Greater Incidence of Both Fatal and Nonfatal Strokes in Disadvantaged Areas
The Northeast Melbourne Stroke Incidence Study

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Background and Purpose—Greater stroke mortality has been reported among lower socioeconomic groups. We aimed to determine whether fatal, nonfatal, and overall stroke incidence varied by socioeconomic status.

Methods—All suspected strokes occurring in 22 postcodes (population of 306,631) of Melbourne, Australia, during a 24-month period between 1997 and 1999 were found and assessed. Multiple overlapping sources were used to ascertain cases with standard clinical definitions for stroke. Socioeconomic disadvantage was assigned in 4 bands from least to greatest using an area-based measure developed by the Australian Bureau of Statistics.

Results—Overall stroke incidence (number per 100,000 population per year), adjusted to the European population 45 to 84 years of age, increased with increasing socioeconomic disadvantage: 200 (95% CI, 173 to 228); 251 (95% CI, 220 to 282); 309 (95% CI, 274 to 343); and 366 (95% CI, 329 to 403; \( \chi^2 \) for ranks; \( P<0.0001 \)). Similar incidence patterns were observed for both fatal and nonfatal stroke. Nonfatal stroke contributed most to this incidence pattern: 146 (95% CI, 122 to 169); 181 (95% CI, 155 to 207); 223 (95% CI, 194 to 252); and 280 (95% CI, 247 to 313; \( \chi^2 \) for ranks; \( P<0.0001 \)).

Conclusions—In this population-based study, both fatal and nonfatal stroke incidence increased with increasing socioeconomic disadvantage. The greater contributor to this incidence pattern was nonfatal stroke incidence. This may have implications for service provision to those least able to afford it. Area-based identification of those most disadvantaged may provide a simple and effective way of targeting regions for stroke prevention strategies. (Stroke. 2006;37:877-882.)

Key Words: cerebrovascular disorders ■ epidemiology ■ incidence ■ socioeconomic factors

Despite declining mortality in recent years, stroke remains a major cause of death and disability in many Western countries. Increased stroke mortality has been consistently reported among those with manual occupations and lower educational attainment, a phenomenon that could be attributable to greater stroke incidence or case fatality or both. There is preliminary evidence that the increased stroke mortality among low socioeconomic groups may be attributed to greater incidence. However, despite many of these studies being conducted using most of the “ideal” criteria for stroke incidence studies, analyses were restricted to age bands excluding older ages at which stroke more commonly occurs. We aimed to determine whether the incidence of fatal, nonfatal, and overall stroke varied by socioeconomic disadvantage in a large unselected population-based sample of incident stroke cases.

Methods

Study Population
The methods of the original North East Melbourne Stroke Incidence Study (NEMESIS) have been detailed previously. The same methods were used in the present study, which comprised a separate 2-year case ascertainment period of an expanded 22 postcode area of inner north east Melbourne between May 1, 1997, and April 30, 1999 (population 306,631).

Ascertainment of Cases
The methods for case finding met the criteria for “ideal” stroke incidence studies using multiple overlapping sources. The ex-
panded study region contains 7 public and 11 private hospitals and 2 public and 2 private specialist rehabilitation hospitals. Ten other public hospitals, 17 private hospitals, 4 public rehabilitation/special-ist aged care hospitals, and 5 private rehabilitation hospitals located outside the study area were also surveyed.

Sources of case finding included daily admission and stroke unit lists of the major public and private hospitals within the study region and in nearby areas. To complement these “hot pursuit” procedures, all hospitals provided computerized discharge lists of patients with International Classification of Diseases (ICD), Ninth Revision codes 430 to 438, 342, and 781 and ICD Tenth Revision codes I60 to I69, G45, G45, G81, and R25 to R29.89. Surveillance at some public hospitals located outside the study area and most small private hospitals was by this means alone.

Nonhospital sources were also surveyed rigorously, including: regu-lar contact with general practitioners, physicians (165), neurologists (86), and geriatricians and rehabilitation specialists (47) practicing inside and outside the study region; and monthly contact with managers of all 61 nursing homes and 56 hostels located within the study region. The study was also advertised in Divisional General Practice newsletters and newspapers. Finally, lists of patients in whom stroke was noted as either a primary or secondary cause of death were supplied by the Australian Bureau of Statistics (ABS). In these latter cases, further information was sought from hospital and nonhospital sources to determine eligibility.

Potential cases were reviewed by a panel of stroke experts comprising between 2 and 4 neurologists and an epidemiologist. Clinical details of all potential cases were presented, and panel consensus was required for inclusion.

Follow-Up
When patients died during the 12-month period after stroke, medical records or death certificates were reviewed to establish the timing of death. The National Death Index was used to determine whether any patients lost to follow-up had died.

Definitions
Stoke was defined according to the World Health Organization (WHO) definition as “rapidly developing clinical signs of focal (or global) disturbance of cerebral function lasting >24 hours (unless interrupted by surgery or death) with no apparent cause other than of vascular origin.”

To be included, events must have been detected and diagnosed by a medical practitioner within 28 days of onset. Confirmation of stroke on imaging was not required for stroke diagnosis. First-ever-in-a-lifetime strokes were defined as those occurring in patients with no previous event. Past history of stroke was deter-mined using all available information from hospital records and general practitioners.

The presence of a clinically silent stroke found on imaging was not considered to be stroke. All subarachnoid hemorrhages were included whether or not there were focal neurological signs. A “possible stroke” was defined as any episode of neurological disturbance suggestive of stroke but with insufficient information for definitive diagnosis or when it was unclear whether the focal neurological disturbance lasted >24 hours or <24 hours. “Possible” and “CT only” strokes were not included in the incidence figure. Occupation of patients and spouses was used to classify individual socioeconomic status based on 6 levels of skill.34 The presence of hypertension and current smoking was obtained from medical records. Hypertension was defined as a known history.

Index of Relative Socioeconomic Disadvantage
The Index of Relative Socioeconomic Disadvantage (IRSD) was developed by the ABS from 1996 census data and was constructed using principal component analysis. It is derived from attributes such as low income, low educational attainment, high unemployment, and jobs in relatively unskilled occupations. These factors are weighted more heavily than other included variables such as “percent dwellings with no motor cars,” “proportion of people divorced,” and “private dwellings occupied by 2 or more families.” The scores are standardized (mean 1000; SD 100). Approximately 95% of all index scores lie between 800 and 1200. Low scores denote more disadvan-tage (eg, areas having more people with relatively unskilled occupations) than high scores (eg, areas having less people with low educational attainment).

Allocation of Socioeconomic Regions and Calculation of Incidence
The 22 postcode regions were ordered by IRSD, divided into 4 approximately equivalent population sizes, and then categorized according to the level of disadvantage within each region (see supplemental Table I, available online at http://stroke.ahajournals.org). These levels of IRSD were 805 to 952 (most disadvantaged), 958 to 1059 (disadvantaged), 1104 to 1127.6 (less disadvantaged), and 1127.8 to 1162 (least disadvantaged).

For each IRSD group, incidence rates (number per 100 000 population per year) are reported as crude rates20 and rates age standardized to the “world” and “European” populations of Segi.21 These standardizations eliminate the influence of different age distributions on incidence rates being compared, allowing unbiased compar-isons between populations.22 The same age adjustments were under-taken for those dying within (fatal incidence) or surviving to (nonfatal incidence) 12 months of their first-ever incident stroke. Thus, fatal incidence corresponds to 12-month mortality. The χ² for ranks test was used to determine whether overall incidence, fatal incidence, and nonfatal incidence varied according to IRSD.20 An extension of this test for trend was used to assess the validity of the IRSD (4 categories) as a measure of individual socioeconomic status (using the 6 skill levels based on occupation).20

Results
In total, 5490 potential stroke patients were referred to the study. After careful review, 4069 were excluded: 2165 (53.2%) were

<table>
<thead>
<tr>
<th>Socioeconomic Disadvantage</th>
<th>Population Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least disadvantaged</td>
<td></td>
</tr>
<tr>
<td>First-Ever No.</td>
<td>Male (%)</td>
</tr>
<tr>
<td>346</td>
<td>253 (73.1)</td>
</tr>
<tr>
<td>Less disadvantaged</td>
<td></td>
</tr>
<tr>
<td>381</td>
<td>269 (70.6)</td>
</tr>
<tr>
<td>Disadvantaged</td>
<td></td>
</tr>
<tr>
<td>321</td>
<td>228 (71.0)</td>
</tr>
<tr>
<td>Most disadvantaged</td>
<td></td>
</tr>
<tr>
<td>371</td>
<td>285 (76.4)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>1421</td>
<td>1035 (72.8)</td>
</tr>
</tbody>
</table>

*Mean and proportion of first-ever strokes only; †missing values in smoking status are 59 (23%) in the least disadvantaged, 42 (16%) in the less disadvantaged, 20 (9%) in the disadvantaged, and 23 (8%) in the most disadvantaged; ‡there are 10 missing values in hypertensive status (<1.0%).
not stroke, 936 (23.0%) were outside the study time frame, 555 (13.6%) were transient ischemic attacks, and 355 (8.7%) resided outside the geographically defined study region. An additional 42 patients had evidence of hemorrhage or infarction on computed tomography, but the symptoms did not comply with the study definition. There were 16 additional “possible” first-ever strokes, these patients having considerable other comorbidities.

A final diagnosis of stroke was made in 1421 individuals, with 1035 (72.8%) having a first-ever-in-a-lifetime stroke. The mean age was 74.6 years, 43.9% were male (Table 1), and 89.8% of patients underwent brain imaging or autopsy.

Crude fatal stroke incidence was lower in the most disadvantaged areas than the least disadvantaged areas ($\chi^2$ for ranks; $P<0.05$; Figure 1). In contrast, when these figures were adjusted to the European population 45 to 84 years of age, fatal stroke incidence increased with increasing socioeconomic disadvantage: 55 (95% CI, 40 to 69) for least disadvantaged; 70 (95% CI, 54 to 87) less disadvantaged; 86 (95% CI, 68 to 104) disadvantaged; and 86 (95% CI, 68 to 104) most disadvantaged ($\chi^2$ for ranks; $P<0.005$; Figure 1). Similarly, incidence of nonfatal stroke adjusted to the same population was 146 (95% CI, 122 to 169); 181 (95% CI, 155 to 207); 223 (95% CI, 194 to 252); and 280 (95% CI, 247 to 313) with increasing levels of socioeconomic disadvantage ($\chi^2$ for ranks; $P<0.0001$).

For males, the European adjusted incidence rates increased with increasing disadvantage: least disadvantaged 115 (95% CI, 94 to 136); less disadvantaged 125 (95% CI, 104 to 147); disadvantaged 147 (95% CI, 123 to 170); and most disadvantaged 195 (95% CI, 168 to 223; $\chi^2$ for ranks; $P<0.0001$; Figure 2). A similar pattern was seen among females.

Applying the age-specific stroke incidence rates observed in the least disadvantaged areas to the overall study population, we calculated that 864 strokes (95% CI, 823 to 906) would have occurred if the entire population had the same stroke incidence rates as those in the least disadvantaged category. This would have reduced the overall number of incident strokes in the study population by 16.5%.

Information on occupation was available among 844 first-ever stroke patients. When we assessed the validity of the area-based measure of socioeconomic disadvantage (4 categories) as a measure of individual socioeconomic status against the 6 skill levels (based on occupation), the $\chi^2$ statistic for overall mean trend was 106.56 ($P<0.00001$).

Those most disadvantaged had greater proportions of smokers and people with hypertension (Table 1). Information on smoking status was lacking in 13.9% of participants.

**Discussion**

The most important finding of this study is that stroke incidence increased with increasing socioeconomic disadvantage, being greatest among the most disadvantaged. Similar findings for socioeconomic status, whether based on deprivation scores, educational attainment, or occupation status, have not been shown previously in a population-based study, except among studies in which age was restricted.\(^4,7,9,10,12\) These restricted age bands did not include the ages at which stroke most commonly occurs. Therefore, this is the first time that this has been reported in an unselected population-based sample.

Second and equally important, we demonstrated that both fatal and nonfatal stroke incidence were greater in most disadvantaged areas. Based on previous findings of increased stroke mortality with more disadvantage, as measured by manual occupations\(^2\) and low income,\(^9,10,12\) the greater incidence of fatal strokes is not unexpected. However, this is the first report of an increased incidence of nonfatal stroke
among this disadvantaged group. Indeed, nonfatal stroke occurrence appears to be the main contributor to the increased overall incidence in the most disadvantaged areas and is likely to result in a high personal and economic burden among this group.

Other investigators, using hospital-based and restricted age group populations, have reported that lifestyle factors such as smoking and hypertension account for part but not all of the observed increase in stroke rates among the more disadvantaged.4,8 The remainder is most likely attributable to either inaccurately measured or unmeasured risk factors because long-term exposure to risk factors is difficult to quantify.

In risk factor surveys conducted elsewhere in Australia, smoking and hypertension were more prevalent among those with manual occupations than professional occupations.2 Therefore, it is possible that the observed differences in stroke incidence between categories of socioeconomic disadvantage are partly explained by differences in the prevalence of these factors. Interestingly, the observed greater proportion of our stroke patients who smoked and had hypertension in those more disadvantaged provide some support that this is the case, although the presence of missing data does not allow this to be stated with certainty (Table 1).

In ensuring that incidence rates are accurate, every effort must be made to ascertain all strokes. This requires the use of multiple overlapping sources and “hot pursuit” techniques. However, cases may still be missed, particularly when patients seek treatment outside the hospital system or in small private hospitals outside the study area. In the present study, we made every effort to obtain these cases. Through our network of contacts with medical practitioners, nursing homes, and with death certifications, we identified a total of 80 (7.7%) first-ever stroke patients who were not acutely admitted to hospital. We also identified an additional 23 (2.2%) who attended a casualty department but were then sent home without being admitted. Furthermore, $\approx 20\%$ of first-ever stroke patients sought medical care outside the area, with about one-third of these being admitted to out-of-area small
TABLE 2. Key Quality Assessment Criteria for Areas of Socioeconomic Disadvantage

<table>
<thead>
<tr>
<th>WHO MONICA Data Quality Criteria</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO recommended range</td>
<td>10%</td>
<td>&lt;40%</td>
<td>5%</td>
<td>&gt;75%</td>
</tr>
</tbody>
</table>
| Least disadvantaged               | 4.0%| 20.8%| 7%  | 80%
| Less disadvantaged                | 15.9%| 25.7%| 7.0%| 61%
| Disadvantaged                    | 22.2%| 19.7%| 5.5%| 45%
| Most disadvantaged               | 4.4%| 15.8%| 3.3%| 45%
| Total                            | 16.7%| 22.5%| 5.1%| 58%

Quality assessment items. I indicates proportion of fatal cases (28 days) not hospitalized; II, 28-day case fatality; III, proportion of survivors (28 days) not hospitalized; IV, ratio of stroke death rate (at 28 days) in project area to stroke death rate in 1997 Australian mortality statistics.

private hospitals. Thus, a large number of stroke patients have been identified by nonhospital and out-of-area sources, these being the cases often missed in surveillance procedures.

Despite these extensive efforts to identify all cases it appears, on first inspection, that younger male patients in more affluent areas may have been underascertained (Table 1). However, on closer inspection of the population denominators, we found that the least disadvantaged population had a greater proportion of females, with more of them being >65 years of age (both \( \chi^2 \) for ranks; \( P<0.0001 \)). The older mean age and female predominance among stroke patients in the least disadvantaged category is therefore more likely a consequence of the age and gender structure of the population denominator than underascertainment of young males with stroke.

Assessment of our data quality using the criteria proposed by the WHO Monitoring Trends and Determinants in Cardiovascular Disease (MONICA) investigators (Table 2)\(^23\) show: (1) an appropriate proportion of fatal cases occurring outside hospital (16.7%); (2) a 28-day case fatality that is not too large (22.5%); (3) a reasonable proportion of out-of-hospital stroke survivors (5.1%); and (4) a disproportionately low ratio (0.58) of 28-day stroke death in the study region when compared with 1997 Australian mortality statistics.

Although the lesser proportion of deaths might indicate underascertainment of fatal strokes, there are 3 reasons that this is unlikely. First, we rigorously evaluated the medical histories of all people for whom stroke was listed on their death certificates, as well as obtaining all coroners’ records for stroke. Second, mortality figures in Table 2 include only those dying within 28 days of stroke, whereas national cerebrovascular disease mortality figure will include those having a stroke within months (or even years) of death. Finally, we previously reported significant inaccuracies in death certification for stroke within this region,\(^15\) and so Australian mortality statistics for stroke might be overestimated. Together, these findings may explain the comparatively low proportion of strokes deaths observed in our population.

We further assessed data quality using the above criteria for each socioeconomic area. In those most disadvantaged, the proportion of strokes (both fatalities and survivors) occurring outside of hospital is below the cut-off levels suggested by Asplund et al,\(^23\) suggesting an underestimation of these cases. A more likely explanation is that the most disadvantaged use hospital services more often than those less disadvantaged. Indeed, given that public hospital care is free of charge in Australia, whereas a modest copayment is required to visit a general practitioner, this is a plausible explanation. Moreover, 3.3% of survivors in this most disadvantaged group attended a hospital emergency department and were sent home without being admitted, a group likely to comprise the milder stroke cases usually treated in the community. This provides additional support that this group of people preferentially access hospital services.

There are limitations to the categorizations of IRSD we used. First, the scores are based on census data and, although they have been derived in a systematic manner, are based on assumptions about disadvantage. Second, we used postcode areas (with populations ranging from 3300 to 28 541) to categorize socioeconomic disadvantage. Socioeconomic disadvantage is not homogeneous within each postcode, and so these population divisions are necessarily an average of these heterogeneous areas. However, this generalization would tend to result in an underestimation of differences between socioeconomic groups, so it is possible that the actual differences in stroke incidence between these groups are even greater. Support for the validity of area-based categorization of socioeconomic disadvantage is provided by the strong association observed between the 4 regions of socioeconomic disadvantage and the 6 skilled levels of occupation among the 844 participants (81.5%) for whom this latter information was available.

It is also possible that census data do not include all residents (eg, illegal immigrants may not be included in the denominator). If such people more often reside in areas with greater disadvantage, then incidence may be overestimated. However, because these people tend to be younger and age adjustment has less influence on incidence figure in younger age groups (because there are more young people than old people), it is unlikely to account for the trends observed.

The strength of this study lies in the population-based setting, with ascertainment of all cases within a defined geographic region using a rigorous protocol and resultant large sample size. In addition, we included all age groups, all those not attending hospital for treatment, and all those dying in the community.

In conclusion, the present study provides evidence for a strong association between stroke incidence and socioeconomic disadvantage. This association was evident for both fatal and nonfatal stroke incidence, with the latter providing the greater contribution to the difference in stroke incidence. These findings highlight the fact that heterogeneity of stroke incidence may occur within relatively small areas. If we can reduce the socioeconomic inequities in the population, large reductions in stroke incidence might be achievable. Targeting stroke prevention to areas of more socioeconomic disadvantage may provide a simple and effective population approach to reduce stroke incidence. This has considerable advantages over the classical high-risk approach in that it does not involve the high cost of screening usually required using that approach.
Acknowledgments

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References

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