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# Comparing average levels and peak occurrence of overnight sound in the medical intensive care unit on A-weighted and C-weighted decibel scales☆

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ABSTRACT

*Purpose:* Sound levels in the intensive care unit (ICU) are universally elevated and are believed to contribute to sleep and circadian disruption. The purpose of this study is to compare overnight ICU sound levels and peak occurrence on A- vs C-weighted scales.
*Materials and Methods:* This was a prospective observational study of overnight sound levels in 59 medical ICU patient rooms. Sound level was recorded every 10 seconds on A- and C-weighted decibel scales. Equivalent sound level (Leq) and sound peaks were reported for full and partial night periods.
*Results:* The overnight A-weighted Leq of 53.6 dBA was well above World Health Organization recommendations; overnight C-weighted Leq was 63.1 dBC (no World Health Organization recommendations). Peak sound occurrence ranged from 1.8 to 23.3 times per hour. Illness severity, mechanical ventilation, and delirium were not associated with Leq or peak occurrence. Equivalent sound level and peak measures for A- and C-weighted decibel scales were significantly different from each other.
*Conclusions:* Sound levels in the medical ICU are high throughout the night. Patient factors were not associated with Leq or peak occurrence. Significant discordance between A- and C-weighted values suggests that low-frequency sound is a meaningful factor in the medical ICU environment.
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## 1. Introduction

Critically ill patients experience sleep loss, poor sleep quality, and circadian misalignment. Causality is multifactorial and may include physiologic, psychological, and environmental factors [1-3]. Studies using 24-hour polysomnography in medical intensive care unit (MICU) patients demonstrate severely reduced overall sleep time, decreased slow wave sleep, limited rapid eye movement sleep, frequent arousals, and increased sleep during daytime hours [3-7]. Similar findings have been observed in healthy subjects exposed to recordings of intensive care unit (ICU) sounds [8].

Health care providers struggle to balance the urgent needs of critically ill patients with the empiric observation that ICUs are loud and disruptive. Concerns regarding the impact of the ICU environment on the cognitive and psychiatric outcomes of patients were raised early in the inception of ICUs [8-13]. However, critical care units are still characterized by high sound levels that, in turn, may contribute to sleep deprivation, circadian disruption, and delirium. There have been improvements in treatment and prevention of delirium and promotion of sleep [14,15], but understanding of how characteristics of the ICU environment, such as sound, impact patient sleep, circadian orientation, and delirium continues to be incomplete.

Sound has characteristics of amplitude or sound pressure (perceived as loudness, measured in decibels [dB]), frequency (perceived as pitch, measured in Hertz), and time pattern [16]. Decibel levels are reported on a logarithmic scale that accommodates the large range of sound intensity in our environment. The threshold for human hearing is set at 0 dB; painful sound is 140 dB. A change in 3-5 dB is perceptible to the human ear and a change of 10 dB represents approximate doubling of sound amplitude [16,17]. Noise is unwanted or undesirable sound and is subjectively identified by the listener.

The sound level equivalent (Leq) reflects the average amplitude or sound pressure over an indicated interval. It is most commonly reported on either an A-weighted (unit dBA) or C-weighted (unit dBC) scale. Weighted scales integrate sound levels across varying frequencies and give higher or lower weights to particular frequencies. For example,

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reporting of sound in dBA units gives more weight to the higher-frequency tones most readily heard by the human ear. The C-weighted scale incorporates a wider range of sound frequency and is weighted equally across low and high frequencies. Discordance between A- and C-weighted measures indicates the presence of a high proportion of low-frequency sound [18]; low-frequency sound is associated with building machine noise such as air handlers and small machine noise such as the "hum" from computers or televisions [19].

Studies of patients interviewed post-ICU discharge identified lack of sleep and "noise" as significant stressors and linked noise to sleep loss [17,20-23]. Average ICU sound levels are typically between 55 and 65 dBA [24-29] despite World Health Organization (WHO) recommendations for hospital sound averages and maxima of 30 and 40 dBA, respectively [30]. Maximum sound levels exceed 80 dBA in most studies of acute or critical care environments [24,25,31,32]. Studies of critically ill patients demonstrate correlations between sound peaks greater than 75 dBA and polysomnographic arousals from sleep with approximately 17% to 18% of nighttime arousals occurring at the time of sound peaks [5,33].

The purpose of this study is to report overnight sound levels (amplitude and peak occurrence) in MICU patient rooms and to examine associations between sound levels and patient characteristics. Peak occurrence was measured in absolute and relative terms, and concurrent measures on A- and C-weighted scales were compared for differences. Patient characteristics include severity of illness, use of mechanical ventilation, use of vasopressors, need for contact precautions, and presence of delirium. We hypothesized that these factors were either associated with sound producing machines or may require a higher degree of bedside presence that would increase sound levels.

## 2. Methods

### 2.1. Study design and setting

This was a prospective observational study investigating sound levels in the rooms of critically ill patients. The study was conducted in the MICU of a 1000-bed tertiary hospital. The MICU was built in 2009 and is rectangular in shape with rooms on all 4 sides around a central core of workstations, supply closets, and conference rooms (Fig. 1). Every patient has a private room with 3 solid walls and a hallway wall with a curtain and sliding clear glass door. There is no central nursing station. There is a main entrance desk that is continuously staffed by administrative personnel who answer phones and open the locked unit door. Most nurses (>70%) work 12-hour shifts from 0700 to 1900 hours and 1900 to 0700 hours. Daytime physician staffing uses a traditional academic pyramid of one attending physician supported by fellows, residents, interns, advanced practice nurses, and physician assistants who conduct interdisciplinary rounds during the morning and perform work during the afternoon. Overnight physician staffing includes 3 intensivists and the on-call resident and intern who work from 1900 to 0700 hours. Visitors are allowed in the unit 24 hours a day. It is hospital policy that all patients receive a "quiet kit" that includes earplugs, eye masks, and suggestions for being quiet after 2100 hours.

### 2.2. Study patients and ethical considerations

Study rooms in MICU were selected based on presumed average sound qualities, with the goal of excluding rooms that may be extremely noisy or quiet. Therefore, rooms by the main MICU entrance which were subject to high staff and equipment traffic and corner rooms with lower traffic were excluded (Fig. 1). The sample included patients older than 18 years who were admitted to MICU study rooms. Patients were eligible for screening if they had been admitted within the 48 hours before the next sound recording period. Patients were excluded if they were non-English speaking, expected to die in the next 24 hours, receiving comfort care only, undergoing therapeutic hypothermia, or expected to be transferred from the MICU before completing the overnight sound recording period. All study procedures were approved by the institutional review board/human investigations committee. Consent was obtained according to standard procedures.

### 2.3. Clinical data collection and sound recordings

Patient data were abstracted from the electronic medical record and included need for contact precautions, mechanical ventilation, vasopressor use, and severity of illness. Delirium was determined during daily interview via the Confusion Assessment for the ICU scale [34]. Contact precaution status was considered "yes" if visitors to a patient's room were required by the hospital to don a protective gown before entering. Mechanical ventilation was considered positive if the patient was ventilated during the night of observation. Vasopressor use was positive if norepinephrine, epinephrine, neosynephrine, dopamine, or vasopressin was used for 1 hour or more during the 24 hours surrounding the overnight sound monitoring period. Severity of illness was defined by the

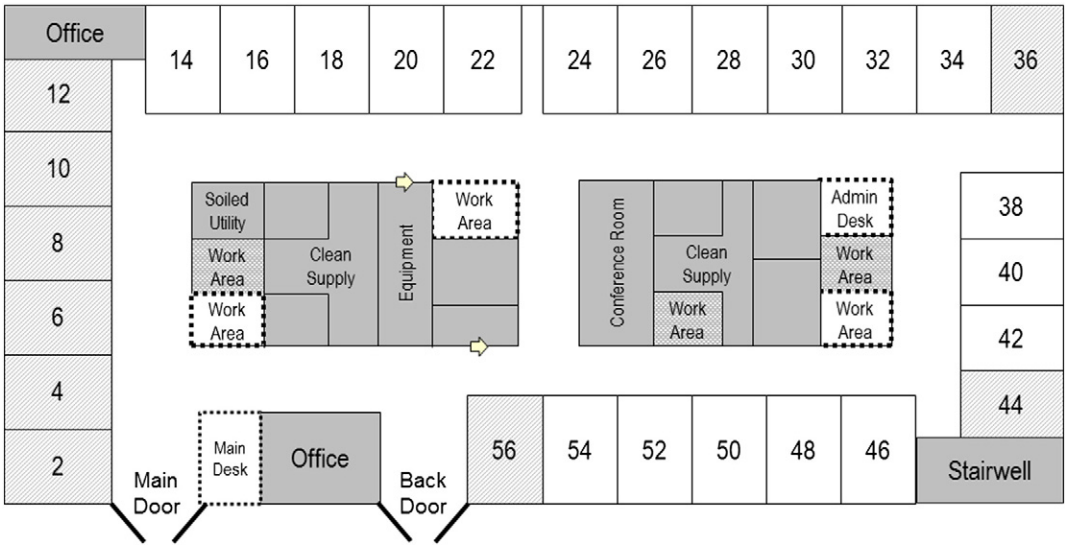


**Fig. 1.** Medical ICU floor plan. Patient rooms are indicated by sequential even numbers; gray-lined rooms were excluded from the study. Staff work areas were either enclosed (gray) or open (white with dashed borders).

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