Age- and Sex-Specific Trends in Fatal Incidence and Hospitalized Incidence of Stroke in Scotland, 1986 to 2005

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Background—Temporal trends in stroke incidence are unclear. We aimed to examine age- and sex-specific temporal trends in incidence of fatal and nonfatal hospitalized stroke in Scotland from 1986 to 2005.

Methods and Results—Mean age at the time of first stroke was 70.8 (SD, 12.9) years in men and 76.4 (12.9) years in women. Between 1986 and 2005, rates fell in men from 235 (95% CI, 229 to 242) to 149 (144 to 154) and in women from 299 (292 to 306) to 182 (177 to 188). Poisson modeling showed that temporal trends were influenced by age with declines in incidence of hospitalized stroke starting later in younger than older age groups. In both men and women aged under 55 years, the overall incidence rate of stroke was significantly higher in 2005 than in 1986.

Conclusions—We report in a whole country that the overall incidence of stroke declined steadily and substantially between 1986 and 2005, with a relative reduction in the risk of stroke of 31% in men and 42% in women. Reductions in rates of both hospitalized and nonhospitalized fatal stroke contributed to this overall decline. The increase in incident stroke rates in young people is of concern. (Circ Cardiovasc Qual Outcomes. 2009;2:475-483.)

Key Words: stroke ▪ epidemiology ▪ sex

Stroke is a major public health issue.1,2 In 2002, stroke was the third leading cause of death worldwide and was responsible for almost 3 million deaths.3,4 Stroke is associated with substantial morbidity, and a high proportion of individuals hospitalized with stroke experience significant permanent physical and psychological disability.5 Stroke mortality rates have declined in most Western European countries and the United States6,7; however, trends in incidence are not clear and there are conflicting reports of stable, increasing, and decreasing rates.8–14 It is likely that different methodological approaches have contributed to these disparate findings.

Consequently, it is difficult to draw firm conclusions regarding temporal trends in the incidence of stroke especially at a population level. These conflicting findings highlight the need for large scale population based studies carried out over protracted time periods and using consistent methodologies which will allow a more valid analysis of temporal trends in stroke incidence. No previous studies have described separately the incidence of stroke for hospitalized and nonhospitalized fatal events in men and women in different age groups in an entire country over 3 decades.

The aim of the current study therefore was to examine trends in the incidence of hospitalized and nonhospitalized fatal stroke in Scotland between 1986 and 2005 using General Register death data and the linked Scottish Morbidity database which records all hospitalizations and deaths in Scotland and allows analysis on an individual patient level.

Methods

Admissions to National Health Service (NHS) hospitals account for virtually all hospitalizations for stroke in Scotland. The Information and Statistics Division (ISD) of the NHS in Scotland collects data on all discharges from NHS hospitals using the Scottish Morbidity Record (SMR) Scheme. In Scotland primary and secondary health care is provided to all citizens, free at point of access, by the NHS. NHS hospitals deliver virtually all elective and emergency hospital care. Data from patient case records are used to code up to 6 diagnoses at the time of discharge according to the World Health Organization Classification of Diseases (ICD 9 before 1996, ICD 10 after 1996). The term “discharge” includes both live discharges and deaths. These data are routinely linked to information held by the General Register Office for Scotland. The General Register Office for Scotland records information relating to all deaths in Scotland including those that occur in individuals not previously hospitalized. Scotland has an estimated population of 5.14 million, of whom 51.7% are women and 19.5% are aged 65 and older.15

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WHAT IS KNOWN

- Stroke mortality rates have declined in most Western European countries and the United States.
- Trends in incidence are not clear, and there are conflicting reports of stable, increasing, and decreasing rates.

WHAT THE STUDY ADDS

- There have been encouraging declines in the incidence of first stroke events in Scotland between 1986 and 2005.
- Reductions in rates of both hospitalized and nonhospitalized fatal stroke contributed to this overall decline.
- The risk of hospitalization for incident stroke fell in all age groups, except in those aged under 55 years, in whom the risk of hospitalization increased by 31% and 22% in men and women respectively.

All hospitalizations in Scotland where stroke was coded as the principal (first position) or a secondary (second to sixth position) diagnosis at discharge from the period 1981 to 2005 were identified along with all deaths where stroke was coded in the first position. The following ICD 9 and ICD 10 codes were used to identify stroke (ICD 10 codes are italicized): 430 (subarachnoid hemorrhage), 431 (intracerebral hemorrhage), 433 (occlusion and stenosis of precerebral arteries), 434 (occlusion of cerebral arteries), 436 (acute, but ill-defined, cerebrovascular disease), I60 (subarachnoid hemorrhage), I61 (intracerebral hemorrhage), I63 (cerebral infarction), I64 (stroke, not specified as hemorrhage or infarction). SMR identifies prior hospital admission for stroke during the study period. The following comorbidities were identified using principal and secondary diagnoses for any admission or in a previous admission. The following comorbidities were identified using principal and secondary diagnoses for any previous hospitalizations in the past 5 years and secondary diagnoses recorded in the incident stroke hospitalization: diabetes, cancer, respiratory disease, heart failure, peripheral arterial disease, atrial fibrillation, essential hypertension, renal failure, coronary heart disease, rheumatic/valvular heart disease, venous thromboembolism, depression, parkinsonism, dementia, falls and fractures, and alcohol misuse. Nonhospitalized fatal events were defined as all individuals experiencing a first stroke or in a previous admission. The following ICD 9 and ICD 10 codes were used to identify stroke diagnoses of cerebrovascular disease within 5 years. Secondary diagnoses of cerebrovascular disease may have been coded during that admission or in a previous admission. The following comorbidities were identified using principal and secondary diagnoses for any previous hospitalizations in the past 5 years and secondary diagnoses recorded in the incident stroke hospitalization: diabetes, cancer, respiratory disease, heart failure, peripheral arterial disease, atrial fibrillation, essential hypertension, renal failure, coronary heart disease, rheumatic/valvular heart disease, venous thromboembolism, depression, parkinsonism, dementia, falls and fractures, and alcohol misuse. Nonhospitalized fatal events were defined as all individuals whose deaths were principally attributed to stroke but who had no prior hospital admission for stroke during the study period.

All analyses were conducted for men and women separately. Annual age- and sex-specific rates of incident events for total, nonhospitalized fatal, and hospitalized stroke were calculated using denominator data from the 1981, 1991, and 2001 censuses, with interpolation and extrapolation for the intracensus years. Fractional polynomial analysis17 was used to determine the best fitting relationship between incidence of all first stroke, hospitalization for stroke, and nonhospitalized fatal stroke and year. This approach will fit either a curvilinear or a linear trend line, whatever provides the best fit to the data. Poisson regression analysis was used to model the temporal trends in incidence of all first stroke, hospitalized stroke, and nonhospitalized fatal stroke with adjustment for age. Model fit was assessed using pseudo R². The assumptions of the Poisson model were tested by estimation of overdispersion parameters in negative binomial models. All analyses were carried out using Stata (version 10). A significance level of 0.05 was used throughout. The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

Results

Study Populations

All Incident Stroke (Fatal and Nonfatal)

From January 1, 1986, to December 31, 2005, there were 213 358 incident strokes in Scotland. Of these, 123 264 (57%) were in women (Table 1). Mean age at the time of first stroke was 70.8 (SD, 12.9) years in men and 76.4 (12.9) years in women. The mean age of women remained stable, whereas the mean age of men declined slightly from 71.2 years in 1986 to 70.2 years in 2005 (P<0.05). The age distribution of individuals experiencing a first stroke changed over the study period with an increasing proportion of strokes in the young (<55 years) and very old (>84 years). In 1986 in men, 9.1% of all strokes occurred in individuals aged <55 years and 9.7% in those aged >84 years. By 2005, these figures had increased to 13.6% and 12.6%, respectively. In women in 1986, 5.5% of all strokes occurred in individuals aged <55 years and 22.8% in those aged >84 years. By 2005, these figures had increased to 9.3% and 30.1%, respectively.

Hospitalized Incident Stroke

Between 1986 and 2005, there were 157 639 first hospitalizations for stroke in Scotland, of which 70 726 (45%) were men (Table 1). The mean age at admission was 69 (SD, 13.1) years in men, 74 (13.3) years in women. This did not change significantly over the study period. First hospitalization rates for stroke increased with age. An increase in the proportion of first hospitalization for stroke in the young (<55 years) and very old (>84 years) was observed between 1986 and 2005. Over the study period, there was a 4-fold increase in the percentage of men and women hospitalized with stroke who had a comorbid diagnoses of essential hypertension or atrial fibrillation.

Table 1. Distribution of Hospitalized Stroke, Nonhospitalized Fatal Stroke, and All-incident Strokes by Age in Scotland, 1986 to 2005

<table>
<thead>
<tr>
<th>Age Group, y, n (%)</th>
<th>Men</th>
<th>Age, y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>55 to 64</td>
<td>8992 (82.2)</td>
<td>69.2 (13.1)</td>
</tr>
<tr>
<td>65 to 74</td>
<td>12743 (88.9)</td>
<td>76.4 (10.8)</td>
</tr>
<tr>
<td>75 to 84</td>
<td>21638 (82.2)</td>
<td>761 (7.8)</td>
</tr>
<tr>
<td>≥85</td>
<td>20985 (72.1)</td>
<td>1593 (11.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age Group, y, n (%)</th>
<th>Men</th>
<th>Age, y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>55 to 64</td>
<td>6368 (60.1)</td>
<td>79753 (100)</td>
</tr>
<tr>
<td>65 to 74</td>
<td>8117 (27.9)</td>
<td>14336 (100)</td>
</tr>
<tr>
<td>75 to 84</td>
<td>4225 (39.9)</td>
<td>26310 (100)</td>
</tr>
<tr>
<td>≥85</td>
<td>10593 (100)</td>
<td>29102 (100)</td>
</tr>
</tbody>
</table>
fibrillation, and a 2-fold increase in comorbid diagnoses of diabetes or coronary heart disease (Tables 2 and 3).

The proportion of “stroke not specified” discharge diagnoses fell markedly from 76.8% in 1986 to 31.0% in 2005 in men and from 78.7% to 35.1% in women. A corresponding increase was observed in the proportion of strokes identified as cerebral infarction (13.1% increasing to 51.1% in men, 10.3% increasing to 46.8% in women) and intracerebral hemorrhage (5.0% increasing to 12.4% in men, 3.9% increasing to 10.5% in women) from 1986 to 2005. The proportion of first stroke hospitalization attributable to subarachnoid hemorrhage did not change over time and accounted for approximately 5% in men and 7% in women.

First hospitalizations for stroke accounted for 78.6% of all-incident strokes in men and 70.5% in women. These figures varied substantially with age so that 92.2% of men and 91.4% of women aged <55 years were hospitalized compared to only 60.1% of men and 53.1% of women aged >84 years. In addition, the proportion of all individuals with an incident stroke who were alive and hospitalized, as opposed to nonhospitalized fatal strokes, rose over the study period so that in 1986 67.6% of men and 61.5% of women with an incident stroke were hospitalized increasing to 78.5% of men and 70.5% of women in 2005. Increases were seen in all age groups but were greater in the elderly than in younger age groups.

Nonhospitalized Incident Fatal Stroke

There were 55,719 fatal incident stroke events between 1986 and 1995, of which 36,351 (65.2%) were in women. The mean age of men was 76.4 years (SD, 10.8), and this increased during the study period from 75.1 (SD, 9.8) in 1986 to 77.0 (SD, 11.9) in 2005. Women were on average more than 5 years older with a mean age of 81.8 years. There was a similar shift in the age distribution of women with an incident nonhospitalized fatal strokes event with a marked increase in the proportion of elderly in 2005 compared to 1986. For example, in 1986 in women aged 75 to 84 years there were 1193 fatal stroke incident stroke events accounting for 43.8% of all-incident events compared to only 374 (33.1%) in 2005.

Age-Standardized Population Rates

All Incident Stroke (Fatal and Nonfatal)

Overall age standardized rates for all strokes (per 100,000 population) were greater in women than in men and fell steadily during the study period. In men rates fell from 235 (95% confidence interval 229 to 242) in 1986 to 149 (144 to 154) in 2005 and in women from 299 (292 to 306) to 182 (177 to 188).

Hospitalized Incident Stroke

The overall age standardized rate of first hospitalization for stroke (per 100,000 population) in men was 155 (150 to 161) in 1986, this rose to 170 (165 to 176) in 1993, then fell to 125 (121 to 130) in 2005. In women, the rate was 179 (173 to 184) in 1986, and a similar rise to a rate of 192 (187 to 198) in 1994 was observed before the rate fell to 140 (135 to 144) in 2005.

Nonhospitalized Incident Fatal Stroke

Incidence of fatal nonhospitalized stroke fell steeply in men and women during the study period. In men rates fell from 80 per 100,000 population (76 to 84) in 1986 to 24 (22 to 26) in 2005. There were similar marked declines in women in whom the rate fell from 121 (116 to 125) in 1986 to 43 (40 to 45) in 2005.

Multivariable Modeling

Year and age groups were significantly associated with the rate of first stroke and also for first hospitalized stroke and nonhospitalized fatal stroke (P < 0.0001 for both men and women). Interaction terms between year and age groups were found to be significant (P < 0.0001 for both men and women) in all 3 groups. The observed and model predictions of rates of first stroke and for hospitalized and nonhospitalized fatal stroke are plotted against year for each age group and are shown in Figure 1 for men and Figure 2 for women.

All-incident Stroke (Fatal and Nonfatal)

Overall there was a steady reduction in the rate of incident stroke in men and women during the study period so that the relative risk (RR) of incident stroke in 2005 versus 1986 was 0.69 (0.65 to 0.74) in men and 0.58 (0.50 to 0.67) in women. However, these figures masked differences between age groups with an increase in rates seen in men and women aged <55 years in whom the RR of stroke in 2005 versus 1986 was 1.19 (1.11 to 1.27) and 1.17 (1.01 to 1.36) in men and women, respectively. Reductions in rates were seen in all other age groups.

Hospitalized Incident Stroke

A decrease in the rate of first hospitalizations was noted in later study years (Figures 1A and 2A). These declines started at different times for each age group. For men, under 55 years the rate started to decrease in 2001 (Figure 1B), for 55- to 64-year-olds in 1997 (Figure 1C), for 65- to 74-year-olds in 1995 (Figure 1D), for 75- to 84-year-olds in 1986 (Figure 1E), and for >84-year-olds in 1993 (Figure 1F). For women,

### Table 1. Continued

<table>
<thead>
<tr>
<th>Age Group, y, n (%)</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>86913 (70.5)</td>
<td>74.2 (13.3)</td>
</tr>
<tr>
<td>36351 (29.5)</td>
<td>81.8 (10.1)</td>
</tr>
<tr>
<td>123264 (100)</td>
<td>76.4 (12.9)</td>
</tr>
</tbody>
</table>
the corresponding years are 2000, 1993, 1992, 1986, and 1993. In men aged <55 years the RR of admission in 2005 versus 1986 was 1.31 (1.22 to 1.40). Similarly, the RR of admission increased in women aged <55 years in 2005 versus 1986, RR 1.22 (1.13 to 1.32). In all other age groups the RR of admission fell over time.

Nonhospitalized Incident Fatal Stroke
The risk of experiencing a fatal nonhospitalized stroke in 2005 compared to 1986 fell by two thirds in men and in women with a RR of 0.30 (0.23 to 0.40) and 0.32 (0.25 to 0.42) in men and women, respectively. Larger declines were seen in those aged 55 to 64, 65 to 74, and 75 to 84 years than in the youngest and oldest age groups. For example, the RR of experiencing a nonhospitalized fatal incident stroke in 2005 versus 1986 was 0.24 (0.22 to 0.27) in men aged 65 to 74 years compared to just 0.58 (0.44 to 0.78) in men aged <55 years.

Discussion
Overall Temporal Trends in Stroke Incidence
This large population based study included 213 358 individuals diagnosed with an incident stroke. The overall incidence of stroke declined steadily and substantially between 1986 and 2005 (relative reduction of 31% in men and 42% in women). Reductions in rates of both hospitalized and nonhospitalized fatal stroke contributed to this overall decline. Declines in nonhospitalized fatal stroke were larger and rates fell by 70% in men and 68% in women between 1986 and 2005. Trends in the overall incidence of hospitalized stroke

Table 2. Trends in Age, Stroke Subtype, and Comorbidity of First Hospitalizations for Stroke in Scotland in Men, 1986 to 2005

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean (SD) age, y</th>
<th>Age group, %</th>
<th>Stroke subtype, %</th>
<th>Reported comorbidities, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986/1987</td>
<td>Mean (SD) age, y</td>
<td>Age group, %</td>
<td>Stroke subtype, %</td>
<td>Reported comorbidities, %</td>
</tr>
<tr>
<td>1988/1989</td>
<td>69.3 (12.7)</td>
<td>11.5</td>
<td>5.1</td>
<td>6.4</td>
</tr>
<tr>
<td>1990/1991</td>
<td>69.4 (12.6)</td>
<td>11.5</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>1992/1993</td>
<td>69.4 (12.8)</td>
<td>11.3</td>
<td>5.1</td>
<td>5.7</td>
</tr>
<tr>
<td>1994/1995</td>
<td>69.6 (13.0)</td>
<td>11.8</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>1996/1997</td>
<td>69.2 (13.3)</td>
<td>12.4</td>
<td>5.1</td>
<td>5.3</td>
</tr>
<tr>
<td>1998/1999</td>
<td>69.3 (13.1)</td>
<td>12.8</td>
<td>5.1</td>
<td>5.9</td>
</tr>
<tr>
<td>2000/2001</td>
<td>69.0 (13.1)</td>
<td>13.1</td>
<td>5.2</td>
<td>5.9</td>
</tr>
<tr>
<td>2002/2003</td>
<td>69.1 (13.2)</td>
<td>13.9</td>
<td>5.3</td>
<td>5.5</td>
</tr>
<tr>
<td>2004/2005</td>
<td>69.2 (13.3)</td>
<td>14.0</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>2006/2007</td>
<td>68.9 (13.6)</td>
<td>14.9</td>
<td>5.5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

DVT indicates deep vein thrombosis.
were more complex, increasing from 1990 to reach a peak in 1994 after which it began to decline. By 2005 the overall probability of incident hospitalization with stroke had fallen by 16% in men and 19% in women relative to 1986.

This decline in incident hospitalization is similar to a number of other population-based studies, including a recent study in Quebec involving 101,831 stroke episodes which reported declining hospitalization rates of cerebral infarction, particularly from 1998 to 2002.18 and the U.S. National Hospital Discharge Survey which also found a decline in stroke hospitalization rates between 1997 and 2004.13 The Finnish Hospital Discharge Register identified 165,366 incident strokes and reported declining rates in men and women between 1991 and 2002.10 The declines in stroke incidence rates observed in whole populations are very encouraging.

Unlike studies such as the National Hospital Discharge Survey which examined hospitalization rates,13 they allow us to be confident that this is attributable to a genuine reduction in first events, uncomplicated by large numbers of recurrent events. However, there are no studies with which to compare our population-based rates for all-incident stroke and nonhospitalized fatal stroke. Although the Finnish Study examined identified temporal trends in deaths from incident stroke, it did not examine rates of nonhospitalized fatal stroke in men and women and different age groups.10

**Table 3. Trends in Age, Stroke Subtype, and Comorbidity of First Hospitalizations for Stroke in Scotland in Women, 1986 to 2005**

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean (SD) age, y</th>
<th>Age group, %</th>
<th>Stroke subtype, %</th>
<th>Reported comorbidities, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986/1987</td>
<td>73.7 (12.6)</td>
<td>&lt;55 y</td>
<td>Subarachnoid haemorrhage</td>
<td>Diabetes</td>
</tr>
<tr>
<td>(n=8740)</td>
<td></td>
<td>7.8</td>
<td>7.0</td>
<td>6.3</td>
</tr>
<tr>
<td>1988/1989</td>
<td>74.3 (12.7)</td>
<td>55 to 64 y</td>
<td>Intracerebral haemorrhage</td>
<td>4.0</td>
</tr>
<tr>
<td>(n=8716)</td>
<td></td>
<td>11.1</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>1990/1991</td>
<td>74.3 (12.8)</td>
<td>65 to 74 y</td>
<td>Cerebral infarction</td>
<td>10.3</td>
</tr>
<tr>
<td>(n=8784)</td>
<td></td>
<td>24.9</td>
<td>10.3</td>
<td>10.3</td>
</tr>
<tr>
<td>1992/1993</td>
<td>74.4 (12.9)</td>
<td>75 to 84 y</td>
<td>Not specified</td>
<td>78.7</td>
</tr>
<tr>
<td>(n=9449)</td>
<td></td>
<td>39.1</td>
<td>78.7</td>
<td>78.7</td>
</tr>
<tr>
<td>1994/1995</td>
<td>74.1 (13.5)</td>
<td>&gt;=85 y</td>
<td>Subarachnoid haemorrhage</td>
<td>7.0</td>
</tr>
<tr>
<td>(n=9433)</td>
<td></td>
<td>17.1</td>
<td>7.0</td>
<td>6.3</td>
</tr>
<tr>
<td>1996/1997</td>
<td>74.2 (13.3)</td>
<td>55 y</td>
<td>Intracerebral haemorrhage</td>
<td>4.0</td>
</tr>
<tr>
<td>(n=8619)</td>
<td></td>
<td>11.1</td>
<td>3.9</td>
<td>4.0</td>
</tr>
<tr>
<td>1998/1999</td>
<td>74.1 (13.7)</td>
<td>65 to 74 y</td>
<td>Cerebral infarction</td>
<td>10.3</td>
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<tr>
<td>(n=8868)</td>
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<td>24.9</td>
<td>10.3</td>
<td>10.3</td>
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<tr>
<td>2000/2001</td>
<td>74.1 (14.0)</td>
<td>75 to 84 y</td>
<td>Not specified</td>
<td>78.7</td>
</tr>
<tr>
<td>(n=8551)</td>
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<td>39.1</td>
<td>78.7</td>
<td>78.7</td>
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<tr>
<td>2002/2003</td>
<td>74.1 (14.0)</td>
<td>&gt;=85 y</td>
<td>Subarachnoid haemorrhage</td>
<td>7.0</td>
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<tr>
<td>(n=8114)</td>
<td></td>
<td>17.1</td>
<td>7.0</td>
<td>6.3</td>
</tr>
<tr>
<td>2004/2005</td>
<td>74.2 (14.0)</td>
<td>55 y</td>
<td>Intracerebral haemorrhage</td>
<td>4.0</td>
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<tr>
<td>(n=7639)</td>
<td></td>
<td>11.1</td>
<td>3.9</td>
<td>4.0</td>
</tr>
</tbody>
</table>

DVT indicates deep vein thrombosis.
different age groups. The decline in incidence for hospitalized stroke started later in younger age groups and in those aged less than 55 years only began to decline from 2001 and 2000 in men and women, respectively. In 2005, the risk of hospitalized incident stroke in these young people was 31% greater in men and 22% greater in women compared to 1986. A few studies have reported population-based age- and sex-specific temporal trends in stroke incidence rates, with conflicting findings. Similar to the results of our study, the National Hospital Discharge Survey found that stroke hospitalization rates started to decline in 1997 but only in those aged 65 years and greater. No change was observed in younger age groups. In the Quebec Study, there was actually a small increase in stroke hospitalization rates in the under <55-year-olds but with substantial declines in all other age groups. The Oxford Vascular Study also described increasing rates of incident stroke in those aged 45 to 54 years, although these were based on very small numbers of events (13 strokes in 1981 to 84 and 15 in 2002 to 4). A number of other studies, including the Perth Community

Figure 1. Rates of first stroke for men plotted against year for all ages (A), <55 years (B), 55 to 64 years (C), 65 to 74 years (D), 75 to 84 years (E), and ≥85 years (F) (lines with circles indicate total rates; lines with squares, first hospitalization rates; lines with triangles, out of hospital death rates; black lines, observed rates; gray lines, predicted rates). Rate ratios (95% CIs) for total rates comparing 2005 with 1986 are shown.
Stroke Study and Auckland Regional Community Stroke Study, reported declines in incident stroke rates across all age groups.\textsuperscript{20,21} In contrast to these findings, a number of other studies have reported stable or increasing stroke incidence.\textsuperscript{8,11,12} However, only 1 was population-based using the Swedish Hospital Discharge Register and was restricted to individuals aged 35 to 65 years in whom an increase in stroke incidence was seen.\textsuperscript{8} This age restriction may have contributed to their findings if, in Sweden as in Scotland, greater declines in incidence occurred in older individuals.\textsuperscript{8} Although the Stroke Registry in Dijon reported stable stroke incidence rates between 1985 and 2004, the data were stratified into only 2 groups (less than and equal to or greater than 85 years).\textsuperscript{14} The Stroke Register in Malmo, Sweden found increasing incidence of stroke between 1989 and 1998 which was greater in younger age groups.\textsuperscript{11} Thus few studies have examined age- and sex-specific trends in stroke incidence, presumably because of relatively small numbers especially in younger age groups. The examination of age-specific trends is important as presentation of standard-

**Figure 2.** Rates of first stroke for women plotted against year for all ages (A), <55 years (B), 55 to 64 years (C), 65 to 74 years (D), 75 to 84 years (E), and $\geq 85$ years (F) (lines with circles indicate total rates; lines with squares, first hospitalization rates; lines with triangles, out of hospital death rates; black lines, observed rates; gray lines, predicted rates). Rate ratios (95% CIs) for total rates comparing 2005 with 1986 are shown.
ized results can mask important differences between age groups. Description of temporal trends in stroke hospitalization on a population basis is vital for healthcare planning and evaluation of interventions. It is however important to also consider nonhospitalized fatal stroke events which are excluded when examining hospital discharge data. There have been dramatic declines in the incidence of nonhospitalized fatal stroke, which were especially evident in the elderly with the risk falling by 74% in men and 73% in women aged 75 to 84 years. Nonhospitalized fatal strokes comprise a mix of individuals managed at home and those who die suddenly from an incident event. Small prospective studies such as the Stroke Register in Malmo, Sweden and the Soderham Study, also in Sweden, have estimated that the majority of individuals who experience a stroke are hospitalized, 95% in both studies. It is likely that the proportion of individuals who experience a stroke and are hospitalized has increased in recent years in line with the development of stroke units and more active management.

**Strengths and Weaknesses of the Study**

No other study has examined incident stroke hospitalizations and deaths in an entire country over 3 decades. The size of our study has allowed us to examine age- and sex-specific temporal trends in stroke incidence that until now have been poorly described. As with any study of this type there are limitations. Hospital discharge data will only identify patients admitted to hospital with stroke and will exclude those managed at home. Several community-based studies report that more than 80% of patients with stroke are managed in hospital, including the South London Stroke Register in which 85% of individuals with a first stroke were hospitalized between 1995 and 2002. Estimates vary, and this figure is likely to have increased over time. In the Perth Community Study, the proportion of individuals hospitalized over time increased from 78.5% in 1989 to 1990 to 92.3% in 2000 to 2001, although these figures are based on small numbers. In addition, by including fatal stroke events we will capture those individuals who experience a severe stroke and whose death is managed at home. The validity of death certificate data has been questioned in the estimation of stroke-related mortality as it is believed to underestimate stroke-related burden. However, our study aims to measure incidence of stroke and linkage of hospital discharge data to mortality data has enabled us to identify a single incident event. The FINMONICA Stroke Register Study Group assessed the validity of hospital discharge data and cause of death data and suggested that these data could, with caution, be used for incidence studies. We have used discharge coding to identify the study cohort. Although internal validation studies of the Scottish Morbidity Record Scheme have proved these data to be accurate, the diagnostic accuracy and overall quality of data may vary on an institutional basis. In addition, although classification of stroke subtype has increased over time after the widespread introduction of computed tomography and MRI, it remains nonspecified in approximately one third of cases. It is difficult to compare these figure with other studies that have examined routine hospital discharge data, as a number of other studies have either not described the proportion of nonspecified strokes or have included them in the ischemic category. Population-based data from hospital discharge at present lacks treatment and clinical detail as well as information regarding ethnicity. However, Scotland is relatively homogenous in ethnicity, and in the 2001 census only 2.01% of individuals were from ethnic minority groups. In our study an incident stroke was defined as a hospitalization with a principal diagnosis of stroke with no previous hospitalization for cerebrovascular disease within the previous 5 years. We acknowledge that a small proportion of individuals, roughly 3%, will have experienced a previous stroke outwith this period. As this study examines temporal trends, it is especially important to avoid a temporal bias that may affect the interpretation of the findings. Looking back to 1981 would potentially introduce a temporal bias as the incidence of “true” incident events would increase over the study period, whereas the incidence of unknown “false” incident events would decrease over time. Application of a consistent 5-year look back will introduce a small but systematic bias that should not impact on the observed temporal trends. Finally, though some losses to follow-up might be expected, emigration of people of “pensionable age” from Scotland was <2% per decade.

Why has stroke incidence declined and why did this decline start earlier in older age groups than in younger age groups? Stroke trends reflect changes in major risk factors, particularly blood pressure. Primary preventive strategies and risk factor modification have undoubtedly helped to reduce incidence of strokes along with other vascular events such as myocardial infarction. It is possible that the earlier and more rapid decline in stroke incidence seen in older individuals is a reflection of secular trends compounded by more aggressive primary and secondary prevention in those with known adverse risk profiles or existing vascular disease. The rise in incident stroke hospitalization seen in men and women aged less than 55 years is a worrying finding. There are a number of potential explanations including increasing levels of obesity and binge drinking, as well as increasingly sedentary lifestyles.

The age distribution and medical profile of individuals hospitalized with an incident stroke appears to be changing. Although the mean age of hospitalization remained relatively stable over the time period, the proportions of young and very elderly increased. One in 7 individuals hospitalized with a first stroke in 2004 to 2005 were under the age of 55 years compared to 1 in 9 in 1986 to 1987. There are very few data with which to compare these figures. Most studies examining stroke incidence have not examined the age distribution of men and women hospitalized with stroke, and, of those that have, most have used broad age categories. In the Quebec Study, 7% of individuals hospitalized with stroke were aged less than 55 years in 1988 rising slightly to 8% in 2002. This is less than the proportion seen in this study, however the Quebec Study included all hospitalizations, not just first, and we would therefore expect this population to be older. In the Oxford Vascular Study 10% of men and 6% of women with an incident stroke in 2002 to 2004 were aged less than 55 years. Neither of these studies reported significant increases
in the proportion of young people contributing to the total burden of stroke. These changes may in part reflect a reduced hospital admission and diagnostic threshold, especially at the extremes of age. Changes in admission and diagnostic threshold may also have impacted on stroke incidence rates. Although the majority of individuals who experience a first stroke are now hospitalized, the likelihood of admission to hospital has increased slightly over time, especially in the elderly. A reduced admission threshold in the elderly may also have contributed to the reduction in incidence observed for nonhospitalized fatal stroke. Diagnostic threshold may have changed so that more sophisticated imaging techniques have enabled identification of minor strokes in younger people who may not have been diagnosed with cerebrovascular disease previously. Although the incident rates of stroke declined over time, there was an increase in the proportion of individuals coded with comorbid diagnoses. Although this in part could be attributable to improvements in coding of secondary diagnoses, this finding supports the suggestion that there is more aggressive primary and secondary prevention with recognition and management of adverse risk factors such as hypertension and diabetes.

In conclusion, we have shown encouraging declines in the incidence of first stroke events between 1986 and 2005. Reductions in rates of both hospitalized and nonhospitalized fatal stroke contributed to this overall decline. The risk of hospitalization for incident stroke fell in all age groups except in those aged under 55 years in whom the risk of hospitalization increased by 31% and 22% in men and women in those aged under 55 years in whom the risk of hospitalization for incident stroke fell in all age groups except fatal stroke contributed to this overall decline. The risk of hospitalization declined over time, especially in the younger age groups. This finding supports the suggestion that there is a reduction in primary and secondary prevention with recognition and management of adverse risk factors such as hypertension and diabetes.

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