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Observations of Acoustic Interruptions Versus Ambient Sound Levels With Perceived Sleep Quality During Critical Illness

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ICUs are loud and there is an association between ambient sound and worsened sleep quality. In contrast to ambient sound, short acoustic interruptions or sound spikes—for example, brief alarm tones—cause arousal from sleep in healthy patients, but remain understudied in critically ill patients, despite the observed frequency of ICU alarms. We collected greater than 2.3 million values of ambient sound (every second) among 14 patients in the ICU over a median of two nights (interquartile range, 1–2) each. We identified brief acoustic interruptions/sound spikes—increases of greater than or equal to 20 dB above ambient—over 1 second. Patients experienced a median of five interruptions greater than or equal to 20 dB (interquartile range, 2–12) per night. Each interruption was associated with a 1-point decrease in patient reported quality of sleep, as assessed by the Richards Campbell Sleep Questionnaire. Our observations suggest a possible relationship between acoustic interruptions and worsened perceived sleep.

KEY WORDS: acoustics; environment; noise; sleep; sound

To the Editor:

It is well recognized that the ICU is loud, with ambient sound levels routinely exceeding 50 dB, even during the night (1, 2), and that these sounds may lead to worse quality sleep (3–7). Among the various approaches to improve sleep quality during critical illness—including earplugs (8–12), behavioral interventions (13, 14), and structural modification (15)—none has had a consistent effect, with minimal reduction in ICU sound levels over 40 years (1, 16). One potential intervention to improve sleep quality is the use of "white noise" as an auditory mask to "block" brief and unpredictable sounds occurring during critical care. White noise was proposed over 30 years ago (17) and a small study of four patients suggested that it could decrease the perception of environmental sound (18), such as brief sound spikes.

Sound spikes are a type of acoustic interruption, which are both audibly distinct from ambient sound and louder. During critical illness, sound spikes might be single alarm beeps against the context of continuous background talking. As the human brain can ignore continuous background noise, but is less able to ignore sudden changes, these acoustic interruptions can result in awakening from sleep. To our knowledge, no previous studies have examined the occurrence of these sound spikes/acoustic interruptions during critical illness and their relationship with perceived sleep quality. We hypothesized that worsened perceived sleep may be related to these acoustic interruptions and that increasing ambient background noise might be protective against these acoustic interruptions, functioning as an auditory mask or white noise.

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We report the findings of a quality improvement project as part of a Doctor of Nursing Practice degree to measure the occurrence of acoustic interruptions against background noise during critical illness. As a quality improvement initiative, Institutional Review Board approval was waived. We continuously recorded sound levels among 14 critically ill patients in a cardiovascular ICU at a sampling resolution of 1 Hz. After data collection, we identified the occurrence of acoustic interruptions, defined as an episode when the sound level increased greater than or equal to 20 dB from the previous value (therefore within 1 s). This 20-dB threshold was selected as a value from previous studies, which was high enough to likely elicit an auditory polysomnographic arousal (18–20). Polysomnographic arousals are an electroencephalographic episode indicated a temporary awakening from sleep. Arousals can resolve or can lead to actual awakening. Arousals occur both with and without auditory stimulation during sleep and vary widely based on the individual, sleep stage, and environmental conditions.

Our outcome measure was perceived sleep quality for each patient each night and was assessed using the Richards Campbell Sleep Questionnaire (RCSQ). The RCSQ reports perceived sleep-quality totals and subscores and has been previously validated and used during critical illness (13, 21). RCSQ total scores range from 0 to 600, with higher scores indicating better sleep. Using panel regression for repeated measures with random effects, clustered by patient, we examined the relationship between the number of acoustic interruptions of greater than or equal to 20 dB above ambient noise and RCSQ scores. We then repeated this analysis, examining the relationship between ambient noise levels for each patient and the patients' perceived sleep quality obtained the following morning.

We collected data on 14 patients. Patients were 62 years old (interquartile range [IQR], 53–66) and five were female. Ten patients were admitted for acute decompensated heart failure or acute coronary syndrome. Two patients had decompensated valvulopathies, one was status postheart transplantation, and one was admitted for sepsis. Among these patients, we obtained over 2.3 million sound values over a median of two nights (IQR, 1–2) each. From 22:00 to 05:00 each night, patients experienced sound levels of 53 dB (IQR, 49–56 dB). During this time, 1,029 interruptions of greater than or equal to 20 dB increase over 1 second occurred a median of five times (IQR, 2–12), mean 10 (± SD 15) per patient per night. Four patients experienced at least 20 acoustic interruptions each from 22:00 to 05:00. Lowering the threshold to greater than or equal to 15 dB, 4,861 acoustic interruptions occurred a median of 31 (IQR, 11–62) and mean of 48 (±49) times per patient per night, with four individuals experiencing greater than 120 interruptions per night. An example patient night displaying ambient sound and overlying acoustic interruptions is shown in **Figure 1**.

In regression analysis, there was a statistically significant worsening of RCSQ total score with increasing occurrences of acoustic interruptions greater than or equal to 20 dB (β coeff, –1.1 [95% CI, –1.14 to –1.11]; $p < 0.001$), implying a 1-point decrease in RCSQ for every acoustic interruption per patient per night. Though the effect was small, increasing ambient sound was statistically associated with improved RCSQ scores (β coeff, 0.2 [95% CI, 0.18–0.22]; $p < 0.001$), implying a 0.2-point increase in RCSQ for every 1 dB increase in ambient sound level per patient per night.

Our data suggest that there is a potential relationship between the number of acoustic interruptions that achieve an auditory threshold of greater than or equal to 20 dB above background and worsened perceived sleep quality. In this cohort, with every acoustic interruption, there was a 1-point lower RCSQ value. Additionally, our findings showed an association between increasing ambient noise as protective against worsened sleep quality. Our findings are coincidental at this point, and we hypothesize an association. Our findings have many limitations and should be

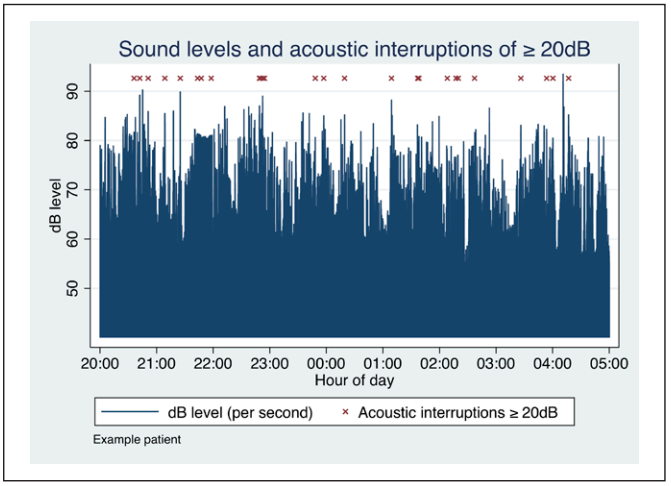

Figure 1. Single patient example of nightly sound levels and acoustic interruptions of ≥ 20 dB.

interpreted cautiously. First, it is not possible for us to determine the relationship between the acoustic interruption and the source of the sound, nor is it possible to exclude the possibility that another noxious stimuli or event prior to or after the sound might have been the cause of worsened perceived sleep. Second, the clinical significance of the finding is not well defined at this point. The statistical association was significant, but the size of the coefficient was small, with a larger relationship between the interruptions and worsened perceived sleep than between increasing background white noise and improved perceived sleep. Although we only analyzed 14 patients, this amounted to greater than 2.3 million sound values analyzed. Finally, we were not powered to do multivariate adjustment at the patient level, which may influence the results; our findings necessitate repeating among a larger number of patients. Additional studies of simultaneous polysomnographic recordings to characterize the relationship between these auditory interruptions, polysomnographic arousals, and perceived sleep quality are also warranted.

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Drs. Almberg and Tonna designed the study, helped in study conduct, and drafted the article. All authors helped in data acquisition and analysis, revised the article for important intellectual content, and had approved the final article for publication. Dr. Tonna had full access to the study data and takes responsibility for the data integrity, accuracy, and integrity of the submission as a whole.

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