Published in final edited form as:

J Stroke Cerebrovasc Dis. 2015 February ; 24(2): 388–393. doi:10.1016/j.jstrokecerebrovasdis.2014.09.007.

Ischemic stroke subtype and presence of sleep-disordered breathing: the BASIC Sleep Apnea Study

Devin L. Brown, MD¹, Ashkan Mowla, MD², Mollie McDermott, MD¹, Lewis B. Morgenstern, MD^{1,3}, Garnett Hegeman III, RPSGT⁴, Melinda A. Smith, DrPH¹, Nelda M. Garcia, BS¹, Ronald D. Chervin, MD, MS⁴, and Lynda D. Lisabeth, PhD^{1,3}

¹Stroke Program, University of Michigan, Ann Arbor, Michigan, USA

²Department of Neurology, University at Buffalo, The State University of New York, Buffalo, NY, USA

³Department of Epidemiology, University of Michigan School of Public Health, Ann Arbor, MI, USA

⁴Sleep Disorders Center, University of Michigan, Ann Arbor, Michigan, USA

Abstract

Goal—Little is known about the prevalence of sleep apnea (SA) across ischemic stroke subtypes. Given the important implications for SA screening, we tested the association between SA and ischemic stroke subtype in a population-based study.

© 2014 by National Stroke Association. All rights reserved.

Corresponding Author: Devin L. Brown, M.D., M.S., The Cardiovascular Center – Stroke Program, 1500 E. Medical Center Drive - SPC#5855, Ann Arbor, Michigan, United States 48109-5855, Phone (734) 936-9075, Fax (734) 232-4447, devinb@umich.edu.

The work was performed at the University of Michigan, Ann Arbor, MI

Disclosures:

- Brown is funded by NIH grants R01 NS062675, R01 HL098065, R01 NS070941, and U10 NS086526.
- Mowla and McDermott have nothing to report.
- Morgenstern receives research support from St. Jude Medical Corp and NIH (R01 NS 38916, R01 NS062675, R01 HL098065, R01 NS070941, R01 NS073595, U01 NS062835, U01 NS056975). He receives compensation for expert witness defense work for non-industry stroke cases.
- Chervin receives support through NIH grants R01 NS070941, R01 HL098065, R01 HL105999, and R43 HL117421; was involved with unrestricted educational gifts to the University of Michigan from Philips Respironics and Fisher Paykel; has served on the advisory boards for the non-profit Sweet Dreamzzz and the NHLBI; has consulted for Proctor & Gamble, MC3, and Zansors; serves as a section editor for UpToDate; is editing a book for Cambridge University Press; and has produced copyrighted material, patents, and patents pending, owned by the University of Michigan, for screening, diagnosis, and treatment of sleep disorders. He serves on the Boards of Directors for the American Academy of Sleep Medicine, American Sleep Medicine Foundation, American Board of Sleep Medicine, Associated Professional Sleep Societies, and International Pediatric Sleep Association.
- Hegeman is supported by R01 HL098065.
- Smith and Garcia are supported by R01 NS38916, R01 NS062675, R01 HL098065.
- Lisabeth is funded by R01 NS38916, R01 NS062675, R01 HL098065, and R01 NS070941.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Methods—Within the Brain Attack Surveillance in Corpus Christi Project, ischemic stroke patients were offered SA screening with the ApneaLink Plus™ (n=355). A neurologist assigned TOAST subtype (with an additional category for nonlacunar infarctions of unknown etiology) using hospital records. Unadjusted and adjusted (demographics, BMI, NIHSS, diabetes, history of stroke/TIA) logistic and linear regression models were used to test the association between subtype and SA or apnea-hypopnea index (AHI).

Findings—Median age was 65 and 55% were male; 59% were Mexican American. Median time from stroke onset to SA screen was 13 days (IQR: 6, 21). Overall, 215 (61%) had SA (AHI ≥ 10). Median AHI was 13 (IQR: 6, 27). Prevalence of SA by subtype was: cardioembolism, 66%; large artery atherosclerosis, 57%; small vessel occlusion, 68%; other determined, 50%; undetermined etiology, 58%; and nonlacunar stroke of unknown etiology, 63%. Ischemic stroke subtype was not associated with SA in unadjusted (p=0.72) or adjusted models (p=0.91) models. Ischemic stroke subtype was not associated with AHI in unadjusted (p=0.41) or adjusted models (p=0.62).

Conclusion—In this population-based stroke surveillance study, ischemic stroke subtype was not associated with the presence or severity of SA. Sleep apnea is likely to be present after ischemic stroke, and the subtype should not influence decisions about SA screening.

Keywords

ischemic stroke; stroke subtype; sleep-disordered breathing; sleep apnea; epidemiology

INTRODUCTION

Sleep-disordered breathing (SDB) has important relevance to ischemic stroke. Not only is it highly prevalent post stroke,(1) but it is also an independent risk factor for stroke(2–4) and poor stroke outcomes.(5) While the benefits of SDB treatment in stroke patients are not currently established, simple methods to identify subgroups of stroke patients at particularly high risk would be useful for clinical and research purposes. Currently, the American Stroke Association does not provide specific guidelines about SDB screening after stroke, but acute stroke guidelines do advise careful observation and prevention of oxygen desaturations.(6) If the prevalence of SDB differs across ischemic stroke subtypes, subtype identification may inform decisions about the need to screen for SDB. Furthermore, an association between subtype and SDB may provide insight into the pathophysiology of post-stroke SDB and its associated risk factors. We therefore tested the association between the presence and severity of SDB and ischemic stroke subtype in a population-based stroke study.

MATERIALS AND METHODS

Subjects

Ischemic stroke patients were identified through the Brain Attack Surveillance in Corpus Christi (BASIC) project, a population-based stroke surveillance study in Nueces County, Texas. Detailed methods have been previously reported.(7, 8) In summary, all cases of ischemic stroke and intracerebral hemorrhage (ICH) involving Nueces County residents with an age 45 or greater are identified from each of the seven acute care community hospitals in the county through active and passive surveillance. No academic medical

centers are present in this community. Active surveillance, that includes prospective review of admission logs for validated stroke symptom terms, is supplemented by passive surveillance for specific ICD-9 codes (430–438, excluding codes 433.x0 and 434.x0 (x = 1–9), 437.0, 437.2, 437.3, 437.4, 437.5, 437.7, 437.8, and 438). The county is geographically isolated, which facilitates complete case capture. Study neurologists use source documentation to validate each case. Subjects who enroll in BASIC are offered sleep apnea screening with the ApneaLink Plus™ device. These studies are performed in the subjects' current venue (acute stroke hospitalization, home, etc.). Current use of supplemental oxygen, current mechanical ventilation or other positive pressure ventilation, and pregnancy are exclusionary. Subjects are offered enrollment if they meet eligibility criteria within 30 days of stroke symptom onset if identified through active surveillance and 45 days if identified through passive surveillance. Patients with ICH were excluded from analysis as this study used a classification system restricted to ischemic stroke patients and due to the small numbers of ICH patients enrolled. The University of Michigan and Corpus Christi hospital systems' Institutional Review Boards approved this project. Written informed consent was obtained from each subject or a surrogate if the patient were not able to consent for him or herself.

Ischemic stroke subtype and clinical data

For subjects who were identified as eligible for sleep apnea assessment from 9/8/10 - 3/7/13, detailed records including diagnostic test results, EKGs, radiology reports, admission notes, and discharge summaries were reviewed by a board-certified neurologist with stroke fellowship training, masked to age, race/ethnicity, and SDB status. Each case was classified into one of five stroke subtype categories of the Trial of the ORG 10172 in Acute Stroke Treatment (TOAST)(9) study: large-artery atherosclerosis, cardioembolism, small-vessel occlusion, stroke of other determined etiology, and stroke of undetermined etiology.(9) An additional category of “nonlacunar stroke of undetermined etiology” was designated for large strokes that did not have sufficient evidence to be categorized as large-artery atherosclerosis or cardioembolism, or that qualified for both, as has been used in BASIC previously.(10) Information on presence or absence of a large artery source and presence or absence of a high or medium risk cardioembolic source was identified, based on TOAST criteria. If sufficient tests had not been performed to exclude a large artery source (evaluation of the relevant cervical vessels of the relevant distribution) or cardioembolic source (EKG and an echocardiogram needed if cardioembolic source not already known), this was also noted.

Information on race/ethnicity and sex were obtained through a baseline interview, and information about age, vascular risk factor data, weight and height (for body mass index (BMI) calculations) were ascertained from the medical record. Initial National Institutes of Health Stroke Scale (NIHSS) scores were obtained directly from the medical record or abstracted from the medical record based on standard methods.(11)

Sleep apnea assessment

Sleep apnea was assessed with the ApneaLink Plus™, a validated(12–19) portable respiratory monitor that measures nasal pressure, oxygen saturation, pulse, and respiratory

effort. Consistent with ApneaLink's default settings used in successful validation studies, (13, 16, 17) an apnea was defined by 10 seconds of nasal pressure reduction by 80% of baseline. Consistent with the American Academy of Sleep Medicine 2007 guidelines, the prevailing guidelines at this study's onset, an hypopnea was defined by 10 seconds of nasal pressure reduction by 30%, if followed by an oxygen desaturation of 4% (unless oximetry data were missing for a significant portion of recording, in which case it was defined by 10 seconds of nasal pressure reduction of 50%).(20) The apnea-hypopnea index (AHI, correlation between ApneaLink™ Plus and full polysomnography, 0.94)(21) was calculated as the sum of all apneas and hypopneas averaged over the hours of the study. The central apnea index (correlation between ApneaLink™ Plus and full polysomnography, 0.97)(21) was calculated as the number of central apneas averaged over the hours of the study. Prior to automated analysis by the ApneaLink Plus™ software, a registered polysomnographic technologist reviewed each recording to eliminate artifacts and to adjust any inappropriately scored events. Sleep-disordered breathing was defined conservatively as an AHI 10 given the high sensitivity and specificity for this threshold, and the overwhelming predominance of obstructive rather than central events in stroke patients.(13, 15, 22)

Statistical Methods

Descriptive statistics were used to summarize demographics and baseline data. Logistic regression was used to test the association between stroke subtype and SDB, the primary outcome measure, unadjusted and adjusted for these pre-specified potential confounders: age, sex, race/ethnicity, BMI, diabetes, prior history of stroke/TIA, and NIHSS. To assess the overall association between stroke subtype and SDB, a model with subtype modeled categorically as a series of 4 dummy variables (referent was small vessel) was compared with a model without the subtype variable using a likelihood ratio test ($\chi^2_{df=4}$), with and without adjustment. The association between presence of a large artery source (modeled categorically as yes, no, insufficient tests) and presence of a cardioembolic source (modeled categorically as high risk source, medium risk source, no source, insufficient tests) and SDB were tested similarly, with no source as the referent. Linear regression was used to test the association between subtype and AHI, the secondary outcome measure, unadjusted and adjusted for the potential confounders described above. The natural logarithm of the AHI plus one was used instead of AHI given its skewness. Model assumptions were tested with visual inspection of appropriate residual and diagnostic plots. To assess the overall association between subtype and AHI, unadjusted and adjusted models with and without the subtype variables were compared with F tests. Subjects of American Indian race and non-Hispanic ethnicity (n=5) and those with a subtype of other determined etiology (n=2) were excluded from regression models due to small numbers. Analyses were performed with TIBCO Spotfire S+® 8.1 for Windows or R version 2.13.1.

RESULTS

Of 684 ischemic stroke subjects interviewed in BASIC, 515 met eligibility criteria for sleep apnea testing. Of the 378 (73%) who consented and had ApneaLink Plus™ studies performed consecutively between 9/8/10-3/7/13, 23 had insufficient ApneaLink Plus™ data.

The remaining 355 subjects are included in this analysis. Demographic and baseline information is found in Table 1. Median time from stroke onset to ApneaLink™ Plus study was 13 days (IQR: 6, 21), with no difference by SDB status ($p=0.24$). The median AHI was 13 (interquartile range (IQR): 6, 27) and 218 (61%) had SDB. The median central apnea index was 0.0 (IQR: 0.0, 2.0). Seventy percent of men had SDB (median AHI 18 (IQR: 8, 32)); 51% of women had SDB (median AHI 10 (IQR: 5, 21)). Of NHWs, 54% had SDB; while 67% of MAs had SDB. A large artery source was identified in 51 (14%), no large artery source in 227 (64%), while the remainder ($n=77$, 22%) had insufficient tests to exclude a large artery source. A high risk cardioembolic source was identified in 65 (18%), a medium risk source in 40 (11%), no cardioembolic source in 174 (49%), and the remainder had insufficient tests to exclude a cardioembolic source ($n=76$, 21%). Eighteen subjects (5%) had both a cardiac source (medium or high risk) and a large artery source identified. Nonlacunar stroke of unknown etiology was the most common (36%) TOAST subtype identified, followed in descending order by undetermined etiology (32%), cardioembolism (18%), small-vessel occlusion (7%), large-artery atherosclerosis (6%), and other determined etiologies (1%). Distribution of TOAST subtype was similar by sex (men/women: 36%/37% nonlacunar stroke of unknown etiology, 26%/39% undetermined etiology, 21%/15% cardioembolism, 8%/6% small-vessel occlusion, 8%/4% large-artery atherosclerosis, 1%/0% other determined etiologies; $p=0.07$). Median AHI and SDB prevalence by subtype and presence of cardioembolic or large artery source are found in Table 2.

Subtype was not associated with SDB in unadjusted ($X^2_{df=4} = 2.0$, $p = 0.72$) or adjusted analysis ($X^2_{df=4} = 1.0$, $p = 0.91$). Similarly, large artery source ($X^2_{df=4} = 2.4$, $p = 0.30$) and cardioembolic source ($X^2_{df=4} = 6.5$, $p = 0.09$) were not associated with subtype. However, in the adjusted analysis, compared with no source, a high risk cardiac source was associated with SDB (odd ratio (OR) 2.32 (95% confidence interval (CI): 1.12, 4.83)), while medium risk source (OR 0.85 (95% CI: 0.40, 1.83)) and insufficient tests (OR 1.17 (95% CI 0.64, 2.14)) were not. Subtype was not associated with AHI in unadjusted ($F=1$, $p=0.41$) or adjusted ($F= 0.67$, $p=0.62$) analyses.

DISCUSSION

This large population-based study of ischemic stroke patients shows that the prevalence of SDB is greater than 50% in all ischemic stroke subtypes, classified by the modified TOAST criteria, but that subtype is not associated with either presence of SDB or severity of SDB. Similarly, the presence of a large artery source, irrespective of the TOAST subtype classification, is also not associated with presence or severity of SDB. The results suggest that identification of ischemic stroke subtype or simply identification of a large artery source should not influence the decision to screen for SDB post stroke given the high prevalence across all subtypes. While no overall association was identified between cardioembolic source and SDB, identification of a high risk cardioembolic source, compared with no source, was associated with the presence of SDB. Nonetheless, given the high prevalence of SDB in those with a medium risk source and no source, practical decisions about SDB screening are unlikely to be influenced by these results.

Previous knowledge about the association between ischemic stroke subtype and SDB is limited. One prior study of only 50 subjects also showed no association between SDB (AHI 10) and TOAST subtype.(23) A second study of 90 subjects suggested that the large-artery atherosclerosis subtype was more common in subjects with an AHI ≥ 30 than in those with an AHI <10 .(24) Other studies that used non-TOAST classification schemes showed either no association between subtype and SDB (n=147)(25) or a higher AHI in those with lacunar infarctions (n=8) than anterior circulation cortical strokes (n=53)(26) based on the Oxfordshire Community Stroke Project classification. Our study extends the literature through the study of this topic in a larger cohort of stroke patients and with the use of the additional TOAST subcategory of undetermined etiology for those with nonlacunar infarctions of unclear source. Unlike the previous studies, our study was also performed within a population-based stroke study in a community without an academic medical center, so referral bias was limited.

The frequency of undetermined etiologies in the current study was higher than in some other population-based studies from outside the US,(27–30) but it appears that subjects with an insufficient diagnostic evaluation are sometimes excluded from the results in other studies rather than assigned to the undetermined etiology category.(30) Our frequency of undetermined etiologies is more in keeping with other population-based work in the US.(10, 31) Our high prevalence of undetermined etiologies may also be partially attributable to the presence of only community hospitals and our strict adherence to the definition of small-vessel occlusion to include only those with a presentation consistent with a classical lacunar syndrome.

The association found in the current study between a high risk cardioembolic source and SDB may be due to a higher prevalence of SDB in those with cardiac disease. Sleep-disordered breathing has a known association with heart failure, atrial fibrillation, and coronary disease.(32) We did not account for a history of cardiac conditions in our models to avoid over-adjustment, as these conditions are part of the definition of cardioembolic subtype.

Limitations to this study include the use of a portable respiratory monitor for the assessment of SDB rather than gold-standard polysomnography performed in a sleep laboratory. However, the device used has been well-validated,(12–19) and is more practical than polysomnography for use in patients with recent stroke.(33) Furthermore, most research investigations of post-stroke SDB do not use polysomnography.(1, 5, 24, 26, 34, 35) Stroke subtype was determined based on retrospective chart review, and some subjects were classified as an undetermined etiology due to incomplete diagnostic evaluation. This limitation is inherent to this type of observational work, but does also result in increased generalizability of findings. Use of the TOAST criteria may have increased the proportion of undetermined etiology compared with other classifications.(36) Because this study included a high proportion of Mexican Americans, the results may not be generalizable to communities with a different racial/ethnic distribution. However, demographics, stroke risk factors, and stroke severity of ischemic stroke patients who participate in sleep apnea screening are similar to the overall BASIC population, which increases the generalizability within this community. Stroke severity was low overall likely due to the population-based

nature of this study performed without the referral bias of an academic medical center. Lastly, inability to review actual images, which were unavailable, as opposed to radiology reports, may have obscured infarction size in some cases and raised the frequency of undetermined etiologies.

This large study in a bi-ethnic community shows that ischemic stroke subtype is not associated with either post-stroke SDB presence or SDB severity. Thus, ischemic stroke subtype should not influence the decision to screen for sleep apnea in post-stroke patients. The high prevalence of SDB after stroke, in this population-based study and previous reports, suggest that systematized screening for SDB may be considered.

Acknowledgments

Grant support: This work was funded by the NIH (R01 NS070941, R01 HL098065, and R01 NS038916).

Reference List

1. Broadley SA, Jorgensen L, Cheek A, et al. Early investigation and treatment of obstructive sleep apnoea after acute stroke. *J Clin Neurosci*. 2007; 14:328–333. [PubMed: 16790349]
2. Munoz R, Duran-Cantolla J, Martinez-Vila E, et al. Severe sleep apnea and risk of ischemic stroke in the elderly. *Stroke*. 2006; 37:2317–2321. [PubMed: 16888274]
3. Redline S, Yenokyan G, Gottlieb DJ, et al. Obstructive Sleep Apnea Hypopnea and Incident Stroke: The Sleep Heart Health Study. *Am J Respir Crit Care Med*. 2010; 182:269–277. [PubMed: 20339144]
4. Yaggi HK, Concato J, Kernan WN, Lichtman JH, Brass LM, Mohsenin V. Obstructive sleep apnea as a risk factor for stroke and death. *N Engl J Med*. 2005; 353:2034–2041. [PubMed: 16282178]
5. Turkington PM, Allgar V, Bamford J, Wanklyn P, Elliott MW. Effect of upper airway obstruction in acute stroke on functional outcome at 6 months. *Thorax*. 2004; 59:367–371. [PubMed: 15115859]
6. Jauch EC, Saver JL, Adams HP, et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. *Stroke*. 2013; 44:870–947. [PubMed: 23370205]
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. [PubMed: 15286023]
8. Piriyaawat P, Smajsova M, Smith M, et al. Comparison of active and passive surveillance for cerebrovascular disease: The Brain Attack Surveillance in Corpus Christi (BASIC) Project. *Am J Epidemiol*. 2002; 156:1062–1069. [PubMed: 12446264]
9. Adams HJ, Bendixen B, Kappelle L, et al. Classification of subtype of acute ischemic stroke: Definitions for use in a multicenter clinical trial. *Stroke*. 1993; 24:35–41. [PubMed: 7678184]
10. Uchino K, Risser JM, Smith MA, Moye LA, Morgenstern LB. Ischemic stroke subtypes among Mexican Americans and non-Hispanic whites: the BASIC Project. *Neurology*. 2004; 63:574–576. [PubMed: 15304600]
11. Williams LS, Yilmaz EY, Lopez-Yunez AM. Retrospective Assessment of Initial Stroke Severity With the NIH Stroke Scale. *Stroke*. 2000; 31:858–862. [PubMed: 10753988]
12. Baisch A, Afshar S, Hörmann K, Maurer JT. Use of a screening device for sleep apnea in clinical practice. *HNO*. 2007; 55:90–92. [PubMed: 17149630]
13. Chen H, Lowe AA, Bai Y, Hamilton P, Fleetham JA, Almeida FR. Evaluation of a portable recording device (ApneaLink™) for case selection of obstructive sleep apnea. *Sleep Breath*. 2009; 13:213–219. [PubMed: 19052790]
14. Einhorn D, Stewart DA, Erman MK, Gordon N, Philis-Tsimikas A, Casal E. Prevalence of sleep apnea in a population of adults with type 2 diabetes mellitus. *Endocr Pract*. 2007; 13:355–362. [PubMed: 17669711]

15. Erman MK, Stewart D, Einhorn D, Gordon N, Casal E. Validation of the ApneaLink™ for the Screening of Sleep Apnea: a Novel and Simple Single-Channel Recording Device. *J Clin Sleep Med*. 2007; 3:387–392. [PubMed: 17694728]
16. Ng SS, Chan TO, To KW, et al. Validation of a Portable Recording Device (ApneaLink) for identifying Patients with Suspected Obstructive Sleep Apnea Syndrome (OSAS). *Intern Med J*. 2009; 39:757–762. [PubMed: 19220528]
17. Nigro CA, Serrano F, Aimaretti S, González S, Codinardo C, Rhodius E. Utility of ApneaLink for the diagnosis of sleep apnea-hypopnea syndrome. *Medicina*. 2010; 70:53–59. [PubMed: 20228025]
18. Ragette R, Wang Y, Weinreich G, Teschler H. Diagnostic performance of single airflow channel recording (ApneaLink) in home diagnosis of sleep apnea. *Sleep Breath*. 2010; 14:109–114. [PubMed: 19714380]
19. Wang Y, Teschler T, Weinreich G, Hess S, Wessendorf TE, Teschler H. Validation of microMESAM as screening device for sleep disordered breathing. *Pneumologie*. 2003; 57:734–740. [PubMed: 14681746]
20. Iber, C.; Ancoli-Israel, S.; Chesson, A.; Quan, S. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology, and Technical Specifications. Westchester, Ill: American Academy of Sleep Medicine; 2007.
21. ResMed I. ApneaLink™ Plus White Paper (D2231–127). 2009. http://www.resmed.com/us/documents/D2231-127_ApneaLink_Plus_White_Paper.pdf
22. Bassetti C, Aldrich M. Sleep apnea in acute cerebrovascular diseases: final report on 128 patients. *Sleep*. 1999; 22:217–223. [PubMed: 10201066]
23. Iranzo A, Santamaria J, Berenguer J. Prevalence and clinical importance of sleep apnea in the first night after cerebral infarction. *Neurology*. 2002; 58:911–916. [PubMed: 11914407]
24. Bassetti CL, Milanova M, Gugger M. Sleep-Disordered Breathing and Acute Ischemic Stroke: Diagnosis, Risk Factors, Treatment, Evolution, and Long-Term Clinical Outcome. *Stroke*. 2006; 37:967–972. [PubMed: 16543515]
25. Turkington P, Bamford J, Wanklyn P, Elliott M. Prevalence and predictors of upper airway obstruction in the first 24 hours after acute stroke. *Stroke*. 2002; 33:2037–2042. [PubMed: 12154259]
26. Harbison J, Ford GA, James OF, Gibson GJ. Sleep-disordered breathing following acute stroke. *QJM*. 2002; 95:741–747. [PubMed: 12391386]
27. Bejot Y, Caillier M, Ben Salem D, et al. Ischaemic stroke subtypes and associated risk factors: a French population based study. *Journal of Neurology, Neurosurgery & Psychiatry*. 2008; 79:1344–1348.
28. Hajat C, Heuschmann PU, Coshall C, et al. Incidence of aetiological subtypes of stroke in a multi-ethnic population based study: the South London Stroke Register. *J Neurol Neurosurg Psychiatry*. 2011; 82:527–533. [PubMed: 20974649]
29. Lovett JK, Coull AJ, Rothwell PM. Early risk of recurrence by subtype of ischemic stroke in population-based incidence studies. *Neurology*. 2013; 62:569–573. [PubMed: 14981172]
30. Kolominsky-Rabas PL, Weber M, Gefeller O, Neundoerfer B, Heuschmann PU. Epidemiology of Ischemic Stroke Subtypes According to TOAST Criteria: Incidence, Recurrence, and Long-Term Survival in Ischemic Stroke Subtypes: A Population-Based Study. *Stroke*. 2001; 32:2735–2740. [PubMed: 11739965]
31. Woo D, Gebel J, Miller R, et al. Incidence Rates of First-Ever Ischemic Stroke Subtypes Among Blacks: A Population-Based Study. *Stroke*. 1999; 30:2517–2522. [PubMed: 10582971]
32. Somers VK, White DP, Amin R, et al. Sleep Apnea and Cardiovascular Disease: An American Heart Association/American College of Cardiology Foundation Scientific Statement From the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing In Collaboration With the National Heart, Lung, and Blood Institute National Center on Sleep Disorders Research (National Institutes of Health). *Circulation*. 2008; 118:1080–1111. [PubMed: 18725495]

33. Brown DL, Chervin RD, Kalbfleisch JD, et al. Sleep Apnea Treatment After Stroke (SATS) Trial: Is It Feasible? *J Stroke Cerebrovasc Dis.* 2013; 22:1216–1224. [PubMed: 21784661]
34. Parra O, Arboix A, Montserrat JM, Quinto L, Bechich S, Garcia-Eroles L. Sleep-related breathing disorders: impact on mortality of cerebrovascular disease. *Eur Respir J.* 2004; 24:267–272. [PubMed: 15332396]
35. 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. [PubMed: 23346154]
36. Amort M, Fluri F, Weisskopf F, et al. Etiological classifications of transient ischemic attacks: subtype classification by TOAST, CCS and ASCO--a pilot study. *Cerebrovasc Dis.* 2012; 33:508–516. [PubMed: 22538846]

Table 1

Baseline characteristics of ischemic stroke subjects (n=355).

	Median or N (% or IQR)
Age	65 (57, 77)
Race/ethnicity	
Non-Hispanic white	125 (35)
Hispanic	210 (59)
American Indian	5 (1)
Black	15 (4)
Male	197 (55)
Hypertension	291 (82)
Dyslipidemia	173 (49)
Prior stroke/TIA	95 (27)
Diabetes	166 (47)
Coronary artery disease	99 (28)
Atrial fibrillation	41 (12)
Current smoker	83 (23)
Former smoker	58 (16)
Excessive alcohol intake	47 (13)
NIHSS	4 (2,7)
Body mass index	28 (25, 33)

Table 2

Prevalence and severity of sleep-disordered breathing (AHI ≥ 10) by ischemic stroke subtype and presence of large artery or cardioembolic source.

	AHI Median (IQR)	Sleep apnea n (%)
Stroke subtype		
Cardioembolic (n=64)	16 (7, 32)	42 (66)
Large artery (n=23)	13 (6, 27)	13 (57)
Small vessel (n=25)	17 (7, 27)	17 (68)
Other determined (n=2)	15 (12, 17)	1 (50)
Undetermined (n=113)	12 (5, 22)	65 (58)
Nonlacunar of unknown etiology (n=128)	15 (7, 30)	80 (63)
Large artery source		
Yes (n=51)	21 (8, 34)	36 (71)
No (n=227)	12 (6, 27)	132 (58)
Insufficient tests (n=77)	15 (6, 23)	50 (65)
Cardioembolic source		
High risk source (n=65)	22 (12, 35)	50 (77)
Medium risk source (n=40)	15 (7, 24)	23 (58)
No high or medium risk source (n=174)	12 (6, 23)	100 (57)
Insufficient tests (n=76)	12 (6, 32)	45 (59)