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NOISE IN THE INTENSIVE CARE UNIT (ICU)

Daniela T. Cianci and S. Kanapathipillai
School of Mechanical and Manufacturing Engineering,
The University of New South Wales, Sydney 2052, Australia
s.kanapathipillai@unsw.edu.au

Abstract

A comprehensive literature review of noise levels in the hospital intensive care unit (ICU) revealed that noise is a problem in the ICU. Numerous studies conducted in overseas hospitals consistently found that the noise levels exceeded recommended levels. Patients in the ICU are in a critical condition. Noise can prevent a person from sleeping and can be offensive. Sleep deprived patients may experience slow tissue growth and depression coupled by the strain of being in a serious state of health.

A study was conducted that involved a noise level analysis of a prominent Australian hospital's ICU. It found that the noise levels exceeded the maximum recommended design sound level prescribed by Standards Australia Investigation into the cause of the high noise levels revealed a number of sources. Recommendations were made to reduce noise levels in the ICU and design features were suggested that could reduce sound exposure to the patients.

1. INTRODUCTION

Hospital noise in general has been a topic of interest in many hospitals around the world. Numerous studies in hospitals consistently found that noise levels exceeded recommended levels [1], [2]. Khan et al state that noise levels in ICU are exceedingly high. Excessive noise can affect the comfort of a patient, interrupt or prevent sleep, and be offensive. Sleep is an important part of a patient's recovery that promotes physical and emotional healing [4], [6]. Sleep deprived patients may suffer a range of psychological conditions, such as depression, confusion, impaired memory and paranoia. The physical affects include slow tissue repair, an increased susceptibility to infection and less tolerance to pain. Therefore, noise in the ICU was a critical area that warranted investigation.

The recommended design sound levels for building interiors as stated by Standards Australia (AS/NZS 2107:2000) are defined in terms of the A-weighted time equivalent continuous sound level, L_{Aeq}. For a fluctuating A-weighted sound over a period of time, the L_{AeqT} is the constant sound level that would have the same total acoustical energy as the real fluctuating A-weighted noise over the same period of time [3]. The Standard states that for an Intensive Care Ward the *Satisfactory* L_{Aeq} is 40 dB(A) and the *Maximum* L_{Aeq} is 45 dB(A).

The Satisfactory level is defined by the Standard to be acceptable and not intrusive by most people for an ICU. The Maximum level is defined as the level above which in an ICU most people start to become dissatisfied with. The levels recommended by the Standard are a guide for determining people's acceptance to noise in the ICU and a benchmark for designers.

As technology advances and the number of medical devices increase noise pollution in the ICU is a concern. Two studies were performed, firstly a determination of the L_{Aeq} measured in 15-minute intervals over a 24-hour period to ascertain whether noise levels within the ICU were within the recommended design noise levels. Secondly, an individual noise identification study was performed to determine the maximum sound pressure levels (SPL) of commonly occurring noises within the ICU. The ICU investigated had 12 beds and approximately 25 people working at any one time. Patients were permitted 2 visitors at a time except between the hours of 1 pm and 3 pm for the patient's quiet period.

2. NOISE LEVEL ANALYSIS

An AS 1259 compliant Noise Logger measured noise levels at 3 bedsides for 24-hours. The microphone was positioned as close as possible to the patient's head so as to record the noise patients were routinely exposed to.

2.1 Results

The results of the $L_{Aeq,15}$ measurements have been graphed alongside the maximum and minimum SPL, (L_{Amax}, L_{Amin}) recorded in each 15-minute interval.

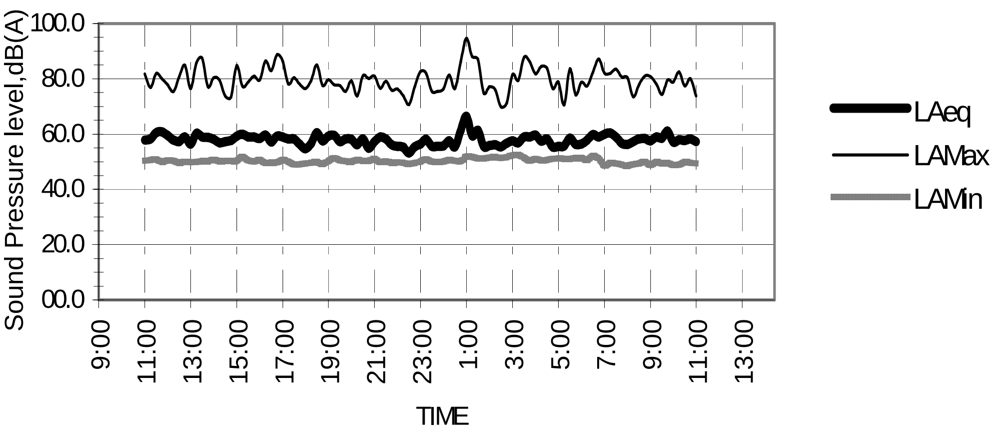

Figure 1. Noise levels in ICU Bed 1 plotted in average 15-minute intervals over a 24-hour period

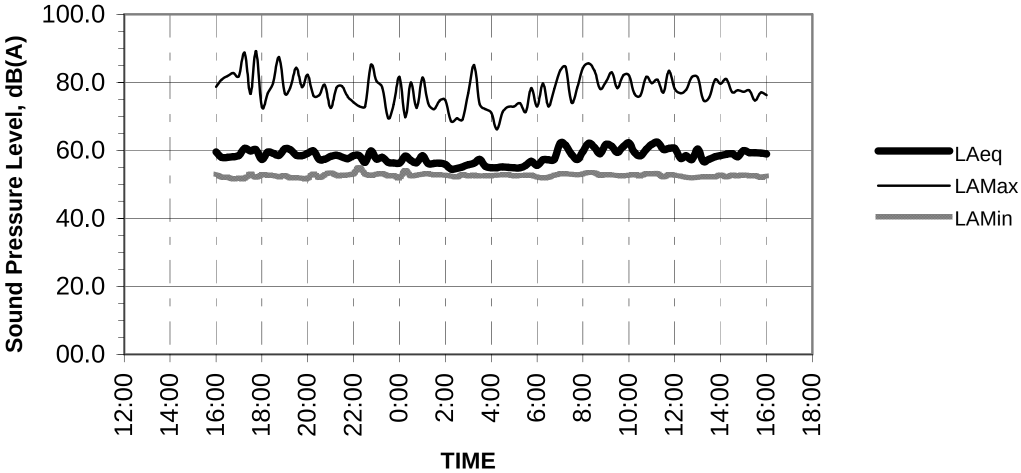

Figure 2. Noise levels in ICU Bed 2 plotted in average 15-minute intervals over a 24-hour period

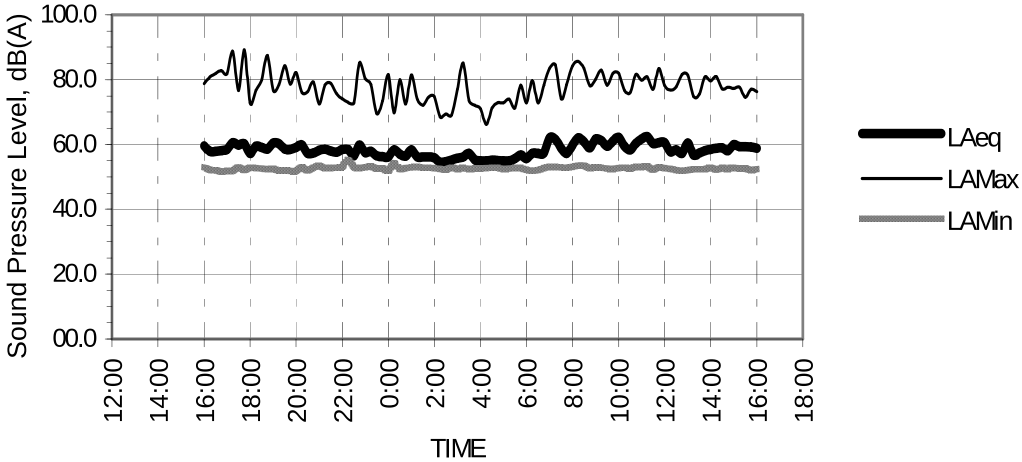

Figure 3. Noise levels in ICU Private Room 1 plotted in average 15-minute intervals over a 24-hour period

The average $L_{Aeq,15}$ for the 24 hours is tabulated in Table 1. Private Room 1 had the lowest 24-hour average $L_{Aeq,15}$. The maximum recommended design sound level is 45 dB(A), the $L_{Aeq,15}$ in each location always exceeded this level.

During the quiet period the average $L_{Aeq,15}$ at Bed 1 and in Private Room 1 was higher than their 24-hour average. The maximum sound pressure level recorded in the ICU occurred at approximately 1 am and was 94.7 dB(A).

Table 1. Summary of results

	24hr Average $L_{Aeq,15}$ dB(A)	Average $L_{Aeq,15}$ for 'Quiet Period' 1 pm - 3 pm dB(A)	Minimum $L_{Aeq,15}$ dB(A)	Maximum Sound Pressure Level dB(A) and Time Event Occurred		Minimum Sound Pressure Level dB(A)
Bed 1	57.9	58.16	53.2	94.7	1 am	48.5
Bed 2	58.6	58.55	54.9	89.2	5:45 pm	51.6
Private Room 1	56.7	58.88	52.0	86.7	3:15 pm	47.5

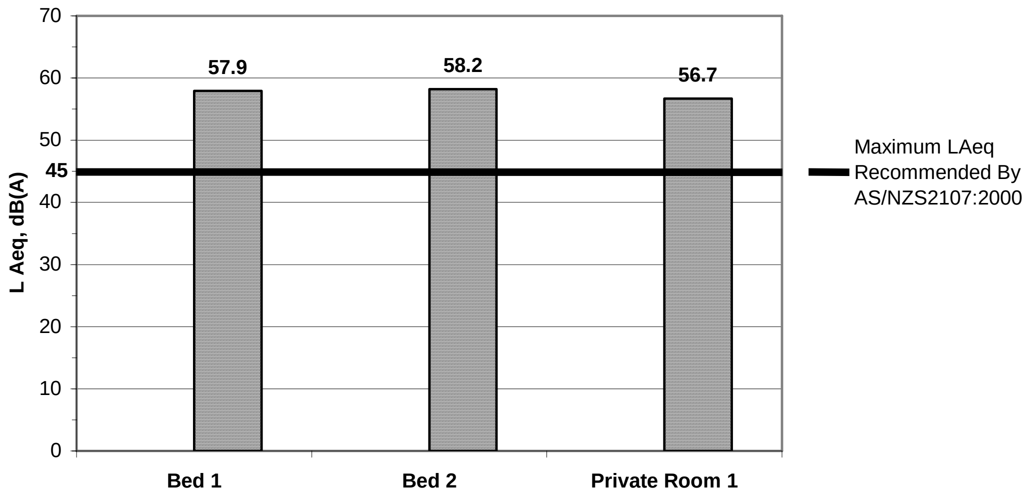

Figure 4. Graphical comparison of 24-hr average L_{Aeq} at each location

The results show that the $L_{Aeq,15}$ was never below 45 dB(A) in the ICU. Therefore, the noise levels exceeded the recommended design sound level range prescribed by Standards Australia. The average 24-hour $L_{Aeq,15}$ levels measured were in excess of the maximum L_{Aeq} of 45 dB(A) by more than 11 dB(A). The human ear's response to an increase in sound pressure level is not linear. An increase of ten 10 decibels results in a doubling of perceived loudness.

The time interval used was 15 minutes. Therefore, the maximum sound pressure level, L_{Amax} recorded was the maximum level that occurred in the 15-minute time interval. The wake-up threshold for a healthy person is 60 dB(A) and for a sick person it is 10 dB(A) lower [6]. The L_{Amax} recorded in the ICU was always above 60 dB(A). Therefore, at least one noise peak of 60 dB(A) or more occurred at least every 15 minutes in the ICU. This would suggest that patients' sleep patterns would have been disrupted.

Sudden changes of sound level can cause excessive excitement and 'startle' reactions, which after repeated occurrence could leave the patient at a heightened state of alarm and not return to the initial level [6]. It is in this state that patients are susceptible to the psychological effects, annoyance and anger and the physical effects of noise such as increased blood pressure and adrenaline secretion [5]. Patients can accumulate a considerable sleep deficit while in the ICU which continues to alter sleep duration even after they are transferred to a ward [5]. Medication and sedatives would influence the arousal response of the patients, but not all patients are sedated in the ICU. Research has revealed that it is wrong to assume that sedated patients are unable to hear [6], that acoustic stimulus is still transferred to the brain. Patients receiving Aminoglycosidic antibiotics can incur hearing damage if exposed to an average noise level of greater than 58 dB(A) [4].

The highest L_{Amax} measured was 94.7 dB(A) at approximately 1 am at Bed 1. A noise measuring 94.7 dB(A) is greater than the noise level of a pneumatic drill. The average $L_{Aeq,15}$ for the quiet period suggests that this time is not particularly quiet. The average noise levels were found to be higher than the 24-hour average for Bed 1 and Private Room 1.

3. NOISE IDENTIFICATION

A Brüel and Kjær sound level meter (SLM) type 2260 Investigator was placed on a tripod at the approximate height of a patient's head while in bed. The A-weighted instantaneous SPL, L_{AINST} of events that caused the SLM reading to fluctuate significantly from the average background noise were manually recorded along with the approximate distance from the SLM to the source of the noise.

3.1 Results

Table 2. Sources of noise and their maximum A-weighted instantaneous sound pressure level, L_{AINST}

Source	**Distance from SLM (m)**	**Maximum L_{AINST} (dB(A)**
Metal drawer closed	1	64.3
Metal bin closed	0.5	74.8
Electric floor polisher	1.5	71.1
Moving chairs	4	74.4
Sink (pipes vibrate)	1	68.7
Phone ringing	2.5	61.3
Conversation between nurses	8	78.8
Sliding curtain for privacy	2	70.7
Preparing medication (metal bench)	1.5	61.9
Suctioning patient	2	78.8
CPAP (open oxygen source)	4	68.1
Equipment Alarms	3	63.3

The noise identification study identified a number of sources of noise that would have contributed to the elevated noise levels measured in the 24-hour study. The most interesting was the high sound pressure level produced by a bin lid closing.

Metal hitting metal produces high sound pressure levels. A maximum L_{AINST} of 61.9 dB(A) was measured when medication was being prepared on the metal bench beside the patient 1.5 m away from the SLM. There is a metal workbench beside every patient bed. Another surprising source of noise was the curtains that separate the ward beds. When it was closed to provide privacy for a patient, a maximum L_{AINST} of 70.7 dB(A) (2 m from SLM) was recorded. The hooks sliding on the track were the cause of this high sound level.

The Individual Noise Assessment identified a possible procedure that may have contributed to the high levels. It was the Continuous Positive Airway Pressure, CPAP used to force air into the nasal passages to overcome blockages in the airway and stimulate normal breathing. Noise from the CPAP when measured four meters from the SLM had an average L_{AINST} of 67.3 dB(A) and a maximum L_{AINST} of 68.1 dB(A). This would certainly elevate the $L_{Aeq,15}$ as the procedure lasts for quite some time. Another medical procedure that may have occurred is Suctioning (removal of fluid from throat and mouth). A maximum SPL level of 78.8 db(A) was recorded during this procedure.

It was found that the average $L_{Aeq,15}$ during the quiet period was sometimes higher or very near to the 24-hour average $L_{Aeq,15}$. This indicates that the quiet period was not always a peaceful time for the patients to rest. Part of the Individual Noise Assessment was conducted during the quiet period. It was observed that during this time there was a changeover of staff as nurses went on lunch breaks, thus, an increase in conversation with regards to the patient's requirements and condition. Staff also congregated together and talked, as it was also a time for them to relax without the patients' visitors present. Upon discussion with one of the nurses present during this time, it was revealed that the quiet period was indeed a time for the staff to unwind without the family of the patients around. This explains the elevated noise levels during the supposedly 'quiet period'.

4. RECOMMENDATIONS

The most simple and inexpensive recommendation that can be given is to make people aware of the issue of noise in the ICU. Designers, engineers and architects need to give more consideration to noise control and design for a quiet environment to assist patients with their recovery. Staff and visitors need also be made aware of the levels of noise in the ICU. Conversation was a common source of noise that needs to be limited. Posters encouraging people to wash their hands feature prominently in the ICU. Similar signs need to be displayed that encourage people to be mindful of the noise they make. Staff need to observe the quiet period and not use the time to talk to other staff members.

Conversation between medical staff should not be held near the patients. There are conference areas and tearooms; therefore, they should be used. One must also realise that a patient will involuntarily listen to this conversation. Careful planning of the arrangement of the ICU could greatly reduce the level of noise exposure to the patients. Patient beds could be arranged so they are away from utility rooms and as far from walls as allowable to avoid reverberation. Doors to private rooms should not be directly facing other patient beds on the ward. Noise sources such as the bed buzzer alarm; intercom speaker and telephones should not be directly opposite doors to private rooms to limit the amount of direct sound entering the rooms. Patients requiring noisy medical procedures could be located in a designated area of the ICU away from other patients or placed in a private room.

Sound absorbing ceiling and wall panels could greatly reduce noise exposure to the patients. Panels are commercially available that have anti-bacterial properties making them suitable for hospital environments. Anti-microbial paints can also be applied to panels to prevent growth of bacteria and spread of disease. Acoustic panels reducing noise propagation should be standard in the design of ICUs.

Higher frequencies are perceived to be more annoying by humans. Metal or hard objects impacting produce high frequency noise due to the small contact time. Hard surfaces should be avoided where possible, the use of laminates and rubber should be preferred if metals such as stainless steel are not a requirement. Screens aid noise control by placing an obstacle between the source and the observer. If they are made of a suitably solid material, they prevent direct sound reaching the observer. They are not a perfect method of noise control as diffraction around the top of the screen occurs. This method of noise control could be applied to nurse workstations reducing the amount of direct noise to patients from telephones and talking.

5. CONCLUSION

The noise level analysis of the intensive care unit revealed that the noise levels are too high. The levels exceed the maximum recommended design sound level of 45 dB(A) by at least 11 dB(A). In terms of perceived loudness, a 10 dB(A) increase in SPL is approximately a doubling of loudness. Noises above the wakeup threshold regularly occurred, thus, almost certainly depriving patients of sleep. It is known that sleep deprived patients can experience a number of physical and psychological affects. Therefore, it is concluded that noise is a serious problem in the ICU. Investigation into the cause of the high noise levels revealed that most of the noise patients were exposed to could be prevented or reduced.

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