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CONTINUING EDUCATION

Environmental Noise Sources and Interventions to Minimize Them

A Tale of 2 Hospitals

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Noise has been shown to interfere with the healing process and can disrupt the patient's experience. This study assessed patients' and staff's perceptions of noise levels and sources in the hospital environment and identified interventions to reduce the noise level. The interventions significantly reduced noise as perceived by patients and staff. Identification of a structured process to identify noise sources and standardization of noise measurement methods can improve the patient hospital experience. **Key words:** *environmental noise*, *hospitalization*, *inpatients*, *interventions*, *noise reduction*

THE PROCESS of delivering patient care in a hospital often generates noise. Examples include discussions of patient care or treatment requirements among health-care team members, carts delivering food or supplies, equipment alarms on pumps and monitors, industrial floor cleaners, and even footsteps from persons wearing hard-soled footwear. Although certain sources and levels of noise are necessary, the hospital setting has many noise-related activities that disrupt patients' experience and interfere with the healing process.[1] Increased noise has been linked to stress reaction; sleep disturbance; and increased heart rate, blood pressure, and muscle tension, creating an issue that broadly affects multiple disciplines and departments in the provision of hospital care.

While conducting a quality improvement project, nurses working the night shift on a patient care unit (PCU) found that unsolicited comments from patients alerted them of noises that were disruptive to patients' sleep.[2] Further investigation revealed that noises perceived by patients as bothersome were occurring throughout the day and night.

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Implementation of several interventions indicated that noise could be successfully reduced on that PCU. On the basis of the impact the noise reduction interventions had on patients' perceptions of the environment, we chose to replicate the project across all PCUs in 2 hospitals.

STUDY AIMS

The purposes of this study were to identify noise sources and implement noise reduction interventions with an outcome aimed at controlling noise levels at 2 Mayo Clinic Hospitals.

The following specific study aims focused on assessments of noise on PCUs before and after implementation of noise control interventions:

1. identify the time of day and noises that were most bothersome in the hospital environment as reported by patients, nursing staff, and nursing leadership;
2. describe noise control interventions implemented;
3. describe the level of noise on PCUs as identified by patients and nursing staff;
4. compare decibel readings before and after noise reduction interventions were implemented on selected PCUs;
5. identify noise control interventions that could be easily replicated across diverse PCU environments; and
6. explore differences and similarities in noise readings between 2 noise measurement devices.

LITERATURE REVIEW

Much of the literature addressing the measurement of noise and impact of change in acute care settings was published in the mid- to late 1990s. More recent publications indicate that issues of environmental noise continue to exist, and practitioners seek to find solutions that positively affect patients' hospital experience. We highlight some of the older literature because of its value in supporting the importance of reducing hospital noise.

Evidence exists that noise can produce many damaging psycho-physiological effects including sleep disturbances,[3-5] stress reactions,[3,6] increased vital sign parameters (blood pressure, heart rate, respiratory rate, body temperature),[5-8] and acute drops in SaO_2.[5] In addition, noise exposure has been demonstrated to delay wound healing and decrease weight gain,[1] impair immune function,[9] and impair hearing.[10] Changes in behavior and muscle tension were noted both during the exposure to loud noise and sustained after the exposure ended.[11]

Sources of loud noise in the hospital environment can be identified by self-report (patient and staff questionnaires or surveys),[12,13] directly assessing noise levels with a dosimeter,[14,15] or polysomnography.[4,16] Both subjective and objective data are valuable in identifying sources, defining a threshold for disruption, and assisting in decision making for implementation of noise control interventions and/or environmental modification.

Prior studies of modifying noise levels in hospital environments exist. Sleep enhancement protocols have been shown to be a successful intervention to reduce noise levels and increase patient sleep.[17-19] Patients and staff in postanaesthesia recovery areas perceived decreased noise levels when ambient music was played.[20]

Although it has been demonstrated that noise can have many detrimental effects, evidence also exists that reductions in noise levels can be obtained through combinations of staff education,[2,21] environmental modification of physical surroundings,[3,22-24] and behavioral modification.[25-27] Many studies have evaluated interventions on individual PCUs; however, none were found that evaluated the implementation of noise control measures throughout an entire hospital. We attempted to identify, measure, and reduce noise levels across an entire hospital environment.

METHODS

Design

A mixed-method research design (quantitative and descriptive qualitative) was used to expand the methodology of an earlier quality improvement project implemented at the study setting on 1 PCU.[2] Baseline noise levels were measured objectively using noise dosimeters and subjectively by both patient and staff perceptions. Once sources and levels were identified, noise reduction interventions were implemented. Both subjective and objective data were again collected 1 month after implementation of noise reduction interventions and 6 months from preintervention data.

Setting and sample

The study was conducted at 2 hospitals affiliated with the Mayo Clinic, a large Midwestern quaternary care and referral-based system. Fifty-seven PCUs of varying size with a wide range of clinical foci were included. A convenience sample of 30 patients from each of 55 PCUs ($n = 1650$) was planned for both the pre- and postnoise assessments, with an actual response rate of 47% ($n = 775$) and 43% ($n = 704$), respectively. Inclusion criteria for the patient participants included the ability to read and write in English, self-reported unimpaired hearing ability, identified by nursing staff as alert, oriented, and on the unit for a minimum of 12 hours prior to data collection. No patient surveys, though, were obtained from the 2 preoperative waiting areas. Staff response rates were 53% (2016/3830) and 43% (1652/3847) and included registered nurses, licensed practical nurses, patient care assistants, and unit secretaries working on the PCUs and preoperative waiting areas.

Instruments

Patient and staff surveys and unit environmental noise assessment

The survey and assessment instruments developed by the investigators were based on existing noise literature and previous experience. Face and content validity were established for both the patient and staff surveys through review provided by both industrial hygiene and nursing experts. Input from PCU nursing staff, nurse researchers, and nursing leadership group (nurse manager, clinical nurse specialist, and nursing education specialist) was also obtained. Both patient and staff survey instruments used a 5-point Likert response scale of *very quiet* to *very loud* for rating noise levels during 4 separate periods of a day—morning (7 AM to noon), afternoon (noon to 5 PM), evening (5 PM to 10 PM), or night (10 PM to 7 AM). The survey also asked the respondent to identify a noisiest time of the day.

Bothersome noises were identified using a pick-list with the opportunity for multiple choices, and participants could also list about other noises not addressed on the pick-list. Comments including suggestions for controlling bothersome noises were solicited on the survey. All noise control interventions implemented on the PCU prior to the start of the study were also identified. Patient surveys were in a pen-and-paper format. Staff surveys were sent electronically through individual intranet e-mail distribution lists.

Noise dosimeter and sound-level meter

Dosimeters and sound-level meters measure environmental noise. The 2 devices measure noise differently, and both were used to illustrate differences in measurement and the importance of consistency in noise-level measurement. Three general field work type II noise dosimeters (Quest Technologies, Q-300, Oconomowoc, Wisconsin) were used to collect pre- and postintervention noise levels measured in decibels (dB) on 31 PCUs (12 randomly selected and 19 voluntary units). The dosimeter measurements were obtained by industrial hygienists according to Occupational Safety and Health Administration standard methods (29CFR1910.95, 80 dB Threshold, 5 dB Exchange, and A-weighted filter noted as dB(A)). In addition, a general field work type II sound-level meter (Quest Technologies, 2900, Oconomowoc, Wisconsin) was utilized on 4 PCUs to log additional noise measurement parameters for post-intervention comparisons. All instruments were calibrated prior to each use utilizing the manufacturer's procedures and equipment (Quest Technologies, QC-10, Calibrator, 114 dB at 1000 Hz).

Procedures

Following institutional review board approval, preintervention data were collected. The unit-specific data were then shared with staff who used the data to identify and implement noise reduction interventions. Postintervention data were obtained 6 months after the preintervention data were collected. Data collection included all identified assessments as well as dosimeter measurements.

To maintain confidentiality of the data, data from the assessments were entered by an administrative assistant into a Microsoft Access database and then reviewed and analyzed by the research team. All paper documents were stored in a locked cabinet. Postintervention summary data were also sent to each PCU nursing leadership group for review.

Environmental data collection

The Environmental Noise Pre and Post Assessment tools to measure noise-related activities and issues were completed by the nursing leadership group. There also was an opportunity to describe any unit-based noise control activities that were already in progress, as some PCUs had already chosen noise control as a priority quality improvement project. The postintervention assessment was completed in the same manner and required leadership team responses regarding perceived success related to the PCU noise control interventions.

Staff data collection

Staff data were collected utilizing a web-based survey link sent to employees through the use of unit based e-mail distribution lists. The data were aggregated electronically at both the unit and departmental levels.

Patient data collection

Informed consent for each patient's participation in the study was obtained by unit staff members who had completed the institutional review board competency in protection of human subjects. Completed surveys were placed in a sealed envelope and sent to a central location.

Dosimeter and sound-level meter data collection

Noise dosimeters were placed at a central desk location on 31 units and recorded readings over a 24-hour period. A journal accompanied the dosimeter with directions for staff to log any extenuating circumstances that may have occurred during the recording time period that may explain unusual readings. During the postintervention assessment period, a sound-level meter was placed adjacent to the noise dosimeter, and data were collected simultaneously on 4 PCUs selected by the investigators for comparison standards.

Intervention implementation data collection

After receiving the preintervention data, the unit nursing leadership groups were asked to identify and implement at least 1 noise control intervention within the next 2 to 4 weeks. The Environmental Noise Education/Information Tool served to guide the identification of unit-specific noise control interventions for implementation.

Data analysis

Descriptive statistics were used to characterize the sample. Frequencies were calculated to answer the first 3 study aims. Differences between staff and patient responses related to time of day when noise was perceived as most bothersome were compared using the Student t test for unpaired means. Analyses were completed utilizing SPSS, Inc (Cary, North Carolina) statistical software. P values $< .05$ were considered statistically significant.

Content analysis of patient and staff comments was completed by an experienced qualitative nurse researcher with theme analysis by investigators to ensure the trustworthiness of the data. Themes were identified using ATLAS software, a state-of-the-art qualitative research software to help manage the large data set and to discern systematic patterns and interrelationships.

Analysis of the dosimeter data included a line graph developed for each of the 31 PCUs on the basis of the measured sound level from the noise dosimeter. This sound level, referred to as the slow max level, was calculated by recording the highest sampled sound levels during the dosimeter's run time (24 hours) and displaying them minute-by-minute.

Next, the average sound level measured from the noise dosimeter over the run time (24 hours) was compiled on a bar chart. This average, noted as Lavg, used the Occupational Safety and Health Administration parameters specified in the Hearing Conservation Amendment,[28] including an 80-dB threshold, 5-dB exchange rate, and A-weighting filter noted as dB(A). As specified in the "Methods" section, any sound below the threshold was not included in the average.

RESULTS

Morning was identified as the most bothersome period of the day. Voices were perceived as the most bothersome by patients and staff (Table 1). There were no differences in noises identified as most bothersome between staff and patients; therefore, the data were combined. The top 6 most bothersome noises are listed plus a cumulative value for other noises identified. The qualitative data resulted in the emergence of the following 4 themes: (1) equipment: infrastructure (eg, pagers, carts); (2) equipment: patient-related (eg, monitors, pumps); (3) environment (eg, activities at nurses station, doors); and (4) human factors (eg, voices, footwear, and visitors). Noise control interventions initiated and identified by staff on the PCUs are found in Table 2.

Table 1. Time of day and noises most bothersome

	Pre, *n* (%)	Post, *n* (%)
Staff	435 (36)	367 (40)
Patient	235 (41)	192 (40)
Time of day most bothersome	Morning	Morning
Bothersome noises[a]	$n = 2016$	$n = 1652$
Voices	660 (33)	556 (34)
Carts traveling in hall	347 (17)	269 (16)
Foot traffic in hall	329 (16)	257 (16)
Cardiac monitor alarms	253 (13)	172 (10)
Overhead pages	184 (9)	132 (8)
Pulse oximeter alarm	178 (9)	143 (9)
Other	162 (8)	135 (8)

[a]Participants could choose more than 1 bothersome noise; therefore, the total percentage is >100.

Table 2. Noise control interventions initiated on patient care units

Interventions	Pre, %	Post, %
Close patient doors	64	66
Dim lights at night[a]	55	58
Limit overhead page	44	51
Lower speaking voices	43	51
Alarms turned down as far as safely possible	27	27
Ringers on phones turned down	26	31
Quiet signs posted	18	28
Other sounds controlled	13	17
Quiet carts[b]	10	11
White noise[c]	4	6

[a]When lights are dimmed, people tend to talk in softer voices.[2,17,18]
[b]Cart wheels.
[c]Background noise.

Noise was significantly reduced with interventions except on the night shift (Table 3). Patients' ratings' of noise were significantly lower ($P < .001$) than staffs' at all time periods both pre- and postintervention.

Thirty-one of 57 PCUs comprised the sample of units where noise dosimeter measurements were taken. Staff received a comparison of pre- and postintervention dB(A) readings measured on their own unit as well as a departmental summary that allowed for comparison of their unit noise readings to other units. This provided an opportunity for

Table 3. Rating level of noise: Staff and patient[a]

	Pre		Post		Difference between pre & post, *P*
	n	Mean (SD)	*n*	Mean (SD)	
Morning (7 AM to 12 noon)					
Staff	1204	3.83 (0.65)	902	3.85 (0.66)	
Patient	763	2.81 (0.90)	690	2.68 (0.89)	
Combined	1967	3.44 (0.91)	1592	3.34 (0.96)	0.003
Afternoon (12 noon to 5 PM)					
Staff	1201	3.61 (0.66)	906	3.57 (0.65)	
Patient	728	2.77 (0.87)	661	2.68 (0.82)	
Combined	1929	3.29 (0.85)	1567	3.20 (0.84)	0.001
Evening (5 PM to 10 PM)					
Staff	1205	3.31 (0.67)	908	3.28 (0.66)	
Patient	707	2.63 (0.90)	644	2.53 (0.84)	
Combined	1912	3.06 (0.83)	1552	2.97 (0.82)	0.002
Night (10 PM to 7 AM)					
Staff	1157	2.74 (0.71)	892	2.72 (0.72)	
Patient	707	2.08 (0.98)	648	2.05 (0.96)	
Combined	1864	2.49 (0.88)	1540	2.44 (0.89)	0.155

[a]Response set values: 1 (*very quiet*), 2 (*quiet*), 3 (*good/neutral*), 4 (*loud*), 5 (*very loud*).

staff to review how their noise reduction intervention(s) may have impacted their actual noise levels and how their unit noise reduction interventions compared to interventions initiated by other PCUs. Thirteen units had decibel readings averaged over the 24-hour period that decreased following noise control interventions, and 18 had averaged readings that increased. Dosimeter data averaged across all of the 31 PCUs increased from 32 dB(A) during the preassessment to 36 dB(A) during the postassessment.

Noise control interventions that could be replicated across PCUs were identified. These interventions included padding chart holders, padding pneumatic tube drop-stations on the PCUs, and installing quieter paper towel dispensers. The team also created signage "As a courtesy to patients, please limit use of this phone" and posted them near telephones proximal to patient rooms as reminders to staff. A second message "To help promote a healing environment, please keep voices soft" has been posted in visitor waiting areas. This message is currently under consideration for posting on electronic message boards throughout both hospitals.

The final aim was designed to compare sound-level readings from 2 different measurement devices (sound-level meter and noise dosimeter) placed on 4 selected PCUs. Although there are several ways to measure noise levels in dB(A), all dB(A) measurements are not the same and may result in large differences in numerical dB(A) values. To illustrate this, the dB(A) values measured on 1 PCU include the 24-hour $L_{avg} = 31$, as measured by a noise dosimeter, and 4 values measured with a sound-level meter: $L_{eq} = 56$, $L_{dn} = 62$, $L_{10} = 59$, and slow max level = 84. All values were measured simultaneously and yet offer different dB(A) values. This presents problems when published studies offer dB(A) values, yet do not completely describe the methodology. The reader may assume that all dB(A) values are the same.

DISCUSSION

The delivery of patient care in hospitals involves a certain amount of noise. Minimizing noise perceived as noxious or bothersome can improve the environment of care for both patients and staff. This is the only study known to the investigators that expanded noise reduction methodology across 57 PCUs in 2 hospitals.

Although somewhat expected, morning was identified as the time of day when noise was most bothersome. This may be explained by the observance of 4 of the 5 most bothersome noises common to the delivery of patient care: voices, carts, traffic, and cardiac monitor alarms. The fifth most common noise was identified as overhead paging in the preintervention data collection period and pulse oximeter alarms for the postintervention data collection period. Our results were similar to those of other studies in the literature that defined noise sources using survey methods.[2,12,13] Morning is typically when the most staff and visitors would be arriving on the PCU, which may cause the increase in noise. In addition, scheduling of tests and morning care routines (eg, bathing and changing bed linens) all contribute to sources and levels of noise.

Noise control intervention frequency increased pre- to postintervention in our hospitals and were found to be common tasks such as using soft voices, closing doors, dimming lights, and limiting overhead paging. These modifications of environmental physical surroundings can be found in studies conducted on a single nursing unit[22–24] as well as behavioral modifications.[25–27] Furthermore, use of sleep enhancement protocols incorporates aspects of these items.[17–19] Awareness of environmental noise had an impact alone on the number of interventions used by staff.

A significant difference was noted between pre- and postmean noise ratings when combining staff and patient responses for 3 out of 4 periods of the day. The combined mean noise ratings decreased in all 4 time categories from pre- to postintervention assessment. Nighttime was not found to be statistically significant as it was already identified as quiet. A reduction in rating of noise levels was noted after interventions were put in place. Furthermore, staff rated the noise in the morning as close to loud, whereas patients rated noise on the high side of quiet. Beyond statistical significance, this is an important finding clinically. The location of where noise is heard (hospital bed vs in the hallway) may contribute to differing perceptions.

Objectively assessing noise with a dosimeter helped quantify actual noise,[14,15] although there are considerations and context to consider when using this equipment. Actual noise level readings were higher after noise reduction interventions were implemented, but the perception of bothersome noise was reported to decrease by both patients and staff. The hospital patient census was higher during the postintervention measurement period, possibly accounting for the increase in actual noise-level readings. A dilution effect occurs when comparing the average level across 31 PCUs. Although individual units demonstrated changes, the averages across all units were difficult to realize. Finally, regardless of actual noise levels, the attention given to the issue of noise as part of the patient experience may have contributed to the overall perception of a quieter hospital environment.

Inconsistencies in noise data comparisons in the literature had been noted. Various articles describe noise in the healthcare environment but do not utilize the same or do not elaborate on the evaluation methods in their comparisons.[7,16,29,30] Complete sampling methodology was described in only 5 of the many articles reviewed.[6,14,15,17,26] Unless one fully understands the noise sampling method, it is easy to conclude that the sampling method and dB(A) levels are comparable from study to study. Findings from our study demonstrate how easily noise measurements can be misinterpreted and emphasize the need for consistency. Standardization of noise measurements would allow comparison across studies. A thorough understanding of the various methods used in conducting studies of environmental noise, and when comparing results across studies in the literature, is warranted.

Limitations

In generalizing the results of this study, one should consider several limitations. The size and geographic location of this medical facility may limit comparison to other acute care settings. A convenience nonrandom sampling strategy to identify both patient and staff participants may have introduced bias. Because the pre- and postintervention data collection occurred nearly 6 months apart, different patients completed the surveys. To a certain extent, it is possible that different staff members may have provided the pre- and postdata on the basis of new hires and attrition. In some PCUs, controlling noise had been prioritized as a quality improvement project, and environmental changes had already been implemented. Although the data collection instruments were developed on the basis of the literature and piloted prior to use in the study, there are no psychometric properties available for them beyond face and content validity. The study did not include control units, which may have allowed for randomization of units and a stronger study design. We did not collect unit census data nor did we collect data about the flooring for the units. Both of these factors may have influenced noise levels. Differences in perception of noise by patients and staff may have been influenced by the fact that patients are there 24 hours of a day and nurses' shift is typically 8 to 12 hours.

Nevertheless, the results of this study highlight the similarities between patients' and staffs' identification of bothersome noises in the hospital environments and expand on current attempts to study and reduce noise in acute care hospitals. The importance of how one measures noise has been identified. A difference in perception of bothersome noise levels and actual noise level readings are worth noting.

CONCLUSIONS

A structured process can help healthcare institutions identify noise sources. Although many variables affect hospital environmental noise, there remains a lack of consensus on standards and methods used to assess a quiet environment or identify actual levels of noise conducive for healing. This study contributes important information about the types of noise and perception of noise levels in a large, hospital environment. Furthermore, this study illustrates some of the pitfalls of noise assessment and interpretation. Standardization of noise measurement methods may allow better comparison and interpretation of noise studies. Interventions at the individual PCU level may have a greater impact to decrease noise in hospital environments. Periodic assessment of hospital noise levels can help identify new noises and reinforce interventions that have been put in place to maintain a quiet environment.

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