Wake-up stroke is not associated with sleep-disordered breathing in women

Devin L. Brown, MD, Chengwei Li, MPH, Ronald D. Chervin, MD, MS, Erin Case, BA, Nelda M. Garcia, BS, Susan D. Tower, MD, and Lynda D. Lisabeth, PhD

Correspondence
Dr. Brown
devinb@umich.edu

Neurology: Clinical Practice February 2018 vol. 8 no. 1 8-14 doi:10.1212/CPJ.0000000000000412

Abstract

Background

We sought to investigate the frequency of wake-up stroke (WUS) and its association with sleep-disordered breathing (SDB) in women.

Methods

Within a population-based study, women with acute ischemic stroke were asked about their stroke symptom onset time. SDB screening was performed with the well-validated ApneaLink Plus device; SDB was defined by a respiratory event index ≥ 10 . Logistic regression was used to test the association between SDB presence and severity and WUS unadjusted and adjusted for potential confounders including prestroke depression and sleep duration.

Results

Among 466 participants, the median age was 67.0 years (interquartile range [IQR] 58.0, 77.0), 55% were Mexican American, and the median initial NIH Stroke Scale score was 3.0 (IQR 1.0, 6.0). Stroke symptom onset occurred during nocturnal sleep (25.3%), during a nap (3.9%), during wakefulness (65.9%), or unknown (4.9%). In those with SDB screening performed ($n = 259$), a median of 11 days (IQR 5, 17) poststroke, WUS was not associated with the presence or severity (respiratory event index) of SDB in unadjusted or adjusted analysis.

Conclusions

In this population-based study, WUS represented about 30% of all generally mild severity ischemic strokes in women and was not associated with SDB.

Stroke Program (DLB, CL, EC, NMG, LDL) and Sleep Disorders Center and Department of Neurology (RDC), University of Michigan Medical School; Department of Epidemiology (CL, EC, NMG, LDL), University of Michigan School of Public Health, Ann Arbor; and Corpus Christi physician (SDT), TX.

Funding information and disclosures are provided at the end of the article. Full disclosure form information provided by the authors is available with the full text of this article at Neurology.org/cp.

The 466 respondents were interviewed at a median of 6.5 days (IQR 3, 15) from stroke symptom onset.

Patients with wake-up stroke (WUS) represent a particularly challenging group for treatment because of strict time eligibility criteria for thrombolytic therapy, and are the target of much research.¹ Sleep-disordered breathing (SDB), found in the majority of patients poststroke,² has been hypothesized to be causally linked to WUS.³ Three small studies (n = 71–88 with physiologic SDB assessment) that excluded severe stroke patients have suggested a higher prevalence of SDB in those with WUS than those without,^{4,5} although this finding was limited to men in one of the studies.⁶ Overall, the relationship between SDB and WUS has not been well-characterized and data have not been population-based. In this study, we identified women from a population-based stroke study to assess the prevalence of WUS using patient interviews, and assessed the association between poststroke SDB and WUS accounting for potential cofounders, including prestroke sleep duration, an important factor not previously considered.

Methods

Detailed methods of the Brain Attack Surveillance in Corpus Christi (BASIC) Project have been published.⁷ Briefly, active (screening of admission logs, wards, and intensive care units) and passive (screening of ICD-9/ICD-10 codes) surveillance were used to identify stroke patients from all acute care hospitals in Nueces County, Texas. Residents of Nueces County ≥45 years of age with an ischemic stroke (January 1, 2012, to May 5, 2016) were offered study enrollment and baseline interviews were performed as soon as possible poststroke. Demographics and medical history were ascertained from medical records (age, risk factors, body mass index, and initial stroke severity) and from patient interviews shortly after enrollment (race/ethnicity, smoking, alcohol, self-report of prestroke depression, prestroke sleep duration [“How many hours of sleep do you usually get a night (or when you usually sleep)?”], and Berlin questionnaire). WUS was determined with the question “Did your first stroke symptoms come on while you were asleep? That is, did you awaken with the symptoms?” Response options were: (1) Yes, the symptoms came on while I was asleep for the night; (2) Yes, the symptoms came on while I was taking a nap; (3) No, the symptoms came on while I was awake; or (4) I don’t know. This question was included in an interview module asked only of women. Participants answered for themselves; no proxy interviews included this question.

Participants enrolled in BASIC were offered enrollment into an SDB substudy for SDB screening if they were identified within 30 days of symptom onset through active surveillance, or within 45 days if identified through passive surveillance. Participants were excluded from the SDB substudy for pregnancy or current use of oxygen, mechanical ventilation, or positive pressure ventilation.

SDB screening was performed with the well-validated Apnea-Link Plus,⁸ a home sleep apnea test that monitors nasal pressure, oxygen saturation, pulse, and respiratory effort. Detailed methods and settings used in the BASIC SDB substudy have been published, including definitions for apneas and hypopneas.⁹ The respiratory event index (REI) was estimated as the number of apneas and hypopneas per hour of recording, and an REI ≥10 was considered evidence of SDB. With this threshold, the device has a very high sensitivity and specificity.⁸

Participants’ demographic and baseline characteristics were compared by WUS and non-WUS status with χ^2 and Kruskal-Wallis tests, as appropriate. Logistic regression was used to test the unadjusted and adjusted association between REI or SDB and WUS only among Mexican Americans and non-Hispanic whites, as other race/ethnicities had too few participants for inclusion. Sequential models were built with prespecified covariates as displayed in the results tables. Because missingness was so infrequent, casewise deletion was used. SAS version 9.3 (SAS Institute, Cary, NC) was used for analyses.

Standard protocol approvals, registrations, and patient consents

Written informed consent was obtained from each participant and the study was institutional review board–approved by the University of Michigan and both local hospital systems.

Results

Of 1,034 women with validated ischemic strokes, 730 were interviewed; 466 answered the WUS question (246 women were interviewed via proxy and were not asked WUS information). As expected, participants who were directly interviewed had lower median NIH Stroke Scale scores than those who had proxy-based interviews (3.0 [interquartile range (IQR) 1.0, 6.0] vs 11.0 [IQR 4.0, 19.0]). The 466 respondents were interviewed at a median of 6.5 days (IQR 3, 15) from stroke symptom onset. Of these respondents, 118 (25.3%) had the onset of stroke symptoms during nocturnal sleep, 18 (3.9%) during a nap, and 307 (65.9%) during wakefulness; 23 (4.9%) were uncertain. Characteristics of all respondents with known onset (n = 443) are found in table 1, and for those who completed an SDB screening test (n = 259, median 11 [IQR 5, 17] days from stroke symptom onset), in table 2. Clinical characteristics were similar between participants with and without WUS. SDB (REI ≥10) was present in 53% of participants overall with no difference between WUS and non-WUS

Table 1 Baseline characteristics in women with ischemic stroke who woke with stroke symptoms (wake-up stroke [WUS]) and those who did not (non-WUS), all race/ethnicities

	Overall (n = 443), n (%)	WUS (n = 136), n (%)	Non-WUS (n = 307), n (%)	p Value
Age, y, median (IQR)	67.0 (58.0, 77.0)	67.5 (58.5, 75.0)	67.0 (58.0, 78.0)	0.313
Race/ethnicity				0.435
Mexican American	243 (54.9)	77 (56.6)	166 (54.1)	
Non-Hispanic white	164 (37.0)	48 (35.3)	116 (37.8)	
African American	26 (5.9)	6 (4.4)	20 (6.5)	
Other	10 (2.3)	5 (3.7)	5 (1.6)	
Hypertension	362 (81.7)	112 (82.4)	250 (81.4)	0.817
Diabetes	222 (50.1)	76 (55.9)	146 (47.6)	0.106
High cholesterol	235 (53.1)	73 (53.7)	162 (52.8)	0.860
Atrial fibrillation	63 (14.2)	17 (12.5)	46 (15.0)	0.490
Coronary artery disease	107 (24.2)	32 (23.5)	75 (24.4)	0.838
Congestive heart failure	39 (8.8)	16 (11.8)	23 (7.5)	0.143
Current smoker	87 (19.6)	23 (16.9)	64 (20.9)	0.336
Alcohol use (drinks per week)				0.990
None	122 (27.5)	37 (27.2)	85 (27.7)	
<1	230 (51.9)	70 (51.5)	160 (52.1)	
1–14	84 (19.0)	27 (20.0)	57 (18.6)	
>14	7 (1.6)	2 (1.5)	5 (1.6)	
History of stroke/TIA	121 (27.3)	36 (26.5)	85 (27.7)	0.791
History of prestroke depression ^a	178 (40.4)	54 (39.7)	124 (40.7)	0.851
Sleep duration, h				
Total, median (IQR) ^a	7.0 (6.0, 8.0)	8.0 (6.0, 8.0)	7.0 (5.0, 8.0)	0.430
Short, ≤6	172 (38.8)	51 (37.5)	121 (39.5)	0.913
Normal, 7–8	192 (43.3)	60 (44.1)	132 (43.1)	
Long, ≥9	78 (17.6)	25 (18.4)	53 (17.3)	
Prestroke high risk of sleep apnea (Berlin)	241 (54.4)	77 (56.6)	164 (53.2)	0.533
NIHSS, median (IQR) ^a	3.0 (1.0, 6.0)	3.0 (1.0, 6.0)	3.0 (1.0, 6.0)	0.795
BMI, median (IQR)	29.3 (25.8, 35.3)	29.0 (25.8, 34.2)	30.1 (25.8, 35.4)	0.342

Abbreviations: BMI = body mass index; IQR = interquartile range; NIHSS = NIH Stroke Scale.

^a History of prestroke depression: 0.5% missing; sleep duration: 0.2% missing; NIHSS: 1.6% missing.

participants (table 2). WUS was not associated with REI (table 3) or SDB (table 4) in models unadjusted or adjusted for potential confounders. Congestive heart failure was positively associated with WUS (tables 3 and 4).

Discussion

This population-based study identified WUS in almost a third of female stroke patients, affirming its clinical

significance, but did not demonstrate an association between WUS and SDB or REI. These relationships were not confounded by prestroke sleep duration or prestroke depression. In fact, women with and without WUS were generally clinically similar, except for an association between heart failure and WUS. Although this novel finding requires additional investigation, speculative explanations could include atrial fibrillation or hypercoagulability.¹⁰ Of note, in our fully adjusted model, atrial fibrillation was not significant.

Table 2 Baseline characteristics in women with ApneaLink data who woke with ischemic stroke symptoms (wake-up stroke [WUS]) and those who did not (non-WUS), among those with ApneaLink data

	Overall (n = 259), n (%)	WUS (n = 74), n (%)	Non-WUS (n = 185), n (%)	p Value
Age, y, median (IQR)	65.0 (58.0, 75.0)	66.0 (59.0, 72.0)	65.0 (57.0, 75.0)	0.748
Race/ethnicity				0.930
Mexican American	149 (57.5)	42 (56.8)	107 (57.8)	
Non-Hispanic white	89 (34.3)	26 (35.1)	63 (34.1)	
African American	16 (6.2)	4 (5.4)	12 (6.5)	
Other	5 (1.9)	2 (2.7)	3 (1.6)	
Hypertension	207 (79.9)	59 (79.7)	148 (80.0)	0.961
Diabetes	139 (53.7)	44 (59.5)	95 (51.4)	0.237
High cholesterol	137 (52.9)	38 (51.4)	99 (53.5)	0.753
Atrial fibrillation	31 (12.0)	6 (8.1)	25 (13.5)	0.226
Coronary artery disease	60 (23.2)	16 (21.6)	44 (23.8)	0.709
Congestive heart failure	20 (7.7)	9 (12.2)	11 (6.0)	0.091
Current smoker	57 (22.0)	14 (18.9)	43 (23.2)	0.448
Alcohol use				0.920
None	66 (25.5)	19 (25.7)	47 (25.4)	
<1	138 (53.3)	40 (54.1)	98 (53.0)	
1–14	50 (19.3)	13 (17.6)	37 (20.0)	
>14	5 (1.9)	2 (2.7)	3 (1.6)	
History of stroke/TIA	80 (30.9)	23 (31.1)	57 (30.8)	0.966
History of prestroke depression ^a	108 (41.7)	25 (33.8)	83 (44.9)	0.102
Sleep duration, h				
Total, median (IQR) ^a	7.0 (5.0, 8.0)	7.0 (6.0, 8.0)	7.0 (5.0, 8.0)	0.534
Short, ≤6	107 (41.3)	29 (39.2)	78 (42.2)	0.832
Normal, 7–8	101 (39.0)	31 (41.9)	70 (37.8)	
Long, ≥9	51 (19.7)	14 (18.9)	37 (20.0)	
Prestroke high risk of sleep apnea (Berlin)	146 (56.4)	40 (54.1)	106 (57.3)	0.635
NIHSS, median (IQR) ^a	3.0 (1.0, 6.0)	3.0 (1.0, 5.0)	3.0 (1.0, 6.0)	0.473
BMI, median (IQR)	29.3 (25.7, 35.0)	28.6 (25.6, 33.0)	30.1 (26.1, 35.5)	0.182
REI	11.0 (6.0, 21.0)	11.0 (5.0, 22.0)	10.0 (6.0, 21.0)	0.930
SDB (REI ≥10), %	53.3	55.4	52.4	0.665
Oxygen desaturation index	7.0 (3.0, 16.0)	7.5 (3.0, 20.0)	7.0 (3.0, 16.0)	0.450
Central apnea index	0 (0, 1.0)	0 (0, 1.0)	0 (0, 1.0)	0.261

Abbreviations: BMI = body mass index; IQR = interquartile range; NIHSS = NIH Stroke Scale; REI = respiratory event index; SDB = sleep-disordered breathing.
^a History of prestroke depression: 0.4% missing; NIHSS: 1.9% missing.

Our findings extend prior work through use of a much larger sample, population-based study design, ethnically diverse sample, and adjustment for a potentially important confounder, prestroke sleep duration, not previously

addressed. The difference in our results compared with those of previous studies may be due to differences in study design or to a true association between WUS and SDB in men but not women. The respective study populations

Importantly, the inclusion of strokes with onset during non-nocturnal sleep (naps) added almost 5% to the estimate of WUS in this study.

could also differ, although our study sample showed similar age and baseline stroke severity to those reported in previous studies that did demonstrate an association between WUS and AHL.^{4–6} Our negative finding is consistent with the results found in women in the only prior study that performed a sex-specific analysis.⁶

Importantly, the inclusion of strokes with onset during non-nocturnal sleep (naps) added almost 5% to the estimate of WUS in this study. Stroke onset during non-nocturnal sleep is often ignored⁴ and thus generates an underestimate of WUS. The estimate provided by this and some studies^{4,6} suggests that WUS is higher (~one-third) than other studies suggest.^{3,5} Our result is also in keeping with estimates from the large International Stroke Trial.¹¹ In this study, participants with WUS had a milder presentation (e.g., more presented fully conscious, and more had lacunar syndromes) than non-WUS participants. In contrast, other studies that limited enrollment to milder stroke patients did not find differences in stroke severity at presentation.^{4,5} Furthermore, a population-based study found more severe stroke severities at presentation among

Table 3 Association between respiratory event index (REI) modeled continuously and wake-up stroke (n = 259), unadjusted and sequentially adjusted for potential confounders

	Unadjusted OR (95% CI)	Model 1, OR (95% CI)	Model 2, OR (95% CI)	Model 3, OR (95% CI)
REI	1.01 (0.99–1.03)	1.01 (0.99–1.03)	1.01 (0.99–1.03)	1.01 (0.99–1.03)
Age		1.00 (0.98–1.03)	1.00 (0.97–1.03)	1.00 (0.97–1.03)
Mexican American (vs non-Hispanic white)		0.91 (0.50–1.65)	0.91 (0.50–1.66)	0.84 (0.42–1.68)
Hypertension				0.69 (0.29–1.63)
Diabetes				1.36 (0.67–2.76)
Prior stroke/TIA				0.88 (0.44–1.80)
Atrial fibrillation				0.40 (0.13–1.23)
Congestive heart failure				4.83 (1.49–15.62)
Current smoker				0.83 (0.34–1.98)
Alcohol use				
<1 (vs none)				0.72 (0.33–1.56)
1–14 (vs none)				0.53 (0.19–1.46)
>14 (vs none)				1.39 (0.18–10.49)
Body mass index				
25–29.9 (vs <24.9)				1.67 (0.70–3.98)
30–34.9 (vs <24.9)				0.87 (0.33–2.28)
35–39.9 (vs <24.9)				0.69 (0.20–2.38)
≥40 (vs <24.9)				0.32 (0.07–1.38)
NIH Stroke Scale score				0.95 (0.89–1.04)
History of prestroke depression			0.72 (0.40–1.29)	0.60 (0.32–1.45)
Sleep duration, h				
Short, ≤6 (vs 7–8)			0.84 (0.45–1.59)	0.72 (0.37–1.45)
Long, ≥9 (vs 7–8)			0.90 (0.42–1.97)	0.66 (0.28–1.56)
Prestroke high risk of sleep apnea (Berlin)			0.88 (0.49–1.59)	—

Abbreviations: CI = confidence interval; OR = odds ratio.

Table 4 Association between sleep-disordered breathing, defined by respiratory event index (REI) ≥ 10 , and wake-up stroke, unadjusted and adjusted for potential confounders

	Unadjusted OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
REI ≥ 10	1.139 (0.648–2.002)	1.138 (0.635–2.037)	1.201 (0.664–2.174)	1.262 (0.645–2.472)
Age		1.005 (0.979–1.031)	1.0 (0.973–1.028)	1.0 (0.967–1.035)
Mexican American (vs non-Hispanic white)		0.934 (0.515–1.692)	0.931 (0.511–1.698)	0.830 (0.411–1.676)
Hypertension				0.681 (0.286–1.621)
Diabetes				1.352 (0.666–2.745)
Prior stroke/TIA				0.870 (0.427–1.773)
Atrial fibrillation				0.378 (0.122–1.170)
Congestive heart failure				5.067 (1.571–16.342)
Current smoker				0.821 (0.342–1.971)
Alcohol use				
<1 (vs none)				0.718 (0.332–1.549)
1–14 (vs none)				0.520 (0.188–1.443)
>14 (vs none)				1.437 (0.188–10.971)
Body mass index				
25–29.9 (vs <24.9)				1.726 (0.729–4.085)
30–34.9 (vs <24.9)				0.916 (0.356–2.354)
35–39.9 (vs <24.9)				0.743 (0.224–2.458)
≥ 40 (vs <24.9)				0.339 (0.080–1.437)
NIH Stroke Scale score				0.954 (0.878–1.036)
History of prestroke depression			0.708 (0.392–1.277)	0.594 (0.310–1.139)
Sleep duration, h				
Short, ≤ 6 (vs normal, 7–8)			0.828 (0.437–1.570)	0.709 (0.353–1.429)
Long, ≥ 9 h (vs normal, 7–8)			0.915 (0.420–1.993)	0.659 (0.279–1.554)
Prestroke high risk of sleep apnea (Berlin)			0.895 (0.494–1.619)	—

Abbreviations: CI = confidence interval; OR = odds ratio.

WUS participants.¹² However, this analysis was based on chart review rather than patient or family interview. Whether absent or less accurate stroke onset information from more severe stroke patients has substantially biased the literature is therefore unclear.

Limitations include absence of full polysomnography. The ApneaLink does not provide information about sleep or arousals; thus, severity of SDB may have been underestimated for some patients, such as those with substantial insomnia. However, the ApneaLink is well-validated and should not function differently between WUS groups. The stroke symptom onset question was asked only of women, but stroke disproportionately affects women, and sex-specific risk factors require better understanding. Participants with proxy interviews who were excluded from the current study

had more severe strokes than those who participated in the BASIC interview and SDB substudy, which could have introduced selection bias. However, stroke severity is not associated with poststroke SDB in this and other populations.^{13,14} Nevertheless, because our sample included generally mild severity strokes, our results may not be generalizable to more severe female stroke patients. Other differences between participants and nonparticipants may exist that could have influenced the observed associations. However, our sample was representative of the overall BASIC population in demographics and clinical characteristics except for having a slightly higher representation of Mexican Americans and therefore a higher prevalence of diabetes, and therefore is likely reflective of the Corpus Christi community given the population-based nature of the study design.

Author contributions

D.L. Brown: drafted the manuscript, made contributions to the design, interpretation of data, study supervision, obtained funding. C. Li: drafted portions of the manuscript, performed the analysis, contributed to the interpretation of data. R.D. Chervin: edited the manuscript for intellectual content, made contributions to the interpretation of data. E. Case: edited the manuscript for intellectual content, contributed to the interpretation of data, contributed to acquisition of data, provided study supervision. N.M. Garcia: edited the manuscript for intellectual content, contributed to acquisition of data, provided study supervision or coordination, and gave final approval of the manuscript. S.D. Tower: edited the manuscript for intellectual content. L.D. Lisabeth: edited the manuscript for intellectual content, made contributions to the design, interpretation of data, study supervision, obtained funding.

Acknowledgment

This study was performed in the Corpus Christi Medical Center and CHRISTUS Spohn Hospitals, CHRISTUS Health System, Corpus Christi, Texas.

Study funding

This work was funded by the NIH (R01 NS070941, R01 HL098065, and R01 NS038916). The funding source played no role in the decision to submit this analysis for consideration or in the interpretation of data.

Disclosure

D.L. Brown serves as a steering committee member for Northern Manhattan Initiative for Minority Involvement in Clinical Trials (NIMICT); has received funding for travel or speaker honoraria from Associated Professional Sleep Societies; serves on the editorial board of *Neurology*[®] and served on the editorial board of *Stroke*; and has received research support from CVR Global, Inc., AHRQ, NIH (NINDS, NHLBI), Blue Cross Blue Shield of Michigan Foundation, and Michigan Department of Community Health. C. Li receives research support from NIH, including funding from U10 NS086526. R.D. Chervin has served on the Board of Governors (unpaid) for Sweet Dreamzzz Detroit and on the Sleep Disorders Research Advisory Board for NIH; was involved with unrestricted educational gifts to the University of Michigan from Philips Respironics and Fisher-Paykel; holds an endowed professorship funded by Respironics and Sepracor; has received a speaker honorarium from American Academy of Neurology and funding for travel from American Academy of Sleep Medicine and International Pediatric Sleep Association; serves as an Associate Editor for *Sleep*, on the editorial boards of *Sleep Medicine* and *Journal of Clinical Sleep Medicine*, as Co-Editor-in-Chief for *Sleep Specialty*, and as Section Editor for Pediatric Sleep Medicine for UpToDate; holds patents re: (1) System and method for analysis of respiratory cycle-related EEG changes in sleep-disordered

breathing, (2) Automated polysomnographic assessment for rapid eye movement sleep behavior disorder, (3) A novel device to generate continuous positive airway pressure, (4) A novel pharmacologic approach to treatment for obstructive sleep apnea, and (5) Questionnaire for pediatric sleep problems (copyrighted by University of Michigan); receives publishing royalties from UpToDate (as Editor) and from Cambridge University Press for editing a book; serves as a consultant for Proctor & Gamble, Zansors, and MC3; serves on Board of Directors for American Academy of Sleep Medicine (immediate Past President), American Sleep Medicine Foundation, American Board of Sleep Medicine, Association of Professional Sleep Societies, and International Pediatric Sleep Association; conducts sleep studies (12% effort) at University of Michigan Sleep Disorders Center; receives research support from NIH, University of Michigan, Fox Foundation, and National Multiple Sclerosis Foundation; receives stock/stock options/Board of Directors compensation from Secretary IgA; and receives license fee payments for Questionnaire on sleep apnea in children, licensed by Zansors from University of Michigan. E. Case receives research support from NIH. N. Garcia receives research support from NIH. S. Tower reports no disclosures. L.D. Lisabeth reports research support from NIH (NHLBI, NINDS, NIMHD) and PCORI. Full disclosure form information provided by the authors is available with the full text of this article at Neurology.org/cp.

Received June 9, 2017. Accepted in final form September 6, 2017.

References

1. Barreto AD, Fanale CV, Alexandrov AV, et al. Prospective, open-label safety study of intravenous recombinant tissue plasminogen activator in wake-up stroke. *Ann Neurol* 2016;80:211–218.
2. Johnson KG, Johnson DC. Frequency of sleep apnea in stroke and TIA patients: a meta-analysis. *J Clin Sleep Med* 2010;6:131–137.
3. Kim TJ, Ko SB, Jeong HG, et al. Nocturnal desaturation in the stroke unit is associated with wake-up ischemic stroke. *Stroke* 2016;47:1748–1753.
4. Hsieh SW, Lai CL, Liu CK, Hsieh CF, Hsu CY. Obstructive sleep apnea linked to wake-up strokes. *J Neurol* 2012;259:1433–1439.
5. Šiarnik P, Kollár B, Carnická Z, et al. Association of sleep disordered breathing with wake-up acute ischemic stroke: a full polysomnographic study. *J Clin Sleep Med* 2016;12:549–554.
6. Koo BB, Bravata DM, Tobias LA, et al. Observational study of obstructive sleep apnea in wake-up stroke: the sleep TIGHT study. *Cerebrovasc Dis* 2016;41:233–241.
7. Morgenstern LB, Smith MA, Lisabeth LD, et al. Excess stroke in Mexican Americans compared with non-Hispanic whites: the Brain attack surveillance in Corpus Christi Project. *Am J Epidemiol* 2004;160:376–383.
8. Ng SS, Chan TO, To KW, et al. Validation of a portable recording device (Apnea-Link) for identifying patients with suspected obstructive sleep apnea syndrome (OSAS). *Intern Med J* 2009;39:757–762.
9. Brown DL, McDermott M, Mowla A, et al. Brainstem infarction and sleep-disordered breathing in the BASIC sleep apnea study. *Sleep Med* 2014;15:887–891.
10. Riccio PM, Klein FR, Pagani Cassará F, et al. Newly diagnosed atrial fibrillation linked to wake-up stroke and TIA: hypothetical implications. *Neurology* 2013;80:1834–1840.
11. Moradiya Y, Janjua N. Presentation and outcomes of “wake-up strokes” in a large randomized stroke trial: analysis of data from the international stroke trial. *J Stroke Cerebrovasc Dis* 2013;22:e286–e292.
12. Mackey J, Kleindorfer D, Sucharew H, et al. Population-based study of wake-up strokes. *Neurology* 2011;76:1662–1667.
13. Fisse AL, Kemmling A, Teuber A, et al. The association of lesion location and sleep related breathing disorder in patients with acute ischemic stroke. *PLoS One* 2017;12:e0171243.
14. Lisabeth LD, Sánchez BN, Chervin RD, et al. High prevalence of post-stroke sleep disordered breathing in Mexican Americans. *Sleep Med* 2017;33:97–102.