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Objective and Subjective Characteristics of Sleep after Coronary Artery Bypass Graft Surgery in the Early Period: A Prospective Study with Healthy Subjects

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ABSTRACT

Background. The purpose of this study was to investigate changes in sleep characteristics by examining both subjective tests and objective parameters such as actigraphic sleep analysis in patients who underwent coronary artery bypass graft surgery (CABG).

Patients and Methods. Forty-five patients who underwent CABG operations and did not have any sleep disturbance were examined. They were evaluated by subjective and objective sleep parameters at the beginning of the examination and on the fifth postoperative day. Forty healthy subjects who did not undergo the operation were also evaluated.

Results. The Pittsburgh Index and Epworth values in the postoperative group were significantly higher, but Maintenance of Wakefulness Test lengths were significantly shorter than in the preoperative and control groups. Sleep latency, napping episodes, total napping periods, and fragmentation index values of the postoperative group were significantly higher, but sleep efficiency values were significantly lower than in the preoperative and control groups.

Conclusion. The cause of sleeplessness after CABG surgery may be the temporary deterioration of circulation in the centers of the brain stem and hypothalamus, which control sleep and awakening. It can be proposed that the improvement of the circulation in these centers a couple of months after the operation help to regain sleep control, and thus sleep disturbances disappear.

INTRODUCTION

Coronary artery bypass graft (CABG) surgeries are now being widely used. Emerging complications, deteriorations of immune systems, and the delay of wound healing are factors that lengthen hospital stay and are the main causes of morbidity and mortality [Redeker 1993]. Sleep is an important phenomenon that affects all of these issues [Carskadon 1994]. Sleeplessness, poor sleep quality, and lack of sleep continuity (difficulty falling asleep, restless sleep with frequent nocturnal awakenings, and early morning awakenings) are common among patients during recovery after CABG surgical procedures and may have important effects on morbidity, mortality, and quality of life [King 1988; Tack 1990; Schaefer 1996; Redeker 2002]. Although these are common and frequent complaints, the associations between changes in sleep pattern and a patient's general well-being are not well understood. Many studies attempting to explain these problems have been performed with the use of polysomnography and questionnaire forms [Sadeh 1995; Lockley 1999; Monk 2003].

Alterations of sleep patterns, deprivation of total sleep time (TST), increments of slight sleepiness, suppressed rapid-eye-movement sleep, increased daytime napping episodes and durations, and, as a consequence of these factors, decreased sleep efficiency (SE) after CABG surgeries have been reported in numerous studies [Redeker 1993, 1996, 2001, 2002, 2004; Schaefer 1996; Edell-Gustaffson 1999; Hunt 2000]. Only objective parameters have been evaluated in some studies [Redeker 1993, 1996, 2002, 2004], and only subjective parameters in others [Schaefer 1996; Edell-Gustafson 1999; Hunt 2000]. None of these studies contain control groups that comprise healthy subjects. Thus, this prospective study that uses both of these measures of sleep and contains a control group was planned in hope of contributing to the knowledge about sleeplessness in the early period after CABG surgery.

PATIENTS AND METHODS

Eighty-five alert, oriented patients were each given a wrist actigraph to wear. The study group consisted of 45 patients (23 male and 22 female) who were admitted to the clinic for CABG surgery with the use of cardiopulmonary bypass. The other 40 healthy subjects (20 male and 20 female) in nearly the same age range were evaluated as controls. None of the patients had any sleep disturbance or neurologic disorder such as stroke or tremor affecting the nondominant arm movement (because of the need to wear a wrist actigraph), anxiety, or peptic ulcus. None of the patients were taking any drugs related to sleep disorders or central nervous system depressants.

All patients completed the Hamilton Anxiety Rating Scale and other anxiety measurements. The subjects with high

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Table 1. Demographic Findings of the Subjects

	Study Group		Control Group		
	Female	Male	Female	Male	*P*
Total no. of subjects	22	23	20	20	
Age >60 y, n	11	12	11	11	
Age <60 y, n	11	11	9	9	
Age mean (range), y	58.77 ± 7.78 (43.00-68.00)	61.21 ± 6.82 (49.00-72.00)	59.80 ± 7.38 (43.00-68.00)	62.05 ± 6.40 (49.00-72.00)	.562*
P	.268†		.310†		

*P determined by 1-way analysis of variance.
†P determined by Wilcoxon signed rank test.

scores were excluded from the study. All patients were instructed to complete a standard sleep diary. Sleep assessment questionnaires were completed by the patients and control subjects in the morning hours. The Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), and Maintenance of Wakefulness Test (MWT) were used. The study was approved by the institutional ethics committee. All participants gave their written informed consent. Participation in this study was over a period of nearly 10 days, including preoperative measurement of the primary study at least 3 days before surgery and a consecutive 5- to 8-day period during the first postoperative week for the study group. Control group subjects wore the wrist actigraphs over a 7-day period continuously. Wrist actigraphs were not used during the operative day or on the first postoperative day.

The sleep instruments used in this study included subjective materials such as a standard sleep diary and the PSQI and objective parameters such as actigraphy. Participants were instructed to wear wrist actigraphs continuously except during the bathing period, to avoid immersing the device in water. Subjects were told to press the button of the event marker when falling asleep and waking from sleep to indicate the time in bed. They completed a sleep diary each morning during the period of actigraph use. These diaries were used to record daily bed times, times of sleep onset, frequency and duration of awakenings during the sleep period, final awakening time, and napping (sleep outside of the major sleep period) times during the day to provide some information about sleep latency (SL), frequency of prolonged awakenings, and TST.

PSQI is a subjective measurement that evaluates sleep quality and disturbances during the past month. All subjects answered 19 questions, and results were assessed as “good sleep quality” for scores ≤5 or as “bad” for scores >5.

ESS was used to evaluate the general level of self-reported daytime sleepiness during the past week. The ESS score can total to 24, and those results that were ≥10 were assessed as indicating sleepiness.

MWT was performed by forcing the subjects to maintain their wakeful state in a silent and dim room for 4 20-minute periods, with a 2-hour break after each period. Average wakefulness time was calculated by dividing the total sum of the length of the wakeful periods that the patients were able to maintain by 4.

The actigraphs were applied to participants’ nondominant wrists on the first postoperative morning and worn continuously throughout a 5-day period to evaluate sleep duration and continuity as well as to obtain some information about daytime naps. All watches were calibrated prior to use and set to collect data at 30-second epochs and a maximum frequency of 32 Hz. Device sensitivities were determined to indicate that motor activities ≥20 indicated being awake. A minimum of 10 minutes without motor activity after pressing the marker was determined to be sleep onset. Motor activities <5 were assessed as occurring in a sleep period in the analysis of napping. Nap times were determined to be a minimum of 5 and a maximum of 15 minutes. The primary sleep period was recognized based on the times that contributors depressed the event markers to indicate “lights out” and “lights on.” TST was calculated by removing any period of awakening from the TST during the night.

Daily sleep and daytime activity variables, SL (time from lights out to sleep onset), percentage of wakefulness after sleep onset, and total activity score parameters were determined. Computer programs were used to determine the levels of activity/inactivity, sleepfulness/wakefulness parameters such as duration of time in bed for the nocturnal sleep period and TST during the major sleep period, and percentage of time spent asleep. Total awake time, percentage of time spent awake, number/frequency of awakenings, duration of awakenings, SE (nocturnal sleep time/time in bed), and nap times were also calculated. There were no missing data due to the removal of actigraphs for bathing or other purposes.

Statistical Analysis

These data were entered into the SPSS version 10 program (Chicago, IL, USA). Wilcoxon signed rank test, 1-way analysis of variance, Pearson correlations, and hierarchical multiple regression analysis were used for statistical evaluation. A P value <.05 was considered significant.

RESULTS

In the study group, the mean age was 61.2 years for male patients and 58.7 years for female patients. In the control group, the mean age was 62.0 years for male patients and 59.8 years for female patients. There were no statistically significant age or sex differences between the groups (Table 1).

Table 2. Sleep Parameters of Study and Control Groups*

	Preoperative Group		Postoperative Group		Control Group	
	Female	Male	Female	Male	Female	Male
Subjective parameters						
PSQI (range), point	3.14 ± 0.83 (2.00-5.00)	2.97 ± 0.95 (1.00-5.00)	5.55 ± 0.96† (4.00-7.00)	6.09 ± 0.79† (4.00-8.00)	2.70 ± 1.33 (0.00-4.00)	2.67 ± 1.42 (0.00-4.00)
ESS (range), point	2.05 ± 0.90 (0.00-6.00)	2.39 ± 0.86 (0.00-6.00)	6.23 ± 1.01† (4.00-9.00)	6.16 ± 1.08† (3.00-8.00)	2.00 ± 1.21 (0.00-6.00)	2.04 ± 1.11 (0.00-6.00)
MWT (range), min	17.90 ± 1.32 (14.00-19.00)	18.39 ± 1.06 (14.00-20.00)	16.31 ± 1.01 (14.00-18.00)	16.60 ± 1.21 (15.00-19.00)	18.00 ± 1.07 (17.00-20.00)	17.60 ± 1.00 (14.00-20.00)
Objective parameters						
SL (range), min	15.55 ± 8.33 (10.00-30.00)	16.13 ± 7.45 (9.00-30.00)	22.77 ± 6.24† (15.00-35.00)	23.39 ± 6.55† (11.00-40.00)	16.00 ± 7.11 (10.00-31.00)	17.00 ± 7.43 (10.00-32.00)
TST (range), h/night	7.17 ± 0.64 (6.00-8.05)	7.08 ± 0.43 (6.25-8.06)	6.13 ± 0.98‡ (4.25-7.42)	6.00 ± 0.88‡ (4.20-8.20)	7.18 ± 0.56 (6.39-8.45)	7.09 ± 0.61 (5.59-8.00)
Total activity score (range), no./night	9851 ± 7353 (1034-23028)	8608 ± 7200 (1334-22280)	5779 ± 7861‡ (1243-23591)	5980 ± 8200† (3421-23571)	8700 ± 7324 (3000-23800)	9780 ± 7215 (2100-21980)
WASO (range), min	14.59 ± 2.01 (5.00-60.00)	14.13 ± 2.02 (6.00-61.00)	36.14 ± 2.71† (20.00-70.00)	34.17 ± 2.53† (21.00-69.00)	14.30 ± 2.00 (6.00-61.00)	15.00 ± 2.01 (5.00-62.00)
FI (range), no./d	9.44 ± 1.21 (2.00-17.80)	8.43 ± 1.23 (1.90-17.00)	15.54 ± 2.30† (1.90-19.50)	15.70 ± 2.01† (2.42-19.90)	8.80 ± 1.19 (2.00-18.00)	9.33 ± 1.20 (1.89-18.00)
SE (range), %	93.70 ± 12.00 (59.00-98.00)	92.65 ± 15.21 (59.00-99.00)	68.20 ± 14.92† (45.40-88.20)	66.71 ± 11.17† (45.00-80.00)	94.70 ± 1.21 (51.00-98.00)	94.01 ± 0.94 (50.00-98.00)
Daytime napping episodes (range), no./d	2.31 ± 0.44 (1-4)	2.86 ± 1.19 (1-4)	5.45 ± 1.80† (2-11)	5.70 ± 1.20† (2-11)	2.45 ± 1.04 (0-4)	2.41 ± 0.71 (0-4)
Total nap duration (range), min/d	32.02 ± 4.00 (15.00-55.00)	33.00 ± 4.13 (15.00-59.00)	98.00 ± 8.23† (24.11-143.00)	99.00 ± 9.32† (24.91-151.07)	30.10 ± 4.10 (15.00-57.00)	31.00 ± 4.20 (15.00-60.40)

*Wilcoxon signed rank test was used for comparing the preoperative and postoperative values of the study group, and 1-way analysis of variance was used for comparing the preoperative and postoperative values with the control group's values. PSQI indicates Pittsburgh Sleep Quality Index; ESS, Epworth Sleepiness Scale; MWT, Maintenance of Wakefulness Test; SL, sleep latency; TST, total sleep time; WASO, wakefulness after sleep onset; TAS, total activity score; FI, fragmentation index; SE, sleep efficiency.

†$P < .001$.

‡$P < .01$

In the study group, patients experienced uncomplicated recovery from surgery. Descriptive statistics obtained on the activity variables are shown in Table 2. In the study group, postoperative PSQI and ESS scores were significantly higher and postoperative MWT times were significantly shorter than the preoperative values (Table 2). In the study group, SE was found to be decreased in the postoperative period according to the preoperative era ($P < .001$) (Figure 1). Night sleep times were fragmented significantly in the postoperative period in the study group (Figure 2). For the postoperative period, PSQI and ESS scores of the study group were significantly higher and MWT times were significantly shorter than in the control group (Figure 3).

DISCUSSION

Sleep quality and disturbances including wake time and duration of night arousals were the most important aspects related to mental health. The perception of poor sleep may be most relevant to mental health, whereas its objective characteristics may be more relevant to functional performance. Sleep disturbance, poor sleep quality, and sleep continuity (difficulty falling asleep, restless sleep with frequent nocturnal awakenings, and early morning awakenings) are common among patients during recovery after cardiac surgical procedures and may have important effects on mor-

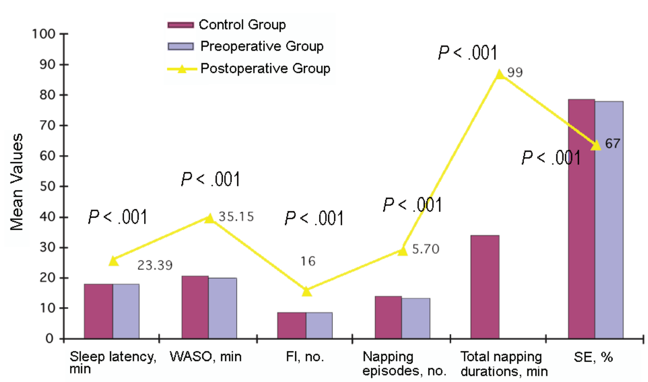

Figure 1. Objective alterations in preoperative and postoperative sleep parameters. *P* determined by Wilcoxon signed rank test.

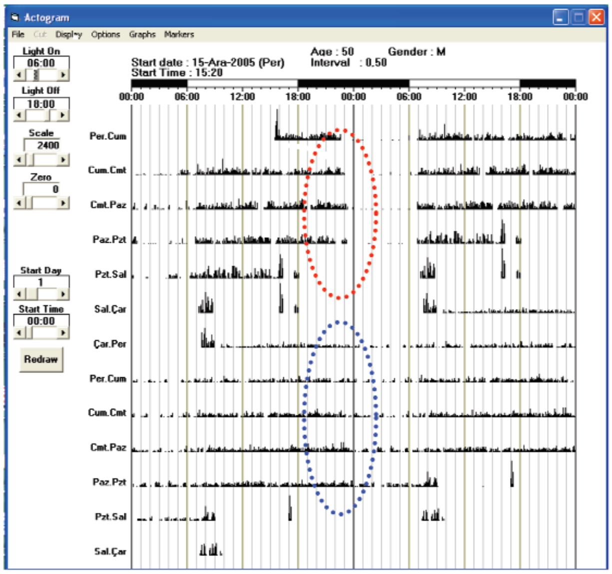

Figure 2. Example of a subject's sleep times. Red lines show preoperative night sleep. Blue lines show postoperative night sleep. Fragmentation of the postoperative night sleep is remarkable. WASO indicates wakefulness after sleep onset; FI, fragmentation index.

bidity, mortality, and quality of life [Redeker 2001, 2002; King 1988; Tack 1990; Schaefer 1996; Simpson 1996]. These common complaints are frequent, but the associations between changes in sleep pattern and the patient's general well-being are not well understood.

Many studies attempting to explain these problems have been performed with the use of polysomnography and questionnaire forms [Sadeh 1995; Lockley 1999; Monk 2003]. Alterations of sleep patterns, deprivation of TST, increments of slight sleepiness, suppressed rapid-eye-movement sleep, increased daytime napping episodes and durations and, as a consequence of these factors, decreased SE after heart operations have been reported in numerous studies [Hayter 1983; Redeker 1993, 1996, 2002, 2004; Schaefer 1996; Edell-Gustaffson 1999; Hunt 2000]. It was reported that sleep disturbances ceased by the end of first postoperative week [Redeker 1996; Lukkarinen 1998; Chocron 2000].

Only objective parameters have been evaluated in some studies [Redeker 1993, 1996, 2002, 2004], and only subjective parameters in others [Schaefer 1996; Edell-Gustaffson 1999; Hunt 2000]. None of these studies contain control groups that comprise healthy subjects. Thus, this prospective study that uses both of these measures of sleep and contains a control group was planned in hope of contributing to the knowledge about sleep disturbances after CABG surgery.

Preoperative sleep formation is important to determine the sleep state in the postoperative period. In other words, the preoperative sleep state is the indicator of the postoperative sleep state [Edell-Gustaffson 1999]. The determination of the preoperative sleep situation is important to differentiate between sleep disturbances that previously existed or those that have newly emerged. For this reason, we chose study subjects without sleep disturbances. By performing this selection we have attempted to study only the effect of the operation on sleep parameters and efficiency after the operation.

Women had significantly more nap episodes and longer nap durations than men. In female subjects, SLs were found to be decreased and TSTs and SEs were increased in comparison to male subjects in our study. Female subjects' arousal periods and frequencies in night sleep were higher and their SEs were lower than male subjects'. This difference was more apparent among older female subjects [Reyner 1995]. SLs for women were longer than for men in another report [Schmitt 1996]. Long SLs, fragmented night sleep, and decreased SEs were found to be significantly recovered 1 month after CABG surgery [Redeker 2002].

Major operations such as CABG surgery may cause apparent anxiety or depression in the preoperative period. These situations may distort sleep formation. Patients who undergo CABG surgery and have anxiety or depression preoperatively may complain intensely and frequently about their sleep [Edell-Gustaffson 1999]. For this reason, we used the Hamilton Anxiety Rating Scale and chose subjects without anxiety or depression, thereby eliminating the interference of these factors.

Some other factors that affect night sleep time are daily nap episodes and their total time. More frequent nap episodes cause an increased night SL. In this situation night sleep duration will be lessened [Carskadon 1994]. We found that SLs lengthened, nocturnal awakenings increased, night sleep was more fragmented, and SEs lessened in the subjects who had increased daily nap episodes and total nap durations.

The effect of cardiopulmonary bypass on the formation of sleep has not been extensively discussed in the literature. Disturbed circulation in the centers relating to sleep during cardiopulmonary bypass may be the cause of temporary dysfunction in these regions. Some hypoxic processes that affect cerebral autoregulation were commenced during the cardiac operations with the use of cardiopulmonary bypass [Plomondon 2001]. This hypoxic process may cause distortion in the circulation in the brain stem and hypothalamus, which are responsible for the regulation of sleep and awakening. As a result of this confusion, these centers may temporarily fail to regulate cyclic sleep times. So we expect that this temporary disarrangement of sleep may recover sometime

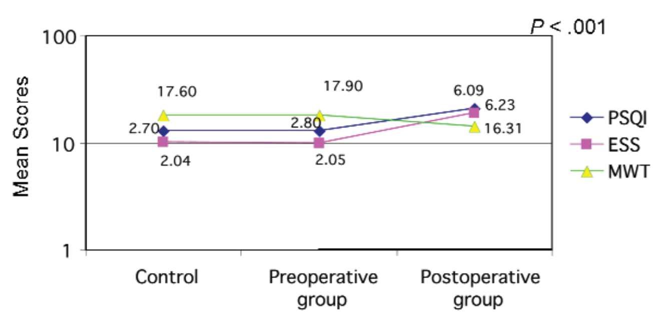

Figure 3. Subjective alterations in preoperative and postoperative sleep parameters. *P* determined by Wilcoxon signed rank test. PSQI indicates Pittsburgh Sleep Quality Index; ESS, Epworth Sleepiness Scale; MWT, Maintenance of Wakefulness Test.

after the operation. Many studies using self-written patient questionnaires report that postoperative sleep disturbances ceased 1 month after CABG surgery [Redeker 1996, 2002; King 1988; Tack 1990; Schaefer 1996].

More fragmented night sleeping and frequent daily naps have been reported after CABG surgery, which are similar to our results [Redeker 1993, 1996]. In some studies, sleep complaints decreased from 69% in the first postoperative week to 39% at the end of the first postoperative month [King 1988]. In our study group, sleep effectiveness (a patient's perception of the degree to which the whole sleep time was felt to be effective regarding sleep quality and length) was highest in the preoperative measurement but gradually decreased and reached the lowest value on the third postoperative day, and then increased to a higher postoperative value on the sixth postoperative day. By the end of the first week after CABG surgery, improvements in both subjectively and objectively reported sleep were observed. Our results show that sleep patterns were disturbed in the early postoperative period, and these disturbances and complaints disappeared after some time.

The cause of sleep disturbances after CABG surgery with the use of cardiopulmonary bypass may be the temporary deterioration of circulation in the centers of the brain stem and hypothalamus, which control sleeping and awakening. It can be proposed that the improvement of circulation in these centers a couple of months after the operation helped to regain sleep control, and thus sleep disturbances disappeared. Further investigations that can measure glucose and oxygen levels and the mediators related to sleep in the neuronal structures by the use of single photon emission computerized tomography and positron emission tomography may be required to explain sleep disturbances after CABG surgery.

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