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The Sound of Urgency: Understanding Noise in the Emergency Department

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Abstract

Hospital noise is a worldwide issue, with detrimental effects on health and healing. The busy emergency department (ED) typically generates excess noise. Few studies have investigated noise levels within the Australian ED. This study examines noise in this setting, in turn suggesting how noise levels may be reduced. Noise level measurements occurred in 4 locations within the ED during peak staff and patient flow times over selected 7-hour periods. These were compared to the available standards and guidelines and supplemented by regular staff surveys documenting perceived noise. Findings indicated that all 4 locations exceeded the maximum recommended levels by up to 20 dB. Staff perception surveys suggested that most noise was created by people (conversations). Reducing noise in the ED may be achieved by (1) decreasing the generation of noise and (2) reviewing building layout and introducing physical noise controls such as noise-absorbing ceiling tiles and acoustic barriers/curtains.

Keywords

acoustics, emergency department noise, healing environments, hospital noise, noise levels

Background

An ability to detect and decode sounds is essential for all human beings. Sound typically plays a key role in communication between people and is likely to be found in most community environments. Unnecessary sound (noise) has been known to have adverse effects on physical and emotional health.[1-3] The negative effects of noise can be pervasive in many situations, including health care settings. Noise can negatively impact on the care environment, affecting people in various ways. As Florence Nightingale once said, "Unnecessary noise, then, is the most cruel absence of care which can be inflicted either on sick or well."[4]

Introduction to Noise

Noise is defined as undesirable sound that interferes with hearing[5] and is commonly identified as unwanted sound.[1] Sound is created through pressure variations oscillating through a medium, most commonly air, which the ear can detect. These sound waves occur over a wide range of frequencies, with the human hearing spectrum occurring over the range of 20 Hz to 20 000 Hz and the most sensitive range being between 1000 Hz and 5000 Hz.[6]

Sound pressures in the audible range vary greatly in magnitude and hence are represented on a logarithmic decibel scale. Since it is not practical to examine noise at every frequency, the spectrum can be apportioned into a set of ranges known as bands. Octave bands are commonly used in

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industrial acoustic analysis. One-third octave bands are also utilized, particularly in noise control applications. The nature of one-third octave bands represents the noise in ranges a third smaller than those in the octave bands. In other words, in octave bands there is 1 measurement per band whereas in one-third octave bands, there will be 3 measurements equally distributed within the band. The additional data provide a more detailed depiction of the frequency content of the noise being analyzed.

Noise descriptors are also used to summate noise through a given period.[6] Standards and guidelines generally use the continuous equivalent noise descriptor (L_{eq}), which is the averaged noise levels over a period. For more statistical analysis the L_N, L_{Max}, and L_{Min} descriptors are also used. L_{Max} and L_{Min} are the maximum and minimum measured sound levels, respectively. L_N is the noise level heard for N% of the time. For example, L_{10} is a measure of the maximum levels reached, and L_{90} is a measure of residual background noise.

In addition, sound weighting filters are applied in analysis to compensate for the human ear's natural filtering system. The A-weighting filter is most commonly used in references and standards as it approximates the human perception of sound.[6] An average healthy human ear is sensitive enough to notice at least 1dB(A) of difference. An overexposure to high noise levels may cause irreversible hearing damage along with other health implications.[7]

Noise in Emergency Departments

In most community indoor environments noise will be present; however, direct links to health effects and health risk are challenging to identify. Nevertheless, the measurement of noise and its effects on people has received increasing attention in recent times.[8,9] The World Health Organization (WHO) has created guidelines for community noise, which are applicable worldwide. The WHO recommendation[1] for hospitals is that indoor hospital ward rooms should have a sound level of 30dB(A), with a maximum of 40dB(A). It also indicates that hospital treatment rooms are to keep noise as low as possible. The Australian Standards (AS2107:2000[10]) recommend a building design level for "casualty areas" and "nurses stations" as having a satisfactory and maximum sound level of 40 dB(A) and 45 dB(A), respectively. "Waiting rooms" have a recommended level of 40 dB(A) and maximum of 50 dB(A).

There have only been a few studies looking at noise in acute hospital settings in an Australian context. An ICU study[11] found averaged noise levels of 56 to 58 dB(A), with peaks up to 95dB(A). In another study, an emergency department (ED) averaged levels reaching up to 64dB(A).[12] Research in similar settings has been conducted internationally.[1,13-17] Most of these studies found health care noise levels to be well above the recommended guidelines. Emerging from all of these studies is an expressed concern about the effects of high noise levels in health care settings.[18] Due to its high volume of activity and typically stressful patient care needs, the sound environment of the ED demands further investigation.

Competing needs exist: The patients require a healing atmosphere for their treatment, and at the same time it is the work context for hospital staff who repeatedly spend long periods of time in this environment. This means that the sound levels must be minimized for the healing process but high enough to sustain the interaction required for health care delivery. Noise within hospitals has previously been identified as emanating from several sources including humans, machinery, alarms, and building noises.[19] Prolonged exposure to the accumulated noise can interrupt the regular flow of work and is likely to impede healing processes. Research has shown that with elevated noise levels in the complex ED environment, people exposed were likely to experience additional adverse physical and psychological effects.[20] These effects ranged from minor annoyance or distraction to increased stress levels, communication disruptions, hearing loss, and/or cardiovascular strain.[2,21-23]

The objective of this study is to extend previous studies of noise within health care environments, through the investigation of noise levels in the ED within an Australian context. It then seeks to identify the sources of noise in order to develop strategies aimed at reducing the detrimental effects of noise within the ED environment. Unlike previous investigations, this study explores both patient and staff areas.

Method

This study involved the analysis of noise obtained from 2 data sources: (1) physical measures obtained from a noise data logger and (2) a survey completed by hospital staff during the measuring period. This systematic study was conducted in the ED of a large urban tertiary hospital. The ED featured a number of separate but linked patient care areas, as further outlined in the following. In conjunction with liaising hospital staff, a noise monitoring schedule was organized to measure each area on 3 different days for 7 hours (from 1 PM to 8 PM), capturing the expected peak flow times (from 2 PM to 4 PM and from 6 PM to 8 PM). This study was approved by the relevant Area Health Service Ethics Committee.

Measurement Areas

The physical environment of the ED was characterized by flat hard surfaces of painted walls, linoleum floor coverings, high ceilings (approximately 2.7 m from the ground), thin curtains of synthetic material, items on wheels (such as beds, monitors, ambulance trolleys, wheelchairs), and automatic or swinging doors. There was no apparent sound insulation or dedicated sound absorptive materials, other than hospital resources such as blankets on beds and the people themselves.

Limited time and resources meant that only a selection of locations was monitored for this study. The 4 areas nominated were considered by hospital staff to be the noisiest locations from the ED. These were known as the triage, the bridge, the emergency medical unit (EMU), and the waiting room. These locations were high-flow traffic areas where patients, staff, or both were exposed to noise. Each exact location for the noise logger setup was approved by staff to (1) minimize interference with regular work practices and (2) ensure that it did not represent a physical hazard related to movement and activities. To notify people about recording, appropriate signage was displayed on and around the secured equipment.

- The triage (27.3 m^3)—located at the entrance of the ED—is the first point of contact for patients arriving at the ED, who typically present with undiagnosed and unstable conditions and in multiple numbers.[24] The triage process involves rapid assessment, interpretation of clinical history and physiological findings, categorization of urgency, and disposition to an appropriate management area.[25] The triage episode is generally expected to take no more than 2 to 5 minutes, balancing speed and thoroughness with timely access to necessary clinical intervention. After assessment, patients may be directed back to the attached waiting room, to subacute treatment rooms, or into the ED acute treatment area via locked restricted-access doors. This area forms a thoroughfare for staff entering and leaving the ED to access the main hospital and ED offices, and a transit point for patients being transported to the main hospital for further assessment or admission.
- The bridge (48.6 m^3): This physically elevated area is the main area for clinical documentation and computer access for medical staff, and the nurse in charge is stationed here. The bridge is centrally located within the acute area of the ED, surrounded by several entrances for the ED, including the entrance from the waiting room, the ambulance bay, and the ED reception and triage office area as well as the flow of people accessing the entrances. This area is encircled by patients in the acute patient treatment area, and in one direction the resuscitation area. Mobile medical equipment is also stored in various locations close to the bridge.
- The EMU (405.3 m^3): Situated at one side of the department behind the acute area, this is a short-stay (<23 hours) observation area for patients who are relatively stable. The EMU is assumed by staff to be quieter than the other areas (as based on personal communication with the researchers) and acts as a patient rest area prior to discharge. Less-intense treatment activity occurs here; however, routine activities such as moving beds and staff interactions typically occur. A small documentation station exists in this area, with clusters of mobile medical equipment stored close by.
- The waiting room (148.8 m^3): Located at the entrance of the hospital ED, this area anecdotally shows widely varying noise levels depending on the unpredictable flow of patients and their family/carers at any given time. Patients with less urgent conditions or injuries may need to wait for considerable periods for treatment. Nevertheless, they are likely to be experiencing pain and stressful health problems while they wait. A range of challenging and loud social behaviors are often observed by staff in this area. This area is situated close to road access, the car park, and the emergency services helicopter landing pad. These external transport sounds can also be heard in the waiting room.

Materials

Physical noise measurements were taken using an environmental noise logger (RTA04; Renzo Tonin & Associates, New South Wales, Australia). The system consisted of 3 major elements: an International Electrotechnical Commision-approved class 1 integrating sound level meter (CESVA SC310; Renzo Tonin & Associates); an appropriate power source; and a weatherproof hard case. The case integrated an adjustable stand for the microphone which connected to the sound level meter. The noise logging device was initially calibrated and set up in accordance with the Australian Standards[26-28] to ensure the validation of results. The majority of the testing was measured in one-third octave band spectrum analysis over the 20 Hz to 10 kHz frequency range which ensured that the measured data detailed the distribution of noise across frequencies, especially those which are sensitive to human hearing.

A survey developed and distributed by the liaising staff identified noise patterns in order to understand the links between the experienced and measured noise levels. This survey was substantially based on Topf's Disturbance Due to Hospital Noise Scale,[19] and was modified by liaising with staff in order to address the local conditions and context. The survey required staff to indicate the perceived severity of particular noise sources on a 1 to 5 scale (1 = never; 5 = extremely). The listing of particular noise sources included people-related noise (conversations and patient-related noise), noise created by processes (administration including phones and the public address system, transport, meals, machinery), and mechanical noise (doors, moving beds, machinery). The survey was completed by staff on a regular basis during the noise logger measurement periods and appears in the online Appendix A.

Process

The systematic approach involved setting up the sound level meter to log measurements in dB with an A-weighted filter. In addition, the measurements were taken in spectrum analysis mode that processed the data in either one-third octave or octave frequency bands. The levels were sampled in 15-minute intervals in the LO range (30dB-100dB) and FAST response (a response time of 1/8 second) settings, in accordance with the WHO guidelines. The microphone was set up to be at least 1.5 m above floor level, in accordance with AS1055, which was approximately the standing level of the human ear. After completing measurements, internally processed data (following standard algorithms) were exported from the noise logger into a

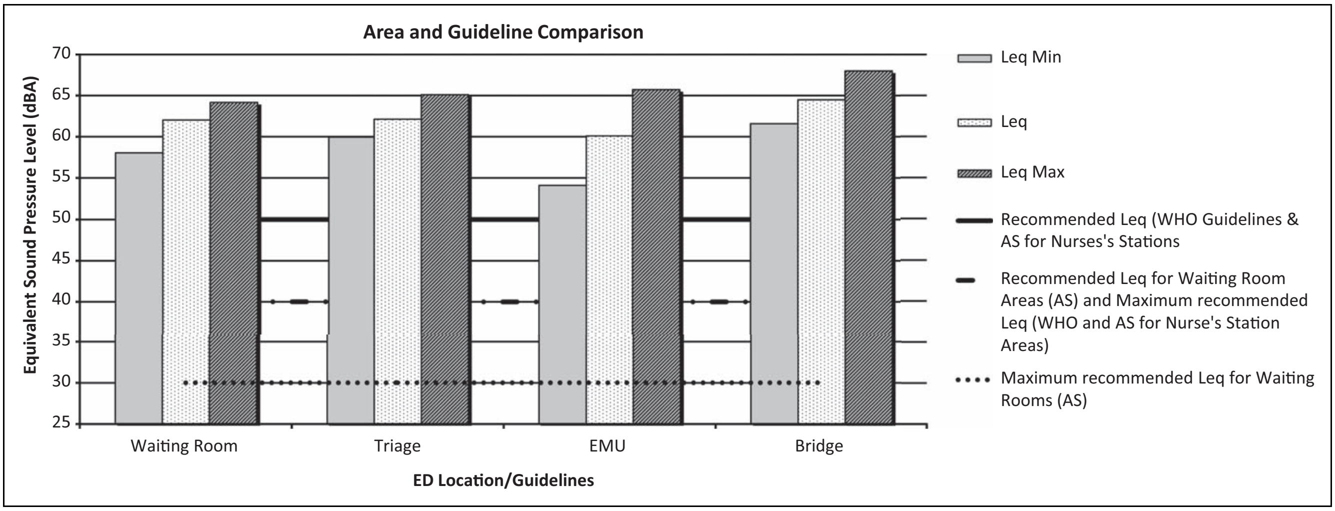

Figure 1. Area and guideline comparison.

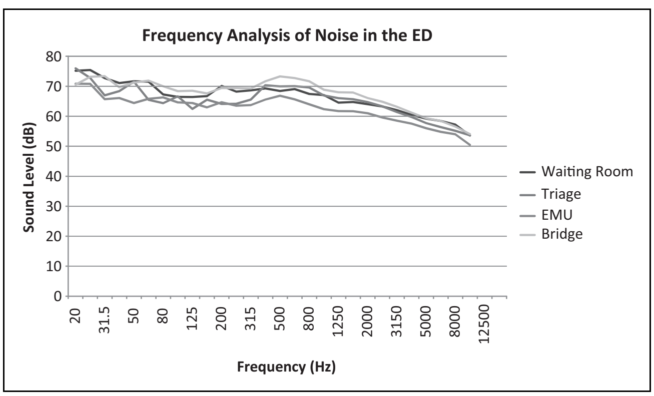

Figure 2. Frequency analysis of noise in the emergency department (ED).

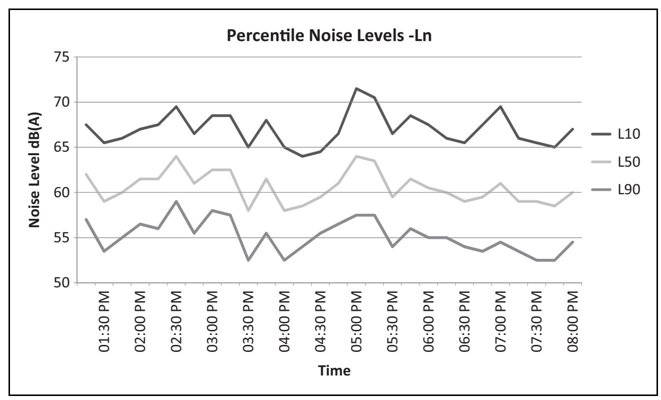

Figure 3. Percentile noise levels-Ln.

Microsoft Excel (Microsoft, Redmond, Washington) spreadsheet from which summary tables and figures were generated relating to locations and noise features. Results of the staff noise survey were collated, entered, and analyzed using descriptive statistics and then compared to the results of the physical noise measurements.

Results

All of the areas had an L_{eq} of over 50 dB(A), with averaged values of 60 dB(A) or higher for all the locations throughout the 7 continuous hours of testing. A summary of the results throughout the locations can be seen in Figure 1. The L_{eq} values for each of the areas exceed the AS2107 recommendation[10] by at least 10 dB(A). In comparison to the WHO guidelines,[1] the measurement(s) exceeded the recommended level by at least 20 dB(A).

In a comparison of the 4 locations, the bridge was the noisiest area with average sound pressure levels reaching up to 68 dB(A). The EMU had the lowest $L_{eq,}$7 hours, but had the greatest varying range throughout the 7 hours and had the potential to be noisier than some of the other areas. The waiting room experienced noise that varied through a compact range, only varying less than 7 dB(A), indicating that the noise in the waiting room was constant in comparison to the other locations. The triage area had consistent average levels throughout the 3 days but had a slightly larger range in comparison to the waiting room. The triage had an average closer to the maximum L_{eq} for that time, which suggests that noise levels were predominantly high, with only a few quieter periods.

Noise levels across the frequency spectrum from 20 to 31.5 Hz were over 70 dB. The curve shown in Figure 2 is relatively flat, showing a slight peak around 500 Hz. The relatively even spread across the frequencies implies that there was no dominant noise source. This suggests that the noise was predominantly mitigated through the ED as it reflected off surfaces in the vicinity. Further investigation needs to look at the impact of each noise source for each area to determine the cause of the small peak.

The bridge reached instantaneous peaks over 90 dB(A) which is at least 50 dB(A) over the recommended maximum. This can be seen in Figure 3, which represents the noise levels heard for a certain percentage of time denoted by L_N, where N

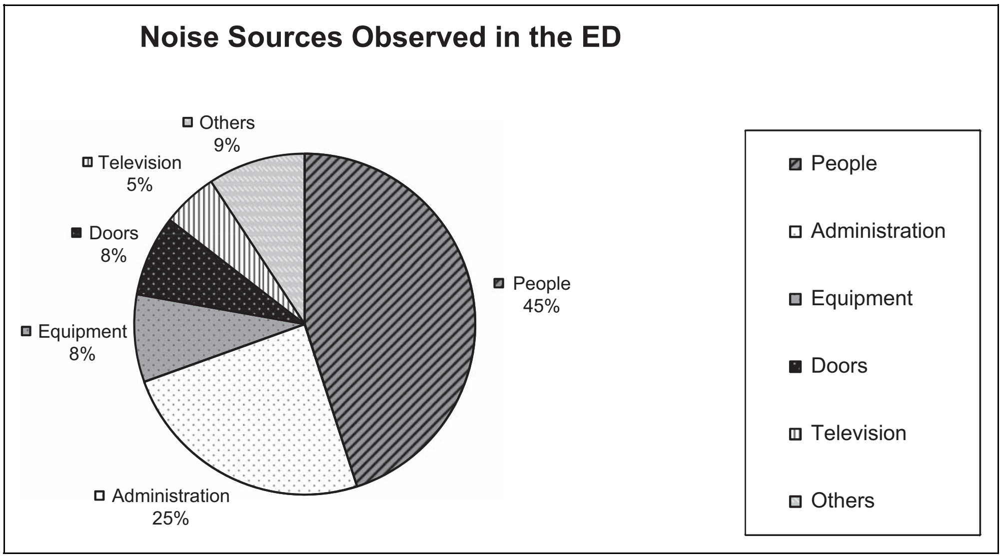

Figure 4. Noise sources observed.

is the percentage of time for which the noise is heard. For 90% of the time, the noise is above 50 dB(A) which exceeds the hospital recommendations by at least 5 dB(A) for the Australian Standard and 10dB for the WHO guidelines.

Based on the survey, the many sources of noise identified were grouped into the following: people-related noise, administration noise, noise from equipment, and other various sources (see Figure 4). People-related noise, although mainly conversational, also included patient-related noise such as coughing, moaning, and various other noises. Conversations alone made up 38% of the chart. The second-most-dominant noise was other forms of communications such as administrative matters, phones, and the intercom system. Medical equipment, whether it was through alarms or the physical movement of the equipment, was another significant contributor to noise in the ED. Other prominent noise sources included the television and the sound of doors. Various sources of noise that were evident but not predominantly heard included patient transport, rubbish collection, bathroom noises, curtain opening/closing, and meal servicing.

In order to further understand the experience of noise in the ED, perceived noise from the survey was compared to the actual measured physical noise levels. At certain times common trends could be seen, where heightened noise levels correlated with surveys identifying higher levels of noise from several sources during the time of the recording. As it was out of scope to measure the noise emitted by the different noise sources, it was not possible to distinguish the levels contributed by particular sound sources in the measured data. Hence, there was no direct link between the physical data and the survey perceptions.

Discussion

This study has provided insights into noise in an Australian ED by monitoring and assessing noise levels in high patient and staff occupied areas. The data collected found elevated noise levels above the guidelines (WHO,[1] AS,[10] American National Standards Institute,[29] and Environmental Protection Agency [US][30]), consistent with the previous studies. The highest level of L_{eq} measured exceeded the recommended levels by at least 20dB(A). This disturbing trend of elevated noise levels through multiple studies emphasizes health care noise as an issue that needs to be addressed.

Further to this, a survey has described the perception of noise by staff working in the environment, thereby assisting with identifying noise sources that may be distracting and possibly increase irritation and annoyance. The most prominent noise sources indicated by the survey were people-related noise—conversations between staff and patients. Although communication is important in this critical environment, people need to be aware that the noise they create via conversation spreads throughout the department. Many of the noise sources evaluated from the survey can be addressed by increasing awareness that can lead to changes in practice. However, further noise control measures may need to be applied to lower the noise levels to meet the stated recommendations and guidelines.

Staff typically considered the EMU to be a quiet patient rest area. However, physical measures showed that the EMU area experienced almost equal amounts of noise compared to the other locations. There was only a 1% difference between the triage and EMU, and a 2% difference to the bridge. The most likely reason for this is caused by the ED layout—a large open area where sound propagates with little or insufficient noise mitigation controls. Although located on different sides of the department, there was no direct division (barrier) between the EMU and the bridge. Therefore, noise was likely to propagate from one area to the other. The flatness of the frequency curve supports the notion that noise that spreads throughout this ED was not caused by a single significant source and instead resulted from sound from multiple sources reflecting in the enclosed ED. Further study into reverberation characteristics of the room would assist in determining the specific nature of noise propagation.

Management staff have suggested that the feeding back of results of the measured noise levels to ED staff has prompted an increase in awareness about the problem of noise, as has been noted in previous studies in the ICU.[11,31,32] In addition, systematic documentation of the noise problem in the ED has provided an opportunity for further discussion of the results, reflection on actions that could be taken, and further dissemination of the findings to hospital management, with a view to addressing the noise issue.

Limitations

A major limitation to this project was the availability of noise-logging equipment and logistical time restrictions to its use. Ideally, measurements should be taken simultaneously; however, only one noise logger was available. The unpredictability and variability of the ED meant that each day when the measurements were taken, different people and different clinically demanding situations were present. Due to this, the same noise conditions could not be measured simultaneously in different parts of the ED, thereby placing constraints on the interpretation of the results. There were also limitations on measurement of areas due to logistical considerations, such that the subacute area of the ED was not assessed. This area is similar in character to the bridge surrounded by patient treatment areas, with a workbench as the main location for medical and nursing documentation and computer access. The proximity of patients to this area is closer than the acute area, but each subacute treatment cubicle has its own door opposing the workbench. The effect of this situation in relation to noise levels is currently unknown and should be further assessed in the future.

Additionally, the scope of this project only required noise levels to be monitored in third-octave band capturing peak flow hours in 4 locations of the ED. Noise properties were limited to those captured from the third-octave band mode; noise was only considered from 1 PM to 8 PM; and only 4 locations of the ED were depicted in this study. These limitations restricted the data variability available for evaluation.

Although the staff survey was completed regularly, some inconsistencies occurred due to workload and clinical issues. In addition, individual perceptions by staff were likely to vary due to audible range and auditory acuity, depending on individual sensitivities. To address this issue, further analysis of the noise emanating from the range of noise sources in the ED is required.

Our study showed a distinct pattern of elevated noise in the ED. Further research needs to be undertaken in order to gain a deeper insight into the sources of high noise levels and their propagation throughout the department. Although further research is needed to fully comprehend the ED environment, implementable recommendations have been developed aimed at keeping noise to a minimum.

Recommendations

Improving the acoustic environment involves 2 main components. The first requires eliminating unnecessary noise, that is, noise that could be reduced, such as loud talking or noisy closing doors. The second involves managing the noise that is inevitable for this setting, such as verbal communication and essential equipment alarms. Elimination of unnecessary noise does not always require additional sound treatment. Instead, the noise source itself can be evaluated to reduce the noise to a minimal amount in order to function.

A previous study[33] proposed a revision of the building layout and materials while reducing noise from the sources. From the surveys, the majority of the noise experienced emanated from people (staff and patients). Although communication is an important factor, the people in the ED should be educated to become aware of the noise they create and the effect it has. An appropriate system can be created through training staff and putting up appropriate signage to introduce a noise compliance schedule whereby patients, staff, and visitors are aware that noise should only be present where necessary. Communication equipment (intercoms, pagers, and phones) and medical machinery with adjustable volumes should be limited to a level that will enable the device to effectively function while keeping noise to a minimum. Controlling noise by directly addressing the noise source minimizes the propagation of unnecessary noise to other ED areas.

With the advancement of technology, the development of physical acoustic controls have been able to minimize the spread of noise.[34] Controls that are used to dampen or eliminate noise can be classified as either active or passive. Active noise control is a recent concept that utilizes electroacoustical means to cancel out the noise being heard. Passive noise control involves insulation or dampening, which works best on reducing middle to high range frequencies. Although there is promise in active noise control,[35,36] especially for addressing lower frequencies, passive control would be all that is necessary in managing the noise in the ED.

Due to the particular setting of hospitals, passive noise control materials would need to meet existing standards prior to installation, such as infection control, to ensure that hazards are not introduced into this critical environment. Acoustic absorbers and blockers such as treating ceiling tiles and acoustic-treated barriers (for example, doors, curtains, mobile walls) can be introduced to ensure that the noise is distributed appropriately. In particular, it is important that the short-stay (<23 hours) EMU area has effective noise control. Partitioning this section from the rest of the department will lessen the noise traveling from the rest of the department to this patient rest area. Additionally, an initial study of using music to counteract the negative impact of noise has been completed,[2] and a further study is about to commence within this setting.

Final Conclusions

The ED is a critical care environment where people are naturally prone to stress. Noise is a factor that can impede the quality of the health care services delivered. It has the potential to affect anyone who is exposed "*inflicted on either sick or well*" (Florence Nightingale[4]), which includes patients, staff, and visitors.

Studies show that hospital noise is a worldwide issue, which needs both attention and efforts at resolution, in order to improve patient care and staff well-being. Although appropriate noise controls are being researched, actions can be taken to address the noise sources present in the ED. The most opportune control that could effectively be implemented is to increase awareness and introduce a noise compliance schedule whereby noise is kept to a minimum. As Tsiou and colleagues expressed, "generally workers in the field need to be made aware of and sensitive to the issue [of noise]. Awareness means this: if the door squeaks—oil it, if the telephone rings loudly—lower the volume, if the trolley's wheelbase is broken—have it replaced, don't leave inhalers, respirators or other equipment switched on unnecessarily, when you speak—do not shout and keep your voice lower still at night."[37(p837)] Actions speak louder than words.

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Declaration of Conflicting Interests

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