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Variations in Circadian Rhythms of Activity, Sleep, and Light Exposure Related to Dementia in Nursing-Home Patients

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Summary: We measured 24-hour circadian-rhythm patterns of activity and sleep/wake activity in a group of nursing-home patients (58 women and 19 men with a mean age of 85.7 years). Severely demented patients were contrasted with a composite group of moderately, mild, or not-demented patients. Sleep/wake activity and light exposure were recorded with the Actillume recorder. Cosinor analyses were computed to determine the mesor, amplitude, acrophase, and circadian quotient of the activity rhythms. The diagnosis of dementia was based on the Mini Mental Examination and on examination of medical records. Sleep was extremely fragmented in both groups of nursing-home patients. Severely demented patients slept more both at night and during the day, but there were no significant differences in the number of awakenings during the night or in the number of naps during the day when compared to the composite group of moderate, mild, or no-dementia patients. The severely demented group had lower activity mesor, more blunted amplitude, and were more phase delayed (i.e. had later acrophases) than the other group. In addition, the severely demented patients spent less time exposed to bright light. These results confirm that circadian rhythms in nursing-home patients are disturbed with more disturbance in the severely demented. Much of the disturbance may be related not just to age but to mental status. **Key Words:** Dementia—Sleep—Nursing-home residents—Circadian rhythms.

With advancing age, fragmented sleep leads to daytime napping, which helps contribute to the disorganization of circadian rhythms. Sleep in the nursing-home environment has been shown to be extremely disturbed and fragmented (1–4). Investigators interviewing nursing-home patients about their sleep found that many met criteria for clinical sleep disturbances (5,6). Others have used direct observations of patients to monitor wake and sleep (7–10). These studies have confirmed that nursing-home patients spend extended time in bed and sleep more frequently during the day. Factors such as dementia, medication use, specific sleep pathophysiology (such as sleep-disordered breathing), depression, poor light exposure, chronic bedrest, and lack of structured lifestyle all contribute to the fragmented sleep in nursing-home patients (1,11) and to the continued disruption of circadian rhythms.

In order to understand how dementia interacts with sleep/wake activity and circadian rhythms of activity, we compared sleep and circadian-rhythm variables in institutionalized patients with severe dementia contrasted to a composite group of those with moderate, mild, or no dementia.

METHODS

Subjects

Fifty-eight women and 19 men participated in this study. Of these, 29% were competent and able to give their own consent and 71% needed a guardian's approval. The mean age of the group was 85.7 years (SD = 7.3, range = 60–100 years). Fifty-five lived on a skilled-nursing wing, 18 lived on an intermediate-care wing, and four lived on an assisted-living wing.

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Apparatus

Sleep/wake activity was recorded with an Actillume portable recorder (Ambulatory Monitoring, Inc.). The Actillume is a small device, approximately 1 × 3 × 6 cm, worn on the wrist. It contains a piezoelectric linear accelerometer (sensitive to 0.003 g and above), a log-linear photometric transducer (sensitive from <0.01 lux to >100,000 lux), a microprocessor, 32K RAM memory, and associated circuitry. The orientation and sensitivity of the accelerometer are optimized for highly effective sleep–wake inference from wrist activity that has been previously validated (12). The activity-channel data were proportional to the mean bi-directional acceleration averaged over each minute; however, it has been shown that motion in all axes produces activation of the accelerometer. Illumination measurements were roughly log linear.

Data from the Actillume were transferred, via an interface, to a PC-computer and then analyzed separately in day intervals vs. night intervals for: total minutes and percent of sleep, total minutes and percent of wake, number of awakenings, and length of each awakening. Day was defined as 0600 to 2200 hours; night was defined as 2200 to 0600 hours. Sleep/wake activity was inferred by an automated algorithm (12). Sleep/wake-activity data derived from the Actillume were compared to sleep/wake data derived from electroencephalogram (EEG) in a sub-set of these nursing-home patients. The correlation for determining total sleep time was $r = 0.91$ ($p < 0.001$). In addition, Actillume data were also compared to observational data (consisting of observing patients for 30 seconds every 30 minutes between 1000 hours and 1930 hours). Compared to direct observations, the sensitivity (ability to detect wake) of the Actillume was 87% whereas the specificity (ability to detect sleep) was 90% (13).

Procedure

Data for this study were collected at two nursing homes, the San Diego Hebrew Home and its sister facility, Seacrest Village. Each patient had sleep/wake activity measured with an Actillume recorder. As part of a larger study, the Actillume was worn for three consecutive 24-hour baseline periods, only being removed for bathing. The Geriatric Depression Scale (GDS) (14) and Mini Mental Status Examination (MMSE) (15) were administered, medical charts were abstracted, and medications were noted.

Data analyses

Data were analyzed for the entire group and for two groups representing different severities of dementia.

TABLE 1. *Patients with severe dementia and moderate, mild, or no dementia*

	SDG (n = 55)	MMNDG (n = 22)	p value
MMSE			
Mean	9	25	<0.001
SD	5.8	3.2	
Range	0–19	21–30	
Age (years)			
Mean	85	87	0.31
SD	7.9	5.6	
Range	60–100	74–96	
GDS			
Mean	11	9.7	0.36
SD	5.8	6.1	
Range	2–27	1–20	

Patients were divided into a Severe Dementia Group (SDG, MMSE < 20, n = 55) and a composite group of Moderate, Mild, or No Dementia Group (MMNDG, MMSE > 20, n = 22). Table 1 lists the characteristics of each group. Mann-Whitney tests were used to examine differences between the two groups. The 5% level was used to determine statistical significance.

In addition, least-squares analyses fit 24-hour cosines, from which the mesor, acrophase, amplitude, and, thus, the circadian quotient were estimated.

RESULTS

Twenty-four-hour sleep patterns and dementia

The mean score on the MMSE was 12.8 (SD = 8.8, range = 0–30); 71% were severely demented (MMSE ≤ 19).

When the SDG was compared to the MMNDG, they slept more both during the day and during the night and, conversely, spent less time awake. Spearmen correlations confirmed the association between dementia and total minutes of sleep at night with the more demented patients sleeping longer ($r_s = -0.33$, $p < 0.05$). There were no significant differences in the number of awakenings at night, number of naps during the day, or the length of time subjects remained awake between naps (see Table 2). The sleep fragmentation is illustrated in Fig. 1. In this patient, sleep fragmentation was so severe that it was almost impossible to tell night sleep from day sleep.

Circadian features

Circadian rhythms in activity of the SDG and MMNDG were compared (see Table 3). There were no significant correlations between MMSE and circadian variables. However, the severely demented patients had lower mesors, later acrophases (i.e. were

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TABLE 2. *Mean (SD) sleep in severe dementia and moderate, mild, or no dementia*

	SDG (n = 55)	MMNDG (n = 22)	p value
Day[a]			
Percent sleep	29 (20)	15 (11)	0.0021
Minutes sleep	265 (188)	137 (95)	0.0024
Percent wake	71 (20)	85 (11)	0.0021
Minutes wake	641 (201)	760 (139)	0.010
Number naps	20 (11.2)	15 (9.7)	0.13
Mean time awake (minutes)	45 (37)	57 (45)	0.28
Night			
Percent sleep	58 (22)	45 (21)	0.016
Minutes sleep	275 (104)	211 (99)	0.017
Percent wake	42 (20)	55 (24)	0.19
Minutes wake	198 (98)	259 (180)	0.19
Number naps	15 (5.6)	15 (6.7)	0.91
Mean time awake (minutes)	15 (12.7)	21 (27.6)	0.69

[a] Day was defined as 0600 to 2200 hours; night was defined as 2200 to 0600 hours. Day and night minutes recorded do not add up to 24 hours (1,440 minutes) due to brief times when the Actillumes were removed.

TABLE 3. *Mean (SD) of circadian rhythms of activity for severe dementia and moderate, mild, or not-demented nursing-home patients*

	SDG (n = 55)	MMNDG (n = 22)	p value
Mesor	7.8 (13.4)	10.8 (8.9)	0.0030
Acrophase	1409 hours (180 minutes)	1329 hours (107 minutes)	0.025
Amplitude	5.2 (14.6)	5.6 (4.7)	0.029
Circadian quotient	0.52 (0.29)	0.56 (0.20)	0.40

more phase delayed), and more blunted amplitudes. There was no significant difference in circadian quotient (defined as the amplitude : mesor ratio—the larger the quotient, the better the rhythm); in fact, neither group had a robust rhythm.

Illumination exposure

There were significant correlations between mental status and light exposure. The more severely demented the patients (i.e. the lower the MMSE), the less time they spent in >1,000 lux illumination ($r_s = 0.27$, $p < 0.05$) and the lower the mean lux exposure during the day ($r_s = 0.28$, $p < 0.05$) and at night ($r_s = 0.39$, $p < 0.005$). In the SDG, 47% of the patients spent 0 minutes in illumination >1,000 lux, but in the MMNDG, only 20% spent 0 minutes in illumination >1,000 lux (p = 0.023) (see Table 4). The median number of minutes of exposure >1,000 lux was 9 minutes for the MMNDG and only 1 minute for the SDG.

There were no significant differences in the mean level of light exposure during the day for those in the SDG (mean = 394 lux) vs. those in the MMNDG (mean = 381 lux). However, the SDG had a significantly lower maximum light exposure (mean = 8,449 lux) than the MMNDG (mean = 10,262 lux) (p = 0.045). At night, the SDG were exposed to a significantly lower mean level of light (mean = 33.7 lux) than the MMNDG (mean = 75.3 lux) (p = 0.0094).

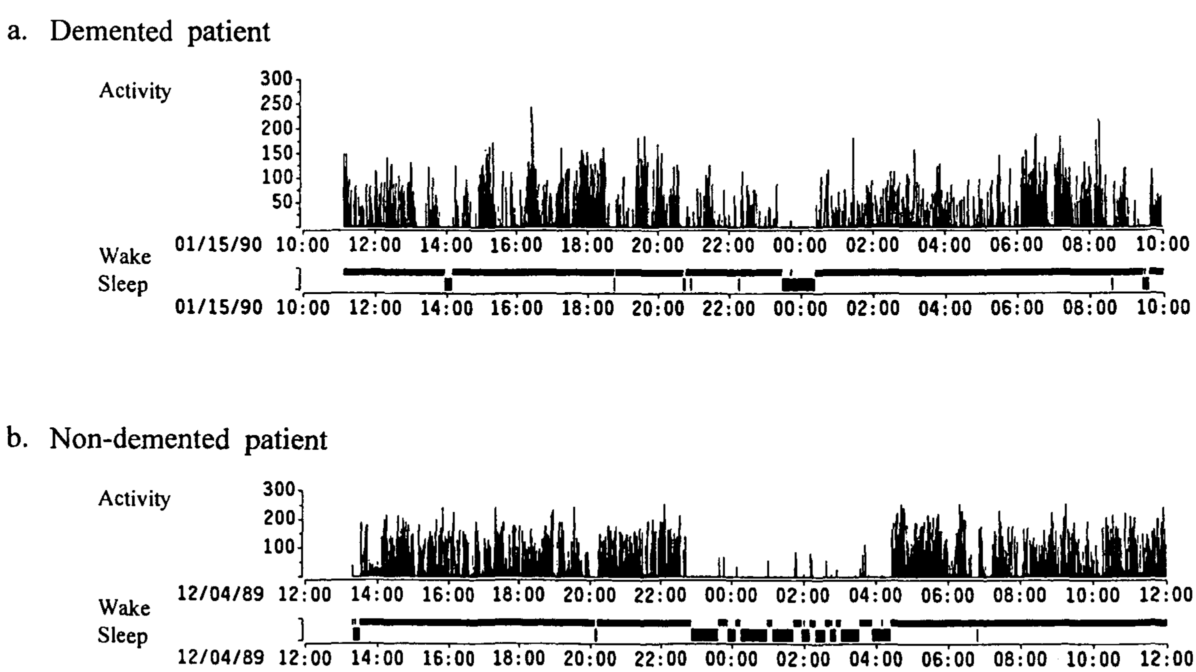

FIG. 1. Activity plot of a nursing-home patient with severe sleep fragmentation. There were no long intervals of consolidated wake or sleep.

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TABLE 4. *Number of minutes of exposure to >1,000 lux*

Minutes	SDG (n = 55) (%)	MMNDG (n = 22) (%)
0	47	20
1–10	22	32
>10	31	48

Depression

The mean GDS depression score for all subjects was 10.6 (SD = 5.9, range = 1–27); 80% scored below 15, indicating mild to no depression. There were no significant correlations between depression scores and sleep variables. However, the more depressed patients spent less time exposed to light ≥1,000 lux ($r = -0.27$, $p < 0.05$).

Effect of illness on sleep

Relationships between the sleep variables and different medical and psychiatric diagnoses (based on medical records) were analyzed. Illness categories analyzed included cardiovascular disease, pulmonary disease, endocrine disease, malignancy, central nervous system disease, gastrointestinal disease, renal disease, and infectious disease. Patients who snored slept less per 24 hours (mean = 333 minutes) than patients who did not snore (mean = 494 minutes, p = 0.05). (Note, snoring was assessed by direct observation by research staff and/or by questioning the nursing staff on night shift.) Other illness categories were unrelated to differences in sleep. Although nursing-home patients often had multiple medical diagnoses, only dementia showed an effect on quality of sleep.

DISCUSSION

These data confirm that nursing-home patients have very fragmented sleep and spend very little time in bright light. In particular, the sleep and light exposure of the severely demented group differed from patients with mild, moderate, or no dementia.

Our laboratory previously reported sleep patterns in patients in a different nursing home using a different wrist-activity recording technology (an analog wrist actigraph, i.e. tracing was hand scored) (16,17). The patients were asleep for a mean of 11.7 hours and awake for a mean of 12.3 hours per day. Sleep was distributed throughout the 24-hour recording period. On average, no single hour consisted of complete sleep or complete wake. Rather, a period of sleep and some awakening occurred during each hour with patients waking up between 2.0–6.4 times per hour.

Aharon-Peretz et al. (18) also used wrist activity to study sleep in ambulatory patients with mild or moderate dementia. Those patients with multi-infarct dementia had disrupted sleep; however, the sleep/wake activity of those with Alzheimer's Disease (AD) did not differ from normal controls. Their study, however, did not address sleep/wake disturbances in institutionalized patients with severe dementia.

In the current study, all the nursing-home patients had disturbed sleep. It was surprising to find that the severely demented patients did not have more disturbed sleep than the composite group of moderate, mild, and not-demented patients (i.e. they did not wake up more often during the night). On the other hand, the severely demented patients did spend more time sleeping both at night and during the day. In a questionnaire study of AD patients and their caretakers, data indicated that dementia was correlated with more time spent in bed and more naps during the day (19). Polygraph studies of demented patients have shown that, compared to normal aged-matched controls, demented patients showed lower sleep efficiency and more arousals and awakenings during the night (20–25). However, most polygraph studies compared community-dwelling demented patients to controls and not to other more severely demented, nursing-home patients. These studies, by necessity, most likely excluded severely demented patients who would not tolerate sleeping in a sleep laboratory (26). Our population of demented institutionalized patients, the majority of which were severely demented, may not be comparable to community-dwelling demented patients studied by others. Vitiello et al. found a positive correlation between sleep disruption and level of dementia, with fragmented sleep at night and daytime sleepiness both increased in the more severely demented patients (4).

The rest–activity (sleep–wake) rhythm is very disturbed in AD patients and correlates with severity of dementia (27). Bliwise and colleagues suggested that sleep disturbance in AD may be related to loss of ability to process environmental zeitgebers (i.e. cues) such as night vs. day and dark vs. light (26,28). The fragmented sleep found in nursing-home patients may indeed be related to inappropriately timed sleep and wake, perhaps secondary to a weakening of circadian rhythms and optic nerve and SCN degeneration.

In this sample, the severely demented patients spent a median time in bright light >1,000 lux of only 1 minute. Almost half of the severely demented patients spent 0 minutes of light exposure above 1,000 lux. This low amount of bright-light exposure might be a cause of some sleep and circadian rhythm changes seen in these patients, although the low bright-light exposures might also be a consequence of the demented behavior (e.g. cannot be left alone outside).

The circadian rhythms of activity of the severely

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demented patients differed from those of the composite group of moderate, mild, and no-dementia patients. These results corroborate reports of other investigators (27,29,30). Similar to reports by Satlin et al., severely demented patients were more phase delayed and had a more blunted circadian rhythm (29). There was no significant difference in the number of patients in each group that were wheelchair bound and no patients were bed-ridden or totally immobile, so activity level per se would not account for differences in activity rhythms.

Some discussion is needed about the technology used to determine sleep/wake activity. The Actillume correlated well with direct observations. The correlations between the Actillume and EEG for distinguishing wake from sleep may seem low at first glance. However, it is important to recall that, although the EEG is considered the "gold standard", it is questionable how reliable sleep scoring based on EEG is in this population (13,26,31). The wake EEG of demented patients frequently is composed of diffuse slow activity including frequencies traditionally scored as sleep in the normal individual (26). In addition, alpha frequencies, traditionally scored as relaxed wakefulness, are decreased in this population (32). In his review of sleep and dementia, Bliwise concludes that the discrimination between wake and sleep based on EEG measures is extremely difficult in dementia (26). Others have also questioned the reliability of EEG measurement in this population (33). Therefore, although the Actillume data compared to EEG data look like they may not be robust, in fact, the Actillume seems to be a reliable way to determine sleep and wake periods in patients who are otherwise unable to tolerate traditional sleep-recording techniques (13).

In summary, severely demented elderly patients differ from those with mild, moderate, or no dementia in circadian rhythms, sleep, and light exposure. We continue to study the phenomena by randomizing bright-light treatments in an effort to determine the causal influence of bright light on sleep and rhythms. Further research will need to examine what aspects of severe dementia predispose these patients to deterioration of their 24-hour cycles.

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