Mortality Rates for Stroke in England From 1979 to 2004
Trends, Diagnostic Precision, and Artifacts

Michael J. Goldacre, FFPHM; Marie Duncan, PhD; Myfanwy Griffith, MSc; Peter M. Rothwell, MD

**Background and Purpose**—Stroke mortality appears to be declining more rapidly in the UK than in many other Western countries. To understand this apparent decline better, we studied trends in mortality in the UK using more detailed data than are routinely available.

**Methods**—Analysis of datasets that include both the underlying cause and all other mentioned causes of death (together, termed “all mentions”): the Oxford Record Linkage Study from 1979 to 2004 and English national data from 1996 to 2004.

**Results**—Mortality rates based on underlying cause and based on all mentions showed similar downward trends. Mortality based on underlying cause alone misses about one quarter of all stroke-related deaths. Changes during the period in the national rules for selecting the underlying cause of death had a significant but fairly small effect on the trend. Overall, mortality fell by an average annual rate of 2.3% (95% confidence interval 2.1% to 2.5%) for stroke excluding subarachnoid hemorrhage; and by 2.1% (1.7% to 2.6%) per annum for subarachnoid hemorrhage. Coding of stroke as hemorrhagic, occlusive, or unspecified varied substantially across the study period. As a result, rates for hemorrhagic and occlusive stroke, affected by artifact, seemed to fall substantially in the first part of the study period and then leveled off.

**Conclusion**—Studies of stroke mortality should include all mentions as well as the certified underlying cause, otherwise the burden of stroke will be underestimated. Studies of stroke mortality that include strokes specified as hemorrhagic or occlusive, without also considering stroke overall, are likely to be misleading. Stroke mortality in the Oxford region halved between 1979 and 2004. (Stroke. 2008;39:2197-2203.)

**Key Words:** stroke ■ mortality ■ death certificate ■ England

Stroke mortality rates declined from the 1950s to 1980s in North America and Western Europe, but in many countries this decline has since leveled-off. Stroke incidence also appeared to decline in the 1960s and 1970s in the United States,5 Asia,6 and Europe:5–11 but this latter decline has also leveled off, and most studies during the 1980s and 1990s have shown either no change12–16 or more commonly an increase in age- and sex-adjusted incidence.17–26

In contrast, UK stroke mortality rates based on death certification have declined steeply in recent decades.2,27 The decline in the UK appears to be consistent with a 40% decline in population-based stroke incidence and mortality in Oxfordshire, UK, between 1981 to 2004 and 2002 to 2004,28 but national mortality data could have overestimated the time trends in the UK as a whole because of changes in the practice of death certification. Conventional mortality statistics are based on the selection of 1 underlying cause from each death certificate. For some deaths where stroke is regarded by the certifying physician as contributing to death, stroke may not be certified as the underlying cause. Until the mid-1990s, the underlying cause of death was the only measure routinely coded and analyzed for national mortality statistics in England: before then, other causes of death on death certificates were generally disregarded. Because of this, routine statistics, based on underlying cause alone, tend to underestimate mortality attributable to each individual disease. A further potential problem in using data on the underlying cause of death alone is that the coding rules for selecting the underlying cause of death change from time to time. An important example was the rigorous implementation in England in 1984 of rule 3 of the ninth revision of the International Classification of Diseases.29,30 This rule specified that certain diseases, which can be modes of dying (such as pneumonia or heart failure) rather than causes of death, should not be selected as the underlying cause of death if another “primary condition” (such as stroke) is present. The instructions for the compilers of official statistics specify that, if the disease that is certified by the doctor as the underlying cause of death “can be considered a direct sequel of another reported condition, select this primary condition” as the underlying cause.29

Received November 12, 2007; final revision received December 17, 2007; accepted December 19, 2007.
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**Stroke** is available at http://stroke.ahajournals.org

DOI: 10.1161/STROKEAHA.107.509695
There were further changes to the rules for selecting the underlying cause of death in England in 1993 and 2001.\textsuperscript{31,32} All certified causes of death in the former Oxford Regional Health Authority population were routinely coded from 1979 as part of the Oxford Record Linkage Study (though they did not become available for England as a whole until the 1990s).\textsuperscript{33} To better understand the apparently large decline in stroke mortality in England, we were therefore able to analyze stroke mortality overall and by subtype, and report on trends in mortality for all mentions of deaths certified as stroke, as well as underlying cause, in Oxford from 1979 and in England from 1996.

**Methods**

**Populations**

The former Oxford National Health Service Region covered 4 counties of England (population 2.5 million). Unlike other parts of England, every cause of death on each death certificate—not just the underlying cause—was recorded for its residents from 1979. The underlying cause was selected and coded according to the rules that prevailed nationally in England at the time. Following convention, all certified causes of death—underlying cause plus causes elsewhere on the certificate—are termed “mentions” in this article.

The English national data were analyzed from mortality files supplied by the English Office for National Statistics (ONS); the files cover the period 1996 to 2005. Some deaths that occur within a year are not registered until after the end of the year. For that reason, we identified deaths in 2004 when they were in the dataset for 2005; but we confined the analysis presented here, both for England and for Oxford, to an end-year of 2004. Deaths were coded to the ninth revision of the International Classification of Diseases (ICD9) for the years 1979 to 2000 and to ICD10 for 2001 to 2004 for both datasets.\textsuperscript{29,32}

**Analysis**

For each population, we selected all certificates with a mention of subarachnoid hemorrhage (SAH) (ICD9 430, ICD10 I60), other hemorrhagic stroke (ICD9 431 to 432, ICD10 I61 to I62), occlusive stroke (ICD9 433 to 434, ICD10 I63), unspecified stroke (ICD9 436, ICD10 I64), all cerebrovascular disease including SAH (ICD9 430 to 434,436,438; ICD10 I60 to I64,I69) and all cerebrovascular disease excluding SAH (ICD9 431 to 434,436,438; ICD10 I61 to I64,I69). In the grouped analyses, a death with 2 stroke diagnoses in the group on the death certificate was counted once only as a death from the grouped diagnosis. We age-standardized overall and within broad age groups by applying the age-specific death rates, in 5-year age groups up to the age of 85 years, in each population in each year to the European standard population to calculate standardized rates for each calendar year or group of years. Population denominators were not available in 5-year age groups over 85 years. We also calculated the 95% confidence intervals on the rates. To assess long-term trends and their significance, we calculated the average annual percentage change over time in mortality rates for mentions by fitting regression models to the logarithms of the annual death rates. In the case of the Oxford population, we also grouped the rates into 3 broad time periods defined by differences between them in the national rules for the selection of underlying causes of death—1979 to 1983, 1984 to 1992 and 1993 to 2004.\textsuperscript{30,31}

**Results**

Mortality rates for all types of stroke decreased substantially between 1979 and 2004 in the Oxford region. The profile of...
the decline over time differed considerably between the different types of stroke (Figure).

**Stroke (Excluding Subarachnoid Hemorrhage)**

Analysis of death by underlying cause identified only about three-quarters of all certified stroke deaths (Table 1). The percentage varied significantly according to time period (Table 1). In the Oxford region, analysis by underlying cause identified 80% (10 749/13 480) of deaths in 1979 to 1983, 84% (20 459/24 236) in 1983 to 1992, and only 75% (23 737/31 689) in 1993 to 2004. As measured by mentions (Figure b, upper line), there was a decline in stroke mortality that was substantial, steady, and consistent over time. As measured by underlying cause alone (Figure b, lower line), in addition to the steady decline there was a downward shift in the death rate between the years 1984 to 1992 and 1993 to 2000 and a smaller upward shift in 2001 to 2004. The downward shift is an artifact attributable to changes in coding rules: it reflects the reduction in stroke deaths that were coded with stroke as the underlying cause (Table 1). The upward shift in 2001 reflects changes that followed the adoption of the 10th revision of the International Classification of Diseases. The shifts in underlying cause of death are noteworthy because mortality rates based on the underlying cause alone are generally the only rates available for stroke in official English mortality statistics.

Mortality rates for stroke (excluding SAH) were higher in men than women in each age group up to 85 years (Table 1). The apparent convergence of rates for men and women in the highest age group probably reflects the fact that we were unable to age-standardize within the over-85s, combined with the fact that there are many more elderly women than men in the population. In the Oxford region from 1979 to 2004, death rates based on mentions fell significantly by an average of 2.3% per year overall. There were larger falls of 3.3% to 4.1% in the age groups 55 to 64 and 65 to 74 years. The decline in mortality rates in people aged 75 years and over was significantly smaller than that in the 55 to 64 and 65 to 74 age groups (as shown by the fact that the confidence intervals on the percentage changes do not overlap; Table 1). A significant average annual fall of 3.5% overall, based on mentions, was seen in England from 1996 to 2004 (3.7% for men and 3.2% for women). Mortality rates for stroke were about 7% lower in the Oxford region than in England, both for underlying cause (658.4 and 702.7 deaths per million) and mentions (898.2 and 957.7 deaths per million), but the general pattern of decline was similar in the 2 populations.

**Specific Types of Stroke as a Percentage of All Stroke**

There was substantial variation over the years in the percentage of deaths from stroke where the type of stroke was specified. When a change in stroke mortality overall coin-

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**Table 1. Age-Specific Mortality Rates* for Stroke Excluding Subarachnoid Hemorrhage, Showing Deaths Coded as Underlying Cause (UC) and as Mentions (M), Percentage of Mentions With Stroke as Underlying Cause (UC/M%), and Average Annual Change in Mention-Based Rates**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>n</th>
<th>Underlying Cause Rates per Million</th>
<th>Mentions Rates per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men: Oxford</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 to 54</td>
<td>975</td>
<td>47.7</td>
<td>39.9</td>
</tr>
<tr>
<td>55 to 64</td>
<td>2164</td>
<td>725.3</td>
<td>539.5</td>
</tr>
<tr>
<td>65 to 74</td>
<td>6805</td>
<td>3188.4</td>
<td>2600.1</td>
</tr>
<tr>
<td>75 to 84</td>
<td>11 814</td>
<td>10 405.3</td>
<td>9640.5</td>
</tr>
<tr>
<td>85+</td>
<td>5805</td>
<td>22 593.8</td>
<td>22 988.9</td>
</tr>
<tr>
<td>Oxford (15+)</td>
<td>27 563</td>
<td>1113.4</td>
<td>1003.6</td>
</tr>
<tr>
<td>Women: Oxford</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 to 54</td>
<td>662</td>
<td>35.8</td>
<td>27.6</td>
</tr>
<tr>
<td>55 to 64</td>
<td>1470</td>
<td>520.7</td>
<td>374.3</td>
</tr>
<tr>
<td>65 to 74</td>
<td>5757</td>
<td>2297.9</td>
<td>1876.7</td>
</tr>
<tr>
<td>75 to 84</td>
<td>16 689</td>
<td>9406.3</td>
<td>8261.6</td>
</tr>
<tr>
<td>85+</td>
<td>17 264</td>
<td>26 098.0</td>
<td>25 377.6</td>
</tr>
<tr>
<td>Oxford (15+)</td>
<td>41 842</td>
<td>1001.7</td>
<td>884.1</td>
</tr>
<tr>
<td>England (15+)</td>
<td>311 273</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Total: Oxford</td>
<td>69 405</td>
<td>1057.5</td>
<td>943.9</td>
</tr>
<tr>
<td>England</td>
<td>517 120</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*Age-standardized within 5-year age groups, except in the over-75 age group (see text).
‡Change between percentage of mentions coded as underlying cause in the asterisked period, statistically significant at $P<0.05$; ‡‡$P<0.01$; ‡‡‡$P<0.001$.
§Statistically significant change.

(Continued)
cides with a change in the percentage of strokes that are of specified type, the change in mortality for the specified types of stroke may be hard to interpret. For example, in the Oxford region, the type of stroke—occlusive or hemorrhagic—was specified in 41% of all underlying cause stroke deaths in 1979, falling to 33% in 1984, 20% in 1994, and then increasing to 30% in 2004. It follows that, when a fall in overall stroke mortality coincides with a change in the percentage of strokes that are of hemorrhagic or occlusive type on death certificates, the change in mortality for the specified types of stroke may be hard to interpret. For example, in the Oxford region, the type of stroke—occlusive or hemorrhagic—was specified in 41% of all underlying cause stroke deaths in 1979, falling to 33% in 1984, 20% in 1994, and then increasing to 30% in 2004. It follows that, when a fall in overall stroke mortality coincides with an increase in the percentage of deaths in which the type of stroke is specified, the decline in rates for the individual type of stroke are artifactually exaggerated. This is seen in the first half of the period (Figure d and e) when there was a substantial apparent fall in mortality rates for strokes specified as hemorrhagic or occlusive. When a fall in overall stroke mortality coincides with an increase in the percentage of stroke with specification of type, the fall seen overall will not be reflected as much (if at all) in the trends for the individual types of stroke. This is what is seen for hemorrhagic and occlusive stroke from the late 1980s (Figure d and e) when the mortality rates for each type of stroke appeared to level out.

Table 2 shows summarized mortality rates for occlusive and hemorrhagic stroke subtypes, and for all stroke, in the first and second parts of the study period. The apparent fall in hemorrhagic and occlusive stroke in the first period is exaggerated by changes in certification practice; and the apparent leveling off in the second period is attributable, at least in part, to further changes in practice in recording stroke type on death certificates. Consideration of the individual components in combination—hemorrhagic stroke, occlusive stroke, and stroke of unspecified type (Figure d, e, c)—shows the steady downward trend overall (Figure b; Table 2).

**Subarachnoid Hemorrhage**

Analysis of underlying cause of death identified more than 90% of all deaths with SAH on the death certificate (93.1% 2918/3133 of the deaths in Oxford, 91.1% 20 961/23 003 of those in England; Table 3). SAH rates, measured as underlying cause, were affected by the coding changes of 1984 and 1993 (Table 3). The percentage of deaths with SAH on the certificate, that were coded as the underlying cause, was

<table>
<thead>
<tr>
<th>Stroke Type</th>
<th>% Change</th>
<th>95% CI</th>
<th>% Change</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>All stroke including subarachnoid hemorrhage</td>
<td>-2.4</td>
<td>-2.8</td>
<td>-2.0</td>
<td>-2.8</td>
</tr>
<tr>
<td>All stroke except subarachnoid hemorrhage</td>
<td>-2.4</td>
<td>-2.8</td>
<td>-2.0</td>
<td>-2.8</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>-3.6</td>
<td>-5.1</td>
<td>-2.1</td>
<td>-2.3</td>
</tr>
<tr>
<td>Occlusive stroke</td>
<td>-9.9</td>
<td>-11.6</td>
<td>-8.1</td>
<td>-1.7</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>-8.0</td>
<td>-9.1</td>
<td>-6.9</td>
<td>0.1</td>
</tr>
</tbody>
</table>
significantly higher in 1984 to 1992 than in the periods before and after.

Mortality rates for SAH fell substantially in Oxford from 1979 to the late 1980s (Figure f; Table 2). For several years after that, the profile is somewhat inconsistent with a hint of a rise, a plateau, and then a further fall (Figure f). However, numbers of deaths in each year are fairly small and confidence intervals are wide. Considering the period 1992 to 2004 overall (Table 2), there was a significant fall in death rates for SAH. From the late 1990s, the data for SAH mortality both for Oxford and England show a consistent fall. Rates in England fell from 1996 to 2004 with an average annual change, similar in men and women, of $1.8\%$ (95% confidence interval $0.9$ to $2.7$).

Mortality rates for SAH in people aged 55 years and over were substantially higher in women than men (Table 3) and, in this respect, show a striking contrast with the higher rates in men than women in other stroke (Table 1). In people aged less than 55, SAH comprised 36.7% of all SAH and other stroke combined (951/2588 deaths). In people aged 55 years and over, SAH comprised 1.9% of deaths from the combined cerebrovascular diseases (2182/111 792).

**Discussion**

Our results show substantial falls in stroke mortality in the Oxford region, in both sexes and all age groups, over a recent 26-year period. Mortality rates for stroke, recorded as underlying cause and as mentions, halved in this English population between 1979 and 2004. This decline is therefore consistent with the previously reported 40% decline in population-based stroke incidence and mortality in Oxfordshire, UK, between 1981 to 1984 and 2002 to 2004. The population-based estimate was based on relatively small number of fatal strokes and had a wide confidence interval. Our current analysis, based on much larger numbers, suggests that it was nevertheless reasonably precise. Similar falls in total stroke mortality have been reported recently in a US population.

Our data show that deaths attributable to stroke, if considered as only the underlying cause, miss about a quarter of all deaths with stroke as a certified cause. Consequently, in using data on underlying cause of death alone, as the commonly used measure, the population “burden” of stroke as a cause of death is substantially underestimated. However, it is also possible that some mentions might include deaths in people who have had a stroke in the past but where the stroke had little causal relevance to the death. This is particularly likely with long-time intervals between stroke and death.

The impact of coding changes on death certification is not widely recognized. The coding rule changes in the UK in 1984, 1993, and 2001 had some impact on death certification of stroke as the underlying cause of death, but the effect was fairly small. Nonetheless, because data about all certified causes of death are now available, it is prudent to consider...
numbers and rates based on mentions as well as those for underlying cause in studies of trends in stroke mortality.

Improvements in stroke prevention and stroke care appear to be largely responsible for the substantial decrease in mortality observed. The Oxford Vascular Study (2004) found reductions in stroke incidence and mortality between 1981 and 2004 to be associated with significant increases in the use of preventive treatments such as antihypertensives and cholesterol lowering drugs and major reductions in premorbid risk factors such as smoking and cholesterol levels.28 The implementation of the National Stroke Audit Program in England should result in continued improvements in care and survival.36 The majority of stroke deaths in the UK do not have the type of stroke on the death certificate (with the exception of subarachnoid hemorrhage). The extent to which stroke is certified without specification of type, and therefore classified and coded as stroke “unspecified,” has varied over time and no doubt varies from place to place. It follows that considerable caution is needed in interpreting mortality data for occlusive and hemorrhagic stroke rather than stroke overall. In the past decade the pattern of stroke, overall, better reflects the reality of stroke incidence and mortality than that of the subtypes. We can only speculate about why doctors have changed their practice of attributing stroke deaths to particular types of stroke or to stroke generically. It is possible that the introduction of scanning led initially to an increasing tendency to certify subtypes; and that thereafter, paradoxically, experience with scanning led to the recognition in the 1990s that clinical presentation did not necessarily reliably predict pathological subtypes. This might have influenced a shift back to generic certification.

In summary, after considering the impact of artifact, there has been a steady and consistent decline in stroke mortality in England, year on year, over the past 25 years with no evidence of any slow-down.

Sources of Funding

The Unit of Health-Care Epidemiology is funded by the English Department of Health’s National Co-ordinating Centre for Research Capacity Development.

Disclosures

None.

References


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*Stroke.* 2008;39:2197-2203; originally published online June 5, 2008;
doi: 10.1161/STROKEAHA.107.509695

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

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