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Hospital volume and stroke outcome: does it matter?

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Does it matter?

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ABSTRACT

Background: Although hospital–outcome relationships have been explored for a variety of procedures and interventions, little is known about the association between annual stroke admission volumes and stroke mortality. Our aim was to determine whether facility type and hospital volume was associated with stroke mortality.

Methods: All hospital admissions for ischemic stroke were identified from the Hospital Morbidity database (HMDB) from April 2003 to March 2004. The HMDB is a national database that contains patient-level sociodemographic, diagnostic, procedural, and administrative information across Canada. Ischemic stroke was identified through patient's principal diagnosis recorded using the International Classification of Diseases (9 and 10). Multivariable analysis was performed with generalized estimating equations with adjustment for demographic characteristics, provider specialty, facility type, hospital volume, and clustering of observations at institutions.

Results: Overall, 26,676 patients with ischemic stroke were admitted to 606 hospitals. Seven-day stroke mortality was 7.6% and mortality at discharge was 15.6%. Adverse outcomes were more frequent in patients treated in low-volume facilities (<50 strokes/year) than in those treated in high volume facilities (100 to 199 and >200 strokes patients/year) (for 7-day mortality: 9.5 vs 7.3%, $p < 0.001$; 9.5 vs 6.0%, $p < 0.001$; for discharge mortality: 18.2 vs 15.2%, $p < 0.001$; 18.2 vs 12.8%, $p < 0.001$). The difference persisted after multivariable adjustment or when hospital volume was divided into quartiles.

Conclusions: High annual hospital volume was consistently associated with lower stroke mortality. Our study encourages further research to determine whether this is due to differences in case mix, more organized care in high-volume facilities, or differences in the performance or in the processes of care among facilities. *Neurology*® **2007;69:1-1**

Over the last two decades, much research has focused on the relationship between patient volumes in health services delivery and clinical outcomes. High patient volumes generally correlate with lower mortality, although most studies focus on diagnostic procedures or surgical interventions.[1]

As a major contributor to premature death and disability, stroke represents an enormous global public health challenge.[2,3] Although clinical predictors of stroke mortality are well established, other health care determinants of clinical outcomes have not been

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systematically explored. In particular, there is a paucity of research evaluating the influence of hospital characteristics on clinical outcome after ischemic stroke. Striving for optimal delivery of health care to patients with acute ischemic stroke mandates evaluation of these health-system factors.

The primary goal of this study was to determine whether facility characteristics (hospital type and annual volume of stroke patients) are associated with in-hospital mortality after ischemic stroke. Our secondary objective was to identify other system determinants of early stroke mortality.

METHODS We identified all patients with ischemic stroke admitted to acute care hospitals in Canada between April 1, 2003, and March 31, 2004, through the Hospital Morbidity and Mortality Database (HMDB) managed by the Canadian Institute for Health Information. The HMDB is a national database that contains patient-level sociodemographic, diagnostic, procedural, and administrative information across Canada. Reporting to the HMDB is mandatory in Canada. The major inclusion criterion was an admission to an acute care facility with a principal diagnosis of ischemic stroke as identified through patient's principal diagnosis recorded using the International Classification of Diseases, either the 9th (ICD-9) or 10th (ICD-10) revision (ICD-9 codes 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and ICD-10 codes I63, I64).[4,5] All provinces and territories, except Manitoba and Quebec, use ICD-10 codes. We applied the methodology as defined by the Agency for Healthcare Research and Quality to calculate the 7-day in-hospital mortality and discharge mortality rates for ischemic strokes.[6] The rationale for using the 7-day in-hospital mortality includes the advantages of high case ascertainment and limited influence of length of stay when comparing different facilities. It has been previously used by the Organization for Economic Co-operation and Development for comparing stroke and acute myocardial infarction outcomes among different countries because other indicators (30-day stroke mortality) may not capture mortality occurring after discharge particularly where major differences exist in length of stay among different facilities.[7,8] Moreover, the provision of acute stroke care, identification of the stroke mechanism, and most important cost-related decisions are generally achieved within the first week of admission.[9]

Because of major prognostic differences, patients with TIA, intracerebral hemorrhage, and subarachnoid hemorrhage were excluded. Records containing invalid health care numbers were excluded.

Canada's health care system includes government-funded universal public provision of physician and hospital services and the absence of co-payments and other patient charges.[10] There are 680 acute care facilities across the country reporting to the HMDB, which covers 99.8% of all acute care hospitals. Stroke patients were admitted to 606 acute care facilities including academic and community hospitals and rural and urban facilities from all provinces and territories.

We evaluated the association between the following variables and early stroke mortality: patient age (categorized as <65, 65 to 74, 75 to 84, and ≥85 years old), co-morbid conditions, facility type by location (rural/urban), facility teaching status (academic/nonacademic), most responsible provider, and annual number of ischemic stroke cases treated by hospital (categorized). For patients transferred between hospitals, the day of admission was defined as the day of presentation to the initial acute care facility.

We used the Charlson–Deyo co-morbidity index to quantify patients' co-morbid conditions.[11] This index is a summary score based on the presence or absence of 17 medical conditions. A score of zero implies no co-morbid index, and higher scores indicate a greater burden of co-morbidity. For the purpose of this study, Charlson–Deyo index scores were categorized into none, one, two, or three or more co-morbid conditions.[12,13] Serious medical complications during hospitalization (intracerebral hemorrhage, pneumonia, decubitus ulcer, and urinary tract infection) were also identified. The weekend was defined as the period from midnight on Friday to midnight on Sunday. All other times were defined as weekdays.[14]

Socioeconomic status was estimated through an approach developed by Statistics Canada that assigns neighborhoods to five equally sized quintiles based on income data reported on the 2001 Census.[15] A higher quintile value of a residential area is associated with higher socioeconomic status of residents in that area.

Hospital teaching status was defined according to the Association of Canadian Academic Healthcare Organizations. We defined hospital experience as the annual number of stroke patients admitted to an individual hospital in the 2003 to 2004 fiscal year.[16] This definition is based on a number of prior reports investigating in-hospital mortality among patients with specific diagnoses or undergoing specific procedures in community settings.[1,17]

Each hospital in the HMDB is assigned a unique encrypted identifier. This identifier was used to determine the annual acute ischemic stroke volume for each hospital that contributed to the database. As expected in administrative clinical databases, no specific data were available for acute neurologic status (such as the NIH Stroke Scale) or measures of functional disability (such as the Barthel Index and modified Rankin Scale). We were able, however, to adjust for some other important clinical predictors in the multivariable analysis, including age, sex, and co-morbid illness.

Statistical analysis. Descriptive statistics were used to assess the association between various patient and hospital characteristics and stroke mortality. To compare these characteristics across volume groups (table 1), we used Pearson χ^2 test for categorical variables and one-way analysis of variance for continuous variables.

Two different analytical approaches were used to determine the effect of hospital volume on stroke mortality. First, hospital volume was measured as the number of annual stroke admissions. Based on the approximate criteria of the weekly average of stroke patients treated per year (<1/week, 1 to 2/week, 2 to 4/week, and 4 or more/week), the annual stroke admission rates per hospital were categorized into: low volume (<50 patients/year), medium volume (50 to 99 patients/year), medium-high volume (100 to 199 patients/

Table 1 Baseline characteristics by facility volume

Characteristic	Annual stroke volume by facility: Low <50, n = 5,273	Medium 50–99, n = 4,722	Medium–high 100–199, n = 10,075	High >200, n = 6,606	p Value
Age, y; mean (SD)	75.7 (12)	75.2 (12)	73.7 (12)	72.4 (13)	<0.001
Age <65 (%)	869 (16.5)	837 (17.7)	2,125 (21.0)	1,609 (24.4)	
Age 65–74 (%)	1,146 (21.7)	1,105 (23.4)	2,436 (24.2)	1,599 (24.2)	
Age 75–84 (%)	2,001 (38.0)	1,759 (37.3)	3,622 (36.0)	2,285 (34.6)	
Age ≥85 (%)	1,257 (23.8)	1,021 (21.6)	1,892 (18.8)	1,113 (16.8)	
Gender					
Female (%)	2,569 (48.7)	2,326 (49.3)	4,929 (48.9)	3,174 (48.1)	0.59
Charlson co-morbidity index score					
0	3,569 (67.7)	3,199 (67.7)	6,894 (68.4)	4,765 (72.1)	0.005
1	733 (13.9)	646 (13.7)	1,380 (13.7)	730 (11.1)	
2	485 (9.2)	486 (10.3)	935 (9.3)	573 (8.7)	
≥3	486 (9.2)	391 (8.3)	866 (8.6)	538 (8.1)	
Most responsible physician					0.005
GP	948 (18.0)	908 (19.2)	1,792 (17.8)	863 (13.1)	
Specialist	4,325 (82.0)	3,814 (80.2)	8,283 (82.2)	5,743 (86.9)	
Complications					
Pneumonia	176 (3.3)	181 (3.8)	365 (3.6)	192 (2.9)	0.026
Urinary tract infection	162 (3.1)	181 (3.8)	375 (3.7)	153 (2.3)	<0.001
Intracerebral hemorrhage	12 (0.23)	15 (0.32)	21 (0.21)	11 (0.17)	0.4
Pulmonary embolism	31 (0.6)	31 (0.7)	49 (0.5)	31 (0.5)	0.13
Decubitus ulcer	13 (0.25)	15 (0.32)	17 (0.17)	9 (0.14)	0.13
ICU admission	505 (9.6)	476 (10.1)	1,508 (14.9)	815 (12.3)	<0.001
Length of stay, d; median (25th–75th)	8 (4–19)	8 (4–19)	8 (4–18)	8 (4–17)	0.19

GP = general practitioner; ICU = intensive care unit.

year), and high volume (≥200 patients/year). Second, facilities were divided into quartiles based on annual patient volumes (quartile 1, 1 to 62 cases/year; quartile 2, 63 to 141 cases/year; quartile 3, 142 to 197 cases/year; and quartile 4, >198 cases/year).

We used generalized estimating equations to fit the models (link function: logit), to account for clustering of patients within institutions and provide more accurate CIs than would be provided by simple logistic regression. Compound symmetry (exchangeable) was selected as the correlation structure.[18,19] The association between hospital volume and stroke mortality was expressed as the odds ratio (OR) and 95% CI.

In developing the models, a $p < 0.25$ on univariate analysis was used as a screening cutoff. Those factors achieving this level of significance were then included in a multivariable analysis. Only variables achieving $p < 0.05$ were left in the final multivariable model.

Potential two-way interactions selected a priori between age and sex, and hospital type (teaching status, location) and experience in stroke management were explored. None of the interaction terms were significant.

The association between stroke volume at each hospital and the institutional mortality rate was represented in a scatterplot and the predicted probability of death was calculated using fractional polynomial regression (hospital volume expressed as a continuous variable). The strength of fractional polynomial analyses is their flexibility and better representation of adjusted data for nonlinear associations.[20]

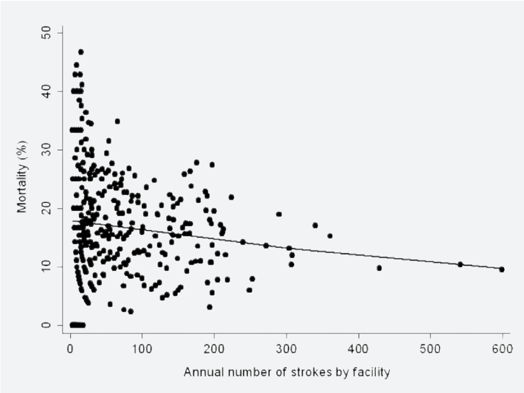
We also used random-effect models to evaluate the consistency of our results. Risk-adjusted mortality rates for each hospital volume group were derived from random-effect models as reported by other authors.[21]

All statistical analyses were performed using a commercially available software package (SAS statistical software 1999, version 8, Cary, NC, SAS Institute Inc., and STATA version 7.0, StataCorp LP, TX).

Ethics. The study protocol was approved by the Ethics Review Board at St. Michael's Hospital, University of Toronto, Toronto, Canada. As the identity of the patients was kept completely anonymous, no specific informed consent was required. The data pooling center was blinded to hospital identity.

Data quality. According to a reabstraction study performed by the Canadian Institute for Health Information for the quality assurance, after the implementation of ICD-10, diagnoses in the database agree with diagnoses in the charts in 92% of stroke cases. The agreement of the coding of data

Figure 1 Institutional stroke mortality by hospital volume



Scatterplot showing the institutional mortality rate by annual number of ischemic strokes by facility (hospital stroke volume). The line represents the predicted probability of hospital mortality according to the fractional polynomial regression analysis. Each dot represents the observed mortality rate by facility.

collected for day of admission was 97% and for death was greater than 99%. Nonmedical and sociodemographic data elements in this study had agreement rates ranging from 96 to 100%.[22]

Other Canadian studies on hospital coding of stroke and vascular risk factors using ICD-9 and ICD-10 have shown a similarly high agreement rate.[23,24] In one study, ICD-9 coding was excellent with 90% (95% CI, 86 to 92) and ICD-10 was similarly good with 92% (95% CI, 88 to 95) of strokes correctly coded.[5]

RESULTS We analyzed 26,676 patients with ischemic stroke admitted to 606 hospitals across Canada from April 1, 2003, to March 31, 2004. Mean age was 74 ± 13 years; 5,440 (20%) were younger than 65 years, and 5,283 (19.8%) were older than 85 years. There was a similar proportion of men (51%) and women (49%). Twenty percent of patients were treated in teaching hospitals, 24% of patients were admitted to rural facilities, and in 17% of hospital admissions the most responsible provider was a general practitioner. Three thousand three hundred four (12.4%) of stroke patients were admitted to the intensive care unit (ICU). Mean length of hospital stay was 16 (range 1 to 115) days. Table 1 summarizes characteristics of the patients in each category based on annual hospital volume.

There was a significantly lower incidence of pneumonia (2.9 vs 3.4%; $p = 0.03$) and urinary tract infections (2.3 vs 3.1%; $p < 0.001$) in high-volume hospitals. No significant differences were observed for other complications including: pulmonary embolism, deep venous thrombosis, intracranial bleeding, and decubitus ulcer (table 1).

In-hospital mortality. Overall, 7-day in-hospital mortality was 7.6% (2,039/26,676) and mortality at discharge was 15.6% (4,165/26,676). The distribution of annual hospital stroke volume and institutional mortality rates is presented in figure 1 ranging from 0 to 47% for all facilities, with four outliers of 42 to 47%. Institutional mortality ranged from 0 to 47% in low volume, 2.4 to 34.8% in medium volume, 3.1 to 27.8% in medium-high volume, and 6.0 to 21.9 in high-volume hospitals.

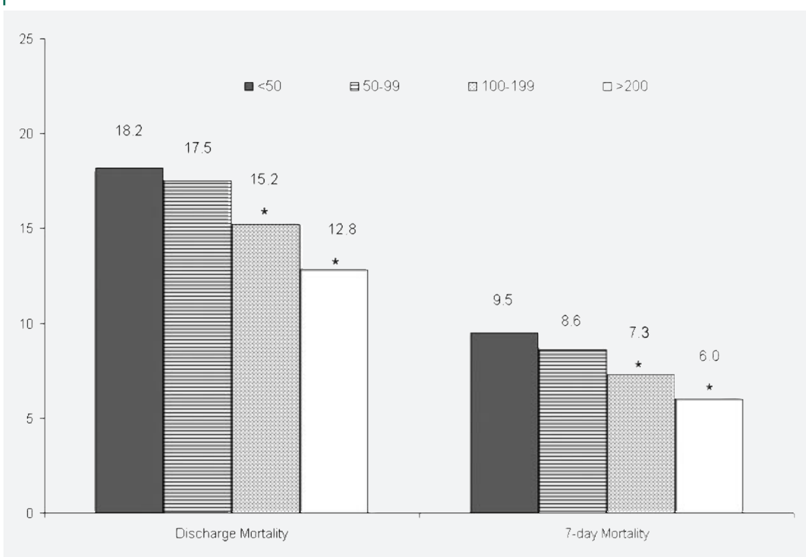
Crude and risk-adjusted mortality rates by facility group are shown in figures 2 and 3. High hospital volume was associated with lower stroke mortality. Mortality at 7 days was 37% lower in high-volume hospitals when compared with low-volume facilities (9.5 vs 6.0%; $p < 0.001$). Results were similar when hospital volumes were analyzed as quartiles, with 7-day mortality rates of 9.4, 7.4, 7.8, and 6% ($p < 0.001$) for quartiles 1, 2, 3, and 4.

Exclusions of interfacility transfers did not change the results with 7-day in-hospital mortality rates of 11.3, 10.0, 9.0, and 8.4% for low-, medium-, medium-high-, and high-volume hospital.

In the univariable analysis (table 2), age, facility type, admission to the ICU, weekend admission, low-income neighborhood, and annual hospital volume were associated with both 7-day mortality and stroke mortality at discharge. Rural location and pulmonary embolism were associated with 7-day mortality, whereas the type of health care provider (general practitioner vs specialist), urinary tract infection, and decubitus ulcer were associated only with stroke mortality at discharge.

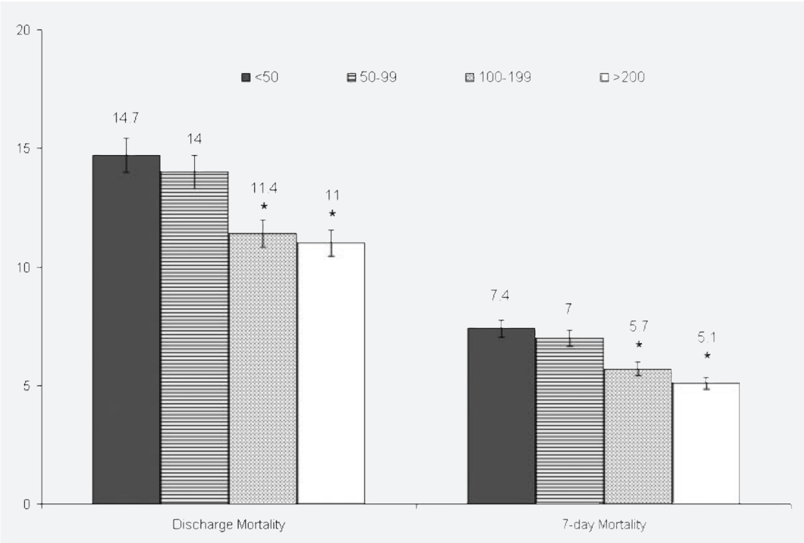
Table 3 displays the results of the multivariable analysis using generalized estimating equa-

Figure 2 Crude mortality rate by facility group



Numbers inside the bars indicate the annual numbers of events per 100 stroke patients (mortality rate) for each facility group. *$p < 0.001$ when stroke mortality is compared with low-volume facilities (less than 50 stroke patients/year).

Figure 3 Risk-adjusted mortality rate by facility group



This figure shows the risk-adjusted mortality rates by facility group derived from random-effect models. Random-effects models were constructed to account for the effect of hospital volume on outcome using the STATA command xtlogit. For the adjusted death rates by hospital volume, mortality was adjusted by age, gender, Charlson index, admission to the intensive care unit, most responsible provider, admission on weekend, neighborhood income, facility type (teaching/nonteaching), and location (urban/rural). Numbers inside the bars indicate the annual numbers of events per 100 stroke patients (mortality rate) for each facility group. *$p < 0.001$ when stroke mortality is compared with low-volume facilities (less than 50 stroke patients/year). I = 95% CI.

tions. After adjusting for age, sex, co-morbid conditions and other covariates, patients treated at medium-high-volume (100 to 199 stroke patients/year) and high-volume (>200 stroke patients/year) centers had a 23% (95% CI 64 to 92%) and 34% (95% CI 53 to 83%) reduced odds of 7-day in-hospital death compared with low-volume facilities. Results were similar for mortality at discharge. Similar coefficients were obtained when major medical complications were included in the model or when interfacility transfers were excluded from the analysis. Other predictors of in-hospital mortality were older age, admission to an ICU, and admission on a weekend (table 3). Similar results were obtained by using random-effect models (data not shown).

DISCUSSION In this large population-based study, we found that the low annual hospital stroke volume, admission on the weekend, admission to the ICU, and advanced age were associated with increased 7-day in-hospital mortality. Similarly, low annual volume of stroke admissions, advanced age, admissions to the ICU, general practitioner as the most responsible provider, and low neighborhood income were associated with increased mortality at discharge.

Major advances have been made during the last several decades in stroke prevention, acute treatment, and rehabilitation, but less attention has been given to the influence of variations in the delivery of services on stroke mortality.[16,25-27]

Although measuring and understanding the relationship between patient volume and outcome in the delivery of services has been explored since the 1970s,[17,27-29] most studies have focused on surgical procedures and medical interventions. Lower mortality in high-volume hospitals has been reported for coronary artery angioplasty and bypass graft surgery, aortic aneurysm repair, surgery for lung, gastric, pancreatic, colorectal and breast cancer, hip replacement, and transurethral prostatectomy among others.[28,30-34] Most of those studies were conducted in hospital settings and included relatively small numbers of patients. In the field of neurologic sciences, studies on volume–outcome relationships have been performed for different surgical procedures including brain tumor resection, spine surgery, head trauma, carotid endarterectomy, and cerebral aneurysm surgery. For example, studies have shown that in-hospital mortality increases when the annual number of craniectomies for aneurysms is lower than 30 and when carotid endarterectomies are performed by less experienced surgeons (<5 procedures/year).[19,27,35,36]

Previous studies suggested that experience in the management of a clinical condition may directly affect patient outcomes ("practice makes perfect"). For surgical conditions, the effect may be dual: by directly increasing experience with a surgical procedure and indirectly improving outcomes through better practices and general hospital care.[17,30,37]

Differences in processes of care between facilities with high and low annual stroke volume may explain the observed relationship between volume and in-hospital death, and it may be possible to improve such processes at all hospitals using such programs as the "Get with the Guidelines" in the United States and the Canadian Stroke Strategy initiatives in Canada.[38-40] Indeed, this potential is illustrated by the wide range of 7-day in-hospital mortality outcomes among small- to medium-sized hospitals, implying (even though the estimates are unadjusted for stroke severity) that some smaller hospitals are likely providing excellent care.

Factors influencing early stroke mortality are likely different from variables predicting long-term outcome; indeed, stroke severity (i.e., NIH Stroke Scale score) is the most important predictor of early mortality from a neurologic death. Previous studies of stroke patients reported in-

Table 2 Univariable analysis for 7-day and discharge mortality

Characteristic	7-day in-hospital mortality			Mortality at discharge		
	Alive, n = 24,637 (%)	Dead, n = 2,039 (%)	*p* Value	Alive, n = 22,511 (%)	Dead, n = 4,165 (%)	*p* Value
Patient characteristics						
Age, y; mean (SD)	73.6 (13)	78.9 (11)	<0.0001	73.0 (13)	79.9 (11)	<0.0001
Age <65 (%)	5,241 (96.3)	199 (3.7)	0.005	5,112 (94.0)	328 (6.0)	0.005
Age 65–74 (%)	5,932 (94.4)	354 (5.6)		5,601 (89.1)	685 (10.1)	
Age 75–84 (%)	8,856 (91.6)	811 (8.4)		8,009 (82.9)	1,658 (17.1)	
Age ≥85 (%)	4,608 (87.2)	675 (12.8)		3,789 (71.7)	1,494 (18.3)	
Sex			0.35			0.12
Male (%)	12,652 (92.5)	1,025 (7.5)		11,588 (84.7)	2,089 (15.3)	
Female (%)	11,985 (92.2)	1,014 (7.8)		10,923 (84.0)	2,076 (16.0)	
Charlson co-morbidity index score			0.39			0.89
0	17,045 (92.5)	1,382 (7.5)		15,564 (84.5)	2,863 (15.5)	
1	3,222 (92.3)	267 (7.7)		2,947 (84.5)	542 (15.5)	
2	2,282 (92.0)	197 (8.0)		2,081 (84.0)	398 (16.0)	
≥3	2,088 (91.5)	193 (8.5)		1,919 (84.1)	362 (15.9)	
Day of admission			0.0027			0.039
Weekday	18,571 (92.6)	1,476 (7.4)		16,970 (84.7)	3,077 (15.3)	
Weekend	6,066 (91.5)	563 (8.5)		5,41 (83.6)	1,088 (16.4)	
Facility type			0.002			<0.0001
Teaching hospital	4,835 (93.4)	344 (6.6)		4,464 (86.2)	715 (13.8)	
Community hospital	19,802 (92.1)	1,695 (7.9)		18,047 (84.0)	3,450 (16.0)	
Facility location			0.001			0.32
Rural	5,800 (91.4)	547 (8.6)		5,331 (84.0)	1,016 (16.0)	
Urban	18,837 (92.7)	1492 (7.3)		17,180 (84.5)	3,147 (15.5)	
Annual hospital stroke volume[†]			<0.0001			<0.0001
Low (<50 admissions)	4,774 (90.5)	499 (9.5)		4,316 (81.8)	957 (18.5)	
Medium (50–99 admissions)	4,317 (91.4)	405 (8.6)		3,895 (82.5)	827 (17.5)	
Medium-high (100–199 admissions)	9,338 (92.7)	737 (7.3)		8,542 (84.8)	1,533 (15.2)	
High (≥ 200 admissions)	6,208 (94.0)	398 (6.0)		5,758 (87.2)	848 (12.8)	
Most responsible physician			0.24			0.01
GP	4,147 (91.9)	364 (8.1)		3,749 (83.1)	762 (16.9)	
Specialist	20,490 (92.5)	1675 (7.5)		18,762 (84.7)	3,403 (15.3)	
Admission to ICU						
Yes	2,818 (85.3)	486 (14.7)	<0.001	2,426 (73.4)	878 (26.6)	<0.001
No	21,819 (93.4)	1,553 (6.6)		20,085 (85.9)	3,287 (14.1)	
Complications						
Pneumonia	843 (92.2)	71 (7.8)	0.88	772 (84.5)	142 (15.5)	0.95
Urinary tract infection	793 (91.0)	78 (9.0)	0.14	712 (81.7)	159 (18.3)	0.03
Intracerebral hemorrhage	55 (93.2)	4 (6.8)	0.80	50 (84.8)	9 (15.2)	0.94
Pulmonary embolism	138 (97.2)	4 (2.8)	0.03	119 (83.8)	23 (16.2)	0.85
Decubitus ulcer	50 (92.6)	4 (7.4)	0.95	40 (74.1)	14 (25.9)	0.04
Neighborhoodincome (quintile)[*]			0.002			0.001
1	5,271 (91,6)	481 (8.4)		4,818 (83.4)	934 (16.2)	
2	5,025 (91.8)	448 (8.2)		4,549 (83.1)	924 (16.9)	
3	4,862 (92.7)	383 (7.3)		4,463 (85.1)	782 (14.9)	
4	4,327 (92.9)	332 (7.1)		3,988 (85.6)	671 (14.4)	
5	3,832 (93.5)	267 (6.5)		3,513 (85.7)	586 (14.3)	
NA	1,320 (91.2)	128 (8.8)		1,180 (81.5)	268 (18.5)	

*Annual hospital stroke volume defined as the number of stroke admissions per facility was categorized into: low volume (<50 patients/year), medium volume (50–99 patients/year), medium-high volume (100–199 patients/year), and high volume (≥200 patients/year).

†Corresponds to five equally sized quintile neighborhoods income based on the 2001 Census data.

GP = general practitioner; ICU = intensive care unit.

Table 3 Multivariable analysis: institutional predictors of stroke mortality*

	7-day in-hospital mortality			Mortality at discharge		
	Adjusted OR	95% CI		Adjusted OR	95% CI	
Age, y						
<65	Ref.	—	—	Ref.	—	—
65–74	1.61	1.34	1.93	1.96	1.68	2.30
75–84	2.64	2.24	3.12	3.55	3.09	4.08
>85	4.51	3.77	5.39	7.35	6.38	8.47
Gender, male	0.96	0.88	1.06	0.97	0.90	1.05
Charlson index score = 0						
0	Ref.	—	—	Ref.	—	—
1–2	1.01	0.90	1.13	0.96	0.88	1.04
>3	1.16	0.97	1.37	1.02	0.90	1.15
Facility type						
Community	Ref.	—	—	Ref.	—	—
Teaching	1.03	0.85	1.25	1.01	0.83	1.24
Facility location						
Rural	Ref.	—	—	Ref.	—	—
Urban	0.97	0.85	1.12	1.12	0.99	1.25
Most responsible physician						
Specialist	Ref.	—	—	Ref.	—	—
GP	1.05	0.93	1.19	1.12	1.01	1.26
Admission to ICU	3.13	2.59	3.77	3.17	2.64	3.81
Neighborhood income						
3rd quintile	Ref.	—	—	Ref.	—	—
Low (1st–2nd quintiles)	1.10	0.97	1.25	1.10	1.00	1.22
High (4th–5th quintiles)	0.96	0.83	1.10	0.96	0.87	1.06
Admission weekend	1.16	1.04	1.29	1.06	0.98	1.16
Annual hospital stroke volume†						
Low (<50 admissions)	Ref.	—	—	Ref.	—	—
Medium (50–99 admissions)	0.94	0.78	1.13	0.95	0.81	1.10
Medium-high (100–199 admissions)	0.77	0.64	0.92	0.78	0.66	0.92
High (≥200 admissions)	0.66	0.53	0.83	0.70	0.56	0.88

*Adjusted for age, sex, hospital type and location, admission on weekend, most responsible provider, neighborhood income, admission to the intensive care unit, Charlson index, and hospital volume, accounting for clustering by hospital using generalized estimating equations.
†Annual hospital stroke volume defined as the number of stroke admissions per facility was categorized into: low volume (<50 patients/year), medium volume (50–99 patients/year), medium-high volume (100–199 patients/year), and high volume (≥200 patients/year).
OR = odds ratio; GP = general practitioner; ICU = intensive care unit.

hospital mortality rates ranging from 3 to 9%, but analyzed overall hospital mortality rather than at 7 days.[16,41-44] Most studies found that advanced age, pre-existing congestive heart failure, and atrial fibrillation were risk factors for in-hospital death. A study from the University of Washington[44] analyzed in-hospital mortality in a retrospective cohort of 23,058 patients with ischemic stroke from 137 community hospitals. They found that annual hospital volume categorized as <100, 100 to 299, and >300 was not associated with in-hospital mortality. Similarly, the German Stroke Registry study group analyzed stroke mortality in 104 regional stroke centers.[16] A total of 13,440 stroke patients were included and overall in-hospital mortality was 4.9%. Such a low mortality may be explained by differences in stroke severity and by the inclusion of regional stroke centers, which have a higher level of expertise than general acute care facilities. Nevertheless, in univariable analysis, high-volume facilities (>250 annual strokes treated/hospital) had a significantly lower mortality rate, but this association was confounded by age and was not a significant predictor in the multivariable analysis.

Previous data from Canada have shown that weekend admission is associated with higher early mortality.[14,45] The finding that the Charlson–Deyo co-morbidity index score was not associated with early stroke mortality is not unexpected, because the overwhelming determinant of early stroke outcome is the severity of brain injury, irrespective of co-morbid conditions. In contrast, later mortality due to aspiration pneumonia, pulmonary embolus, or other complications of immobility preferentially affects patients with significant co-morbid illness.[16,26,42,46] It is important that gender was not found to be a predictor of early death in this large cohort. Several studies have concluded that female gender is a predictor of poor outcome among ischemic stroke patients, an effect that may be ameliorated with thrombolysis.[47] However, gender appears to be a contributor to later outcomes, similar to the role of co-morbid illness.[48,49]

We believe that our study represents an important first step in understanding the association between stroke outcomes and hospital volume. These results would seem to support the idea of centralization of stroke care to regional stroke centers. On the other hand, whereas regionalization of stroke care may improve stroke outcomes (by reducing the risk of poorer outcomes associated with treatment at low-volume hospitals), this strategy is not always possible and may limit timely access to thrombolysis for geographic reasons.

Our study has several strengths. First, this study was done countrywide rather than at a few targeted institutions or regional stroke centers. Second, it includes a large number of patients admitted to a broad spectrum of hospitals. Third, the assessment of outcomes was objective, not susceptible to research bias. Fourth, our results were consistent through different analytical approaches (hospital volume divided in quartiles, exclusion of interfacility transfers, random-effect models). Finally, our study shows a robust effect of hospital volume demonstrated in the volume–outcome analysis for patients admitted with ischemic stroke.

Several limitations deserve comment. First, we used administrative health data, which lack information on stroke severity and other clinical factors needed for detailed case-mix adjustment. It is possible that high-volume teaching facilities may be more likely to receive patients with severe strokes due to triage for thrombolysis, but also that patients with devastating strokes, who are not expected to recover, would be less likely to be transferred to high-volume facilities for specialized care. However, our analysis did account for patient age, co-morbid conditions, and admission to ICU, which is also important for adjustment of stroke complexity. In addition, we also attempted to address this limitation by analyzing the results with the exclusion of transfers, which may potentially bias the results if less severe patients were transferred to high-volume institutions. Second, we have limited information on processes of stroke care delivery. Although we show a clear volume–outcome effect, this observational study does not identify the mechanisms through which higher case volumes can translate to better outcomes. It is also possible that other unmeasured variables, not included in the analysis (e.g., number of acute care beds, hospital resources) may explain the observed differences. Third, we do know that inconsistencies in coding, including co-morbid conditions and medical complications, exist in administrative databases, which may have masked any true association. Finally, although errors in stroke coding remain possible, it is likely, given previous research using Canadian administrative data showing high specificity of stroke coding,[5,22] that such errors resulted in a reduced sensitivity and underascertainment of cases, rather than significant misclassification bias.

Our national population-based study showed a robust inverse relationship between hospital volume and stroke mortality. As all admissions were covered by a universal, government-funded health insurance system with no co-payments, accessibility and costs do not explain our findings. Our study encourages further research identifying potentially remediable factors in reducing stroke mortality.

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