Economic Evaluation of Australian Stroke Services

A Prospective, Multicenter Study Comparing Dedicated Stroke Units With Other Care Modalities

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Background and Purpose—Level I evidence from randomized controlled trials demonstrates that the model of hospital care influences stroke outcomes; however, the economic evaluation of such is limited. An economic appraisal of 3 acute stroke care models was facilitated through the Stroke Care Outcomes: Providing Effective Services (SCOPES) study in Melbourne, Australia. The aim was to describe resource use up to 28 weeks poststroke for each model and examine the cost-effectiveness of stroke care units (SCUs).

Methods—A prospective, multicenter, cohort study design was used. Costs and outcomes of stroke patients receiving 100% treatment in 1 of 3 inpatient care models (SCUs, mobile service, conventional care) were compared. Health-sector resource use up to 28 weeks was measured in 1999. Outcomes were thorough adherence to a suite of important clinical processes and the number of severe inpatient complications.

Results—The sample comprised 395 participants (mean age 73 [SD 14], 77% first-ever strokes, males 53%). When compared with conventional care (n = 84), costs for mobile service (n = 209) were significantly higher (P = 0.024), but borderline for SCU (n = 102, P = 0.08; $AUD12 251; $AUD15 903; $AUD15 383 respectively). This was primarily explained by the greater use of specialist medical services. The incremental cost-effectiveness of SCUs over conventional care was $AUD9867 per patient achieving thorough adherence to clinical processes and $AUD16 372 per patient with severe complications avoided, based on costs to 28 weeks.

Conclusions—Although acute SCU costs are generally higher, they are more cost-effective than either mobile service or conventional care. (Stroke. 2006;37:2790-2795.)

Key Words: cost-effectiveness ■ stroke management ■ stroke units

Stroke is a high-cost, chronic condition. The lifetime costs of first-ever strokes, estimated as $AUD1.3 billion in Australia for 1997,1 are expected to increase given an ageing population. With most acute stroke patients (89%) in Australia admitted to hospital,1 effective management is important. It has been shown that stroke care units (SCU) provide improved patient outcomes reducing mortality and morbidity by about 20% compared with conventional care (CC).2,3 The reasons for the improved outcomes achieved by SCUs remain unclear. However, there is consensus that a focused multidisciplinary approach in a localized ward with ongoing education and specialization are essential.3 Adherence to important processes of care may also be a factor.4–7 Nevertheless, only 20% of Australian acute public hospitals offer SCUs.8

Although there is worldwide interest in identifying cost-effective clinical management strategies, economic evaluations of alternative models of stroke management are few,9–11 with none in Australia. Most studies use length of hospital stay to describe stroke management costs12,13; however, it is a crude surrogate measure which is insensitive and not generalizable.

An economic appraisal of stroke care was facilitated through the SCOPES (Stroke Care Outcomes: Providing Effective Services) study, which examined the structure, process, resource utilization and outcomes of care for stroke patients in Victoria, Australia.5 Previously, we provided evidence for the increased uptake of SCUs through the delineation of factors that contribute to their greater effectiveness. This included the development of process indicators, which were demonstrated to be adhered to more often in SCUs. In addition, there was improved survival if all or all except one applicable indicator was completed.5

Received April 11, 2006; final revision received July 18, 2006; accepted August 9, 2006.

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Stroke is available at http://www.strokeaha.org

DOI: 10.1161/01.STR.0000245083.97460.e1

2790
This is the first Australian study to economically evaluate acute stroke care models using patient-level data. We aimed to: (i) describe the costs associated with each model up to 28 weeks post stroke onset, and (ii) examine the cost-effectiveness (efficiency) of SCU and mobile inpatient service (MS) compared with CC. The primary hypothesis was that SCUs would be more cost-effective up to six months in terms of adherence to clinically important process of care indicators and avoidance of severe complications. As SCOPES was not powered to detect statistically significant differences in death or dependency, these surrogate end points were used.

Methods
The methods for SCOPES, a prospective, multicenter cohort design, have been previously published. In brief, 468 participants were recruited from 8 different public hospitals in Victoria (Australia). All eligible hospitals participated and included facilities admitting more than 100 stroke patients annually that had a stroke care model operating >12 months. While some heterogeneity existed between the SCUs, all had the key characteristics described in the literature. Patient eligibility included all consecutive admissions of first-ever or recurrent strokes (ischemic or intracerebral hemorrhage only) presenting to hospital within 3 days of onset and aged ≥18 years. Participating hospitals provided Human Research Ethics Committee approval and subjects provided informed consent.

Definitions
Stroke: vascular lesion of the brain resulting in a neurological deficit persisting for at least 24 hours or resulting in the death of the individual.

Stroke Care Unit: a designated (geographically localized) ward area where a dedicated multidisciplinary stroke team focuses its expertise.

Mobile Service: a dedicated, hospital-based multidisciplinary team, which reviews stroke patients located in different wards throughout a hospital.

Conventional Care: general medical ward care with no dedicated stroke service or health professional team.

Economic Perspective: broad health sector including costs and outcomes for the government (as third party payer) and patients.

Stroke Subtypes Included: partial anterior circulation infarcts, posterior circulation infarcts, lacunar infarcts and intracerebral hemorrhage.

Direct Hospital Costs: costs traceable back to individual patients.

Indirect Hospital Costs: costs apportioned to patients to cover overheads and infrastructure expenses (eg, administration).

Process Indicators: fifteen clinically important indicators including: (1) activities within 24 hours (CT scan, swallowing assessment, allied health assessment, neurological observations); (2) documentation of premorbid function and discharge needs; and (3) management practices (enteric feeding if nil orally for >48 hours, measures to avoid aspiration, deep vein thrombosis prophylaxis, fever management and use of antiplatelet agents at discharge (protocol developed before published guidelines for acute therapy).

Completeness of Care (indicator adherence): “Thorough adherence” was adherence to all, or all except one, applicable process indicators. Applicability was determined for each indicator based on its relevance to individual patients (eg, antiplatelet agents were only applicable for ischemic events).

Severe Complications or Comorbidities: Any new vascular medical condition (stroke progression, recurrent stroke or acute myocardial infarction) or adverse event (eg, aspiration pneumonia) occurring during acute hospitalization and considered incapacitating, life threatening or resulting in a prolonged stay or increased patient acuity.

Data Collection
Cost Data
A microcosting approach using individual patient resource-use data were used. Resource use attributable only to the index stroke was measured for a median 28-week period and included prehospital referral and transport costs obtained via self-report or from hospital medical records.

Costs of the acute admission were sourced directly from hospital finance departments. Five of the 8 hospitals provided clinical costing data for each patient, in accordance with the Clinical Costing Standards Association of Australia. In 4 of these 5 hospitals, a “bottom-up” costing approach entailed the tracking of resources used by individual patients. All operating costs of individual cost centers were included, thereby enabling differentiation between the models. Hospitals typically apportioned indirect costs on a monthly basis, which allowed variations in patient caseload and staff fluctuations to be captured. An itemized breakdown was available for the direct costs, but indirect costs by subcategories were not available for MS.

For 1 MS hospital, average costs per category of care were extrapolated from the other 2 MS hospitals. The absence of patient-level clinical costing data for the 2 CC hospitals was overcome by obtaining average cost data for a patient group matched by ICD-10 codes from a comparable CC hospital in Melbourne.

All participants recorded posthospital resource-use in a diary. Stroke-specific resource-use was then obtained by self-report using a standardized telephone interview schedule. Where information was unclear or incomplete, follow-up calls were made, wherever possible, to service providers.

Posthospital costs were based on the unit costs used in the Australian stroke cost-of-illness study, obtained from professional associations and national references, such as the Medicare Benefits Schedule (refer to supplemental Table I of “unit costs,” available online at http://stroke.ahajournals.org). Costs were adjusted to the 1998 reference year using the Total Health Price Inflation factor, and are reported in AU.

Acute Care Outcomes
Health outcomes were: (1) adherence to a suite of applicable, high priority process indicators to reflect best-practice and as a surrogate measure for better survival; and (2) rates of severe medical complications. The data for these end points was obtained directly from audit of patient medical records by trained clinical data abstractors using standardized proformas with prespecified definitions. Whereas hospital data abstractors were not blinded to the models of care, inter-rater
reliability was assessed and longer-term outcomes including resource-use were obtained by a blinded researcher.5

Statistical Analysis
Costs and benefits for participants receiving 100% treatment in 1 of the 3 acute care models were compared. Discounting was unnecessary as both costs and benefits occurred in the same year. Mean costs were reported to estimate incremental cost-effectiveness ratios, and paired comparisons made assuming unequal variances. Standard tests for categorical data (Fisher exact test and Pearson χ² test) and nonparametric tests (Mann-Whitney) were used for paired comparisons. Incremental cost-effectiveness ratio were determined (ie, net cost of the extra unit of benefit) of SCU and MS relative to the comparator (CC). Sensitivity analysis was undertaken for thorough adherence to process indicators using @RISK software (Palisade Corp, 1997).

Sensitivity analysis was undertaken for thorough adherence to process indicators using @RISK software (Palisade Corp, 1997). The 97% uncertainty range (median, 2.5 and 97.5 percentile) was calculated with 5000 iterations (Monte Carlo simulation) and based on a triangular distribution of ±10% around costs and effects. Level of significance was P<0.05. Statistical analysis was undertaken using Excel (97) and Intercooled Stata 8.0.

Results

Participating Hospitals
All 3 SCU and the 3 MS sites were in tertiary teaching hospitals although MS hospitals were smaller in terms of bed numbers. Although the 2 CC facilities were in smaller suburban hospitals, the average cost data used for CC participants was extrapolated from a larger (nonteaching) hospital.

TABLE 1. Characteristics of Cohort by Treatment Model

<table>
<thead>
<tr>
<th>100% Treatment in Care Type</th>
<th>SCU*</th>
<th>MS*</th>
<th>CC*</th>
<th>SCU vs MS</th>
<th>SCU vs CC</th>
<th>MS vs CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>102</td>
<td>209</td>
<td>84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age stroke onset median (Q1, Q3)†</td>
<td>75 (64, 81)</td>
<td>76 (65, 84)</td>
<td>77 (68, 87)</td>
<td>0.099</td>
<td>0.019</td>
<td>0.180</td>
</tr>
<tr>
<td>Stroke Subtype n (%)†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total anterior circulation infarct</td>
<td>11 (11)</td>
<td>47 (23)</td>
<td>17 (20)</td>
<td>0.107</td>
<td>0.092</td>
<td>0.268</td>
</tr>
<tr>
<td>Partial anterior circulation infarct</td>
<td>30 (29)</td>
<td>45 (22)</td>
<td>24 (29)</td>
<td>0.107</td>
<td>0.092</td>
<td>0.268</td>
</tr>
<tr>
<td>Posterior circulation infarct</td>
<td>15 (15)</td>
<td>29 (14)</td>
<td>6 (7)</td>
<td>0.107</td>
<td>0.092</td>
<td>0.268</td>
</tr>
<tr>
<td>Lacunar infarct</td>
<td>31 (30)</td>
<td>65 (31)</td>
<td>31 (37)</td>
<td>0.107</td>
<td>0.092</td>
<td>0.268</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>15 (15)</td>
<td>23 (11)</td>
<td>6 (7)</td>
<td>0.107</td>
<td>0.092</td>
<td>0.268</td>
</tr>
<tr>
<td>Length of stay median (Q1, Q3)†</td>
<td>8 (4, 16)</td>
<td>7 (5, 14)</td>
<td>9 (5, 15)</td>
<td>0.646</td>
<td>0.400</td>
<td>0.490</td>
</tr>
<tr>
<td>Male, n (%)§</td>
<td>61 (60)</td>
<td>104 (50)</td>
<td>45 (54)</td>
<td>0.116</td>
<td>0.457</td>
<td>0.606</td>
</tr>
<tr>
<td>First-ever stroke, n (%)§</td>
<td>81 (79)</td>
<td>165 (79)</td>
<td>59 (70)</td>
<td>1.000</td>
<td>0.173</td>
<td>0.128</td>
</tr>
<tr>
<td>Admission Glasgow Coma Score=15</td>
<td>69 (68)</td>
<td>123 (59)</td>
<td>52 (62)</td>
<td>0.139</td>
<td>0.442</td>
<td>0.693</td>
</tr>
<tr>
<td>Urinary incontinence &lt;72 hours of stroke</td>
<td>38 (37)</td>
<td>97 (46)</td>
<td>35 (42)</td>
<td>0.144</td>
<td>0.550</td>
<td>0.517</td>
</tr>
<tr>
<td>Severe complication or co-morbidity n(%)§</td>
<td>6 (6)</td>
<td>33 (16)</td>
<td>21 (25)</td>
<td>0.017</td>
<td>&lt;0.001</td>
<td>0.069</td>
</tr>
<tr>
<td>Aspiration pneumonia**</td>
<td>3 (50)</td>
<td>7 (21)</td>
<td>5 (24)</td>
<td>0.017</td>
<td>&lt;0.001</td>
<td>0.069</td>
</tr>
<tr>
<td>Stroke progression**</td>
<td>2 (33)</td>
<td>6 (18)</td>
<td>5 (24)</td>
<td>0.017</td>
<td>&lt;0.001</td>
<td>0.069</td>
</tr>
<tr>
<td>Total adherence to priority indicators (n/i-0) n (%)§</td>
<td>12 (12)</td>
<td>11 (5)</td>
<td>0 (0)</td>
<td>0.062</td>
<td>0.001</td>
<td>0.037</td>
</tr>
<tr>
<td>Thorough adherence to priority indicators (n/i-1) n (%)§</td>
<td>36 (35)</td>
<td>27 (13)</td>
<td>3 (4)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.018</td>
</tr>
<tr>
<td>Discharge destination†</td>
<td>0.137</td>
<td>0.104</td>
<td>0.873</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>38 (37)</td>
<td>71 (34)</td>
<td>27 (32)</td>
<td>0.137</td>
<td>0.104</td>
<td>0.873</td>
</tr>
<tr>
<td>Inpatient rehabilitation</td>
<td>47 (46)</td>
<td>82 (39)</td>
<td>32 (38)</td>
<td>0.137</td>
<td>0.104</td>
<td>0.873</td>
</tr>
<tr>
<td>Aged care (nursing home or hostel)</td>
<td>8 (8)</td>
<td>24 (12)</td>
<td>12 (14)</td>
<td>0.137</td>
<td>0.104</td>
<td>0.873</td>
</tr>
<tr>
<td>Other hospital</td>
<td>2 (2)</td>
<td>4 (2)</td>
<td>2 (2)</td>
<td>0.137</td>
<td>0.104</td>
<td>0.873</td>
</tr>
<tr>
<td>Cost to discharge (average) - all strokes¶</td>
<td>$6187</td>
<td>$7078</td>
<td>$4676</td>
<td>0.103</td>
<td>&lt;0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>- first stroke</td>
<td>$6274</td>
<td>$6103</td>
<td>$4680</td>
<td>0.003</td>
<td>&lt;0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>- recurrent stroke</td>
<td>$5851</td>
<td>$10 737</td>
<td>$4665</td>
<td>0.001</td>
<td>0.223</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total costs (average) - all strokes¶</td>
<td>$15 383</td>
<td>$15 903</td>
<td>$12 251</td>
<td>0.748</td>
<td>0.082</td>
<td>0.024</td>
</tr>
<tr>
<td>- first strokes</td>
<td>$16 072</td>
<td>$14 599</td>
<td>$12 826</td>
<td>0.431</td>
<td>0.154</td>
<td>0.380</td>
</tr>
<tr>
<td>- recurrent strokes</td>
<td>$12 726</td>
<td>$20 791</td>
<td>$10 893</td>
<td>0.009</td>
<td>0.471</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*SCU: stroke care unit (excludes 73 patients who received only some SCU care), MS: mobile inpatient service, CC: conventional care.
For paired comparisons, the following are used: †Mann-Whitney test; ‡Pearson χ² test; §Fisher exact test; ¶t tests with unequal variances assumed.
**Main types of severe complications or comorbidities recorded, individual numbers too small for meaningful interpretation.

Medical complications included falls, urinary tract infections, aspiration pneumonia, other chest infections, decubitis ulcers, deep vein thrombosis. Comorbidities were defined as progression of index stroke, a recurrent stroke or acute myocardial infarction.
Of the 468 SCOPES participants, 395 (84%) were patients receiving 100% care in 1 of the 3 care models (SCU 102, MS 209, CC 84; Figure). The economic analysis included 305 first-ever and 90 recurrent stroke patients, of which the mean age was 73 (SD 14) and 53% were male. The participants were comparable in terms of age, gender, stroke subtype, stroke severity and length of acute hospital stay (Table 1). The 73 excluded cases not receiving 100% treatment in a SCU did not differ from included patients in terms of age, gender and stroke subtype; however, more had upper-limb weakness on admission and were incontinent within 72 hours of stroke.

### Cost Analysis

Table 2 outlines the resource categories and associated average costs per patient for each category by care model. When compared with CC ($AUD12 251), average costs to 28 weeks for both MS ($AUD15 903, P = 0.024) and SCU ($AUD15 383, P = 0.08) were higher.

Prehospital costs, accounting for about 3% of total average costs, exhibited minimal variation between the 3 models. The major component was ambulance transport to hospital. Acute hospital costs accounted for between 34% (CC) and 41% (SCU) of average total costs. Direct hospital costs accounted for a higher proportion of acute costs in CC (81%) than the other 2 models (SCU 77%, MS 66%). The categories of acute direct costs varied according to care model with higher costs for nursing, medical and emergency in SCU than CC. Nursing costs were consistently the largest acute cost component for each model (between 20% to 28%), with SCUs spending more. Average medical costs in SCUs were significantly greater than for MS and CC, whereas MS had lower imaging, but higher pathology costs.
The major postacute cost driver across all models was rehabilitation, with the average cost of $AUD6637 for SCU patients accounting for as much as 69% of these costs (MS 61%, CC 56%).

Acute Outcome Analysis
SCUs were superior to CC in terms of quality of care with almost 10 times the rate of patients with thorough adherence to process indicators (353 per 1000 compared with 36, \( P = 0.001 \)). The difference between MS and CC was also significant (Table 3). The rate of severe complications was significantly lower for SCU patients (59 per 1000) compared with CC (250), \( P = 0.001 \).

Incremental Cost-Effectiveness
The incremental cost of SCUs achieving another patient with thorough adherence was $AUD9867 (median $9977 [$4810–$14 885]) over the CC cost (compared with MS $AUD39 039). In terms of avoiding additional patients with severe complications, the incremental cost-effectiveness of SCU over CC was $AUD16 372, less than half that of MS over CC ($AUD39 629). SCUs were “dominant” compared with MS in that for lower costs, they produced better results for both outcome measures (Table 3).

Discussion
This study provides further evidence of the superiority of care delivered in a geographically localized unit. SCUs were cost-effective and the additional cost in providing SCUs compared with CC was found to be justified given the greater health benefits in terms of delivering best practice processes and avoiding severe complications. Our analysis was strengthened by the use of individual patient resource-use data from a prospective, multicenter study.

Although this study lacked power to detect differences in “hard” outcomes, we have previously established that our definition of “thorough adherence” was directly linked to a 3-fold improvement in odds of survival at discharge when differences in age, gender and stroke severity were taken into account. Therefore, this end point was an appropriate surrogate measure of effectiveness. Our adjusted odds of being independent at 6 months (modified Rankin score 0 to 2) for cases receiving 100% treatment in a SCU compared with CC was 1.23 (95% CI, 0.52 to 2.9) which is consistent with the Cochrane meta-analysis.3

The generalizability of these results may be limited given differences in stroke care treatment patterns between countries, study perspective, timeframe and cost methodology. Nevertheless, although different end points were used, the findings generally accorded with the economic evaluation by Patel et al.11 This is the first Australian study to detail the costs and cost-effectiveness of different acute care models, and it provides important information to underpin increased investment in SCUs.

Every effort was made to ensure that costs for the different models were derived on the same basis. However, the higher acute costs of SCUs and MS may possibly stem from a better accounting system in the larger hospitals, such as a more finely grained method for apportioning costs between cost centers. Nevertheless, each site reported that they conformed to agreed standards for clinical costing.16 In addition, these sites may have had more senior nonclinical staff and utility costs (electricity, gas, water). Furthermore, SCUs were located within mixed ward settings (usually either neurology or another specialty), which were likely to be associated with a higher order of costs than general medical wards. For example, one SCU cost-center included renal dialysis resulting in higher average costs being apportioned to all patients in that ward. Also, tertiary hospitals are characterized by higher teaching and research loads, and the increased staff costs may not have been offset by economies of scale.

Another explanation for higher costs in SCUs was the provision of more and/or more costly care to patients. Nursing and medical care were consistent drivers of acute costs. More specialized or experienced nursing and medical staff probably accounted for the higher direct costs of SCU patients, given the likelihood of their higher salaries. The higher postacute costs of SCU patients may reflect different management practices between the models of care as more

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### Table 3. Outcomes by Care Models: All Strokes

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Model</th>
<th>SCU</th>
<th>MS</th>
<th>CC</th>
<th>SCU vs MS</th>
<th>SCU vs CC</th>
<th>MS vs CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. per 1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorough adherence to process of care measures</td>
<td>353</td>
<td>129</td>
<td>36</td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.018</td>
</tr>
<tr>
<td>At least one severe complication</td>
<td>59</td>
<td>158</td>
<td>250</td>
<td></td>
<td>0.017</td>
<td>&lt;0.001</td>
<td>0.069</td>
</tr>
<tr>
<td>Incremental cost-effectiveness ratios $\text{(AUD)}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean $\text{§}$</td>
<td>Dominant</td>
<td>$9867</td>
<td>$39 039</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean $\text{§}$</td>
<td>Dominant</td>
<td>$16 372</td>
<td>$39 629</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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1 Obtained from 2-sided Fisher exact test; 2 differences in costs between 2 models of care divided by the difference in health benefit gained; §based on total costs to 28 weeks; ||more health benefits coupled with cost savings (win-win).
SCU patients used rehabilitation and had specialist medical follow-up. This additional resource use of SCUs is justified by their better outcomes.\(^9\),\(^11\)

This study only applied to a subset of typically moderate strokes\(^5\) and may not be representative of the entire stroke population.\(^1\) However, because process indicators are often universally applicable irrespective of stroke type or severity, they permit a more generalizable estimate of outcome than rates of severe complications. Several potential sources of bias arose because of reliance on self-reported information from telephone follow-up surveys and the abstraction of end point data from medical records. Although research officers were not blinded to the model of care when auditing medical records, a 10% random reaudit indicated acceptable inter-rater reliability.\(^5\) Furthermore, all follow-up telephone interviews, including the resource-use schedule, were conducted by a research officer blinded to the model of care received by participants.

This study confirms the cost-effectiveness of dedicated SCUs over the first 28 weeks, and provides information important to policymakers concerned with stroke care management and associated resource allocation decisions.

**Acknowledgments**

The involvement of the study participants, project officers and the assistance and cooperation of the Finance Departments of the participating hospitals in providing clinical costing data is acknowledged. It should be noted that coauthors Donnan and Davis are the heads of dedicated stroke units in their respective hospitals. They were not directly involved in the collection of data or analysis of the results.

**Sources of Funding**

The SCOPES study was supported by the Department of Human Services Victoria, the Ian Potter Foundation and the National Stroke Foundation of Australia.

**Disclosures**

None.

**References**

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Stroke. 2006;37:2790-2795; originally published online September 28, 2006;
doi: 10.1161/01.STR.0000245083.97460.e1
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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