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Quality of Care

Quality Improvement Initiative to Reduce Nighttime Noise in a Transplantation and Cellular Therapy Unit

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A B S T R A C T

Sleep is an essential biologic function vital for physiologic rest, healing, and emotional well-being. Sleep disruption is commonly seen in patients and caregivers with lengthy hospital stays such as patients undergoing hematopoietic stem cell transplantation and cellular therapy (TCT). Sleep disruption can lead to increased stress and fatigue, affecting caregivers' ability to support their loved one. The global aim of our quality improvement initiative was to improve sleep quality in TCT patients and caregivers. The smart aim of our project was to decrease nighttime hallway noise from 47 dB to 43 dB and decrease the number of overnight noise peaks greater than 60 dB from 865 to 432 in 6 months. Through a cross-sectional quantitative and qualitative evaluation of sleep we had previously identified poor sleep quality, and with a cross-sectional focus group analysis of patients, caregivers, and medical staff we identified the factors associated with poor sleep. Hallway noise was a major factor. A simplified failure mode analysis identified 4 main key drivers; unobtrusive nighttime cleaning process, nighttime awareness maintenance system, quiet nighttime nursing system, and reliable nighttime awareness system. Several plan-do-study-act interventions took place and were adopted. From January to June 2018 the overnight mean decibel level decreased from 47 dB to 44 dB (6% reduction). Overnight noise spikes above 60 dB decreased from a mean of 865 spikes to a mean of 463 spikes (46% reduction). With a quality improvement initiative, we identified the causes of hallway nighttime hospital unit noise that negatively impact sleep and through a team-based approach performed interventions that successfully mitigated these factors.

INTRODUCTION

Sleep is a biologic function essential for physiologic rest, hormonal and metabolic processes, immune function, and emotional well-being [1,2]. Poor sleep quality can negatively affect the body's metabolism and diminish cognitive performance, and it is associated with increased incidence of depression and decreased quality of life [3-14].

A decreased ability to fight infection is associated with poor sleep; sleep deprivation studies have revealed alteration in various measures of immune function, such as production and levels of cytokines [6], effects on population diversity, and function of circulating neutrophils [10], and prospective studies have showed that a worse Quality Sleep Index score after hospitalization is associated with increased mortality risk [15]. Sleep disruption is commonly seen in hospitalized patients and their families, particularly in patients with lengthy hospital stays such as those undergoing transplant or receiving cellular therapy (TCT) [1]. TCT is associated with prolonged hospitalization, lasting from 30 days to several months, with patients and families experiencing a series of physical, social, and psychological stressors that lead to sleep disruption [16,17]. In adult patients the effects of prolonged sleep disruption during hospitalization have shown to persist for months after discharge, affecting sleep quality and quality of life [18-20]. Hospitalized patients along with their caregivers experience repeated interruptions and intermittent loud noises that compromise sleep quality [1,21], such as frequent room entries, overnight administration of medication, monitor

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alarms, hospital staff, and cleaning services [8,18]. Delany et al. [22] reported staff as the most common source of sleep disruption, accounting for 35% of all noise. Sleep disruption in the caregivers of hospitalized patients can lead to increased stress and fatigue and decreased quality of life and can ultimately affect caregivers' ability to support their loved one [23-26].

The World Health Organization recommends that average hospital sound levels should not exceed 35 dB overnight [27]. Additionally, the nighttime recommendation for the general population is 40 dB outside because adverse health effects are observed at the level above 40 dB, these adverse effects include sleep disturbance, insomnia, and increase use of sleeping aids [27] (Figure 1). Several studies looking at hospital decibel levels and the effect on sleep have been conducted. Average sound levels in intensive care unit settings have been reported to exceed 40 dB, with peak noises above 85 dB during the day and overnight [22,28-30]. Sound peaks greater than 80 dB have been described in intensive and intermediate respiratory care units, and electroencephalogram has been used to study patient's arousal in relation to noise, which showed a strong correlation between the number of peaks above or equal to 80 dB and arousal from sleep [31]. Al-Samsam et al. also studied sleep patterns in 11 intensive care unit patients using polysomnography and observed that wake states occurred at a decibel level of 75 dB [32], whereas Gädeke et al. [33] studied 126 children (3 to 63 weeks old) and found that noise levels of 75 dB led to obvious sleep disturbance or awakening in patients. Determination of acoustic disruption of sleep due to hospital noises was also studied using encephalogram and showed that electronic sounds were more arousing and associated with changes in vital signs [34], and a study of sleep–wake cycles in mechanically ventilated patients showed that environmental noise was responsible for 17% of the awakenings from sleep [35]. Topf and Davis [36] found that sound levels in the intensive care unit setting of a mean of 56 dB interfered with rapid eye movement sleep in adult volunteers. Finally, in an observational within case-controlled study comparing sleep quality at home and at the hospital, children and parents had less sleep in the hospital than at home, with sound levels measuring an average of 48.6 dB in the hospital compared with 34.7 dB at home [37].

Rationale

Using the Model for Improvement [38] we conducted a quality improvement initiative to decrease overnight noise on the TCT unit at Cincinnati Children's Hospital Medical Center. We performed a cross-sectional quantitative and qualitative evaluation to determine barriers to sleep in the inpatient setting with TCT patients and caregivers [1]. Patients and caregivers identified sounds in the hallway, loud talking at the nursing station, noise from trash pulls, and room door opening/closing as factors that lead to nighttime sleep interruptions [1]. Before any interventions, we found a median overnight (2100 to 0700) decibel level on the TCT unit of 47 dB. Further, we measured the amount of ambient noise on the floor (noise measurement with total silence) as 38 dB. Additionally, we found a median of 865 noise peaks above 60 dB each night.

Available Knowledge

Sleep disruption and noise pollution have been recognized for years, with most studies looking at interventions to reduce noise in critical care units. Richardson et al. [39], through a multimethod approach, was able to decrease average peak decibel levels over 24 hours from 94 dB to 77.5 dB. Behavioral modification programs have shown that patients have better sleep when light and sound levels are decreased and after implementation of quiet time and nondisturbance periods [40], which resulted in reduced noise levels. Gardner et al. [41] conducted a multicenter nonrandomized trial of 299 patients in an acute care setting where they evaluated noise level, sleep status, sleepiness, and well-being and showed significant differences in mean decibel level and number of awake and asleep periods in the quiet time intervention group. To our knowledge, no studies have specifically addressed nursing and structural interventions to reduce nighttime unit noise in patients with prolonged hospitalizations or in TCT units.

Specific Aims

The aim of this initiative was to decrease hallway noise and the number of high decibel peaks on the inpatient TCT unit overnight. The smart aims of our project were to decrease the median nighttime hallway noise from 47 dB to 43 dB and to decrease the number of overnight noise peaks greater than 60 dB from 865 to 432 over a 6-month period. A level of 43 dB was chosen given that a decrease of over 3 dB correlates to a decrease of the sound intensity to half.

METHODS

Setting and Context

Cincinnati Children's Hospital Medical Center is a large, urban pediatric medical center, and the TCT service performs approximately 110 transplants per year. The TCT unit contains 36 rooms that accommodate a patient and caregiver. Patients undergoing TCT require frequent nursing interventions for laboratory monitoring, medication administration, transfusions, nutrition support, and cleaning services. Because of the acuity of these patient populations, nighttime monitoring occurs at least every 4 hours. The clinical

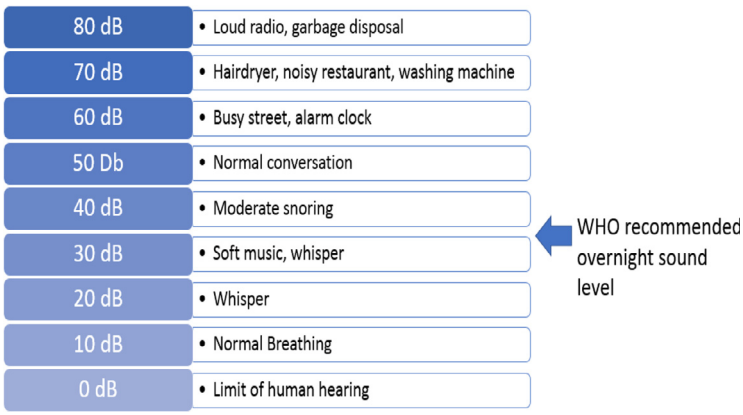

Figure 1. Decibel levels of common sounds. WHO indicates World Health Organization.

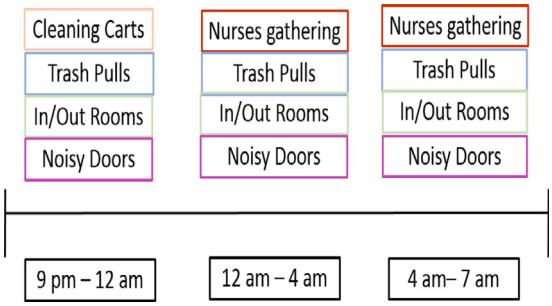

Figure 2. Identifiable sources of hallway noise in the Bone Marrow Transplant Unit overnight.

providers caring for patients include 14 attending physicians, 15 fellows, 7 nurse practitioners, and 6 hospitalists. The hospitalists provide 24-hour coverage for all patients. The TCT unit employs approximately 130 bedside registered nurses (RN) and 30 patient care assistants (PCA). Family members take an active role in the care of patients in the TCT unit as participants in the Family Advisory Council and through daily patient/family-centered rounds [42].

Observation and Development of Key Drivers

In January 2018 we created a team consisting of a charge nurse, a group of nighttime RNs and PCAs, a member of environmental services (EVS), a unit coordinator, and parents of hospitalized patients to be part of the quality improvement initiative. The team reviewed current and published nighttime hospital sound level recommendations and used a digital decibel sound meter for nighttime recording. Failure modes and potential interventions were recognized and key drivers identified. Several plan-do-study-act (PDSA) interventions for each key driver took place and were adopted with involvement of other hospital services and staff. Our focus was to develop a standardized team-based approach to make highly reliable changes and therefore attain sustainable results.

We obtained baseline information using decibel level sound meters that were placed in the unit hallways for a 10-day period. This investigation revealed the median nighttime (10 hours, from 2100 to 0700) sound level was 47 dB and the median sound spikes above 60 dB were 865 per night. Simultaneously, nighttime nurses observed and documented hourly identifiable sources of hallway noise in the TCT unit that helped recognize the nighttime process of events (Figure 2). Additionally, families identified overnight trash pulls as a significant cause of increased noise.

With this information we developed the main key drivers involved in the process: family engagement, unobtrusive nighttime cleaning process, nighttime awareness maintenance system, quiet nighttime nursing system, and reliable nighttime awareness system (Figure 3). After baseline data were obtained, we were able to test potential interventions for improvement.

Interventions

Family engagement

Family members helped identify other sources of noise as they formed part of our quality improvement team. The nighttime events were discussed with family members who helped communicate unknown noise sources by staff, provided useful intervention ideas, and continued to communicate and provide feedback to the team.

Unobtrusive nighttime cleaning process

Rooms on the TCT unit have 2 trash cans, 1 in the bathroom and 1 in the room. Through observation and involvement of the EVS team, we learned trash pulls were unnecessarily completed twice or on occasion 3 times during the nighttime shift, commonly happening approximately between 2100 and 2300 and then again between 0100 and 0400. EVS personnel needed to open the room door, come in the room, remove the trash bag, and place a new one for each trash can in the room. Changes were made, adapted, and adopted with the last trash pull for TCT unit now at 2100.

EVS personnel double-bagged trash cans for the night in case trash pulls during the night were needed, making the process quicker and less disruptive. After 2200 no trash pulls were scheduled, but for those who required an overnight trash pull, we created an Overnight Waste Pull Sheet, to be filled out by the RN or PCA and reviewed each night by the EVS team.

Nighttime awareness maintenance system

Because of the frequent need of room entrance required in TCT patients, we worked along with hospital maintenance services to decrease the noise caused by patient room doors, hallway sterile equipment closets, and wall-mounted workstations, which when closing would transmit noise inside the patient's room. Patient doors had a rubber stopper placed in the doorframe to slow and decrease noise when door is closing. Stoppers were also placed on the hallway closets and in wall-mounted workstations.

Quiet nighttime nursing system

A bone marrow transplant "Night Ninja Program" was created, formed by nurses with experience working nightshift. The Ninja Program consisted of teaching and sharing techniques used to provide undisruptive nighttime care to patients and increase awareness on the importance of sleep with the goal to decrease talking and gathering in nursing stations and outside patients' rooms. Ninety percent of the nighttime staff completed an online educational course on the significance of sleep and a training course to become a nighttime ninja. On completion the nurses received a nighttime ninja uniform along with a badge with a checklist to review nightly.

Reliable nighttime awareness system

Educational lectures were given to nighttime staff regarding importance of sleep in the general population and in hospitalized patients and families. During the meetings nighttime staff provided feedback on the project and new ideas for intervention, strategies to solve problems, and difficulties

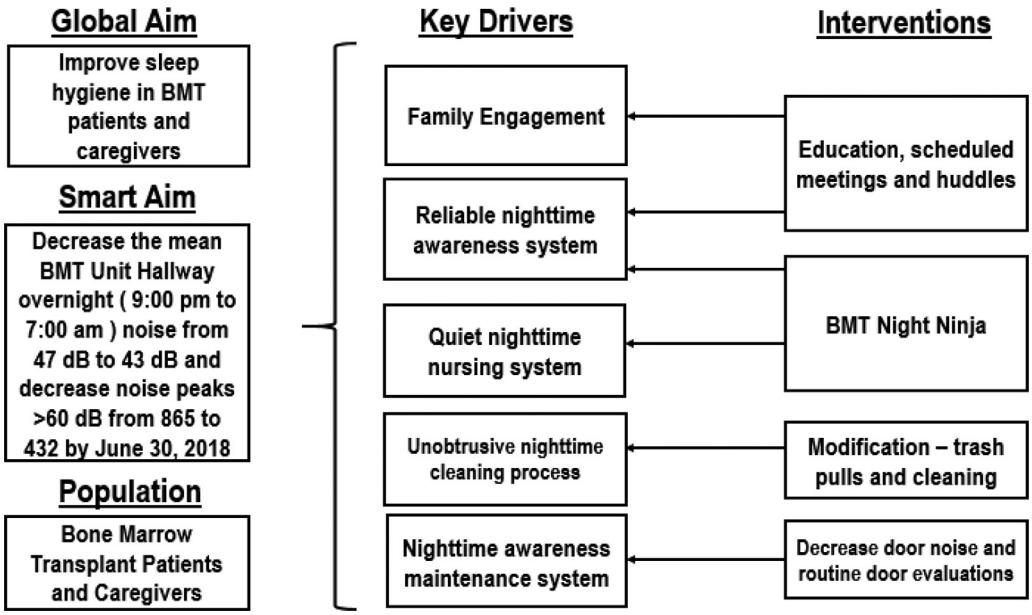

Figure 3. Key driver diagram. BMT indicates bone marrow transplant.

encountered. Nighttime staff was updated weekly with 10-minute huddles where feedback was provided, changes were made, and results reviewed.

Study of the Improvement

Through the intervention process, interval overnight sound decibels were measured. Nightly trash pull sheets were collected to ensure compliance and an establsihed establishment of process. Maintenance evaluations were scheduled to ensure continuous monitoring, and confirmation of completion of night ninja program by all staff was documented.

Data Collection/Measures

Overnight decibel sound levels measurement was collected on average twice weekly from 2100 hours to 0700 hours. The decibel level was measured every 2 seconds. Three different decibel meters were used, and each decibel meter was placed in the same hallway location in the 3 hallways during data gathering and the intervention period.

Analysis

An annotated run chart and control chart with the average decibel level per night and a run chart with levels above 60 dB per night were developed and updated monthly. A median was established and illustrated as the centerline on all run charts, and an upper and lower control limits along with the centerline was annotated in the control chart. Standard industry criteria were used to determine if observed changes in measures were common-cause variation (chance of random variation) or special-cause variation (specific assignable cause) such as our interventions [43].

Ethical Considerations

The present initiative fell within the Cincinnati Children's Hospital Medical Center institutional review board's guidance for quality improvement projects that did not constitute human subjects research.

RESULTS

The study period was from January 2018 to June 2018. The initial PDSA testing on changes implemented to the overnight trash pull system occurred in February and March 2018 and was adopted in April 2018. Nursing training started in April 2018, and by June 2018 nurses had reviewed and completed the online training course and received their uniform and checklist badge. In April and May 2018, the stoppers to patient room doors, hallway closets, and wall-mounted workstations were completed. During the study period there was a decrease in the decibel level from a median of 47 dB to 44 dB (6% reduction) along with decreased variability (Figure 4) and a decrease in overnight noise spikes above 60 dB from a median of 865 spikes to a median of 463 spikes (46% reduction) (Figure 5).

DISCUSSION

Hospitalizations of patients undergoing TCT and their caregivers is associated with prolonged hospital stays that lead to sleep disruption in both patients and caregivers. Sleep disruption negatively affects the healing course and recovery of patients after TCT and can also affect the ability of the caregivers to support their loved one. High levels of nighttime noise in hospital wards and units along with a description of its impact in patient health has been widely described in the literature, but initiatives to address this problem are lacking. In this article we describe a team approach initiative to decrease nighttime unit noise with the global aim of improving sleep quality in TCT patients and caregivers. This quality improvement initiative identified factors involved in nighttime hallway unit noise that negatively impact sleep and described the interventions performed to successfully mitigate these factors.

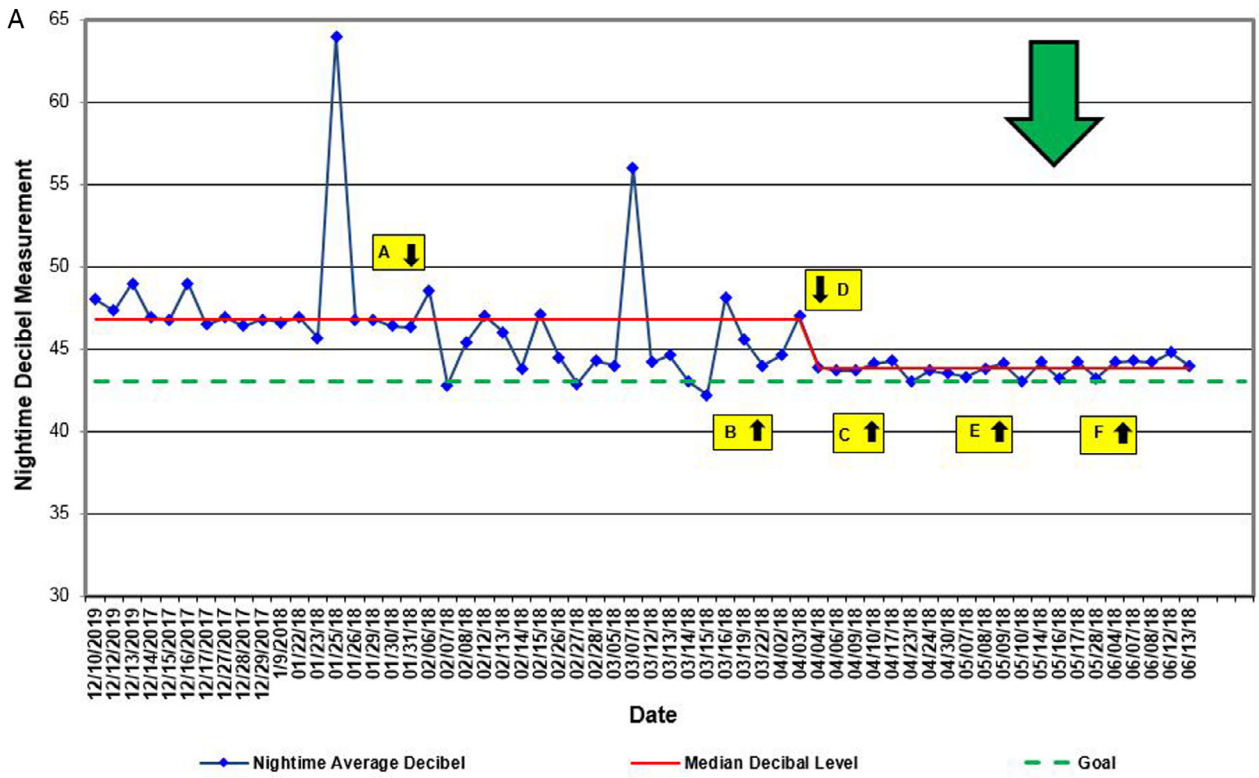

Figure 4. (A) Decrease in the decibel level from a median of 47 dB to 44 dB (6% reduction). A: PDSA # 1 (unobtrusive nighttime cleaning process) modification of trash pulls and cleaning trialed in 2 rooms; B: PDSA # 1 (quiet nighttime nursing system) first nursing training and education; C: PDSA # 3 (nighttime awareness maintenance system) door rubber stoppers placed; D: PDSA # 10 (unobtrusive nighttime cleaning process) changes and interventions adopted; E: PDSA # 8 (nighttime awareness maintenance system) stoppers to doors, closets, and wall-mounted stations; F: PDSA # 20 (quiet nighttime nursing system) bone marrow transplant ninja program adopted. (B) Decrease variability of nighttime decibel level with consequently tighter control limits.

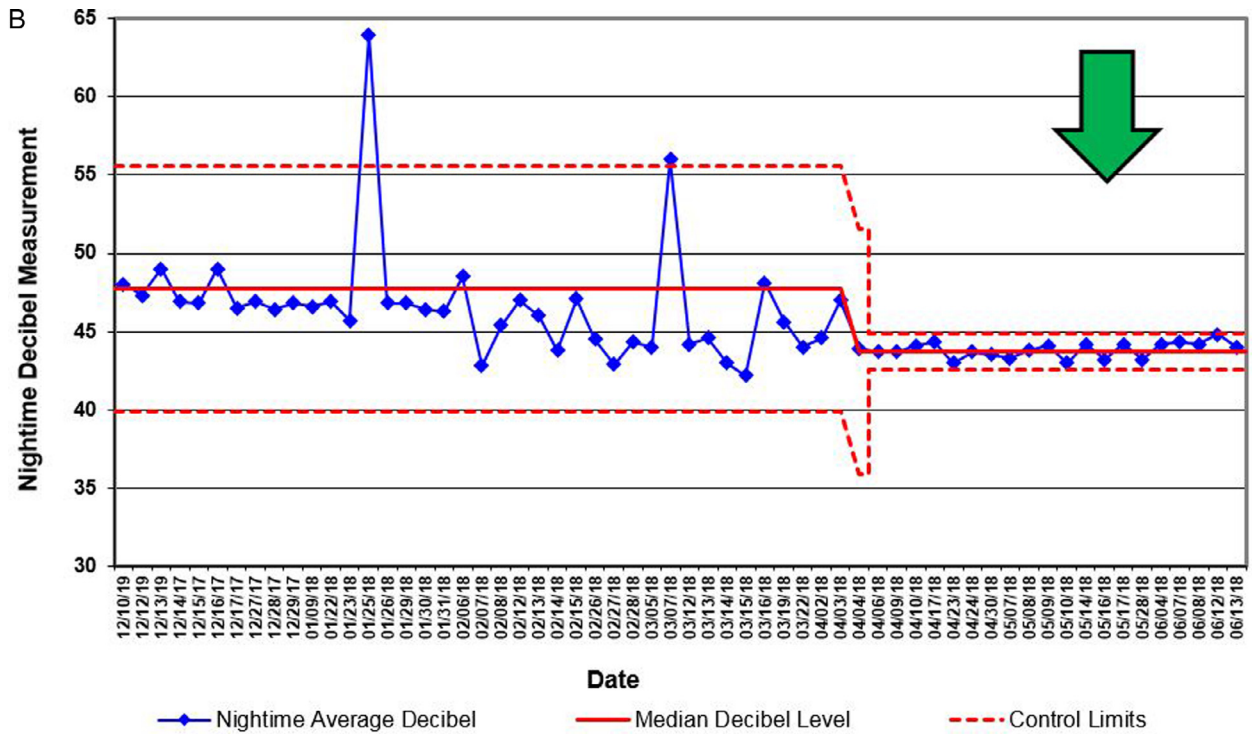

Figure 4 Continued.

Interpretation

The most important factor leading to successful interventions and results in our project was the initial observation of the events that happen during the nighttime period in the TCT unit. Through observation, we identified the causes of high levels of nighttime noise, and many of these were easy to address and mitigate. For example, during the observation period we saw that most rooms had signs on the doors requesting not to

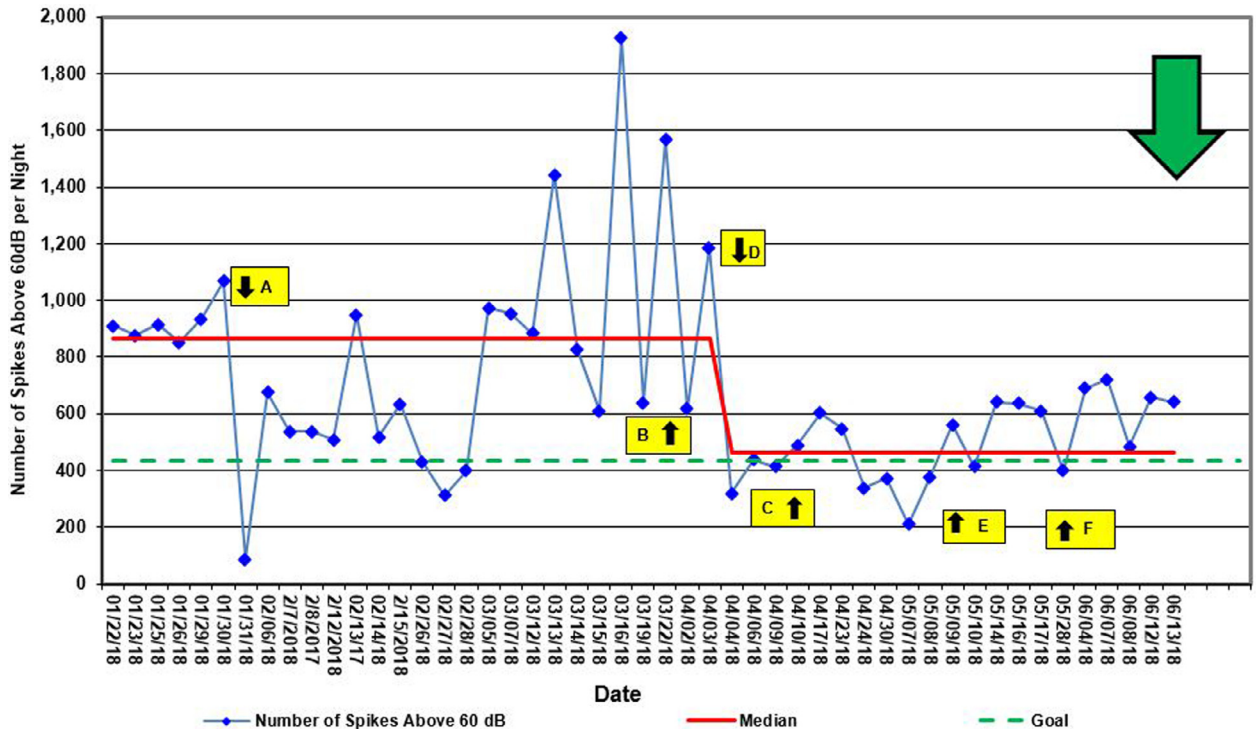

Figure 5. Decrease in the decibel level from a median of 865 spikes to a median of 463 spikes (46% reduction). A: PDSA # 1 (unobtrusive nighttime cleaning process) modification of trash pulls and cleaning trialed in 2 rooms; B: PDSA # 1 (quiet nighttime nursing system) first nursing training and education; C: PDSA # 3 (nighttime awareness maintenance system) door rubber stoppers placed; D: PDSA # 10 (unobtrusive nighttime cleaning process) changes and interventions adopted; E: PDSA # 8 (nighttime awareness maintenance system) stoppers to doors, closets, and wall-mounted stations; F: PDSA # 20 (quiet nighttime nursing system) bone marrow transplant ninja program adopted.

have trash pulls overnight or after midnight. Posteriorly we learned from the hospital EVS how their system was structured and that unnecessary trash pulls were happening after midnight in all rooms regardless of need. Working along the EVS team we made changes, providing trash pulls only to patient's rooms that required it overnight; this reduced trash pulls significantly, which translated to a decrease in nighttime spikes above 60 dB. We believe this intervention had 1 of the strongest impacts in the reduction of nighttime noise. There are currently no signs on the doors regarding requests for cleaning services, and this intervention has now spread to other units in the hospital.

We believe changes in the cleaning system along with the adjustments made by the hospital maintenance services by placing stoppers in patient doors, hallway cabinets, and wall stations have a high level of reliability and will be sustainable because these changes will function under any existing condition. For example, new personnel or increasing census in the unit will not affect these processes.

We believe the most challenging of our interventions was the development of a successful quiet nighttime nursing system and a reliable nighttime awareness system. This is challenging because of the high number of healthcare staff that forms part of this unit, which includes approximately 70 RNs and 10 PCAs who work nightshift. This large number of healthcare providers makes it hard to have consistency, involvement, and personal compromise with the project. The establishment of a leading group of engaged nighttime nurses with experience in the TCT unit and creation of the nighttime ninja program have been very successful in providing continuous education on the importance of sleep in patients and families as well as providing positive feedback. We believe because of the lower level of reliability of this intervention due to frequent changes in staff, it will require continuous supervision to maintain engagement in the project.

Limitations

There were several limitations to our study. We are unable to evaluate the impact of these interventions on patient and caregiver sleep because of the heterogeneous nature of patients admitted to our unit. However, patients, families, and staff subjectively noted the improvements in patient sleep due to decreased noise. Additionally, the baseline decibel level on the TCT unit is approximately 38 dB, which is attributable to ventilation and plumbing. Thus, further decreases in overnight noise levels are likely impossible without major construction.

Future Directions

This qualitative improvement initiative is being generalized to other units in our institution, and currently the changes in the overnight cleaning system have been established in 3 additional units at Cincinnati Children's Hospital Medical Center. We have plans to further develop the nighttime awareness initiative by working on environmental changes (eg, diming lights automatically at nighttime). Along with this project is an ongoing project that evaluates different nursing nighttime bundles of care with the goal to decrease sleep disruption inside patients' rooms, and we plan on merging these projects together.

Conclusion

We described an initiative to decrease nighttime noise in a pediatric bone marrow transplant unit. An understanding of systems already in place before establishing any changes was essential to achieve successful results. We recommend a team approach to make highly reliable and sustainable changes. We believe this initiative can be translated to similar medical units where patients and caregivers are at risk of poor sleep quality. This article was prepared using the SQUIRE 2.0 guidelines [44].

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REFERENCES

1. Coleman K, Flesch L, Petiniot L, et al. Sleep disruption in caregivers of pediatric stem cell recipients. *Pediatr Blood Cancer*. 2018;65:e26965.
2. Watson PL, Ceriana P, Fanfulla F. Delirium: is sleep important? *Best Pract Res Clin Anaesthesiol*. 2012;26:355–366.
3. Guyon A, Balbo M, Morselli LL, et al. Adverse effects of two nights of sleep restriction on the hypothalamic-pituitary-adrenal axis in healthy men. *J Clin Endocrinol Metab*. 2014;99:2861–2868.
4. Morselli LL, Guyon A, Spiegel K. Sleep and metabolic function. *Pflugers Arch*. 2012;463:139–160.
5. Rüger M, Scheer FA. Effects of circadian disruption on the cardiometabolic system. *Rev Endocr Metab Disord*. 2009;10:245–260.
6. Bovbjerg DH. Circadian disruption and cancer: sleep and immune regulation. *Brain Behav Immun*. 2003;17(Suppl 1):S48–S50.
7. Idzikowski C. Impact of insomnia on health-related quality of life. *Pharmacoeconomics*. 1996;10(Suppl 1):15–24.
8. Franck L, Wray J, Gay C, Dearmun AK, Alsberge I, Lee KA. Where do parents sleep best when children are hospitalized? A pilot comparison study. *Behav Sleep Med*. 2014;12:307–316.
9. Cohen S, Doyle WJ, Alper CM, Janicki-Deverts D, Turner RB. Sleep habits and susceptibility to the common cold. *Arch Intern Med*. 2009;169:62–67.
10. Christoffersson G, Vågesjö E, Pettersson US, et al. Acute sleep deprivation in healthy young men: impact on population diversity and function of circulating neutrophils. *Brain Behav Immun*. 2014;41:162–172.
11. Meijer AM, Habekothé HT, Van Den Wittenboer GL. Time in bed, quality of sleep and school functioning of children. *J Sleep Res*. 2000;9:145–153.
12. Cappuccio FP, Stranges S, Kandala NB, et al. Gender-specific associations of short sleep duration with prevalent and incident hypertension: the Whitehall II Study. *Hypertension*. 2007;50:693–700.
13. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*. 2008;31:619–626.
14. Aronen ET, Paavonen EJ, Fjällberg M, Soininen M, Törrönen J. Sleep and psychiatric symptoms in school-age children. *J Am Acad Child Adolesc Psychiatry*. 2000;39:502–508.
15. Martin JL, Fiorentino L, Jouldjian S, Mitchell M, Josephson KR, Alessi CA. Poor self-reported sleep quality predicts mortality within one year of inpatient post-acute rehabilitation among older adults. *Sleep*. 2011;34:1715–1721.
16. Packman W, Weber S, Wallace J, Bugescu N. Psychological effects of hematopoietic SCT on pediatric patients, siblings and parents: a review. *Bone Marrow Transplant*. 2010;45:1134–1146.
17. Dandoy CE, Davies SM, Flesch L, et al. A team-based approach to reducing cardiac monitor alarms. *Pediatrics*. 2014;134:e1686–e1694.
18. Elliott R, McKinley S, Cistulli P. The quality and duration of sleep in the intensive care setting: an integrative review. *Int J Nurs Stud*. 2011;48:384–400.
19. Elliott R, McKinley S, Cistulli P, Fien M. Characterisation of sleep in intensive care using 24-hour polysomnography: an observational study. *Crit Care*. 2013;17:R46.
20. Bijwadia JS, Ejaz MS. Sleep and critical care. *Curr Opin Crit Care*. 2009;15:25–29.
21. Herbert AR, de Lima J, Fitzgerald DA, Seton C, Waters KA, Collins JJ. Exploratory study of sleeping patterns in children admitted to hospital. *J Paediatr Child Health*. 2014;50:632–638.
22. Delaney LJ, Currie MJ, Huang HC, Lopez V, Litton E, Van Haren F. The nocturnal acoustical intensity of the intensive care environment: an observational study. *J Intensive Care*. 2017;5:41.
23. Meltzer LJ, Moore M. Sleep disruptions in parents of children and adolescents with chronic illnesses: prevalence, causes, and consequences. *J Pediatr Psychol*. 2008;33:279–291.
24. Meltzer LJ, Davis KF, Mindell JA. Patient and parent sleep in a children's hospital. *Pediatr Nurs*. 2012;38:64–71. quiz 72.
25. McCann D. Sleep deprivation is an additional stress for parents staying in hospital. *J Spec Pediatr Nurs*. 2008;13:111–122.
26. Klassen AF, Klaassen R, Dix D, et al. Impact of caring for a child with cancer on parents' health-related quality of life. *J Clin Oncol*. 2008;26:5884–5889.
27. Kim R, Berg M. Summary of night noise guidelines for Europe. *Noise Health*. 2010;12:61–63.
28. Darbyshire JL, Young JD. An investigation of sound levels on intensive care units with reference to the WHO guidelines. *Crit Care*. 2013;17:R187.

29. Hill JN, LaVela SL. Noise levels in patient rooms and at nursing stations at three VA medical centers. *HERD*. 2015;9:54–63.
30. Nannapaneni S, Lee SJ, Kashiouris M, et al. Preliminary noise reduction efforts in a medical intensive care unit. *Hosp Pract (1995)*. 2015;43:94–100.
31. Aaron JN, Carlisle CC, Carskadon MA, Meyer TJ, Hill NS, Millman RP. Environmental noise as a cause of sleep disruption in an intermediate respiratory care unit. *Sleep*. 1996;19:707–710.
32. Al-Samsam RH, Cullen P. Sleep and adverse environmental factors in sedated mechanically ventilated pediatric intensive care patients. *Pediatr Crit Care Med*. 2005;6:562–567.
33. Gädeke R, Döring B, Keller F, Vogel A. The noise level in a childrens hospital and the wake-up threshold in infants. *Acta Paediatr Scand*. 1969;58:164–170.
34. Buxton OM, Ellenbogen JM, Wang W, et al. Sleep disruption due to hospital noises: a prospective evaluation. *Ann Intern Med*. 2012;157:170–179.
35. Freedman NS, Gazendam J, Levan L, Pack AI, Schwab RJ. Abnormal sleep/wake cycles and the effect of environmental noise on sleep disruption in the intensive care unit. *Am J Respir Crit Care Med*. 2001;163:451–457.
36. Topf M, Davis JE. Critical care unit noise and rapid eye movement (REM) sleep. *Heart Lung*. 1993;22:252–258.
37. Bevan R, Grantham-Hill S, Bowen R, et al. Sleep quality and noise: comparisons between hospital and home settings. *Arch Dis Child*. 2018;104:147–151.
38. Kaminski GM, Schoettker PJ, Alessandrini EA, Luzader C, Kotagal U. A comprehensive model to build improvement capability in a pediatric academic medical center. *Acad Pediatr*. 2014;14:29–39.
39. Richardson A, Thompson A, Coghill E, Chambers I, Turnock C. Development and implementation of a noise reduction intervention programme: a pre- and postaudit of three hospital wards. *J Clin Nurs*. 2009;18:3316–3324.
40. Olson DM, Borel CO, Laskowitz DT, Moore DT, McConnell ES. Quiet time: a nursing intervention to promote sleep in neurocritical care units. *Am J Crit Care*. 2001;10:74–78.
41. Gardner G, Collins C, Osborne S, Henderson A, Eastwood M. Creating a therapeutic environment: a non-randomised controlled trial of a quiet time intervention for patients in acute care. *Int J Nurs Stud*. 2009;46:778–786.
42. Muething SE, Kotagal UR, Schoettker PJ, Gonzalez del Rey J, DeWitt TG. Family-centered bedside rounds: a new approach to patient care and teaching. *Pediatrics*. 2007;119:829–832.
43. Amin SG. Control charts 101: a guide to health care applications. *Qual Manag Health Care*. 2001;9:1–27.
44. Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 (Standards for QUality Improvement Reporting Excellence): revised publication guidelines from a detailed consensus process. *BMJ Qual Saf*. 2016;25:986–992.