Background and Purpose—Accurate information about resource use and costs of stroke is necessary for informed health service planning. The purpose of this study was to determine the patterns of resource use among stroke patients and to estimate the total costs (direct service use and indirect production losses) of stroke (excluding SAH) in Australia for 1997.

Methods—An incidence-based cost-of-illness model was developed, incorporating data obtained from the North East Melbourne Stroke Incidence Study (NEMESIS). The costs of stroke during the first year after stroke and the present value of total lifetime costs of stroke were estimated.

Results—The total first-year costs of all first-ever-in-a-life time strokes (SAH excluded) that occurred in Australia during 1997 were estimated to be A$555 million (US$420 million), and the present value of lifetime costs was estimated to be A$1.3 billion (US$985 million). The average cost per case during the first 12 months and over a lifetime was A$18 956 (US$14 361) and A$44 428 (US$33 658), respectively. The most important categories of cost during the first year were acute hospitalization (A$154 million), inpatient rehabilitation (A$150 million), and nursing home care (A$63 million). The present value of lifetime indirect costs was estimated to be A$34 million.

Conclusions—Similar to other studies, hospital and nursing home costs contributed most to the total cost of stroke (excluding SAH) in Australia. Inpatient rehabilitation accounts for 27% of total first-year costs. Given the magnitude of these costs, investigation of the cost-effectiveness of rehabilitation services should become a priority in this community. (Stroke. 2001;32:2409-2416.)

Key Words: Australia ■ cerebrovascular disorders ■ costs and cost analysis ■ incidence

Stroke is a costly disorder that has previously been estimated to be responsible for ≈4% of the total costs of disease and 2% of total attributable direct health care costs in Australia. As the Australian population is rapidly aging and the incidence of stroke increases with age, it is likely that the incidence of stroke will rise, placing an increased strain on health care and community resources. For this reason, a clear understanding of the current patterns of resource use and costs of stroke in this community are required to appropriately inform priority setting and health service planning.

Acute hospitalization and nursing home care are known to be major contributors to the total costs of stroke worldwide. However, little attention has been paid to the costs of postacute care (eg, treatment by allied health professionals, provision of aids and equipment, and home modifications), the “out-of-pocket” (nonreimbursed) costs to stroke patients and their families, and the “time” costs associated with the provision of informal care to stroke survivors.

A number of cost-of-illness (COI) studies for stroke have been conducted by means of an incidence-based approach. The incidence-based approach estimates the present value of the lifetime costs for all new (incident) cases occurring during a given reference year, even though many costs will actually be incurred during future years. This is the method of choice if the consequences of preventative and treatment strategies are to be appreciated in terms of their effects on lifetime costs and options for change evaluated in terms of their economic efficiency. The incidence-based approach requires the modeling of future costs with the uncertainties inherent in this approach. In contrast, the prevalence-based approach provides an estimate of the costs of all cases (new and existing) of disease in a given reference year and, as such, provides useful data for health service planning.
planning. There is only one incidence-based study that can be regarded as a comprehensive lifetime COI model because it includes the majority of costs to society.\textsuperscript{13}

The purpose of the present study was to develop a comprehensive incidence-based COI model for stroke to estimate the total (direct and indirect) costs of stroke (excluding SAH) in Australia. The study was performed as one component of the North East Melbourne Stroke Incidence Study (NEMESIS) (see below).

**Materials and Methods**

**Overview of Methodology**

COI models for the lifetime economic costs of cerebral infarction, intracerebral hemorrhage (ICH), and unclassified stroke (see definitions below) were constructed with the use of an incidence-based, “bottom-up” costing approach, from a societal perspective. The costs of SAH and transient ischemic attacks were not assessed. The aggregate total cost and average cost per person during the first year after stroke and the present value of the aggregate lifetime costs and average lifetime costs per person were calculated for all first-ever-in-a-lifetime strokes estimated to have occurred in Australia in 1997. The aggregate first year and lifetime costs of stroke were the sum of the costs of cerebral infarction, ICH, and unclassified stroke. The average cost per person was determined by dividing the aggregate total costs of all subtypes by the total number of stroke cases. All costs and earnings were estimated in 1997 Australian dollars. Future costs and earnings were discounted with a 5\% discount rate. Discounting is basically a compound interest calculation performed in reverse and is required because as a society we have a “positive rate of time preference,” that is, we generally prefer to postpone costs and enjoy benefits now.\textsuperscript{16} A 5\% discount rate has recently been considered appropriate.\textsuperscript{5,13,17} Purchasing power parity (see OECD website: www.oecd.org/std/ppp/pps.htm) was used to convert estimates in Australian dollars to the equivalent value in US dollars.

“Purchasing power” is the amount of real goods and services each unit of currency will buy and “purchasing power parity” exists when the equivalent amounts of two currencies have identical purchasing power in their respective countries.

**Definition of Stroke Cases**

Stroke was defined according to the World Health Organization epidemiological definition of stroke: rapidly developing clinical signs of focal (or global) disturbance of cerebral function lasting >24 hours (unless interrupted by surgery or death) with no apparent cause other than of vascular origin.\textsuperscript{18} TIA\textsuperscript{s} are excluded by this definition. Cases of SAH were excluded from this analysis because there were no resource-use data to complete access to these patients for follow-up. “First-ever-in-a-lifetime” strokes were defined as those strokes occurring in patients without any prior stroke event.

Incidence rates based on first-ever-in-a-lifetime cerebral infarction, ICH, and unclassified stroke and obtained from NEMESIS were used.\textsuperscript{19} The methods used in NEMESIS have previously been reported in detail.\textsuperscript{20} Briefly, this is a community-based stroke incidence study conducted in urban Melbourne, Australia, during a 12-month period between 1 May 1996 and 30 April 1997. The study area had a total population of 133 816. The methodology used to obtain stroke cases was based on the recommendations for the conduct of “ideal” stroke incidence studies.\textsuperscript{21,22} Each registered case was categorized as cerebral infarction or ICH on the basis of the CT findings when performed within 28 days of the stroke event. Cases of stroke that did not undergo CT, MR imaging, or autopsy were determined to be unclassified. Follow-up procedures ensured that the investigators were aware of recurrent stroke events or deaths that occurred among the cohort during the first 12 months after stroke.

**COI Model**

The COI models for cerebral infarction, ICH, and unclassified stroke were developed with the use of linked spreadsheets. Key spreadsheets contained (1) age- and sex-specific population estimates as determined by population census; (2) age- and sex-specific stroke incidence rates; (3) estimated proportion of cases dead at 1 day, 3 days, 12 days, 28 days, 3 months, 6 months, and 12 months after stroke; (4) numbers of stroke cases surviving at each time point after stroke; (5) detailed resource-use data during the first 12 months after first-ever-in-a-lifetime stroke (percent of cases and mean frequency of use); (6) detailed resource use data during the first 12 months after recurrent stroke (percent of cases and mean frequency of use); (7) unit costs; (8) expected numbers of recurrent events over 5 years; (9) numbers of surviving cases over subsequent years; and (10) workforce participation, participation in unpaid productive domestic activity, and average wage rates.

Included categories of resource-use were determined after an extensive review of the COI literature for stroke and incorporated the assessment of an expert panel of clinicians about the likely patterns of care for stroke patients in Melbourne, Australia. Costs during the first year after first-ever-in-a-lifetime stroke were estimated by means of resource-use data obtained from NEMESIS. We assumed that incidence rates and resource-use data obtained from NEMESIS were representative of the general situation when estimating total costs of stroke in Australia.

“Rest of life” costs (ie, costs beyond the first year after stroke) were modeled with the use of published long-term survival and recurrence rates from the Oxfordshire Community Stroke Project,\textsuperscript{23} incremental resource-use data for recurrent strokes obtained for the first year after stroke from the NEMESIS cohort (see below), and the investigators’ assessment about continuing resource use by long-term stroke survivors who have no recurrent events. In general, stroke-related resource use that still occurred 12 months after stroke was considered to be ongoing. Beyond 5 years after stroke, survivors were deemed to have no further stroke recurrence and to have the same average remaining lifetime in years as members of the general Australian population of the same sex and age.\textsuperscript{24}

The value of time lost from productive activity (indirect costs) up to age 65 years was estimated both for those in the paid workforce and for those engaged in unpaid productive domestic activity before stroke. Both mortality and morbidity costs were included. An approximation of the frictional method\textsuperscript{25,26} was used to calculate mortality costs. This method estimates production losses only for the so-called frictional period after the loss of a paid worker from an organization. This is the period of time required by an organization to restore its production level to that which existed before the absence of a sick worker. In this study, mortality costs for the frictional period were estimated to be ~10\% of the mortality costs as estimated with the standard Human Capital Approach (Jan Olsen, unpublished data, 1999).

We assumed that the prestroke workforce participation rate among 3-month survivors in the NEMESIS cohort of stroke cases was representative of the prestroke workforce participation rate of all stroke cases in Australia in 1997. In addition, we assumed that those not in the paid workforce at the time of stroke had similar levels of participation in productive domestic activity as age- and sex-matched members of the general Australian population. For those who survived 3 months, morbidity costs were included for the first 12 months after stroke (costs for people who died before this time were included in mortality costs). Morbidity costs were defined as work-time lost as the result of hospitalization and attendance for stroke-related medical and health services. We assumed that for every day spent in hospital, 2 additional days were required for recovery before return to work and that for each attendance for a medical or other health service, there was a further loss of 0.37 days of productive activity.\textsuperscript{27} For those in the paid workforce, productive time lost was valued using the “replacement cost approach.” This approach values productive activity according to the cost of substitut-
ing unpaid activity with a paid worker. Domestic activity was valued according to the average hourly rate for house cleaners in 1997 ($A11).

Included Data

**Australian Population**

Age- and sex-specific population projections for 1997, based on data obtained in the 1996 population census, were provided as commissioned work by the Australian Bureau of Statistics.

**Incidence Rates, Case Fatality, and Stroke Recurrence**

The annual age-specific incidence rates and case-fatality for the major stroke subtypes among men and women in NEMESIS were used.29 Details of any stroke recurrence during the first 12 months after stroke were recorded for all first-ever-in-a-lifetime stroke cases registered in NEMESIS.

**Place of Accommodation Before and After Stroke**

Information about place of residence (home, nursing home, other supported accommodation) at the time of stroke and at 3, 6, and 12 months after stroke was routinely sought.

**Health Care and Community Resource Use**

Health care and community resource use during the first 12 months after stroke was documented as part of the follow-up for all stroke cases in NEMESIS.

Every attempt was made to identify all costs incurred by society as a consequence of stroke and to only include costs that were stroke-related. Methods included review of hospital medical records and review of nursing home and hostel case notes. Details of acute hospital care were recorded for all registered cases. Trained research nurses conducted repeated interviews (3, 6, and 12 months after stroke) with surviving patients and/or their next-of-kin in the patients’ homes through the use of structured questionnaires. Early on in the study, patients were asked to keep a diary noting health care and community resource use between scheduled interviews. Unfortunately, few patients maintained these diaries with any regularity. Information about all postacute and community-based resource use in the 12 months after stroke and any out-of-pocket costs was thus obtained at interview. These data were verified with treating doctors, health care institutions, and so forth, as required. For example, if a patient was uncertain how many times he attended outpatient physiotherapy, the treating service was contacted to obtain resource use details. For each type of resource used (Table 1), the nature and frequency of use was documented.

When a stroke case had received any assistance with activities of daily living, the nominated primary care giver was also interviewed to document the nature and amount of assistance provided. These primary care givers were also asked about any out-of-pocket costs they incurred as a consequence of the stroke. When stroke cases had not been participating in the paid workforce before stroke, we asked the reasons for nonparticipation, for example, retired or home duties.

For each use of health care and community resource during each follow-up period, we calculated the proportion of cases of each stroke subtype using that particular resource and the average stroke-related frequency of use. Because we were interested in all possible frequency values and our use of frequencies was for further calculation in a multiplicative model to estimate total costs, average rather than median values were considered more appropriate. These data were directly applied to the estimated total number of survivors of each subtype at each time point after stroke to obtain the total number of occasions of service or resource units consumed during the first year after stroke.

**Unit Costs**

Best estimates of the market prices of resource unit costs expressed in 1997 Australian dollars were used. All prices obtained in years before or after 1997 were adjusted by means of the total health price index (a measure of inflation).28 Previously published data for unit costs were used.7,29–31

### TABLE 1. Categories of Resource Use Included in Follow-Up Questionnaires

- Subsequent hospitalization for stroke-related problems or complications
- Emergency department attendances
- Rehabilitation hospital admissions
- Outpatient rehabilitation
- Specialist medical care
- General practitioner care
- Allied health and alternative therapies
- Tests (radiology, pathology, other)
- Prescription medication
- Over-the-counter medications
- Provision of special equipment and aids
- Home modifications
- Ambulance transfers
- Day hospitals (community rehabilitation centers) and day centers
- Provision of community services
- Aged care and psychogeriatric assessment teams
- Paid domestic assistance
- Respite care
- Informal care provided by family and friends

**Nursing Home Costs**

Two different unit costs were used when calculating nursing home costs. For cases having a stroke while resident in a nursing home, their level of care was assumed to increase from the average ($A594.97/wk) to the highest care category ($A900.20/wk) throughout the first year after stroke. For cases newly admitted to a nursing home after stroke, a unit cost of $A23 282 per annum was used. This represents the average total cost of nursing home care based on Commonwealth Government funding data less the average Australian expenditure on rent and food (because these latter costs would have been incurred in any case).32

**Acute Hospitalization Costs**

The average cost per case of cerebral infarction and ICH registered in NEMESIS and admitted to the Austin and Repatriation Medical Center was used to calculate the costs of acute hospitalization. These costs were obtained from the hospital’s own financial costing system (transition 2). This is a well-developed financial costing system that was considered to provide the most precise available estimate of inpatient costs for stroke patients.32 A unit cost of $A5029 was used for unclassified stroke. This latter cost was an average of the costs of all the Australian National-Diagnosis Related Group (AN-DRG) codes (a case-mix funding formula) allocated to unclassified stroke cases in NEMESIS across all participating hospitals.

**Inpatient Rehabilitation Costs**

Inpatient rehabilitation costs were those as determined by means of the mixed per-diem/per episode funding model recommended by the authors of the Australian National Sub-Acute and Non-Acute Patient Classification (AN-SNAP).34 This method takes into account both the length of stay and relative intensity of resource use for different categories of stroke patients according to age, disability level, and cognitive ability.

**Aids and Equipment and Home Modifications**

The out-of-pocket costs reported by stroke patients were used. The costs of aids and equipment that were provided on loan were included in hospital costs.

**Time Costs of Informal Care**

The unit cost used was $A5.86/h (one third of the average Australian weekly wage in 1997).
Sensitivity Analysis
A range of 1-way sensitivity tests was performed to assess the robustness of the total cost estimates. This procedure included variation of the discount rate (0%, 3%, and 7%). The costs of hospitalization were recalculated with the average costs of the included AN-DRGs. Care giver costs were estimated by means of the replacement cost approach. Tests were also performed by substituting the lower and upper bounds of the 95% CIs for the proportions of cases resident in a nursing home before stroke, cases hospitalized for acute care, cases admitted for inpatient rehabilitation, and cases newly admitted to a nursing home after stroke.

Ethics
This study was approved by ethics committees at each of the participating institutions. Informed consent was obtained from each participant before any interview was conducted. When the participant was cognitively impaired, dysphasic, or had altered consciousness, consent was obtained from the next-of-kin.

Results
Overall, 275 first-ever-in-a-lifetime stroke cases were registered in NEMESIS. Brain imaging (CT or MRI) or autopsy was performed in 91% of first-ever-in-a-lifetime events. During the first year after first-ever-in-a-lifetime stroke, 10% (95% CI, 6% to 14%) of cases had a recurrent stroke.

Using incidence rates of stroke subtypes from NEMESIS and Australian population data, we estimated the total number of first-ever-in-a-lifetime strokes (cerebral infarction, ICH, and unclassified) that occurred in Australia in 1997 to be 29 289. Of these, 22 246 were cerebral infarction, 4548 were ICH, and 2945 were unclassified cases.

Among the NEMESIS cohort, 82% of first-ever-in-a-lifetime stroke cases were living in their own home before stroke, 6% were living in other supported accommodations, 7% were living in a nursing home, and for the remaining 5%, the place of residence was unknown. Among the 3-month survivors of first-ever-in-a-lifetime stroke who were interviewed, 10% had newly moved to a nursing home.

Of all registered first-ever-in-a-lifetime cases, 88% were admitted to the hospital for acute treatment, with an average length of stay of 13 days. The average cost of acute inpatient care for cerebral infarction and ICH admitted to Austin and Repatriation Medical Centre was $A6371 and $A8424, respectively. Detailed postacute resource-use data were obtained for 165 (67%) 3-month stroke survivors registered in NEMESIS, of which 127 were first-ever-in-a-lifetime stroke. There were significant differences in the characteristics of NEMESIS cases that were interviewed and those that were not interviewed (Table 2). Men, stroke patients treated in private hospitals, stroke patients born overseas, and those with a preferred language other than English were all under-represented in the interviewed group. Of the interviewed 3-month survivors of first-ever-in-a-lifetime stroke, 45% were admitted for a period of inpatient rehabilitation, with a mean length of stay of 46 days. The average cost per rehabilitation admission was estimated to be $A13 627. A summary of the postacute resources used during the first year after stroke is presented in Table 3.

Among the NEMESIS cohort <65 years of age at the time of stroke, only 45% of men and 43% of women who survived 3 months after stroke were in the paid workforce before stroke.

### TABLE 2. Comparison of Interviewed Cases and Cases Not Interviewed in NEMESIS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Interviewed n = 165 %*</th>
<th>Not Interviewed n = 82 %*</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean</td>
<td>73</td>
<td>72</td>
<td>0.81†</td>
</tr>
<tr>
<td>Male sex</td>
<td>47</td>
<td>62</td>
<td>0.027‡</td>
</tr>
<tr>
<td>Admitted to hospital</td>
<td>91</td>
<td>88</td>
<td>0.44‡</td>
</tr>
<tr>
<td>First-ever stroke</td>
<td>77</td>
<td>79</td>
<td>0.68‡</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>10</td>
<td>15</td>
<td>0.89‡</td>
</tr>
<tr>
<td>Unclassified stroke</td>
<td>7</td>
<td>9</td>
<td>0.726‡</td>
</tr>
<tr>
<td>Admitted to private hospital</td>
<td>7</td>
<td>21</td>
<td>0.002‡</td>
</tr>
<tr>
<td>Born in Australia</td>
<td>73</td>
<td>45§</td>
<td>&lt;0.00004‡</td>
</tr>
<tr>
<td>Preferred language is English</td>
<td>80</td>
<td>58</td>
<td>0.0006‡</td>
</tr>
</tbody>
</table>

*These figures are percentages unless otherwise indicated.
† t Test.
‡ x² Test.
§ Information unavailable on 9% excluded cases.
|| Information unavailable on 18% of excluded cases.

Aspirin                                           | 2 692 075               |
Ticlopidine                                       | 538 925                 |
Warfarin, 5 mg                                    | 989 706                 |
Other medication (eg, antihypertensive agents)     | 4 687 374               |
Community rehabilitation centers, No. of contacts  | 105 320                 |
Inpatient respite care, No. of bed days            | 56 376                  |
Outpatient rehabilitation, No. of contacts         | 76 328                  |
Investigations, total No. of tests                 | 126 693                 |
Pathology                                         | 13 527                  |
Radiology (including carotid duplex)              | 10 557                  |
Other tests (including echocardiogram)            | 135 968                 |
Specialist medical care, No. of contacts          | 62 342                  |
General practitioner care, No. of contacts         | 55 526                  |
Postacute ambulance transfers, No. of trips       | 35 957                  |
Private allied health care (eg, physiotherapy), No. of contacts | 11 057 |
Aged care assessment teams, No. of contacts       | 10 557                  |
Community services, eg, “meals on wheels,” No. of contacts | 11 057 |
Hospital emergency department care, No. of attendances | 11 057 |

Using the above data, a hierarchy of costs during the first year after first-ever-in-a-lifetime stroke was calculated and is shown in Table 4. The total first-year costs (direct service use, care giver time, out-of-pocket, and production losses) for all first-ever-in-a-lifetime strokes that occurred in Australia in 1997 were estimated to be A$555 million (US$420 million). This represents ≈43% of the present value of total lifetime costs for these cases. The largest components of this total were acute hospitalization (28%; A$154 million), inpatient rehabilitation (27%; A$150 million), and nursing home care.
First-ever-in-a-lifetime strokes that occurred in Australia in 1997 incurred during the first year and accounted for (11%; A$63 million). The costs of lost production were all (US$695 million), or 2% of total health services expenditure in 1997. The present value of lifetime costs of all first-ever strokes occurring in Australia in 1997, through the use of an incidence-based approach, was A$1.3 billion (US$985 million). This estimate is substantially less than the total costs of A$1.779.3 million (1997 value) reported by the Quality of Care and Health Outcomes Committee of the National Health and Medical Research Council (NHMRC). This earlier study included all strokes but assumed similarity of resource use for all stroke subtypes. Although the inclusion of the ~5% of strokes caused by SAH would be expected to increase the cost estimate somewhat in comparison to our own, this earlier estimate is 35% higher. This difference is largely explained by the overestimation of both the indirect costs of lost income of female care givers (A$368 million [1997 value]) and nursing home costs (A$418 million) in the earlier study (see below). It is unclear how the authors of the NHMRC study determined the proportion of surviving male stroke patients who have female care givers who stay home to care for them. Further, it was assumed that all female care givers are unable to work for the remaining lifetime of the stroke patient to whom they provide care and that these female care givers would otherwise have the same workforce participation as all women of the same age. However, in NEMESIS, the majority of informal care givers were not in the paid workforce at the time of the stroke and most care givers provided care at the

![Table 4. Summary of Total Costs During First Year After First-Ever-in-a-Lifetime Strokes That Occurred in Australia in 1997]

<table>
<thead>
<tr>
<th>Resource Category</th>
<th>Cost, Australian Dollars (000,000)</th>
<th>% of Total First-Year Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute hospitalization</td>
<td>154</td>
<td>28</td>
</tr>
<tr>
<td>Inpatient rehabilitation</td>
<td>150</td>
<td>27</td>
</tr>
<tr>
<td>Nursing home care</td>
<td>63</td>
<td>11</td>
</tr>
<tr>
<td>Indirect costs*</td>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>Rehospitalization for stroke complications</td>
<td>28</td>
<td>5</td>
</tr>
<tr>
<td>Carer time costs (opportunity cost approach)</td>
<td>22</td>
<td>3.9</td>
</tr>
<tr>
<td>Out-of-pocket costs†</td>
<td>18</td>
<td>3.2</td>
</tr>
<tr>
<td>Hospitalization for recurrent stroke event</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Medications</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Community rehabilitation centers</td>
<td>10</td>
<td>1.8</td>
</tr>
<tr>
<td>Ambulance transfers for acute care</td>
<td>8</td>
<td>1.5</td>
</tr>
<tr>
<td>Respite care</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Outpatient rehabilitation</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Investigations (eg, pathology, radiology)</td>
<td>5.7</td>
<td>1</td>
</tr>
<tr>
<td>Carer out-of-pocket costs</td>
<td>4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Specialist medical care</td>
<td>4.0</td>
<td>0.7</td>
</tr>
<tr>
<td>General practitioner care</td>
<td>3.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Ambulance transfers (postacute)</td>
<td>3.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Allied health professionals</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Emergency department care (acute)</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Aged care assessment teams</td>
<td>1.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Community services</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Emergency department care (postacute)</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Preadmission general practitioner care</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>Grand total</td>
<td>555</td>
<td>100</td>
</tr>
</tbody>
</table>

*The present value of total indirect costs of stroke are included here. This is because with the frictional approach, all included indirect costs are incurred during the early months after stroke.
†Includes aids, equipment and home modifications, alternative and herbal medications, transport costs, private domestic assistance, and miscellaneous out-of-pocket costs not included in other cost categories.

(11%; A$63 million). The costs of lost production (indirect costs) amounted to A$34 million. Because the frictional method was used, the costs of lost production were all incurred during the first year and accounted for ~6% of total first year costs. The average total cost per case (inclusive of care giver time costs) during the first year after first-ever-in-a-lifetime stroke was A$18 956 (US$14 361). In contrast, the average total cost per case during the first year after recurrent stroke was A$21 786 (US$16 505).

Through the use of a prevalence-based approach, total stroke costs in 1997 were estimated to be A$917 million (US$695 million), or <2% of total health services expenditure in 1997. The present value of lifetime costs of all first-ever stroke cases that occurred in Australia in 1997 was estimated to be A$1.3 billion (US$985 million) or ~A$44 000 (US$34 000) per case. The present value of the lifetime costs of nursing home care for all first-ever stroke cases that occurred in Australia in 1997 was A$276 million (21% of the present value of total lifetime costs). The incremental cost of recurrent strokes accounted for 5% of total lifetime costs.

The findings of sensitivity analysis are shown in Table 5. When future costs were undiscounted, estimated lifetime costs were 25% greater. With the range of other tests performed, the total first-year and lifetime costs varied by up to 13%. First-year costs were most sensitive to variation of the proportion of cases admitted for inpatient rehabilitation.

**Discussion**

This is the first comprehensive, incidence-based estimate of the total costs of stroke (excluding cases of SAH) in Australia and, as such, provides unique information of relevance to future health care planning. However, the total cost estimates are based on patterns of resource use during the first year after stroke among stroke patients living in a small geographic area of urban Melbourne and in close proximity to the Austin and Repatriation Medical Center (a center of excellence for stroke care and research). It is very likely that patterns of resource use vary considerably throughout Australia, particularly because many Australian communities are remote from tertiary hospital facilities. As resource-use data become available from other parts of Australia, the strength of the current estimates will be further assessed. An important further consideration is that there were significant differences between NEMESIS cases that were interviewed and not interviewed (Table 2). Thus there are remaining uncertainties about the patterns of resource use among those cases of stroke that did not undergo follow-up interviews. However, the sensitivity analyses provide evidence for the robustness of the model because these have explored the limits of likely resource use for the total group of stroke patients.

The estimated present (1997) value of the total lifetime costs of all first-ever-in-a-lifetime strokes occurring in Australia in 1997, through the use of an incidence-based approach, was A$1.3 billion (US$985 million). This estimate is substantially less than the total costs of A$1.779.3 million (1997 value) reported by the Quality of Care and Health Outcomes Committee of the National Health and Medical Research Council (NHMRC). This earlier study included all strokes but assumed similarity of resource use for all stroke subtypes. Although the inclusion of the ~5% of strokes caused by SAH19 would be expected to increase the cost estimate somewhat in comparison to our own, this earlier estimate is 35% higher. This difference is largely explained by the overestimation of both the indirect costs of lost income of female care givers (A$368 million [1997 value]) and nursing home costs (A$418 million) in the earlier study (see below). It is unclear how the authors of the NHMRC study determined the proportion of surviving male stroke patients who have female care givers who stay home to care for them. Further, it was assumed that all female care givers are unable to work for the remaining lifetime of the stroke patient to whom they provide care and that these female care givers would otherwise have the same workforce participation as all women of the same age. However, in NEMESIS, the majority of informal care givers were not in the paid workforce at the time of the stroke and most care givers provided care at the
expense of family or leisure time rather than at the expense of paid employment.\textsuperscript{36}

Through the use of the prevalence-based approach, total stroke costs for 1997 were estimated to be A$917 million, or <2% of total health services expenditure. Our estimate is 35% less than the prevalence-based estimate of the combined direct and indirect costs of stroke of $A1.4 billion (1997 value) provided by Carter and colleagues\textsuperscript{27} for the year 1989 to 1990. The costs of SAH and TIA were included in this earlier study, and this may explain some of the observed difference. However, the standard human capital approach was used to estimate mortality costs in this latter study, and as a result, mortality costs will have been overestimated.

Acute hospitalization has been confirmed as a major contributor to the total costs of stroke in Australia. However, nursing home costs were substantially less than previously estimated.\textsuperscript{7} Notwithstanding differences in methodology, this is principally because of the high mortality rates among stroke patients who were already resident in a nursing home at the time of stroke (76% of this population had died within 3 months of stroke). New admissions to a nursing home after stroke were thus largely replacing those stroke cases that had their stroke and died while resident in a nursing home. This finding is consistent with the findings from a community-based stroke incidence study in Sweden.\textsuperscript{10} When the pre-stroke costs of assisted living and nursing home care were taken into account in this Swedish population, there were no additional costs associated with assisted living and nursing home care during the first 2 years after stroke. Similarly, in a community-based cohort of stroke cases in the United States, the difference in the number of nursing home days between stroke cases and age- and sex-matched control subjects was not statistically significant.\textsuperscript{37} This was attributed to the high early mortality rate for stroke cases who were nursing home residents at stroke onset.

The costs of inpatient rehabilitation during the first year after first-ever-in-a-lifetime were substantial, and the total cost of rehabilitation (inpatient and outpatient) formed the largest component of first-year costs. The costs of inpatient rehabilitation have not been reported separately in existing prevalence-based Australian COI studies for stroke,\textsuperscript{27,38} largely because of difficulties in separating out the costs of admissions for rehabilitation from the costs of other stroke-related admissions in official data. A previous estimate of the costs of rehabilitation was approximately half the current estimate.\textsuperscript{7} In this previous study, a lower proportion of cases was estimated to receive a period of inpatient rehabilitation (20% versus 45% of first-ever cases in NEMESIS), and these cases were assumed to have a shorter average length of stay (30 versus 46 days in NEMESIS). A substantially lower unit cost was also used ($A10 500 per episode versus $A13 627 per episode in NEMESIS). The strengths of the current findings relate to their basis in patient-specific, length-of-stay data from a community-based cohort of stroke patients. Patients were treated in a variety of public and private institutions providing inpatient rehabilitation services and were stratified according to the AN-SNAP case mix categories.\textsuperscript{34} However, there is evidence that the patterns of provision of rehabilitation services vary across Australia.\textsuperscript{39,40} Consequently, the rehabilitation costs presented in this study may not be generalizable across all states. Despite this, the relative importance of rehabilitation costs as a contribution to

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost/Case in First Year, Australian Dollars</th>
<th>Cost/Case Over Lifetime, Australian Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>18 956</td>
<td>44 428</td>
</tr>
<tr>
<td>0% Discount rate</td>
<td>18 956</td>
<td>55 681</td>
</tr>
<tr>
<td>3% Discount rate</td>
<td>18 956</td>
<td>48 245</td>
</tr>
<tr>
<td>7% Discount rate</td>
<td>18 956</td>
<td>41 431</td>
</tr>
<tr>
<td>Indirect costs: HCA approach</td>
<td>18 956</td>
<td>48 535</td>
</tr>
<tr>
<td>Hospital costs: AN-DRG costs</td>
<td>18 241</td>
<td>43 714</td>
</tr>
<tr>
<td>Carer costs: Replacement approach</td>
<td>19 667</td>
<td>50 032</td>
</tr>
<tr>
<td>Low proportion NH cases</td>
<td>19 160</td>
<td>45 837</td>
</tr>
<tr>
<td>High proportion NH cases</td>
<td>18 609</td>
<td>41 883</td>
</tr>
<tr>
<td>Low proportion hospitalized</td>
<td>18 738</td>
<td>44 164</td>
</tr>
<tr>
<td>High proportion hospitalized</td>
<td>19 150</td>
<td>44 647</td>
</tr>
<tr>
<td>Low proportion inpatient rehabilitation</td>
<td>16 795</td>
<td>42 267</td>
</tr>
<tr>
<td>High proportion inpatient rehabilitation</td>
<td>21 432</td>
<td>46 904</td>
</tr>
<tr>
<td>Low proportion hospital discharge to NH</td>
<td>18 159</td>
<td>39 759</td>
</tr>
<tr>
<td>High proportion hospital discharge to NH</td>
<td>19 900</td>
<td>50 229</td>
</tr>
<tr>
<td>Low proportion discharged to NH from inpatient rehabilitation</td>
<td>18 345</td>
<td>41 012</td>
</tr>
<tr>
<td>High proportion discharged to NH from inpatient rehabilitation</td>
<td>19 762</td>
<td>49 411</td>
</tr>
</tbody>
</table>

HCA indicates human capital approach; AN-DRG, Australian National Diagnosis-Related Groups; and NH, nursing home.
the total costs of stroke has not been previously recognized. Given the magnitude of rehabilitation costs, the cost-effectiveness of rehabilitation interventions requires urgent investigation.

Indirect costs (A$34 million) represented <3% of the present value of the total lifetime costs of stroke in this study, substantially less than a previous Australian estimate (A$988.3 million [1997 value]) and the majority of estimates worldwide. This is simply a consequence of the different methodologies used to estimate indirect costs in COI studies. In this study, an approximation of the frictional approach (10% of human capital estimate) was used to estimate mortality costs rather than the traditional human capital approach. The latter approach assumes that production losses continue for what would have been the remaining work lifetime of the sick or deceased worker (usually to age 65 years). In societies with significant unemployment, the frictional method provides more realistic estimates of production losses to the economy as any lost worker can eventually be replaced. Furthermore, the prestroke workforce participation rates reported for the NEMESIS cohort were used in the calculation of production losses. These participation rates were substantially less than the 73.4% and 53.9% that were the general workforce participation rates for men and women in Australia in May 1997.

The small indirect costs are consistent with the age of onset of stroke (most cases occur in those of retirement age) and also with the notion that stroke cases in general have more prestroke disability than people of the same age and sex among the general population and thus are unlikely to have the same prestroke workforce participation as the general population of same sex and age. The high level of preexisting disability among stroke patients is also evident when the costs of community services for first-ever-in-a-lifetime cases are considered (0.1% of first year costs). These costs are small because the majority of stroke cases who receive community services after the stroke were receiving similar services before the stroke.

The time costs of caring for disabled stroke survivors and the additional out-of-pocket costs to stroke patients not included as a component of other cost categories were substantial in the first year and have not been included in previous COI studies for stroke. The majority of informal care provided to stroke patients was at the expense of family time or leisure time. We considered that one third of the average Australian weekly wage was a conservative estimate of the opportunity cost of providing informal care to stroke survivors during leisure or family time, in which the opportunity cost of any activity is the benefit foregone by not using the same resources for the next best alternative use. The replacement cost approach would overestimate the true cost of informal care because it is unlikely that any society would be prepared to pay for the complete replacement of care provided by relatives and friends when some of that care could be considered nonessential.

In summary, the findings from the present study represent the first comprehensive incidence-based estimate of the costs of stroke in Australia. A broad and inclusive range of costs was included, and every effort was made to include only those costs that were stroke-related and were additional to the prestroke situation. Future work will build on the existing models, for example, by incorporating resource use data from rural Australia and other urban regions of Australia so that the strength of the current findings can be explored. The effects of preventative and treatment strategies on costs and outcomes can also be assessed.

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