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Impact of a Stroke Unit on Length of Hospital Stay and In-Hospital Case Fatality

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Background and Purpose—Randomized trials have demonstrated reduced morbidity and mortality with stroke unit care; however, the effect on length of stay, and hence the economic benefit, is less well-defined. In 2001, a multidisciplinary stroke unit was opened at our institution. We observed whether a stroke unit reduces length of stay and in-hospital case fatality when compared to admission to a general neurology/medical ward.

Methods—A retrospective study of 2 cohorts in the Foothills Medical Center in Calgary was conducted using administrative databases. We compared a cohort of stroke patients managed on general neurology/medical wards before 2001, with a similar cohort of stroke patients managed on a stroke unit after 2003. The length of stay was dichotomized after being centered to 7 days and the Charlson Index was dichotomized for analysis. Multivariable logistic regression was used to compare the length of stay and case fatality in 2 cohorts, adjusted for age, gender, and patient comorbid conditions defined by the Charlson Index.

Results—Average length of stay for patients on a stroke unit (n=2461) was 15 days vs 19 days for patients managed on general neurology/medical wards (n=1567). The proportion of patients with length of stay >7 days on general neurology/medical wards was 53.8% vs 44.4% on the stroke unit (difference 9.4%; $P<0.0001$). The adjusted odds of a length of stay >7 days was reduced by 30% ($P<0.0001$) on a stroke unit compared to general neurology/medical wards. Overall in-hospital case fatality was reduced by 4.5% with stroke unit care.

Conclusions—We observed a reduced length of stay and reduced in-hospital case-fatality in a stroke unit compared to general neurology/medical wards. (*Stroke*. 2009;40:18-23.)

Key Words: case fatality ■ Charlson Index ■ length of stay ■ stroke ■ stroke unit

S everal clinical trials have demonstrated the superiority of interdisciplinary stroke unit care over conventional care on general neurology/medical wards.[1–7] A majority of these studies come from Europe. The effectiveness of stroke units in reducing mortality, institutionalization, and dependence has been confirmed in meta-analysis of randomized controlled trials.[8] However, the impact of stroke units on length of hospital stay is less well-defined. Because length of stay is the single largest determinant of inpatient hospital costs, these data are important for policy makers. The Cochrane review of stroke unit trials concluded that stroke units minimally did not result in longer lengths of stay.[9]

At our institution, before 2001, stroke patients were cared for on both the general neurology service and the general medical service. Approximately 50% of strokes were admitted to the general neurology service. In 2001, a multidisci-

plinary stroke unit was opened at Foothills Hospital, which serves as a tertiary stroke center for a referral population of ≈1.5 million. A majority of patients with stroke diagnosed are admitted directly to the unit from the emergency department. It is a comprehensive, dedicated stroke unit that provides both acute and rehabilitative care for patients who have had an acute stroke. The stroke unit exists in 2 locales: (1) a 12-bed high-observation unit shared by Neurology and Neurosurgery where stroke patients requiring invasive blood pressure monitoring, external ventricular drains, or who have received tissue plasminogen activator in the previous 48 hours are managed until they are stable enough to be moved to the larger subacute unit; (2) a main subacute stroke unit that began with 14 beds, expanded to 18 beds, and is staffed by a multidisciplinary team consisting of nurse practitioners, nurses, neurologists, rehabilitation physicians, social work-

Table 1.   Stroke Definitions and Codes Identified by ICD-9-CM and ICD-10

	ICD-9-CM		ICD-10	
Stroke Type	Code	Definition	Code	Definition
AIS	362.3	Retinal vascular occlusion	H34.1	Central retina artery occlusion
	433.x1	Occlusion and stenosis of precerebral arteries	I63.x	Cerebral infarction
	434.x1	Occlusion of cerebral arteries	I64.x	Stroke, not specified as hemorrhage or infarction
	436	Acute, but ill-defined cerebrovascular disease		
ICH	431.x	Intracerebral hemorrhage	I61.x	Intracerebral hemorrhage
SAH	430.x	Subarachnoid hemorrhage	I60.x	Subarachnoid hemorrhage
TIA	435.x	Transient cerebral ischemia	G45.x	Transient cerebral ischemic attacks and related syndromes

ICH indicates intracerebral hemorrhage.

ers, medical staff, and occupational, physical, and speech therapists. This team is not a mobile stroke team but a dedicated group assigned to the stroke unit ward. Biweekly meetings are conducted with all staff to discuss patient progress and to facilitate discharge planning. Rehabilitation interventions begin immediately. Stroke thrombolysis was routinely available at Foothills Hospital during the entire study period. A key concept in understanding our stroke unit is that it is both a geographic locale and a dedicated team. Finally, patients with a diagnosis of subarachnoid hemorrhage were cared for by the general neurosurgical service and no changes in this model of care occurred over the 2 periods.

We assessed the length of stay and in-hospital case fatality between patients managed on the stroke unit and those managed on general neurology/medical wards (before the stroke unit) at the Foothills Medical Center to assess whether a stroke unit has the potential to reduce the length of stay and in-hospital case fatality.

Materials and Methods

Study Design

A retrospective study of 2 cohorts at the Foothills Medical Center in Calgary, Alberta, was conducted. Stroke patients were identified from discharge abstracts from a comprehensive administrative database from the Calgary Health Region. We compared a cohort of stroke patients managed on general neurology/medical wards in the Foothills Medical Center from January 1, 1998 to March 31, 2000, before the stroke unit was established, with a similar cohort of stroke patients managed on a stroke unit during January 1, 2003 to March 31, 2005. During the period 1998 to 2000, ≈50% of stroke patients were admitted to the general neurology service and the remainder to the general medical service. After the establishment of the stroke unit in 2001, a run-in period was excluded from analysis to allow for protocols to be put in place and staff training to occur. After January 1, 2003, a majority of stroke patients were admitted to the stroke unit.

Before fiscal year 2002–2003, medical centers in Alberta used the International Classification of Diseases, 9th Revision-Clinical Modification (ICD-9-CM) to code hospital discharge abstracts, whereas at the beginning of 2002, the 10th revision for the International Classification of Diseases (ICD-10) replaced ICD-9 province-wide. The new ICD-10 system is more comprehensive than ICD-9. Improvements in areas such as number of codes and an expanded external cause framework are expected to make the ICD-10 a more streamlined system.[10,11] Stroke definitions are shown in Table 1.

Modified Deyo-Charlson Index

The Deyo-Charlson Index is a weighted comorbidity index based on administrative coding of 17 disease states.[12,13] It has been validated

as a predictor of stroke mortality,[14] and it has been used for risk adjustment of other outcomes including length of stay.[13,15–17] For the cohort on the general neurology/medical wards (1998–2000), comorbid conditions were classified with a modified version of the Deyo-Charlson Index on the basis of hospital discharge ICD-9-CM codes. For the cohort in the stroke unit (2003–2005), comorbidities were defined by an ICD-10 coding algorithm, developed by Quan's translation of the Charlson Index from the usage of ICD-9-CM codes[18].

Each of the indicated diagnoses is assigned a weight to be summed to provide a patient's total score. As described previously,[14] diagnoses of cerebrovascular disease (weight 1) and hemiplegia (weight 2), which are included in the Deyo-Charlson Index, were excluded in the modified index for this study, because they are reflected in the condition being evaluated in stroke patients. We dichotomized the modified Deyo-Charlson Index according to the original index[12] as low (modified Charlson Score <1) and high (modified Charlson Score >2).

Statistical Analysis

Data management and statistical analyses were performed using the STATA statistical package (Version 8.0; STATA Corporation). Data are shown using standard descriptive statistics. Continuous variables were compared with the t test for normally distributed variables. Categorical variables were compared with χ^2 test. Because the distribution of the length of stay in both cohorts is highly right-skewed, the length of stay was dichotomized after being centered to the median (7 days). The primary outcomes were total length of stay, length of stay >7 days or <7 days, and in-hospital case-fatality. Multivariable logistic regression models were fitted to the whole data set to adjust for the effects of prognostic variables for the assessment of the effect of stroke unit care on length of stay when 2 cohorts (stroke unit vs general neurology/medical wards) were compared. The prognostic variables included age, sex, and heterogeneity of patient comorbid conditions identified by dichotomized Deyo-Charlson Index and sum Deyo-Charlson score, respectively. The dependent variable was dichotomized length of stay. $P<0.05$ was considered statistically significant.

In secondary analysis, we fitted logistic regression models with 2-way interaction terms including related Charlson comorbidities (those individual comorbidity variables with significant probability values) to assess whether these comorbidities showed potential confounding or effect modification. In subgroup analysis, comparisons of length of stay were further evaluated within strata of stroke types and dichotomous Charlson Index.

To identify whether the in-hospital case fatality and length of stay in a stroke unit changed when compared with general neurology/medical wards, multivariable analyses adjusted for age, gender, and individual Charlson comorbidity were performed overall and by stroke type to estimate the impact of stroke unit care on in-hospital case fatality.

Table 2. Characteristics and Frequency of Deyo-Charlson Comorbidities (%) of Study Population in 2 Cohorts

	General Neurology/ Medical Wards	Stroke Unit	P
N of Patients	1567	2461	
Age, mean, yr (SD)	67 (15.5)	68 (15.4)	0.12
Female (%)	48.6	45.9	0.10
Distribution of stroke types* (%)			
AIS	60	61	<0.001
TIA	14	22	
ICH	14	10	
SAH	12	7	
Myocardial infarction	14.7	10.5	<0.001
Congestive heart failure	10.9	7.9	0.001
Peripheral vascular disease	3.6	4.9	0.042
Dementia	1.8	4.8	<0.001
Chronic pulmonary disease	9.8	6.1	<0.001
Rheumatic disease	2.8	1.1	<0.001
Peptic ulcer disease	1.5	1.1	0.23
Mild liver disease	0.3	0.5	0.42
Diabetes without chronic complication	13.5	14.7	0.31
Diabetes with chronic complication	3.7	3.6	0.89
Hemiplegia	27.2	27.0	0.89
Renal disease	0.7	3.9	<0.001
Cancer	2.9	2.0	0.07
Moderate or severe liver disease	0.2	0.1	0.33
Metastatic solid tumor	1.5	1.3	0.54
AIDS/HIV	0.1	0.1	0.65
Proportion of patients with low modified Charlson Index (%)†	82	83	0.36
Modified Charlson score, mean (SD) (median)	0.8 (1.3) (0)	0.8 (1.2) (0)	

*Stroke types: AIS, TIA, ICH, SAH.
†Modified Charlson Index excluded comorbidity condition of cerebrovascular disease and hemiplegia from Deyo-Charlson Index.

Results

Between January 2003 and March 2005, 2461 patients were admitted to the stroke unit, whereas 1567 stroke patients were admitted to the general neurology/medical wards during January 1998 to March 2000. Patients were admitted to the stroke unit from the emergency room (87% in the present study), from the neurological step-down unit (12%), and rarely from the clinic (<1%) or from another ward (<1%). There were no significant differences in average age and gender between 2 cohorts (Table 2). The proportion of acute

Table 3. Length of Hospital Stay Adjusted for Modified Charlson Index Between 2 Cohorts

Cohorts	General Neurology Wards	Stroke Unit	P
All patients			
Mean (SD)	19 (27)	15 (24)	<0.0001
Median (IQR)	9 (4–21)	6 (3–17)	<0.0001
Low Charlson Index (score ≤1)			
Mean (SD)	19 (27)	15 (24)	<0.0001
Median (IQR)	8 (4–20)	6 (3–15)	<0.0001
High Charlson Index (score ≥2)			
Mean (SD)	22 (29)	20 (24)	0.168
Median (IQR)	10 (5–29)	9 (4–25)	0.339

IQR indicate intraquartile range (range between 25th and 75th quartile).

ischemic stroke (AIS) in each cohort is similar (60% vs 61%) but more intracerebral hemorrhage (14% vs 10%) and sub-arachnoid hemorrhage (SAH; 12% vs 7%) patients were treated on general neurology/medical wards compared to the stroke unit. There were more transient ischemic attack (TIA) patients (22% vs 14%) managed on the stroke unit compared to general neurology/medical wards. Stroke unit patients were more likely to have dementia, renal disease, and peripheral vascular disease, but less likely to have pulmonary disease, past myocardial infarction, or congestive heart failure (Table 2). The discharge status in 2 cohorts is similar with respect to comparable proportion of patients discharged to home (stroke unit vs neurology/medical wards: 82.2% vs 82.7%; $P=0.78$).

Average length of stay was longer in patients managed on general neurology/medical wards compared with those managed on the stroke unit (19 vs 15 days; Table 3). This shorter length of stay was observed in patients with low but not high modified Charlson Index (Table 3 and Figure 1). The proportion of overall patients with a length of stay >7 days was 9.4% ($P<0.0001$) greater on general/medical wards compared to the stroke unit. In analysis stratified by stroke type, we found that the stroke unit was associated with reduced length of stay for ischemia patients (AIS and TIA) but not for hemorrhagic stroke types (intracerebral hemorrhage and
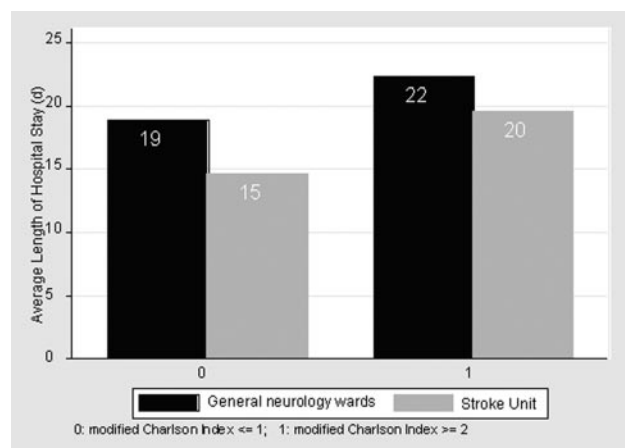

Figure 1. Relationships between modified Charlson Index and length-of-stay (days) in 2 cohorts.
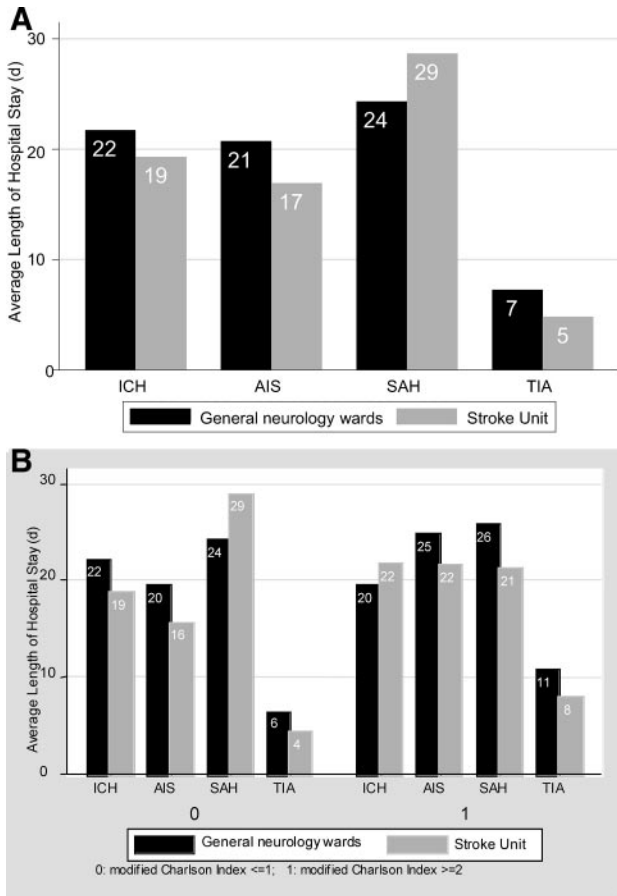
Figure 2. A, Length of hospital stay between 2 cohorts by stroke type. AIS indicates acute ischemic stroke; TIA, transient ischemic attack; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage. B, Length of hospital stay between cohorts by stroke type adjusted for Charlson Index.

SAH; Figure 2A,B). The direction of effect was for reduced length of stay in intracerebral hemorrhage patients but the smaller sample size prevented a precise estimate. Thus, the increased proportion of TIA patients on the stroke unit does not account for the overall effect. In subgroup analysis, the proportion of AIS patients with a length of stay >7 days is 6.5% (P=0.0017) greater on general wards compared to the stroke unit. Similarly, the proportion of TIA patients with a

length of stay >7 days is 10.6% less on the stroke unit (P<0.0001).

On the stroke unit, 82% of patients had modified Charlson comorbidity scores of 0 or 1 vs 83% of patients in general neurology/medical wards had scores of 0 or 1 (P=0.36; χ^2 test). The Charlson Index predicted length of stay with higher scores being associated with longer length of stay. For patients with high Charlson Index, the stroke unit effect for ischemia (AIS and TIA) was muted but still present. For intracerebral hemorrhage and SAH, discordant and nonintuitive results were seen (Table 3, Figure 2b).

The adjusted odds of a length of stay >7 days was reduced by 22% (P<0.0001) on the stroke unit compared to general neurology/medical wards for all stroke patients, adjusted for age, gender, and dichotomized Charlson Index. AIS patients in stroke unit have 23% reduced adjusted odds (P<0.0001) and TIA patients in stroke unit have 50% reduced odds (P<0.0001) of having a length of stay >7 days compared to those AIS and TIA patients, respectively, in general wards. Every 1-point increase in the Charlson Index was associated with a 26% increase in the odds of a length of stay >7 days (stroke unit vs general neurology/medical wards; P<0.0001) adjusted for age and gender for overall patients. We noticed that there were 3 significant individual comorbidities (P<0.05) that predicted length of stay greater than 7 days. These were congestive heart, dementia, and peptic ulcer disease. However, none of them showed effect modification by cohort when interaction terms were further examined.

The in-hospital case fatality of stroke patients on general neurology/medical wards was 16.6% vs 12.1% on the stroke unit (difference 4.5%; P=0.0001). Stroke unit care significantly reduced overall in-hospital case fatality (adjusted OR, 0.70; P<0.0001). The adjusted OR for case fatality rate in hospital (stroke unit vs general neurology/medical wards) by each stroke type is similarly reduced for ischemic stroke types. For intracerebral hemorrhage, the direction of effect is a nonsignificant 8% reduction in case fatality with stroke unit care; no effect is evident for subarachnoid hemorrhage (Table 4).

Discussion

Few studies of North American stroke units exist. Our retrospective study of a Canadian stroke unit shows that

Table 4.   Comparison of In-hospital Case Fatality for Overall Patients and by Stroke Type in 2 Cohorts

Stroke Type	ICH		AIS		SAH		TIA		All Patients	
Cohort	A	B	A	B	A	B	A	B	A	B
N of Patients	215	245	945	1503	192	183	215	530	1567	2461
N of Death	80	71	126	175	52	50	2	2	260	298
Case fatality (%)	37.2	29.0	13.3	11.6	27.1	27.3	0.93	0.38	16.6	12.1
P*	0.06		0.215		0.958		0.349		0.0001	
Adjusted OR† (95% CI)	0.57 (0.31–1.03)		0.77 (0.60–0.97)		0.65 (0.36–1.19)		0.51 (0.32–0.81)		0.70 (0.58–0.84)	
P‡	0.063		0.03		0.162		0.005		< 0.0001	

A: the cohort (1998–2000) in general neurology wards; B: the cohort (2003–2005) in the stroke unit.

*P of Z-test in comparison of proportion of death by stroke type and in overall patients.

†Adjusted OR in stroke patients managed on the stroke unit compared with those managed on general neurology wards, adjusted for age, gender, and individual Charlson Comorbidity.

‡P of Wald test in multivariable logistic regression analyses.

stroke unit care is associated with a reduced length of stay and reduced in-hospital case fatality. Our observed case-fatality reduction is concordant with a 5% mortality reduction by stroke unit care observed in a recently published large Italian observational cohort study.[1]

What might explain the different length of stay? There is no indication that the differences were attributable to patient differences, because there are comparable demographic characteristic and similar overall comorbid conditions (same average Charlson score and coordinate distribution of Charlson Index) among them. The distribution of TIA, intracerebral hemorrhage, and SAH were unbalanced in the 2 cohorts with a higher prevalence of TIA on the stroke unit. TIA patients naturally have a shorter length of stay. However, subgroup analyses by stroke type suggest that case mix is not the explanation.

The 2 cohorts were minimally unbalanced on several baseline comorbid conditions. However, we did not identify any evidence of effect modification by individual comorbid illnesses on length of stay after multivariable logistic regression analyses. The adjustment for individual comorbid factors suggested that the observed benefits of stroke unit care on the length of stay are more significant in ischemic stroke patients than in hemorrhagic stroke patients, and are independent of age, gender, and comorbid conditions. In addition, more patients overall were managed on the stroke unit compared to the general neurology/medical wards. This effect was almost entirely attributable to an average 4-day reduction in length of stay, allowing a greater throughput of patients on the stroke unit.

It is less clear why hemorrhage patients did not show a more dramatic effect. However, we believe our results on intracerebral hemorrhage simply lack precision. The direction of effect and magnitude of effect for both length of stay and case fatality are similar to those seen for ischemic stroke. For subarachnoid hemorrhage, there is no effect whatsoever. The most likely explanation is that SAH patients were cared for on the general neurosurgical service during both periods. In one sense the SAH patients functioned as a positive control and the lack of effect for SAH patients who were not exposed to any changes in their type of care is also concordant with the stroke unit effect. Alternately, SAH patients often remain in hospital for observation during the period when they are susceptible to vasospasm and this period, usually 21 days, is fixed because of the biology of the disease.

A key consideration is whether this shorter length of stay comes at the expense of patient outcomes. Patients who experience neurological death usually do so in the first few days after stroke resulting in a shorter length of stay. However, during the same period, Field et al[19] have reported that in-hospital mortality from stroke of all types has fallen and readmission for recurrent stroke after TIA have decreased nearly 50% (Michael D. Hill, unpublished data, 2007). Consistently, we observed a significant reduction in mortality. This further bolsters our finding that management of stroke patients in a stroke unit is associated with a sustained reduction in length of hospital stay compared to general neurology/medical wards.

In any study of active clinical care in different period, other interventions in the evolution of care may be a source of residual confounding. During the period undergoing study, we have observed a gradual increase in the proportion of all stroke patients undergoing thrombolyses from <5% to 12% (Michael D. Hill, unpublished data, 2007). We have become more aggressive in admitting and investigating TIA patients because of new evidence identifying the high early risk of stroke that emerged during the study period. We have increased the size, personnel, and expertise of our team. The city of Calgary has experienced tremendous population growth over the period of study, which has brought increased volume to our service. All of these factors may be potential sources of residual confounding, as described by Davenport et al.[20]

However, the stroke unit effect, in part, is defined by the organization of care that has responded to these changes. It is robust and attributable to organization. Such organization improves care, hastens recovery, and reduces the need for inpatient rehabilitation. Inherent in such organization is discharge planning; biweekly meetings facilitate this process and ensure prompt discharge from acute care.

From the economic perspective of the hospital, shorter length of stay in the stroke unit as found in the present study appears promising. The principal costs of care relate to the bed-day costs. A study of another Canadian stroke unit[21] suggested that a 2-day reduction in length of stay per stroke unit patient translates into a saving of more than $2.1 million per 1000 patients treated. This estimate would be doubled in our case, with a 4-day reduction in length of stay. At $1200 per hospital bed-day at our hospitals and 1000 patients per year, 5 years of stroke unit care has resulted in an estimated $24 million savings. Despite the Consensus Statement from the Brain Attack Coalition[22] and several national bodies in Europe,[23] United States,[24] and Canada[25] recommending that stroke unit care be widely implemented, organized stroke unit care is not yet widely available in Canada.[26] This is changing with the evolution of the Canadian Stroke Strategy. Economic analyses should be conducted with attention to the full chain of care and not just length of say. However, given the potential cost-savings, it is remarkable that we have not accomplished more already.

Our perspective, taken from the point of view of the acute care hospital, is relevant for managing hospital resources. However, other perspectives may be important. If there is an overall increase in the time spent in managed care (ie, inpatient rehabilitation), then the only achievement is a shift in budget envelopes from acute care to rehabilitation. We believe that this is not the case for stroke unit care in Calgary. Approximately 20% of stroke unit patients in Calgary require and are discharged to an inpatient rehabilitation unit. Because of the nature of the Canadian system, limited inpatient rehabilitation bed resources mean that patients destined for rehabilitation wait in hospital and have the longest length of stay in the acute care hospital; in Calgary, on average, patients who go to inpatient rehabilitation have a length of stay that is 3 days longer. Further, we know that in the stroke literature, morbidity reduction parallels mortality reduction. The overall reduction in case fatality suggests that we have

not made a trade-off of reducing length of stay only to have patients die outside of the stroke unit. Therefore, although we have focused on the hospital length of stay in this article, we believe the results represent the more generalizable, broad, positive effects of stroke unit care.

We are cognizant of the potential limitations of using administrative data sources. However, we have previously shown that Calgary administrative data coding is highly sensitive, specific, and reliable.[27] A key limitation of any use of administrative data are the inability to adjust for baseline stroke severity. By stratifying our analysis by stroke type, we have mollified this concern. Further, we have no reason to believe that stroke severity, overall, was any different between the 2 cohorts. Finally, the modified version of the Charlson Index in our study ignored previous strokes, which may impact the undercoding of comorbid conditions among patients and biased the results toward lower significance.

In conclusion, our observations support the view that the multidisciplinary stroke unit, which focuses on both acute care and acute rehabilitation, has an independent effect on reducing length of stay. The effect is large and seems to imply the potential for large cost-savings, which may help administrators endorse the development of stroke unit care in North America. Such development should occur with prospective study to better-define the effect of stroke units in routine care/health service in the future.

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Disclosures

None.

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