_{50}	L_{90}	L_{99}
Servo ventilator 900 C	i	75	78	77	75	70	69
Servo ventilator 900 C (power failure)	i	78	82	80	77	73	70
Evita	i	64	69	68	63	54	52
Sirecust 302 D	c	67	68	68	67	66	65
Hellige 610 (weak)	v	56	61	60	55	53	53
Hellige 610 (strong)	v	74	77	75	74	73	72
Diginfusa Habel	c	62	64	62	61	61	61
MGVG-IP	c	58	59	59	58	57	56
Volumed	s	57	64	63	49	42	39
Haemodialysis	c	56	60	57	56	56	55

Alarm type is indicated as i for intermittent, c for continuous, v for variable, s, for single (activated manually to produce an intermittent signal for the measurement

Discussion

In order to assess the data it is helpful to recall that the sound pressure level (SPL) in dB(A) is proportional to the logarithm of the sound intensity (incident sound energy/m^2.s). A consequence of this logarithmic scale is that a rise in SPL of, e. g. 3 dB, 6 dB or 10 dB, corresponds to an increase in sound energy by a factor of 2, 4 or 10, respectively. The A-weighted SPL quoted in dB(A) makes allowance for the fact that the human ear is most sensitive in the range from 500 Hz to 7 kHz and is rather insensitive to very low and very high frequencies. An SPL increase of 10 dB roughly corresponds to a doubling of subjective loudness sensation.

For a better idea of the perception of noise, Table 3 shows a list of SPL values of everyday life, so that we can compare the obtained measurements with familiar levels.

Our measurements show that the constant background noise and the L_{eq} in the ICU are very similar during the day and night (60 dB(A)) with sound peaks of 70 dB(A) and more at irregular intervals. This short-duration events of elevated intensity are irritating precisely because of their irregular occurrence, interrupting periods of relative quiet. The annoyance caused by noise depends more on L_1 (SPL for 1 percent of time) indicating rare events of high intensity. Indeed, the SPL of the ICU exceeds the permissible noise exposure for 24 h of 45 dB(A) recommended by the US Environmental Protection Agency [5]. Noise constantly disturbs ICU patients, because the intervals between the sound spikes are very short. Even at night the longest quiet interval was only 22 min.

Table 3. Examples of tpyical sound pressure levels in dB(A)

0 – 10:	oppressing quiet
10 – 20:	rustling leaves
20 – 30:	internal noise in houses with good sound insulation
30 – 40:	base level at night in urban quarter
40 – 50:	passing car (inside house with closed windows)
50 – 65:	quiet speech and music
65 – 80:	loud speech and music
80 – 90:	traffic noise on main road
90 – 100:	disco
100 – 120:	propeller plane during takeoff
120 – 140:	jetliner during takeoff

Experimental studies with animals have demonstrated that the pituitary-adrenal axis is stimulated by noise and that noise exceeding 70 dB(A) causes vasoconstriction [4]. Sleep is disturbed by noise, an experience everyone has already made [4].

It has been suggested that high-intensity noise in the incubator can induce hearing loss in preterm neonates and that this stress can be the cause of sensory deprivation [6, 7]. Noise can be one of the reasons for so-called ICU psychosis [4]. Clinical studies have reported that the ability to solve problems and to tolerate frustration decreases when peoble are exposed to noise [3, 8].

It is undesirable for patients in critical condition to be irritated by the additional stress factor noise. But noise also exerts severe stress on the medical staff and must be considered one of the important stressors of ICU nurses, even if its health hazard is not easy to prove [3, 8 – 11].

The staff should be reminded of noise levels and the organisation of work at an ICU should respect patients' circadian rhythm.

Some alarms can be muted at night [2]; most alarms reach an SPL of loud music or traffic on a main road (Table 2). Some alarms even reach the SPL of a diesel truck (84 dB) or the cockpit of a propeller aircraft (88 dB) [11].

Whenever possible, alert patients should be separated from unconscious patients undergoing highly invasive intensive therapy. A headphone with selected music can screen patients from external noise and influence their mood [12].

Part of the internal noise is caused by people who are usually unaware that they are creating a disturbance. Therapy discussions should not be held at the beside. Teaching rounds with residents and students (65 – 70 dB(A)) should be kept as short as possible: actual test findings, X-rays and treatment can be discussed in a separate conference room. With the increasing number of technical appliances, different categories of alarms could be useful to distingusih between life-threatening events and insignificant disturbances [13].

Hospitals pay much attention to external sources of noise, such as street traffic or incoming planes, but little effort is made to control internal noise [2, 13].

The increasing number of technical appliances in the hospital changes sound pressure levels (SPL), therefore, noise should be controlled routinely and adequate measures initiated to ensure its reduction.

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