

Noise Levels in a Medical Intensive Care Unit

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Abstract: This study was undertaken to investigate and analyze noise pollution in a large Chinese governmental hospital's medical intensive care unit and compare to the WHO guidelines. This cross-sectional study was conducted in a MICU at a public governmental teaching hospital in Fujian province between July and August of 2017. A WENSN® WS1361 Integrated Sound Level Meter (China) was used for continuous every five seconds one week noise levels recording. After this measurement, the decibel meter was used for recording different location of isolation rooms and open bays, including occupied and unoccupied patient, and recording sound events occurs in the ICU to identify sources of noise. Peak and average noise levels were obtained from the meter, and data were downloaded from the WS1361 into a laptop computer. The measured mean equivalent sound pressure levels (L) and standard Aeq deviation over one week period were 66.64 ± 7.57 dB(A), with acute spikes reaching 119.7 dB(A), the average sound level for a 24 hour period in a work day was 68.03 ± 5.07 dB(A). These are higher than the current daytime environmental noise limit of 40-45 decibels in China and WHO. Mean work day noise was significantly louder than weekend time, there was a significant difference in work days and weekend ($t=16.85; P=0.000$). There was a statistical difference between the day time and night time shifts ($t=34.67; P=0.000$). The isolation rooms were significantly quieter than the open-bay rooms ($t=46.15; p=0.00$), sound levels in the occupied and unoccupied rooms also had significant difference ($t=17.26; P=0.000$). Two types of noise resources, including twenty kinds sources were identified and measured, mean noise levels ranged from of 61.33 to 79.21 dB(A). This study shows noise levels in intensive care units were exceeded the recommended. The study of the influence of noise on patient and staff is needed, and noise reduction strategies must be conduct in ICU.

Keywords: Noise; Noise Levels; Noise Measurement; Medical Intensive Care Units; Nursing

1. Introduction

In the past half century, the development of science and technology have afforded medical countless new equipment and machines that have allowed patients to undergo medical procedures with improved outcomes[1,2]. However, these beneficial advances are accompanied by the corresponding noises that result from their use[3,4]. In addition, poor design of hospital acoustic environment also contributes to increased noise[5,6].

Noise, defined as unwanted sounds, could affect people both psychologically and physiologically[7]. Noise also has been defined as an accidental sound wave without any rhythm or harmony which can interfere with hearing[8]. To quantify sound levels, the decibel, an arithmetically non-dimensional linear scale, defines measured sound pressure[9,10], in which sound is measured as the force per unit area that sound waves produce. For sound pressure measurement that closely resembles the normal curve for loudness frequency of the human ear, the internationally agreed 'A' weighted filter is used[11].

A hospital intensive care unit (ICU) is designed to treat critically ill patients who need special care and treatment, sometimes at nearly the same extreme level required in an operating room[12,13]. ICUs contain many sources of noise, such as aspirators, monitors, mechanical ventilators, computers, printers, air conditioning vents, and others[14]. The adverse effects of elevated noise in hospitals have been documented in many researches, high noise levels interfere with communication, leads to attention loss, irritability, fatigue, headache, muscle contractures, increased heart rate and blood pressure, in addition to worsened quality of sleep both in the healthcare professionals' team and patients[15-19].

The improvement of technology has increased noise levels in Intensive Care Units, many hospitals fail to meet the limits of noise guidelines recommend by the World Health Organization. The assessment of noise and the impact of noise pollution have been extensively studied in the developed countries, but there were not many studies about this in China.

Noise generated in ICUs has increased in recent decades due to a substantial increase in the number of devices with acoustic alarms, and background noise by actions and speaking of healthcare professionals[14,20,21]. Many researches show that noise levels measured in ICU are far exceeding the recommended standards for hospitals and generally measured around

60–70 dB (A), with peaks rising up to 80–120 dB (A)[2,20-27]. The World Health Organization has drawn up guidelines for community noise management, the recommended noise levels in hospital should be 35-40 dB(A) in the daytime and 30-40 dB(A) in the evening[1,20,28,29]. According to the Emission Standard for Community Noise of China, the background noise limit for a medical institution is 40-45 dB at daytime and 30-35 dB at nighttime.

Due to the importance of noise pollution level in the ICU, the purpose of this study was to measure noise level in an MICU, compare the results to recommended levels, identify some sources of noise and to develop effective noise reduction strategies in the future.

2. Materials and Methods

2.1 Ethical

The hospital ethics committee approved the study. The patients and MICU staff were informed about this study, no individuals were recruited for participation in the study and patient care was not affected during the collection of data.

2.2 Study Design and Setting

This was a cross-sectional study. It is a quantitative, descriptive and exploratory study using data collected in a MICU at a public governmental teaching hospital in Fujian province between July and August of 2017. The hospital is located on the crossroads of main road in the heart of Fuzhou municipal (province capital, 7,115,370 inhabitants), MICU is on the hospital's sixth floor and has a rectangular shape, including 15 open-bay rooms and 5 isolate rooms, five of the rooms are contact isolation rooms with 3 walls and a automatic door, whereas the other patient care bays are open bays with 2 walls and a curtain.

2.3 Instrument

The equipment used in this study included a portable computer equipped with the Sound Level Meter software (provided with the device) and a sound level meter with a tripod.

The variable noise was measured using a WENSN ® WS1361 Integrated Sound Level Meter (WENSN, Shenzhen, Guangdong) with scale A and scale C, and fast and slow two channels, the readings are in Decibel, A-weighted (dBA) units representing the sound level measured with the A-weighting network on the sound level meter. Officers from the Aural Displays and Bioacoustics Branch were consulted regarding the reliability and validity of the

WS1361. the WS1361 provided a direct reading of sound over the ranges of 30–130 dB(A), with accuracy of ± 0.5 dB(A) at 25 degree centigrade. with an accuracy of less than ± 1 dB(A) over temperature ranges 0–50 °C.

Scales A and C under fast mode were used to register the data because that speed makes it possible to measure kinds of noise that do not oscillate rapidly. Scale A (dBA), is the filtering method that simulates the receptive characteristics of the human ear and it is recommended to capture continuous noise, mostly used for measuring environmental noise. A common method used in the discussion of noise pollution is the equivalent continuous noise level (Leq) expressed in dB(A), the other variables obtained were percentile level LN, such as the L10 and L90, the maximum and minimum noise levels recorded at the same measurement period

2.4 Data Collection

The data were collected during 2015, according to the Emission standard for community noise (China, 2008), the WS1361 equipment was placed at approximately a distance of 1 m from the sound sources or 0.5 m from reflector, set up on a tripod and 1.2 m from the floor. Utilizing this distance from the floor, the equipment was placed in the middle of the nursing station and patient room and so on. The device was calibrated according to the manufacturer's instructions for standardization purposes before starting each measuring task.

Measurements were made in 4 phases, the noise level measurements did not, at any time, interfere with the work of the staff. A major concern during the data-collection procedure was to ensure that no bias existed while the measurements were being taken.

Phase 1 Implement pilot measurement to confirm the reliability and validity of the data collected. With prior authorization from the hospital and department management, first day was explained the purpose of the research and where the measuring was taking place to the staff including physician, nurse and other person in MICU. After that, the WS1361 equipment with a tripod was continually placed in the middle of the nursing station started to pilot measurement. Because of the direct measurement of noise levels within a clinical environment meant there was the potential for staff influence the noise levels primarily through the 'Hawthorn effect' inasmuch that individuals who are aware of their participation in a study change their behavior accordingly[28,30-32]. Pilot measurement would help to

reduce the possible influence hospital staff may have had on the noise levels being recorded in their respective areas[14]. This phase constants one week, the data was discarded.

After one week pilot measurement, the staffs were familiar with the equipment and researchers to continue with their routine activity. In phase 2, the ambient noise in the MICU was measured. The sound levels meter placed at the same position of phase 1, without the knowledge of the staffs when the measuring was started, the researcher who collected data was in there sporadically as before. This phase constants one week, from Monday to Sunday, the day shift (8:00 a.m. to 8:00 p.m.), versus night shift (8:00 p.m. to 8:00 a.m.) and work days (Monday to Friday) versus weekend days (Saturday and Sunday) were considered in the analysis.

Phase 3 was to make measurement in both occupied and unoccupied patient rooms in different location of the unit.

In phase 4, measurements of different events or routine activities to identify sources of noise in MICU were taken. Any specific events that were thought to contribute to excessive noise were also to be measurement and documented.

Phase 3 and phase 4 were took place in day time (8 a.m. to 12 a.m. and 2 p.m. to 6 p.m.) which recommend by the Emission standard for community noise (China, 2008). During the measurement, at 24 hours intervals the device was connected to a computer with the Sound Level Meter software that stored and read the data specifics. When the collection was complete, the data were transferred to SPSS, for analysis.

2.5 Statistical Analysis

Descriptive results were given in frequencies and percentages. Continuous variables were compared using the Student t test. If more than 2 variables were compared, a 1-way analysis of variance (ANOVA) was used. Statistical significance was defined as a P value<0.05. Data are shown as mean±SEM. All data analysis was performed using the Statistical Package for the Social Sciences for Windows 19.0 (SPSS Inc., Chicago, IL, USA).

3 Result

During the study, the beds occupation rate in the MICU was 98%, similar to the same period of last two years 99% and 97%, staffs present as usual and without any construction change.

The measured mean equivalent sound pressure levels (L) and standard Aeq deviation over one week period were 66.64 ± 7.57 dB(A), with acute spikes reaching 119.7 dB(A), Mean work day noise was significantly louder than weekend time, there was a difference in work days and weekend(Table 1).

Table 1- Noise levels recorded by week time in MICU

Variables	L _{Aeq}	Minimum	Maximum	L ₁₀	L ₉₀
Hold week	66.64(7.57)	60.98(3.91)	84.58(9.27)	72.97(5.30)	63.44(2.54)
Work days	67.13(3.30)	61.87(3.75)	88.62(8.49)	75.67(4.33)	64.32(2.43)
Weekend	63.39(7.94)	59.19(3.78)	78.41(7.72)	67.58(1.58)	61.67(1.78)
t	16.85	2.62	3.68	8.75	3.50
P	0.000	0.028	0.005	0.000	0.007

Result express as mean(standard deviation)

The average overall sound level for a 24 hour period obtained in a work day during the continuous weekly measurement was 68.03 ± 5.07 dB(A).When comparisons were made between nursing shifts (day and night), mean noise levels reported ($t=34.67; P=0.000$) were found to be statistically significant differences(Table 2).

Table 2- Noise levels recorded by nursing shift in MICU

Variables	L _{Aeq}	Minimum	Maximum	L ₁₀	L ₉₀
Hold day	68.03(5.07)	61.99(2.35)	81.96(9.11)	72.96(5.51)	66.23(3.55)
Day	70.25(4.91)	62.59(2.52)	88.66(4.02)	76.74(3.28)	67.83(3.19)
Night	65.80(4.16)	61.39(2.04)	75.60(8.45)	69.19(4.63)	64.62(3.20)
t	34.67	2.55	7.60	6.98	4.17
P	0.000	0.018	0.000	0.000	0.000

Result express as mean(standard deviation)

Noise levels were variety in different location of the department, dataset recorded in bedside showed that room near nursing station had higher mean noise levels than those far from it, the distribution of the noise levels measured in different location are given on Table 3. Mean noise levels in isolation rooms was significantly different($t=46.15; p=0.00$) with the open-bay layout rooms(Table 4), the results also showed that the sound levels in the occupied and unoccupied rooms had significant difference($t=17.26; P=0.000$).

To determine the dominant noise sources, the magnitude and frequency of noise sources were obtained, two types of noise resources were identified and measured, equipment and its

alarm and human vocalization (Table 5).

Table 3- Noise levels in different locations of MICU

Locations	Mean	SD	Minimum	Maximum	Confidence limit (99%)
Bed 1	67.30	4.70	59.1	83.7	66.44-68.16
Bed 2	64.01	3.56	58	82.9	63.35-64.66
Bed 3	63.03	4.13	56.1	89.1	62.27-63.79
Bed 4	69.25	4.89	60.5	87.3	68.35-70.15
Bed 5	66.73	3.52	60.9	91.1	66.09-67.38
Bed 6	67.11	3.54	60.7	79.6	66.46-67.77
Bed 7	66.24	6.26	59.2	90.9	65.09-67.39
Bed 8	64.74	3.70	58.8	76.2	64.06-65.42
Bed 9	65.94	3.82	60.1	87.6	65.23-66.64
Bed 10	66.19	5.57	58.4	92.1	65.17-67.22
Bed 11	61.31	3.46	56.5	86.9	60.67-61.94
Bed 12	66.23	5.01	58.3	90.2	65.30-67.15
Bed 13	64.51	3.52	58.6	89.6	63.86-65.15
Bed 14	66.19	3.90	59.7	82.9	65.48-66.91
Bed 15	69.36	3.87	62.5	87.8	68.65-70.07
Bed 16	58.76	2.14	55.2	66.3	58.34-59.16
Bed 17	63.49	2.68	58	78.8	63.00-63.99
Bed 18	57.69	3.64	51.8	66.4	57.01-58.35
Bed 19	58.07	6.74	51.7	97.8	56.65-59.49
Bed 20	56.33	2.96	53.2	77.1	55.78-56.87

Table 4 Noise levels recorded by room type and occupation

Locations	Mean (SD)	t	P
Room type (Unoccupied)			
Open bay	63.94 (3.29)	46.15	0.000
Isolated	51.83 (2.00)		
Occupation (Isolated room)			
Unoccupied	51.83 (2.00)	17.26	0.000
Occupied	56.33 (2.96)		

Table 5- Noise sources and levels recorded in the MICU

Events	Mean	Standard Deviation
Mechanical noise		
Cardiac monitor	74.26	6.68

Ventilator	70.20	3.06
Vacuum extractor	72.12	5.73
Infusion pump	71.34	4.20
Atomization device	64.54	6.05
Oxygen	64.58	3.99
Medical cart	73.04	9.76
Radiology	73.61	8.14
Printer	72.57	7.13
Telephone ring	74.12	6.15
Human vocalization		
Nursing intervention	70.64	8.13
Medical treatment	71.41	4.69
Replacing beds	73.42	5.18
Patient admitting	74.02	7.09
Centralize visiting	73.20	4.43
Conversation	75.51	6.99
Bedside endorsement	79.21	5.49
Conference	61.33	6.28
Footsteps	64.76	3.43
Cleaning or sweeping	74.35	5.09

4 Discussion

The results of our study showed that the constant measurement of mean sound level during a week and a work day were 66.64 dB(A) and 68.03 dB(A), respectively, with maximum level reach 119.7 dB(A). Consistent with and correlate well with previous studies in ICU throughout the different countries with average sound level measurements between 60 to 80 dB and peaks reaching over 110 dB[2,18,20-22,24-27,29,32,33]. Those results were far beyond the standards recommended by WHO and the Emission Standard for Community Noise of China for hospitals and ICU. However, a recent literature review reported that no study found that the noise level in the ICU was within the recommended levels by the WHO and/or the EPA[14,19,20,26].

The distribution of mean noise levels measured for 24 hours in a work day vary systematically over the day, and the data recorded evidenced a higher level in the day shift. This finding similar to the results of some studies in which sound levels in the ICU were lower at night than during the day[2,8-10,12,14,20,24,26,33-35]. The mean noise levels measured at each location differ statistically, the wards located close to nurses' station were suffer higher mean noise levels than those away from it(Table 3). Though the ICU is as an

emergency unit, our study found mean noise levels was significant different in work day and weekend, work days were shown to be more noisy, this was perhaps there were different work routines and different number of staff present between work day and weekend.

It can be seen from the results that the level of noise in different locations of department and the mean minimum noise level during one week measurement period did not drop below 50 dB(A), this can be explained by the very nature of the environment, the ambient environment of the MICU is filled with high noise levels. Noise in a public hospital is unavoidable but at the same time, long-term noise exposure is regarded as a health hazard[36], and numerous previous studies had showed that high noise level has deleterious physical and psychological effects on both patient and staff, such as hypertension, altered heart rates and muscle tone, headaches, hearing loss, mental confusion, low attention span and irritability[4,15-19,25,31,34,37-42].

According to Emission standard for industrial enterprise noise at boundary (China,2008), 8 hours of continuous exposure to a noise level of 85 dB is permissible daily. Although the mean noise levels during constant measurement period no values above 85 dB in this study, the mean maximum noise level was close to it, and the work day had exceeded it (88.62 ± 8.49). Typically, the maximum noise level events did not continuously over an 8-hour per day, most were intermittently about 30 seconds. This value may indicate the risk of developing negative effects solely from the exposure. However, the longer noise exposure, the higher risk obtained, and patients and healthcare staff may be affected alike. Ways and means of reducing the levels of noise in preclinical should be taken into consideration because these noise levels have a potential to cause damage over a prolonged exposure.

Previous literature show that, since the 1960s, the average noise levels inside hospitals have increased by an average of 0.38 dBA (day) and 0.42 dBA (night) per year[43]. As noise in a workplace may originate from several sources, noise levels increased in ICUs maybe due to a substantial increase in the number of devices with acoustic alarms, and background noise by actions and speaking of healthcare professionals[14].

In our study, as there were many active noise sources at the same time and sound events were not isolated, we were not able to appreciate the entire noise sources, two types of noise resources, mechanical noise and human vocalization, including twenty kinds' sources that

familiar in ICU were identified, and most of those noise sources' mean levels are higher than average level of the day (Table 5), thus, those noise sources may be the main events related to increased noise levels in ICU.

The exact source of excessive noise pollution within the ICU is multi-factorial, some researchers suggested that the majority of noise created in their ICU was created by mechanical alarms[25,32], while others discovered that medical and more so nursing staff were just as responsible for noise production in the ICU[11,24,44]. Obviously, it is difficult to attribute blame to which source is responsible.

Our study found there was significant difference between occupied wards and unoccupied wards which without equipment operated, and there was statistically significant differences in work day and less staff present's weekend. It makes clear that both mechanical noise and human vocalization contribute to make our MICU a noisy environment. Furthermore, the potentially poor acoustical design in the ICU may be integrated together to increased noise levels.

As noted by Konkani and Oakley[12] reduction of sound levels in hospital ICUs to the recommended level of 45 dB(A) is clearly an important goal, there is a great deal of work remains to be done to make significant progress in this area. A calm and pleasant healing environment may benefit both patients and health care staff alike[3,5,27,29,37,42,45,46].

There were a few limitations to our study. Although there was a pilot measurement to confirm the reliability and validity of the data collected, the potential for the Hawthorne effect still cannot be ruled out. Without implementing long-term constant measurements, the nursing staff may have been more cautious about their behaviour and intentionally decreased the noise level. Because there were so many noise sources at a time in MICU, it was difficult to identify the noise sources separately and measure noise levels in different locations at the same time. We did not measure the spectral content of the sound, neither. In addition, we made no measurements of the perception in both health care staff and patient, and the influence of noise on them.

5 Conclusion

The findings of this study validate those of other studies conducted in MICU, it showed that MICU is indeed a noisy environment, the excessive sound levels that do not meet Chinese or WHO's standards and recommendations for hospital and ICU. The MICU noise levels were found to be high especially during day time and work days. The distribution of noise levels in different locations and different room styles were differed significantly, and there is still need to elucidate the exact sources of noise. In conclusion, this study makes it clear that action strategies should be taken to reduce noise levels in ICU.

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