Predicting Readmission Stroke Type Among Blacks and Whites in California

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Background: It is generally assumed that initial and recurrent strokes are of the same type, but data from South London, United Kingdom; Lausanne, Switzerland; and other studies suggest this may not be true for certain subtypes. In these studies, however, the number of recurrent strokes observed during the follow-up period was small, thereby limiting the ability of these studies to provide reliable estimates of stroke type concordance. *Methods:* Using a large, diverse, inpatient database, this study sought to: (1) estimate the relative agreement (Cohen's kappa) between initial and recurrent stroke types for blacks and whites; and (2) develop a risk-adjusted logistic model for readmission stroke type, with the initial admission stroke type as the main predictor and race, other sociodemographic variables, and clinical and hospital characteristics as potential covariates. *Results:* Stroke type concordance was similar for blacks (kappa = 0.77, 95% confidence interval [CI] = 0.71-0.83) and whites (kappa = 0.77, 95% CI = 0.74-0.79). In the adjusted logistic regression models, the initial admission stroke type strongly predicted the readmission stroke type (subarachnoid hemorrhage: odds ratio [OR] = 738.31, 95% CI = 422.58-1289.93; intracerebral hemorrhage [ICH]: OR = 80.86, 95% CI = 61.57-106.19; ischemic: OR = 125.81, 95% CI = 96.12-164.67). Other patient factors, but not race, also predicted readmission stroke type (e.g., younger age increased the odds of having an subarachnoid hemorrhage readmission; atrial fibrillation increased the odds of having an ICH readmission; older age, diabetes mellitus, and heart failure increased the odds of having an ischemic stroke readmission). *Conclusion:* This study showed that the initial stroke type and other factors were independently associated with the readmission stroke type and that patterns of stroke type concordance were similar for blacks and whites. These results may help to identify patients in high-risk subgroups who are more likely to have a recurrent hemorrhagic stroke, which could inform patient treatment decisions. For example, patients with atrial fibrillation may be at greater risk for having an ICH readmission because of the adverse effects of anticoagulant therapy, antiplatelet treatment, or both, which should be investigated further. **Key Words:** Stroke classification—subarachnoid hemorrhage—intracerebral hemorrhage—recurrence—racial differences.

It is generally assumed that initial and recurrent strokes are of the same type,[1-4] but there is evidence, including data from South London, United Kingdom,[5] and Lausanne, Switzerland,[6] to suggest that this may not be true for certain subtypes. Indeed, it has been reported that a change in stroke type may occur in more than 40% of recurrences. Predicting recurrent stroke type is important because this information may guide patient treat-

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Received June 1, 2005; accepted August 2, 2005.

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1052-3057/$—see front matter

doi:10.1016/j.jstrokecerebrovasdis.2005.08.003

ment decisions.[7] In previous studies, however, the number of recurrent stroke events observed during the follow-up period was small, thereby limiting the ability of these studies to provide reliable estimates of stroke type concordance, especially for the hemorrhagic cases. Therefore, it is not clear to what extent the initial stroke type determines the stroke type of later events. In addition, to the authors' knowledge, no prior investigation has reported concordance data specifically for blacks, although the latter represent a high-risk group for stroke incidence,[8-10] mortality,[11,12] and perhaps recurrence.[1,13-16] Accordingly, using a large and diverse inpatient database for the state of California, this study sought to: (1) estimate the relative agreement between the initial and recurrent stroke types for blacks and whites; and (2) develop a risk-adjusted prediction model for readmission stroke type using logistic regression, with the initial admission stroke type as the main predictor.

Methods

Study Population

For this hospital-based retrospective cohort study, data from the Agency for Healthcare and Research Quality, California State Inpatient Databases for the year 2000 were used.[17] These files contain discharge abstract data from community hospitals, as defined by the American Hospital Association, which include all nonfederal, short-term, general, and other specialty hospitals as well as urban and teaching institutions.[18] The selection of cases was based on the following criteria[19]: ischemic stroke was defined using all discharge diagnoses and the *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes 433.x1 for occlusion/stenosis of the precerebral arteries (where "x" equals 0, 1, 2, 3, 8, or 9), 434 for occlusion/stenosis of the cerebral arteries (excluding 434.x0, where "x" equals 0, 1, or 9), and 436 for acute but ill-defined stroke; subarachnoid hemorrhage (SAH) was defined using only the primary discharge diagnosis and *ICD-9* code 430; intracerebral hemorrhage (ICH) was also defined using only the primary discharge diagnosis and *ICD-9* code 431. In addition, cases were excluded if the presence of traumatic brain injury (i.e., *ICD-9* codes 800, 804, 850-854) or rehabilitation care (i.e., *ICD-9* code V57) was noted in the chart. In summary, the codes used in this study included acute stroke events resulting from ischemic infarction or hemorrhage. This algorithm was used to define not only the initial (index) stroke admission for a patient but also to define stroke readmissions (i.e., any stroke admission occurring after the index event) for the same patient.

Tirschwell and Longstreth[19] have previously shown that this algorithm is both accurate and reliable, with positive predictive values and relative agreements (Cohen's kappa) reported to be at least 89% and 82%, respectively, for each major stroke type. Certainly, alternative algorithms have been considered and discussed by others.[20-22] For example, Goldstein[22] has described an approach for the selection of ischemic strokes based on only the primary discharge diagnosis (without accounting for cases associated with trauma or rehabilitation). This method, however, does not perform as well as the one given here in terms of both accuracy and reliability. Further, as Tirschwell and Longstreth[19] demonstrated, relying on only the primary discharge diagnosis may bias administrative samples toward more benign stroke cases that are unrepresentative and, therefore, they recommend avoiding this approach.

For the purposes of this study, a stroke readmission was considered a stroke recurrence, as others have done,[6,15,23] although the latter is typically meant to include both hospitalized and nonhospitalized stroke events. Further, the index admission defined in this study may not represent a first-ever stroke event. Prior work has shown that the annual risk for recurrence is greatest during the first year after the initial stroke event and that this risk is less than 20%.[2-4,14] Therefore, to increase the likelihood of partially identifying first-time events, cases were also excluded if they had a stroke hospitalization in the preceding year using the same criteria given above. In addition, ischemic stroke admissions with evidence of hemorrhagic conversion (<1% of the total) were excluded, as suggested by others, owing to the difficulty of assigning such cases to one of the major stroke types.[5,6] Because the purpose of this study was to examine stroke type patterns among patients having a stroke readmission, this study was also limited to those cases having at least one recurrent stroke admission during the same calendar year. Further, this study was restricted to a comparison of non-Hispanic black and white patients with stroke aged 15 years and older on the index admission as coded on the discharge abstract. Finally, patients with missing covariate information were excluded, but these cases represented less than 3% of the total and, therefore, it is unlikely that this exclusion had any substantial impact on the major findings.

Study Measures

For both the concordance and multivariate analyses, the main outcome was readmission stroke type and the main predictor was the initial admission stroke type. In the regression models, potential covariates were based on the index admission and included sociodemographic factors, comorbid conditions, procedures performed, in-hospital duration, discharge disposition, and hospital characteristics.

Statistical Analysis

For the nominal data in this analysis, stroke type concordance was assessed using Cohen's unweighted kappa rather than percent agreement because the latter may be misleading because it does not account for the apparent agreement as a result of chance alone and, therefore, tends to give overly optimistic values. Type-specific kappa values were based on 2 × 2 tables for each stroke class (specific stroke type on readmission yes/no *v* specific stroke type on the index admission yes/no). Overall kappa values were based on 3 × 3 tables using all stroke classes (stroke type on readmission SAH/ICH/ischemic *v* stroke type on the index admission SAH/ICH/ischemic).

For comparison, data from two previously published studies were assessed for stroke type concordance. In the South London Community Stroke Register Study,[5] ischemic strokes included nonlacunar and lacunar infarcts, whereas unclassified strokes were excluded to make table entries comparable with the current study. As this was a population-based study, nonhospitalized stroke events were included and, therefore, the data were presented as recurrent rather than readmission stroke type. In the Lausanne Stroke Registry Study,[6] ischemic strokes included nonlacunar noncardioembolic, nonlacunar cardioembolic, and lacunar infarcts. Further, because SAH strokes were not included in the data for this study, overall kappa values were based on a 2 × 2 table.

For the multivariate analysis, the dichotomous outcome (i.e., readmission stroke type: SAH *v* other; ICH *v* other; and ischemic *v* other) was analyzed using logistic regression. A parsimonious model was then derived using a stepwise selection procedure for covariates at the 0.1-level of significance, with race forced into each adjusted model. To account for the possible within-subject correlation between repeated stroke events, generalized estimating equations with an exchangeable correlation structure were used. All statistical analyses were performed with software (SAS, Version 9.1, SAS Institute Inc, Cary, NC).

Results

Patient characteristics are summarized in Table 1 according to stroke type on the index admission. In general, blacks tended to be younger than whites. As expected, hypertension and diabetes mellitus were more common among blacks, and atrial fibrillation and ischemic heart disease were more common among whites, especially for those having an ischemic stroke hospitalization. This study also found that blacks were less likely to have had a urinary tract infection during their admission. Other noticeable differences included the observation that blacks were less likely to have a do-not-resuscitate order in their chart, and blacks were more likely to be hospitalized at institutions having a larger bed capacity than whites.

Concordance between the index and recurrent stroke types are summarized in Table 2. In general, blacks and whites had similar patterns. For example, with both groups, stroke type agreement was greatest for SAH (kappa = 0.93, 95% confidence interval [CI] = 0.87-0.99 for blacks; kappa = 0.87, 95% CI = 0.84-0.90 for whites) and lowest for ICH (kappa = 0.68, 95% CI = 0.59-0.77 for blacks; kappa = 0.68, 95% CI = 0.64-0.71 for whites). For blacks, the overall concordance kappa was 0.77 (95% CI = 0.71-0.83), which was lower than the apparent percent agreement of 0.94 (723 of 768). For whites, the overall concordance kappa was also 0.77 (95% CI = 0.74-0.79), and this too was lower than the apparent percent agreement of 0.94 (4045 of 4325). Corresponding indices for the two previously published studies were both lower than the values given for the current study (Table 3).

The logistic regression analysis is summarized in Tables 4 through 6. This analysis included a total of 768 stroke readmissions for blacks (38 SAH + 72 ICH + 658 ischemic strokes) and 4325 for whites (249 SAH + 438 ICH + 3638 ischemic strokes). In the crude model (model 1) of Table 4, having an SAH greatly increased the odds of having an SAH readmission (odds ratio [OR] = 1017.51, 95% CI = 611.52-1693.03). This association was essentially unchanged after adjustment for race (model 2), but was attenuated with further covariate adjustment (OR = 738.31, 95% CI = 422.58-1289.93) (model 3). Younger age also increased the odds of having an SAH readmission. For the crude model (model 1) of Table 5, having an initial ICH admission increased the odds of having an ICH readmission (OR = 81.75, 95% CI = 62.53-106.88). Neither race (model 2) nor additional predictors changed this relationship much (OR = 80.86, 95% CI = 61.57-106.19) (model 3). Atrial fibrillation also increased the odds of having an ICH readmission, whereas age had no significant effect. In the crude model (model 1) of Table 6, having an initial ischemic stroke admission increased the odds for having an ischemic stroke readmission (OR = 142.26, 95% CI = 109.62-184.83). As with other stroke types, race (model 2) did not essentially change this association, but further covariate adjustment did attenuate it (OR = 125.81, 95% CI = 96.12-164.67) (model 3). Older age, diabetes mellitus, and heart failure also increased the odds of having an ischemic readmission.

Discussion

Few studies have examined agreement patterns between index and recurrent stroke types.[1-6] In general, conflicting results exist as to what extent the initial stroke type determines the recurrent stroke type. The authors approached this issue by applying rigorous statistical methods to a large, diverse database to obtain reliable estimates of concordance. The data showed that maximal agreement occurred with SAH (kappa = 0.88). Such high levels of concordance could suggest that an underlying

Table 1. *Summary of patient characteristics by stroke type on index admission, California state inpatient databases, year 2000*

	SAH stroke admission					ICH stroke admission					Ischemic stroke admission				
	Blacks total = 35		Whites total = 206		Chi square test	Blacks total = 62		Whites total = 376		Chi-square test	Blacks total = 543		Whites total = 3198		Chi-square test
Variable	n	%	n	%	*P* value	n	%	n	%	*P* value	n	%	n	%	*P* value
Age, y					**<.01**					**<.01**					**<.01**
15-54	26	74.3	90	43.7		18	29.0	45	12.0		72	13.3	224	7.0	
55-64	5	14.3	40	19.4		20	32.3	45	12.0		84	15.5	311	9.7	
65-74	4	11.4	40	19.4		10	16.1	82	21.8		185	34.1	755	23.6	
75-84	0	0.0	30	14.6		9	14.5	138	36.7		143	26.3	1203	37.6	
≥85	0	0.0	6	2.9		5	8.1	66	17.5		59	10.9	705	22.1	
Male	9	25.7	62	30.1	.60	25	40.3	189	50.3	.15	219	40.3	1368	42.8	.29
Medicare/Medicaid	12	34.3	87	42.2	.38	37	59.7	267	71.0	.07	417	76.8	2543	79.5	.15
Hypertension	25	71.4	86	41.7	**<.01**	49	79.0	261	69.4	.12	432	79.6	2119	66.3	**<.01**
Diabetes mellitus	5	14.3	18	8.7	.30	19	30.6	60	16.0	**<.01**	226	41.6	895	28.0	**<.01**
Atrial fibrillation	2	5.7	23	11.2	.33	9	14.5	80	21.3	.22	98	18.0	932	29.1	**<.01**
Heart failure	2	5.7	7	3.4	.50	3	4.8	25	6.6	.59	63	11.6	442	13.8	.16
Ischemic heart disease	3	8.7	22	10.7	.70	6	9.7	70	18.6	.08	133	24.5	897	28.0	.09
Hypokalemia	0	0.0	4	1.9	.40	3	4.8	18	4.8	.99	30	5.5	144	4.5	.30
Urinary tract infection	0	0.0	30	14.6	**.02**	6	9.7	51	13.6	.40	48	8.8	367	11.5	.07
Head CT/MRI scan	9	25.7	49	23.8	.80	22	35.5	120	31.9	.58	167	30.8	949	29.7	.61
Carotid endarterectomy	0	0.0	0	0.0		0	0.0	0	0.0		2	0.4	39	1.2	.08
LOS ≥4 days	28	80.0	146	70.9	.26	45	72.6	238	63.3	.16	345	63.5	2001	62.6	.68
DNR order in chart	0	0.0	12	5.8	.14	2	3.2	69	18.4	**<.01**	31	5.7	441	13.8	**<.01**
LT care discharge	1	2.9	3	1.5	.55	1	1.6	5	1.3	.86	9	1.7	68	2.1	.48
Hospital size ≥200 beds	30	86.7	164	79.6	.40	39	62.9	230	61.2	.80	381	70.2	1950	61.0	**<.01**
Nonprofit hospital	27	77.1	150	72.8	.59	46	74.2	265	70.5	.55	385	70.9	2313	72.3	.49

CT, computed tomography; *DNR,* do not resuscitate; *ICH,* intracerebral hemorrhage; *LOS,* length of hospital stay; *LT,* long-term; *MRI,* magnetic resonance imaging; *SAH,* subarachnoid hemorrhage.

P values in **bold** represent variables with significant differences between blacks and whites based on the Pearson Chi square test.

Table 2. *Patterns of readmission stroke types, California state inpatient databases, year 2000*

Stroke type on readmissions	Blacks Stroke type on index admission				Whites Stroke type on index admission				Blacks and whites Stroke type on index admission			
	SAH	ICH	Ischemic	Total	SAH	ICH	Ischemic	Total	SAH	ICH	Ischemic	Total
SAH	**36**	1	1	38	**216**	18	15	249	**252**	19	16	287
ICH	1	**51**	20	72	18	**305**	115	438	19	**356**	135	510
Ischemic	2	20	**636**	658	14	100	**3524**	3638	16	120	**4160**	4296
Total	39	143	657	768	248	423	3654	4325	287	495	4311	5093
$Kappa_{SAH}$ (95% CI)		0.93 (0.87-0.99)				0.87 (0.84-0.90)				0.88 (0.85-0.90)		
$Kappa_{ICH}$ (95% CI)		0.68 (0.59-0.77)				0.68 (0.64-0.71)				0.68 (0.64-0.71)		
$Kappa_{ischemic}$ (95% CI)		0.77 (0.71-0.84)				0.78 (0.76-0.81)				0.78 (0.76-0.80)		
$Kappa_{overall}$ (95% CI)		0.77 (0.71-0.83)				0.77 (0.74-0.79)				0.77 (0.73-0.78)		

CI, Confidence interval; *ICH,* intracerebral hemorrhage; *SAH,* subarachnoid hemorrhage.
Values in **bold** represent concordant stroke type frequencies; kappa = 0 indicates no agreement beyond chance, kappa = 1 indicates perfect agreement.

genetic mechanism is involved in recurrent stroke type determination. The fact that nontraumatic SAH is known to be associated with several heritable conditions including saccular/berry aneurysms, polycystic kidney disease, α_1-antitrypsin deficiency, sickle cell anemia, Ehlers-Danlos syndrome, fibromuscular dysplasia, and other connective tissue disorders is consistent with this view.[24] Blacks had a somewhat higher SAH concordance level (kappa = 0.93) than whites (kappa = 0.87), which could represent random variation. Alternatively, this observation might be explained by the younger age distribution, which could reflect a genetic predisposition, and/or the higher prevalence of hypertension, which could imply a greater risk of aneurysm rupture, that black patients with SAH had in this study.

The data also showed that the lowest agreement occurred for ICH (kappa = 0.68). This is not surprising given that this stroke type is known to be associated with several risk factors including hypertension, amyloid angiopathy, and vascular malformations.[25] The extent of agreement is also likely influenced by the location of ICH, with lobar sites (e.g., elderly patients with amyloid angiopathy) associated with greater agreement than deep hemispheric sites (e.g., patients with hypertension).[26] Similarly, ischemic stroke is associated with a number of important risk factors (e.g., hypertension, diabetes mellitus, other vascular diseases) and pathophysiologic mechanisms (e.g., large vessel arteriosclerosis, cardiogenic embolus, small vessel occlusion).[25] Therefore, with this stroke type, less than excellent concordance was demonstrated as well (kappa = 0.78). When all stroke classes were considered, the overall agreement between the initial and recurrent stroke types was 0.77 using kappa and 0.94 using percent agreement. This difference in values illustrates what was stated earlier about the latter index being overly optimistic because it does not account for

Table 3. *Patterns of recurrent/readmission stroke types for some previously published studies*

Stroke type on recurrence	South London study[5] United Kingdom Stroke type on index event				Lausanne study[6] Switzerland Stroke type on index event			
	SAH	ICH	Ischemic	Total	SAH	ICH	Ischemic	Total
SAH	**1**	0	0	1				
ICH	0	**5**	6	11		**11**	5	16
Ischemic	1	8	**80**	89		8	**97**	105
Total	2	13	86	101		19	102	121
$Kappa_{ICH}$ (95% CI)		0.34 (0.07-0.61)						
$Kappa_{ischemic}$ (95% CI)		0.36 (0.10-0.62)						
$Kappa_{overall}$ (95% CI)		0.37 (0.11-0.63)				0.57 (0.35-0.78)		

CI, Confidence interval; *ICH,* intracerebral hemorrhage; *SAH,* subarachnoid hemorrhage.
For the South London study, ischemic = nonlacunar + lacunar infarcts, unclassified strokes were excluded to make table entries comparable with the current study; for the Lausanne study, ischemic = nonlacunar noncardioembolic + nonlacunar cardioembolic + lacunar infarcts; values in **bold** represent concordant stroke type frequencies; kappa = 0 indicates no agreement beyond chance, kappa = 1 indicates perfect agreement.

Table 4. *Multivariate logistic regression models: Odds of having a subarachnoid hemorrhage readmission, California state inpatient databases, year 2000*

	Model 1		Model 2		Model 3	
Variable	OR	95% CI	OR	95% CI	OR	95% CI
Initial SAH admission	**1017.51**	611.52-1693.03	**1017.63**	611.33-1693.96	**738.31**	422.58-1289.93
Black race			0.91	0.53-1.54	0.77	0.42-1.40
Age, y						
15-54					1.00	
55-64					0.53	0.23-1.24
65-74					0.47	0.21-1.03
75-84					**0.36**	0.16-0.80
≥85					**0.10**	0.03-0.32
Diabetes mellitus					**0.45**	0.26-0.77
Hypokalemia					2.11	0.71-6.28
Nonprofit hospital					0.69	0.40-1.19

CI, Confidence interval; ICH, intracerebral hemorrhage; *OR,* odds ratio; *SAH,* subarachnoid hemorrhage.

OR values in **bold** represent variables significantly associated with the odds of having an SAH readmission; for all models, generalized estimating equations were used assuming an exchangeable correlation structure; this logistic regression analysis included n = 287 SAH + 510 ICH + 4296 ischemic stroke readmissions.

agreement as a result of chance alone and, therefore, its exclusive use should be avoided.

The overall stroke type concordance in this study was substantially higher than that for the South London Community Stroke Register Study[5] (kappa = 0.37) and the Lausanne Stroke Registry Study[6] (kappa = 0.57). These discrepancies may be related to the small numbers of recurrent events that were available in those prior studies, especially for the hemorrhagic cases. This view is supported by the fairly wide CIs demonstrated for the kappa values of the South London and Lausanne studies. Differences in study design and case mix may have also contributed to the results. For example, the South London study was population-based and included hospitalized and nonhospitalized cases during a 6-year period, whereas the Lausanne study was hospital-based, like the current study, and included only hospitalized ischemic and ICH cases during a 6-year period. The larger number of events and similar study design may explain why the Lausanne data were more comparable with the data reported here.

Several researchers have suggested that lack of agreement between the index and recurrent stroke types implies that additional unrecognized factors beyond the initial stroke type influence the stroke type determination of repeated events.[5-7] This explanation was proposed by Yamamoto and Bogousslavsky[6] and has been referred to as the hypothesis of the multifactorial origin of stroke recurrence. In contrast, as discussed by Hillen et al,[5] many clinicians assume that strokes recur in the same form as that of the index presentation, and this thinking may guide diagnostic and therapeutic decision making. To the extent that this assumption is incorrect, patients with stroke may receive less than optimal or even inap-

Table 5. *Multivariate logistic regression models: Odds of having an intracerebral hemorrhage readmission, California state inpatient databases, year 2000*

	Model 1		Model 2		Model 3	
Variable	OR	95% CI	OR	95% CI	OR	95% CI
Initial ICH admission	**81.75**	62.53-106.88	**81.81**	62.57-106.96	**80.86**	61.57-106.19
Black race			0.94	0.64-1.40	1.02	0.68-1.51
Diabetes mellitus					**0.60**	0.43-0.83
Atrial fibrillation					**1.42**	1.03-1.95
Heart failure					**0.52**	0.32-0.86

CI, Confidence interval; *ICH,* intracerebral hemorrhage; *OR,* odds ratio; *SAH,* subarachnoid hemorrhage.

OR values in **bold** represent variables significantly associated with the odds of having an ICH readmission; for all models, generalized estimating equations were used assuming an exchangeable correlation structure; this logistic regression analysis included n = 287 SAH + 510 ICH + 4296 ischemic stroke readmissions.

Table 6. *Multivariate logistic regression models: Odds of having an ischemic stroke readmission, California state inpatient databases, year 2000*

	Model 1		Model 2		Model 3	
Variable	OR	95% CI	OR	95% CI	OR	95% CI
Initial ischemic admission	**142.26**	109.62-184.62	**142.41**	109.73-184.83	**125.81**	96.12-164.67
Black race			1.08	0.73-1.58	1.17	0.78-1.76
Age, y						
15-54					1.00	
55-64					1.33	0.81-2.17
65-74					**2.00**	1.30-3.07
75-84					**2.19**	1.44-3.31
≥85					**2.69**	1.66-4.36
Diabetes mellitus					**1.98**	1.41-2.80
Atrial fibrillation					**0.66**	0.48-0.92
Heart failure					**1.87**	1.14-3.04
Head CT/MRI scan					1.32	0.99-1.77
Hospital ≥200 beds					0.80	0.60-1.06

CI, Confidence interval; *CT*, computed tomography; *ICH*, intracerebral hemorrhage; *MRI*, magnetic resonance imaging; *OR*, odds ratio; *SAH*, subarachnoid hemorrhage.

OR values in **bold** represent variables significantly associated with the odds of having an ischemic stroke readmission; for all models, generalized estimating equations were used assuming an exchangeable correlation structure; this logistic regression analysis included n = 287 SAH + 510 ICH + 4296 ischemic stroke readmissions.

propriate care that could affect them adversely. In their recurrent stroke prevention guidelines, Hanley et al[27] point out that controversy remains regarding the standard of practice for treating patients with stroke. They also note that substantial gaps exist in the application and implementation of information derived from clinical trials addressing stroke prevention. Importantly, as Lees[7] has emphasized, if the cause of recurrent stroke type is multifactorial, then having a multifactorial approach to patient treatment is essential.

This study is one of the first to demonstrate not only that the index stroke type independently predicts readmission stroke type but that several other factors are important as well. For example, younger age increased the odds of having an SAH readmission. This is not surprising given that patients with SAH in this study had a younger age distribution than other patients with stroke, which is consistent with prior reports.[28,29] This younger presentation for SAH may relate to genetic factors, as mentioned above. In addition, environmental factors, such as smoking, excessive alcohol consumption, and illicit drug use, may contribute to this higher risk among younger adults. In contrast, atrial fibrillation, but not age, increased the odds of an ICH readmission. In this study, as in others, patients with ICH were older than those with SAH but slightly younger than those with ischemic stroke. The lack of age effects may reflect the heterogeneity among patients with ICH mentioned earlier. Atrial fibrillation, however, may represent the adverse effects of anticoagulant therapy, antiplatelet therapy, or both among patients with stroke and a high bleeding risk. This is an important finding given the debate concerning the appropriate treatment of patients with hemorrhagic stroke.[30,31] Indeed, the results of this study may be useful for subsequent risk stratification and decision making in the absence of obvious clinical findings. For example, for those patients at greatest risk of having a recurrent hemorrhagic stroke (e.g., those having an initial hemorrhagic stroke, younger adults), the use of anticoagulant or antiplatelet therapy should be questioned even if they have indications otherwise, such as a history of chronic atrial fibrillation.[7,32]

Regarding ischemic stroke readmission, the important predictors included increasing age, heart failure, and diabetes mellitus. The age effects are consistent with what is known about the epidemiology of strokes in that the elderly have a greater risk for ischemic events, as age may reflect the cumulative effects of multiple lifetime exposures along with the aging of the brain and the arteries.[29,33,34] Heart failure is commonly caused by ischemic heart disease, especially among the elderly, and may represent a marker of long-term atherosclerosis, which is widely recognized as a risk factor for ischemic cerebral infarction.[35] Diabetes mellitus is also an established risk factor for stroke.[36] Others have suggested that diabetes mellitus may increase the risk for a thromboembolic event through several potentially synergistic mechanisms including glycosylation-induced acceleration of atherosclerosis, promotion of plaque formation through hyperinsulinemia, and adverse effects on cholesterol levels.[37]

To the authors' knowledge, no prior investigation has reported race-specific concordance rates or has examined the potential effects of race on recurrent stroke type. In the current study, the authors were unable to show a significant association between race and readmission stroke type in the logistic regression analysis. These results were supported by the stroke type concordance patterns between blacks and whites, which were comparable. Consequently, although the causal factors contributing to a first stroke may differ between blacks and whites, the data given here suggest that the underlying pathophysiologic mechanisms influencing the recurrence of a given stroke type are similar. Importantly, these results imply that prevention efforts aimed at reducing subsequent type-specific strokes should be effective in both racial groups.

On the index admission, there were some differences between black and white stroke patients. As expected, hypertension and diabetes mellitus were more common among blacks, which increases their risk for stroke, especially for ischemic events, whereas atrial fibrillation and ischemic heart disease were more common among whites, which could increase their risk for cardioembolic stroke. As mentioned earlier, blacks tended to be younger, which could reflect some genetic predisposition for stroke. They were also more likely to be hospitalized at institutions with higher bed capacities, which may indicate that black patients with stroke have access to larger urban medical centers for their stroke care. Whites were more likely to have a urinary tract infection, which could suggest a complication of in-hospital care (e.g., extended use of an indwelling Foley catheter),[38] and do-not-resuscitate order in their chart, which could be a marker for a poor prognosis (e.g., functional status, quality of life, poor response to earlier treatment, patients' preferences for less burdensome care, or inappropriate omissions of other potentially life-sustaining care).[39]

When interpreting the findings of this study, several potential limitations should be kept in mind. First, as with most studies using administrative data, the current study is limited by a lack of detailed clinical information for each case. This analysis partially adjusted for some elements of disease severity by using surrogate markers such as discharge disposition and length of hospital stay. In addition, this study accounted for coexisting conditions (e.g., hypertension, diabetes mellitus) and procedures performed (e.g., carotid endarterectomy) that may influence acute management and subsequent recurrence risk. Second, the index stroke admission may not have represented the first-ever stroke that a patient had. However, as mentioned before, most of these admissions will be first-time strokes, especially with the removal of those having a stroke admission during the preceding year. Indeed, it was previously shown that about 12% of the patients with stroke had a stroke readmission during the 12-month period, which compared well with the cumulative 1-year recurrence rates from population-based studies; the distribution of stroke counts was also similar to that found in other studies.[16] Third, this investigation did not include nonhospitalized stroke events, which likely include mild cases, in which patients may not seek medical attention at all, and severe cases, in which patients may die before being hospitalized. But most patients with stroke in the United States do become hospitalized[8,10,20,40] and, consequently, it is unlikely that this had an appreciable impact on the major findings reported here. Fourth, in the current study, those receiving a head computed tomography/magnetic resonance imaging scan during the index stroke admission accounted for less than half of the total. Although it is possible that so few patients received head imaging, it is more likely that most patients received scans before admission during their stay in the emergency department.[41-43] Indeed, head computed tomography is routinely done to rule out a hemorrhagic stroke in any acute case as part of the initial workup and in determining therapeutic options (e.g., whether or not antiplatelet treatment should be initiated, as with ischemic stroke). Consequently, head imaging performed during the hospitalization may represent follow-up care (e.g., to confirm initial results, to determine extent of injury for an actively progressing stroke).[43] Finally, hospital records rather than self-reports were used for racial classifications. However, when dually enrolled Medicare and Medicaid cases were considered, hospital records were shown to be fairly reliable for the classification of blacks and whites, but less so for other racial/ethnic groups.[44] Further, self-reports may not capture the perceptions of observers, which may be more relevant for identifying the potential effects of racism and discrimination.[45]

In conclusion, this study demonstrated that the initial admission stroke type and other patient factors were independently associated with the readmission stroke type. These findings indicate that multiple factors contribute to the determination of stroke type recurrence. In the clinical setting, different causes of recurrent stroke type could suggest a more appropriate stroke workup for acute cases. Moreover, these differences could indicate an alternative therapeutic regimen that is optimal for subgroups of patients with stroke. Finally, this study found that blacks and whites had similar patterns of stroke type concordance, which was also supported by the regression analysis. These results may suggest that both groups would benefit from intervention efforts targeting recurrent strokes of a given type.

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