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Hospital Environmental Effects on Sleep in Adults With Traumatic Brain Injury in Rehabilitation

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Abstract

Purpose: The aim of this study was to describe sleep patterns of adults with traumatic brain injury and examine effects of environmental stressors (patient care activities and light) on patterns of sleep.

Design: A descriptive, correlational, explanatory design was used for this study.

Methods: Sixty-three subjects with traumatic brain injury (>18 years) on an acute traumatic brain injury rehabilitation unit wore an Actiwatch for 48 hours to collect light and sleep data. Patient care activity data were collected between 11 p.m. and 7 a.m.

Findings: Patient care activities and light occurred between 11 p.m. and 7 a.m. Nighttime sleep duration and sleep efficiency were explained by patient care activities, whereas light explained wake time after sleep onset.

Conclusion: Patient care activities and light serve as environmental stressors that affect sleep.

Clinical Relevance: Results necessitate examining the need and timing of nursing care activities and light during nighttime. Findings provide a basis for policy changes that optimize sleep.

Keywords: Traumatic brain injury; sleep; environmental stressors.

Introduction

Each year in the United States, an estimated 1.7 million people sustain traumatic brain injuries (TBIs) with motor vehicle crashes, gunshot wounds, falls, and sports-related head trauma as the leading causes. Of those, more than 282,000 require inpatient hospitalization for injuries (Centers for Disease Control and Prevention, 2017), with many requiring rehabilitation (Murphy & Carmine, 2012). Depending on the severity of injury, TBI can result in impairments in function, cognition, emotion, and behavior (Levine & Flanagan, 2010). In addition to these impairments, disrupted sleep patterns are a common problem after TBI (Baumann, 2016; Sandsmark, Elliot, & Lim, 2017). Prevalence rates of sleep disturbance for persons with TBI range between 30% and 84% and are higher than those in the general population (Mathias & Alvaro, 2012).

Sleep is a restorative process that is necessary not only for survival but also for recovery. Sleep allows the body time to replenish energy stores in the brain that have been depleted during wakefulness (Scharf, Naidoo, Zimmerman, & Pack, 2008) and plays a vital role in a person's physical, mental, and emotional health, as well as quality of life. After trauma, sleep is needed for cell growth and repair, maintaining a healthy immune system, and neuronal rest and repair (National Institute of Neurological Disorders and Stroke, 2014). The importance of sleep is even more important for persons with TBI in the acute rehabilitation setting, because there are intense cognitive and physical demands placed on patients in order to optimize recovery efforts.

A variety of factors contribute to changes in sleep patterns in persons with TBI, including the underlying illness, neuronal changes that occur with brain injury, and psychological factors. Trauma to the brain predisposes persons with TBI to sleep disturbance due to damage to areas of the brain responsible for regulation of sleep. These physiological changes cannot be controlled; consequently, the importance of managing environmental factors that can disturb sleep is a priority. Nursing and medical care provided to patients in the hospital setting can serve as stressors for individuals recovering from illness or injury (Friese, 2008). Studies in intensive care units and acute

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care settings have found that patient care activities and light during nighttime hours can cause sleep disturbance (Bano et al., 2014; Le et al., 2012). Patient care activities can disturb sleep, whereas exposure to light during times of sleep or lack of exposure to light–dark contrast can disrupt the circadian rhythms (Bano et al., 2014; Cho, Joo, Koo, & Hong, 2013). These environmental factors conflict with promoting adequate sleep and recovery efforts in this vulnerable population. Although studies suggest that environmental stressors affect sleep in acute care settings, little is known about how patient care activities and light affect sleep in the rehabilitation setting.

As persons recover from TBI, it is essential to promote effective sleep patterns to maximize physical and cognitive improvements because significant gains in recovery occur during acute inpatient rehabilitation (Agrawal & Joshi, 2014). The functional, cognitive, and emotional deficits associated with brain injury highlight the importance of addressing factors that can affect sleep patterns while in the rehabilitation setting. The purposes of this study were to describe the sleep patterns of adults with TBI in the acute rehabilitation setting as well as examine the effects of environmental stressors, including exposure to light and patient care activities on patterns of sleep. Research questions included the following:

1. What are the sleep patterns for the quantity (sleep duration [SD] and sleep time [ST]) and quality of sleep (wake after sleep onset [WASO] and sleep efficiency [SE])?
2. What are the types and number of patient care activities that occur during nighttime?
3. What is the light exposure during nighttime sleep?
4. What are the relationships among the number of nighttime patient care activities, nighttime exposure to light, SD, WASO, and SE?
5. Controlling for age, severity of injury, and pain, what effect do patient care activities and exposure to light during nighttime hours have on SD, WASO, and SE?

Methods

Study Design

A descriptive, correlational, explanatory design was used for this study.

Sample and Setting

A convenience sample of 63 subjects with TBI was recruited from an acute TBI rehabilitation unit. The target population was adults who suffered a first-time TBI who were in the acute rehabilitative phase of recovery, regardless of the severity of brain injury. Inclusion criteria were (a) first time TBI subjects admitted to the acute inpatient rehabilitation unit with the diagnosis of TBI, (b) 18 years of age or older, (c) English speaking, and (d) able to participate in 3 hours of therapy each day. Exclusion criteria were (a) subjects who had any prior documented diagnosed sleep disorder, (b) patients with non-TBIs, (c) patients with a documented diagnosis of preexisting depression or anxiety disorder, or (d) patients on isolation precautions.

Measurements

Patient Care Activities

An investigator-developed tool called the Patient Care Environmental Stressor Log (PCESL) was used to measure direct patient care activities (DPCAs) performed by professional or nonprofessional staff between the hours of 11:00 p.m. and 7:00 a.m. This time frame was chosen to identify the types and number of patient care activities occurring during nighttime hours while patients are usually sleeping and to minimize potential error by having only one shift of nurses document on the PCESL. Patient care activities were documented in 15-minute increments and included vital signs, assessments, medications, dressing changes, restraint application or removal, repositioning, bathing, dressing, toileting, transfers, radiological procedures, tracheostomy care, suctioning, venipuncture, or other patient care activities not listed on the data collection form. Prior to initiating the study, nursing staff members were educated through group sessions on how to complete the PCESL and agreed to document patient care activity data.

Systematic reliability checks were completed alternating Day 1 and Day 2 on every fifth subject for a total of 13 subjects, comparing percent agreement between patient care activities documented on the PCESL with patient care activities documented in the electronic medical record (EMR). Results indicated an agreement between the PCESL flowsheet and the EMR documentation to be between 94% and 100%.

Sleep

Sleep patterns, including SD (time between the start and end of sleep), ST (time scored as sleep between the start and end of nighttime sleep), WASO (time scored as wake between the start and end of nighttime sleep), and SE (nighttime ST divided by the standard 8-hour rest interval [480 minutes] times 100 measured as a percentage), were measured using the Actiwatch 2 (Philips Respironics, Inc., Murrysville, PA) activity logger. An Actiwatch 2 unit is a small waterproof device that has the appearance of a wristwatch that measures movement that is translated into sleep or wake. The Actiwatch 2 uses an accelerometer that

monitors occurrence and degree of motion. As the degree and speed of motion increase, the voltage increases, which is stored as activity counts (Philips Respironics, 2015). The activity threshold value for this study was set at 40, because studies have shown limitations of actigraphy include overestimating ST due to scoring quiet wakeful periods as sleep (Sadeh, 2015). A 1-minute epoch was used to collect sleep and light data.

Actigraphy has been compared to polysomnography in numerous studies using a variety of different populations. In a systematic review by Van De Water, Holmes, and Hurley (2010), results suggest that the accuracy of actigraphy as compared to polysomnography depends on the variables of interest, population being studied, algorithm and threshold used, and the make and model of the actigraph unit. In another study of 31 subjects with insomnia, correlations between actigraphy and polysomnography were $r = .92$ for total ST, $r = .77$ for SE, and $r = .85$ for WASO (Sanchez-Ortuno, Edinger, Means, & Almirall, 2010).

To test interdevice reliability of the actiwatches, the primary investigator (PI) wore three actiwatches on the same wrist to compare sleep data. SD had 100% agreement across the three watches. SE results had close agreement across watches, with Actiwatch A at 88.13%, Actiwatch B at 87.71%, and Actiwatch C at 88.30%. Wake time after sleep onset also had small differences with Actiwatch A at 17 minutes, Actiwatch B at 19 minutes, and Actiwatch C at 16 minutes. These small differences could have been related to the sequential timing of applying and removing the watches.

Previous studies have described potential sources of error, including the Actiwatch interpreting sleep as wake (false positive) or wake as sleep (false negative). Wake periods can be interpreted as sleep when the subject is awake, but without movement. Contrarily, sleep can be interpreted as wake if a subject has movement such as tremor or spasticity when sleeping. To address these potential sources of error, information about presence of paresis, contracture, or spasticity was obtained as part of the screening process from either the physician history and physical, or the physical or occupational therapy admission assessments in the EMR. The information was used to determine which wrist the Actiwatch was applied based on the recommendations of Zollman, Cyborski, and Duraski (2010), suggesting the Actiwatch be placed on the limb with the least paresis, contracture, or spasticity to improve accuracy of sleep measurements. If there was no evidence of paresis, contracture, or spasticity, the watch was placed on the nondominant wrist. Five subjects had paresis of the upper extremity; therefore, the Actiwatch was placed on the opposite wrist.

Light

Light was measured in lux with an optical sensor on the Actiwatch 2 (Philips Respironics). The optical sensor has sensitivity similar to the human eye with a lumen sensitivity range of 0.01 lux to 150,000 lux (Philips Respironics, 2015). The light monitor measures the amount and duration of illuminance of white light. Measures of illuminance of the Actiwatch 2 were compared to National Institute of Standards and Technology-traceable light sources and testing apparatus (Philips Respironics, 2008). A random sample of Actiwatch 2 activity monitors were exposed to four commonly used types of white light. Results indicated agreement between the Actiwatch 2 and the National Institute of Standards and Technology-traceable photometer (Philips Respironics, 2008).

To test the interdevice reliability, the PI wore three watches inches apart on the left arm simultaneously during one night between 11:00 p.m. and 7:00 a.m. Total light exposure ranged between 3.53 and 3.72 lux, indicating good agreement. Similarly, mean lux was $M = 0.01$ lux (100% agreement), and the mean maximum lux exposure ranged from 0.02 to 0.07 lux across the three watches. The difference in lux exposure and maximum lux exposure results could have been attributed to positioning of the arm, small differences in the positioning of the watch, or the angle of the light in relation to the watch.

Age, Pain, and Severity of Injury

Age was obtained from the EMR. Pain was measured as the number of episodes of pain medication given during the 48-hour data collection period and obtained from the medication administration record. The severity of injury was measured using the first Glasgow Coma Scale score after the initial injury.

Procedures

An institutional review board approval was obtained prior to initiating the study. If persons with TBI met inclusion criteria and were unable to provide consent, the legal authorized representative (LAR) was contacted. A total of 204 potential subjects were screened for eligibility between March 2016 and January 2017. Sixty-nine subjects met inclusion criteria. Of the 69, three subjects and one LAR declined enrollment, one left against medical advice before consent was obtained, and one subject who consented was discharged before sleep data were obtained. Of the remaining 63, 36 subjects agreed to participate, and 27 LARs consented on behalf of the subject. One hundred thirty-five subjects did not meet eligibility criteria. Patient care activity was collected between 11:00 p.m. and 7:00 a.m. for two consecutive nights while

sleep and light data were collected continuously for two consecutive days/nights.

Data Analysis

Descriptive statistics were used to describe characteristics of the study sample, to assess for violations of assumptions of the statistical techniques, and to address Research Questions 1–3. Correlation analysis using the Pearson product–moment coefficient was used to determine the strength and direction of the relationship among continuous variables. Hierarchical multiple regression analyses were used to determine if patient care activities and light explained sleep while controlling for age, severity of injury, and pain.

Results

Demographic and Clinical Characteristics

The mean age for 63 subjects was 50.71 years (*SD* = 20.28). The majority were male (*n* = 48, 76.2%) and Caucasian (*n* = 42, 66.7%). A majority of subjects were single (*n* = 35, 55.6%) and employed (*n* = 32, 50.8%) at the time of injury.

Approximately 50% (*n* = 32, 50.8%) of subjects had a subarachnoid hemorrhage. Twenty-nine subjects (46.0%) had a subdural hematoma, whereas 16 (25.4%) had a cerebral contusion. Twenty-six subjects had one type of brain injury, whereas 25 subjects had two distinct injuries and 12 subjects had three distinct injuries. Twenty-one subjects (33.3%) had no comorbidities, and 22 subjects (34.9%) had hypertension. A fall resulted in the TBI for approximately half of the subjects (*n* = 32, 50.8%), whereas 13 subjects' TBI (19.0%) was the result of a motor vehicle crash. The mean Glasgow Coma Scale score was 11.40 (*SD* = 3.34), representing a moderate brain injury. Thirty-four subjects (54%) were classified as mild TBIs, 14 (22.2%) were moderate, and 15 (23.8%) were severe.

Mean time since injury was 17.33 days (*SD* = 24.44), with a median of 11 days. Time since injury outliers (*n* = 5) ranged from 35 to 153 days. The mean number of pain medication episodes during the study period was 3.47 (*SD* = 2.93). Although therapy start times varied for participants between Day 1 and Day 2, therapy began at 9:00 a.m. or earlier on 52% of the days, and 58.7% (*n* = 37) of the subjects did not have a roommate. Constant supervision (CS) was provided for 23 subjects on both days of wearing the Actiwatch, whereas 39 subjects did not require CS. One subject required CS only on Day 1.

Quantity and Quality of Sleep

Mean nighttime SD was *M* = 428.94 minutes (*SD* = 60.44), whereas mean ST was *M* = 346.48 minutes (*SD* = 70.62). SE was *M* = 72.18% (*SD* = 14.71). Overall subjects' WASO was 82.47 minutes (*SD* = 38.56; see Table 1).

Patient Care Activities

The number of total DPCAs occurring between 11:00 p.m. and 7:00 a.m. was summed and averaged for two nights. The mean number of DPCAs was *M* = 5.43 (*SD* = 3.25). The five most common DPCAs were toileting (*M* = 1.38, *SD* = 1.09), vital signs (*M* = 1.10, *SD* = 0.42), assessment (*M* = 0.83, *SD* = 1.40), medications (*M* = 0.79, *SD* = 0.85), and repositioning (*M* = 0.38, *SD* = 2.10). The mean number of DPCAs between 11:00 p.m. and 1:00 a.m. was 1.22 (*SD* = 1.65) compared to 2.19 (*SD* = 2.33) between 1:00 a.m. and 5:00 a.m. and 2.30 (*SD* = 1.74) between 5:00 a.m. and 7:00 a.m.

Light

During nighttime hours, mean light exposure was 1.74 lux (*SD* = 5.03). Total light exposure was 760.83 lux (*SD* = 2,222.10), and maximum light exposure was 38.57 lux (*SD* = 45.69; see Table 2).

Relationships Among Study Variables

There was a significant negative relationship between DPCAs and SD (*r* = –.27, *p* = .035). There was a significant moderate negative relationship between the number of DPCAs and SE (*r* = –.38, *p* = .001), whereas there was a significant positive relationship between DPCAs and WASO (*r* = .28, *p* = .028).

There was no statistically significant relationship between maximum exposure to light between 11:00 p.m. and 7:00 a.m. and SE (*r* = –.08, *p* = .548) or SD (*r* = .14, *p* = .275), whereas there was a moderate positive relationship (*r* = .36, *p* = .004) found between maximum exposure to light during nighttime hours and WASO (see Table 3). Hierarchical multiple regression analysis showed that controlling for age, severity of injury and pain, and

Table 1 Quantity and quality of sleep

						95% CI	
Variable	*M*	(*SD*)	Range	Median	Skew	LL	UL
SD	428.94	(60.44)	177–479	449.00	−2.25	413.72	444.17
ST	346.48	(70.62)	65.50–441	360.00	−1.35	328.	364.26
SE (%)	72.18	(14.71)	13.65–91.8	75.00	−1.35	68.48	75.89
WASO	82.47	(38.56)	10.50–207	79.00	0.66	72.76	92.18

Note. *N* = 63. CI = confidence interval; LL = lower limit; UL = upper limit; SD = sleep duration; ST = sleep time; SE = sleep efficiency; WASO = wake after sleep onset.

Table 2 Light levels

Variable	*M*	(*SD*)	Median	Range	Skew	95% CI *LL*	95% CI *UL*
Average light	1.74	(5.03)	0.36	.01–36.06	5.65	0.47	3.00
Total light	760.83	(2222.10)	159.15	2.99–16110.45	5.78	201.20	1320.45
Maximum light	38.57	(45.69)	23.66	.01–190.97	1.61	27.07	50.08

Note. Light levels measured in lux per night. CI = confidence interval; LL = lower limit, UL = upper limit.

DPCAs explained SE ($p < .01$) and SD ($p < .01$), whereas light explained WASO ($p < .05$; see Table 4).

Discussion

Sleep Quantity and Quality

Both the actual time spent sleeping (ST) and the efficiency of sleep were low, whereas the time spent awake during nighttime hours was high. In this study, nighttime sleep was analyzed based on ST during a defined 8-hour period. These findings may have been different if the start of sleep was prior to 11:00 p.m. or extended beyond 7:00 a.m. Although the 8-hour time frame was chosen to identify the effects of environmental stressors during nighttime hours and to what extent the stressors affected sleep, this predetermined time frame may have affected the findings of actual nighttime sleep by counting late evening or early morning sleep as daytime sleep.

The National Sleep Foundation (NSF; Ohayon et al., 2017) recommends 7–9 hours of sleep for adults 18–65 years and 7–8 hours for 65 years and older (Hirshkowitz et al., 2015). In addition, recommendations for SE are 85% or greater and 20 minutes or less for WASO. Based on these recommendations by the NSF, subjects did not have an adequate quantity of sleep or a good quality sleep. Because the NSF does not specify sleep needs for healthy persons versus those recovering from illness or injury, it is unclear whether these recommendations are appropriate for persons with TBI in the early stages of recovery. Similar findings in the literature are consistent in reporting that TBI subjects in the hospital setting sleep less during nighttime hours (Chiu, Chen, Chen, Chuang, & Tsai, 2013; Towns et al. 2016), have poor SE (Chen et al., 2015), and have increased WASO (Chiu et al., 2013) with the potential to impact recovery.

DPCAs and Quantity and Quality of Sleep

Direct patient care activities occurred throughout the night and were a significant predictor of nighttime SD. Although the time frame for the analysis of DPCAs was not consistent (2, 4, and 2 hours), these time frames represented early night, middle of the night, and early morning activities and suggested that DPCAs were not always clustered together, but rather occurred throughout the night. Patient care activities during the nighttime are often conducted either as a routine standard care practice, based on convenience related to workflow across all shifts, or as a result of a patient-initiated need, both decreasing nighttime sleep.

Direct patient care activities were a significant independent positive predictor of WASO, although it became nonsignificant when light was added to the model in the final step. Several possible causes for this finding were explored. Multicollinearity between DPCAs and maximum light exposure could be a potential cause but was not substantiated because the correlation between DPCAs and maximum light exposure was $r = .22$. To further explore these findings, a trimmed model was constructed to exclude subjects with low lux levels to determine if measurement error contributed to findings. In the trimmed model, unexpectedly, DPCAs did not contribute to explaining WASO. Although the intent was to determine if measurement error altered results, findings did not support this assumption. Finally, specification error was considered as a possible reason for these results. Other environmental stressors such as noise that may have influenced the results were not explored. Further investigation is needed in future studies to examine other environmental stressors that may affect sleep.

Direct patient care activities were also a significant independent negative predictor of SE. Because the five most common patient care activities performed during nighttime hours (toileting, vital signs, assessment, medication

Table 3 Correlations of main study variables

Measure	1	2	3	4	5	6	7	8
1. SD	—							
2. SE	.84**	—						
3. WASO	.03	−.52**	—					
4. DPCA	−.27*	−.38**	.28*	—				
5. MaxLux	.14	−.08	.36**	.22	—			
6. Age	−.07	−.04	−.03	.04	.10	—		
7. Pain	−.03	−.04	.03	.18	−.15	−.30*	—	
8. GCS	.00	.05	−.09	−.42**	−.02	.43**	−.22	—

Note. $N = 63$. SD = sleep duration; SE = sleep efficiency; WASO = wake after sleep onset; DPCA = direct patient care activities; MaxLux = maximum lux exposure; GCS = Glasgow Coma Scale.
*$p < .05$, two tailed. ** $p < .01$, two tailed.

Table 4 Regression analysis for variables explaining sleep

	SD β	WASO β	SE β
Model 1			
Age	−.09	.01	−.09
GCS	.03	−.10	−.08
Pain	−.05	.01	−.05
Model 2			
DPCA	−.32*	.32*	−.45**
Step 2			
Adjusted R^2	.022	.020	.101*
Model 3			
DPCA	−.39**	.23	−.45**
MaxLux	.23	.32*	.02
Step 3			
Adjusted R^2	.056	.106*	.086

Note. SD = sleep duration; WASO = wake after sleep onset; SE = sleep efficiency; GCS = Glasgow Coma Scale; DPCA = direct patient care activities; MaxLux = maximum lux exposure.
$N = 63$.

administration, and repositioning) may involve waking patients to accomplish the task, it is not surprising that DPCA would at least partially explain an increase in WASO and a decrease in SE.

Total variance values in WASO and SE accounted for by DPCAs and maximum light exposure combined were 10.6% and 8.6%, respectively. These data suggest that there are additional factors that contribute to subjects having poor quality of sleep during nighttime hours. Damage to sleep centers in the brain, resulting from the trauma (Vermalaelen, Grieffenstein, & deBoisblanc, 2015) as well as biochemical, hormonal (Shekleton et al., 2010), medical, pharmacological, (Vermalaelen et al., 2015), and other environmental stressors (Gabor et al., 2003), have been found to be factors contributing to sleep disturbance. Although many of these additional factors are not modifiable, findings from this study highlight the importance of managing factors that can be controlled.

Light and Quantity and Quality of Sleep

Maximum light exposure did not contribute to explaining nighttime SD or SE. Although there were no significant findings between maximum light exposure, and SD or SE measured by actigraphy, the literature indicates that even low levels of light may affect sleep architecture. Cho et al. (2013) used polysomnography to measure sleep architecture in a sample of 10 healthy adults when exposed to low levels of light during nighttime hours. Participants exposed to 40 lux light placed 1 m away from their eyes during ST resulted in decreased Stage 3 and Stage 4 non-rapid eye movement (NREM) slow-wave sleep (SWS) ($p < .0001$), increased Stage 1 sleep ($p = .044$), and increased arousals ($p = .003$) compared to participants with lights off during nighttime sleep. Because the current study did not measure sleep with polysomnography, it is unknown whether sleep architecture was affected by light in this sample of TBI subjects. Additional investigation is needed into the relationship between maximum light exposure at night and SD and SE.

Maximum light exposure was a significant independent positive predictor of WASO. Light serves as a key environmental signal that synchronizes the biological clock (Czeisler & Buxton, 2011) but can have detrimental effects on sleep patterns, sleep architecture, and circadian rhythms when there is exposure to light during nighttime hours (Cho et al., 2013). Light has been referred to as light pollution with negative effects on human physiology and circadian rhythms (Stevens et al., 2007). As a result, the impact of light exposure during nighttime hours cannot be underestimated in a setting where sleep is necessary to participate at an optimal level for recovery.

Conclusion

Sleep disturbances were found to be common in the TBI population in the rehabilitation setting. Sleep disturbances were characterized by decreased nighttime ST, increased WASO, and decreased SE. Although causes of sleep disturbance are multifactorial and can include biological, hormonal, physical, and psychological factors, environmental stressors including patient care activities and light exposure have also been shown to contribute to disturbed sleep. Direct patient care activities occurred throughout the night, and although light exposure during nighttime hours was low, it did occur during nighttime hours. Given the brevity of inpatient rehabilitation, it is essential for healthcare providers to examine environmental factors that serve as stressors and ultimately impact sleep patterns.

Implications for Nursing

Findings from this study highlight the role that environmental stressors play on quantity and quality of sleep. Because studies have shown that significant gains in recovery occur during the acute inpatient rehabilitation phase of recovery (Agrawal & Joshi, 2014), the importance of optimizing sleep to promote positive outcomes cannot be underestimated. There are numerous opportunities for nursing staff to promote improved quantity and quality of sleep. Routine nighttime activities such as vital signs or blood draws can be performed during daytime hours, whereas care that is necessary should be clustered to allow more uninterrupted sleep. Altering the timing of pain medication administration to immediately prior to sleep or adjusting medications to prevent waking patients

in the middle of the night can also optimize sleep. Although some patient care activities such as repositioning are necessary, they should be performed with as little interruption as possible, such as limiting the amount of light and performing the intervention quietly. Nurses' role in promoting a restful environment can contribute to short- and long-term recovery. The intense therapy needed to improve both cognitive and physical function of persons with TBI takes enormous energy and effort on the part of the TBI survivor; thus, promoting sleep in the rehabilitation setting must be a priority.

Information from this study provides evidence of the need for healthcare providers to examine activities that are necessary during nighttime hours as opposed to activities that are scheduled for hospital convenience. Promoting sleep patterns that optimize recovery is an interdisciplinary issue that should be addressed by all healthcare providers responsible for the care of persons with TBI. Findings from this study have also provided information that will be useful when evaluating standard care practices and provide a basis for making policy changes to optimize sleep in the hospital setting.

Limitations

The study was performed at one study site limiting the generalizability of the study findings. Also, because this study used a convenience sample of TBI subjects, selection bias could have affected external validity. Although there are many benefits to using actigraphy in the clinical setting, actigraphy has been found to have low specificity so that periods of quiet restfulness are potentially scored as sleep, thus overestimating ST.

Several issues arose regarding measurement of light. Because the nursing staff was not blinded to the study, changes in patterns of light exposure or patient care activities may have occurred introducing bias and influencing results. In addition, the light monitor being positioned under blankets 63.9% of the time impacted the validity and reliability of light data. The effects of patient care activities and light on sleep patterns were investigated, although other environmental factors such as noise were not measured. This study controlled for pain, although sleep medications and other medications that could have affected sleep patterns were not investigated. This study monitored sleep patterns for two consecutive days and nights, although extended periods of time for monitoring sleep beyond 48 hours would have allowed for examination of sleep patterns over time.

Conflict of Interest

The authors declare no conflicts of interest.

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