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Association between hospital volume, processes of care and outcomes after acute ischaemic stroke: a prospective observational study

Runhua Zhang ,[1,2] Gaifen Liu,[2,3] Yuesong Pan,[2,3] Maigeng Zhou,[1] Yongjun Wang[2,3]

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[1]National Center for Chronic and Noncommunicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing, China
[2]Department of Neurology, Beijing Tiantan Hospital, Capital Medical University, Beijing, China
[3]Department of Statistics, China National Clinical Research Center for Neurological Diseases, Beijing, China

Correspondence to
Professor Maigeng Zhou; zhoumaigeng@ncncd.chinacdc.cn and
Dr Yongjun Wang; yongjunwang@ncrcnd.org.cn

ABSTRACT

Objectives There is uncertainty with respect to the hospital volume and clinical outcomes for patients with stroke. This study aimed to assess the association between hospital volume, processes of care and outcomes after ischaemic stroke.

Design A multicentre prospective cohort study.

Setting Two hundred and seventeen secondary or tertiary public hospitals from China.

Participants A total of 17 550 patients within 7 days of acute ischaemic stroke were included.

Main outcome measures The outcomes included all-cause mortality, poor outcome, recurrent stroke, and combined vascular events at 3 months and 1 year. The patients were divided into four groups based on quartiles of the hospital volume. We compared the difference in the process of care across the groups and estimated the effects of hospital volume on mortality, poor outcome, recurrent stroke, and combined vascular events at 3 months and 1 year. Restricted cubic splines were used to illustrate the association between hospital volume and clinical outcomes.

Results There were no significant differences in the process of care across the four groups. When adjusted for confounders, the effect of hospital volume on mortality, recurrent stroke and combined vascular events was not significant. However, compared with the highest quartile, the patients in the lowest quartile of hospital volume tend to have poor outcome at 1 year (OR=1.29, 95% CI 1.01 to 1.64, p=0.0393). The restricted cubic spline analyses suggested a non-linear relationship between hospital volume and 1-year combined vascular events and poor outcome at 3 months and 1 year.

Conclusions We found no significant associations between hospital volume, processes of care at the hospital, and mortality, recurrent stroke, and combined vascular events in patients with ischaemic stroke. However, hospital volume may be associated with poor outcome at 1 year.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The sample size was large, involving 217 institutions across the country.
- ⇒ To the best of our knowledge, this is the first study investigating the relationship between stroke volume in a hospital, process of care and outcomes in China.
- ⇒ The study has some limitations. Some processes of care, especially post-discharge, could not be obtained in this study.
- ⇒ The participating hospitals were volunteers, and unavoidable selection bias could not be eliminated.

INTRODUCTION

Previous studies have shown that the number of patients treated in a hospital (hospital volume) may be associated with surgical outcomes in aortic valve replacement, carotid endarterectomy, coronary artery bypass surgery and cancer-related surgeries.[1–5] The volume–outcome relationship was also described in some medical conditions, including heart failure, acute myocardial infarction, pneumonia and brain injury.[6–8] The magnitude of the association varied significantly in a previous study.[9] Studies reporting an inverse relationship lacked significance to make volume-based referral recommendations.[10] Several studies have examined the association between hospital stroke volume and mortality for patients who had a stroke. However, the results were controversial. Some found that patients who had a stroke in high-volume hospitals had decreased case fatality,[11 12] but some had not.[13 14] Most of the studies evaluated the short-term mortality; studies investigating long-term outcomes were limited. Furthermore, the associations between hospital volume and recurrent stroke and poor outcome were not well characterised.

We hypothesise that the hospitals with higher volume may be characterised by a high quality of care, which in turn improves the prognosis of patients who had a stroke. This study aimed to examine the association between hospital stroke volume and outcomes, including mortality, recurrent stroke, combined vascular events, and poor outcome at 3 months and 1 year after stroke onset. We also examined the association between hospital stroke volume and the process of care for ischaemic stroke.

METHODS

Study design and setting

The Second China National Stroke Registry (CNSR II) was a national multicentre hospital-based cohort study. CNSR II was launched in June 2012 in China. The primary objectives were to evaluate the delivery of stroke care and identify suboptimal performance metrics to be improved.[15] The hospitals were selected based on similar criteria in CNSR I launched in 2007, which had been published elsewhere.[16] After assessing the hospital characteristics, such as location, teaching status, number of beds and annual stroke discharges by the steering committee, a total of 219 hospitals were included in CNSR II.[17]

Study population

Consecutive patients were recruited from June 2012 to January 2013. The inclusion criteria were as follows: (1) age 18 years or above; (2) presentation within 7 days of onset of index acute ischaemic stroke (AIS), transient ischaemic attack (TIA), intracerebral haemorrhage or subarachnoid haemorrhage, which were confirmed by brain CT or MRI; and (3) direct hospital admission from a physician's clinic or emergency department. A total of 25 018 patients (19 604 (78%) with AIS) were included in CNSR II.

There were 1200 (6.12%) patients lost at 3 months and 2306 (11.76%) patients lost at 1 year. We excluded the patients who missed information on the process of care and those who were lost to follow-up at 3 months and 1 year. Finally, 17 550 patients and 16 482 patients with AIS were eligible for evaluating the association between hospital volume and 3-month outcomes and 1-year outcomes, respectively. A total of 17 438 patients achieved a modified Rankin Scale (mRS) at 3 months, and 16 462 patients achieved mRS at 1 year.

Data collection

Data were collected following a standardised form by trained research coordinators. Data on demographics, health insurance, education, smoking, drinking, comorbidities (hypertension, diabetes, hyperlipidaemia, atrial fibrillation, history of stroke or TIA) and medication history were extracted from medical records. National Institutes of Health Stroke Scale (NIHSS) at admission and mRS prior to the index event were assessed through a face-to-face interview.

Hospital stroke volume was defined as the annual number of stroke discharges. The annual stroke discharges of each hospital were obtained via the hospital survey when they applied to participate in this study. Additionally, hospital characteristics, such as location, academic status, the presence of stroke unit and the number of beds, were obtained in the survey.

Process measures

We selected 10 recommended process measures from the national guidelines and the Get With The Guidelines-Stroke (GWTG-Stroke).[18] Process measures are shown in online supplemental table 1. There were four acute phase process measures, namely (1) intravenous recombinant tissue plasminogen activator in patients who arrived within 2 hours after symptom onset and were treated within 3 hours; (2) antithrombotics within 2 days after admission; (3) deep vein thrombosis (DVT) prophylaxis and (4) dysphagia screening. There were six process measures at discharge: (1) antithrombotic medication; (2) antihypertensive medication for patients with hypertension; (3) hypoglycaemic medication for patients with diabetes; (4) anticoagulation for atrial fibrillation; (5) lowering low-density lipoprotein cholesterol (LDL-C) medication and (6) smoking cessation. Additionally, we calculated a binary defect-free measure of care, defined as the patient receiving all the processes for which they were eligible.[19 20] Process measures were applied only to qualified patients in the absence of documented contraindications or any other rationale as to why therapy was not provided.[21]

Clinical outcomes

All patients were followed up at 3, 6 and 12 months by telephone or face-to-face interview. Trained research coordinators collected the clinical outcomes. In this study, the outcomes included all-cause mortality, poor outcome, recurrent stroke, and combined vascular events at 3 months and 1 year. Each case fatality was identified from the attended hospital where the patient was treated or by a death certificate from the local citizen registry. Stroke recurrence was defined as a new ischaemic stroke or haemorrhagic stroke within 3 months or 1 year after symptom onset. Composite vascular events included myocardial infarction, recurrent stroke and vascular death. The poor outcome was defined as mRS of 3–6.

Statistical analysis

The patients were categorised into four groups based on quartiles of hospital volume: Q1 (<300/year), Q2 (300–436/year), Q3 (437–722/year) and Q4 (>722/year). Continuous variables were described as mean±SD or median and IQR. Categorical variables were described as proportions. The patient characteristics were compared using analysis of variance, Kruskal-Wallis test or X^2 test. Additionally, to obtain the p for trend, we used Cochran-Mantel-Haenszel non-zero correlation tests for continuous variables and Cochran-Mantel-Haenszel row mean scores for categorical variables.

Generalised estimating equations with an exchangeable working correlation matrix were used to evaluate the association between hospital volume, the process of care and outcomes adjusting for the cluster effect within the hospital. In the adjusted models, age, sex, health insurance (urban resident basic medical insurance, new rural cooperative medical scheme, commercial insurance, self-payment), education (elementary or below, middle school, high school or above), previous or current smoking, drinking, comorbidities (hypertension, diabetes, hyperlipidaemia, atrial fibrillation, history of stroke), NIHSS at admission and hospital characteristics (academic status, number of beds, presence of stroke unit and location) were included. Additionally, the defect-free measure of care was included in the adjusted model when estimating the association between hospital volume and outcomes. We used the Kaplan-Meier method to depict the cumulative hazards of all-cause mortality and recurrent stroke. ORs and corresponding 95% CIs were used with the hospital volume of Q4 as reference. Additionally, we used restricted cubic splines with five knots at the 5th, 35th, 50th and 95th centiles to model the association between hospital volume and outcomes. We tested for non-linearity by using the Wald statistics.

All analyses were performed by SAS V.9.4 (SAS Institute) and R V.3.5.1. All p values were two tailed with a significant level of 0.05.

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

A total of 17 550 patients with AIS from 217 hospitals across China were included in this study. The process of patient selection is shown in figure 1. Patients included in the current study and those excluded were largely comparable (online supplemental table 2). Table 1 describes the baseline characteristics of the included hospitals and patients.

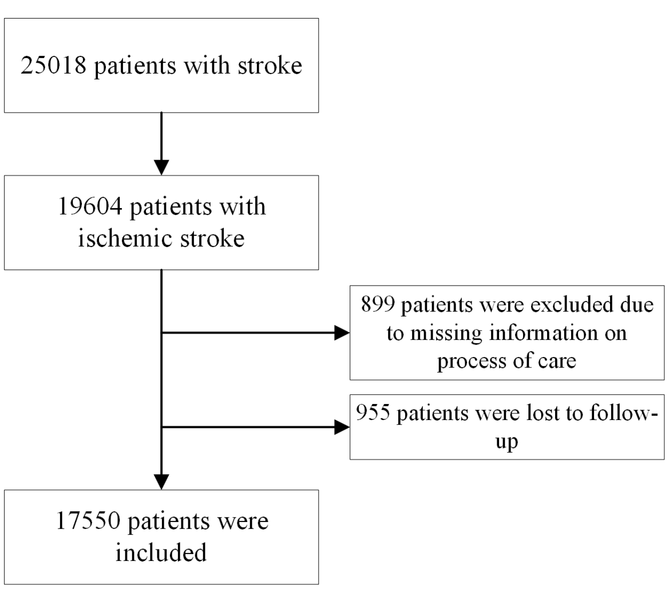

Figure 1 The flow chart for patient selection.

Of the 217 hospitals, 125 (57.6%) were teaching hospitals. The high-volume hospitals were likely to be teaching hospitals. Overall, 121 hospitals (55.8%) had certified stroke units. There were 121 hospitals in the east of China, 66 around the middle and 30 in the west. The average hospital volume was 437 per year, ranging from 136 to 2048.

The mean age was 65 (57–74) years, and 63.6% of the patients were male. The median NIHSS at admission was 4 (2–7) and the median days of hospitalisation were 13 (9–16). Compared with the high-volume hospitals, there were more women, and the patients were older in low-volume hospitals. The patients in high-volume hospitals were more likely to have diabetes and hyperlipidaemia but less likely to have atrial fibrillation. The proportions of patients taking antiplatelet and lipid-lowing agents were higher in high-volume hospitals than that in low-volume hospitals.

Association between hospital volume and process measures

Table 2 lists the rates of achievement in process measures. Compared with the hospitals of Q4, the unadjusted OR of defect-free measure of care was 0.88 (95% CI 0.62 to 1.25) for Q1, 1.13 (95% CI 0.82 to 1.56) for Q2 and 1.15 (95% CI 0.81 to 1.62) for Q3. No significant difference was found in individual process measures, except the DVT prophylaxis for Q3 (OR=2.22; 95% CI 1.26 to 3.91; p=0.0059), antithrombotic medication at discharge for Q2 (OR=1.74; 95% CI 1.09 to 2.76; p=0.0196) and LDL-C-lowering medication for Q3 (OR=1.60; 95% CI 1.10 to 2.33; p=0.0134) (online supplemental table 3).

Table 3 shows the adjusted ORs for process measures. After adjusting for the patients and hospital characteristics, the adjusted OR of defect-free measure of care was 0.93 (95% CI 0.61 to 1.42) for Q1, 1.25 (95% CI 0.85 to 1.85) for Q2 and 1.11 (95% CI 0.76 to 1.63) for Q3. All the individual performance measures show no significant association (all p>0.05).

Association between hospital volume and 3-month and 1-year outcomes

Of the included patients, 1322 (7.53%) died within 1 year after stroke onset. The Kaplan-Meier plot for mortality within 1 year is shown in figure 2. The 3-month and 1-year mortality was different across the four groups (3-month mortality, 4.95% vs 3.64% vs 4.33% vs 3.39%, p=0.0011; 1-year mortality, 9.59% vs 7.69% vs 8.39% vs 7.16%, p=0.0006) (table 4). At 3 months and 1 year, the mortality was slightly higher in Q1 hospitals (OR at 3 months=1.54, 95% CI 1.13 to 2.09, p=0.0059; OR at 1 year=1.48, 95% CI 1.17 to 1.88; p=0.0013), but not in Q2 or Q3 hospitals compared with Q4 hospitals. However, the difference was not significant when adjusted for potential factors (table 5).

A total of 3683 (21.12%) patients experienced poor outcome at 3 months and 3701 (22.48%) at 1 year (table 4). Patients treated in low-volume hospitals were more likely to have a higher rate of poor outcome at 3

Table 1 Hospital and patient characteristics by quartiles of hospital volume

Characteristic	Total (n=17 550)	Q1 hospitals <300/year (n=3371)	Q2 hospitals 300–436/year (n=5386)	Q3 hospitals 437–722/year (n=3281)	Q4 hospitals >722/year (n=5512)	P value	P for trend
Hospital characteristics							
Number of hospitals	217	53	56	53	55		
Teaching hospital	125 (57.6%)	23 (43.4%)	23 (41.1%)	37 (69.8%)	42 (76.4%)	<0.0001	<0.0001
Stroke unit	121 (55.8%)	24 (45.3%)	24 (42.9%)	35 (66%)	38 (69.1%)	0.0062	0.0017
Beds	1000 (600–1650)	600 (500–800)	780 (515–1000)	1300 (1000–2000)	1500 (1200–2200)	<0.0001	<0.0001
Geographical region							
East	121 (55.8%)	29 (54.7%)	35 (62.5%)	28 (52.8%)	29 (52.7%)	0.6967	<0.0001
Middle	66 (30.4%)	15 (28.3%)	13 (23.2%)	20 (37.7%)	18 (32.7%)		
West	30 (13.8%)	9 (17%)	8 (14.3%)	5 (9.4%)	8 (14.5%)		
Patient characteristics							
Male	11 163 (63.6%)	2126 (63.1%)	3349 (62.2%)	2108 (64.2%)	3580 (64.9%)	0.0183	0.0085
Age	65 (57-74)	66 (57-75)	65 (57-74)	66 (58-74)	64 (55-73)	<0.0001	<0.0001
Health insurance							
URBMI	8959 (51%)	1715 (50.9%)	2552 (47.4%)	1568 (47.8%)	3124 (56.7%)	<0.0001	<0.0001
NRCMS	6932 (39.5%)	1369 (40.6%)	2440 (45.3%)	1394 (42.5%)	1729 (31.4%)		
Commercial insurance	60 (0.3%)	8 (0.2%)	27 (0.5%)	4 (0.1%)	21 (0.4%)		
Self-payment	1599 (9.1%)	279 (8.3%)	367 (6.8%)	315 (9.6%)	638 (11.6%)		
Education							
Elementary or below	7934 (45.2%)	1693 (50.2%)	2430 (45.1%)	1678 (51.1%)	2133 (38.7%)	<0.0001	<0.0001
Middle school	4109 (23.4%)	715 (21.2%)	1286 (23.9%)	661 (20.1%)	1447 (26.3%)		
High school or above	5507 (31.4%)	963 (28.6%)	1670 (31%)	942 (28.7%)	1932 (35.1%)		
Previous or current smoking	7818 (44.5%)	1457 (43.2%)	2406 (44.7%)	1455 (44.3%)	2500 (45.4%)	0.2676	0.0836
Drinking	5277 (30.1%)	872 (25.9%)	1681 (31.2%)	995 (30.3%)	1729 (31.4%)	<0.0001	0.0001
Medical history							
Hypertension	11 386 (64.9%)	2156 (64%)	3511 (65.2%)	2136 (65.1%)	3583 (65%)	0.6614	0.459
Diabetes	3630 (20.7%)	658 (19.5%)	1097 (20.4%)	673 (20.5%)	1202 (21.8%)	0.0599	0.0086
Hyperlipidaemia	2128 (12.1%)	372 (11%)	808 (15%)	384 (11.7%)	564 (10.2%)	<0.0001	0.0001
Atrial fibrillation	1185 (6.8%)	212 (6.3%)	402 (7.5%)	280 (8.5%)	291 (5.3%)	0.0001	0.0174
Stroke or TIA	5918 (33.7%)	1084 (32.2%)	1886 (35%)	1113 (33.9%)	1835 (33.3%)	0.0411	0.8641
Medication history							
Antiplatelet	3444 (19.6%)	599 (17.8%)	1008 (18.7%)	712 (21.7%)	1125 (20.4%)	<0.0001	0.0002
Anticoagulation	178 (1%)	33 (1%)	69 (1.3%)	35 (1.1%)	41 (0.7%)	0.0467	0.0696
Antihypertension	7868 (44.8%)	1454 (43.1%)	2592 (48.1%)	1401 (42.7%)	2421 (43.9%)	<0.0001	0.1248
Lipid-lowering medicine	1207 (6.9%)	195 (5.8%)	487 (9%)	241 (7.3%)	284 (5.2%)	<0.0001	0.0002
Antidiabetics	2782 (15.9%)	500 (14.8%)	875 (16.2%)	509 (15.5%)	898 (16.3%)	0.2276	0.1842
NIHSS at admission	4 (2–7)	4 (2–7)	4 (2–6)	4 (2–8)	4 (2–7)	<0.0001	<0.0001
Days of hospitalisation	13 (9–16)	13 (10–16)	13 (9–15)	13 (9–16)	13 (10–16)	<0.0001	0.0211

NIHSS, National Institutes of Health Stroke Scale; NRCMS, new rural cooperative medical scheme; TIA, transient ischaemic attack; URBMI, urban resident basic medical insurance.

months (23.41% vs 19.51% vs 21.37% vs 21.15%, p=0.0003; $OR_{Q1\ versus\ Q4}$=1.22, 95% CI 1.01 to 1.47, p=0.0377) and 1 year (25.69% vs 20.71% vs 21.81% vs 22.65%, p<0.0001; $OR_{Q1\ versus\ Q4}$=1.29, 95% CI 1.08 to 1.54, p=0.0043). When adjusted for potential factors, Q1 hospitals still had a higher rate of poor outcome at 1 year compared with Q4 hospitals ($OR_{Q1\ versus\ Q4}$=1.29, 95% CI 1.01 to 1.64, p=0.0393).

There were 1199 (6.83%) patients with recurrent stroke within 1 year. The Kaplan-Meier plot for recurrent stroke within 1 year is shown in figure 3. The recurrence rate was similar across the four groups (7.15% vs 7.59% vs 6.85% vs 6.38%, p=0.1121) (table 4). No significant association was found between hospital volume and stroke recurrence at 3 months and 1 year. Similar results were observed for combined vascular events (table 5).

In figures 3–6, we used restricted cubic splines to illustrate the relationship of all-cause mortality, poor outcome, stroke recurrence and combined vascular events with hospital stroke volume. The

Table 2 The rates of achievement in process measures

Process measures	Total N1/N2 (achievement rate, %)	Q1 hospitals N1/N2 (achievement rate, %)	Q2 hospitals N1/N2 (achievement rate, %)	Q3 hospitals N1/N2 (achievement rate, %)	Q4 hospitals N1/N2 (achievement rate, %)
rt-PA	217/1303 (16.7)	36/250 (14.4)	75/497 (15.1)	25/200 (12.5)	81/356 (22.8)
Early antithrombotic	14 555/17 243 (84.4)	2802/3303 (84.8)	4508/5307 (84.9)	2903/3199 (90.7)	4342/5434 (79.9)
Dysphagia screening	14 876/17 550 (84.8)	2630/3371 (78.0)	4860/5386 (90.2)	2615/3281 (79.7)	4771/5512 (86.6)
DVT prophylaxis	3367/5079 (66.3)	630/944 (66.7)	1006/1481 (67.9)	689/914 (75.4)	1042/1740 (59.9)
Antithrombotic medication	14 722/16 002 (92)	2845/3058 (93.0)	4481/4765 (94.0)	2839/3089 (91.9)	4557/5090 (89.5)
Lowering LDL-C medication	7700/11 597 (66.4)	1436/2247 (63.9)	2591/3621 (71.6)	1523/2120 (71.8)	2150/3609 (59.6)
Antihypertensive medication for hypertension	8867/13 385 (66.2)	1712/2611 (65.6)	2764/4207 (65.7)	1710/2470 (69.2)	2681/4097 (65.4)
Hypoglycaemic medication for diabetes	3662/4898 (74.8)	685/907 (75.5)	1114/1494 (74.6)	721/901 (80.0)	1142/1596 (71.6)
Anticoagulation for AF	303/1437 (21.1)	43/278 (15.5)	86/468 (18.4)	87/325 (26.8)	87/366 (23.8)
Smoking cessation	6712/7819 (85.8)	1227/1457 (84.2)	2098/2406 (87.2)	1213/1456 (83.3)	2174/2500 (87.0)
Defect-free measure of care	5816/17 550 (33.1)	992/3371 (29.4)	1965/5386 (36.5)	1150/3281 (35.1)	1709/5512 (31.0)

N1 indicates the number of patients who received the process of care, and N2 indicates the number of patients eligible.
AF, atrial fibrillation; DVT, deep vein thrombosis; LDL-C, low-density lipoprotein cholesterol; rt-PA, recombinant tissue plasminogen activator.

multivariable-adjusted restricted cubic splines showed a 'J-shaped' association between volume and all-cause mortality and poor outcome, indicating a significant non-linear association between volume and poor outcome at 3 months and 1 year (p for non-linear=0.0096 and <0.0001, respectively), as well as combined vascular events at 1 year (p for non-linear=0.0242).

DISCUSSION

Our analysis of a large population of 17 550 patients with ischaemic stroke suggested that no significant difference in the process of care was observed for patients in lower volume hospitals compared with that for patients in higher volume hospitals. There was no association between hospital volume and mortality, stroke recurrence, and combined vascular events at 3 months and 1 year. In contrast, we found that the patients in the lowest volume quartile had a significantly higher rate of poor outcome at 1 year than the patients in the highest quartile.

Previous studies found that high volume was associated with improved outcomes suggesting that volume is a surrogate for quality of care. The quality of care can be

Table 3 The association between hospital volume and process measures

Performance measures	Q1 vs Q4 Adjusted OR (95% CI)	Q1 vs Q4 P value	Q2 vs Q4 Adjusted OR (95% CI)	Q2 vs Q4 P value	Q3 vs Q4 Adjusted OR (95% CI)	Q3 vs Q4 P value
rt-PA	1.54 (0.61 to 3.89)	0.3614	1.46 (0.68 to 3.14)	0.3343	0.71 (0.35 to 1.48)	0.3634
Early antithrombotic	0.68 (0.20 to 2.32)	0.5364	1.17 (0.30 to 4.55)	0.8245	1.07 (0.36 to 3.18)	0.9020
Dysphagia screening	0.76 (0.33 to 1.74)	0.5104	2.19 (0.86 to 5.55)	0.0987	0.90 (0.42 to 1.92)	0.7845
DVT prophylaxis	1.02 (0.52 to 2.01)	0.9504	1.09 (0.57 to 2.09)	0.7936	1.55 (0.84 to 2.83)	0.1594
Antithrombotic medication	1.26 (0.61 to 2.61)	0.5391	1.27 (0.61 to 2.64)	0.5277	1.16 (0.63 to 2.15)	0.6375
Lowering LDL-C medication	0.92 (0.57 to 1.50)	0.7460	1.03 (0.62 to 1.70)	0.9224	1.20 (0.78 to 1.84)	0.4134
Antihypertensive medication for hypertension	0.99 (0.71 to 1.38)	0.9395	0.92 (0.67 to 1.27)	0.6152	1.11 (0.81 to 1.53)	0.5041
Hypoglycaemic medication for diabetes	1.02 (0.67 to 1.55)	0.9210	1.06 (0.69 to 1.65)	0.7818	0.97 (0.65 to 1.46)	0.8888
Anticoagulation for AF	0.63 (0.34 to 1.16)	0.1365	0.87 (0.53 to 1.44)	0.5848	1.05 (0.61 to 1.78)	0.8681
Smoking cessation	0.56 (0.10 to 2.97)	0.4939	0.67 (0.12 to 3.63)	0.6421	2.08 (0.25 to 17.2)	0.4961
Defect-free measure of care	0.93 (0.61 to 1.42)	0.7412	1.25 (0.85 to 1.85)	0.2634	1.11 (0.76 to 1.63)	0.5853

AF, atrial fibrillation; DVT, deep vein thrombosis; LDL-C, low-density lipoprotein cholesterol; rt-PA, recombinant tissue plasminogen activator.

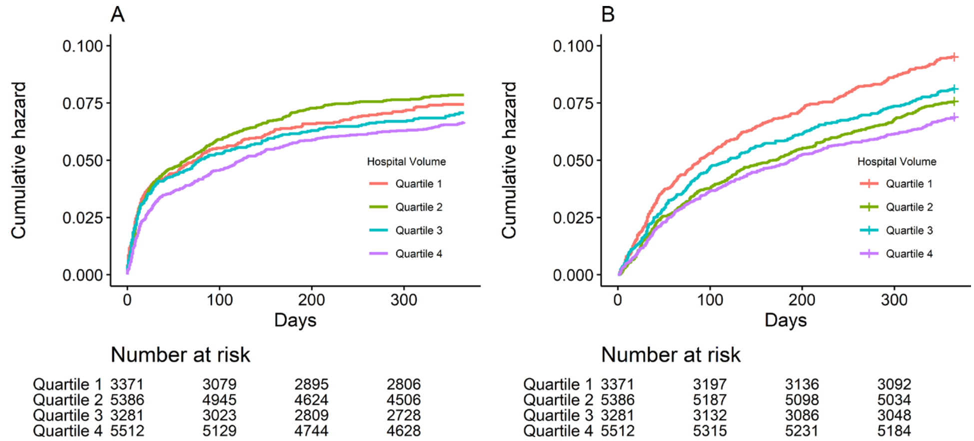

Figure 2 The Kaplan-Meier curve for mortality (A) and recurrent stroke (B) within 1 year.

assessed from outcome, process and structure.[22] Usually, hospital volume is used as a structure metric of quality of care. However, the underlying mechanisms of interplay between structure and process are complex.[23] Two existing studies showed that the patients in high-volume hospitals received more process of care than patients in low-volume hospitals.[13 23] Potential mechanisms were proposed to explain this association, including substantial experience ('practice makes perfect') and the availability of advanced techniques and devices in high-volume hospitals.[7 23] In contrast, we did not find an association between hospital stroke volume and process measures in the current study. This was similar to a study from GWTG-Stroke, where 790 US hospitals (322 847 patients who had an ischaemic stroke or TIA) were assessed and no differences in performance measures were observed between high-volume and low-volume hospitals after adjusting for patient baseline characteristics.[18] Previously, many initiatives for improving the quality of care have been implemented to standardise the quality of care in hospitals, such as GWTG-Stroke, Australian Stroke Clinical Registry and CNSR,[24] which may minimise the variability in the quality of care between high-volume and low-volume hospitals.

During the past decades, a significant number of studies evaluated the volume–outcome association. Many, but not all, found a reverse relationship between volume and outcome.[9] Several studies revealed that patients who had a stroke in high-volume hospitals may experience lower short-term mortality than patients in low-volume hospitals.[11 12 25 26] However, we found no improvement in the mortality rate for patients in high-volume hospitals. Several reasons may explain this discrepancy. First, the hospital volume varied in these studies. Moreover, stroke severity, adjusted or not, remained an essential factor affecting prognosis.[13] Most studies to date lack data on stroke severity, and use comorbidity or comorbidity index score to adjust the case mix.[11 12 25 26] Herein, we used the NIHSS score at admission to adjust the stroke severity. Our findings are compatible with a Danish nationwide cohort study of 63 995 patients admitted to stroke units.[23] This study found no association between volume and 30-day mortality and 1-year mortality rates after adjusting for patient baseline characteristics, stroke unit, university

Table 4 The rates of clinical outcomes according to quartiles of hospital volume

Outcome	Q1	Q2	Q3	Q4	P value
3 months					
Mortality, no (%)	167 (4.95)	196 (3.64)	142 (4.33)	187 (3.39)	0.0011
Poor outcome, no (%)*	783 (23.41)	1042 (19.51)	698 (21.37)	1160 (21.15)	0.0003
Stroke recurrence, no (%)	178 (5.28)	297 (5.51)	166 (5.06)	238 (4.32)	0.0298
Combined vascular events, no (%)	183 (5.43)	303 (5.63)	168 (5.12)	247 (4.48)	0.0440
1 year					
Mortality, no (%)	306 (9.59)	393 (7.69)	256 (8.39)	367 (7.16)	0.0006
Poor outcome, no (%)†	817 (25.69)	1058 (20.71)	665 (21.81)	1161 (22.65)	<0.0001
Stroke recurrence, no (%)	228 (7.15)	388 (7.59)	209 (6.85)	327 (6.38)	0.1121
Combined vascular events, no (%)	236 (7.40)	406 (7.94)	216 (7.08)	368 (7.18)	0.3986

*A total of 17 438 patients achieved modified Rankin Scale at 3 months.
†A total of 16 462 patients achieved modified Rankin Scale at 1 year.

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Table 5 The association between hospital volume and clinical outcomes

Outcome	Q1 vs Q4 OR (95% CI)	Q1 vs Q4 P value	Q2 vs Q4 OR (95% CI)	Q2 vs Q4 P value	Q3 vs Q4 OR (95% CI)	Q3 vs Q4 P value
3 months						
Mortality						
Unadjusted	1.54 (1.13 to 2.09)	0.0059	1.09 (0.85 to 1.40)	0.4772	1.26 (0.89 to 1.79)	0.1861
Adjusted	1.27 (0.88 to 1.83)	0.2062	0.99 (0.75 to 1.30)	0.9179	1.18 (0.82 to 1.68)	0.3708
Poor outcome						
Unadjusted	1.22 (1.01 to 1.47)	0.0377	0.95 (0.81 to 1.11)	0.5341	1.06 (0.89 to 1.26)	0.4937
Adjusted	1.17 (0.91 to 1.52)	0.2269	0.95 (0.74 to 1.22)	0.6891	0.96 (0.75 to 1.22)	0.7185
Recurrent stroke						
Unadjusted	1.27 (0.92 to 1.75)	0.1403	1.21 (0.91 to 1.61)	0.1992	1.16 (0.85 to 1.58)	0.3563
Adjusted	1.16 (0.83 to 1.62)	0.3798	1.11 (0.79 to 1.56)	0.5474	1.11 (0.78 to 1.56)	0.5620
Combined vascular events						
Unadjusted	1.27 (0.92 to 1.76)	0.1391	1.19 (0.89 to 1.60)	0.2437	1.14 (0.83 to 1.56)	0.4304
Adjusted	1.15 (0.82 to 1.61)	0.4109	1.09 (0.78 to 1.53)	0.6167	1.08 (0.76 to 1.52)	0.6763
1 year						
Mortality						
Unadjusted	1.48 (1.17 to 1.88)	0.0013	1.13 (0.93 to 1.38)	0.2097	1.22 (0.96 to 1.54)	0.0996
Adjusted	1.15 (0.89 to 1.47)	0.2829	0.98 (0.79 to 1.22)	0.8663	1.05 (0.82 to 1.35)	0.6743
Poor outcome						
Unadjusted	1.29 (1.08 to 1.54)	0.0043	0.94 (0.81 to 1.09)	0.4317	1.00 (0.86 to 1.17)	0.9917
Adjusted	1.29 (1.01 to 1.64)	0.0393	0.98 (0.78 to 1.24)	0.8758	0.85 (0.68 to 1.06)	0.1566
Recurrent stroke						
Unadjusted	1.20 (0.91 to 1.59)	0.1939	1.18 (0.93 to 1.49)	0.1853	1.08 (0.83 to 1.40)	0.5552
Adjusted	1.08 (0.81 to 1.43)	0.6025	1.05 (0.80 to 1.37)	0.7277	1.01 (0.77 to 1.32)	0.9491
Combined vascular events						
Unadjusted	1.11 (0.84 to 1.45)	0.4583	1.10 (0.87 to 1.39)	0.4307	1.00 (0.77 to 1.30)	0.9906
Adjusted	0.97 (0.75 to 1.27)	0.8487	0.96 (0.75 to 1.24)	0.7727	0.92 (0.71 to 1.19)	0.5181

The adjusted covariates included age, sex, health insurance (urban resident basic medical insurance, new rural cooperative medical scheme, commercial insurance, self-payment), education (elementary or below, middle school, high school or above), previous or current smoking, drinking, comorbidities (hypertension, diabetes, hyperlipidaemia, atrial fibrillation, history of stroke), NIHSS at admission, hospital characteristics (academic status, beds, stroke unit and location) and the composite measure of care.
NIHSS, National Institutes of Health Stroke Scale.

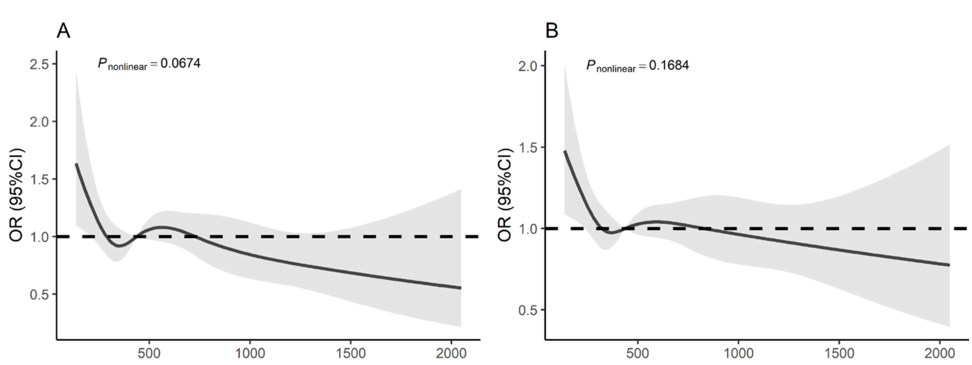

Figure 3 Association between hospital stroke volume and all-cause mortality. (A) Hospital volume and 3-month all-cause mortality. (B) Hospital volume and 1-year all-cause mortality. The reference point is the median value of hospital volume (476 annual stroke discharges) in all patients.

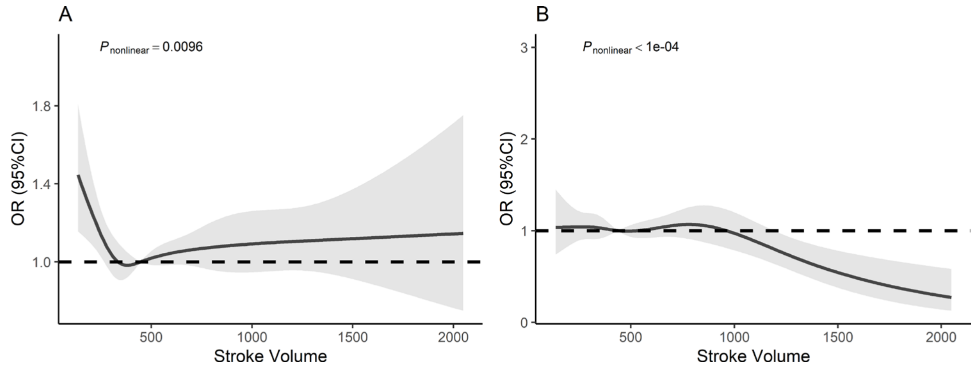

Figure 4 Association between hospital stroke volume and poor outcome. (A) Hospital volume and 3-month poor outcome. (B) Hospital volume and 1-year poor outcome. The reference point is the median value of hospital volume (476 annual stroke discharges) in all patients.

status and quality of care. Mortality may be insensitive to detecting nuances in patient prognosis.[23]

Besides mortality, we also examined the association between hospital volume and poor outcome, stroke recurrence and combined vascular events. To our knowledge, this is the first time the association between volume and poor outcome at 3 months and 1 year in patients with AIS was evaluated in a study. Compared with the highest quartile of hospitals, patients in the lowest quartile had a higher rate of poor outcome at 1 year after adjusting for potential confounders. The poor outcome may be more sensitive in detecting changes in patient prognosis. The underlying mechanisms of the association between volume and poor outcome are not known. Though there was no significant difference in the process of care during the acute phase and at discharge between low-volume and high-volume hospitals, the differences in some other processes of care after discharge may explain this association. Patients in high-volume hospitals may undergo more processes after discharge, such as limb rehabilitation, which can improve poor outcome. The association between volume and poor outcome may be mediated by medical care after discharge. However, data on post-discharge management were not routinely documented; hence, data could not be extracted from all patients and analysed. In the future, the association between volume, the process of care after discharge and long-term outcomes is needed for further exploration. Despite the significant association, we did not think it was reasonable to regionalise stroke care because patient transfers may lead to a delay in admission, offsetting some benefits of being admitted to large-volume hospitals.[11]

Several limitations in this study should be acknowledged. First, the hospitals that participated in the CNSR were volunteers; therefore, selection bias cannot be completely eliminated. The sampled hospitals enrolled may not be representative of the general hospitals in China. Second, although 10 processes of care were evaluated, other processes of care such as mechanical thrombectomy and the care patients received after discharge could not be assessed. The differences in unassessed process measures may explain the association between volume and poor outcome. Third, there is a cluster effect within hospitals and physicians. Although we considered the cluster effect within hospitals by using the generalised estimating equations, we could not adjust the cluster effect within physicians. Moreover, due to variability among patients, hospital characteristics, and performance of care across varied regions and countries, our results may not be applicable to other countries. Finally, the mortality rate in our study was lower than the studies from other countries. Several reasons could explain this. First, most of the included patients had minor strokes (NIHSS ≤4). Second, although we used the central death registry to

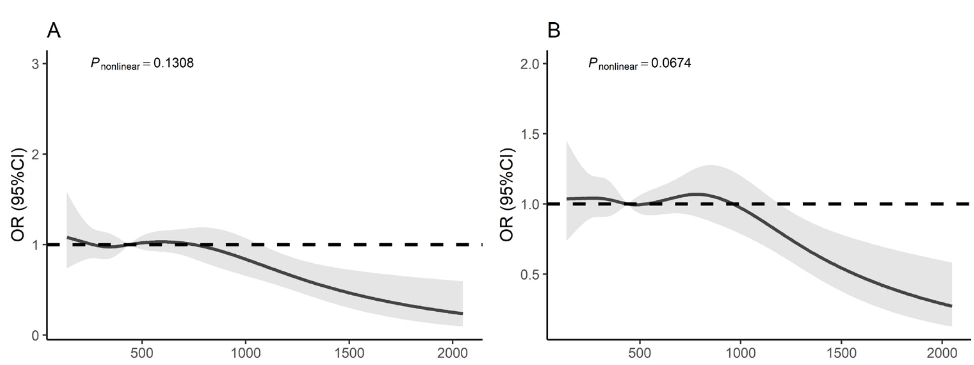

Figure 5 Association between hospital stroke volume and recurrent stroke. (A) Hospital volume and 3-month recurrent stroke. (B) Hospital volume and 1-year recurrent stroke. The reference point is the median value of hospital volume (476 annual stroke discharges) in all patients.

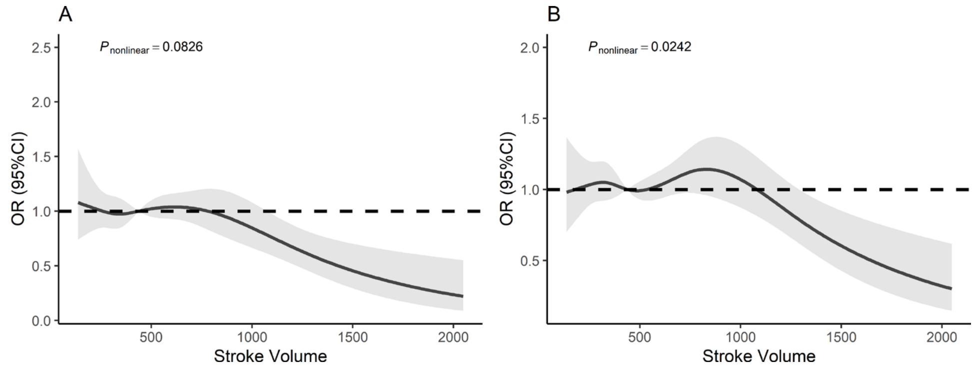

Figure 6 Association between hospital stroke volume and combined vascular events. (A) Hospital volume and 3-month combined vascular events. (B) Hospital volume and 1-year combined vascular events. The reference point is the median value of hospital volume (476 annual stroke discharges) in all patients.

obtain the vital status of those patients lost to follow-up, we failed to obtain the vital status of all patients. This may lead to bias. Further studies on volume and clinical outcome, especially the poor outcome, are needed to confirm our results.

CONCLUSIONS

Using the large national stroke registry, we found no association between hospital stroke volume, the process of care and 1-year mortality. However, the patients in the lowest quartile of hospitals had increased rates of poor outcome compared with the patients in the highest quartile of hospitals. Further studies need to be conducted to examine whether the medical care after discharge mediates the association between stroke volume and poor outcome. Better understanding of the association between structure, processes and outcomes can help identify the best way to improve stroke prognosis.

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Patient consent for publication Parental/guardian consent obtained.

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ORCID iD

Runhua Zhang http://orcid.org/0000-0003-4825-191X

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