Identification and Modification of Environmental Noise in an ICU Setting*

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Study objectives: **Noise levels in the hospital setting are exceedingly high, especially in the ICU environment. We set out to determine what caused the noises producing sound peaks ≥80 A-weighted decibels (dBA) in our ICU settings, and attempted to reduce the number of sound peaks ≥80 dBA through a behavior modification program.**

Design: **The study was divided into two separate phases: noise identification and a trial of behavior modification. During the noise identification phase we simultaneously recorded sound peaks and the loudest noise heard subjectively by one observer in the medical ICU (MICU) and the respiratory ICU (RICU). During the behavior modification phase of the study we implemented a behavior modification program, geared toward noise reduction, in all of the MICU staff. Sound levels were monitored before and at the end of the behavior modification trial.**

Setting: **The MICU and RICU of a 720-bed teaching hospital in Providence, RI.**

Participants: **All ICU staff during the study period.**

Interventions: **Once the noises that were determined to be amenable to behavior modification were identified, a behavior modification program was conducted during a 3-week period in our MICU. Baseline and post-behavior modification noise recordings were compared in 6-h intervals after sites were matched by number of patients in a room and Acute Physiology and Chronic Health Evaluation II (APACHE II) scores.**

Measurements and results: **We identified several causes of sound peaks ≥80 dBA amenable to behavior modification; television and talking accounted for 49%. We also significantly reduced the 24-h mean peak noise level (p=0.0001), as well as the mean peak noise level (p=0.0001) and the number of sound peaks ≥80 dBA (p=0.0001) in all 6-h blocks except for the 12 AM to 6 AM period.**

Conclusions: **We conclude that many of the noises causing sound peaks ≥80 dBA are amenable to behavior modification and that it is possible to reduce the noise levels in an ICU setting significantly through a program of behavior modification.** ***(CHEST 1998; 114:535–540)***

Key words: behavior modification; decibel; ICU; noise; sleep

Abbreviations: APACHE II=Acute Physiology and Chronic Health Evaluation II; dBA=A-weighted decibel; EPA=Environmental Protection Agency; MICU=medical ICU; RICU=respiratory ICU

Previous investigations at our institution have shown that the level of noise in the hospital setting is exceedingly high.[1,2] The initial study done in our institution demonstrated that peak sound levels were high in all hospital settings, but were greater than 80 A-weighted decibels (dBA) in our ICU settings.[1] This is in marked contrast to the US Environmental Protection Agency (EPA) recommendations that noise in hospitals not exceed 45 dBA during the day and 35 dBA at night.[3] One of the consequences of this noise pollution is sleep deprivation and fragmentation. Recent work from our laboratory demonstrated a significant association with sound peaks ≥80 dBA and arousals from sleep.[2] Another recent study also found that patients have

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sleep fragmentation, detected as transient EEG arousals, when they receive tone bursts during all stages of sleep.[4] Sleep deprivation has been demonstrated to affect task performance, general mood, and level of alertness, and can lead to increased daytime fatigue.[5-8] Observational studies have shown that at least one third of sleep-deprived subjects have symptoms consistent with "ICU psychosis" syndrome[9] and that patients identify staff noises as the most disturbing.[10] It is also possible that sleep deprivation may adversely affect respiratory muscle function[11] and ventilatory control,[12] and potentially hinder weaning from mechanical ventilation. Noise has also been implicated as causal of hearing loss, especially in patients concomitantly receiving ototoxic drugs such as aminoglycosides.[13,14] Additionally, noise has been implicated in contributing to critical care nurse burnout.[15] The purpose of the current study was to determine the causes of noise pollution in the hospital setting and to determine if behavior modification could have an impact on noise in the ICU.

Materials and Methods

Site Selection

This study was conducted in two phases at Rhode Island Hospital, a 720-bed university-based teaching hospital in Providence, RI. The specific locations within the hospital for the sound measurements were chosen based on a previous study done at Rhode Island Hospital by Meyers et al,[1] which evaluated sound levels in four different settings throughout the hospital and found that sound was consistently elevated above the EPA's recommended levels. The present study took place from August 1995 through August 1997 in three-bed rooms in both the respiratory ICU (RICU) and the medical ICU (MICU). These hospital sites demonstrated the highest sound levels in our previous study.

Sound Monitoring

Sound levels were measured in dBA using a sound level meter with internal storage capabilities (model 700; Larson Davis; Provo, Utah). The sound meter was calibrated by Larson Davis prior to the start of the noise identification phase of the study. For the behavior modification phase of the study, the meter's calibration was checked daily (acoustic calibrator, model CA 150; Larson Davis). For the most accurate estimate of what a patient would be hearing, the sound meter was placed in the position of a patient's head while lying in bed. During the noise identification phase, the observer (T.C.) also sat next to the head of the same bed which the sound meter occupied. During recording periods, peak sound was monitored continuously and stored in the sound meter. The time interval length, or the time period during which the sound meter analyzes and records the noise it detects, was set at 15 s for the noise identification phase of the study and at 60 s for the behavior modification portion. The stored data was then downloaded to an IBM computer and transferred to a computer (Macintosh; Apple Computers; Cupertino, Calif) for data analysis.

Study Design

This study was divided into two separate phases: noise identification and a trial of behavior modification.

Noise Identification

The goal for the first part of our study was to identify what actual individual noises were causing the high peak sound levels that had been observed in our previous studies.[1,2] Although many of the sounds, such as ventilator alarms, are set at a fixed decibel level, many other sounds, such as talking or the single television located in the center of the room, would potentially fluctuate. Loudness would vary depending on the time of day or whether other noises were occurring at the same time; *ie*, one might talk louder to be heard over television or ventilator noise.

This phase of the study was conducted in both the MICU and RICU. On 16 separate occasions, we measured peak sound levels in 15-s intervals for 10 consecutive min. A 15-s interval was used as it was thought to be the most reasonable time interval in which an observer could identify and record a given sound. These time blocks were equally divided between the MICU and RICU; 11 of the time blocks were in the morning (6 AM to 12 PM) and five were in the afternoon (12 PM to 6 PM). An observer (T.C.) recorded the loudest noise perceived by the human ear during each 15-s interval. The same observer was present for all 16 separate time blocks. Prior to the start of this phase of the study, this observer had a complete audiologic exam that showed normal frequency hearing.

Behavior Modification

The objective of this part of the study was to attempt to reduce the number of sound peaks greater than 80 dBA in the MICU, as these sound peaks have previously been correlated with sleep disturbance.[2] This part of the study was conducted in a three-bed room in the MICU. The MICU was chosen because it is a physically confined unit with a dedicated nursing staff, and a designated housestaff team for each month of the year. Initial baseline peak decibel levels were recorded over a number of days. The sound was recorded at 60-s intervals, as in our previous studies.[1,2]

Careful attention was paid to the number of patients in the room during all recording sessions, as well as the number of devices with alarms such as IV pumps, monitors, and ventilators. Acute physiology and chronic health evaluation II (APACHE II)[16] scores were calculated for all patients at the end of a 24-h recording interval in order to objectively stratify the patients' severity of illness on any given day. Once an adequate number and diversity of baseline days had been recorded, we then began the behavior modification program.

The behavior modification program consisted of a comprehensive educational program directed at all of the MICU staff, including the nurses, physicians, secretaries, and respiratory therapists. This educational program included discussions about noise pollution and the impact of noise on patients and on the work environment. In addition, it highlighted the types of noise that were thought to occur most frequently and also were caused by modifiable human behaviors. The causes of noise that were thought to be most amenable to behavior modification, as identified in the first portion of the study, were television, talking, beepers, and the intercom system. Suggestions for modifying these behaviors were made. These included turning off the large central televisions in the patient rooms, placing beepers in the vibrate mode, decreasing the use of the intercom, turning down the volume on the overhead speakers, adhering strictly to visiting hours and to the number of visitors at the bedside at any given time, and decreasing or eliminating any loud or unnecessary conversation from the patient bedside. Every effort was made to provide in-service training to all of the MICU staff by checking schedules and performing multiple in-services to maximize the number of staff educated. To further reduce the noise level from visiting physicians, the consult fellows and the medicine house-staff on the wards were notified of the nature of the study and asked to assist by paying attention to the noise they made when in the MICU. During the in-service training, handouts were given to all personnel to review the reason for the study, and tables were given listing common sounds and their corresponding decibel levels. The behavior modification program was implemented for 3 weeks. Signs were posted to remind the staff of the importance of noise reduction. Regular spot checks of the MICU were made to monitor cooperation. The recording equipment was attended to daily so the staff would not be aware of when recordings were being obtained, in an attempt to avoid an exceptional amount of cooperation on days when recording was known to occur.

At the end of the first 2 weeks of the behavior modification program, daily recordings were obtained in the three-bed MICU room. The number of devices with alarms was recorded, along with the number of patients in the room and the patients' APACHE II scores at the end of a 24-h recording period.

Data analysis was performed on two baseline days and two post-behavior modification days, during which the number of patients in the room and the patients' severity of illness as determined by APACHE II score were as closely matched as possible. The patients' APACHE II scores on each of these days are presented in Table 1. The mean APACHE II score was 13 in the baseline period and 16 during the behavior modification period.

Statistical Analysis

Data were analyzed using Microsoft Excel for Windows (version 5.0; Microsoft Corp; Redmond, Wash). Statistical analysis was performed using the StatView SE+ Graphics computer program (Abacus Concepts; Berkeley, Calif). In the noise identification part, standard means were obtained for all the individual noises. In the behavior modification portion, an unpaired, two-tailed Student's t test was used to compare the data from before and during the noise modification period. χ^2 analysis was used to compare the number of sound peaks ≥80 dBA before and at the end of behavior modification. Data are expressed as mean±SEM.

Results

Noise Identification

We were able to identify 12 individual noises that contributed to the high peak sound levels. The mean peak sound levels for these noises ranged from 74.8 to 84.6 dBA. Table 2 lists these noises with the percent occurrence and mean peak sound levels detected. The miscellaneous category encompasses noises such as suctioning, banging, coughing, and alarms that didn't occur frequently enough to separate them out. Fifty-one percent of the noises identified were potentially modifiable, with television and talking being the most prominent.

Behavior Modification

The mean peak sound levels were very high in the MICU, both before and at the end of the trial of behavior modification (80.0±0.1 dBA and 78.1±0.1 dBA, respectively). This change did represent a significant decrease (p=0.0001). We then examined four 6-h time periods. The midnight to 6 AM period was the most quiet in both the baseline and post-behavior modification phases (see Table 3). The individual time periods were then analyzed to determine whether there was any difference in noise levels before and during behavior modification. As shown in Table 3, the mean peak sound level decreased significantly in all of the time periods

Table 1—*Mean APACHE II Scores*

	Patient 1	Patient 2
Baseline day 1	19	9
Baseline day 2	16	7
Behavior modification day 1	23	11
Behavior modification day 2	19	9

Patient 1 and 2 refers to any patient placed in two specific beds.

Table 2—*Major Causes of Noise in the MICU and RICU Settings*

Noise	Percent of Time*	Mean Peak Sound±SEM, dBA
Air conditioner	2	74.8±1.2
IV alarm	0.9	77.3±2.0
Ventilator	8	78.0±1.1
Monitor alarm	20	79.0±0.7
Television	23	79.1±0.5
Ventilator alarm	5	79.7±1.3
Telephone	0.8	79.9±2.5
Nebulizer	0.6	80.6±0.6
Oximeter alarm	5	81.1±1.6
Intercom	0.5	83.7±2.1
Miscellaneous	7	84.0±1.1
Beeper	0.9	84.3±5.5
Talking	26	84.6±0.7

*Percent of total observation time of 160 minutes.

Table 3—*Comparison of Mean Peak Sound Levels Before and During Behavior Modification, in dBA**

Time Period	Baseline	Behavior Modification	p Value
12 AM to 6 AM	74.8±0.2	76.9±0.2	0.0001
6 AM to 12 PM	82.2±0.3	79.5±0.3	0.0001
12 PM to 6 PM	82.7±0.3	78.5±0.2	0.0001
6 PM to 12 AM	80.3±0.3	77.5±0.2	0.0001
Total	80.0±0.1	78.1±0.1	0.0001

*Data presented as mean±SEM.

Table 4—*Comparison of the Number of Sound Peaks ≥80 dBA Before and During Behavior Modification**

Time Period	Baseline	Behavior Modification	p Value
12 AM to 6 AM	147/720	192/720	0.0063
6 AM to 12 PM	421/720	324/720	0.0001
12 PM to 6 PM	460/720	241/651	0.0001
6 PM to 12 AM	335/720	219/720	0.0001
Total	1,363/2,880	976/2,811	0.0001

*Number of sound peaks ≥80 dBA recorded during a given number of 1 minute time blocks. Data were available for a slightly shorter time period from 12 PM to 6 PM during behavior modification.

except for the midnight to 6 AM time period, which actually had a statistically significant increase (p=0.0001).

We then counted the number of sound peaks ≥80 dBA before and at the end of behavior modification. There was no significant difference in the number of sound peaks ≥80 dBA between the two baseline days or the two post-behavior modification days. As shown in Table 4, there were 1,363 periods out of a possible 2,880 1-min time blocks in the baseline periods in which the peak sound levels were ≥80 dBA. This is in significant contrast to the 976 periods out of 2,811 1-min time blocks during the behavior modification phase in which the peak sound levels reached ≥80 dBA (p=0.0001). Table 4 also shows the number of sound peaks ≥80 dBA for each 6-h time period. There was a significant decrease in the number of sound peaks ≥80 dBA for the 6 AM to 12 PM, 12 PM to 6 PM, and the 6 PM to 12 AM time periods. The midnight to 6 AM period had the lowest number of sound peaks ≥80 dBA in both phases of the study. There actually was an increase in the number of sound peaks ≥80 dBA in that time period. Figure 1 shows the percentage change in number of sound peaks ≥80 dBA for each of the time periods of the study.

Discussion

Several important issues regarding environmental noise were highlighted in this study. First, we demonstrated again that sound levels in our hospital are extremely high. This corresponds to sound measurements obtained in previous studies at our hospital.[1,2] In one study, we found the mean peak sound level in our MICU to be 83.6 dBA.[1] Our study showed slightly lower, but still very high, mean peak sound levels in the MICU (80.0 dBA). Environmental noise in hospitals has received attention in the medical literature. The EPA recommends that noise levels in the hospital setting not exceed 45 dBA during the day and 35 dBA at night.[3] Several other studies have also documented sound levels higher than those recommended by the EPA. Soutar and Wilson[17] did overnight sound monitoring in an acute care unit and found average sound levels of 66 dBA, and Falk and Woods[18] monitored two acute care rooms for a 24-h period and found a mean peak sound level of 60.1 dBA. Yassi et al[19] found noise levels as high as 68.0 dBA in the MICU in a hospital in Manitoba, Canada, and Hargest[20] found that noise levels exceeded 75

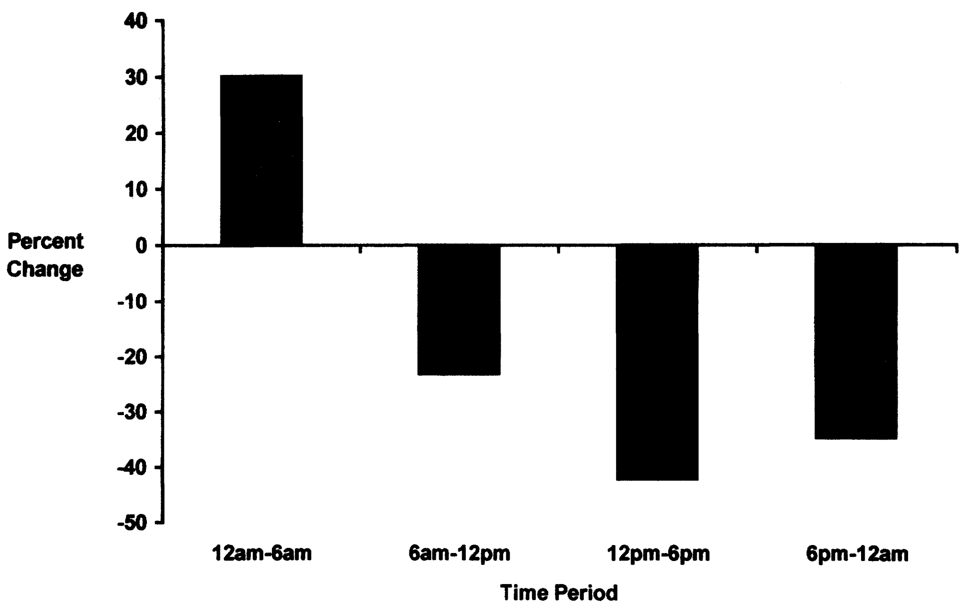

FIGURE 1. The percent change in the number of sound peaks ≥80 dBA are shown for four 6-h time blocks.

dBA in three of six intensive care areas checked in one institution in South Carolina. Bovenzi and Collareta[21] found thousands of sound peaks >70 dBA during the day in an ICU setting in Italy. This demonstrates that noise pollution in the ICU setting is not a problem limited to this country alone.

The second issue concerned the causes of the elevated peak sound levels. The causes of the noise pollution were easily identified and could be broken into two groups. The first group consisted of noises that were made by equipment with preset volume determinants. For instance, mechanical ventilator alarms are preset by the manufacturing company to assure patient safety. Many of the items in this group could not be modified because of the importance of alerting staff when there was a problem with a patient. The second group of noises were related to human behavior and, thus, were potentially modifiable. In fact, greater than 50% of the noises could be attributed to human behavior.

The initial noise identification portion of the study had several limitations. The noise identified was subjective. We tried to minimize this fact by using the same observer for all of the time blocks. This allowed for consistency in the identification of individual noises. We also limited the time blocks for noise identification to 10 min so that the observer could maintain concentration. In addition, the peak sound levels attached to each noise item were enhanced by the cumulative sounds in the room.

Using the first part of the study to determine which contributors to noise pollution could potentially be modified to reduce the peak sound levels, we set up a 3-week trial in the MICU. Any noise believed to be amenable to behavior modification was identified and then a plan to modify the behavior was adapted. For example, it was suggested that all beepers be placed in the vibrate mode, that the large central televisions be turned off, that the intercoms be used for emergencies only, and that talking be minimized in the patient care areas. We understand that the ICU setting is often chaotic and prone to multiple, unpredictable disruptions, but it was still possible to decrease sound with some simple behavior modification. Even a small amount of sound reduction would be perceived as a large reduction in noise; because the dBA scale is logarithmic, a sound 10 dBA lower is actually perceived as half as loud.

We made every effort possible to provide in-service training to all of the MICU staff and as many of the non-MICU staff who were likely to be in the MICU for any meaningful period of time. We targeted the nursing staff, respiratory therapists, and ward secretaries. We also trained the head of respiratory therapy and the nursing managers so they could inform any staff we might have missed. Staff schedules were reviewed and in-service training was done in multiple sessions to insure that as many staff as possible were educated. The medical housestaff working in the MICU were also educated. Consulting services and visiting housestaff were made aware of the study and asked to cooperate with our behavior modification program whenever they had reason to be in the MICU. In spite of these efforts, it is possible that some personnel were not fully educated.

As the severity of illness of patients in the MICU varies on a daily basis, we recorded the APACHE II scores of all of the patients in the study room throughout the behavior modification phase of the study. We then matched two behavior modification days with two baseline days when there were two patients in the room by closest APACHE II scores. The APACHE II scores of all the study patients are presented in Table 1. The behavior modification group actually had an overall higher average APACHE II score than the baseline group. This would make a negative result to our study more likely: sicker patients are likely to require more frequent medical and nursing care, which could potentially cause more noise. Despite this, we were still able to significantly decrease noise in the MICU.

We were able to have a significant impact on the noise level in the MICU during three out of four of the time blocks (Tables 3 and 4 and Fig 1). The 12 AM to 6 AM time block actually had an increase in the number of sound peaks ≥80 dBA; however, the overall number of sound peaks ≥80 dBA was markedly less than during any other time blocks in the study both before and during behavior modification. This is consistent with the findings of Meyers et al.[1] The mean peak sound level was also markedly lower during the 12 AM to 6 AM time period (Table 3). We speculate that the reason for the failure of our study during the 12 AM to 6 AM time period was that those hours are inherently the quietest time in the hospital setting. There are fewer staff interactions with patients, and less likelihood of noise-causing behavior that (*eg*, talking or television viewing) that could be modified during those hours.

We are not the first group to attempt behavior modification to control levels of hospital noise, although we are the only group who specifically targeted the intensive care setting. Webber[22] reported a 6% decrease in noise-related complaints at Presbyterian Hospital in San Francisco after the implementation of a behavior modification program; Nazzaro[23] reported a 20% reduction in everyday hospital noise with an antinoise campaign based largely on behavior modification.

We draw a few conclusions from this study: (1) A large portion of the noise that occurs in the ICU setting is amenable to behavior modification. (2) During the late night and early morning hours, ICU noise levels are lowest; this is consistent with less noise-generating staff-patient interaction during that time. (3) Behavior modification is possible and it is effective in reducing noise levels in an ICU setting; given the potential benefits to patients and staff, behavior modification should be advocated strongly. We are not alone in this opinion, as a recent review of sleep in the ICU by Krachman et al[24] stated that "physicians and nursing staff should be educated as to how their own talking in the unit can have such a dramatic effect on sleep loss." Perhaps setting an official noise control policy would be beneficial and perpetuate the results we obtained. Additionally, changing the physical environment of an ICU may also influence noise levels. A design featuring more private rooms, built with walls and ceiling panels that minimize noise reflection and intensity, and small bedside televisions or pillow speakers would decrease noise levels. Additionally, placing staff workstations and nursing stations outside of patient rooms and creating conference areas appropriate for holding rounds or other group discussions might also help decrease sound levels. Another possible solution to noise pollution would be to alter patients' immediate environmental perception with the use of earplugs, for instance. Further investigations into feasible ways to decrease sound levels and to determine noise's overall impact on sleep in the ICU setting are needed.

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