Original Contributions

Stroke Unit Care in a Real-Life Setting

Can Results From Randomized Controlled Trials Be Translated Into Every-Day Clinical Practice? An Observational Study of Hospital Data in a Large Australian Population

Melina Gattellari, PhD; John Worthington, MBBS; Bin Jalaludin, PhD; Mohammed Mohsin, PhD

Background and Purpose—In randomized trials, acute stroke units are associated with improved patient outcomes. However, it is unclear whether this evidence can be successfully translated into routine clinical practice. We aimed to determine the effect of a coordinated rollout of funding for 22 stroke units on patient outcomes in Australia.

Methods—A multicenter observational study was undertaken using health administrative data recording admissions for a primary diagnosis of ischemic stroke from July 2000 to June 2006. Analyses were stratified by hospital type (major principal referral, smaller nonprincipal referral hospitals).

Results—We analyzed 17,659 admissions for ischemic stroke. Among major principal referral hospitals with acute stroke units, the proportion of admissions resulting in death or discharge to home was unchanged after stroke unit rollout (10.7% vs 10.6% and 44.1% vs 45.0%, respectively; \( P = 0.37 \)). In contrast, significant differences in discharge destination were noted across time among smaller nonprincipal referral hospitals (\( P < 0.001 \)). Before the rollout of stroke units, 13.8% of admissions to smaller hospitals resulted in a death, decreasing to 10.5% after stroke units were implemented. Discharges to home increased from 38.8% to 44.5%. Discharges to nursing homes decreased from 6.3% to 4.9%. Differences across time remained significant when controlling for patient demographics, comorbidities, indicators of poor prognosis, and clustering of outcomes at hospital level. Improved outcomes were observed across all ages and among patients with indicators for a poor prognosis.

Conclusions—This multicenter analysis of a large Australian population of hospital stroke admissions demonstrates short-term benefits from implementing stroke units in nonprincipal referral hospitals. (Stroke. 2009;40:10-17.)

Key Words: health services ■ mortality ■ stroke

Evidence from randomized controlled trials demonstrates that stroke unit care reduces the odds of death attributable to stroke by 14% and death and disability by 18%.1 Stroke units are now recommended as the minimum standard of care for all patients admitted to hospital with a diagnosis of stroke.2

Many centers worldwide have implemented stroke units hoping to replicate outcomes achieved in randomized studies. It cannot be assumed, however, that the benefits of stroke units are realized because results from randomized trials do not necessarily translate into real-world settings.3

Most existing evaluations in real-world settings study small samples and/or use data from single centers. A recent review of observational studies evaluating stroke unit care highlighted the difficulties of assessing real-world implementation.4 Existing studies were heterogeneous in terms of study design and length of follow-up. All multicenter studies included in the review were cross-sectional in design.4 Further, uncertainties remain as to whether stroke unit care reduces mortality among those with a poor prognosis at the time of stroke, namely those presenting with severe stroke and elderly patients.4

In Australia, significant restructuring of stroke care has occurred in New South Wales (NSW),5,6 the state comprising one-third of the country’s population.7 A coordinated rollout of funding for 22 multidisciplinary stroke units in metropolitan areas was delivered, with funding awarded to the first stroke unit in February 2003. The rollout was completed in

Received April 18, 2008; final revision received May 13, 2008; accepted May 22, 2008.

From School of Public Health and Community Medicine (M.G.), The University of New South Wales & Centre for Research, Evidence Management and Surveillance, Division of Population Health, SSWAHS, Liverpool, New South Wales, Australia; Northern Beaches Area Stroke Unit (J.W.), Department of Neurology, Liverpool Health Service, Liverpool, New South Wales, Australia; School of Public Health and Community Medicine (B.J.), The University of New South Wales & Director, Centre for Research, Evidence Management and Surveillance, Division of Population Health, Liverpool, New South Wales, Australia; School of Public Health and Community Medicine (M.M.), The University of New South Wales Clinical Excellence Commission, Sydney, New South Wales, Australia.

Correspondence to Melina Gattellari, Senior Research Fellow, School of Public Health and Community Medicine, The University of New South Wales & Centre for Research, Evidence Management and Surveillance, Division of Population Health, SSWAHS, Locked Bag 7017, Liverpool, New South Wales, Australia 1871. E-mail Melina.Gattellari@sswahe.nsw.gov.au

© 2008 American Heart Association, Inc.

Stroke is available at http://stroke.ahajournals.org

DOI: 10.1161/STROKEAHA.108.523548
July 2004. The 22 hospitals with stroke units include 12 principal referral hospitals, which are large tertiary referral centers, and many had existing organized stroke services. In addition, 10 nonprincipal referral hospitals now offer stroke units in metropolitan areas of NSW. Approximately 10 million Australian dollars were used to either enhance existing stroke services already available in principal referral hospitals or establish new stroke units in the smaller nonprincipal referral centers. Typical uses of funds included colocalization of stroke beds, the purchasing or updating of equipment, such as CT scanners for 24-hour availability, cardiac monitors, and additional salaries for medical, nursing, and other allied health personnel.

The rollout of stroke units represented a major shift and expansion in the organization of stroke care. There exists a unique natural experiment in Australia to address the question of whether the benefits of stroke units demonstrated in randomized controlled trials can be widely realized in real-world clinical practice. Stroke unit implementation in NSW occurred over a defined time period and resource allocation was standardized across sites. We aimed to compare patient outcomes after funding was made available for stroke units compared with the time period before funding was distributed. We hypothesized that there would be a reduction in the percentage of in-hospital deaths associated with ischemic stroke in the period after funding enhancement. We also hypothesized that there would be a higher proportion of admissions resulting in discharge to home. To our knowledge, our analysis represents the largest multicenter real-world study observing the impact of stroke unit care on patient mortality and discharge status.4

Materials and Methods

Database

The Admitted Patient Data Collection is a de-identified census of all patient admissions to hospitals within NSW, Australia.6 NSW is Australia’s most populous state (~6.5 million residents), representing one-third of all people living in Australia.7 The collection records the “primary diagnosis” for each episode of care. Ischemic stroke is coded as an “acute” episode of care during the patient admission. Clinical notes, radiological scans, and other reports are reviewed by a trained medical coder at each hospital who classifies the primary reason for each episode of care using International Classification of Disease version 10 (ICD-10) codes.9 Previous research validating Australian administrative health data sets has shown that primary diagnoses are rarely missing and stroke diagnoses appearing in administrative data sets are accurate 93% of the time.10–12 The Admitted Patient Data Collection records up to 54 other diagnosis, a trained medical coder at each hospital who classifies the primary reason for each episode of care using International Classification of Disease version 10 (ICD-10) codes.9 Previous research validating Australian administrative health data sets has shown that primary diagnoses are rarely missing and stroke diagnoses appearing in administrative data sets are accurate 93% of the time.10–12 The Admitted Patient Data Collection records up to 54 other diagnosis, a trained medical coder at each hospital who classifies the primary reason for each episode of care using International Classification of Disease version 10 (ICD-10) codes.9 Previous research validating Australian administrative health data sets has shown that primary diagnoses are rarely missing and stroke diagnoses appearing in administrative data sets are accurate 93% of the time.10–12 The Admitted Patient Data Collection records up to 54 other diagnosis, a trained medical coder at each hospital who classifies the primary reason for each episode of care using International Classification of Disease version 10 (ICD-10) codes.9 Previous research validating Australian administrative health data sets has shown that primary diagnoses are rarely missing and stroke diagnoses appearing in administrative data sets are accurate 93% of the time.10–12 The Admitted Patient Data Collection records up to 54 other diagnosis, a trained medical coder at each hospital who classifies the primary reason for each episode of care using International Classification of Disease version 10 (ICD-10) codes.9 Previous research validating Australian administrative health data sets has shown that primary diagnoses are rarely missing and stroke diagnoses appearing in administrative data sets are accurate 93% of the time.10–12

Identification of Ischemic Stroke Admissions

We identified all acute episodes of care associated with each separate admission for a primary diagnosis of ischemic stroke using ICD-10 codes 163.x. We included admissions recorded from patients older than 18 years of age who were separated from hospital from July 2000 until June 2006, the date of the most recently available data when information was extracted. Therefore, the data encapsulated 2 time periods, each spanning ~3 years before and 3 years after the rollout of funding for stroke units. We limited our analysis to ischemic stroke because this subtype is managed medically. In contrast, large numbers of hemorrhagic stroke admissions are preferentially managed in principal referral hospitals with neurosurgical units, resulting in patient inflows from smaller nonprincipal referral hospitals to these hospitals. Assessment of stroke unit care for hemorrhagic stroke therefore may be confounded by the effect of neurosurgical treatment and variations in patient case mix.

Identification of Stroke Unit Hospitals

We obtained inception dates for stroke units (personal communication, Mr Mark Longworth, Manager, Stroke Services NSW, unpublished data, 2007). All admissions were coded according to whether the admission was to a hospital offering a stroke unit and, if so, whether the admission was made before or after the month in which funds became available. Hospitals were classified as “principal referral” or “nonprincipal referral” hospitals using classifications made by NSW Health, the administrative body overseeing health care in that state.

Identification of Comorbid Conditions

There is no universally accepted standardized method for assessing comorbidity, and few studies have validated comorbidity schemes using Australian health data sets. We calculated a modified Charlson index score based on an Australian version using ICD-10 codes that has been shown to predict in-hospital mortality.13 We modified scores to exclude codes for cerebrovascular events, because all admissions in our data set would be characterized by these codes. All admissions were classified according to whether they had a record for each of the following comorbid conditions: acute myocardial infarction, congestive heart failure, peripheral vascular disease, dementia, pulmonary disease, connective tissue disorder, peptic ulcer, liver disease, diabetes without complications, diabetes with complications (for example, end-organ damage), renal disease, paraplegia or hemiplegia, cancer, metastatic cancer, severe liver disease, and the presence of human immunodeficiency virus. A weighted Charlson index score was computed according to a previously validated method.13

Indicators of Poor Prognosis

We identified potential markers of poor prognosis in the absence of standardized information documenting the severity of stroke. We considered pneumonia (ICD-10 J13, J14, J15.x, J18.x, J22, J69.0), urinary incontinence (ICD-10 R32, N39.3, N39.4), atrial fibrillation (ICD-10 I48), somnolence, stupor or coma, or other symptoms and signs involving cognitive functions or awareness (ICD-10 R40.x, R41.x), and whether the patient received any mechanical ventilation (included in the data collection as a separate variable) as markers of a poor prognosis. Admissions with any of these indicators recorded on the medical record were considered to represent admissions with an indication of poor prognosis.

Outcomes of Acute Admissions for Ischemic Stroke

Discharge destination is coded according to whether the episode of care results in death, a discharge from hospital to usual residence, a discharge to a nursing home, or a transfer to another hospital or a change in the type of care received within the same hospital (for example, from acute care to rehabilitation). We identified unique admissions to each hospital that had resulted in a death, discharge to the patient’s usual home, or to a nursing home as the last known outcome for patients during their acute hospital stay. Discharges resulting in transfers to other hospitals or to nonacute care wards were considered to represent other reasons for the end of the acute hospital admission. We also calculated length of stay for the acute admission.

Statistical Analysis

Outcomes of Acute Admissions for Ischemic Stroke

We first performed descriptive analyses, reporting discharge destination for admissions occurring before and after the
rollout of funding for stroke units. We stratified analyses by hospital type (principal referral vs nonprincipal referral) because principal referral hospitals represented major tertiary teaching hospitals with existing organized stroke services or a greater level of resources before the time funding rolled out. These hospitals typically used funding to enhance existing services. In contrast, nonprincipal referral hospitals had lower levels of resources for stroke and used funding to establish de novo stroke units. Accordingly, we considered that outcomes for patients treated in principal referral hospitals would provide a benchmark against which the outcomes of nonprincipal referral hospitals could be compared.

The χ² analyses initially determined the effect of time on discharge destination within hospital type. We then conducted multivariate analysis to determine the effect of time (before and after roll-out of funding), controlling for patient demographic variables, Charlson index scores, and indicators of poor prognosis. For these analyses, we considered 2 outcomes: death and discharge from hospital care. There were too few discharges to nursing homes (~5%) to allow a meaningful multivariate analysis of this outcome. Before stratification of our sample into principal referral and nonprincipal referral hospitals, we assessed whether outcomes varied across time according to hospital type. We tested for heterogeneity using a 2-way interaction term between time and hospital type. We tested whether the effect of hospital type was further modified by age and poor prognosis by creating 3-way interaction terms to test in our multivariate baseline model (3-way interaction term for time, hospital type and age, and for time, hospital type, and poor prognosis indication).

We selected age and poor prognosis because others have assessed whether the effect of stroke unit care varied according to these or similar variables. We created a full-factorial baseline model to assess heterogeneity using our interaction terms, controlling for covariates and clustering at the hospital level in multivariate models. If significant heterogeneity was identified, we stratified our sample accordingly to determine the effect of time (before vs after rollout of stroke units), controlling for other significant covariates. Demographic variables considered as potential predictors were sex, age, marital status (married vs other), and country of birth (Australia vs other). Whether a record of private hospital insurance cover was noted provided a proxy indicator of socioeconomic status. Age was modeled continuously as a linear relationship between age, and each of the outcomes was evident. Interhospital variability in outcomes may occur because health care delivery and patient characteristics differ from hospital to hospital. We therefore used generalized estimation equations to control for the clustering or interdependence of outcomes by hospital.

P < 0.05 was considered statistically significant for all analyses. We also calculated median length of stay for the acute admission. Analyses were performed using SPSS Version 15.0.1.16 for Windows and SAS Version 9.1.3 for Windows.17

Results

Acute Admissions for Ischemic Stroke
From July 2000 until June 2006, there were 17 659 hospital admissions for ischemic stroke treated in the 22 hospitals that had received funding for a stroke unit. Almost 10 000 (9991) admissions occurred after funding for stroke units had been allocated to those individual hospitals. Admissions to principal referral hospitals accounted for 12 520 (70.9%) of all ischemic stroke admissions, whereas 5139 (29.1%) were treated in nonprincipal referral hospitals. Principal referral hospitals experienced an increase in admissions from 5515 before the inception of funding to 7005, representing a 27.0% increase in caseload. In comparison, nonprincipal referral hospitals experienced an increase in admissions from 2153 to 2986 (38.7% increase). The total number of admissions over the study period from July 2000 to June 2006 ranged from 602 to 1453 among the 12 principal referral hospitals (median, 1101.5; interquartile range, 930.5–1151.75), whereas the total number of admissions ranged from 164 to 810 among the 10 nonprincipal referral hospitals (median 545.5; interquartile range, 404–627).

Characteristics of Acute Admissions to Hospitals for an Ischemic Stroke
Characteristics of patients were broadly similar before and after stroke unit implementation in principal and nonprincipal referral hospitals (Table 1). Age, Charlson index comorbidity scores, atrial fibrillation, and other indicators of a poor prognosis were similar across time within principal referral hospitals. Patients treated in nonprincipal referral hospitals tended to be older than those treated in principal referral hospitals. Among nonprincipal referral hospitals, there appeared to be an increase in admissions with atrial fibrillation across time (22.2% vs 27.7%).

Deaths and Discharges to Homes After an Acute Admission to Hospital for an Ischemic Stroke
Compared with before, there were no significant shifts in discharge destination across time for acute ischemic stroke admissions treated in principal referral hospitals (P = 0.37; Table 2). One in 10 (10.7%) admissions for an ischemic stroke treated in principal referral hospitals resulted in death before the rollout of funding for stroke units. Similarly, 10.6% of admissions resulted in a death after the distribution of funds. Just less than one-half of all admissions resulted in a discharge to home during both time periods (44.1% and 45.1%, respectively).

In contrast, a statistically significant shift in discharge destination occurred across time for ischemic stroke to nonprincipal referral hospitals (P < 0.0001). Before the rollout 13.8% of admissions resulted in a death compared with 10.5% after the rollout of funding. Discharges to home also increased across the 2 time periods (from 38.8% to 44.5%).

Multivariate Analyses

Deaths
Overall, the effect of time on death for the combined sample of 17 659 admissions was not statistically significant (adjusted odds ratio, 0.90; 95% CI, 0.80–1.02; P = 0.09). However, our multivariate analysis demonstrated significant heterogeneity in mortality across time according to hospital type (P < 0.0001), confirming that the effect of stroke unit implementation differed for principal referral and nonprincipal
referral hospitals. Deaths decreased among nonprincipal referral hospitals (adjusted odds ratio, 0.67; 95% CI, 0.59–0.75) but not among principal referral hospitals (adjusted odds ratio, 0.99; 95% CI, 0.88–1.10) when controlling for patient characteristics, Charlson comorbidity scores, indicators of poor prognosis, and the effects of clustering of outcomes by hospital. The different effect of stroke unit care for principal referral and nonprincipal referral hospitals was not further modified by patient age (3-way interaction term, \( P = 0.56 \)) or whether the admission had an indication for a poor prognosis (3-way interaction term, \( P = 0.82 \)). That is, the significant improvement in mortality for admissions treated in nonprincipal referral hospitals was observed irrespective of age and prognosis. For admissions of patients younger than 75 years, 7.4% resulted in a death during the acute episode of care before the rollout of funding, and 4.9% resulted in death after the rollout of funding. Deaths for admissions of patients between 75 and 85 years decreased from 14.4% to 11.4%. An effect of time (before vs after the rollout of funding) was also demonstrated for admissions of patients older than age 85. In these elderly patients, admissions resulting in deaths decreased from 28.5% to 19.9% (Table 2). Similarly, among admissions of patients without an indication for a poor prognosis, 7.6% resulted in a death before the rollout of funding, compared with 4.7% after the rollout period. For those admissions of patients with an indication of a poor prognosis, deaths decreased from 24.7% to 19.0% (Table 2). Deaths did not change among admissions of patients treated in a principal referral hospital, irrespective of age and prognosis.

### Discharge to Home

There was no significant effect of stroke unit rollout on the proportion of admissions discharged to home for the total sample of admissions analyzed (adjusted odds ratio, 1.10;
Table 2. Discharge Destination of Patients Before and After Implementation of Stroke Units in Principal Referral Hospitals and Nonprincipal Referral Hospitals

<table>
<thead>
<tr>
<th>Discharge Destination</th>
<th>Principal Referral Hospital</th>
<th>Nonprincipal Referral Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before n (%)</td>
<td>After n (%)</td>
</tr>
<tr>
<td>All age groups</td>
<td>N=5515</td>
<td>N=7004*</td>
</tr>
<tr>
<td>Died</td>
<td>588 (10.7)</td>
<td>745 (10.6)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>2434 (44.1)</td>
<td>3158 (45.1)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>304 (5.5)</td>
<td>341 (4.9)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>2189 (39.7)</td>
<td>2760 (39.4)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>8 (4–14)</td>
<td>8 (5–15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Younger than 75 yr†</td>
<td>N=2679</td>
<td>N=3348</td>
</tr>
<tr>
<td>Died</td>
<td>181 (6.8)</td>
<td>214 (6.4)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>1489 (55.6)</td>
<td>1912 (57.1)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>65 (2.4)</td>
<td>75 (2.2)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>944 (35.2)</td>
<td>1147 (34.3)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>8 (4–14)</td>
<td>8 (5–13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between 75 and 85 yr†</td>
<td>N=2035</td>
<td>N=2498</td>
</tr>
<tr>
<td>Died</td>
<td>257 (12.6)</td>
<td>296 (11.8)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>734 (36.1)</td>
<td>944 (37.8)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>139 (6.8)</td>
<td>140 (5.6)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>905 (44.5)</td>
<td>1118 (44.8)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>9 (5–15)</td>
<td>9 (5–15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 85 yr</td>
<td>N=801</td>
<td>N=1158</td>
</tr>
<tr>
<td>Died</td>
<td>150 (18.7)</td>
<td>235 (20.3)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>211 (26.3)</td>
<td>302 (26.1)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>100 (12.5)</td>
<td>126 (10.9)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>340 (42.4)</td>
<td>495 (42.7)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>9 (4–16)</td>
<td>9 (5–16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without an indication of poor prognosis‡</td>
<td>N=3454</td>
<td>N=4292</td>
</tr>
<tr>
<td>Died</td>
<td>176 (5.1)</td>
<td>177 (4.1)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>1797 (52.0)</td>
<td>2397 (55.8)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>113 (3.3)</td>
<td>104 (2.4)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>1368 (39.6)</td>
<td>1614 (37.6)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>7 (4–12)</td>
<td>7 (4–12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any indication of a poor prognosis‡</td>
<td>N=2061</td>
<td>N=2712</td>
</tr>
<tr>
<td>Died</td>
<td>412 (20.0)</td>
<td>568 (20.9)</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>637 (30.9)</td>
<td>761 (28.1)</td>
</tr>
<tr>
<td>Discharged to nursing home</td>
<td>191 (9.3)</td>
<td>237 (8.7)</td>
</tr>
<tr>
<td>Other end of acute admission</td>
<td>821 (39.8)</td>
<td>1146 (42.3)</td>
</tr>
<tr>
<td>Median length of stay (IQR)</td>
<td>10 (5–19)</td>
<td>11 (6–20)</td>
</tr>
</tbody>
</table>

*Missing discharge destination data was noted for 1 admission.
†Age modelled as continuous in multivariate analyses.
‡Admissions classified as having any indication of a poor prognosis if atrial fibrillation, urinary incontinence, pneumonia, coma, somnolence or stupor or other symptoms or signs involving cognitive functions or awareness, or mechanical ventilation were noted in the medical record.
95% CI, 0.93–1.29; \( P = 0.26 \)). However, there was significant heterogeneity in this outcome across time according to hospital type and whether admissions had any indication for a poor prognosis (3-way interaction term, \( P = 0.003 \)). We therefore stratified our sample into principal referral and nonprincipal referral hospitals, and, within these strata, into those admissions with and without an indication of a poor prognosis. Among principal referral hospitals, there was no overall effect of time (adjusted odds ratio, 1.03; 95% CI, 0.84–1.25). A greater proportion of admissions without any indicator of a poor prognosis resulted in a discharge to home after the rollout of funding (52.0% vs 55.8%; adjusted odds ratio, 1.15; 95% CI, 0.96–1.37), whereas slightly fewer admissions with indications of a poor prognosis were discharged to home after funding rollout (30.9% vs 28.1%; adjusted odds ratio, 0.84; 95% CI, 0.66–1.07). Differences were small. In contrast, the rollout of funding for stroke units resulted in more discharges to home among nonprincipal referral hospitals (adjusted odds ratio, 1.30; 95% CI, 1.05–1.60). The effect of time was similar for admissions with and without a poor prognosis (adjusted odds ratio, 1.46; 95% CI, 1.19–1.80; and adjusted odds ratio, 1.24; 95% CI, 0.96–1.59, respectively). Discharges to home increased from 47.8% to 54.2% across time for admissions without a poor prognosis, and from 23.3% to 30.2% among those with a poor prognosis (Table 2).

**Deaths During the Acute Episode of Care From July 2000 Until June 2006**

Across the entire study period, 1944 (11.0%) admissions of patients resulted in a death during the acute episode of care. Of these deaths, 1403 or 72.2% had indications for a poor prognosis. Almost half of admissions resulting in a death (n=812 or 41.8%) had a recorded diagnosis of atrial fibrillation.

**Length of Stay**

Our descriptive analysis of length of stay does not appear to reveal clinically important differences across time for admissions treated in principal or nonprincipal referral hospitals (Table 2).

**Discussion**

To our knowledge, this is the largest multicenter observational study evaluating stroke unit care during the acute phase of stroke in a modern real-world setting. Evidence supporting the benefits of stroke unit care for ischemic stroke appears to have been translated in an Australian setting, at least in the short-term. Good outcomes were maintained in large principal referral hospitals across time, although changes across time generally were not demonstrated for admissions to principal referral hospitals. This result perhaps indicates that a “threshold effect” for stroke unit care had been reached, beyond which it may be unreasonable to expect continued improvement. Significantly reduced in-hospital mortality and an increase in discharges to home were demonstrated in smaller nonprincipal referral hospitals after a rollout of funding for stroke unit implementation. This result was achieved without appearing to increase length of stay. The outcomes approximated those that had been achieved and maintained in larger principal referral hospitals. Overall, the reduced odds of death in the short-term of 0.67 compares favorably with that reported in clinical trials evaluating stroke unit care.1

Improvements in admissions treated in nonprincipal referral hospitals were evident across different ages. In our large data set we were able to demonstrate that the benefits of stroke unit implementation are realized for admissions of patients with any indication of poor prognosis. Although standardized measures for assessing stroke severity exist, this information is not routinely recorded on administrative health databases. To overcome this limitation, we identified 5 markers of poor prognosis in ischemic stroke patients and demonstrated that 72% of admissions resulting in death during the acute phase of stroke had at least 1 of these markers. Whereas stroke unit care improved outcomes for admissions of patients meeting our criteria of a “poor prognosis,” a significant proportion (<20%) still resulted in death.

Without a standardized measure of stroke severity, this potential confounder may not be well-accounted for during analysis. Our index of poor prognosis may have also measured complications. For example, stroke unit care may reduce the prevalence of pneumonia, although shifts across time in the prevalence of pneumonia were not apparent. It is possible that early pneumonia cannot be prevented, but early treatment accounts for reduced mortality. There was no decreasing trend in the prevalence of other prognostic indicators or characteristics across time, indicating that our measure was not sensitive to the care provided but instead identified patients with particularly poor outcomes presumably reflecting stroke severity.

A key goal of implementing stroke units across metropolitan areas was to enhance equity of access and standardize patient outcomes.5,6 Our analysis provides empirical evidence that equity in patient outcomes has been achieved. Admissions of patients to nonprincipal referral hospitals did not appear to have had more favorable prognostic characteristics than admissions to principal referral hospitals. We believe it is unlikely that admission and transfer policies would have affected these results. There is no existing or past transfer policy for patients with stroke by ambulance either preferentially to a hospital with a stroke unit or away from smaller hospitals to larger hospitals (Stroke Services NSW Mark Longworth, Manager, personal communication). Stroke is considered a medical emergency and the standard protocol for medical emergencies is to transfer the patient to the nearest hospital with an available bed in an emergency department. In the data set, <5% of admissions of patients to a nonprincipal referral hospital were documented as transfers to a principal referral hospitals before or after the rollout of funding (4.8%, n=103 vs 3.5%, n=105). Further, admissions of patients with any indication of a poor prognosis were as likely to be transferred from a nonprincipal to a principal referral hospital before or after stroke unit rollout (2.6% vs 3.7%).

Caseload appeared to increase across time, perhaps reflecting the aging Australian community and the increasing numbers of hospitalizations among elderly individuals.18,19 The number of people older than age 75 in NSW has increased from 379,995 in 2001 to 440,450 in 2006.20

**Table 2.** Length of Stay

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Time Period</th>
<th>Discharges to Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Referral</td>
<td>before rollout</td>
<td>47.8%</td>
</tr>
<tr>
<td>Principal Referral</td>
<td>after rollout</td>
<td>54.2%</td>
</tr>
<tr>
<td>Nonprincipal Referral</td>
<td>before rollout</td>
<td>23.3%</td>
</tr>
<tr>
<td>Nonprincipal Referral</td>
<td>after rollout</td>
<td>30.2%</td>
</tr>
</tbody>
</table>
Moreover, hospitalizations have increased among elderly Australians, with a 32.2% increase in hospital separations for men older than 75 years in 2004 to 2005 compared with 2000 to 2001 (670 826 vs 507 620), and 22.6% more hospitalizations among women over the same time period (576 481 vs 706 839). Improved neuroimaging and diagnostic accuracy also may have increased diagnoses of ischemic stroke. Improved outcomes over time reported here do not appear to be the result of changes in patient characteristics.

The strengths of the study include the large sample size, the adjustment of key confounding variables, and the ability to define a time point during which stroke unit care became widely implemented. Australia has offered a unique natural experiment to observe the effects of systematic and equitable implementation of stroke unit care across multiple sites. There were 2 cohorts depending on where admitted patients were treated (ie, principal referral or nonprincipal referral hospital), permitting us to benchmark the outcomes of the smaller hospitals against outcomes achieved by those larger hospitals, which were comparatively well-resourced at the time of funding enhancement. Another large-scale study, performed in Sweden, also reports benefits of real-world implementation of stroke unit care before 1999; however, we are unaware of other examples of a large-scale and coordinated approach to stroke unit implementation in current practice.

We cannot rule out secular trends or unknown confounding effects influencing these results. It is also important to acknowledge that administrative health data are not collected for research purposes. The research literature has shown that primary diagnosis and discharge destination are well-recorded and valid in Australian administrative health data sets. Generally, comorbidities are under-numbered in administrative data sets, although these are accurate when recorded. Charlson comorbidities are likely to be indicated if present in the medical record. Coding standards specify noting all conditions affecting care during a patient’s hospital stay. The unit of analysis was admissions as recorded by individual hospitals. This meant that we could not identify those patients who had been admitted to hospital for ischemic stroke more than once. The analysis was restricted to outcomes during the acute phase of stroke, beyond which in-hospital care continues for a significant proportion of patients. Important process measures (for example, allied health interventions received, time to CT scanning, clinician knowledge and skills) were not determined; yet, it would be of interest to determine if specific processes account for improved outcomes. These findings invite further investigation into longer-term outcomes of stroke unit care. It remains to be seen whether reductions in mortality are still evident 30 days, 90 days, and at 1 year after an ischemic stroke.

Finally, our analysis is of admissions of patients to a hospital with a stroke unit and not to a stroke unit per se. There is no coding for stroke unit admissions. Arguably, a true effect of stroke unit implementation should be evaluated at the hospital level because some patients may be preferentially selected to receive stroke unit care. The impact of any implementation strategy aimed at improving patient outcomes may be best evaluated using data from all admissions rather than restricting the analysis to a potentially select group of patients who are admitted to the specialized stroke ward.

Summary
Evidence from randomized controlled trials indicating the benefits of organized stroke unit care can be translated widely, even to smaller nonprincipal referral hospitals. These benefits are clinically important, can be achieved at a modest cost, and appear to apply to stroke patients of all ages, including the elderly and those with indicators of a poor prognosis.

Acknowledgments
The authors acknowledge Ms Jasminka Muratidi, Manager of Medical Coding, Department of Clinical Information, Sydney South West Area Health Service, for her invaluable advice regarding coding of NSW hospital inpatient statistics data. The authors also thank Mr Mark Longworth, Manager, Stroke Services, New South Wales, for supplying information about stroke unit inception dates in NSW metropolitan hospitals and for insights into current and past stroke service organization in NSW.

Disclosure
Dr John Worthington is Director of the Northern Beaches Stroke Unit, which received funding from NSW Health under the auspices of the Greater Metropolitan Clinical Taskforce (GMCT), Stroke Coordinating Committee (now Stroke Services NSW). Dr John Worthington is a member of Stroke Services NSW (GMCT stroke coordinating committee). Dr Worthington receives no direct financial benefit from GMCT/Stroke Services NSW. No other conflicts of interests are declared. Melina Gattellari was funded by a National Health and Medical Research Council Postdoctoral Training Fellowship (RegKey #803616) and a Commonwealth Department of Health and Aging, Primary Health Care Research, Evaluation and Development Mid-Career Fellowship at the time of analyzing data for the study. The rollout of stroke units was managed and funded by the Greater Metropolitan Clinical Task Force (GMCT). This project has institutional ethics approval by the Medical and Community Human Research Ethics Advisory Panel (Ref. 2007-7-54) of the University of New South Wales.

References


Stroke Unit Care in a Real-Life Setting: Can Results From Randomized Controlled Trials Be Translated Into Every-Day Clinical Practice? An Observational Study of Hospital Data in a Large Australian Population
Melina Gattellari, John Worthington, Bin Jalaludin and Mohammed Mohsin

Stroke. 2009;40:10-17; originally published online October 23, 2008;
doi: 10.1161/STROKEAHA.108.523548

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2008 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/40/1/10

An erratum has been published regarding this article. Please see the attached page for:
/content/40/4/e286.full.pdf

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/
In the article entitled “Stroke Unit Care in a Real-Life Setting: Can Results From Randomized Controlled Trials Be Translated Into Every-Day Clinical Practice? An Observational Study of Hospital Data in a Large Australian Population” by Gattellari et al., several references are incorrect. On page 16, paragraph 3, the sentences “Generally, comorbidities are under-numerated in administrative data-sets, although these are accurate when recorded.”12,18 and “Coding standards specify noting all conditions affecting care during a patient’s hospital stay.”12 should be replaced with “Generally, comorbidities are under-numerated in administrative data-sets, although these are accurate when recorded.”23,24 and “Coding standards specify noting all conditions affecting care during a patient’s hospital stay.”9 The authors have added a reference 24 (cited as Powell H, Lim LL, Heller RF. Accuracy of administrative data to assess comorbidity in patients with heart disease: an Australian perspective. J Clin Epidemiol. 2001; 54:687–693). Furthermore, the authors would like to note that although references 18 and 20, and 19 and 21 are identical, these references are appropriately cited in the text. The authors regret these errors.

The corrected version can be viewed online at http://stroke.ahajournals.org.