Improve the night, improve the day

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Chapter 6

Exploring the effect of nightly infusion pump alarms on sleep in the hospital

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Abstract

Study objectives: Optimal sleep is important for parents and children to cope with life-threatening disease. However, hospital-surroundings are noisy, negatively affecting sleep quality and quantity. We aimed to determine sleep quantity and sleep satisfaction, and their relation to infusion pump alarms in pediatric cancer patients and parents; and sleep quality and daytime impairment in parents.

Methods: Patients (2-18 years), admitted for scheduled anti-cancer therapy were eligible, as were inrooming parents. Frequency and duration of nightly infusion pump alarms were recorded. Patients and parents wore an accelerometer to assess sleep quantity (sleep efficiency, wake after sleep onset, night awakenings) and daily sleep satisfaction was assessed. Parents filled out questionnaires on their sleep quality (PROMIS Sleep Disturbance, Insomnia Severity Index) and daytime impairment (PROMIS Sleep-Related Impairment, PROMIS Fatigue). Sleep quality scores were compared to norms. In children and parents the relation between alarms and sleep was assessed using multilevel analyses.

Results: Nineteen children (age 8.8 ± 4.9 years, 40 nights) and 30 parents (age 41.1 ± 6.3, 46 nights) participated (response 78%). Nightly alarms sounded median 3 times / 6 minutes in parents and 5 times / 10 minutes in children. Parents scored worse than the norm on sleep disturbances (P .01), but not on daytime impairment, 16% experienced clinical insomnia. There was no relation between alarms and sleep quantity or satisfaction for children and parents.

Conclusions: This explorative study showed that alarms sound frequently at night and parents sleep poorly during admissions. However, sleep of children and parents and alarms were not significantly related here. Future research should identify and improve (other) disrupting factors in the hospital.

Introduction

From the moment a child is diagnosed with cancer, families have to deal with the stress that accompanies this diagnosis and subsequent treatment trajectory.[1,2] Stress and sleep are intertwined and influence each other: Distress can lead to hyperarousal and disrupted sleep, and is known as an important trigger and perpetuating factor for insomnia. Disrupted sleep also causes higher arousal and distress.[3,4] Nighttime rest of parents of children with cancer is often disturbed by nighttime care demands and due to sleep problems of the child.[5,6] During treatment, 30-50% of children experience sleep problems, which is significantly more than their healthy peers.[7-9] Parenting practices and strategies associated with the child's sleep often change and become more lax during this period.[9] Cancer and treatment effects such as pain and nausea can also disturb sleep.[10,11] Direct brain injury due to tumor location or treatment can also affect sleep regulatory systems.[10,11] Moreover, the majority of families have to deal with frequent hospitalization, and the inevitable change in sleeping environment during these periods.

Sleep of both children and parents tends to be even more affected during admissions, influencing both sleep quality and quantity, with longer sleep onset latency, lower sleep efficiency and more frequent night awakenings.[12-16] On top of cancer and treatment effects, treatment and nursing care during the night, unfamiliar surroundings with loss of routine, and environmental stimuli such as bright light play an important role in sleep disruption during hospital admissions.[10,12] The most disruptive to sleep, however, are environmental noises, especially when they are meant to be alerting.[17] The World Health Organization guideline states that events generating sound levels of 45 decibel (dB) or greater are associated with disrupted sleep,[18] but in hospitals mean nighttime sound levels exceed 45 dB, with abrupt increases in excess of 80 dB.[14,16] Infusion pump alarms are an important source of these sounds and are mandatory to be at least 45 dB at one meter distance of the pump.[19]

Optimal sleep is important to help parents and children cope with a life-threatening disease. Disrupted sleep has many negative effects, including a lower quality of life.[6-8,20] More specifically, sleep problems in children are associated with worse mood, worse cognitive function and more problematic behavior.[10,21] Parents feel more exhausted, irritable, and forgetful,[5] and less equipped to make medical decisions about their child.[6] In contrast to children admitted once for an acute illness, families with a child with cancer face a long treatment trajectory and often do not get the chance to recuperate once they are back home.

Sleep is often impaired in families dealing with childhood cancer and distress is high, even more so when being hospitalized. Both have many negative daytime consequences. The influence of the hospital environment, especially the generally high sound level, can be more easily adjusted than other factors that influence sleep and stress like cancer, treatment and personal factors. It is, however, unclear to what extent infusion pump alarms contribute to poor sleep in pediatric oncology patients and parents. Therefore, the aim of this explorative study was to determine sleep quality and daytime sleep-related impairment, including fatigue, in parents; and to determine sleep quantity and sleep satisfaction, and the association with nightly infusion pump alarms in pediatric oncology patients admitted to the hospital for immunotherapy or chemotherapy, and in their parents.

Methods

Participants and procedure

In this prospective observational study, performed at the Princess Máxima Center for pediatric oncology in Utrecht, the Netherlands, families were eligible for inclusion if the child was between the age of 2 and 18 years and admitted for a scheduled course of chemotherapy or immunotherapy, for which at least one overnight stay was required. The study was also open to the inrooming caregiver. Since most caregivers are the parents, we will be using the term parents hereafter. If parents alternated rooming-in during the child's hospital stay, each parent was given the opportunity to participate in the study. Families were not eligible during the child's first course of chemotherapy or immunotherapy, to eliminate the additional stress accompanying a first admission. Another exclusion criterion was insufficiently master the Dutch language, as participants were required to fill out the study-questionnaires independently. This study was approved by the Medical Ethical Research Committee of the University Medical Center Utrecht.

Informed consent was obtained and the Empatica E4 wristwatch was attached on the day of admission to the hospital. The wristwatch and other measures are described in detail below. Study duration lasted until hospital discharge, unless admission exceeded seven nights, patients developed a fever / fell ill during admission, or elected to stop prior to that time.

Following regular hospital policy, patients were admitted to a private or a double room and one parent was allowed to sleep in a bed directly next to the child. Patients also occasionally moved between rooms, meaning they could sleep a part of their admission in a private room, and another part in a double room. Infusion pumps were situated next to the patients' bed in a docking station and alarms were audible in the patients' room. The sound levels of the alarms could manually be regulated by the nurse, and could range from 59 to 74 dB, though pumps were mostly set at the lowest level. The infusion pumps were not automatically connected to the nurse call system (NCS), which meant that patients / parents needed to manually alert the nurse by activating the NCS.

Outcomes

Sociodemographic and medical information of children and parents

Parents filled out a general questionnaire about their child and themselves containing information on demographic variables, history of sleep problems, and use of medication. Information on cancer diagnosis and therapy was obtained from hospital records.

Infusion pump alarms of children and parents

Information on timing and duration of infusion pump alarms was collected by a cable-connection to the hospital server. If the infusion pumps were disconnected from the hospital server, for instance during bathroom visits, data was retrieved from the pump itself by our technical staff after the treatment course of the patient was completed. Both data collection methods led to similar information on the date, time, and duration of alarms. Bed and wake times from the sleep diary were used to determine the timeframe in which the participants attempted nighttime sleep. The number and duration of infusion pump alarms during these timeframes were extracted. When admitted in a double room, alarms of both the participants' pump and the other patients' pump were combined. In case bed and wake times were missing from the sleep diaries (five nights), sleep onset and offset were extracted from the Empatica data (described below)).

Sleep quantity of children and parents

Sleep quantity was measured in children and parents using the *Empatica E4 wristwatch (Empatica Inc., Cambridge, United States)* from now on referred to as E4.[22,23] The participants were asked to wear the E4 on their non-dominant wrist day and night during the study period (except when bathing). The E4 data was downloaded daily and was recharged simultaneously. The E4 uses a three axes accelerometer to measure wrist movement at a rate of 32 Hz. An accelerometer has the capability to measure sleep and wake minutes from the absence or presence of wrist movement, this movement is captured by the device (E4) and subsequently translated to sleep and wake minutes through an algorithm on a computer: This is called actigraphy. Actigraphy is generally accepted as a valid and reliable method to measure sleep in both children and adults.[24,25] To support the accelerometer data, bedtime and waketime were reported in a sleep diary, as were the times when the E4 was taken off.

The raw data from the E4 was divided into epochs with one minute intervals. For each epoch of one minute, zero-crossings for all three axis were summed. The Cole-Kripke algorithm was then applied to label each epoch as 'sleep' or 'wake'. This algorithm is mostly used for adults,[26,27] who are most represented in our study sample, but the algorithm has successfully been used in pediatric populations as well.[28-30] Since participant population characteristics and type of study device can influence the performance of the algorithm, we first analyzed the performance of the original Cole-Kripke algorithm in our study population. This original algorithm considers an epoch 'wake' when crossing a threshold of 1.0. The original algorithm significantly over-classified sleep in our population, therefore we altered the study threshold to 0.4. This value was determined by analyzing the Cole-Kripke scores of a subset of participants during their wake and sleep periods and selecting the value that maximized the classification accuracy, as visualized in Figure 1. Sleep onset and offset was determined by a partly automated algorithm used with the support of the sleep diary. First, the algorithm looked for 8 minutes of continuous sleep within 45 minutes of the sleep diary times. If the device was not worn 45 minutes before sleep diary bedtime, sleep onset and offset were manually reviewed by looking at the scored files, to prevent misclassification (since not wearing the device looks similar to sleep for the algorithm). Once each night and morning had a sleep onset and offset time, the epochs between the determined timings were spliced and the sleep outcomes were calculated: total sleep time (TST), defined as number of minutes scored as sleep between sleep onset and offset; wake after sleep onset (WASO), defined as number of minutes scored as wake between sleep onset and offset; sleep efficiency (SE), defined as percentage of sleep between sleep onset and offset; and night awakenings (NA), defined as number of wake blocks interrupting one or more minutes of continuous sleep.

Sleep satisfaction of children and parents

Parents and children were asked to rate daily how satisfied they were with their sleep in the sleep diary. A visual analogue scale (VAS) ranging from one to ten was used for parental sleep and for children below 8 years of age (proxy-report). A VAS with a range from one to five, illustrated with five faces was used for children 8 to 18 years (self-report). Both scales were then converted to a categorical variable ranging from one to five. A higher score indicated better sleep quality.

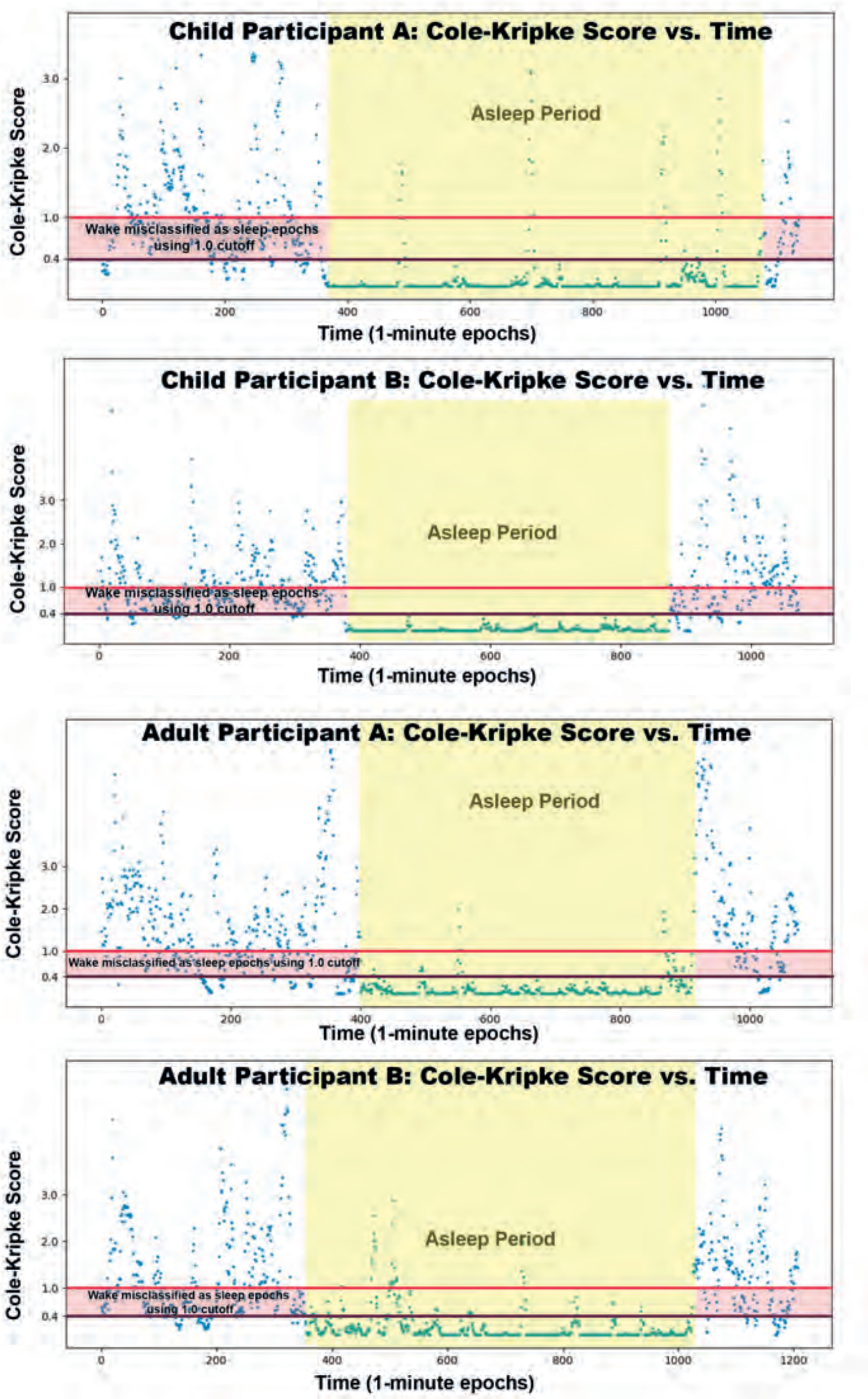

Figure 1 Visualization of rationale for lowering threshold Cole-Kripke algorithm

Sleep quality and daytime impairment of parents

Sleep and fatigue of parents was assessed by self-reported questionnaires on the last day of parents' study participation. Similar to previous studies on sleep during hospital admissions, recall time was the current hospital admission, instead of the original recall time of the questionnaires.[31]

Insomnia severity index (ISI): A reliable and valid, 7-item self-report questionnaire assessing the nature, severity, and impact of insomnia. Questions were answered on a 5-point Likert scale (0 ´no problem´ to 4 ´very severe problem´). The total score ranges from 0 to 28 and is interpreted as follows; absence of insomnia (0-7); sub-threshold insomnia (8-14); moderate insomnia (15-21); and severe insomnia (22-28). Questionnaires with one or more missing items could not be scored (n = 4).[32,33]

Patient Reported Outcomes Measurement Information System (PROMIS) Sleep Disturbance item bank: A reliable and valid 27-item questionnaire, reflective of insomnia-like symptoms. It assesses perception of sleep quality and restoration associated with sleep, perceived sleep difficulties and concerns about falling and staying asleep, and perceptions of adequate and satisfactory sleep.[34,35]

PROMIS Sleep-Related Impairment item bank: A valid and reliable 16-item questionnaire, containing items related to sleepiness, fatigue, and cognitive difficulties during waking hours. In addition, it assesses perceptions of functional impairment during waking hours that are associated with sleep problems or impaired alertness.[34,35]

PROMIS short form Fatigue: A valid and reliable 8-item questionnaire, containing items on the experience of fatigue (intensity, frequency, and duration), and the impact of fatigue on daily activities.[36,37]

Items of the PROMIS item banks and short form were measured on a 5-point Likert scale (1 ´not at all or never´ to 5 ´very much or always´). The official Health Measures scoring service tool was used to calculate T-scores using the US calibration parameters for all participants who filled out at least one item.[38] T-scores are anchored on the US general population, with a mean of 50 and a standard deviation of 10. Higher scores indicate more sleep disturbances.

Statistical analyses

Sociodemographic variables of the participating families and the children's medical variables were described. The median number and duration of infusion pump alarms per night were reported. To describe sleep quantity and satisfaction during hospital admissions, mean sleep satisfaction and E4 outcomes (TST, SE, WASO, and NA) were calculated for parents as well as children. There are no norm scores available for comparison of these outcomes. Self-reported sleep and the daytime consequences parents experienced were described by comparing T-scores to norm scores by using one sample T-tests. A P-value of $< .05$ was considered significant. In addition, we reported the number of parents in each category of the ISI.

To determine the association between sleep satisfaction and quantity and nightly infusion pump alarms in children and parents, linear mixed models were performed using maximum likelihood estimation. As the models could include multiple nights per participant, and parents and children were combined in one model, two random intercepts were included to account for dependency; on individual subject level and on family level. Since it is plausible that children and adults react differently to alarming sounds,[39] secondary analyses were performed separately for children (with random intercept on individual subject level) and parents (with random intercept on individual subject level and on family level). Models were constructed for the outcomes sleep satisfaction, WASO, SE and NA, with number of alarms per night and total duration of alarms per night as independent variables. As a longer sleep duration would automatically infer a greater opportunity for alarms to sound, TST was not included as an outcome. All analyses were performed with SPSS Statistics 25.0.0.2.

Results

Population

In total 36 families were eligible for inclusion and were invited to participate in the study. Eight families declined due to focus on treatment, or due to refusal of the child, resulting in a response rate of 78%. In one participating family only the parents participated, in another family only the child participated. Due to technical problems, infusion pump data was not available in three children and four parents. Out of the families with infusion pump data, five children and two parents did not have any other data and were thus excluded from further analyses. This loss of data was mostly because a child refused to wear the watch, or a parent was distracted by the watch at night and removed it, and then also did not proceed to fill out the sleep diary and questionnaires. The final study population consisted of 19 children (40 nights of data) and 30 parents (46 nights of data). An overview of inclusions is shown in Figure 2. Table 1 shows the demographic and medical characteristics of the samples. Non-participating children (eight families who declined participation

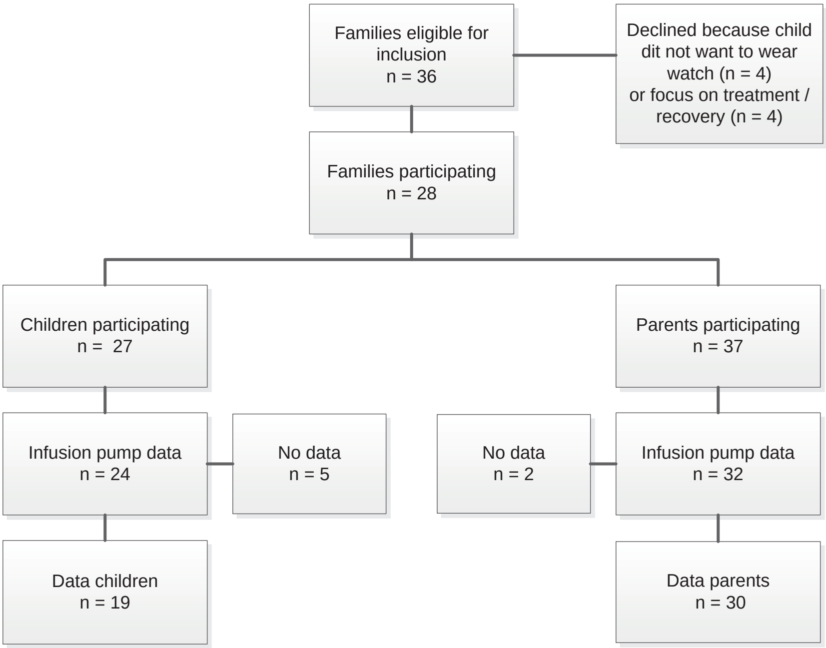

Figure 2 Flowdiagram inclusion

plus three children without infusion pump data) were younger () than participating children (mean age 7.4 ± 5.1 versus 8.8 ± 4.9 years), and duration of admission was longer (6.2 ± 4.6 versus 3.1 ± 1.9 nights). They did not differ in diagnosis, time since diagnosis or sex. Distribution of diagnoses was similar in the study sample (58% solid, 37% hematological, 5% central nervous system), compared to all admissions during the study period (58% solid, 36% hematological, 9% central nervous system). Parents were between 27 and 51 years of age, 29/30 were mothers (57%) or fathers (40%), one grandmother participated. Most parents (89%) had more than one child to take care of. One parent had a history of sleep problems and was using sleep medication, none of the children did.

Description of outcomes

Alarms of children and parents

The alarms sounded median five times during the nighttime sleep of the children and three times during the nighttime sleep of the caregivers. The median duration of the alarms was 10 minutes for children, and 6 minutes for caregivers.

Table 1 Demographic and medical characteristics

	Children not participating (n = 11)	Participating children with data (n = 19)	Parent 1 with data (n = 22)	Parent 2 with data (n = 8)
Age (mean years ± SD; range)	7.4 ± 5.1; 2-16	8.8 ± 4.9; 2-17	40.8 ± 6.5; 27-51	42.0 ± 6.2; 33-50
Sex (n; % female)	5; 45%	8; 42%	14; 64%	4; 50%
Characteristics parents				
Marital status (n; % together with parent of their child)			15; 68%	6; 75%
Number of children (median; range)			2; 1-6	2; 1-3
Educational level (n; %)				
High school			3; 15%	3; 38%
Intermediate vocational training			6; 30%	3; 38%
Higher vocational training / university			11; 55%	2; 25%
Work (n; %)				
Paid job			13; 65%	4; 50%
Currently unemployed			5; 25%	1; 13%
Health insurance act (in part)			2; 10%	3; 38%
Medical characteristics children				
Diagnosis (n; %)				
Hematological	4; 33%	7; 37%		
Solid	7; 58%	11; 58%		
Central nervous system	1; 8%	1; 5%		
Time since diagnosis (median months; range)	4; 1-14	4; 1-21		
Duration of admission (mean nights ± SD; range)	6.2 ± 4.6; 2-7	3.1 ± 1.9; 1-7		

Sleep quantity of children and parents

On average children had a higher SE (mean 93 ± 4 versus 91 ± 5%), less frequent NA (mean 11 ± 5 versus 14 ± 6 times) and lower WASO (mean 48 ± 28 versus 53 ± 30 minutes) than their parents. Twenty-eight percent of children did not get the required amount of sleep (TST) for their age group during admission,[40] although time spent napping during the day was not included. Only 8% of parent slept under the recommended 7 h.[41]

Sleep satisfaction of children and parents

The mean VAS score was 3.2 in parents and 3.7 in children (out of 5 points).

Sleep quality and daytime impairment of parents

On the PROMIS measures, parents reported significantly more sleep disturbances (mean difference 3.7, P .010), but not significantly more sleep-related impairment or fatigue compared to the norm. Fifteen out of 26 parents (58%) experienced subthreshold insomnia and four (16%) experienced clinical insomnia on the ISI during admission. This is more than the 7-8% in the general population.[42] All outcomes are described in Table 2.

Relation between sleep satisfaction, sleep quantity and infusion pump alarms in children and parents

In a total of 86 nights of data, multilevel analyses showed no significant relation between alarms and both the self or proxy-reported sleep satisfaction (VAS-scores), and sleep quantity (WASO, SE and NA). Secondary analyses for children and parents separately revealed no differences between relations in these groups. Results of primary multilevel analyses are shown in Table 3, results of secondary analyses in Table S1 and S2.

Discussion

The aim of this study was to determine sleep quality and sleep-related daytime consequences for parents during scheduled admissions of their child, and to determine the relation between sleep satisfaction, sleep quantity and nightly infusion pump alarms in children and parents dealing with childhood cancer. To achieve this, information on sleep quality of parents, and sleep satisfaction and quantity of children and parents was collected during admission, over a combined period of in total 86 nights.

Table 2 Description of outcomes

	Children	Parents
Sleep quality and fatique (self-reported)		
ISI (%)		
No insomnia		27%
Subthreshold insomnia		58%
Moderate clinical insomnia		12%
Severe clinical insomnia		4%
PROMIS Sleep Disturbance T-score (mean ± SD; range)[a]		54 ± 7; 34 – 71
PROMIS Sleep-Related Impairment T-score (mean ± SD; range)[a]		51 ± 8; 32 – 67
PROMIS Short Form Fatigue T-score (mean ± SD; range)[a]		50 ± 7; 33 – 63
Sleep satisfaction (self- and parent-reported)		
VAS (mean ± SD; range)	3.7 ± 0.7; 2.0 - 5.0	3.2 ± 0.6; 2.0 – 4.0
Sleep quantity		
TST (mean minutes ± SD; range)	585 ± 84; 377 - 792	490 ± 68; 363 - 647
SE (mean % ± SD; range)	93 ± 4; 84 – 99	91 ± 5; 79 - 100
WASO (mean minutes ± SD; range)	48 ± 28; 4 - 119	53 ± 30; 2 - 157
NA (mean ± SD; range)	11 ± 5; 3 - 22	14 ± 6; 2 - 30
Alarms		
Number of alarms (median minutes; range)	5; 1 - 20	3; 0 - 19
Duration of alarms (median minutes; range)	10; 0 - 61	6; 0 - 61

Abbreviations: ISI = Insomnia Severity Index; VAS = Visual Analogue Scale; TST = Total Sleep Time; SE = Sleep Efficiency; WASO = Wake After Sleep Onset; IQR = Interquartile Rang; NA = Night Awakenings

[a] Mean T-score norm population is 50 ± 10.

Table 3 Relation between alarms and sleep satisfaction and quantity in children and parents

Independent variable	Dependent variable	B	Std. Error	P-value
Number of alarms per night	Sleep satisfaction	3.5	0.1	.193
	WASO	44.3	4.9	.088
	SE	91.9	0.7	.445
	NA	12.7	1.0	.541
Duration of alarms per night (in seconds)	Sleep satisfaction	3.5	0.1	.326
	WASO	47.0	4.6	.257
	SE	91.6	0.7	.775
	NA	12.3	0.9	.990

Abbreviations: SE = Sleep Efficiency; WASO = Wake After Sleep Onset; NA = Night Awakenings

Parents reported poor sleep during hospital admissions. The percentage of parents that reported clinical insomnia was twice as high as in the general population, and they reported significantly more sleep disturbances. In the literature there is a large amount of evidence to support the association between poor sleep at night and worse functioning on multiple domains during the day.[10,43] However, in this study parents did not score significantly worse than the norm population on daytime impairment. Since acute insomnia is linked to cognitive and somatic hyperarousal, it is possible that hyperarousal masked daytime symptoms in our study population.[4] In addition to the short term negative daytime consequences of sleep problems, long term persistence of sleep problems is a risk when developing sleep problems during admission. From Rensen et al., we know that in a population of parents of children with cancer, even with 90% off-treatment, the prevalence of sleep problems remains high[1]: Hyperarousal, together with maladaptive behaviors and a continuous stressor (e.g. having a child with cancer) can work as perpetuating factors for chronic insomnia.[4] Though no information on sleep quality of children is reported here, based on previous literature they are also at risk for persistence of sleep problems: In 33-42% of healthy children with sleep problems, these problems persisted from school age to adolescence and adolescence to young adulthood.[44,45] In children admitted due to critical illness, sleep problems remained high until at least 6 months after admission, in-hospital sleep problems were a possible risk factor.[46]

This study shows that infusion pump alarms sound frequently at night during a scheduled admission in the hospital to receive immune and chemotherapy. Vitoux et al., mapped infusion pump alarm frequency in 2018. They found alarms to sound on average 0.18 times per hour, for 2 minutes and 38 seconds per alarm. In a night of 8 h this would come down to 1.4 alarms with a duration of 4 minutes.[47] The higher numbers we found are in line with their finding that alarms tend to sound more frequently in pediatric (critical care) wards than in adult (critical care) wards.[47] In addition, some logistic aspects are explanatory for the high number of nightly alarms: First of all, pumps are used less often to give intravenous fluids and medication to hospitalized adults in a general ward, then for hospitalized adults and children in oncology wards; and no pumps equals no alarms. Secondly, before chemotherapy can be started, blood needs to be drawn and tested; if results meet the criteria for starting chemotherapy, an order must be send to the pharmacy, who then prepare the medication. In practice, this means chemotherapy is started around 2 pm, and runs during the night until approximately 2 am.

We did not find a significant relation between sleep and infusion pump alarms in admitted children and their parents. Based on previous literature this would have been expected. Multiple studies in healthy adults,[48] hospitalized adult patients,[49] but also children admitted for anti-cancer therapy,[12,14,50] found a significant relation between more sounds / higher noise levels, and worse sleep quality and quantity. These studies measured the general sound level during the night, as opposed to infusion pump alarms specifically. An experimental study in healthy participants by Buxton et al., tested the cortical arousal response to 14 different environmental hospital sounds through polysomnography. They found arousal to be greatest in reaction to alerting electronic sounds. The reason this current study did not find a relation could be found in the E4, since this accelerometer was not validated through comparison to polysomnography: The sensitivity and specificity of the E4 to measure sleep is therefore unknown and sleep minutes could have been overestimated as well as underestimated. Secondly, it is possible that 86 nights of data lacks the power to determine a significant relation. Another plausible reason however, is that other disrupting environmental influences clouded the relation between alarms and sleep. For instance, in five families the child's heart rate was also monitored, and heart rate alarms were not taken into account. Also, 14 out of 24 families slept at least part of the admission period in a double room where sound coming from the roommate could have also disturbed sleep. Other sounds like staff conversations, but also light levels and staff interruptions for nighttime nursing care and assessment, were also linked to worse sleep in previous studies.[12,14,50]

Stremler et al. performed focus groups with 30 pediatric nurses and bundled recommendations to improve sleep of patients: Decrease use and volume of alarms; decrease use of overhead lighting and instead use dimmers and soft lighting from machines; cluster nightly nursing assessments; and discuss the division of the child's care with the parents at the beginning of the night shift.[51] Decreasing alarms and lighting needs to come with adequate safety monitoring and is accompanied by a higher financial cost. Simpler and less costly solutions, such as earplugs to block sound and eye masks to block light have also proven effective in improving sleep in the hospital and should be considered to improve overall well-being of patients and their families.[52]

This study had a few limitations. Firstly, as already mentioned, the reliability of the E4 in comparison to polysomnography is unknown. Secondly, no sleep questionnaires capturing subjective sleep in children were used. As there is a lack of psychometrically valid sleep questionnaires covering the whole pediatric age range, different instruments leading to different outcomes would have been needed. Considering the sample size, this study would have been underpowered for proper analyses, and sleep questionnaires for children were therefore not included as an outcome. Thirdly, norm values for comparison of sleep satisfaction and sleep quantity values of our study sample, were unavailable.

In conclusion, pediatric oncology patients and their parents have reduced sleep quantity and quality during hospital admissions. Short term sleep problems often persist throughout later childhood and adulthood. Daytime impairment for parents was comparable to the norm population, but is possibly masked by hyperarousal due to stress and poor sleep. Infusion pump alarms sound frequently at night, though they do not correlate with sleep in our study. Future research should therefore focus on mapping and improving broader disrupting aspects of the hospital environment on sleep.

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Table S1 Relation between alarms and sleep satisfaction and quantity children

Independent variable	Dependent variable	B	Std. Error	P-value
Number of alarms per night	Sleep satisfaction	3.8	0.2	.341
	WASO	40.0	7.0	.170
	SE	93.1	1.0	.516
	NA	11.8	1.3	.268
Duration of alarms per night (in seconds)	Sleep satisfaction	3.8	0.2	.626
	WASO	43.7	6.5	.405
	SE	92.7	0.9	.933
	NA	10.9	1.3	.765

Abbreviations: SE = Sleep Efficiency; WASO = Wake After Sleep Onset; NA = Night Awakenings

Table S2 Relation between alarms and sleep satisfaction and quantity parents

Independent variable	Dependent variable	B	Std. Error	P-value
Number of alarms per night	Sleep satisfaction	3.4	0.1	.079
	WASO	47.1	6.6	.295
	SE	91.2	1.0	.391
	NA	13.5	1.3	.795
Duration of alarms per night (in seconds)	Sleep satisfaction	3.3	0.1	.159
	WASO	48.5	6.2	.406
	SE	91.0	0.9	.598
	NA	13.5	1.2	.746

Abbreviations: SE = Sleep Efficiency; WASO = Wake After Sleep Onset; NA = Night Awakenings


6