Direct Assessment of Completeness of Ascertainment in a Stroke Incidence Study

A.J. Coull, MRCP; L.E. Silver, MSc; L.M. Bull, RN; M.F. Giles, MRCP; P.M. Rothwell, FRCP; on behalf of the Oxford Vascular (OXVASC) Study

Background and Purpose—Validity of comparisons of stroke incidence between studies or time periods depends on the completeness of ascertainment. Ascertainment cannot be reliably assessed indirectly by statistical methods, such as capture–recapture. We report the first use of direct methods to determine the completeness of different ascertainment strategies in a population-based stroke incidence study (Oxford Vascular Study).

Methods—We assessed completeness of 2 different ascertainment strategies: the core methods common to most previous incidence studies and core plus supplementary methods used in some studies (including access to carotid and brain imaging referrals and assessment of patients referred as “transient ischemic attack” or “recurrent stroke”). We assessed completeness of ascertainment in 2 ways. First, we searched anonymized primary care electronic patient records of the whole study population (n=90,542). Second, we interviewed and followed-up a high-risk subset of our study population: all patients who had an acute coronary or peripheral vascular event or a related elective investigation or intervention.

Results—126 strokes were ascertained by the core plus supplementary methods, of which only 108 were identified by the core methods alone. Only 2 additional incident strokes were identified by access to primary care electronic patient records of the whole study population. Assessment and follow-up of 1103 high-risk individuals (5.5% of our total study population aged older than 60 years) identified 16 incident strokes. However, all 16 had already been ascertained by the core plus supplementary methods.

Conclusions—The core methods of ascertainment used in some stroke incidence studies lead to significant underascertainment. However, direct assessment of ascertainment suggests that the supplementary methods used in recent studies can lead to near-complete ascertainment. (Stroke. 2004;35:2041-2047.)

Key Words: epidemiology □ incidence □ stroke

Comparing stroke incidence between studies and measuring changes in incidence over time requires studies to use the same case definitions and methods of ascertainment.1 However, there are few published data on the effect of different methods and intensity of ascertainment on measured incidence rates. Several stroke and/or transient ischemic attack (TIA) incidence studies2–21 have fulfilled the methodological criteria published by Malmgren et al22 and refined by Sudlow and Warlow,23 but there is still considerable variation in methods of ascertainment between these studies (Table 1). Some differences will be related to the organization of health care in the particular country or area, but others are more generic. For example, the studies in Table 1 differed in relation to whether patients referred as “TIA” or “recurrent stroke” were reviewed, and only half used carotid and brain imaging referrals as a method of ascertainment. These supplementary search strategies may have important effects on ascertainment and hence measured incidence rates.

See Editorial Comment, page 2045

Assessment of the completeness of ascertainment is very difficult. Several indirect statistical modeling methods, including capture–recapture,24 have been proposed, but these are poorly validated and are based on several assumptions, the validity of which are often uncertain.25–29 Capture–recapture models have frequently been shown to be unreliable in situations in which these assumptions do not hold true.27–29 For example, when sources are dependent,30 or when some sources have a very low probability of capture,31 capture–recapture methods are inapplicable. It is possible to allow for the violation of these assumptions using covariates, but when some categories have small numbers, the resulting estimates are unstable.32

Direct assessment of the completeness of ascertainment is time-consuming and expensive, and has not previously been attempted in a stroke incidence study, but is likely to be more reliable. We used 2 direct methods to estimate potential
underascertainment in the Oxford Vascular Study (OXVASC). First, to identify nonascertained patients who had presented to medical attention but had not been notified to the study, we accessed anonymized primary care electronic patient records of all of our study population. Second, to estimate the number of individuals who had had a stroke but were not ascertained because they had not been notified to the study or had not presented to medical attention after their stroke, we interviewed and followed-up a subset of our population that we considered to be at high risk for stroke: all patients who had an acute coronary or peripheral vascular event or a related elective investigation or intervention.

Subjects and Methods

Study Population

The population (n=90,542) comprised all patients who were fully registered with 63 family physicians (FP) in 9 primary health care centers in Oxfordshire, UK. In the UK, patients register with an FP who provides primary health care and, when necessary, refers them to secondary care. The FP receives all relevant information about specialist consultations, emergency department attendance, and hospital admissions. Thus, the FP holds a lifelong record of all medical events as well as details of each consultation with the FP. This individual record is transferred to a new FP if the patient moves residence. The collaborating FP practices were chosen if they routinely referred patients to Oxford Hospitals, had an accurate computerized age-sex register (ASR), were willing to refer any patient with a suspected acute cerebrovascular event, and were computerized, allowing searches for cerebrovascular diagnostic codes. The ASR provided accurate and up-to-date estimates of the denominator, allowing easy identification of cross-boundary flow and turnover within the population. The population was 94% white, 3.1% Asian, 1.5% Chinese, and 1.4% black Caribbean.

Case Ascertainment

We attempted to ascertain all incident or recurrent strokes and TIAs occurring between April 1, 2002, and March 31, 2003. Ascertained continued for 3 months until June 30, 2003, for patients presenting late with a TIA or stroke that had occurred on or before March 31, 2003. Case ascertainment included patients who had an event while temporarily away from Oxford, but not visitors to Oxford who were not normally resident or registered with a FP. A liaison FP in each practice checked with colleagues regularly to ensure that all relevant patients were referred, and a study nurse visited each practice monthly. A quarterly newsletter was sent to all FPs. The study was approved by the Oxfordshire Research Ethics Committee. Multiple overlapping sources of case ascertainment were used to identify potential patients using hot and cold pursuit. These are listed as either core methods, common to most previous incidence studies that satisfy the Malmgren criteria, or supplementary methods, used in some previous studies.

Core Methods of Case Ascertainment

In hot pursuit, the following applied: FP referral of all possible acute cerebrovascular events to daily clinic; daily review of computer-generated hospital and emergency department admission registers; daily review of acute medical wards and case note review; and daily review of all case notes of patients dying in hospital.

In cold pursuit, the following applied: weekly review of case notes of patients attending clinics of other local physicians; monthly contact with pediatrics, obstetrics, and other relevant departments; monthly review of hospital diagnostic coding data; monthly visit to coroners office and review of postmortem results; monthly visits to FP practices with regular contact with liaison FP; and quarterly review of Department of Public Health-generated mortality file of all International Classification of Diseases, Tenth Revision (ICD-10) (I64) stroke deaths.

Supplementary methods of case ascertainment are as follows: ascertainment of all patients referred as "TIAs;" follow-up of all patients with incident or recurrent TIA; ascertainment of all cases referred as "recurrent strokes;" and review of all referrals for brain, carotid, or cerebral vascular imaging.

Clinical Assessment, Investigation, and Case Definition

The patients were assessed as soon as possible after the event by a study clinician in a daily stroke and TIA clinic, in hospital, or at home. We attempted to perform a computed tomography brain scan in every case. Informed consent was sought if possible. Otherwise, relatives were contacted to obtain assent. If a patient died before assessment, we attempted to obtain an eyewitness account from a relative as well as reviewed information in FP and hospital notes. For patients with sudden death, the postmortem result was reviewed.

### Table 1. Use of Supplementary Methods of Ascertainment in Recent "Ideal" Stroke Incidence Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>TIAs Assessed and Reviewed</th>
<th>TIAs Followed-Up</th>
<th>Recurrent Strokes Assessed</th>
<th>Carotid and Brain Scan Referrals</th>
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</thead>
<tbody>
<tr>
<td>OXVASC (2002–2004)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>OCSP (1981–1986)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Dijon (1985/1994)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Rochester (1985–1989)</td>
<td>Y</td>
<td>N</td>
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<td>Umbria (1986–1989)</td>
<td>Y</td>
<td>Y</td>
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<td>Valle D’Aosta (1989)</td>
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<td>Fredericksburg (1989–1990)</td>
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<td>Novosibirsk (1992)</td>
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<td>Erlangen (1994–1998)</td>
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<td>Greece (1993–1995)</td>
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<td>N</td>
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<tr>
<td>Melbourne (1996)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
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</table>
The standard WHO definition of stroke was used. TIA was defined as an acute loss of focal cerebral or ocular function with symptoms lasting <24 hours, which after adequate investigation, was presumed to be embolic or thrombotic vascular disease.

**Direct Assessment of Underascertainment**

We used 2 direct methods to assess underascertainment of stroke. First, to detect underascertainment of patients who had presented to medical attention, we searched anonymized electronic patient records of all of our study population in each of the FP practices. Any patients with a diagnostic code related to cerebrovascular disease were identified. If they were not already known to the study, they were contacted after obtaining permission from the FP and then assessed.

Second, to determine underascertainment possibly caused by patients not presenting to medical attention after their stroke, we interviewed a subset of our population who we considered to be at high risk for stroke. Using similar methods to those described for TIA and stroke, we attempted to identify all patients in our study population presenting during the study period or the next 6 months with an acute coronary syndrome (myocardial infarction or unstable angina) or an acute peripheral vascular event (peripheral thromboembolism, critical limb ischemia, aortic aneurysm, etc), or a related elective investigation or intervention (eg, coronary or peripheral angiography, angioplasty, or surgery). All of these patients were interviewed by a study physician and asked about previous diagnoses of TIA or stroke and about neurological symptoms that might be suggestive of TIA or stroke during the study period. Their hospital and FP medical records were also reviewed. All patients were also followed-up for the duration of the study period by face-to-face interview with a study nurse at 1, 3, 6, and 12 months after the event/intervention.

**Analysis**

All strokes were categorized as incident (“first-ever in a lifetime”) or recurrent. All analyses of ascertainment were confined to incident strokes. We determined the effect of core versus core plus supplementary methods of ascertainment on the completeness and speed of ascertainment of incident strokes. We cross-referenced all strokes that were ascertained by the direct methods of assessment of completeness with those identified by the core plus supplementary methods.

**Results**

There were 128 incident strokes identified by all methods of ascertainment, including the direct methods of assessment of completeness, 115 (90%) of which were assessed by a study physician. Twelve patients died before being seen and 1 had the event while abroad, was fully investigated, but refused further follow-up; 117 (91%) were ascertained by hot pursuit and 73 (57%) were hospitalized.

There were 126 (98%) incident strokes identified by the core plus supplementary methods of ascertainment, but only 108 (84%) were identified by the core methods alone. Eighteen (14%) patients were referred by their GP as “TIA” but were found on assessment to be minor strokes, of which 16 would not have been identified by core methods alone. All of these patients were also identified from referrals for brain and carotid imaging. Assessing all patients who were referred as “recurrent” strokes did not identify any first-ever-in-a-lifetime strokes. Follow-up of 118 incident and recurrent TIAs identified 6 incident strokes during the study period, all of which had also been ascertained by core plus supplementary methods.

Using the core plus supplementary methods of case ascertainment, 5 incident strokes were identified from only 1 source, whereas 41 cases had only 1 source of ascertainment by core methods alone (Table 2), of which 28 (71.8%) were identified only through referral by our collaborating FPs. For 18 incident strokes, the supplementary methods of ascertainment were the first source and led to earlier clinical assessment than would have been the case if ascertainment had depended on the core methods alone.

**Direct Assessment of Underascertainment**

The direct methods used to assess the completeness of ascertainment identified only 2 incident strokes that had not been ascertained by core plus supplementary methods. Access to primary care electronic patient records of the whole study population identified 252 patients with a diagnostic code for cerebrovascular disease during the study period, of which 162 were possible strokes. Further investigations of these cases identified 113 incident strokes, of which only 2 had not been otherwise ascertained. One was a 66-year-old man who had a stroke while visiting the United States, where he was fully investigated and had not wanted any further assessment on his return to the United Kingdom. The other was an 81-year-old woman who had a minor ischemic stroke after gynecological surgery, which was not identified on hospital discharge coding but which was reported to her FP.

In addition, we assessed and followed-up 1103 individuals who had a total of 1676 noncerebrovascular events, investigations, or interventions during the study period or the subsequent 6 months. The majority (78%) of these individuals were older than age 60 years and comprised 5.5% of our total study population in this age range. One hundred forty-six of these individuals presented with a rapidly fatal vascular event and therefore could not be questioned or examined. However, the hospital and FP records of all of these individuals were reviewed. Thirty-nine patients refused to consent to questioning or examination and a further 20 refused to consent to follow-up, and all but 5 of these individuals allowed us to review their hospital and FP records.

As expected, these patients did represent a high-risk group. We found 16 patients who had had an incident stroke during the study period, giving a crude incidence of nearly 15 per 1000, which was approximately double the age/sex-adjusted rate expected from the incidence rate of the study population as a whole. However, all of these incident strokes had been ascertained by the core plus supplementary methods. Moreover, we found no patients with a clinical history or signs suggestive of a stroke during the study period who had not presented to medical attention.
Discussion
The Malmgren criteria\textsuperscript{22} for “ideal” stroke incidence studies were published 17 years ago and may no longer reflect current practice. Those studies that have satisfied the criteria have used a commonly accepted set of multiple overlapping sources of ascertainment, including collaboration with FPs, that we have termed the core methods. There is usually direct collaboration with primary care physicians, although the large population covered by the Auckland study\textsuperscript{12} meant that contact was only possible with a random subset of FPs, and the Rochester study\textsuperscript{7} used their unique Record Linkage System, which included primary care. However, additional methods of ascertainment have been used in some studies. Several studies assessed patients referred as TIA in addition to strokes,\textsuperscript{3,7,9,10,12–14} and some of these studies also followed-up patients with TIA.\textsuperscript{2,4,6,9,10,21} Several studies also assessed “recurrent” strokes,\textsuperscript{4,13,16,21} and approximately half reviewed all requests for carotid and brain imaging.\textsuperscript{7,9,10,12,13,16,17,21} Because all of these supplementary methods were used in OXVASC, we were able to assess their usefulness in comparison with the core methods alone.

We found that the core methods alone failed to ascertain 15% of incident strokes. Nearly all of these strokes were, however, identified by the supplementary methods. Assessment of patients referred as TIAs and reviewing brain and carotid imaging referrals were particularly important sources of additional cases and should probably become the norm in planning future “ideal” stroke incidence studies. These supplementary methods also allowed more rapid ascertainment and hence earlier clinical assessment, which is important in terms of accurate diagnosis and clinical phenotyping.

The most novel aspect of our study was the attempt to directly assess the likely completeness of ascertainment. We were fortunate to have access to the anonymized electronic medical records of our whole study population. However, this source did not identify all incident strokes; 90% (113/126) of incident strokes that we identified by our core plus supplementary methods of ascertainment were recorded on the electronic FP patient record, showing that the recording of diagnoses by FPs was reasonably efficient. It is reassuring, therefore, that only 2 additional strokes were identified by this method that had not been ascertained by our core plus supplementary methods.

We also assessed completeness of ascertainment by interview and follow-up of all patients in our study population presenting during the study period or the next 6 months with an acute coronary or peripheral vascular event or a related elective investigation or intervention. Virtually all of these patients were interviewed and examined by a study physician, and their hospital and FP medical records were assessed, or they agreed to review of their records, and the majority consented to be followed-up regularly by face-to-face interview. Although this group included 5.5% of our total study population aged older than 60 years with a high incidence of stroke, we did not identify any individuals with incident stroke who were not ascertained by our core plus supplementary methods or any individuals who had not presented to medical attention after an incident stroke during the study period. It is highly likely that we did miss some incident strokes in the remainder of our study population, but our findings in the high-risk subset suggest that ascertainment was very close to complete.

Potential Shortcomings
Although we believe that our results are internally valid, the main shortcoming of studies of methods of ascertainment in stroke incidence studies is the potential difficulty in generalizing the findings. There are likely to be subtle differences in the way in which the core and supplementary methods of ascertainment are used in different studies, and there are many differences between health care systems that could influence the effectiveness of particular methods of ascertainment. For example, in OXVASC, we are fortunate to have a highly motivated group of collaborating FPs, many of whom were also involved in the previous Oxfordshire Community Stroke Project (OCSP).\textsuperscript{2} Completeness of ascertainment by direct notification from FPs might be lower in studies with less collaborative colleagues in primary care or less cohesive health care systems. Similarly, health care systems differ in the proportion of patients with stroke, particularly minor stroke, who are admitted to hospital for investigation and treatment. This proportion varied from 54% to 95% in the studies listed in Table 1. The relative usefulness of the different methods of ascertainment will therefore differ between studies. The method of assessment of potential stroke patients who are ascertained also differs.

Despite these differences between studies, we believe that some useful and generalizable conclusions can be drawn from our findings. First, the core methods of ascertainment that are regarded as acceptable for an “ideal” incidence study should be supplemented when possible. For example, assessment of all referrals for brain and cerebrovascular imaging was a very useful source of ascertainment in OXVASC and should be possible in most studies. Similarly, assessment of patients referred to secondary care or recorded in primary care as having had a “TIA” identified several patients in OXVASC who had, in fact, experienced a minor stroke. Two other studies reported similar proportions of strokes that were initially referred as “TIA” (7% and14%).\textsuperscript{3,9,10}

Second, our direct methods of assessment of completeness of ascertainment were time-consuming and expensive but identified few additional incident strokes. We therefore conclude that if the same core and supplementary methods of ascertainment that were used in OXVASC are used in other stroke incidence studies in similar health care systems, ascertainment is likely to be close to complete. The previous Perth study\textsuperscript{9,10} falls into this category, and with the exception of follow-up of patients with TIA, several other studies used comparable methods.\textsuperscript{7,16,17}

Acknowledgments
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References
Stroke Incidence Studies

One Step Closer to the Elusive Gold Standard?

Stroke should be studied in a population-wide context because a large proportion of the burden of care for stroke is borne by health services outside the hospital sector and by families of affected patients. Assessing the need for stroke-related prevention strategies and health services, and geographical and secular trends in stroke burden, is best achieved...
with standardized population-based registers. Analyses limited to hospital cases, incomplete mortality data, or cases with varying criteria and definitions may distort results because of nonstandardized measures and nonrepresentative study populations. However, identifying all new stroke events in a population is particularly challenging, so that such epidemiological studies are relatively rare compared with studies using mortality data, hospital-based stroke registers, or incidence studies in younger age groups only.\(^2\)\(^3\) Moreover, even among published population-based stroke incidence studies, there are differences in the methodologies used to ensure completeness of case ascertainment.

Until recently, assessing completeness of case ascertainment in stroke incidence studies has been performed directly (eg, repeated cross-sectional surveys of the study population) and/or indirectly (eg, quality-control procedures, statistical modeling).\(^3\) Although repeated surveys are very expensive, other indirect methods may carry a considerable potential for error,\(^3\) and there is still no standard method of assessment of the completeness of stroke case ascertainment. Although capture-recapture method of case ascertainment is cost-efficient, there is much debate regarding its usefulness given the necessary assumptions that the population is closed; the sources of notification (or lists) are independent; the probability of being on a list should be the same. More extensive techniques for capture-recapture have been proposed to overcome some of the deviations from the assumptions, such as adding covariates to the model.\(^4\) However, these have not been validated in epidemiological studies.

In this issue of *Stroke*, Coull et al report 2 direct methods of stroke case ascertainment used in the Oxford Vascular Study (OXVASC).\(^5\) This article measures the marginal benefits of some new types of direct assessment of accuracy of case ascertainment in a population-based stroke incidence study. In addition to the core methods of case ascertainment used in the first Oxfordshire Community Stroke Project, conducted 20 years ago,\(^6\) the authors used supplementary methods to ascertain all patients with transient ischemic attack (TIA), recurrent strokes, and those referred for neuroimaging studies. The use of these supplementary methods yielded an additional 15% of incident strokes detected over and above the core ascertainment methods only. Direct assessment of the completeness of case ascertainment by regular searching of databases of general practitioners and reviewing of all cardiovascular patients admitted to hospital highlighted only 2 cases that had been missed by both the core and supplementary methods. Direct methods to assess the completeness of case ascertainment can be used when a well-established electronic patient record system is in place. However, it has been shown in this study that interviewing a population at high risk for stroke does not identify any more cases. Coull et al acknowledge that the generalizability of these findings and effectiveness of particular methods of case ascertainment are likely to be limited by community-specific differences in health care systems. Unfortunately, the authors did not conduct capture-recapture analyses to compare these results with indirect assessments of completeness of ascertainment. Such comparisons would yield important information on how best to use indirect methods in the many instances when only incomplete direct data are available.

The study by Coull et al\(^5\) justifies an expansion of the current criteria for “ideal” stroke incidence studies by includ-

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<th>Gold Standards for an “Ideal” Stroke Incidence Study</th>
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<td><strong>Domains</strong></td>
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<td>Standard definitions</td>
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\(^*\)New criteria. †Updated, modified from Sudlow and Warlow.\(^3\)
ing supplementary methods of case ascertainment and direct assessment of underascertainment. In 1987, Malmgren et al published a list of 12 core criteria for “ideal” stroke incidence studies that were related to definitions, methods, and mode of data presentation, by which the quality of population-based studies of stroke could be judged. These criteria have been updated by Bonita (1995), Sudlow and Warlow (1996), and Feigin et al (2003, 2004). Taken together, we propose updated criteria (gold standards) for “ideal” population-based stroke incidence study (Table). We believe that separating these criteria on core and supplementary allows some methodological flexibility in studying stroke incidence based on local resources and health care system while ensuring internal and external validity of the study.

In summary, “ideal” stroke incidence studies based on both core and supplementary criteria are the most valuable source of information for developing evidence-based strategies for stroke prevention and health services and, therefore, should be used whenever possible. Further advancements in computerized medical record-linkage systems are likely to facilitate such studies. However, these “ideal” criteria are not practical for stroke incidence studies undertaken in most settings, particularly in developing countries, where most strokes occur but resources are limited. To address the problem of accurate and comparable stroke incidence studies in less affluent countries and those with scarce research funding, a WHO stepwise stroke surveillance approach can be recommended. The question of validity of capture-recapture methods of case ascertainment in stroke incidence studies remains to be answered. However, refinement of both direct and indirect methods will take us closer to the elusive gold standard.

References
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