Community-Based Stroke Incidence in a Scottish Population

The Scottish Borders Stroke Study

Paul D. Syme, MD; Anthony W. Byrne, MBChB; Ruoling Chen, PhD; Robert Devenny, Mdiv; John F. Forbes, PhD

Background and Purpose—The purpose of this study was to determine the incidence and case fatality of stroke in a geographically defined region of Scotland, a nation with a high cardiovascular risk.

Methods—All strokes occurring in residents of the Scottish Borders (population 106,352) were identified during a 24-month period from 1998 to 2000 using multiple overlapping methods of case-ascertainment. Standard criteria were used to define stroke and case fatality. Stroke subtypes were determined by computer tomography (CT) scan, MRI, or autopsy.

Results—790 strokes were identified; 596 were first-ever-in-a-lifetime strokes (FES). 91.1% of FES underwent CT scan and/or autopsy. The crude annual incidence rate per 100,000 per year was: 280 (95% CI, 258 to 304) overall, 197 (95% CI, 179–217) cerebral infarction, 24 (95% CI, 17–31) intracerebral haemorrhage, 11 (95% CI, 7–16) subarachnoid haemorrhage and 49 (95% CI, 40–59) undetermined stroke. 28 day FES case fatality was 15.9% (95% CI, 13.2 to 19.1) increasing to 26.3% (95% CI, 23.0 to 30.0) at 1 year. Comparing 18 previous worldwide incidence studies with the SBSS showed a similar relative risk of stroke incidence and case fatality for FES and FES subtypes.

Conclusions—The SBSS crude incidence rate is one of the highest in the world but age-adjusted rates, case fatality and relative risk for all stroke and stroke subtypes were not significantly different from the majority of previous studies. Unlike cardiovascular disease, the Scottish risk of stroke would appear to be similar to other populations worldwide.

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Key Words: epidemiology ■ fatal outcome ■ incidence ■ stroke

Within the United Kingdom, stroke incidence studies have previously been performed in England.1–4 However, compared with England, Scotland has a poorer health record for vascular disease.5 Scotland has been considered “the sick man of Europe,” with the highest all-cause mortality in Western Europe. This is largely attributable to vascular disease with mortality from ischemic heart disease, consistently the highest in women since the 1950s and in men second only to Finland.6 Stroke and ischemic heart disease share many risk factors, but stroke incidence has never been accurately measured in Scotland. Here we report the Scottish Borders Stroke Study (SBSS), which was established to address this deficit and fulfilled all the criteria required for an “ideal” community-based incidence study in stroke.7

Subjects and Methods

The SBSS was a community-based incidence study for stroke and transient ischemic attack (TIA) conducted between October 1, 1998, and September 30, 2000. This article reports on incident cases of first-ever-in-a-lifetime stroke (FES) during this period. For inclusion, each patient had to reside within the study area at the time of his/her stroke, and stroke onset had to occur within the study period.

Study Area and Population

The study area was the Scottish Borders region, which covers 4662 km2 in southeast Scotland and is predominantly rural in character (Figure 1). The study population included all individuals with a postal address within this region and was served by 39 general practices, all of which participated in this study. Three estimates of the population at risk were obtained at the beginning, midpoint, and end of the incidence data collection, with an error of inflation of ~2%.8 The mean population was 106,352 (SD 63). The percentage of the population ≥65 years of age was 18.8%; the Scottish average is 16%.

Moderate to severe stroke patients are admitted to the Borders General Hospital (BGH). Minor stroke or TIA is reviewed in a neurovascular clinic at the BGH. A minority of patients are admitted to alternative hospitals: the Western General Hospital (WGH) Edinburgh (the regional tertiary neurology center), the Royal Infirmary Edinburgh (RIE), 6 community hospitals in the region, or 4 district hospitals in neighboring regions. All the above hospitals participated in this study, allowing tracking of cross-boundary flow.
Case Ascertainment

Multiple overlapping methods were used to maximize case ascertainment. The following were asked to notify all cases of possible stroke or TIA, including stroke deaths, in Borders residents: general practitioners, nursing staff within the BGH and the 6 community hospitals, staff at the BGH neurovascular clinic, staff at the other neighboring hospitals, social services, and Chest, Heart, and Stroke Scotland. Research nurses regularly contacted each general practice and the community hospitals and checked all medical wards in the BGH. Discharge lists from the BGH, WGH, and RIE were examined for International Classification of Diseases, Revision 9 (ICD9) codes 430 to 438 and ICD10 codes I60 to I69 and G45. All reports from the BGH radiology database for computed tomography (CT) brain and carotid duplex ultrasound scans were examined for potential stroke cases. The General Register Office for Scotland supplied all death certificates on which ICD codes for cerebrovascular disease appeared. Borders Health Board supplied information on cross-boundary flow and a fortnightly list of ICD-coded deaths. The Information Statistics Division (ISD) Scotland has one of the best index-linked databases for stroke in the world. This allowed thorough identification of “cross-boundary” cases, which is likely to be unique to our study.

Validation

Study validators reviewed all suspected stroke and TIA patients, mostly within 48 hours of their event. All validators received training on stroke neurology, including the training videos for the National Institutes of Health Stroke Scale (NIHSS). Consultant radiologists reported all CT and MRI brain scans. All clinical, autopsy, and CT data were used by the principal investigator (P.D.S.) to achieve final validation. Difficult cases were always discussed within the study team, and problem CT scans were discussed with neuroradiologists at WGH.

All suspected stroke deaths were investigated and circumstances surrounding the death discussed with physicians, general practitioners, nurses, and certifying medical practitioners in all deaths in
which stroke was entered in the death certificate. Supporting evidence for a stroke death was obtained from CT and autopsy findings when available.

**Definitions**

Stroke was defined according to the World Health Organization (WHO) definition as a syndrome of “rapidly developing clinical symptoms and/or signs of focal (or at times global) disturbance of cerebral function lasting more than 24 hours (unless interrupted by surgery or death), with no apparent cause other than of vascular origin.” FES was defined as a stroke with no clinical evidence of a previous stroke event; this included patients with CT scan evidence suggestive of a previous event but on detailed investigation, had no history of a previous event.

Stroke was confirmed on clinical grounds backed up by consistent radiological or autopsy evidence confirming the stroke subtype. The pathological subtype of each stroke was defined by the use of noncontrast CT scanning, which determined whether the stroke event was a cerebral infarct, an intracerebral hemorrhage (ICH), or a subarachnoid hemorrhage (SAH). All stroke events that had neither brain imaging nor autopsy or had a first CT scan >14 days after the event were defined as undetermined strokes (UNDs). TIA was defined as transient episodes of focal cerebral dysfunction or transient monocular dysfunction during which symptoms lasted <24 hours and were presumed to be of vascular origin.

A UND was a stroke based on clinical findings in which a patient had not undergone CT scanning ≤14 days from the onset of symptoms or there was no autopsy evidence to distinguish between infarct and hemorrhage.

A UND was a stroke based on clinical findings in which a patient had not undergone CT scanning ≤14 days from the onset of symptoms or there was no autopsy evidence to distinguish between infarct and hemorrhage.

“Stroke not proven” was defined as those deaths notified to the study that fulfilled the following criteria: (1) cerebrovascular disease ICD codes appeared anywhere on the death certificate; (2) the suspected stroke event had taken place during the study period; (3) on investigation, no new focal neurology was reported; and (4) no brain imaging or autopsy was performed.

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### Data Collection and Analysis

All data were coded and entered into a database specifically designed for this study. The data quality assurance team from ISD Scotland tested data entry. Incidence rates for FES and FES subtypes are reported as crude rates, age-specific rates, and rates standardized to the “World” and “European” populations of Segi. The age- and sex-specific incidence rates were used to adjust crude rates to the mid-1999 populations of Scotland and the United Kingdom. Case fatality rates are presented for 28 days and at 1 year. Comparison was made between male and female FES in the SBSS and other incidence studies worldwide for incidence and mortality. Relative risk (RR) comparison of “World” and “European” age-standardized rates within the SBSS for males and females and between the SBSS and other published incidence studies was made. Kaplan–Meier plots were produced to examine survival curves and risk assessed using Cox hazard regression. The 95% CI is shown for all rates, percentages, and RR calculations.

### Results

In total, 1474 validated events occurred in 1367 notified patients. A total of 790 (53.6%) were identified as stroke, 245 (16.6%) TIA, 401 (27.2%) nonstroke events, and 38 (2.6%) “stroke not proven.” Of the 790 strokes, 596 (75.4%) were FES and 194 (24.7%) were recurrent strokes. A total of 274 (46.0%) FESs occurred in males (mean age of 70.6 years; SD 12.6) and 322 (54.0%) in females (mean age of 76.6 years; SD 12.0).

The median number of sources of notification for each FES case was 3 (range 1 to 6) in the first year of the study and 4 (range 1 to 7) in the second year. Only 34 (5.7%) FESs had a single source of notification. Therefore, case ascertainment was as complete as possible.
Patients were followed through all parts of the service. Analysis of first and second locations of FES patients provided the pattern of admission, which is displayed in Figure 2. In total, 542 (91.0%) patients were reviewed or admitted to a secondary care hospital. CT brain scan was performed on 540 (90.6%) FESs, 178 (33%), 383 (64.2%), and 489 (82.0%) within 2, 7, and 14 days, respectively. Eight (1.3%) patients underwent MRI in addition to CT brain scan. Of the 540, 28 (5.2%) of the patients who underwent CT scan had radiological evidence of previous stroke but no history of a previous event and therefore were defined as FES rather than recurrent stroke.

Autopsies were performed in 11 FES patients, of whom 8 had premortem brain imaging. In total, 543 (91.1%) patients underwent either CT brain scan or autopsy. From this evidence, of the 596 FESs, 419 (70.3%) were cerebral infarct, 50 (8.4%) ICH, 23 (4.0%) SAH, and 104 (17.4%) UND.

Table 1 shows the crude and age-specific incidence of FES per 100,000 per year, including stroke subtypes. The crude incidence for all FESs was 280 per 100,000, with rates of 197 (179 to 217), 24 (17 to 31), 11 (7 to 16), and 49 (40 to 59) for cerebral infarct, ICH, SAH, and UND, respectively. We found a significantly increased risk in males for cerebral infarction (RR, 1.52 [95% CI, 1.1 to 2.09]), SAH (RR, 1.4 [95% CI, 0.44 to 4.41]), and all stroke (RR, 1.35 [95% CI, 1.04 to 1.76]).

Case fatality at 28 days and 1 year were 15.9% (95% CI, 13.2 to 18.6) and 16.0% (95% CI, 13.3 to 18.7), respectively. Table 2 shows the case fatality rates for FESs by subtype and study population.

Table 1. Age-Specific Incidence Rates (per 100,000 Population Per Year) for FES by Subtype in the Scottish Borders (1998–2000)

<table>
<thead>
<tr>
<th>Age Years</th>
<th>Population at Risk</th>
<th>No. Rate 95% CI</th>
<th>No. Rate 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–14</td>
<td>18054</td>
<td>0 0–10 0 0–10</td>
<td></td>
</tr>
<tr>
<td>15–24</td>
<td>10837</td>
<td>0 0–17 0 0–17</td>
<td></td>
</tr>
<tr>
<td>25–34</td>
<td>13693</td>
<td>3 11 2–32 0 0–13</td>
<td></td>
</tr>
<tr>
<td>35–44</td>
<td>15967</td>
<td>8 25 11–49 0 0–12</td>
<td></td>
</tr>
<tr>
<td>45–54</td>
<td>15257</td>
<td>31 102 69–144 4 13 3–34</td>
<td></td>
</tr>
<tr>
<td>55–64</td>
<td>12552</td>
<td>37 147 104–203 7 28 11–57</td>
<td></td>
</tr>
<tr>
<td>65–74</td>
<td>10627</td>
<td>107 503 413–609 10 47 23–87</td>
<td></td>
</tr>
<tr>
<td>75–84</td>
<td>6930</td>
<td>166 1198 1022–1394 16 115 66–187</td>
<td></td>
</tr>
<tr>
<td>≥85</td>
<td>2437</td>
<td>67 1375 1065–1746 13 267 142–456</td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>106352</td>
<td>419 197 179–217 50 24 17–31</td>
<td></td>
</tr>
</tbody>
</table>

*Standardized rates

<table>
<thead>
<tr>
<th>Location</th>
<th>28 day</th>
<th>1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>71 55–90</td>
<td>8 3–16</td>
</tr>
<tr>
<td>Scotland</td>
<td>161 137–188</td>
<td>19 11–30</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>167 143–194</td>
<td>20 12–31</td>
</tr>
</tbody>
</table>

Values are percent (95% CI).

References for study populations shown in parentheses.
19.1) and 26.3% (95% CI, 23 to 30). Table 2 shows case fatality for FES subtypes. Figure 3 shows the Kaplan–Meier survival curves for FES inpatients and outpatients. Most patients died within the first 28 days, with inpatients having a much greater risk of death with a hazard ratio adjusted for age and sex using Cox regression of 3.56 (HRcox, 3.56; 95% CI, 2.22 to 5.72). Case fatality at 28 days was 19.9% and 6.4% for inpatients and outpatients, respectively.

We adjusted our crude incidence to the World population of Segi15 for all ages and did the same for other published studies (Table 3). We then calculated the RR of stroke incidence comparing each study with the SBSS using World age-standardized rates. Fourteen of the 18 studies had a rate ratio (risk of stroke incidence) that was not significantly different from the SBSS. Novosibirsk had a significantly higher risk, with an RR of 1.56 (95% CI, 1.23 to 1.99) despite a modest crude incidence of 231 per 100 000. This is in contrast to Arcadia,19 with a crude incidence of 344 per 100 000, with an RR of 0.82 (95% CI, 0.62 to 1.08). These differences in crude incidence are most likely to be attributable to the much larger proportion of elderly in the population in Arcadia19 (21.1% ≥65 years of age) compared with Novosibirsk (11.0% ≥65 years of age). Three studies had a lower risk. Dijon had a significantly lower RR of 0.56 (95% CI, 0.41 to 0.76), consistent with comparisons made with other study populations. The other 2 studies with a lower RR were done on English populations in urban settings.2,3

Discussion
It is imperative to obtain complete case ascertainment of all stroke events to ensure that incidence rates are accurate. This was achieved by using multiple overlapping techniques and hot pursuit as described previously. There is no private health care for stroke in the Scottish Borders, but people with mild stroke or the very elderly in residential or nursing homes are not always referred for hospital opinion. Every effort was made to obtain these individuals by close liaison with primary care. We identified 40 (6.7%) patients who received general practitioner care only and 14 (2.3%) who were cared for in a community hospital without input from secondary care. All the rest of the FESs were either reviewed in or admitted to a secondary care facility. The validation of stroke was based on clinical grounds supported by CT and autopsy evidence wherever possible. Our CT rate was 94.4% and 83.3% for inpatients and outpatients, respectively, which we believe is as high as it can be in a population-based study.

The WHO Monitoring Trends and Determinants in Cardiovascular Disease20 committee stated that assessment of the data quality obtained from stroke registers can be done using 5 key indicators. The SBSS fulfilled all these criteria allowing multinational comparison. The study was designed using the “ideal” criteria21 to allow comparison with stroke incidence studies worldwide. Our population was also suited to an epidemiological study because it is extremely stable, with little cross-boundary flow, and is served by 1 main hospital. Our crude annual incidence rate of 280 per 100 000 for FES stroke in this Scottish population was not only higher than that in all the studies performed previously within the United Kingdom1–4 but was also among the highest of other “ideal” incidence studies worldwide.19,21,22 The World-adjusted rate for the SBSS is not significantly different from most incidence studies, and the high crude incidence is likely to be attributable to a higher proportion of elderly in the SBSS population (18.8% ≥65 years of age).

CT scanning was used to classify stroke subtypes, and if done after 14 days, they were classified as undetermined because the radiological appearance of ICH can resemble that of infarction beyond this time period.14 Of those studies that quote a cutoff period for CT brain scan, only Perth used 14 days (and share a similar distribution of stroke subtypes with...
### TABLE 3. European Standardized Rates per 100 000 per Year for Different Incidence Studies Worldwide for Different Subtypes of FES for the Age Range 45 to 84 Years

<table>
<thead>
<tr>
<th>Study</th>
<th>Cerebral Infarction</th>
<th>PIH</th>
<th>SAH</th>
<th>All Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eur Std (95% CI)</td>
<td>RR</td>
<td>Eur Std (95% CI)</td>
<td>RR</td>
</tr>
<tr>
<td>Aosta²¹</td>
<td>287 (240–335)</td>
<td>0.99 (0.84–1.17)</td>
<td>60 (39–82)</td>
<td>1.82 (1.19–2.78)</td>
</tr>
<tr>
<td>Arcadia²²</td>
<td>249 (217–281)</td>
<td>0.86 (0.73–1.02)</td>
<td>51 (36–66)</td>
<td>1.55 (1.00–2.39)</td>
</tr>
<tr>
<td>Auckland²²</td>
<td>249 (217–281)</td>
<td>0.86 (0.73–1.02)</td>
<td>51 (36–66)</td>
<td>1.55 (1.00–2.39)</td>
</tr>
<tr>
<td>Belluno²³</td>
<td>183 (166–200)</td>
<td>0.63 (0.53–0.76)</td>
<td>26 (20–32)</td>
<td>0.79 (0.47–1.32)</td>
</tr>
<tr>
<td>Erlangen²¹</td>
<td>247 (217–280)</td>
<td>0.85 (0.72–1.01)</td>
<td>51 (38–67)</td>
<td>1.55 (1.00–2.39)</td>
</tr>
<tr>
<td>Federicksberg²¹</td>
<td>339 (281–397)</td>
<td>1.17 (1.00–1.37)</td>
<td>33 (14–52)</td>
<td>1.00 (0.62–1.62)</td>
</tr>
<tr>
<td>Inherred²¹</td>
<td>106 (87–128)</td>
<td>0.96 (0.74–1.26)</td>
<td>81 (64–101)</td>
<td>0.74 (0.56–0.98)</td>
</tr>
<tr>
<td>London³²</td>
<td>247 (217–280)</td>
<td>0.85 (0.72–1.01)</td>
<td>45 (33–60)</td>
<td>1.36 (0.87–2.14)</td>
</tr>
<tr>
<td>Novosibirsk²¹</td>
<td>312 (283–342)</td>
<td>1.08 (0.92–1.26)</td>
<td>39 (29–50)</td>
<td>1.18 (0.74–1.88)</td>
</tr>
<tr>
<td>Northwest England²</td>
<td>262 (216–308)</td>
<td>0.90 (0.77–1.07)</td>
<td>38 (22–55)</td>
<td>1.15 (0.72–1.84)</td>
</tr>
<tr>
<td>Oxford²</td>
<td>318 (280–355)</td>
<td>1.10 (0.94–1.29)</td>
<td>35 (22–47)</td>
<td>1.06 (0.66–1.71)</td>
</tr>
<tr>
<td>Perth²¹</td>
<td>290 (257–325)</td>
<td>1.00 (0.85–1.18)</td>
<td>33 (23–46)</td>
<td>1.00 (0.62–1.62)</td>
</tr>
<tr>
<td>Rochester²¹</td>
<td>349 (285–413)</td>
<td>1.20 (1.03–1.41)</td>
<td>49 (23–75)</td>
<td>1.49 (0.96–2.31)</td>
</tr>
<tr>
<td>Teess¹</td>
<td>294 (256–332)</td>
<td>1.01 (0.86–1.19)</td>
<td>40 (23–75)</td>
<td>1.21 (0.76–1.92)</td>
</tr>
</tbody>
</table>

Table also shows the world standardized rates per 100 000 per year for all ages. These rates were compared with the SBSS rate to calculate RR. 
Eur Std standardized to European population of Segi per 100 000 per year for the age range 45 to 84 years. 
World Std-standardized to the world population of Segi per 100 000 per year for all ages. 
RR compared with SBSS. 
All rates shown with 95% CI. 
References for study populations shown in parentheses. 

The hospital admission rate was similar to other UK studies and 60% but lower than that in other European countries. Reflecting in the increased severity of admitted strokes, the risk of death was 3.5x greater than that of outpatients. In the studies in which data are available (Table 2), case fatality for cerebral infarct is very similar, as is that for ICH. The differences between the SBSS and other studies are with SAH and UND. The likely reasons for these differences are small numbers of SAH and the different study time period for defining UND. 

We have shown that the crude incidence of stroke in this Scottish population was high and could have been explained by the high cardiovascular risk in Scotland compared with other countries. However, age standardization of incidence rates shows that this high crude incidence is likely to be attributable to the aging nature of the SBSS population and not to an increased stroke vascular risk. Further work at a national level is required to investigate this result because it implies that Scottish cardiovascular and stroke risk are different. 

In the SBSS, 80.0% of FESs occurred in patients 65 years of age, whereas 19.6% occurred in those 65 years of age. In the study population, these age groups made up 18.8% and 2.3% of the population, respectively. Population projections show that the proportion of elderly in the population throughout the world shall increase. For Scotland, it is predicted that between 2001 and 2026, the proportion of the population 65 years of age will rise by 41.8% (from 15.9% to 22.6%), and a greater rise of 60.9% (1.7% to 2.8%) will occur for those 85 years of age. Therefore, the number of stroke cases and burden of stroke on society is likely to increase greatly. Caution is needed when extrapolating to a worldwide situation because nearly all stroke incidence studies have been performed on Western populations with a
similar case mix. However, it is remarkable how close the adjusted rates are in most of these studies, which implies that crude incidence worldwide is also mainly attributable to differences in the proportion of older people in a population and not differences in vascular risk. The study populations compared with the SBSS have been completed over the last 20 years. Although trends in stroke incidence can reliably be determined only by longitudinal studies, it is still interesting that our calculated incidence rate ratios do not demonstrate any obvious trends in risk reduction over this period. These findings, along with a general decline in stroke mortality, could mean an even bigger stroke health burden in the future.

References
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