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Environmental noise levels in hospital settings: A rapid review of measurement techniques and implementation in hospital settings

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Abstract

Background: Hospitals provide treatment to improve patient health and well-being but the characteristics of the care environment receive little attention. Excessive noise at night has a negative impact on in-patient health through disturbed sleep. To address this hospital staff must measure night-time environmental noise levels. Therefore, an understanding of environmental noise measurement techniques is required. In this review, we aim to 1) provide a technical overview of factors to consider when measuring environmental noise in hospital settings; 2) conduct a rapid review on the equipment and approaches used to objectively measured noise in hospitals and identify methodological limitations. **Design**: A rapid review of original research articles, from three databases, published since 2008. Studies were included if noise levels were objectively measured in a hospital setting where patients were receiving treatment. **Results:** 1429 articles were identified with 76 included in the review. There was significant variability in the approaches used to measure environmental noise in hospitals. Only 14.5% of studies contained sufficient information to support replication of the measurement process. Most studies measured noise levels using a sound level meter positioned closed to a patient's bed area in an intensive care unit. **Conclusion**: Unwanted environmental noise in hospital setting impacts negatively on patient and staff health and well-being. However, this literature review found that the approaches used to objectively measure noise level in hospital settings have been inconsistent and poorly reported. Recommendations on best-practice methods to measure noise levels in hospital environments are provided.

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Full Text

INTRODUCTION

"Noise" is defined as sound that is "unwanted",[2],[3],[4] with the environments we encounter every day containing numerous noise sources (i.e. "environmental" noise). Hospitals are noisy environments with sounds produced by equipment, the beeping of pagers, the voices of staff and other patients.[5] The effect that excessive levels of such noise can have on patient care has been the topic of much research. Environmental noise can impact patient safety[6]; an extensive review by Pope reported that environmental noise in hospitals affects the sleep of patients, can increase their blood pressure and diminish their immune responses, as well as a host of other negative side effects.[4]

The World Health Organization (WHO) issued guidelines on the maximum amount of noise that should be present in hospitals. The guidelines suggest that noise on wards should not exceed 30 dB LAeq, whilst noise in treatment rooms should be kept “as low as possible”.[7] However, studies measuring environmental noise in hospitals have identified that such levels are not realistic. It has been noted that the guidelines did not account for the presence of patients, instead referring to buildings that are “empty”.[4] Moreover, noise levels on nursing units “frequently” exceed 100 dB LAeq, this being the equivalent of a car horn and far removed from the WHO guidelines.[4] Numerous other studies have attempted to quantify the levels of noise in hospitals.[5],[8],[9],[10]

There are a number of limitations when measuring noise in hospitals that make a comparison between studies difficult.[9] Noise levels usually vary rapidly with time and so some form of single-figure or average figure is usually reported. There are many factors to consider in noise measurement and not all are appropriate for hospital noise assessment. They include time period, sampling rate, frequency range, frequency weighting, peak, maximum, percentile levels or energy average. Different measuring devices (e.g. sound level meters and dosimeters) and the different ways in which a device can be calibrated yield different results.[4],[9] The purpose of this rapid review was to describe the equipment and approaches used in studies that objectively measured noise levels in hospitals and identify any associated methodological limitations. Recommendations will be developed to guide the accurate measurement, documentation and reporting of environmental noise measurements in hospitals.

METHODS

A “rapid review” enables an evaluation of existing literature using systematic review methods, whilst allowing for a reduction in the breadth and depth of a full systematic review.[11] The WHO guidelines for rapid reviews states that the literature search can be limited to two or more databases with additional limits on date, language and study design.[12] Although potentially relevant research studies might not be identified using this approach, there is evidence to show that conclusions determined from rapid reviews are similar to conclusions reached in more comprehensive reviews.[13]

Search strategy

Original research articles were identified from three databases (Scopus, PubMed and Cochrane Library) to enable identification of research studies published in both medical and acoustics journals. Input from an Information Technologist enabled us to develop a robust search strategy (see Appendix A) which was piloted. Boolean operators were used to combine search terms relating to “noise” and “hospitals”. Several search limits were applied to reduce the breadth and depth of the review, as permitted by rapid review guidelines.[11],[12] Searches were limited to English Language only and due to technological advances in sound measurement, were restricted to articles published in the last ten years (≥2008).

Article selection process

Following removal of duplicates, all articles identified from the searches were screened firstly by title/abstract before full-text screening by one author (R.W.) who had expertise in acoustics. Research of any design was included into the review. A random sub-sample of 20 articles considered relevant for inclusion into the review were independently checked against the entry criteria by two authors (E.H. and F.A.). Included studies fulfilled the following criteria;Research studies focusing on environmental noise measurements in hospitals as a primary aim;Studies conducted in a hospital setting;Studies that report objectively measured noise levels using a device which gives an output in decibel (dB);Studies that report indoor levels of noise in areas where patients (adults and children) are being treated (i.e. wards, intensive care units, operating theatres, out-patient clinics);

Studies reported in English language.

Data extraction

Data were extracted from all included studies into a tabular format by one author (R.W.). To reduce reporting bias, data from a random sample of 20 studies was independently extracted by another author (WJD) and compared with the original data extraction table. Information extracted included authors, year of publication, setting, noise level measurement device details, location of device, time period of measurements, amplitude type, weight network, time constant, calibrations made and type of noise parameter recorded.

Quality appraisal

The way in which the technical aspects of the included studies were reported was appraised by one author (R.W.). To reduce reporting bias, a random sample of 20 articles were appraised independently by another author (H.L.). Classification of the reporting quality of the studies were based on inclusion of the following variables; the setting; the

measuring device used; the location of the device; the time period for the measurement; the type of amplitude measured; the weighting network used; the time constant; the calibration process; and the type of sound level parameter measured (e.g. Leq, Lmax, etc.). Studies were appraised as “comprehensive” if all of these variables were provided in sufficient detail to enable an accurate reproduction of the measurement process; “average” for studies that included information on most of the aforementioned variables, but not all; and “limited” if either vital information was omitted or ambiguities demonstrated in their measurement process, or both. A variable was considered as being “vital” if significant changes in the measurement data could arise if the parameters were changed (this being judged based specifically on the present context of measurements within hospitals). For example, A-weighting in sound pressure level (SPL) measurement attenuates low frequencies heavily with respect to C-weighting and so it is reasonable to suggest that a 24-hour measurement on an ICU with the respective networks applied would yield different results. Given this, failure to indicate the weighting would mean that assumptions would need to be made about the measurement process and this can affect the validity of the data.

RESULTS

[Figure 1] provides an overview of study selection process; 1429 articles were screened (649 from Scopus, 74 from Cochrane and 706 from PubMed), of which, 111 full-texts were assessed for eligibility against inclusion criteria and 76 articles included in the review. The included studies were conducted across 22 countries; USA (26), UK (6), Turkey (5), Taiwan (4), Australia (4), Brazil (3), Canada (3), China (3), India (3), Iran (3), Portugal (2), Germany (2), Sweden (2), France (2), Spain (1), Greece (1), South Africa (1), Finland (1), Switzerland (1), Argentina (1), Belgium (1) and Italy (1). {Figure 1}

Characteristics of the measurement approaches used in studies reporting noise levels in hospitals

[Table 1] presents an overview of the study characteristics and measurement approaches used.{Table 1}

Of the 76 studies that measured environmental noise in hospitals since 2008, noise levels were most commonly measured in an intensive care unit (70% of studies), while the remaining studies reported noise levels in emergency departments, patient wards, operating theatres, a pharmacy department or multiple locations around a hospital. The majority of studies (66%) used some form of Sound Level Meter (SLM), whilst a further 20% used dosimeters to measure noise levels in a hospital setting. There was a large amount of variation in the location of the measuring device between studies, with 47% of studies using the area around the patient’s bed as the location for recording noise measurements. Furthermore, the measurement durations varied widely, with numerous studies recording both day and night noise levels and at different periods of time throughout the day. The majority of studies (96%) explicitly stated that SPLs were measured and 66% of studies used an A-weighting network. The most popular measurement method was the time-average SPL (Leq), being present in 58% of all studies. Lmax (maximum SPL) and Lmin (minimum SPL) were also popular (38% and 28% respectively). The arithmetic “average” of sound levels was calculated in 26% of all studies, but details on this calculation were ambiguous. Each study using this approach was rated as “limited” for reporting quality.

Quality appraisal of measurement approaches

The way in which the technical aspects of the included studies was reported was appraised as “comprehensive” for 11 studies, “average” for 25 studies and “limited” for 40 studies. This means that only 14.5% of the 76 hospital studies included in the review, provided sufficient details to enable the authors to repeat the measurement.

A high proportion of studies were able to provide sufficient information about the measurement process in some areas. With respect to the time periods in which the measurements were conducted, 97% of all studies provided information on both the duration of the measurement process and also the sampling period for measurements. Similarly, most studies (87%) also provided details about the specific location of the measuring instruments.

However, it is important to note that there were a number of key absences across the studies. The time constant, for example, was only discussed in 33% of all studies, whilst only 43% provided information about the calibration process. Moreover, although the details on the frequency weighting function used in the respective studies was generally present, with 78% of studies including this information (65.8% for A-weighting, 10.5% for C-weighting and 1.3% for both), 22% were not explicit as to which network was used.

Recommendations

Based on this review, the following recommendations are provided to guide the accurate measurement and documentation of environmental noise measurements in hospitals.

Purpose. A noise survey may have a variety of different approaches and the specific purpose should be identified. The

noise survey may be designed to assess the noise exposure at specific patient bed spaces, noise exposure of staff or measuring the noise climate of specific rooms or types of setting. The measurements may be made to assess compliance with a benchmark (such as WHO) or to compare with environmental noise levels across similar settings or as part of a noise reduction programme.

SLM setting. The purpose of the noise survey will determine the choice of instrumentation. Currently there is no standardised method for measuring hospital noise. Modern sound level meters are often capable of measuring many different acoustic metrics. The accuracy and comparability of all of these metrics is not guaranteed, not least because permitted tolerances of sound level meters are defined for a limited range of metrics.[1] This makes it difficult for the non-specialist to know what to measure and why. Many of the studies included in this review compared their results to the WHO guidelines, which are expressed in LAeq (A-weighted time-average SPL) and LAFmax (A-weighted maximum SPL measured over a given period of time with 'fast' time constant (i.e. 125ms)).

For most long-term measurement applications in a hospital environment, A-weighting would be most appropriate since it considers the frequency-dependent loudness perception of the human hearing system (i.e. LAeq). There are large meta-analyses of outdoor environmental noise which indicate that variants of LAeq are an adequate predictor of noise annoyance.[88]

Care should be exercised when attempting to measure the maximum SPL, for three main reasons. Firstly, even if a researcher considers a maximum value to be representative of a distribution of noise levels measured in a location, it is unlikely to be generalisable. For example, if a hospital ward measurement is repeated on the next night, a different maximum value will likely occur. Secondly, there are several different ways of measuring a maximum value. For example, Lpeak means decibel value corresponding to the maximum pressure (positive or negative) arriving at the microphone,[1] while LAFmax means the maximum A-weighted SPL measured with a Fast time constant. Lpeak will typically be many decibels higher than LAFmax. Finally, the evidence relating measured maxima to human responses is not as strong as for average values like LAeq, at least for noise exposures below the range where noise-induced hearing loss is likely. This is reflected in the widespread use of LCpeak in workplace noise exposure legislation, but not in standardised methods intended to predict annoyance or disturbance from noise.

If it is desired to measure the maximum SPL, it is recommended that the device be set to 'fast' and A-weighted (i.e. LAFmax). This would allow comparison with WHO guidelines. LA10 (SPL exceeded for 10% of the measurement time period) and LA90 (SPL exceeded for 90% of the measurement time period) would be useful alternative metrics. They are widely used in environmental noise surveys as markers of the near-highest and background sound levels, respectively. Measured over day, night or 24-hour periods, they might also be useful measures of the noise climate on a hospital ward.

Locations. The positioning of the measuring device should be made sufficient for the "point-of-interest" for your study. For example, if a patient's noise exposure is of interest, then a location close to the patient's ear will be more appropriate than a central location in the room. The measuring device should be positioned in a location that is not disruptive to the day-to-day clinical activity of the hospital staff. Any contact with the measuring device during measurements should be avoided as this can affect the maximum SPL to be recorded. Compromises may be required to balance preferences for the ideal location for the point-of-interest with practical considerations. It is important to ensure that any measuring devices are at least 1 m (more if possible) away from any large reflecting surfaces (doors, walls, windows, floors, ceilings, etc.) and that they are on a stable surface, such as being mounted on a tripod. Close reflecting surfaces will increase the measured sound level, dependent on several factors which make the result less generalisable, like the size and acoustic absorption coefficient of the surface.

Documentation and reporting. It is essential to be explicit about the procedure that was followed and equipment used. Failure to document this information can cause the measurement data to be uninterpretable and meaningless. The provision of detailed information will avoid any unnecessary confusion and support the perceived accuracy of your results. The essential information to be reported is as follows:The precise location of the measuring device, using a picture or diagram if necessary.The time period and sampling intervals for the measurement.Equipment manufacturer and model.Equipment calibration process.Time constant and frequency weighting (e.g. LAeq, LAFmax, LA90, etc.).

Data analysis. Researchers should exercise caution when attempting to manipulate the measurement data and avoid this where possible. Instead, all desired measurements and results should ideally come directly from the measuring instrument, and any supporting software, in order to minimise data errors. To calculate the "average" environmental noise level when this is not achievable with the instrumentation at your disposal, then the calculation of the arithmetic mean is not recommended because this does not produce an Leq. Instead, the Leq should be estimated from the measured data and the process used to do described in detail. To avoid confusion the use of the term "average" in this context should be avoided.

CONCLUSION

This rapid review of 76 studies provides a detailed overview of the equipment and approaches used in studies that have measured noise levels in hospitals. There was significant variability in the approaches used to measure environmental noise in hospitals. Few studies (14.5%) contained sufficient technical information to support the replication of the environmental noise measurement process; descriptions on important parameters such as weighting, time constant and measurement time period were missing. In hospital environments, it is recommended to use LAeq or LAFmax. The measurement equipment setting and process should be fully documented with details on device location and the time period of the recording noted. Attempts to average any measured data should be avoided where possible. In addition, most studies measured noise levels using a SLM positioned closed to a patient's bed area in an intensive care unit. It is recommended future studies also measure noise levels in other areas of a hospital such as in-patient wards, where the impact of noise can have a negative impact on patients' health.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Appendix A—Search terms

Scopus database

#1 "noise" [NDEXTERMS]

#2 "noise, occupational" [NDEXTERMS]

#3 "sound" [NDEXTERMS]

#4 "acoustics" [NDEXTERMS]

#5 "loudness perception" [NDEXTERMS]

#6 "sound intensity" [NDEXTERMS]

#7 "acoustic noise measurement" [NDEXTERMS]

#8 "acoustic measuring instruments" [NDEXTERMS]

#9 "noise measuring" [NDEXTERMS]

#10 "psychoacoustics" [NDEXTERMS]

#11 "noise spectrum" [TITLE-ABS]

#12 reverb* [TITLE-ABS]

#13 "noise level" [TITLE-ABS]

#14 "sound level" [TITLE-ABS]

#15 #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14

#16 "intensive care units" [NDEXTERMS]

#17 "neonatal intensive care unit" [INDEXTERMS]

#18 "patients' rooms" [INDEXTERMS]

#19 “hospitals” [INDEXTERMS]

#20 “critical care” [INDEXTERMS]

#21 “health facilities” [INDEXTERMS]

#22 hospital* [TITLE-ABS]

#23 “patients’ ward” [TITLE-ABS]

#24 “patients’ room” [TITLE-ABS]

#25 “emergency room” [TITLE-ABS]

#26 “emergency ward” [TITLE-ABS]

#27 “intensive care” [TITLE-ABS]

#28 “critical care” [TITLE-ABS]

#29 #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28

#30 #15 and #29

Cochrane library

#1 MeSH descriptor: [Noise] explode all trees

#2 MeSH descriptor: [Noise, Occupational] explode all trees

#3 MeSH descriptor: [Sound] explode all trees

#4 MeSH descriptor: [Acoustics] explode all trees

#5 MeSH descriptor: [Loudness Perception] explode all trees

#6 MeSH descriptor: [Psychoacoustics] explode all trees

#7 “noise spectrum” or reverb* or “noise level” or “sound level”:ti,ab,kw (Word variations have been searched)

#8 MeSH descriptor: [Intensive Care Units, Neonatal] explode all trees

#9 MeSH descriptor: [Intensive Care Units] explode all trees

#10 MeSH descriptor: [Patients’ Rooms] explode all trees

#11 MeSH descriptor: [Hospitals] explode all trees

#12 MeSH descriptor: [Critical Care] explode all trees

#13 MeSH descriptor: [Health Facilities] explode all trees

#14 hospital* or “patients’ ward” or “patients’ room” or “emergency room” or “emergency ward” or “intensive care” or “critical care”:ti,ab,kw (Word variations have been searched)

#15 #1 or #2 or #3 or #4 or #5 or #6 or #7

#16 #8 or #9 or #10 or #11 or #12 or #13 or #14

#17 #15 and #16

Pubmed database

#1 “noise” [MeSH Terms]

#2 “noise, occupational” [MeSH Terms]

#3 “sound” [MeSH Terms]

#4 “acoustics” [MeSH Terms]

#5 “loudness perception” [MeSH Terms]

#6 “psychoacoustics” [MeSH Terms]

#7 “noise spectrum” [Title/Abstract]

#8 reverb* [Title/Abstract]

#9 “noise level” [Title/Abstract]

#10 “sound level” [Title/Abstract]

#11 #1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10

#12 “intensive care units” [MeSH Terms]

#13 “intensive care units, neonatal” [MeSH Terms]

#14 “patients’ rooms” [MeSH Terms]

#15 “hospitals” [MeSH Terms]

#16 “critical care” [MeSH Terms]

#17 “health facilities” [MeSH Terms]

#18 hospital* [Title/Abstract]

#19 “patients’ ward” [Title/Abstract]

#20 “patients’ room” [Title/Abstract]

#21 “emergency room” [Title/Abstract]

#22 “emergency ward” [Title/Abstract]

#23 “intensive care” [Title/Abstract]

#24 “critical care” [Title/Abstract]

#25 #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24

#26 #11 and #25

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