Geographic Distribution of Stroke Incidence Within an Urban Population

Relations to Socioeconomic Circumstances and Prevalence of Cardiovascular Risk Factors

Gunnar Engström, MD, PhD; Ingela Jerntorp, RN; Hélène Pessah-Rasmussen, MD, PhD; Bo Hedblad, MD, PhD; Göran Berglund, MD, PhD; Lars Janson, MD, PhD

Background and Purpose—Geographic differences in stroke incidence indicate a potential for prevention. The present study from the city of Malmö, Sweden, sought to investigate whether incidence of stroke in residential areas is related to prevalence of cardiovascular risk factors and socioeconomic circumstances.

Methods—The Stroke Register in Malmö, Sweden, was used for retrieval of the 3540 patients who suffered a first stroke between 1989 and 1998. The Malmö Diet and Cancer cohort (n=28 466) was used to assess area specific prevalence of hypertension, diabetes, smoking, and being overweight and for computation of a cardiovascular risk score. Socioeconomic circumstances for the 17 administrative areas were expressed in terms of a composite score.

Results—Standardized stroke incidence ranged among areas from 437 to 743 per 100 000 for men and from 223 to 518 per 100 000 for women. Socioeconomic score correlated significantly with area-specific stroke rates among men (r=-0.62, P=0.008) and women (r=-0.67, P=0.004). Incidence of stroke was significantly associated with cardiovascular risk score for each area (men, r=0.53, P<0.05; women, r=0.76, P<0.001). The cardiovascular score and the socioeconomic score together accounted for 44% of the geographic variance among men and 63% among women.

Conclusions—Marked differences occurred in stroke incidence among residential areas within this urban population. High-rate areas were characterized by a higher prevalence of smoking, hypertension, diabetes, and being overweight and by inferior socioeconomic circumstances. These risk factors accounted for a substantial proportion of the geographic variance in incidence of stroke. (Stroke. 2001;32:1098-1103.)

Key Words: cigarette smoking ■ epidemiology ■ hypertension ■ social class

Differences in disease occurrence, in terms of time, place, and person, indicate potentials for prevention. Stroke incidence and stroke mortality show substantial geographic variations among and within countries.1–7 To evaluate the feasibility of preventive strategies, studies are needed to assess the extent to which patterns of disease can be accounted for by prevalences of known risk factors.

Studies of geographic patterns of stroke incidence involve methodological problems such as retrieval of nonhospitalized patients and validation of cases, and standardized conditions are important prerequisites for scientific validity.8–10 The city of Malmö in Sweden has about 250 000 inhabitants who live in 18 administrative areas. Stroke patients are referred to and treated at the university hospital, which is the only hospital that provides somatic care in the city. The Stroke Register in Malmö has systematically searched for and validated possible cases since 1989. Previous studies from the city have shown that the age-adjusted incidences of myocardial infarction in the residential areas, which range from 819 to 1453 per 100 000 men and from 160 to 531 per 100 000 women, are related to prevalence of smoking, hypertension, and obesity and to socioeconomic circumstances.12

The aim of the present study was to investigate whether incidences of stroke similarly show geographic differences in this urban population, and to assess to what extent occurrence of disease is associated with socioeconomic circumstances and prevalence of other major risk factors.

Subjects and Methods

Stroke Register in Malmö

The Stroke Register in Malmö was established in 1989.11 The University Hospital is the only hospital for somatic disorders in the city. A specialized nurse from the stroke register (I.J.) has systematically searched for and registered patients with stroke at Malmö.
University Hospital. The research nurse has, together with a senior physician, validated the diagnosis through medical records and in most cases also through a patient interview. The criterion for stroke was rapid development of clinical signs of local or global loss of cerebral function lasting for >24 hours or leading to death at <24 hours, with no apparent cause other than cerebral ischemia or hemorrhage. By definition, patients with transient ischemic attacks were excluded. The criterion for stroke classified as subarachnoid hemorrhage or intracerebral hemorrhage was verification of the clinical picture at CT, lumbar puncture, or necropsy.11

The present study is limited to new patients, 50 to 79 years of age, during the period 1989 to 1998. The lower age limit was set at 50 years of age because few cases occurred below that age; the upper limit was based on a high proportion of patients living in nursing homes and hence supplying no information on area of living. A total of 134 (3.6%) patients who fulfilled the inclusion criteria were excluded because of missing information on area of living. A total of 1925 male and 1615 female patients were included in the study. Of these, 106 (43 men, 63 women) had subarachnoid hemorrhage (ICD-9 code 436).11,13 CT scans were performed in 89% of cases. The 162 women) were registered to have had unspecified strokes (ICD code 434), and 336 (174 men, 1219 women) had cerebral infarction (ICD code 434), and 2710 (1491 men, 1219 hemorrhage (ICD code 431), 2710 (1491 men, 1219 hemorrhage (ICD-9 code 430), 388 (217 men, 162 women) had intracerebral hemorrhage (ICD code 431), 2710 (1491 men, 1219 women) had cerebral infarction (ICD code 434), and 336 (174 men, 162 women) were registered to have had unspecified strokes (ICD code 436).11,13 CT scans were performed in 89% of cases. The proportion of nonhospitalized patients was 5.5%.

Residential Areas and Prevalence of Risk Factors
Malmö’s ∼250 000 citizens live in 18 areas that exhibit substantial differences in terms of socioeconomic circumstances and number of inhabitants14 (Table 1). The harbor area (in which 1 stroke occurred) was excluded from study because so few people lived there; thus, a total of 17 areas were studied.

The Malmö Diet and Cancer cohort was used to assess prevalence of smoking, hypertension, being overweight, and diabetes.15 This cohort was established between 1991 and 1996 and consists of 28 466 subjects (11 206 men and 17 260 women), 45 to 73 years old, from an eligible population of about 74 000 individuals. The participant rates in the different areas ranged from 30% to 55% for men and from 33% to 56% for women.

Smoking Habits, Hypertension, and Body Mass Index
Smoking habits were assessed by a questionnaire. Those who confirmed regular or occasional smoking were counted as smokers. Participant height (in meters) and weight (in kilograms) were measured. Being overweight was defined as body mass index ≥28 kg/m². Blood pressure was measured in each subject twice in the right arm after 5 minutes of rest. Subjects who had systolic blood pressure ≥160 mm Hg or diastolic blood pressure ≥95 mm Hg and subjects who reported treatment for hypertension were classified as hypertensive.16

Diabetes
Information on self-reported treatment for diabetes was available in 25 559 participants and on fasting blood glucose levels in a random subsample of 5350 subjects. Subjects who reported treatment for diabetes and subjects whose blood glucose level exceeded 6.7 mmol/L were considered to have diabetes. Information on diabetes was missing in 7.4% of the participants.

Cardiovascular Risk Score
A risk score for fatal and nonfatal myocardial infarction previously was developed and used to study the geographic pattern of disease in Malmö.12 This risk score was also used in the present study to estimate the burden of cardiovascular risk factors in each area. Risk coefficients, which were derived from another cohort study in Malmö,17 are based on 11 389 men (1172 events) and 8222 women

### Table 1. Cardiovascular Risk Scores and Incidence of Stroke in Residential Areas With Low, Medium, and High Socioeconomic Score

<table>
<thead>
<tr>
<th>Socioeconomic Score</th>
<th>Area No.</th>
<th>Inhabitants 50–79 Years of Age, n</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>-7.2</td>
<td>16</td>
<td>2140</td>
<td>2461</td>
<td>612</td>
<td>435</td>
<td>743</td>
<td>480</td>
<td>2.15</td>
<td>3.66</td>
</tr>
<tr>
<td></td>
<td>-5.4</td>
<td>10</td>
<td>1055</td>
<td>1210</td>
<td>521</td>
<td>388</td>
<td>538</td>
<td>402</td>
<td>2.21</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>-4.4</td>
<td>2</td>
<td>3958</td>
<td>4720</td>
<td>596</td>
<td>398</td>
<td>734</td>
<td>413</td>
<td>2.27</td>
<td>3.87</td>
</tr>
<tr>
<td></td>
<td>-3.1</td>
<td>3</td>
<td>2724</td>
<td>3352</td>
<td>694</td>
<td>531</td>
<td>742</td>
<td>488</td>
<td>2.46</td>
<td>4.08</td>
</tr>
<tr>
<td></td>
<td>-2.2</td>
<td>15</td>
<td>820</td>
<td>975</td>
<td>573</td>
<td>318</td>
<td>627</td>
<td>338</td>
<td>2.51</td>
<td>4.34</td>
</tr>
<tr>
<td></td>
<td>-2.1</td>
<td>4</td>
<td>1566</td>
<td>1649</td>
<td>390</td>
<td>285</td>
<td>437</td>
<td>285</td>
<td>2.33</td>
<td>3.76</td>
</tr>
<tr>
<td>Medium</td>
<td>-1.5</td>
<td>13</td>
<td>1280</td>
<td>1472</td>
<td>594</td>
<td>421</td>
<td>700</td>
<td>518</td>
<td>2.38</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>-1.5</td>
<td>12</td>
<td>4003</td>
<td>4926</td>
<td>605</td>
<td>451</td>
<td>672</td>
<td>463</td>
<td>2.25</td>
<td>3.99</td>
</tr>
<tr>
<td></td>
<td>-0.2</td>
<td>9</td>
<td>2314</td>
<td>3271</td>
<td>795</td>
<td>514</td>
<td>730</td>
<td>438</td>
<td>2.11</td>
<td>3.58</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>1</td>
<td>3436</td>
<td>5766</td>
<td>684</td>
<td>425</td>
<td>657</td>
<td>360</td>
<td>2.16</td>
<td>3.38</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>5</td>
<td>1853</td>
<td>2139</td>
<td>507</td>
<td>327</td>
<td>535</td>
<td>319</td>
<td>2.12</td>
<td>3.01</td>
</tr>
<tr>
<td>High</td>
<td>2.6</td>
<td>14</td>
<td>1300</td>
<td>1259</td>
<td>308</td>
<td>199</td>
<td>439</td>
<td>290</td>
<td>2.06</td>
<td>3.02</td>
</tr>
<tr>
<td></td>
<td>2.9</td>
<td>11</td>
<td>1747</td>
<td>2160</td>
<td>567</td>
<td>389</td>
<td>606</td>
<td>386</td>
<td>2.11</td>
<td>3.56</td>
</tr>
<tr>
<td></td>
<td>3.9</td>
<td>6</td>
<td>2064</td>
<td>2270</td>
<td>538</td>
<td>330</td>
<td>544</td>
<td>323</td>
<td>2.00</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td>4.4</td>
<td>17</td>
<td>1935</td>
<td>2004</td>
<td>413</td>
<td>230</td>
<td>473</td>
<td>273</td>
<td>2.02</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>7</td>
<td>881</td>
<td>853</td>
<td>352</td>
<td>141</td>
<td>497</td>
<td>223</td>
<td>2.09</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>8</td>
<td>428</td>
<td>382</td>
<td>327</td>
<td>209</td>
<td>622</td>
<td>414</td>
<td>2.01</td>
<td>3.02</td>
</tr>
</tbody>
</table>
(142 events), aged 45 to 61 years, who were followed for 13.5±5.0 years. Cox regression analysis was used to calculate the age-adjusted risk coefficients. Risk score was calculated as the exponential function of the sum of the products of the logistic risk coefficients and the risk factors. Logistic risk coefficients (±SE) for men were as follows: smoking, 0.89 (±0.06); hypertension, 0.61 (±0.06); being overweight, 0.25 (±0.07); and diabetes, 0.74 (±0.12). Logistic coefficients (±SE) for women were for smoking, 1.59 (±0.18); hypertension, 0.90 (±0.18); being overweight, 0.23 (±0.20); and diabetes, 1.45 (±0.26). Mean risk scores for men and women from different areas were calculated. Because some of the risk factors were associated with higher relative risks for women than men (although from a much lower absolute level), the mean cardiovascular score was higher for women than men. However, the area-specific risk scores for men and women were highly correlated (r=0.87).

Socioeconomic Circumstances of Residential Areas

Socioeconomic profile of the areas is based on official statistics from the Malmö City Council and data from Statistics Sweden. A socioeconomic score for each area was calculated from 4 variables: migration rate, percentage of residents with foreign citizenship as a proportion of all citizens with foreign background, dependency of social welfare support (with negative signs), and employment rate (with positive sign). These 4 parameters were selected to reflect different aspects of socioeconomic deprivation in Sweden today. The socioeconomic score correlates with other well-known measures of social status; eg, mean income (r=0.81) and unemployment rate (r=−0.91). The socioeconomic score has in several previous studies been associated with pattern of disease (eg, with incidence of12 and long-term survival after myocardial infarction19).

Statistics

Area-specific prevalences of risk factors were adjusted for age by direct standardization with the equivalent average rate method.12,19 Standardization was based on 10-year groups. Annual incidence of stroke between 1989 and 1998 among men and women was similarly age-standardized with the equivalent average rate method. Associations between prevalence of cardiovascular risk factors and stroke incidence, respectively, and the socioeconomic circumstances of the areas were assessed by means of least-squares regressions weighted for participant rates and number of participants in the Malmö Diet and Cancer cohort. . . Association between socioeconomic score and incidence of stroke was weighted for respective number of men and women between 50 and 79 years of age living in each area.

Results

Incidence of Stroke

Age-standardized annual rates (per 100 000) ranged among residential areas from 437 to 743 among men and from 223 to 518 among women (Table 1). Area-specific age-standardized stroke rates for men correlated with those for women (r=0.85, P<0.001).

Prevalence of Cardiovascular Risk Factors

Age-adjusted prevalence of smoking, hypertension, being overweight, and diabetes showed substantial differences among areas (Table 2). These risk factors were more prevalent in areas with a low socioeconomic score. Socioeconomic score was inversely correlated with prevalence of smoking (men, r=−0.66, P<0.01; women, r=−0.68, P<0.01), hypertension (men, r=−0.44, P=0.08; women, r=−0.51, P<0.05), being overweight (men, r=−0.61, P<0.01; women, r=−0.55, P<0.05), and diabetes (men, r=−0.42, P=0.10, women, r=−0.62, P<0.01) and with the cardiovascular risk score (men, r=−0.72, P=0.001; women, r=−0.73, P=0.001).

Stroke Incidence and Socioeconomic Circumstances

Incidence of stroke was significantly higher among men and women from socioeconomically depressed areas (Tables 1 and 3 and Figure 1). The weighted correlation coefficient between the socioeconomic score and stroke incidence in the 17 areas was r=−0.62 (P=0.008) for men and r=−0.67 (P=0.004) for women. Results were similar when only patients with cerebral infarction were included (men, r=−0.55, P=0.02; women, r=−0.63, P=0.006).
Stroke Incidence and Prevalence of Cardiovascular Risk Factors

Correlations between incidence of stroke and prevalence of cardiovascular risk factors are presented in Table 3 and Figures 2 and 3. Area-specific incidence of stroke among women was significantly associated with prevalence of hypertension, smoking, and diabetes and with the cardiovascular risk score (all \( r > 0.55, P < 0.05 \)). Smoking (\( r = 0.54, P < 0.05 \)) and the cardiovascular risk score (\( r = 0.53, P < 0.05 \)) were significantly associated with area-specific stroke rates for men (Table 3). The proportion of all hypertensive men and women who had received treatment for hypertension was higher (although not significantly) in areas with high incidence of stroke (men, \( r = 0.43; \) women, \( r = 0.48 \)). When analysis was restricted to patients with cerebral infarction, correlation between the cardiovascular score and stroke incidence was 0.46 (\( P = 0.06 \)) for men and 0.75 (\( P = 0.001 \)) for women.

Cardiovascular Risk Factors and Socioeconomic Circumstances in Relation to Stroke

The cardiovascular risk score accounted for 28% \( (r^2 = 0.28) \) of the geographic variance in stroke incidence among men and 58% \( (r^2 = 0.58) \) of the variance among women. Corresponding values for socioeconomic score were 39% and 44% for men and women, respectively. When both socioeconomic and cardiovascular scores were entered into the regression model, the explained variance increased to 44% for men and 63% for women.

### Discussion

Geographic differences in stroke incidence have been reported by others.\(^1\)-\(^7\) The extent to which patterns of disease can be explained by socioeconomic circumstances and prevalence of risk factors has received less scientific attention. In a study from the People’s Republic of China, >70% of the geographic variance in stroke incidence could be accounted for by differences in prevalence of hypertension.\(^1\) Smoking

---

**TABLE 3. Correlation Coefficients Among Area-Specific Age-Standardized Incidences of Stroke, Socioeconomic Score, and Prevalence of Major Risk Factors**

<table>
<thead>
<tr>
<th></th>
<th>Age-Standardized Incidence of Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
</tr>
<tr>
<td>Socioeconomic score</td>
<td>-0.62†</td>
</tr>
<tr>
<td>Prevalence of smoking</td>
<td>0.54*</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.25</td>
</tr>
<tr>
<td>Overweight</td>
<td>0.27</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.34</td>
</tr>
<tr>
<td>Cardiovascular score</td>
<td>0.53*</td>
</tr>
</tbody>
</table>

\*\( P < 0.05; \) †\( P < 0.01; \) ‡\( P < 0.001. \)
and hypertension accounted for 21% of the variance in stroke incidence among men and 42% of the variance among women in a study based on the MONICA populations. Correlations between stroke mortality and prevalences of cardiovascular risk factors have been reported in a study from 4 countries around the Baltic Sea and in a study of stroke mortality in 35 populations from the MONICA project. Inferior socioeconomic circumstances have been associated with increased stroke mortality in cohort studies and in studies of the geographic distribution of stroke. Intraurban distributions of stroke have received little scientific attention. Marked geographic differences occurred in stroke incidence within this urban population, and a substantial proportion of the variance could be accounted for by differences in prevalence of risk factors.

Inferior socioeconomic circumstances, expressed in terms of a composite score, were significantly associated with an increased incidence of stroke among both men and women. The socioeconomic score is a measure of the average circumstances in a residential area. The true nature of this relationship (e.g., whether it reflects differences between affluent and deprived areas with regard to early detection of risk individuals or effects of inferior socioeconomic circumstances on individual susceptibility) remains to be evaluated. A statistically significant association existed between socioeconomic circumstances for each area and prevalence of cardiovascular risk factors. Others have reported inverse relationships between socioeconomic circumstances and blood pressure, especially among women, and have suggested that this could be related to the associations with female obesity. Treatment of hypertension is another factor that could be related to socioeconomic circumstances. Previous studies of the relationship between treatment for hypertension and socioeconomic deprivation are not consistent. Primary care in the city of Malmö, which is organized by the community and provided at low cost, is similar for all areas. The proportion of all hypertensive subjects receiving treatment was, if anything, higher in areas with high rates of stroke, and, hence, that the associations were confounded by differences with regard to prescription of antihypertensive treatment seems unlikely. To what extent compliance with treatment could be better in privileged areas remains to be evaluated.

Some methodological issues need to be considered. Each case was validated by the same experienced nurse from the Stroke Register who every day visited hospital units that treat stroke patients. Other hospital units were visited regularly. Methods for retrieval of cases remained unchanged during the study period. The proportion of nonhospitalized cases was 5.5%, which is similar to that in other Swedish studies. Because patients from all residential areas can reach the hospital within 15 minutes and no referral note is needed for patients with acute somatic disorders, the availability of the hospital could be regarded to be similar for patients from all areas. A review of autopsy protocols of sudden deaths in Malmö in 1989 to 1990, 2 years during which almost all deaths outside hospital were autopsied, showed that <1% of all incident strokes (7 patients of differing ages) died before they reached hospital. With these circumstances in mind, we consider it unlikely that biased retrieval and validation of cases could have confounded the geographic pattern of disease. Furthermore, considering the number of patients and the long period of observation (10 years), we concluded that the area-specific incidences have been estimated with adequate precision.

Prevalence of risk factors was assessed in a large, population-based cohort (n = 28,466) examined between 1991 and 1996. Although this cohort was somewhat younger (45 to 73 years) than the 50- to 79-year-old stroke patients in the present study, with regard to time period and age group, good correspondence is seen between the risk factor cohort and stroke patients. An important question is whether the prevalence of risk factors could have been confounded by selection bias. Prevalence of smoking and being overweight was very similar to those from questionnaire-based surveys in which the response rates have been around 75%. Participation rates in the present study were higher in socioeconomically privileged areas. However, as long as the nonattendance rate for risk factor–exposed individuals from privileged areas is not much higher than for exposed individuals from deprived areas, this could not explain our results. Differences between the areas in participation rates and size of population have been taken into account in the analysis. Repeated surveys indicate that differences in prevalence of cardiovascular risk factors between areas have remained unchanged over time. Other studies from the city similarly show that exposure to cardiovascular risk factors varies between groups defined in terms of sociodemographic circumstances.

Marked differences occurred in stroke incidence between residential areas within this urban population. High-rate areas were characterized by a higher prevalence of smoking, hypertension, diabetes, and being overweight and by inferior socioeconomic circumstances. These risk factors accounted for 44% of the stroke variance among men and 63% among women.

Acknowledgments
The present study was supported by grants from the Swedish Council for Social Research and the Vårdal Foundation.

References
7. Lackland DT, Bachman DL, Carter TD, Barker DL, Timms S, Kohli H. The geographic variation in stroke incidence in two areas of the south-
Geographic Distribution of Stroke Incidence Within an Urban Population: Relations to Socioeconomic Circumstances and Prevalence of Cardiovascular Risk Factors
Gunnar Engström, Ingela Jerntorp, Hélène Pessah-Rasmussen, Bo Hedblad, Göran Berglund and Lars Janzon

Stroke. 2001;32:1098-1103
doi: 10.1161/01.STR.32.5.1098

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2001 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/32/5/1098

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/