American Journal of Epidemiology

Vol. 147, No. 3
Printed in U.S.A.

Stroke Incidence among White, Black, and Hispanic Residents of an Urban Community

The Northern Manhattan Stroke Study

Ralph L. Sacco,[1–3] Bernadette Boden-Albala,[2] Robert Gan,[2] Xun Chen,[2,4] Douglas E. Kargman,[2] Steven Shea,[3,5] Myunghee C. Paik,[4] W. Allen Hauser,[1–3] and the Northern Manhattan Stroke Study Collaborators

Stroke mortality is reported to be greater in blacks than in whites, but stroke incidence data for blacks and Hispanics are sparse. The aim of this study was to determine and compare stroke incidence rates among whites, blacks, and Hispanics living in the same urban community. A population-based incidence study was conducted to identify all cases of first stroke occurring in northern Manhattan, New York City, between July 1, 1993, and June 30, 1996. The population of this area was approximately 210,000 at that time, based on 1990 US Census data. Surveillance for hospitalized and nonhospitalized stroke consisted of daily screening of all admissions, discharges, and computed tomography logs at Columbia-Presbyterian Medical Center, the only hospital in the region, and review of discharge lists from outside hospitals, telephone surveys of random households, and contacts with community physicians, Visiting Nurses' Services, and community agencies. Stroke incidence increased with age and was greater in men than in women. The average annual age-adjusted stroke incidence rate at age ≥20 years, per 100,000 population, was 223 for blacks, 196 for Hispanics, and 93 for whites. Blacks had a 2.4-fold and Hispanics a twofold increase in stroke incidence compared with whites. Cerebral infarct accounted for 77 percent of all strokes, intracerebral hemorrhage for 17 percent, and subarachnoid hemorrhage for 6 percent. These data from the Northern Manhattan Stroke Study suggest that part of the reported excess stroke mortality among blacks in the United States may be a reflection of racial/ethnic differences in stroke incidence. *Am J Epidemiol* 1998;147:259–68.

blacks; cerebrovascular disorders; ethnic groups; Hispanic Americans; racial stocks

US public health statistics have shown stroke mortality to be substantially greater among blacks than among whites (1–3). Similarly, national surveys and other recent studies have noted differences in stroke mortality rates between Hispanics and non-Hispanic whites, and even within Hispanic subgroups (4, 5). Population-based stroke incidence studies such as those from Framingham, Massachusetts (6), Rochester, Minnesota (7), and the Lehigh Valley (Pennsylvania/New Jersey) (8) have contributed important information about stroke trends, subtypes, risk factors, and incidence rates in men and women. These studies, however, have been conducted among predominately white populations. Only recently have epidemiologic studies begun to focus on differences in stroke incidence between racial/ethnic groups, especially rates for blacks, and few data regarding stroke risk in Hispanics have been available (9–12). Older hospital-based discharge data from northern Manhattan have suggested not only that blacks appear to be at higher risk of stroke than whites but Hispanics likewise appear to be at greater risk (13).

The growth in the population of blacks and Hispanics in the United States, along with preliminary reports of an excess stroke risk in these racial/ethnic groups, make them important targets for preventive health programs. While it is clear that some evidence demonstrates differences in stroke incidence between whites, blacks, and Hispanics, definitive differences in stroke incidence can best be measured by comparing

Received for publication February 7, 1997, and in final form October 14, 1997.

Abbreviations: CPMC, Columbia-Presbyterian Medical Center; NOMASS, Northern Manhattan Stroke Study; RR, relative risk.

[1] Gertrude H. Sergievsky Center, School of Public Health, Columbia University, New York, NY.
[2] Department of Neurology, College of Physicians and Surgeons, Columbia University, New York, NY.
[3] Division of Epidemiology, School of Public Health, Columbia University, New York, NY.
[4] Division of Biostatistics, School of Public Health, Columbia University, New York, NY.
[5] Department of Medicine, Division of General Medicine, College of Physicians and Surgeons, Columbia University, New York, NY.
Reprint requests to Dr. Ralph L. Sacco, Neurological Institute, Columbia University, 710 West 168th Street, Room 547, New York, NY 10032.

racial/ethnic groups from the same population or community. Such a community-based methodology helps to minimize bias, since all three racial/ethnic groups would reside in the same area, have similar socioeconomic status distributions, and share access to similar health care institutions. Thus, the aim of this prospective population-based study was to compare the incidence of stroke among whites, blacks, and Hispanics aged 20 years or more living in a single community.

MATERIALS AND METHODS

The Northern Manhattan Stroke Study (NOMASS) is an ongoing, prospective, population-based incidence and case-control study designed to determine stroke incidence, risk factors, and outcomes in a multiethnic urban population. Northern Manhattan consists of the area of New York City north of 145th Street, south of 218th Street, bordered on the west by the Hudson River, and separated from the Bronx on the east by the Harlem River. Zip codes for the northern Manhattan incidence study included 10032, 10033, 10034, and 10040. In 1990, the population consisted of nearly 210,000 residents (14).

Identification of subjects

Starting in 1993, subjects eligible for the incidence study were identified. Potential subjects were enrolled in the study if they: 1) were diagnosed with a first stroke between July 1, 1993, and June 30, 1996; 2) had resided in northern Manhattan for at least 3 months; and 3) were at least 20 years of age. Patients with transient ischemic attack (i.e., neurologic deficits lasting less than 24 hours and no stroke found upon brain imaging) were excluded.

An ongoing active surveillance program was used to ascertain all cases of hospitalized and nonhospitalized incident stroke in northern Manhattan. The Columbia-Presbyterian Medical Center (CPMC) is the only hospital in the region, and Statewide Planning and Research Cooperative System data have indicated that approximately 80 percent of all patients with stroke were hospitalized at CPMC (13). To capture these hospitalized stroke cases, we reviewed daily lists of all admissions, discharges, and computed tomography logs at CPMC each day. Patients with a diagnosis of stroke, cerebrovascular accident, subarachnoid hemorrhage, or intracerebral hemorrhage, as well as those with a diagnosis of transient ischemic attack, aphasia, hemiparesis, weakness, coma, syncope, change in mental status, carotid artery stenosis, headache, seizure, loss of consciousness, weakness, dizziness, or vertigo, were screened for diagnosis of a first stroke through medical record review in all cases and through telephone contact with the treating physician or an interview with the patient. Additionally, the consulting neurologist on duty provided study staff with a complete list of the day's stroke admissions and consultations. All potential cases were then discussed with a study neurologist to confirm subject eligibility. Patients who suffered a fatal stroke and those who died soon after stroke onset were included. Patients with a clinical diagnosis of acute stroke who were dead upon arrival at the emergency room were reflected in the admission lists. Information regarding these patients was obtained through the CPMC Emergency Department and through the Medical Examiner's office in the New York City Department of Health.

Subjects were also identified through discharge lists obtained from 14 hospitals outside the immediate region. These hospitals were targeted using data from the Statewide Planning and Research Cooperative System, which confirmed the annual number of northern Manhattan residents seen at other hospitals with a diagnosis of stroke. Primary outside hospitals were defined as those admitting five or more stroke patients from northern Manhattan annually, while those that identified less than five stroke cases annually were labeled secondary outside hospitals. Primary hospitals included St. Luke's Hospital, Roosevelt Hospital, Mt. Sinai Medical Center, Harlem Hospital Center, Montefiore Medical Center, and St. Barnabas Hospital. Secondary hospitals included New York Hospital, New York Downtown Hospital (Beekman), Cabrini Hospital, Beth Israel North Hospital, Lenox Hill Hospital, Metropolitan Hospital, Bellevue Hospital, and St. Joseph's Hospital. The relevant institutional review boards approved the research protocol. Monthly discharge lists of northern Manhattan residents with a primary, secondary, or tertiary diagnosis of stroke (*International Classification of Diseases,* Ninth Revision (15), codes 430–438, 446, and 447) were reviewed by the NOMASS project staff, and medical records at the individual hospitals were abstracted. Eligible patients from primary hospitals were invited for in-person enrollment.

Ongoing community-based surveillance systems were also developed to enumerate nonhospitalized incident strokes. A list of all community physicians in the area, both CPMC-affiliated and non-CPMC-affiliated, was compiled using lists from the CPMC Planning Department and Public Affairs Office; from the New York State Department of Education, which licenses physicians; from the American Medical Association; and from a NOMASS database of participants' primary physicians. After review, a list of physicians was identified on the basis of medical specialty, areas of interest, and types of patients

treated. Some of the medical specialty areas included in this list were neurology, internal medicine, cardiology, family practice, and ophthalmology. These physicians were contacted through multiple surveys and follow-up telephone calls over the 3-year study period. Additionally, contact with Visiting Nurses' Services of New York City was also established. After institutional review board approval had been obtained from Visiting Nurses' Services, all northern Manhattan residents with a diagnosis of stroke for whom a referral for nursing, home health care, physical therapy, or occupational therapy services had been made were identified. Patients were sent notification by Visiting Nurses' Services that the NOMASS staff would be calling them unless otherwise advised by the patient. This list was then sent to the NOMASS project office, and the patients were screened for eligibility with a project neurologist, counted in the incidence data, and invited to an in-person interview.

Another technique used for the ascertainment of incident strokes was random digit dialing (16). This service was provided by Audits and Surveys, Inc. (Langhorne, Pennsylvania), a survey research firm, using trained interviewers who were bilingual in English and Spanish. Both published and unpublished telephone numbers were randomly generated using dual frame sampling, and interviews were conducted to determine stroke status. Among the households identified through this methodology, 86 percent agreed to participate in the telephone survey. The telephone responders were asked a set of questions to determine eligibility, including a question regarding whether they had ever had a stroke. Those who responded "yes" to this question were referred to a study neurologist, who validated the diagnosis of stroke through extensive questioning during follow-up telephone calls. Eligible participants were enrolled, and written consent to review their hospital records was obtained.

Finally, direct community outreach strategies were also utilized to encourage self-referral of stroke patients who may not have been identified from hospital reports or by physicians. Ongoing educational lectures were held at nursing facilities, senior centers, and community meetings. Stroke screening programs incorporating survey instruments and educational materials for stroke recognition and prevention were also provided at health fairs sponsored by community organizations such as churches, local Y's, and cultural organizations. Local media were used each year to reiterate stroke warning signs and symptoms, and the NOMASS telephone number was advertised for self-reporting of stroke. All lectures, survey tools, and media materials were bilingual and were approved by the institutional review board of CPMC. All self-reported stroke patients were evaluated for eligibility by the study team and were enrolled when applicable.

Because of the comprehensive nature of our surveillance system, stroke cases were frequently identified more than once through a number of different sources. To ensure that no patient was enrolled twice, all cases were cross-checked according to the patient's medical record number, Social Security number, birth date, and name.

Race/ethnicity classification

Data were collected on all incident cases through medical record review, as well as personal interview for 67 percent. Sociodemographic data, including age, sex, and race/ethnicity, were recorded. As in the 1990 US Census (14), race/ethnicity was defined by self-identification based on a series of interview questions. Our definitions of race and ethnicity conformed to the definitions set forth in Office of Management and Budget published directive 15 (17). These standards outline a minimum set of racial and ethnic categories required for use in all federal data collection activities. Race was defined by six categories: white, black or Negro, American Indian, Eskimo, Asian or Pacific Islander, and other. Ethnicity was subdivided as Hispanic or non-Hispanic on the basis of the participant's answer to the question, "Are you of Spanish/Hispanic origin?". All participants responding affirmatively as being of Spanish origin or Hispanic were classified as such. All participants classifying themselves as white without any Hispanic origin or black without any Hispanic origin were classified as white (non-Hispanic) or black (non-Hispanic), respectively. In cases wherein the patient was unable to answer questions due to aphasia, coma, dementia, or another condition, a member of the family or a caregiver (proxy) who was knowledgeable about the patient's history was interviewed.

Stroke subtype classification

Patients were classified according to stroke subtype as having cerebral infarction, intracerebral hemorrhage, or subarachnoid hemorrhage. Details of the patient's medical and neurologic history, including stroke risk factors, findings from general and neurologic examinations, and results of laboratory studies, including blood tests, neurovascular Doppler ultrasonographs, electrocardiography, and echocardiography, were recorded. Computed tomographic scanning or magnetic resonance imaging was performed in 99 percent of the cases, and this information was used for stroke subtyping. Patients classified as experiencing

cerebral infarction had evidence of focal neurologic symptoms or signs and brain image documentation of infarction. This classification included infarction due to extracranial or intracranial atherosclerosis, embolism from a commonly accepted cardiac source, lacunar infarction, cryptogenic infarction, conflicting mechanisms, and infarction from other unusual causes. "Intracerebral hemorrhage" included patients with evidence of focal neurologic symptoms or signs and brain image evidence of intraparenchymal hemorrhage. Hemorrhage from trauma or tumor was excluded. Secondary causes of nontraumatic intraparenchymal hemorrhage such as blood dyscrasia or anticoagulant use, arteriovenous malformation, or cavernous angioma were included. "Subarachnoid hemorrhage" included patients with sudden onset of neurologic deficits, headache, neck stiffness, or loss of consciousness with evidence of subarachnoid blood upon brain imaging or xanthochromia or red blood cells in the cerebrospinal fluid upon lumbar puncture. Cases of traumatic subarachnoid hemorrhage were excluded.

Computation of incidence rates

Average annual incidence rates were calculated using the number of first stroke patients in northern Manhattan who were at least 20 years of age, divided by the northern Manhattan population aged ≥20 years according to the 1990 US Census (14). Age-specific rates were calculated for strata defined by sex and race/ethnicity. Direct age-adjusted rates were estimated using age-specific proportions from the 1990 northern Manhattan census for each sex-race/ethnicity subgroup. Standard errors of age-adjusted rates were calculated by fixing the age distributions. Stroke subtype-specific incidence rates were calculated for each sex-race/ethnicity subgroup. Relative rates were calculated using whites as the reference group. Confidence intervals of estimates for log relative rates were obtained using the delta method, which is used to calculate the variance of a differentiable function of an estimator (18).

RESULTS

In 1990, 71 percent of the 210,000 northern Manhattan community residents were at least 20 years old; 32,016 (22 percent) of these persons were white, 19,199 (13 percent) were black, and 91,710 (64 percent) were Hispanic (14). Some sociodemographic characteristics of residents are given in table 1.

Using the full range of surveillance techniques, 2,593 persons were screened between July 1, 1993, and June 30, 1996 (table 2). A total of 1,931 persons were found ineligible, for the following reasons: neurologic symptoms not due to stroke (n = 1,356), prior stroke (n = 234), previously enrolled (n = 121), transient ischemic attack (n = 99), not from northern Manhattan (n = 54), and other (n = 67). During the 3-year study period, the NOMASS surveillance system identified 662 incident strokes, of whom 629 patients (95 percent) were hospitalized and 33 (5 percent) were not (table 2). Among the hospitalized stroke patients, 85 percent were from CPMC, 14 percent were derived from NOMASS outside hospital surveillance, and less than 1 percent were hospitalized elsewhere. Community surveillance identified 24 per-

TABLE 1. Demographic characteristics of residents of northern Manhattan, New York City, 1990*

	No.	%
Age group (years)		
20–24	16,342	11
25–34	37,638	26
35–44	31,611	22
45–54	21,262	15
55–64	13,863	10
65–74	11,251	8
75–84	7,891	6
≥85	3,067	2
Race/ethnicity		
White	32,016	22
Black	19,199	13
Hispanic	91,710	64
Sex		
Female	78,527	55
Male	64,398	45
Education†		
Less than high school	57,484	46
High school diploma	26,636	21
Any college	40,818	33

* 1990 US Census data (14). Includes blacks, whites, and Hispanics aged 20 years or more.

† Based on the northern Manhattan population aged 25 years or more.

TABLE 2. Screening and surveillance for incident stroke and enrollment in the Northern Manhattan Stroke Study, July 1, 1993–June 30, 1996

	Screened		Enrolled	
	No.	%	No.	%
Total patients	2,593	100.0	662	100.0
CPMC* surveillance	2,123	81.9	532	80.4
Outside hospital surveillance	186	7.2	89	13.4
Visiting Nurses' Services	145	5.6	27	4.1
Telephone audit and survey	91	3.5	3	0.5
Community surveillance	48	1.9	11	1.7

* CPMC, Columbia-Presbyterian Medical Center.

cent (n = 8) of the nonhospitalized stroke patients, while the remaining 76 percent (n = 25) were identified through medical networks such as CPMC surveillance, Visiting Nurses' Services, and outside hospitals. When a case was identified through multiple sources, the first source to locate the case was used in surveillance enumeration.

Our community physician survey (response rate = 73 percent; 61/83) indicated that most responding physicians (87 percent) hospitalized all of their stroke patients. However, 13 percent (eight physicians) stated that they sometimes saw nonhospitalized stroke patients. After reviewing patient information with these physicians, we identified 20 patients, 15 of whom were ineligible because their strokes were not first strokes. The random digit dialing telephone survey identified 91 individuals who reported having a stroke, among 14,810 households contacted. After being screened by a neurologist, 68 of these persons were confirmed as having had strokes, 61 of them prevalent strokes. The seven incident stroke patients identified had all been hospitalized. Four were already enrolled in the study, and the remaining three were then included in the incidence counting.

Mean age at stroke among the incidence cohort was 67.6 ± 15 (standard error) years, and 60 percent of the incidence patients were women. Incident stroke rates increased with age for both men and women. Overall, men had greater age-specific stroke incidence rates than did women. Exceptions were 35- to 44-year-olds and those over age 85 years, among whom women had a slightly greater age-specific incidence than men (figure 1). Blacks and Hispanics consistently demonstrated higher incidence rates than whites in all age groups (figure 2). There were racial/ethnic differences in the mean age of stroke incidence, which was highest among whites (mean age = 75.6 ± 13.3 years), intermediate for blacks (69.3 ± 13.7), and lowest among Hispanics (63.2 ± 14.7).

The average annual age-adjusted incidence rate for stroke among residents aged 20 years or more in northern Manhattan was greater for blacks and Hispanics than for whites (223 per 100,000 population for blacks, 196 for Hispanics, and 93 for whites) (figure 3). Among men, blacks and Hispanics had a twofold increase in age-adjusted relative risk of stroke as compared with whites. Among women, blacks and Hispanics were also found to have at least twice the incidence rates of stroke as whites (relative risk (RR) = 2.8 and 2.1, respectively).

Among the incident stroke cases, 77 percent were cases of cerebral infarction, 17 percent were intracerebral hemorrhage, and 6 percent were subarachnoid hemorrhage (table 3). Among infarction cases, men had greater stroke incidence rates than women. The incidence rates among black and Hispanic men were similar and were twice as high as those of white men. Black women had over three times' greater rates of infarction than white women, while Hispanic women had a 2.3-fold increased rate (table 4).

Racial/ethnic differences among intracerebral hemorrhage incidence rates revealed a different pattern. Incidence rates among Hispanic men were greater than those among black men and were almost three times those of white men (RR = 2.9). Black women had the highest rate of intracerebral hemorrhage, over three

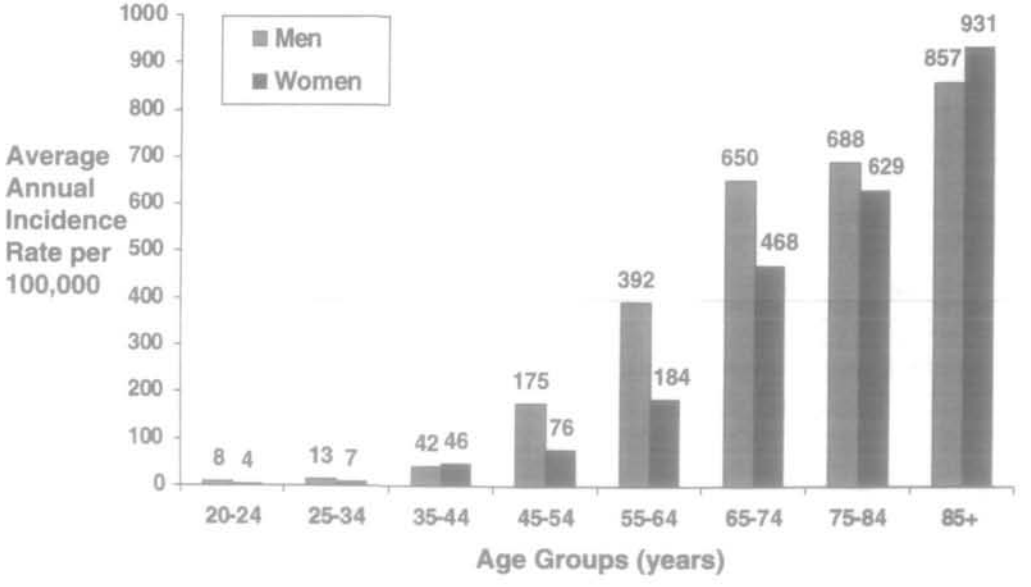

FIGURE 1. Average annual age-specific incidence rates of stroke (per 100,000 population) among persons aged ≥20 years in northern Manhattan, by sex, July 1, 1993–June 30, 1996.

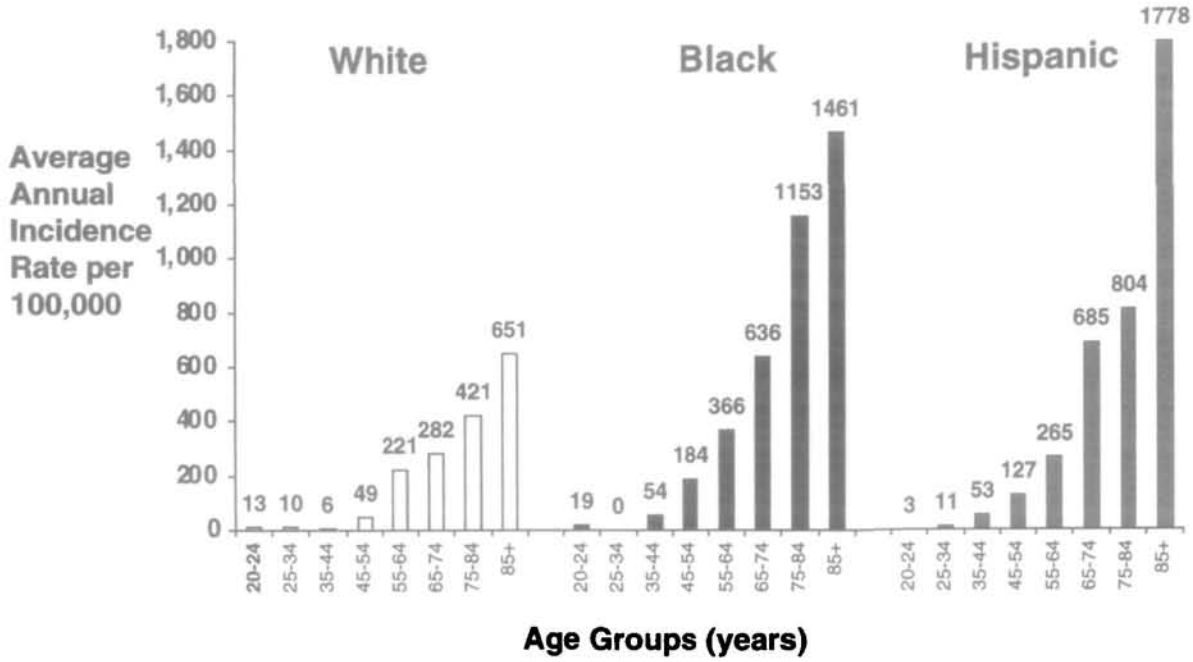

FIGURE 2. Average annual age-specific incidence rates of stroke (per 100,000 population) among whites, blacks, and Hispanics aged ≥20 years in northern Manhattan, July 1, 1993–June 30, 1996.

times that of white women (RR = 3.2), while Hispanic women had twice the intracerebral hemorrhage rate of white women (RR = 2.0). The greatest subarachnoid hemorrhage incidence rate was found in black men; however, the small sample sizes precluded any meaningful comparisons or conclusions.

DISCUSSION

A substantial number of studies have provided important information about stroke incidence (6, 7). Reports generally have shown that stroke increases exponentially with age, and that a greater incidence of stroke is found in men than in women (6, 7, 19–22). Race/ethnicity-specific stroke incidence rates for blacks and Hispanics have rarely been reported because of underrepresentation of these minority groups in past studies like the Honolulu Heart Study, the Rochester cohort, and the Framingham Study (23). Moreover, the racial/ethnic differences in rates seen in comparisons of groups derived from different source populations cannot be attributed solely to race/ethnicity, and are likely to have been influenced by differing sampling methods, populations, and age groups and by inconsistent age standardization of rates (24).

In the multiethnic community of northern Manhattan, we found two- to threefold differences in stroke

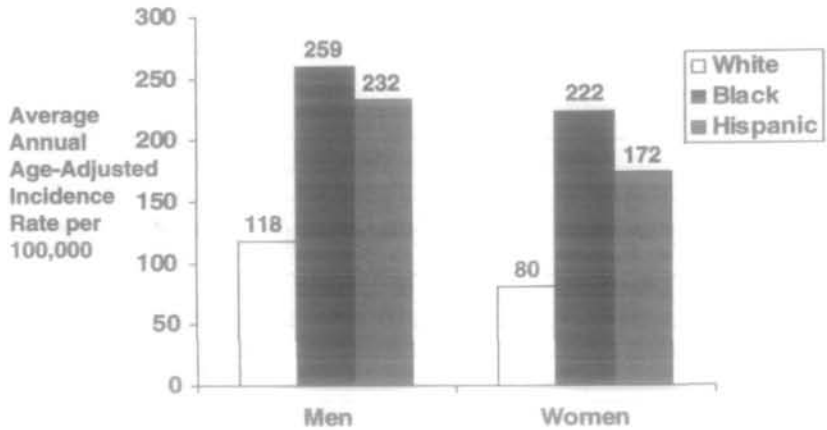

FIGURE 3. Average annual age-adjusted incidence rates of stroke (per 100,000 population) among persons aged ≥20 years in northern Manhattan, by sex and race/ethnicity, July 1, 1993–June 30, 1996.

TABLE 3. Average annual age-adjusted incidence rates (per 100,000) for stroke among persons aged ≥20 years in the Northern Manhattan Stroke Study, July 1, 1993–June 30, 1996

	No	Whites		Blacks		Hispanics	
		Men	Women	Men	Women	Men	Women
All types of stroke	662	(67)* 118.3 ± 14.9†	(95) 80.3 ± 10.1	(48) 259.1 ± 41.3	(100) 222.3 ± 23.3	(176) 231.9 ± 20.8	(176) 171.6 ± 14.2
Cerebral infarct	511	(57) 98.0 ± 13.4	(75) 57.6 ± 8.0	(36) 195.7 ± 36.2	(84) 184.2 ± 21.1	(128) 181.4 ± 19.2	(131) 134.0 ± 12.9
Intracerebral hemorrhage	112	(8) 15.3 ± 5.6	(13) 10.8 ± 3.5	(7) 37.2 ± 15.4	(15) 34.9 ± 9.6	(42) 44.2 ± 7.7	(27) 22.0 ± 4.3
Subarachnoid hemorrhage	39	(2) 4.9 ± 3.5	(7) 11.9 ± 4.9	(5) 26.2 ± 13.5	(1) 3.2 ± 3.2	(6) 6.3 ± 3.0	(18) 15.6 ± 4.3

* Numbers in parentheses, number of cases accrued over the 3-year study period.
† Average ± standard error.

incidence rates, with blacks and Hispanics being at greater stroke risk than whites residing in the same community. The increased incidence and prevalence of stroke among blacks as compared with whites had been reported in earlier studies from Mississippi (25), Alabama (26), Georgia (27), and the Lehigh Valley (21), as well as in more recent studies from Baltimore, Maryland (9). In the Lehigh Valley, where 1.7 percent of the population was black, a standardized morbidity rate of 2.43 for blacks as compared with whites was reported (21). The Baltimore stroke cohort was younger than 45 years of age, yet the black-white relative rate of 2 was similar to our overall findings among blacks and whites in northern Manhattan (9). A recent review of black-white differences in stroke incidence and mortality from different studies investigating hospitalized patients showed consistently higher rates among blacks as compared with whites (23).

The higher incidence rate of stroke among Hispanics as compared with non-Hispanic whites has not been previously reported, except from northern Manhattan (13). Summaries of national data surveys have suggested that among Hispanics subgrouped as Mexican Americans, age-specific mortality rates for stroke may be lower than those in whites (5). Stroke mortality rates in Hispanic subgroups such as Cubans and Puerto Ricans have been reported to be higher than those in Mexican Hispanics, but the relation between these mortality rates and stroke incidence rates among Hispanics needs further explanation (5). Vital statistics data collected over a 30-year period from New Mexico initially showed lower mortality rates for stroke among Hispanics than among whites. However, more recent statistics suggest that risk of stroke mortality among Hispanics in New Mexico has increased and that it now exceeds the white stroke mortality rate (4). In the Lehigh Valley Study, where Hispanics were reported to account for 3.3 percent of the population, the standardized morbidity ratio for Hispanics was 0.73, suggesting that stroke occurrence was less than that for whites (21). Hispanic subgrouping may play an important role in the calculation of stroke incidence rates (5). The Hispanic population in northern Manhattan consisted primarily of Dominicans (63 percent), with Puerto Ricans (15 percent) and other Hispanic subgroups (22 percent) contributing the remainder (28). The distribution of Hispanic subgroups and standard populations in northern Manhattan is different

TABLE 4. Age-adjusted relative risks for stroke at age ≥20 years among blacks and Hispanics in the Northern Manhattan Stroke Study, July 1, 1993–June 30, 1996*

	Blacks				Hispanics			
	Men		Women		Men		Women	
	RR†	95% CI†	RR	95% CI	RR	95% CI	RR	95% CI
All types of stroke	2.2	1.5–3.3	2.8	2.0–3.8	2.0	1.4–2.7	2.1	1.6–2.9
Cerebral infarct	2.0	1.3–3.1	3.2	2.2–4.6	1.9	1.3–2.6	2.3	1.7–3.2
Intracerebral hemorrhage	2.4	0.8–7.2	3.2	1.4–7.4	2.9	1.3–6.4	2.0	1.0–4.3
Subarachnoid hemorrhage	5.3	1.0–30.0	0.3	0.03–2.2	1.3	0.2–6.9	1.3	0.5–3.5

* Whites were used as the reference group.
† RR, relative risk; CI, confidence interval.

from that in the Southwest, which should be considered when comparing the results of our study with findings from New Mexico.

The overall stroke rate largely reflects cerebral infarction incidence, which accounted for 77 percent of all strokes among persons aged 20 years or more. However, racial/ethnic differences in incidence were found among hemorrhagic stroke cases as well. The greatest rates of intracerebral hemorrhage occurred among blacks, concurring with reports from Cincinnati, Ohio (10), and Baltimore (9). In the Cincinnati study, the greater rates of subarachnoid hemorrhage and intracerebral hemorrhage among blacks as compared with whites may have contributed to the excess mortality found among blacks. In that study, blacks had a 2.1-fold greater risk of subarachnoid hemorrhage and a 1.4-fold greater risk of intracerebral hemorrhage than whites, with blacks under 75 years of age having 2.3 times the risk of intracerebral hemorrhage (10). For intracerebral hemorrhage, we also observed a possible age-race/ethnicity interaction, with greater relative risks being seen among younger patients compared with those over age 75. Possible explanations for this interaction include an earlier age of stroke onset in blacks and Hispanics than in whites and the effects of competing causes of mortality, leading to a decreased population at risk in elderly blacks and Hispanics (29). Moreover, a possible interaction between sex and race/ethnicity for intracerebral hemorrhage incidence was noted, with Hispanic men and black women demonstrating the greatest relative incidence of intracerebral hemorrhage compared with white men and women. These observations need further exploration in studies with larger numbers of intracerebral hemorrhage cases. In our study, numbers of subarachnoid hemorrhage cases were too small for any definitive conclusions to be drawn.

Reasons for the racial/ethnic disparities in stroke incidence in our population are not entirely clear. Underlying racial/ethnic differences in socioeconomic characteristics may account for some of the differences found. Previous studies examining racial/ethnic differences in stroke have reported that differences in underlying socioeconomic status accounted for some, but not all, of the racial/ethnic disparity (30, 31). There are socioeconomic status differences among residents of northern Manhattan: 34 percent of whites, 46 percent of blacks, and 61 percent of Hispanics live at or below the 200 percent poverty level (32). Additionally, using education as an indicator of socioeconomic status, the proportion of persons with less than a high school education was greatest among Dominicans (56 percent) and was lower in blacks (27 percent) and whites (9 percent). If socioeconomic status accounted for the majority of the racial/ethnic disparities in stroke incidence, then one would expect Hispanics to have the greatest stroke incidence in northern Manhattan. The relative differences in socioeconomic status in this community are not completely concordant with our racial/ethnic differences in stroke incidence.

Differences in the burden of stroke risk factors among different racial/ethnic groups could also account for differences in stroke incidence. We have previously reported differences in the prevalence of cardiovascular risk factors in an earlier sample of stroke patients, with more hypertension and diabetes mellitus among blacks and Hispanics and more cardiac disease among whites (33). The National Health and Nutrition Examination Survey Epidemiologic Follow-up Study reported that after controlling for hypertension, diabetes, and education, the difference in risk of stroke between blacks and whites was attenuated. However, these historical stroke risk factors could not fully account for increased stroke risk among blacks (34, 35). The San Diego Stroke Data Bank showed no differences in the prevalence of stroke risk factors between whites, blacks, and Mexican Americans, except diabetes (36).

Prior investigators have raised concerns about the exclusion of patients with milder strokes who were not hospitalized (37–39). Although the extensive stroke surveillance system created by NOMASS, with internal checks and overlapping surveillance, was designed to capture all strokes in northern Manhattan, it is possible that some strokes were missed. In our incidence study, every effort was made to include both hospitalized and nonhospitalized stroke patients. Our case identification procedures were not differential with respect to race/ethnicity and could not account for racial/ethnic differences in stroke incidence. While it is not cost-effective to conduct a door-to-door survey to enumerate all strokes, we estimated that approximately one third of all households in northern Manhattan were contacted through the use of random digit dialing. This sampling provided information about the underlying prevalence of stroke in the community and served to sample a large segment of the population. In other population-based stroke incidence studies, the proportion of patients with nonhospitalized stroke has ranged from 3 percent to 28 percent (7, 37–40). Factors such as standards of medical treatment, health care systems, population size, and socioeconomic status may influence the proportion of nonhospitalized cases. Our lower rate of nonhospitalized stroke (5 percent) was not surprising, since studies of northern Manhattan residents have shown that 64 percent of them in 1992 went directly to CPMC for their last routine health care visit (28, 32). Additionally, our

primary care physicians indicated that they hospitalized the vast majority of their stroke patients, perhaps because of the limitations of outpatient services in adequately diagnosing and treating nonhospitalized stroke patients. Given the small geographic area of northern Manhattan, the high density of people, and the large proportion of community residents utilizing CPMC as a primary care provider, it is likely that most patients were hospitalized for their strokes.

An important advantage of our study design was the use of brain imaging to complement the clinical diagnosis of stroke and stroke subtypes. A concern about earlier incidence studies has been the misdiagnosis of "true stroke" and misclassification of stroke subtypes because of lack of computed tomography data (7, 37). Our use of brain imaging in 99 percent of all cases, in combination with our surveillance techniques, effectively established the diagnosis of stroke. Additionally, the use of a diagnostic committee consisting of neurologists blinded as to age, sex, and race/ethnicity assured the unbiased classification of stroke subtype.

To our knowledge, the NOMASS is among the first population-based studies to have compared incidence rates of stroke among whites, blacks, and Hispanics living in the same community. The disparities in stroke incidence rates found among these groups require further investigation through prospective studies. Additional information regarding the impact of racial/ethnic differences in socioeconomic status and stroke risk factors will eventually help investigators to design the most effective treatment and prevention programs.

ACKNOWLEDGMENTS

This work was supported by grants from the National Institute of Neurological Disorders and Stroke (R01 NS 29993) and the General Clinical Research Center (2 M01 RR00645).

The authors acknowledge the support of Dr. J. P. Mohr, Director of Cerebrovascular Research at Columbia-Presbyterian Medical Center; the assistance of Drs. J. Kirk Roberts and Mitchell S. Elkind, research fellows in stroke and neuroepidemiology; and the monumental efforts of the research assistants of the Northern Manhattan Stroke Study.

Northern Manhattan Stroke Study collaborating neurologists: Robert Barrett (Lenox Hill Hospital); Anne Camac and David Sagman (Allen Pavilion, Columbia-Presbyterian Medical Center); Carl Braun (St. Luke's/Roosevelt Hospital Center); John Brust (Harlem Hospital Center); Lorenza Freddo (St. Barnabas Hospital); Daniel Rosenbaum (Montefiore Medical Center); Stanley Tuhrim (Mt. Sinai Medical Center); Alan Brown (St. Joseph's Hospital); Sun Hoo Foo (New York Downtown Hospital–Beekman); Cynthia Harden (New York Hospital–Cornell Medical Center); Saran Jonas (New York University–Bellevue Hospital); Barbara Koppel (Metropolitan Hospital); Chandra M. Sharma (Cabrini Hospital); and Charles Stacy (Beth Israel North Hospital).

REFERENCES

1. Otten MW Jr, Teutsch SM, Williamson DF, et al. The effect of known risk factors on the excess mortality of black adults in the United States. JAMA 1990;263:845–50.
2. Howard G, Anderson R, Sorlie P, et al. Ethnic differences in stroke mortality between non-Hispanic whites, Hispanic whites, and blacks: The National Longitudinal Mortality Study. Stroke 1994;25:2120–5.
3. Gillum RF. Stroke in blacks. Stroke 1988;19:1–9.
4. Kattapong VJ, Becker TM. Ethnic differences in mortality from cerebrovascular disease among New Mexico's Hispanics, Native Americans, and non-Hispanic whites, 1958 through 1987. Ethn Dis 1993;3:75–82.
5. Gillum RF. Epidemiology of stroke in Hispanic Americans. Stroke 1995;26:1707–12.
6. Wolf PA, D'Agostino RB. Secular trends in stroke in the Framingham Study. Ann Epidemiol 1993;3:471–5.
7. Brown RD, Whisnant JP, Sicks JD, et al. Stroke incidence, prevalence, and survival: secular trends in Rochester, Minnesota, through 1989. Stroke 1996;27:373–80.
8. Friday G, Lai SM, Alter M, et al. Stroke in the Lehigh Valley: racial/ethnic differences. Neurology 1989;39:1165–8.
9. Kittner SJ, McCarter RJ, Sherwin RW, et al. Black-white differences in stroke risk among young adults. Stroke 1993; 24(suppl 1):I13–15.
10. Broderick J, Brott T, Tomsick T, et al. The risk of subarachnoid and intracerebral hemorrhages in blacks as compared with whites. N Engl J Med 1992;326:733–6.
11. Chyatte D, Nolte K, Chen T, et al. Changes in the incidence and mortality of intracerebral hemorrhage. (Abstract). Stroke 1992;23:135.
12. Bruno A, Carter S, Qualls C, et al. Incidence of spontaneous intracerebral hemorrhage among Hispanics and non-Hispanic whites in New Mexico. Neurology 1996;47:405–8.
13. Sacco RL, Hauser WA, Mohr JP. Hospitalized stroke in blacks and Hispanics in northern Manhattan. Stroke 1991;22: 1491–6.
14. Bureau of the Census. 1990 census of population and housing. Washington, DC: Bureau of the Census, US Department of Commerce, 1990. (Website: http://venus.census.gov/cdrom/lookup/880124774).
15. World Health Organization. International classification of diseases. Manual of the international statistical classification of diseases, injuries, and causes of death. Ninth Revision. Geneva, Switzerland: World Health Organization, 1977.
16. Olson SH, Kelsey JL, Pearson TA, et al. Evaluation of random digit dialing as a method of control selection in case-control studies. Am J Epidemiol 1992;135:210–22.
17. Office of Management and Budget. Race and ethnic standards for federal statistics and administrative reporting. (Directive no. 15). Federal Register, vol. 43, no. 87, p. 19269 (Thursday, May 4, 1978).
18. Bishop YM, Fienberg SE, Holland PW. Discrete multivariate analysis: theory and practice. Cambridge, MA: The MIT Press, 1975:481.
19. May DS, Kittner SJ. Use of Medicare claims data to estimate national trends in stroke incidence, 1985–1991. Stroke 1994; 25:2343–7.
20. Klag MJ, Whelton PK, Seidler AJ. Decline in US stroke mortality: demographic trends and antihypertensive treatment. Stroke 1989;20:14–21.
21. Alter M, Sobel E, McCoy RL, et al. Stroke in the Lehigh Valley: incidence based on a community-wide hospital register. Neuroepidemiology 1985;4:1–15.
22. Broderick JP, Phillips SJ, Whisnant JP, et al. Incidence rates

of stroke in the eighties: the end of the decline in stroke? Stroke 1989;20:577–82.
23. Gaines K, Burke G. Ethnic differences in stroke: black-white differences in the United States population. Neuroepidemiology 1995;14:209–39.
24. Sudlow CL, Warlow CP. Comparing stroke incidence worldwide: What makes studies comparable? Stroke 1996;27: 550–8.
25. Haerer AF, Anderson DW, Schoenberg BS. Survey of major neurologic disorders in a biracial United States population: The Copiah County Study. South Med J 1987;80:339–43.
26. Gross CR, Kase CS, Mohr JP, et al. Stroke in south Alabama: incidence and diagnostic features—a population based study. Stroke 1984;15:249–55.
27. Heyman A, Karp HR, Heyden S, et al. Cerebrovascular disease in the bi-racial population of Evans County, Georgia. Stroke 1971;2:509–18.
28. Garfield R, Abramson D, eds. Washington Heights/Inwood: the health of a community. The Health of the Public Program. New York, NY: Columbia University, 1995.
29. McCord C, Freeman HP. Excess mortality in Harlem. N Engl J Med 1990;322:173–7.
30. Howard G, Russell GB, Anderson R, et al. Role of social class in excess black stroke mortality. Stroke 1995;26:1759–63.
31. Modan B, Wagener DK. Some epidemiological aspects of stroke: mortality/morbidity trends, age, sex, race, socioeconomic status. Stroke 1992;23:1230–6.
32. Garfield R, Broe D, Albano B. The role of academic medical centers in delivery of primary care: an urban study. Acad Med 1995;70:405–9.
33. Sacco RL, Kargman DE, Zamanillo MC. Race-ethnic differences in stroke risk factors among hospitalized patients with cerebral infarction: The Northern Manhattan Stroke Study. Neurology 1995;45:659–63.
34. Giles WH, Kittner SJ, Hebel JR, et al. Determinants of black-white differences in the risk of cerebral infarction: The National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. Arch Intern Med 1995;155:1319–24.
35. Kittner SJ, White LR, Losonczy KG, et al. Black-white differences in stroke incidence in a national sample: the contribution of hypertension and diabetes mellitus. JAMA 1990; 264:1267–70.
36. Zweifler RM, Lyden PD, Taft B, et al. Impact of race and ethnicity on ischemic stroke: The University of California at San Diego Stroke Data Bank. Stroke 1995;26:245–8.
37. Bamford J, Sandercock P, Dennis M, et al. A prospective study of acute cerebrovascular disease in the community: The Oxfordshire Community Stroke Project 1981–86. I. Methodology, demography and incident cases of first-ever stroke. J Neurol Neurosurg Psychiatry 1988;51:1373–80.
38. Stegmayr B, Asplund K. Measuring stroke in the population: quality of routine statistics in comparison with a population-based stroke registry. Neuroepidemiology 1992;11:204–13.
39. Bonita R, Anderson CS, Broad JB, et al. Stroke incidence and case fatality in Australasia: a comparison of the Auckland and Perth population-based stroke registers. Stroke 1994;25: 552–7.
40. Ricci S, Celani MG, La Rosa F, et al. SEPIVAC: a community-based study of stroke incidence in Umbria, Italy. J Neurol Neurosurg Psychiatry 1991;54:695–8.