Original Article

Sleep Apnea Syndrome and Related Factors in Patients with Stroke

Chiu-Chu Chen[a], Hua Ting[b], Tai-Chung Liou[c], Wen-Chun Liao[def*]

[a] *Department of Nursing, Chung Shan Medical University Hospital, Chung Shan Medical University School of Nursing, Taichung City, Taiwan*

[b] *Sleep Medicine Center, Chung Shan Medical University Hospital, Chung Shan Medical University School of Medicine, Taichung City, Taiwan*

[c] *Department of Radiology, Taichung Tzu Chi Hospital,Buddhist Tzu Chi Medical Foundation, Taichung City, Taiwan*

[d] *School of Nursing and Graduate Institute of Nursing, China Medical University, Taichung City, Taiwan*

[e] *Department of Nursing, China Medical University Hospital, Taichung City, Taiwan*

[f] *Department of Nursing, Asia University, Taichung City, Taiwan*

Background and Purpose: A cross-sectional study design was used to investigate the relationships among stroke status, sleep pattens and severity of sleep apnea syndrome in stroke patients in Taiwan.

Methods: Data from 165 stroke patients were retrieved from a rehabilitation hospital from January 2011 to March 2013. From medical records, information including demographic characteristics, stroke status, anthropometric measurements, health behaviors, medical history, and biochemical test results were collected. Polysomnography (PSG) was performed 1-2 months after stroke, during hospitalization, with the consent of patients and their families.

Results: Eighty percent of the stroke patients suffered from sleep apnea (AHI> 15 times/ hour). Sleep efficiency was low (70.3%±16.4), falling to 69.3% (SD 16.0) in those with severe sleep apnea (AHI≧30 times/hour). Abnormal sleep in patients with severe sleep apnea involved reductions in total sleep time (TST), sleep efficiency, stage N2 duration, stage N2%, and stage R%, as well as increases in sleep onset latency (SOL), wake after sleep onset (WASO), stage W, and arousal index. Severity of sleep apnea in stroke patients was associated with male gender (r_s=.159, P=.041), history of arrhythmia (r_s=.176,P=.024), and advanced age (r=.262, P= .001), as well as high body mass index (BMI) (r=.245,P= .002) and large waist circumference (r=.225,P=.005).

Conclusions: Among patients with stroke there is a high incidence of sleep apnea. Gender, age, history of arrhythmia, BMI, and waist circumference are correlated with severity of sleep apnea. This study highlights the importance of sleep problems and related treatment in patients with stroke.

Key words: stroke, sleep patterns, sleep apnea syndrome

Introduction

According to the Ministry of Health and Welfare, cerebrovascular disease is the third leading cause of death in Taiwan[1]. Although the mortality rate from cerebrovascular insult

* Correspondence: Wen-Chun Liao
RN, PhD Professor, School of Nursing and Graduate Institute of Nursing, China Medical University, Taichung City, Taiwan
Address: 91, Hsueh-Shih Rd., Taichung City 404, Taiwan.
Tel: +886-4-22053366 ext. 7106
E-mail: wcl@mail.cmu.edu.tw

(stroke) has decreased from 58.8 per 100,000 people in 2001 to 50.1 per 100,000 people in 2014, the neurological damage from a stroke typically results in sequelae such as dysfunction in physical activities and dysphagia, which has a substantial impact on patients' ability to perform daily living activities. Such disease-induced disabilities impose a burden on patients and their families. Advances in medical care and studies on risk factors that are relevant to stroke have contributed to a decrease in the mortality rate of patients who have suffered a stroke. However, high mortality and disability rates remain critical problems worldwide[2]. In particular, patients may develop severe obstructive sleep apnea (OSA) following a stroke, which can increase the likelihood of recurrence and the risk of mortality[3,4]. Previous studies have reported that the prevalence rate of experiencing 5 or more apnea and hypopnea index (AHI) events per hour is between 62% and 72% in stroke patients[5-8]. In another study involving 45 patients undergoing stroke rehabilitation, the incidence of experiencing more than 10 AHI events per hour was 91%[9]. Moreover, the incidence of sleep disordered breathing (SDB) was higher in patients with recurrent stroke than in patients with first stroke. This high incidence rate of SDB in stroke patients remains a concern. Sleep apnea may prolong the hospitalization of stroke patients and have a negative impact on their rehabilitation[13].

Overall, the incidence of SDB in stroke patients is high. Risk factors for sleep apnea include age[15-18], male gender[7,17], obesity, high body mass index (BMI)[6,11,17,18], snoring[18], thick neck[6,15], smoking[18], drinking and hypertension[6], as well as a history of atrial fibrillation[10]. People with hypertension, as well as a history of smoking and stroke, are prone to OSA[12]. Severe sleep apnea has a profound impact on the prognosis and mortality of stroke patients[11]. The hazard ratio of mortality for patients with sleep apnea (AHI > 15 events/hr) after adjusting for mean arterial pressure is 6.24 (P = .002) [11]. The duration and type of stroke (hemorrhagic stroke, ischemic stroke, and transient ischemic attack) do not significantly differ among recurrent stroke patients with SDB and first-time stroke patients with SDB[7].

From the results of a 5-year follow-up study, stroke-related risks and mortality rate of stroke patients with sleep apnea can be reduced through long-term treatment[14]. These highlight the importance of early detection and treatment of sleep apnea for reducing the recurrence and negative impact of stroke, thereby improving the quality of life of affected patients. Therefore, treating sleep apnea in patients after stroke is crucial. Assessing risk factors for sleep apnea efficiently highlights those patients who are potentially at risk. The purpose of this study was to investigate the relationships among stroke status, sleep patterns and severity of sleep apnea syndrome in stroke patients in Taiwan.

Methods

Study design and procedure

This study was based on a retrospective research design. Subjects were stroke patients in the rehabilitation ward of a hospital in Taichung, Taiwan. The period of retrospective data collection was from January 1, 2011 to May 31, 2013. Demographic data were collected from medical records. The functional independence measure (FIM) was employed to determine the physical movement and cognitive function of stroke patients. Polysomnography (PSG) was conducted to measure patients' sleep patterns and severity of sleep apnea.

Participants

Hospitalized stroke patients were recruited according to the following criteria: (1) infarction or hemorrhagic stroke diagnosed by a neurologist or rehabilitation physician (International Classification of Disease, Ninth Revision, Codes 430-437); (2) at least 20 years of age; (3) history of neurological deficit lasting for longer than 24 hours; (4) local neurological deficit confirmed on neurological examinations; (5) brain damage and neurological function damage confirmed on computed tomography or magnetic resonance imaging; and (6) total sleep time (TST) ≥ 2 hours (confirmed on PSG)[15]. The exclusion criteria were as follows: (1) patients with diagnosed sleep apnea who had undergone treatment or surgery;

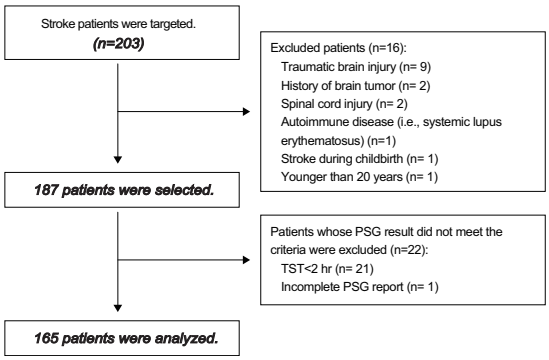

Fig. 1 Study Flow Chart.

(2) patients who had undergone surgery for upper respiratory disease; (3) patients who had suffered a stroke during childbirth; and (4) patients with a history of brain tumor, traumatic brain injury, or autoimmune disease.

A total of 203 stroke patients were identified. Among them, 9 patients with traumatic brain injury, 2 patients with a history of brain tumor, 2 patients with stroke and spinal cord injury, one patient with autoimmune disease, one patient who had suffered a stroke during childbirth, one patient younger than 20 years of age, 21 patients with TST < 2 hours on PSG, and one patient with incomplete PSG report were excluded. Subsequently, 165 patients were enrolled. The study flow chart is shown in Figure 1.

Measurements

(1) Demographic data and physical examination: Information including demographics, stroke status, anthropometric measurements, health behaviors, medical history, biochemical test results, and blood pressure measured in the evening on the day of PSG was collected.

(2) FIM is a measure that is comprised of physical and cognitive domains. Physical domain includes 13 items related to self-care, sphincter control, transfer, and locomotion. Each item is assigned a score from 1 to 7 with 1 referring to "completely dependent" and 7 referring to "fully independent", with a total score from 13 to 91. Cognitive Domain scale includes 5 items related to communication and social cognition with a total score from 5 to 35. Total score was based on the sum of physical and cognition domains and ranged from 18 to 126. The rating scale was as follows: 18 "totally dependent," 19-36 "requires much assistance," 37-54 "moderately dependent," 55-72 "mildly dependent," 73-90 "requires supervision," 91-107 "partially independent," and 108-126 "completely independent." FIM is the most frequently used scale in clinical rehabilitation medicine to assess stroke patients' degree of independence in daily life[19].

(3) On PSG, the numbers of apneas and hypopneas per hour of sleep were calculated to obtain AHI, which was used to determine the severity of sleep apnea. According to the literature[20,21,22], AHI > 15 events/hours is regarded as the threshold at which treatment is required in clinical diagnosis, and this is typically used to determine the severity of sleep apnea. Therefore, in this study, the participants were divided into 3 groups: AHI ≤ 15 events/hours; 15 < AHI < 30 events/hours; and AHI ≥ 30 events/ hours.

(4) Sleep apnea syndrome was classified into 3 categories: obstructive sleep apnea (OSA), central sleep apnea (CSA), and mixed sleep apnea. Sleep apnea sysdrome was classified as predominantly OSA if ≧50% of the events were obstructive and predominantly CSA if ≧50% of the events were central[22].

Data Analysis and Statistical Methods

Data analysis was conducted using the statistical software SPSS Version 18.0. The applied statistical methods were comprised of descriptive statistics (mean, standard deviation [SD], and frequency distribution) and inferential statistics (t test, Chi-square test, analysis of variance, Pearson's correlation, and Spearman's correlation).

Ethics statement

The study protocol was approved by the institutional review board of Chung Shan Medical University Hospital (IRB No.CS-13117). Informed consent was waived.

Results

Demographic data, disease status, health behaviors, and sleep apnea syndrome classification among stroke patients with

Table 1. ***Distributions of demographic data, disease status, health behaviors, and sleep apnea syndrome classification among stroke patients with different severity levels of sleep apnea (N=165).***

Items	*AHI≦15* *n=33*	*15<AHI<30* *n=37*	*AHI≧30* *n=95*	*Effect size*	*P valu*
	n (%)	*n (%)*	*n (%)*		
Age (year)	52.2±12.7	61.9±15.0	63.25±13.1		.000*
Gender				4.492	.106
Male	21(63.6%)	23(62.2%)	74(77.9%)		
Female	12(36.4%)	14(29.8%)	21(22.1%)		
Disease stage[1]				0.265	.876
Acute stage	18(54.5%)	22(59.5%)	52(54.7%)		
Subacute stage	15(45.5%)	15(40.5%)	43(45.3%)		
Disease patterns				4.903	.806
Hemorrhagic type	21(63.6%)	21(56.8%)	41(43.2%)		
Infarct type	12(36.4%)	16(43.2%)	54(56.8%)		
Hemiplegia side				3.426	.489
Right side	17(51.5%)	20(54.1%)	40(42.1%)		
Left side	13(39.4%)	14(37.8%)	50(52.6%)		
Bilateral	3(9.1%)	3(8.1%)	5(5.3%)		
Stroke Location					
Basal ganglia	15(22.1%)	18(26.5%)	35(51.5%)	1.839	.399
Middle cerebra artery	5(11.6%)	11(25.6%)	27(62.8%)	2.571	.276
Cerebral lobe	9(24.3%)	7(18.9%)	21(56.8%)	0.713	.700
Thalamus	5(23.8%)	5(23.8%)	11(52.4%)	0.308	.857
Brain stem	3(18.8%)	3(18.8%)	10(62.5%)	0.195	.907
Cerebellum	2(25.0%)	2(25.0%)	4(50.0%)	0.214	.899
Medical history[2]					
Hypertension	24(72.7%)	31(83.8%)	83(87.4%)	3.837	.147
Stroke	3(9.1%)	10(27.0%)	28(29.5%)	5.570	.062
Diabetes	9(27.3%)	13(35.1%)	32(33.7%)	0.583	.747
Cardiac arrhythmia	1(3.0%)	11(29.7%)	22(23.2%)	8.492	.014‡
Health behavior[3]					
Smoking history	14(42.4%)	16(43.2%)	42(44.2%)	0.035	.983
Drinking history	12(36.4%)	14(37.8%)	37(38.9%)	0.072	.965
Sleep apnea sysdrome classification[4]				176.612	.000*
No apnea	33(100.0%)	0(0%)	0(0%)		
OSA	0(0%)	19(51.4%)	23(24.2%)		

CSA	0(0%)	5(13.5%)	25(26.3%)
Mix	0(0%)	13(35.1%)	47(49.5%)

1. Disease stage is divided into acute stage (onset ≦ 3 months) and subacute stage (onset of 3 to 6 months).
2. Diagnosed history of hypertension (International Classification of Disease, Ninth Revision, Codes 401-402 (exclusion 405)) and taking anti-hypertension drugs; diagnosed history of stroke (International Classification of Disease, Ninth Revision, Codes 430-437); diagnosed history of diabetes (International Classification of Disease, Ninth Revision, Code 250) and regularly taking anti-diabetic agents or insulin injections; diagnosed history of cardiac arrhythmia; stroke location may be in more than one place, thus stroke location according to the stroke site distribution includes all parts of repeat stroke count.
3. Smoking history of more than a pack of cigarettes per week; drinking history of at least once a week; stroke location may be in more than one place, thus stroke location according to the stroke site distribution includes all parts of repeat stroke count.
4. Sleep apnea sysdrome is classified into 3 categories: obstructive sleep apnea (OSA), central sleep apnea (CSA), and mixed sleep apnea sysdrome (Mix).
*5. *P<.001,†P<.01,‡P<.05 (two-tailed), chi-square test.*

different severities of sleep apnea

In this study, we investigated hospitalized patients with stroke. A total of 165 patients were identified based on the inclusion and exclusion criteria. Among them, the average age was 60.8 years (SD = 14.0), and the majority were men. Overall, 20% of the patients had no apnea (AHI <=15 per hour); 22.4% had mild apnea (15<AHI<30); and 57.6% had severe apnea (AHI>=30 per hour). Regarding the disease process, 55.8% of patients were at the acute stage, and a similar proportion of patients had experienced hemorrhagic stroke (50.3%, n = 83) and infarction (49.7%, n = 82). Patients with left hemiparesis and those with right hemiparesis accounted for 93.4% of the total patients. The most common stroke locations were basal ganglia and middle cerebral artery. Moreover, 43.6% of patients had a history of smoking, and 38.2% (n = 63) had a history of drinking. The majority of patients had a history of hypertension, followed by diabetes, stroke, and cardiac arrhythmia.(Table 1).

No significant differences were observed in severity of sleep apnea in terms of demographic data, stroke status, health behaviors (i.e., history of smoking and drinking), or medical history (i.e., hypertension, stroke, diabetes) (Table 1). Only history of cardiac arrhythmia was significantly associated with severity of sleep apnea (Table 1). Patients with advanced age and history of cardiac arrhythmia had higher risk of sleep apnea.

Physical and sleep statuses among stroke patients with different severities of sleep apnea

The distributions of physical and sleep statuses among stroke patients is shown in Table 2. FIM was used to measure the physical and cognitive functions of stroke patients. The average physical FIM was 48.5 (SD = 21.8). Anthropometric measurements included BMI, neck circumference, and waist circumference. Biochemical tests included glucose (GLU AC), alanine amino-transferase (ALT), creatinine, cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). BMI and waist circumference gradually increased across the 3 groups. No significant differences were observed in FIM, BMI, waist circumference, biochemical test results, or blood pressure measured in the evening on the day of PSG. Only neck circumference significantly differed among the 3 groups (Table 2).

Regarding patient sleep patterns and structures, sleep onset latency (SOL), wake after sleep onset (WASO), and rapid-eye-movement (REM) stage % (stage R%) differed significantly among the 3 groups (P< .05). Stroke patients with severe sleep

Table 2. ***Distributions of physical and sleep statuses among stroke patients with different severity levels of sleep apnea (N=165).***

Items	*AHI≦15* *n=33*	*15<AHI<30* *n=37*	*AHI≧30* *n=95*	*F*	*P*
	Mean±SD	*Mean±SD*	*Mean±SD*		
FIM[1]					
FIM(M)	30.9±14.8	29.3±14.1	30.2±14.2	0.108	.897
FIM(C)	18.6±9.7	18.4±8.6	18.6±9.6	0.011	.989
FIM(T)	49.4±23.4	47.4±19.8	48.6±22.1	0.073	.929
Anthropometry					
Body Mass Index (kg/m^2)	22.9±3.0	23.2±3.5	24.2±4.4	1.758	.172
Neck circumference (cm)	39.7±4.9	37.7±3.6	39.9±3.6	4.547	.013‡
Waist circumference (cm)	87.5±9.8	91.0±12.1	92.1±10.4	2.134	.129
Biochemical examination[2]					
GLU AC (mg/dL)	102.5±20.2	105.6±23.5	102.9±21.3	0.188	.829
ALT (IU/L)	28.7±19.5	22.8±14.3	22.4±16.6	1.646	.196
Creatinine (mg/dL)	1.0±0.9	0.8±0.2	0.9±0.3	0.855	.427
Cholesterol (mg/dL)	150.0±40.3	145.0±39.0	146.2±42.2	0.113	.893
Triglyceride (mg/dL)	150.6±75.1	156.8±109.3	129.4±58.5	1.850	.161
HDL-C (mg/dL)	34.5±5.2	32.2±6.2	36.6±13.3	1.650	.197
LDL-C (mg/dL)	88.1±28.5	84.3±27.6	81.1±24.6	0.591	.556
Blood pressure measured in the evening on the day of PSG examination					
Systolic blood pressure (mmHg)	127.3±14.0	128.2±14.2	131.6±13.7	1.550	.215
Diastolic blood pressure (mmHg)	80.4±9.8	79.2±8.7	81.5±10.2	0.759	.470
Sleep Patterns					
Total sleep time (TST)(min)	278.9±57.8	260.0±59.5	252.1±55.5	2.718	.069
Sleep efficiency (%)	74.4±17.3	69.3±17.1	69.3±16.0	1.294	.277
Sleep onset latency (SOL)(min)	28.8±38.6	35.0±39.8	18.6±20.5	4.479	.013‡
Wake after sleep onset (WASO)(min)	25.8±14.1	28.6±16.9	42.4±32.3	1.081	.002†
Sleep structures					
Stage W (min)	70.4±62.4	83.0±57.2	93.8±56.8	2.081	.128
Stage N1 duration (min)	78.3±77.4	62.2±58.8	90.5±78.6	1.980	.141
Stage N1%	21.9±21.0	18.1±16.8	26.8±22.5	2.473	.087
Stage N2 duration (min)	156.8±85.2	157.7±67.0	129.4±77.9	2.623	.076
Stage N2%	46.4±25.1	46.8±19.5	38.3±23.1	2.649	.074
Stage N3 duration (min)	0.8±4.5	1.6±5.4	1.5±7.7	0.163	.850
Stage N3%	0.3±1.4	0.5±1.7	0.6±2.4	0.274	.760

Stage R duration (min)	43.0±25.0	38.5±29.7	30.0±30.6	2.843	.061
Stage R%	12.5±7.4	11.2±8.3	8.2±6.4	5.560	.005‡
Total RDI index	7.5±3.9	20.9±3.9	58.6±19.1	186.823	.000*
Sleep apnea index					
Arousal index	23.5±11.3	26.5±12.0	44.7±19.1	29.203	.000*
Mean SaO2 (%)	94.3±1.8	94.5±2.0	93.1±3.1	5.098	.007
Lowest saturation (%)	85.2±7.0	80.9±10.8	68.4±17.7	20.566	.000*
Oxygen desaturation Index (ODI)	8.8±9.8	13.9±9.8	43.4±23.7	56.763	.000*
Snoring index	543.5±381.7	527.1±400.3	551.6±305.1	0.064	.938

1. *FIM, Functional Independence Measure. FIM(M): measured in physical domain, FIM(C): measured in cognitive domain, FIM(T) : total score. The total scores were the sum of physical and cognitive domain scores and ranged from 18 to 126.*
2. *Biochemical tests: Glucose (GLU AC), Alanine amino-transferase (ALT), Creatinine, Cholesterol, Triglyceride, High density lipoprotein cholesterol (HDL-C), Low density lipoprotein cholesterol (LDL-C).*
3. **P<.001,†P<.01, ‡P<.05 (two-tailed), ANOVA.*

apnea had shorter sleep latency, longer awakening time after sleep, and lower REM sleep percentage (Table 2). Consistent with the index of sleep apnea, patients with severe sleep apnea had highest arousal index, lowest oxygen saturation, and highest oxygen desaturation index (ODI) (Table 2). However, snoring index was not associated with severity of sleep apnea.

Associations of physical and sleep statuses on the severity of sleep apnea

Pearson's correlation was used to explore the associations of FIM, anthropometric data, and biochemical test results with the severity of sleep apnea (Table 3). The results showed that the severity of sleep apnea significantly correlates with higher BMI (r = .245; P = .002), larger neck circumference (r = .081; P = .309), and larger waist circumference (r = .225; P = .005). Motor, cognitive, and total FIM scores, biochemical test results, and diastolic blood pressure measured in the evening on the day of PSG did not significantly correlate with the severity of sleep apnea. The correlation of the severity of sleep apnea with sleep patterns and structure was investigated on Pearson's correlation analysis. The severity of sleep apnea significantly correlated with TST, SOL, WASO, wake stage (Stage W), non-REM (NREM) Stage 2 duration (Stage N2 duration), NREM Stage 2% (stage N2%), stage R%, arousal index, mean oxygen saturation (mean SaO_2), lowest saturation, and ODI (Table 3). Severity of sleep apnea in stroke patients was associated with shorter total sleep time, shorter sleep onset latency, longer awakening time, shorter Stage 2 and REM sleep, and higher sleep apnea index (Table 3).

Discussion

This study targeted stroke patients, among whom 80% had sleep apnea (AHI > 15 events/hr). This prevalence rate was higher than previously reported,[5] with prevalence rates of SDB (AHI ≥ 5 events/hr) ranging from 62% to 72% in some studies[6-8]. The high percentage of patients with sleep apnea might be attributable to the dissimilar AHI-based criteria for defining sleep apnea in previous studies. Another reason is that the physical attributes of Asians increase the likelihood of the development of sleep apnea when compared with Westerners[23]. Hence, the prevalence rate of sleep apnea was comparatively high in this study.

Regarding sleep patterns, the sleep efficiency of an adult is typically higher than 85%. However,

Table 3. ***Associations of physical and sleep statuses with severity of sleep apnea in stroke patients (N=165).***

Items	*R*	*P*
Age (year)	0.262*	.001
Functional Independence Measure		
FIM(M)	-0.047	.549
FIM(C)	0.048	.538
FIM(T)	-0.008	.920
Anthropometry		
Body Mass Index(kg/m^2)	0.245‡	.002
Neck circumference(cm)	0.081	.309
Waist circumference(cm)	0.225†	.005
Biochemical examination		
Glucose AC(mg/dL)	0.027	.773
ALT(IU/L)	-0.055	.498
Creatinine (mg/dL)	0.020	.804
Cholesterol(mg/dL)	0.039	.642
Triglyceride (mg/dL)	-0.107	.204
HDL-C(mg/dL)	-0.145	.135
LDL-C(mg/dL)	-0.053	.583
Blood pressure measured in the evening on the day of PSG examination		
Systolic blood pressure(mmHg)	0.154‡	.049
Diastolic blood pressure(mmHg)	0.052	.700
Sleep Patterns		
Total sleep time (TST)(min)	-0.165‡	.034
Sleep efficiency(%)	-0.092	.240
Sleep onset latency (SOL)(min)	-0.209†	.007
Wake after sleep onset (WASO)(min)	0.162‡	.037
Sleep Structures		
Stage W (min)	0.330*	.000
Stage N1 duration (min)	0.098	.212
Stage N1%	0.110	.160
Stage N2 duration (min)	-0.165‡	.034
Stage N2%	-0.171‡	.028
Stage N3 duration (min)	-0.015	.844
Stage N3%	-0.003	.973
Stage R duration (min)	-0.109	.164

Stage R%	-0.165‡	.035
Sleep Apnea Index		
Arousal index	0.597*	.000
Mean SaO2 (%)	-0.368*	.000
Lowest saturation (%)	-0.574*	.000
Oxygen desaturation index (ODI)	-0.857*	.000
Snoring index	-0.076	.347

*1. *P<.001,† P<.01,‡P<.05 (two-tailed), Pearson's correlation analysis.*

in this study, sleep efficiency was lower than 85% in all patients, regardless of the severity of sleep apnea. In particular, the sleep efficiency of participants in the AHI ≥ 30 group was only 69.3% (SD = 16.0). A sleep cycle is comprised of NREM stages (Stages N1 – N3) and REM stage (Stage R). Stages N1 to N3 are associated with physical recovery, and Stage R is related to brain recovery[21]. These critical stages alternate cyclically throughout the night. Short sleep latency, long awakening time, and short REM sleep in stroke patients with severe sleep apnea imply that these patients have insufficient time for physical and brain recovery. Reductions in total sleep and deep sleep times and sleep onset latency (SOL), as well as an increase in WASO result in difficulty in continuous deep sleep. Due to lack of sleep, stroke patients have a shorter sleep latency and may find it easier to fall asleep during the day. During the REM stages, although the physical body is resting, the brain remains active[23]. People often dream in the REM stage, despite a reduction in their muscle tension and relaxation of the whole body. Sleep apnea also frequently occurs at this stage, and it is hence known as "paradoxical sleep." Thus, people with severe sleep apnea tend to have poor sleep quality. Poor sleep quality may influence their rehabilitation during the daytime and, thus, the effectiveness of rehabilitation.

In this study, severity of sleep apnea significantly correlated with age, gender, history of cardiac arrhythmia, BMI, neck circumference, and waist circumference ($P< .05$). Older patients and males showed stronger association with severe sleep apnea. Patients with a history of cardiac arrhythmia had relatively higher incidence of severe sleep apnea. Patients with high BMI and large neck and waist circumferences also had higher incidences of severe sleep apnea. These findings are similar to those of previous studies[7,17,15,17,18]. Ahnet al. found that the risk factors for SDB patients significantly correlate with a medical history of atrial fibrillation[10]. Chan et al., Marshall et al., Kuo et al., and Chen et al. have reported that BMI and sleep apnea are positively correlated[6,11,17,18]. Numerous studies have identified a thick neck as a risk factor for sleep apnea[6,15].

No significant correlation was observed between sleep apnea severity and stroke location, which is consistent with the findings of Ahn et al. in 2013[10]. In this study, as we were unable to confirm whether stroke patients developed sleep apnea before their stroke, the risk factors could not be determined. However, the observed factors contributing to the correlation between stroke and sleep apnea were similar to those resulting in sleep apnea in the general population, indicating that patients may have had sleep apnea before the occurrence of stroke. Another implication is that stroke is associated with untreated sleep apnea, which is a crucial research finding. Thus, stroke patients with sleep apnea should receive treatment to prevent strokes from recurring and to improve sleep quality to facilitate rehabilitation.

Conclusions

In this study, stroke patients with sleep apnea

(AHI > 15 events/hr) accounted for 80% (n = 132) of the research participants, manifesting the importance of sleep apnea. Stroke patients with sleep apnea have inferior sleep quality. Abnormal sleep patterns involve reductions in TST, sleep efficiency, stage N2 duration and N2%, and stage R% and increases in SOL, WASO, stage W, and arousal index. Correlations of sleep apnea severity with gender, age, history of cardiac arrhythmia, BMI, and waist circumference were statistically significant (P< .05). Patients who were male, older, had a history of cardiac arrhythmia, high BMI and large waist circumference exhibited severe sleep apnea. The findings of this study demostrated abnormal sleep patterns in stroke patients. Health providers should encourage stroke patients to receive active treatment for sleep apnea to improve the quality of their sleep and reduce daytime sleepiness, thereby boosting the effectiveness of their rehabilitation.

Research Limitations and Recommendations

The participants in this study comprised a sample of stroke patients who were recruited from a rehabilitation ward in a hospital in Taichung. Thus, the findings are limited and cannot be inferred to all stroke patients with sleep apnea. Furthermore, because sleep examinations are expensive and require a long time, rehabilitation wards rarely include sleep examination among their regular examinations of hospitalized patients. Therefore, this study did not involve other research units and was unable to confirm whether the targeted stroke patients had developed sleep apnea before the occurrence of stroke. Thus, the causal relationship between stroke and sleep apnea could not be determined.

Conflicts of Interest

The authors declare that they have no financial conflicts of interest.

Acknowledgements

The authors would like to thank all of the participants and the Center of Sleep Medicine of Chung Shan Medical University Hospital Chung Shing Branch. The funding for intramural research programs from Chung Shan Medical University Hospital (No. CSH-2014-A-010) is also highly appreciated.

Reference

1. Ministry of Health and Welfare. Statistical Yearbook of the Republic 100 years of death. 2012. Available at: http://www.doh.gov.tw/CHT2006/DM/DM2_2.aspx?now_fod_list _no=12336&class_no=440&level_no=4.
2. Chang YJ, Ryu SJ, Chen JR, Hu HH, Yip PK, Chiu TF. Guidelines for the general management of patients with acute ischemic stroke. *ActaNeurol Taiwan* 2008;17:275–94.
3. Parra O, Arboix A, Montserrat JM, Quinto L, Bechich S, Garcia-Eroles L, et al. Sleep-related breathing disorders: Impact on mortality of cerebrovascular disease. *EurRespir J* 2004;24:267–72.
4. Lin TH, Huang LY, Hung LC, Fan SH. The first probe for stroke patient's health-related quality of life. *J Health Manag* 2008;6:121–34.
5. Arzt M, Young T, Peppard PE, Finn L, Ryan CM, Bayley M, et al. Dissociation of obstructive sleep apnea from hypersomnolence and obesity in patients with stroke. *Stroke* 2010;41:e129–e134.
6. Chan W, Coutts SB, Hanly P. Sleep apnea in patients with transient ischemic attack and minor stroke: Opportunity for risk reduction of recurrent stroke? *Stroke* 2010;41:2973–5.
7. Johnson KG, Johnson DC. Frequency of sleep apnea in stroke and TIA patients: A meta-analysis. *J Clin Sleep Med* 2010;6:131–7.
8. Tosun A, Köktürk O, Karataş GK, Ciftçi TU, Sepici V. Obstructive sleep apnea in ischemic stroke patients. *Clinics* 2008;63:625–30.
9. Brooks D, Davis L, Vujovic-Zotovic N, Boulias C, Ismail F, Richardson D, et al. Sleep-disordered breathing in patients enrolled in an inpatient stroke rehabilitation program. *Arch*

Phys Med Rehabil 2010;91:659–62.

10. Ahn SH, Kim JH, Kim DU, Choo IS, Lee HJ, Kim HW. Interaction between sleep-disordered breathing and acute ischemic stroke. *J Clin Neurol* 2013;9:9–13.
11. Marshall NS, Wong KK, Liu PY, Cullen SR, Knuiman MW, Grunstein RR. Sleep apnea as an independent risk factor for all-cause mortality: The Busselton Health Study. *Sleep* 2008; 31:1079–85.
12. Xu J, Deng L, Zou X, Liu H, Yu Y, Ding Y, et al. Impact of obstructive sleep apnea-hypopnea sysdrome on cerebral microbleeds in patients with cerebral infarction. *Nan Fang Yi Ke Da Xue Xue Bao* 2012; 32:1362–5. (Article in Chinese)
13. Brown DL, Chervin RD, Kalbfleisch JD, Zupancic MJ, Migda EM, Svatikova A, et al. Sleep apnea treatment after stroke (SATS) trial: Is it feasible? *J Stroke Cerebrovasc Dis* 2013;22:1216–24.
14. Martínez-García MÁ, Soler-Cataluña JJ, Ejarque-Martínez L, Soriano Y, Román-Sánchez P, Barbé Illa F, et al. Continuous positive airway pressure treatment reduces mortality in patients with ischemic stroke and obstructive sleep apnea: A 5-year follow-up study. *Am J Respir Crit Care Med* 2009;180:36–41.
15. Ting H, Lo HS, Chang SY, Chung AH, Kuan PC, Yuan SC, et al. Post- to pre-overnight sleep systolic blood pressures are associated with sleep respiratory disturbance, pro-inflammatory state and metabolic situation in patients with sleep-disordered breathing. *Sleep Med* 2009;10:720–5.
16. Lam JC, Sharma SK, Lam B. Obstructive sleep apnoea: Definitions, epidemiology & natural history. *Indian J Med Res* 2010;131:165–70.
17. Kuo CH, Maa SH, Chang YC, Lin HC. Essential risk factors related to obstructive sleep apnea syndrome. *Chang Gung Nursing* 2011;22:26–37.
18. Chen NH, Shih TS, Wang PC, Lin Y, Chen CW, Chen CJ et al. Sleep quality and the prevalence of related breathing problems in Taiwanese factory workers. *Fu-Jen Journal of Medicine* 2007;5:67–80.
19. Liaw LJ, Lin JH, Ju YH, Liu CK. Reliability of the interview-based functional independence measure in patients with stroke. *Formosan Journal of Physical Therapy* 2002;27:174–82.
20. Ryan CM, Bayley M, Green R, Murray BJ, Bradley TD. Influence of continuous positive airway pressure on outcomes of rehabilitation in stroke patients with obstructive sleep apnea. *Stroke* 2011;42:1062–7.
21. American Academy of Sleep Medicine. The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifications. Westchester, IL: American Academy of Sleep Medicine, 2007.
22. Simms T, Brijbassi M, Montemurro LT, Bradley TD. Differential timing of arousals in obstructive and central sleep apnea in patients with heart failure. *J Clin Sleep Med* 2013;9:773–9.
23. Maa SH. A brief introduction to the obstructive sleep apnea syndrome. *Taitung University Humanities Journal* 2011;1:119–36.