

Sleep and Circadian Disruptors: Unhealthy Noise and Light Levels for Hospitalized Pediatric Stem Cell Transplant Patients

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Abstract

Noise and light levels during hospitalizations can disrupt sleep and circadian health, resulting in worse health outcomes. This study describes patterns of noise and light in an inpatient room of children undergoing stem cell transplants. Objective meters tracked noise and light levels every minute for 6 months. Median overnight sound was 55dB (equivalent to conversational speech), which exceeded recommendations. There were 3.4 loud noises (>80dB) per night on average. Children spent 62% of the 24-hour cycle in non-optimal lighting, with daytime light dimmer than recommended 98% of the time. These data suggest improvements for hospital environment in pediatric cancer patients.

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EDI	equivalent daylight illuminance
SCT	stem cell transplant
SLCs	sound level changes
WHO	World Health Organization

Abstract :

Noise and light levels during hospitalizations can disrupt sleep and circadian health, resulting in worse health outcomes. This study describes patterns of noise and light in an inpatient room of children undergoing stem cell transplants. Objective meters tracked noise and light levels every minute for 6 months. Median overnight sound was 55dB (equivalent to conversational speech), which exceeded recommendations. There were 3.4 loud noises (>80dB) per night on average. Children spent 62% of the 24-hour cycle in non-optimal lighting, with daytime light dimmer than recommended 98% of the time. These data suggest improvements for hospital environment in pediatric cancer patients.

Introduction

Pediatric patients undergoing stem cell transplant (SCT) are hospitalized for extended periods and are at high risk for sleep disturbances due to noise and light disruptions.¹ Poor sleep can lead to adverse health effects, including immune system dysregulation.²⁻⁴ As pediatric SCT patients are immunocompromised and at risk for comorbidities, it is important to optimize their environment for sleep and circadian health.

Noise and light are frequent disruptors of sleep and circadian health in pediatric hospital rooms.⁵ Noise often spikes during the night on pediatric oncology units as a result of staff room entries, medication administrations, and alarms.⁶⁻⁸ Irregular and “unnatural” light-dark cycles can cause circadian disruptions.^{9,10} Noise and light disruptions are independently associated with less sleep among children with cancer.⁸

Within inpatient rooms of children with cancer, noise and light disruptions have been tracked only for brief periods (e.g., three days)¹¹ and primarily focused on nighttime light levels.¹¹⁻¹³ This study expands findings by characterizing noise and light patterns across full 24-hour periods over several months in an inpatient pediatric SCT room.

Methods

Procedures

Over 6 months, we recorded sound and light levels at one-minute intervals within a patient room on the inpatient SCT unit at a children’s hospital in the northeast United States using the Extech SDL600 (noise) and Extech SDL400 (light). Meters were wall-mounted near the head of the bed to approximate the patients’ experience (Figure 1).¹⁴ We recorded admission/discharge dates and patient demographics. The study was deemed exempt by the hospital’s IRB.

Analytic Plan

Data Processing

Analyses were restricted to the dates that rooms were occupied, excluding admission/discharge days. Due to device malfunction, light data were not captured from 03/03/2022 to 05/22/2022, sound data were not captured from 07/07/2022 to 08/13/2022, and <1% of all sound data was corrupted. We manually scanned for and agreed via consensus to remove corrupted data along with the five datapoints preceding and following the affected ones.

Data Analyses

We examined patterns of sound and light across three times of day: overnight (8:00pm-7:59am), daytime (8:00am-3:59pm), and evening (4:00pm-7:59pm). For noise, we evaluated whether median levels at night exceeded 40 dB, the World Health Organization's (WHO) recommended maximum for nighttime noise spikes in inpatient hospital rooms.¹⁵ For light, we determined the percent of time that patients were exposed to inappropriate light levels. Recent consensus-based recommendations for optimal light conditions include exposure to a melanopic equivalent daylight illuminance (EDI) of [?]250 lux during daytime hours, [?]10 lux during the evening, and [?]1 lux overnight.¹⁶ Because our meter was wall mounted, we converted melanopic EDI to vertically measured illuminance by multiplying the recommended melanopic EDI by a correction factor of 1.79 based on a melanopic daylight efficiency ratio of 0.56 for 4000K fluorescent lights.^{17,18} Therefore, the vertically measured illuminance thresholds are 448 lux during the daytime, 18 lux during the evening, and 2 lux overnight. For the nighttime hours, we also measured the frequency of noise spikes >80 dB, sound level changes (SLCs, the difference between two consecutive sound measurements) >17.5 dB, and light spikes >150 lux – all of which are associated with night wakings.^{12,14,19} Data were analyzed using RStudio.

Results

Patient Characteristics

Six pediatric SCT patients aged 1-17 years ($M_{\text{age}} = 8.4 \pm 6.6$) occupied the observed room from February to August 2022. Four patients were male, one was female, and one did not have their sex recorded. Their average length of stay was 31.5 days (range = 13-61). Five had their primary caregiver stay overnight.

Noise

Across all overnight data points, the minimum noise level was 51.4 dB, with a median of 55.0 dB. Overnight noise peaked at 98.4 dB. At least one noise disruption (spike >80 dB or SLCs >17.5 dB) occurred on 96.5% of nights. On an average night, the patients were exposed to 3.4 noise spikes >80dB and 5.6 SLCs >17.5 dB. See Figures 2a-b.

Light

Across a 24-hour day, 61.9% of time was spent in non-optimal light conditions. During the daytime, light was <448 lux 97.5% of the time, with a median of 73.0 lux (range = 0-1454 lux). Light was >18 lux for 58.6% of the evening, with a median of 29.0 lux (range = 0-2370 lux). Overnight, children spent 30.2% of their time in light >2 lux. Light spiked to a maximum of 513 lux at night, with children being exposed to light spikes >150 lux on 4.9% of nights. Notably, those light spikes occurred between 7:00-7:59am. See Figures 2b-d.

Discussion

Hospitalized pediatric SCT patients were consistently exposed to disruptive noise and light. Nighttime noise levels always exceeded WHO recommendations for sleep,¹⁵ with patients exposed to multiple noise spikes associated with night wakings.^{12,14,19} While light levels were frequently dim enough to be conducive to sleep at night, patients were rarely exposed to light bright enough to preserve a healthy circadian rhythm during the day. Furthermore, the afternoon timing of the brightest daytime light exposure was also not ideal for maintaining circadian entrainment.¹⁶

The high noise levels are consistent with a recent review and are a well-known issue for inpatients.⁵ Humans can become accustomed to a persistently noisy environment so long as it is constant – variability may drive night wakings.^{12,14,19} By two different metrics, children in our study were exposed to exceedingly disruptive noise: 3.4 noise spikes >80 dB (roughly equivalent to a gas-powered lawnmower²⁰) and 5.6 SLCs >17.5 dB per night. It may be important to focus intervention efforts on minimizing brief, but problematic, bursts of sound.

Patients were exposed to insufficient light for >97% of the daytime, consistent with prior research among adults.^{14,16} They were also exposed to brighter than recommended light for >50% of the evening and 30% of the night. As children likely benefit from even lower levels of evening light than adult recommendations, we may be underestimating the potential for circadian disruption.¹⁶ The relatively low and afternoon-skewed daytime light, combined with the brighter than recommended light during the evening and early night, is thought to lead to circadian rhythm disruption, longer hospitalizations, and higher morbidity.²¹ Improving circadian health should be an area of growing interest among pediatric researchers and clinicians.²² Future studies should include objective assessments of patients, including sleep disruptions, circadian rhythm timing,^{23,24} and outcomes (e.g., length of stay).

Findings should be considered within the context of study limitations. We did not measure light/sound directly at eye/ear level or assess direct patient outcomes. Furthermore, these results may not be generalizable to all hospitals, inpatient populations, and rooms. For example, room layout and location impact light exposure.²¹

Our findings suggest considerable room for improvement of the inpatient environment to better support sleep and circadian health.^{21,25,26} Although environmental factors are known to be the most common sleep disruptors, the majority of sleep-promoting interventions target individuals' behaviors, not their environments.⁵ Due to the known challenges with sustaining interventions targeting patients or providers, institutions should make systematic changes that prioritize sleep and circadian function (e.g., reducing overnight noise or consolidating procedures^{7,27,28}).²⁹ Almost all section chiefs of hospital medicine rate patient sleep as important, but fewer than half of their hospitals have adopted sleep friendly practices.³⁰ This speaks to the need for the establishment of sleep/circadian health standards that institutions are incentivized to implement.³¹

Conflict of Interest Statement

Eric S. Zhou has received grant funding from Jazz Pharmaceuticals and Harmony Biosciences, and he has received consulting fees from Samsung and MindUP. Brian D. Gonzalez reports fees unrelated to this work from Sure Med Compliance and Elly Health. Jo M. Solet owns stock in and is an advisor to Kunason and Dream Zzzz; she is also an advisor to Lark. The remaining authors have no known conflicts of interest to disclose.

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Legends

Figure 1: Room layout and meter placement.

Figure 2a: Mean noise levels per hour with 95% confidence intervals.

Figure 2b: Frequency of noise spikes >80 dB, SLCs >17.5 dB, and light spikes >150 lux per week

Figure 2c: Mean light levels per hour with 95% confidence intervals.

Figure 2d: Average percent of time spent in inappropriate light conditions across the 24-hour day.

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