Comparison between healthcare quality in primary stroke centers and comprehensive stroke centers for acute stroke patients: evidence from the Chinese Stroke Center Alliance

Zeyu Liu,[a,b,c] Hongqiu Gu,[d,e] Minping Wei,[a,b,c] Xianjing Feng,[a,b,c] Fang Yu,[a,b,c] Jie Feng,[a,b,c] Zixiao Li,[d,e,f] Jian Xia,[a,b,c,**] and Xin Yang[d,e,f,*]

[a]Department of Neurology, Xiangya Hospital, Central South University, Changsha, Hunan, China
[b]Clinical Research Center for Cerebrovascular Disease of Hunan Province, Central South University, Changsha, Hunan, China
[c]National Clinical Research Center for Geriatric Disorders, Xiangya Hospital, Central South University, Changsha, Hunan, China
[d]China National Clinical Research Center for Neurological Diseases, Beijing Tiantan Hospital, Capital Medical University, Beijing, China
[e]National Center for Healthcare Quality Management in Neurological Diseases, Beijing Tiantan Hospital, Capital Medical University, Beijing, China
[f]Department of Neurology, Beijing Tiantan Hospital, Capital Medical University, Beijing, China

The Lancet Regional Health - Western Pacific
2023;38: 100863
Published Online xxx
https://doi.org/10.1016/j.lanwpc.2023.100863

Summary

Background To improve stroke care quality, the guidelines for stroke center construction in China recommended establishing primary stroke centers (PSCs) and comprehensive stroke centers (CSCs). We aimed to compare stroke care quality between the two types of centers.

Methods Data were collected from acute stroke patients admitted to PSCs or CSCs in the China Stroke Center Alliance program. Twenty-one individual guideline-recommended performance measures and two summary measures were compared between the two groups. Multivariable logistic regression models were used to examine the association between stroke center status (CSC vs. PSC) and healthcare quality.

Findings Data from 750,594 stroke patients from 1474 stroke centers (252 CSCs and 1222 PSCs) were analyzed. For many components of healthcare performance in stroke patients, comparable levels of performance were observed between CSCs and PCSs. Nonetheless, CSCs outperformed PSCs in the areas of administering intravenous recombinant tissue plasminogen activator within 4.5 h (aOR = 1.31 [95% CI: 1.07–1.60]), rehabilitation for acute ischaemic stroke (AIS) (aOR = 1.19 [95% CI: 1.01–1.40]), and the provision of hypoglycemic medication and statin therapy upon discharge for AIS (aOR = 1.26 [95% CI: 1.00–1.59] and aOR = 1.28 [95% CI: 1.04–1.59], respectively). More patients with intracerebral haemorrhage and subarachnoid haemorrhage received neurosurgery in CSCs (14.4% vs. 10.6% and 51.0% vs. 33.9%, respectively). Additionally, CSCs had higher in-hospital mortality than PSCs (aOR = 1.33 [95% CI: 1.01–1.73]).

Interpretation Overall PSCs provided equivalent care for many quality measures to CSCs in China with the exception of thrombolysis, rehabilitation access, and medication at discharge for AIS, whereby improvements should be directed. Nevertheless, PSCs have demonstrated lower risk-adjusted in-hospital mortality rates.

Funding The National Key Research and Development Projects of China.

Keywords: Stroke; Healthcare quality; Stroke center; In-hospital mortality

Introduction

Stroke remains the top cause of years of life lost and disability-adjusted life years in China.[1,2] In 2020, a nationwide survey that included 676,394 adults aged ≥40 years revealed that the estimated overall prevalence, incidence, and mortality of stroke were 2.6%, 502.2 per 100,000 person-years, and 343.4 per 100,000 person-years, respectively.[3] Stroke burden in China is continuously escalating, resulting from gradual aging of China's population. Hence, improving

*Corresponding author. China National Clinical Research Center for Neurological Diseases, Beijing Tiantan Hospital, Capital Medical University, No. 119 West Rd, Southern Fourth Ring Road, Beijing 100070, China.
**Corresponding author. Department of Neurology, Xiangya Hospital, Central South University, Changsha, Hunan 410008, China.
E-mail addresses: xjian1216@csu.edu.cn (J. Xia), yangxin@ncrcnd.org.cn (X. Yang).

Research in context

Evidence before this study

In 2015, the guidelines for stroke center construction in China recommended the establishment of primary stroke centers (PSCs) and comprehensive stroke centers (CSCs). We searched the PubMed database from inception to March 31, 2023, for studies that compared care quality and in-hospital outcomes between PSCs and CSCs in China, using the search terms "primary stroke centers" or "comprehensive stroke center" or "stroke center" and "care" or "outcomes" and "China" in articles published in English. We also searched the Wanfang database using the same terms in Chinese. Our literature search found no research articles reporting quality of care and in-hospital outcomes in stroke centers at both levels.

Added value of this study

This is the first study to explore the disparities in quality of stroke care between PSCs and CSCs in China. The findings revealed that while comparable levels of healthcare performance were observed between PSCs and CSCs for many components in patients with acute stroke, PCSs exhibited inferior performance in the areas of administering intravenous recombinant tissue plasminogen activator within 4.5 h, rehabilitation for acute ischaemic stroke (AIS), and the provision of hypoglycaemic medication and statin therapy upon discharge for AIS. Moreover, we noted a significant gap between China's stroke care quality and that of developed countries.

Implications of all the available evidence

Our study identified areas in stroke care that have ample room for improvement, thereby enabling targeted interventions and enhancements in the quality of care provided at PSCs and CSCs across China. Our research firmly supports the idea that balancing medical staff distribution, upgrading their carrying capacity, and promoting adherence to recommended treatment regimens are highly warranted.

stroke care and outcomes has become a national priority in China.[4]

To improve the quality of stroke care, the guidelines for stroke center construction in China issued in 2015 recommended to establish two levels of stroke centers: primary stroke centers (PSCs) and comprehensive stroke centers (CSCs).[5,6] PSCs and CSCs are certified by the Chinese Stroke Association and Chinese Stroke Center Alliance (CSCA). PSCs should possess the necessary personnel, technical resources, and infrastructure to provide standardised stroke diagnosis and treatment, including monitoring and maintenance of vital signs, utilisation of examination techniques for early diagnosis of stroke, targeted interventions for stroke, such as intravenous thrombolysis with recombinant tissue plasminogen activator, normative secondary prevention of stroke, and early rehabilitation following stroke.[6] CSCs are mandated to fulfil the aforementioned prerequisites while also providing specialised diagnostic testing, such as cerebral angiography and transesophageal echocardiography, as well as adequate intensive care, interventional treatment, and neurosurgical treatment for patients with complex or critically ill stroke.[6] From 2015 to 2019, with the establishment of stroke centers, a substantial improvement was observed in the quality of care and outcomes for stroke patients hospitalized in China.[7] However, it remains uncertain whether significant gaps exist in healthcare quality between the two kinds of centers.

The CSCA is a national, multicenter, hospital-based, voluntary, multifaceted interventional, continuous quality improvement initiative designed to collect prospective stroke data concerning guideline-recommended performance measures and clinical outcomes during hospitalisation.[8,9] The present study analyzed results from the CSCA to examine the variations in healthcare strategies for and health outcomes of stroke patients between PSCs and CSCs.

Methods

Chinese Stroke Center Alliance

The CSCA is the most up-to-date and comprehensive quality report of hospitalised patients diagnosed with acute stroke or transient ischemic attacks (TIA) in China. Details of the CSCA program have been published previously.[8] All participating hospitals were mandated to report stroke cases that met the specified inclusion criteria on a monthly basis using a web-based Patient Management Tool (Medicine Innovation Research Center, Beijing, China). The data collected were obtained from routine clinical practice. A systematic collection of data, including patient demographics, medical history, medication history, hospital presentation, initial neurological status, administered medications and interventions, reperfusion strategy, in-hospital outcomes, and complications, was performed for each hospitalisation.

All participating hospitals received healthcare quality assessment and research approval to collect data without requiring individual patient informed consent under the common rule or a waiver of authorization and exemption from their respective institutional review boards. In the data collection process, no changes were made to routine clinical practice. The CSCA program was approved by the Ethics Committee of Tiantan Hospital, Capital Medical University, Beijing, China.

Data collection

This study included 935,175 patients with acute ischaemic stroke (AIS), intracerebral haemorrhage (ICH), or subarachnoid haemorrhage (SAH) at the participating hospitals between August 2015 and August 2019 from 31 provinces in China. The enrolled patients were required to meet the following inclusion criteria: (1) aged 18 years or older; (2) having a primary diagnosis of AIS, ICH, or SAH; (3) within 7 days of symptom onset; and (4) admitted directly to the ward or through the emergency department. AIS, ICH, and SAH were diagnosed in accordance with the Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke in China 2014,[10] Chinese Guidelines for Diagnosis and Treatment of Acute 2014,[11] and Chinese Guidelines for Diagnosis and Treatment of Subarachnoid Hemorrhage 2015.[12] We excluded 183,184 cases without neurological function assessment (including both NIHSS and GCS scores) in clinical examination and 1397 cases with missing discharge status. The final analytic cohort consisted of 750,594 stroke patients (Fig. 1). During the study period, 1476 hospitals in China were registered as stroke centers. The average number of participants per PSC was found to be 427, whereas the average number of participants per CSC was determined to be 909. The detailed lists of CSCs and PSCs can be obtained from the Chinese Stroke Association websites (www.chinastroke.net/).

Performance metrics and in-hospital outcomes

A total of 21 individual guideline-recommended performance measures for in-hospital stroke care were prespecified or updated by the Steering Committee of CSCA based on the national standards, guideline recommendations, and the GWTG-Stroke criteria.[8,13] Of those, 11 were prespecified for AIS patients, including six acute performance measures and five performance measures at discharge: (1) intravenous recombinant tissue plasminogen activator (IV rt-PA) within 4.5 h, (2) endovascular treatment (EVT) within 6 h, (3) early antithrombotics, (4) deep vein thrombosis (DVT) prophylaxis, (5) dysphagia screening, (6) rehabilitation assessment, (7) antithrombotic medication at discharge, (8) anticoagulation for atrial fibrillation (AF) at discharge, (9) antihypertensive medicines for patients with hypertension at discharge, (10) statin therapy for low-density lipoprotein ≥100 mg/dL at discharge, and (11) hypoglycemic medication for diabetes at discharge.

Five performance measures were prespecified for ICH or SAH patients: (1) neurosurgical procedures of ICH or SAH, (2) DVT prophylaxis, (3) dysphagia screening, (4) rehabilitation assessment, (5) antihypertensive medicines for patients with hypertension at discharge. Neurosurgery of ICH included hematoma removal, percutaneous drainage of the hematoma, and decompressive craniectomy. Neurosurgery of SAH included aneurysm clipping, aneurysm embolization, and cerebrospinal fluid shunt. The specific definitions

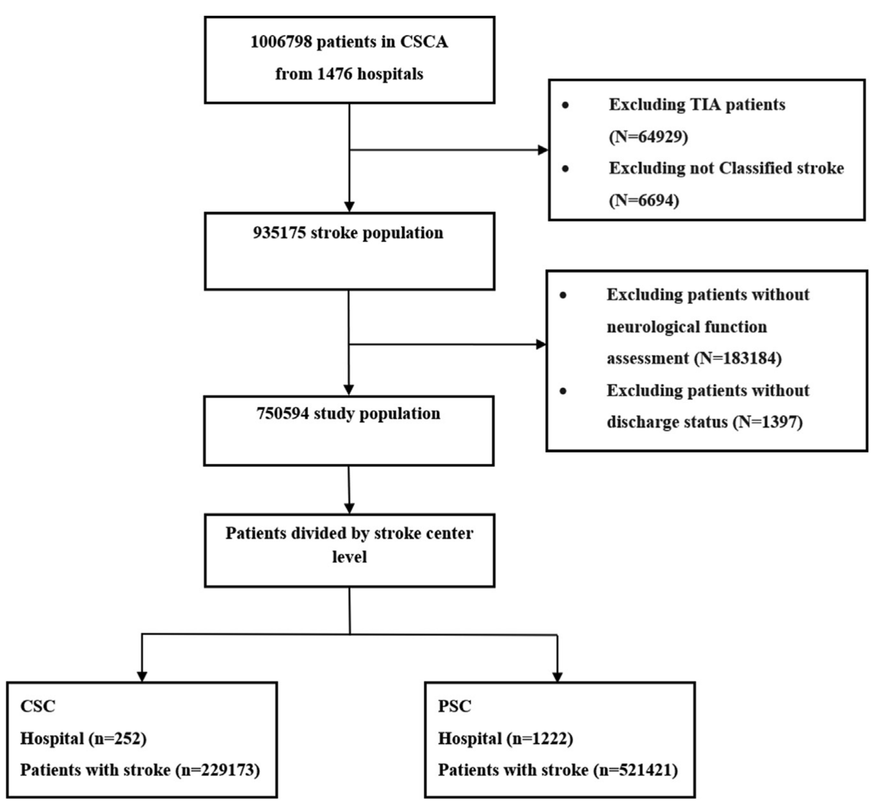


Fig. 1: Flow chart of hospitals and patients classified by stroke center accreditation.

of these performance measures are presented in Supplement Table S1.

In addition, two summary measures were used to summarize the overall conformity with above achievement measures. An all-or-none binary variable represented the proportion of patients who received all performance measures for which they were eligible. Additionally, the composite measure of adherence to evidence-based stroke interventions, ranging from 0 (nonadherence) to 1 (perfect adherence), was defined as the ratio of the number of performance measures actually executed to the total number of eligible performance measures for a patient.[14]

The in-hospital outcomes included in-hospital mortality, discharge against medical advice (DAMA), in-hospital stroke recurrence, direct discharge to home, and length of hospital stay.

Statistical analyses

Continuous variables were expressed as means with standard deviation (SD) or medians with interquartile range (IQR), whereas categorical variables were expressed in terms of frequencies and percentages. Due to the large sample size, comparisons between groups using conventional statistical methods such as the Pearson χ^2 test, independent t test, or Wilcoxon rank sum tests would have been susceptible to false-positive findings. As a result, the absolute standardized difference (ASD) was utilized to compare patients' characteristics, in-hospital treatments, and in-hospital outcomes. Based on prior work, ASD greater than 10% was considered clinically significant.[15]

Multivariable regression models using generalised estimating equations (GEE) to account for clustering by hospitals were used to model the differences in adherence to performance measures or in-hospital outcomes between PSCs and CSCs. Multivariable models with different adjustment levels were also used. Model 1 was an unadjusted logistic regression model, whereas model 2 included age, sex, current smoking status, NIHSS or GCS scores, medical history, hospital grade, and regional distribution. Unadjusted analyses included all available data of eligible participants. The adjusted analyses excluded missing values of GSC or NIHSS score. All variables included in the models satisfied the criteria of Pearson correlation coefficient of less than 0.8 and a variance inflation factor below 10.

The neurological function score (NIHSS score and GCS score) is a common index for clinical evaluation of the severity of stroke. However, it was not a routine clinical practice to measure NIHSS scores or GCS scores.[16] Thus, not all patients had their scores measured. Considering the possible effects of the varying degrees of stroke severity on clinical decisions and clinical outcomes, we excluded the patients without neurological function assessment (including both NIHSS and GCS scores) in clinical practice process during this design phase. To assess selection bias, we compared baseline characteristics of the included and excluded individuals (Supplement Table S3). Again, we assessed the difference in the adherence to the performance measures or in-hospital outcomes between the two kinds of centers in excluded cases. Results of these analyses are presented in Supplementary Materials (Supplement Tables S4–S6).

Despite the fact that neurological assessment was conducted on all participants, a notable proportion of patients with ICH (32.3%) and SAH (19.6%) were solely evaluated using the NIHSS without the GCS scores. Given the relatively high number of missing values for the GSC score, sensitivity analyses were conducted with median-imputed GCS scores to ascertain whether the findings were different from the results ignoring those with missing GCS scores (Supplement Table S7). Results of these analyses are presented in Supplementary Materials.

The data were analyzed overall and in regard to cerebrovascular event types: AIS, ICH, and SAH. All P-values were two-tailed, and $P < 0.05$ was considered statistically significant. All statistical analyses were performed by using software SAS, version 9.4 (SAS Institute Inc.).

Role of funding source

The funders had no role in the study design, data collection, data analysis, interpretation or writing of the manuscript.

Results

Hospital and patient characteristics

Of 1,006,798 patients recruited to the CSCA, 750,594 enrolled across 1474 hospitals were eligible for inclusion in our study. Of these enrolled cases, 678,330 (90.4%) patients had AIS, 64,373 (8.6%) had ICH, and 7891 (1.1%) had SAH. The patients' baseline characteristics are presented in Table 1. Overall, the characteristics of stroke patients differed little between CSCs and PSCs. For AIS, lower rates of previous stroke or TIA were observed in patients from CSCs (29.0% vs. 33.9%, ASD = 10.6%). ICH patients at CSCs were younger than those at PSCs (mean 61.5 vs. 63.5, ASD = 15.8%) and had more minor stroke represented by higher GCS scores (median 14 vs. 13, ASD = 11.2%). SAH patients in CSCs were also slightly but significantly younger (mean 58.7 vs. 61.1, ASD = 18.8%). In addition, the proportion of prior hypertension were less in SAH patients at CSCs than those at PSCs (46.3% vs. 51.7%, ASD = 10.8%).

The hospital characteristics are specified in Supplement Table S2. As stated earlier, of total 1474 hospitals, 252 (17.1%) were CSCs, while 1222 were PSCs (82.9%). Most CSCs were tertiary hospitals, and CSCs were more distributed in eastern China and less distributed in central China.

Variables	Overall (n = 750,594)	CSC (n = 229,173)	PSC (n = 521,421)	ASD (%)
Stroke				
Age in years, Mean ± SD	65.8 ± 12.2	65.0 ± 12.6	66.1 ± 11.9	8.9
Male, n (%)	469,308 (62.5)	147,577 (64.4)	321,731 (61.7)	5.6
Current smoking, n (%)	182,126 (24.3)	60,463 (26.4)	121,663 (23.3)	7.2
NIHSS, Median (IQR)	3 (2–6)	3 (2–7)	3 (2–6)	3.4
N miss (%)	29,464 (3.9)	11,769 (5.1)	17,695 (3.4)	
GCS, Median (IQR)[a]	14 (8–15)	14 (9–15)	13 (8–15)	10.9
N miss (%)	22,340 (30.9)	5469 (24.0)	16,871 (34.1)	
Medical history, n (%)				
Atrial fibrillation/flutter	38,603 (5.1)	13,520 (5.9)	25,083 (4.8)	4.9
Prior stroke/TIA	239,515 (31.9)	65,659 (28.7)	173,856 (33.3)	10.0
Carotid stenosis	9084 (1.2)	2879 (1.3)	6205 (1.2)	0.9
Prior CHD/MI	61,224 (8.2)	18,612 (8.1)	42,612 (8.2)	0.4
Hypertension	489,762 (65.2)	147,709 (64.5)	342,053 (65.6)	2.3
Diabetes mellitus	153,071 (20.4)	50,751 (22.1)	102,320 (19.6)	6.2
Dyslipidemia	54,590 (7.3)	16,844 (7.3)	37,746 (7.2)	0.4
PVD	12,386 (1.7)	3753 (1.6)	8633 (1.7)	0.8
AIS (n = 678,330)				
Age in years, Mean ± SD	66.1 ± 12.0	65.5 ± 12.5	66.4 ± 11.8	7.8
Male, n (%)	425,837 (62.8)	133,431 (64.6)	292,406 (62.0)	5.4
Current smoking, n (%)	168,043 (24.8)	55,906 (27.1)	112,137 (23.8)	7.6
NIHSS, Median (IQR)	3 (2–6)	3 (2–6)	3 (2–6)	4.7
N miss (%)	11,194 (1.7)	4374 (2.1)	6820 (1.4)	
Medical history, n (%)				
Atrial fibrillation/flutter	37,519 (5.5)	13,150 (6.4)	24,369 (5.2)	5.1
Prior stroke/TIA	219,704 (32.4)	59,944 (29.0)	159,760 (33.9)	10.6
Carotid stenosis	8831 (1.3)	2796 (1.4)	6035 (1.3)	0.9
Prior CHD or MI	57,390 (8.5)	17,518 (8.5)	39,872 (8.4)	0.4
Hypertension	439,592 (64.8)	132,344 (64.1)	307,248 (65.1)	2.1
Diabetes mellitus	146,386 (21.6)	48,488 (23.5)	97,898 (20.7)	6.8
Dyslipidemia	51,640 (7.6)	15,911 (7.7)	35,729 (7.6)	0.4
PVD	11,728 (1.7)	3577 (1.7)	8151 (1.7)	0.0
ICH (n = 64,373)				
Age in years, Mean ± SD	62.9 ± 12.8	61.5 ± 13.4	63.5 ± 12.5	15.8
Male, n (%)	40,259 (62.5)	12,870 (65.2)	27,389 (61.3)	8.1
Current smoking, n (%)	12,925 (20.1)	4096 (20.8)	8829 (19.8)	2.5
GCS, Median (IQR)	13 (8–15)	14 (9–15)	13 (8–15)	11.2
N miss (%)	20,794 (32.3)	4978 (25.2)	15,816 (35.4)	
Medical history, n (%)				
Atrial fibrillation/flutter	1007 (1.6)	335 (1.7)	672 (1.5)	1.6
Prior stroke/TIA	18,171 (28.2)	5141 (26.1)	13,030 (29.2)	6.9
Carotid stenosis	226 (0.4)	73 (0.4)	153 (0.3)	1.7
Prior CHD/MI	3475 (5.4)	983 (5.0)	2492 (5.6)	2.7
Hypertension	46,253 (71.9)	13,967 (70.8)	32,286 (72.3)	3.3
Diabetes mellitus	6143 (9.5)	2049 (10.4)	4094 (9.2)	4.0
Dyslipidemia	2713 (4.2)	844 (4.3)	1869 (4.2)	0.5
PVD	598 (0.9)	154 (0.8)	444 (1.0)	2.1
SAH (n = 7891)				
Age in years, Mean ± SD	60.1 ± 12.8	58.7 ± 12.8	61.1 ± 12.8	18.8
Male, n (%)	3212 (40.7)	1276 (42.3)	1936 (39.7)	5.3
Current smoking, n (%)	1158 (14.7)	461 (15.3)	697 (14.3)	2.8
GCS, Median (IQR)	15 (10–15)	15 (10–15)	15 (9–15)	5.6
N miss (%)	1546 (19.6)	491 (16.3)	1055 (21.6)	

(Table 1 continues on next page)

Variables	Overall (n = 750,594)	CSC (n = 229,173)	PSC (n = 521,421)	ASD (%)
(Continued from previous page)				
Medical history, n (%)				
Atrial fibrillation/flutter	77 (1.0)	35 (1.2)	42 (0.9)	2.9
Prior stroke/TIA	1640 (20.8)	574 (19.0)	1066 (21.9)	7.2
Carotid stenosis	27 (0.3)	10 (0.3)	17 (0.3)	0.0
Prior CHD or MI	359 (4.5)	111 (3.7)	248 (5.1)	6.8
Hypertension	3917 (49.6)	1398 (46.3)	2519 (51.7)	10.8
Diabetes mellitus	542 (6.9)	214 (7.1)	328 (6.7)	1.6
Dyslipidemia	237 (3.0)	89 (2.9)	148 (3.0)	0.6
PVD	60 (0.8)	22 (0.7)	38 (0.8)	1.2

Abbreviations: CSC, comprehensive stroke center; PSC, primary stroke center; ASD, absolute standardized differences; SD, standard deviation; NIHSS, National Institutes of Health Stroke Scale; IQR, inter quartile range; GCS, Glasgow coma scale; TIA, transient ischemic attack; CHD, cardiovascular disease; MI, myocardial infarction; PVD, peripheral vascular disease; AIS, acute ischemic stroke; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage. [a]The GCS score is calculated based on patients with ICH and SAH.

Table 1: **Baseline characteristics of the Chinese Stroke Center Alliance population by stroke center level division.**

Health quality measures

The adherence to performance measures is summarized in Table 2. Overall, CSCs slightly outperformed PSCs in all-or-none measure (0.6 vs. 0.5, ASD = 1.4%) in acute stroke patients but no significant difference were observed.

Of total six acute performance measures of AIS, CSCs had higher IV rt-PA rates than PSCs (32.1% vs. 25.3%, ASD = 15.1%). The adherence rates in CSCs for the remaining five acute performance measures were also numerically higher than those of PSCs; however, no significant differences were observed. Additionally, CSCs and PSCs had similar conformity to the adherence to guideline-recommended stroke interventions in ICH patients except that CSCs had a higher rate of neurosurgical procedures (14.4% vs. 10.6%, ASD = 11.3%) and a lower rate of DVT prophylaxis (23.6% vs. 28.0%, ASD = 10.2%) in comparison to PSCs. Compared with PSCs, for SAH, patients in CSCs were more likely to receive neurosurgical procedures (51.0% vs. 33.9%, ASD = 35.3%) and rehabilitation assessment (63.5% vs. 57.7%, ASD = 12.0%) but less likely to receive dysphagia screening (64.6% vs. 70.0%, ASD = 11.6%). The two performance measures DVT prophylaxis and antihypertensive medicines at discharge were numerically higher in PSCs, but this did not reach significance.

Next, multivariate logistic regression using GEE was used to analyze the association between performance and the certification status of stroke centers (CSC vs. PSC). Detailed results including the unadjusted OR and adjusted odds ratios (aOR) are depicted in Fig. 2. The all-or-none measure demonstrated slightly better performance in CSCs, but did not reach statistical significance (aOR = 1.29 [95% CI: 0.75–2.22; P = 0.3530). For AIS, CSCs outperformed PSCs in the areas of IV rt-PA administration within 4.5 h and rehabilitation assessment (aOR = 1.31 [95% CI: 1.07–1.60], P = 0.0080 and aOR = 1.19 [95% CI: 1.01–1.40], P = 0.0338, respectively). In addition, AIS patients exhibited a higher probability of being prescribed hypoglycemic medication and statin therapy upon discharge from CSCs in comparison to those discharged from PSCs (aOR = 1.26 [95% CI: 1.00–1.59], P = 0.0477 and aOR = 1.28 [95% CI: 1.04–1.59], P = 0.0214, respectively). More neurosurgery was administered to patients with ICH and SAH in CSCs than in PSCs, while the difference was not statistically significant (aOR = 1.45 [95% CI: 0.92–2.29], P = 0.1071 and aOR = 1.23 [95% CI: 0.85–1.78], P = 0.2774, respectively). Additionally, the adherence rate of CSCs to dysphagia screening in patients with SAH was significantly lower than that of PSCs (aOR = 0.63 [95% CI: 0.41–0.98], P = 0.0421). The results of the sensitivity analyses, which did not significantly change the results, are provided in the Supplementary Material.

In-hospital outcomes

As indicated in Table 3, patients with stroke in CSCs exhibited a tendency towards higher in-hospital mortality rates (0.9% vs. 0.6%, ASD = 3.5%) and lower rates of DAMA and in-hospital stroke recurrence (4.6% vs. 5.2%, ASD = 2.8% and 6.1% vs. 6.8%, ASD = 2.8%) when compared to those treated in PSCs, but these differences were not significant. In regard to the subtypes of stroke, patients with AIS or ICH in CSCs had a slightly higher in-hospital mortality rate (AIS: 0.6% vs. 0.4%, ASD = 2.8%; ICH: 3.1% vs. 2.3%, ASD = 4.9%) and a somewhat lower DAMA rate (AIS: 4.1% vs. 4.5%, ASD = 2.0%; ICH: 9.6% vs. 10.9%, ASD = 4.3%) than PSCs; however, no significant differences were noted. SAH patients in CSCs had a significantly lower DAMA rate (10.0% vs. 15.7%, ASD = 17.1%) than PSCs. Moreover, ICH and SAH patients in CSCs spent significantly longer days hospitalized compared with those in PSCs (median 15 [IQR, 10–22] vs. 14 [IQR, 9–20], ASD = 10.2%; median 15 [IQR, 8–22] vs. 13 [IQR, 4–20], ASD = 21.9%, respectively). Compared with stroke patients in CSCs, those in PSCs had a higher rate of discharge directly home (90.6% vs. 87.4%, ASD = 10.2%).

Characters	Overall	CSC	PSC	ASD (%)
	Adherence rate, % (N1/N2)[a]	Adherence rate, % (N1/N2)[a]	Adherence rate, % (N1/N2)[a]	
Performance measures of AIS				
Acute performance measures				
IV rt-PA <4.5 h	27.3 (42,217/154,641)	32.1 (14,478/45,089)	25.3 (27,739/109,552)	15.1
EVT <6 h	0.3 (2287/667,365)	0.6 (1136/203,114)	0.2 (1151/464,251)	4.9
Early antithrombotics	88.1 (581,966/660,500)	88.4 (177,632/200,962)	88.0 (404,334/459,538)	1.3
DVT prophylaxis	18.9 (38,808/205,506)	20.5 (14,183/69,249)	18.1 (24,625/136,257)	6.1
Dysphagia screening	83.5 (561,348/672,315)	85.5 (174,890/204,580)	82.6 (386,458/467,735)	7.8
Rehabilitation assessment	75.9 (514,876/678,098)	78.7 (162,369/206,355)	74.7 (352,507/471,743)	9.4
Performance measures at discharge				
Antithrombotics	90.2 (592,617/656,971)	90.1 (179,394/199,153)	90.3 (413,223/457,818)	0.6
Anticoagulation for AF	49.9 (21,356/42,758)	54.6 (8508/15,591)	47.3 (12,848/27,167)	14.6
Antihypertensive medicines for hypertension	79.9 (331,966/415,612)	80.5 (102,799/127,653)	79.6 (229,167/287,959)	2.4
Statin therapy for LDL ≥100 mg/dL	91.5 (612,857/669,674)	91.4 (185,824/203,331)	91.6 (427,033/466,343)	0.7
Hypoglycemic medication for diabetes	87.5 (149,139/170,493)	87.4 (49,846/57,046)	87.5 (99,293/113,447)	0.4
Performance measures of ICH				
Neurosurgical procedures of ICH	11.8 (7233/61,471)	14.4 (2658/18,491)	10.6 (4575/42,980)	11.3
DVT prophylaxis	26.7 (10,279/38,512)	23.6 (2745/11,637)	28.0 (7534/26,875)	10.2
Dysphagia screening	76.1 (48,937/64,267)	75.3 (14,816/19,688)	76.5 (34,121/44,579)	3.0
Rehabilitation assessment	74.5 (47,950/64,353)	76.7 (15,122/19,716)	73.5 (32,828/44,637)	7.3
Antihypertensive medicines for hypertension at discharge	89.3 (46,772/52,391)	90.1 (14,168/15,728)	88.9 (32,604/36,663)	3.8
Performance measures of SAH				
Neurosurgical procedures of SAH	40.4 (3057/7560)	51.0 (1478/2896)	33.9 (1579/4664)	35.3
DVT prophylaxis	28.9 (1291/4467)	26.4 (451/1706)	30.4 (840/2761)	8.8
Dysphagia screening	67.9 (5350/7874)	64.6 (1945/3011)	70.0 (3405/4863)	11.6
Rehabilitation assessment	59.9 (4726/7887)	63.5 (1915/3014)	57.7 (2811/4873)	12.0
Antihypertensive medicines for hypertension at discharge	80.9 (3420/4228)	80.0 (1178/1472)	81.3 (2242/2756)	3.4
Composite measure, mean (SD)	0.8 ± 0.2	0.8 ± 0.2	0.8 ± 0.2	5.5
All-or-none measure	0.5 (3794/750,594)	0.6 (1317/229,173)	0.5 (2477/521,421)	1.4

Abbreviations: CSC, comprehensive stroke center; PSC, primary stroke center; ASD, absolute standardized differences; AIS, acute ischemic stroke; IV rt-PA, intravenous thrombolysis therapy with alteplase; EVT, endovascular treatment; DVT, deep vein thrombosis; AF, atrial fibrillation; LDL, low-density lipoprotein; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage; SD, standard deviation. [a]N1 indicates the number of eligible patients receiving the performance measures; N2 represents the number of patients eligible for the performance measures.

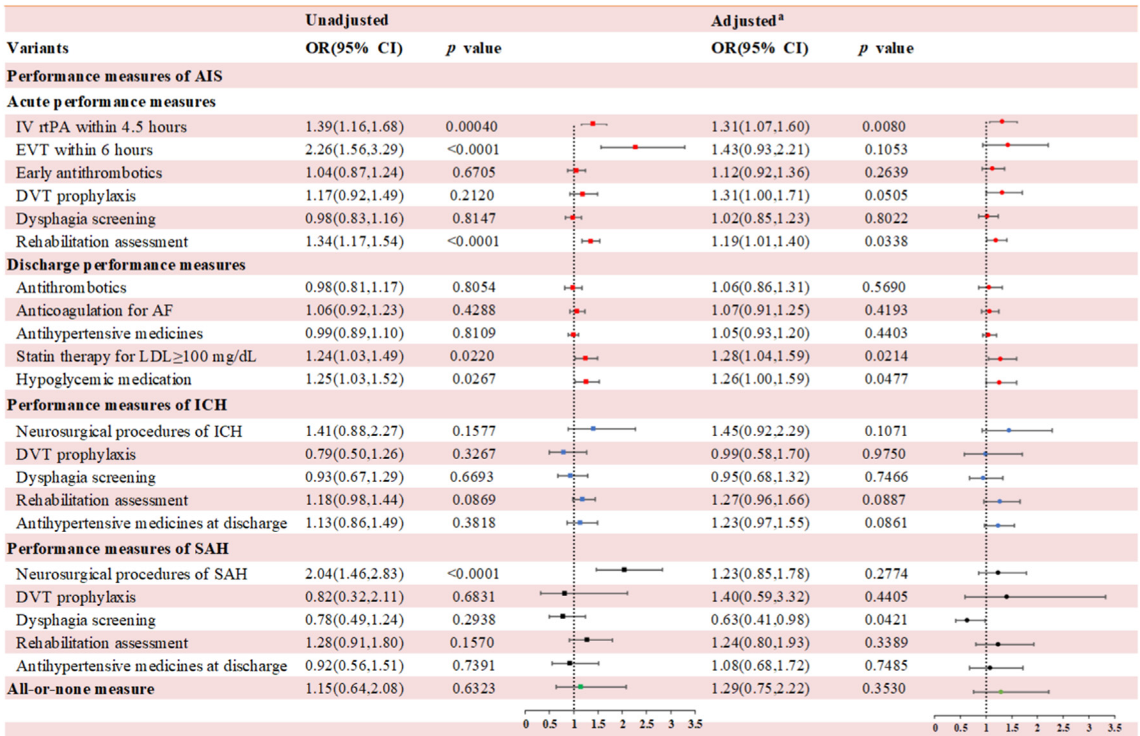
Table 2: **Individual and summary performance measures by stroke center level division.**

Multivariate logistic regression using GEE was also used to analyze the association between in-hospital outcomes and the certification status of stroke centers (CSC vs. PSC). Detailed results are depicted in Fig. 3. Interestingly, CSCs had higher in-hospital mortality rate than PSCs (aOR = 1.33 [95% CI: 1.01–1.73], P = 0.0398). Patients with stroke in CSCs also had a significantly lower probability of being discharged directly to home than those in PSCs (aOR = 0.74 [95% CI: 0.61–0.88], P = 0.00080). No significant differences in in-hospital recurrence were observed between the two center types. Sensitivity analyses are provided in the Supplementary Material, which did not change results above significantly.

Discussion

To the best of our knowledge, this is the first study to examine disparities in stroke care quality and in-hospital outcomes for PSCs and CSCs in China. The healthcare performance of CSCs and PSCs were comparable for many components of stroke care-performance measures in patients with acute stroke. However, disparities between the two types of centers were observed in the administration of IV rt-PA within 4.5 h, assessment of rehabilitation for AIS, and provision of hypoglycaemic medication and statin therapy upon discharge for AIS.

For AIS patients, CSCs had a higher rate of intravenous thrombolysis (within 4.5 h) than PSCs, which are consistent with a prior observational study.[17] This may be because CSCs have more medical resources such as trained doctors and surgical equipment. Stroke care quality largely depends on timely administration of intravenous rt-PA and improved EVT treatment rates.[18,19] It was also worth noting that the rate of intravenous thrombolysis (within 4.5 h) in mainland China was 43.9% lower than that of the same period in the United States (27.3% vs. 71.2%).[20] Likewise, EVT rates reported in our study were also far lower than those in



Variants	Unadjusted OR(95% CI)	p value	Adjusted[a] OR(95% CI)	p value
Performance measures of AIS				
Acute performance measures				
IV rtPA within 4.5 hours	1.39(1.16,1.68)	0.00040	1.31(1.07,1.60)	0.0080
EVT within 6 hours	2.26(1.56,3.29)	<0.0001	1.43(0.93,2.21)	0.1053
Early antithrombotics	1.04(0.87,1.24)	0.6705	1.12(0.92,1.36)	0.2639
DVT prophylaxis	1.17(0.92,1.49)	0.2120	1.31(1.00,1.71)	0.0505
Dysphagia screening	0.98(0.83,1.16)	0.8147	1.02(0.85,1.23)	0.8022
Rehabilitation assessment	1.34(1.17,1.54)	<0.0001	1.19(1.01,1.40)	0.0338
Discharge performance measures				
Antithrombotics	0.98(0.81,1.17)	0.8054	1.06(0.86,1.31)	0.5690
Anticoagulation for AF	1.06(0.92,1.23)	0.4288	1.07(0.91,1.25)	0.4193
Antihypertensive medicines	0.99(0.89,1.10)	0.8109	1.05(0.93,1.20)	0.4403
Statin therapy for LDL≥100 mg/dL	1.24(1.03,1.49)	0.0220	1.28(1.04,1.59)	0.0214
Hypoglycemic medication	1.25(1.03,1.52)	0.0267	1.26(1.00,1.59)	0.0477
Performance measures of ICH				
Neurosurgical procedures of ICH	1.41(0.88,2.27)	0.1577	1.45(0.92,2.29)	0.1071
DVT prophylaxis	0.79(0.50,1.26)	0.3267	0.99(0.58,1.70)	0.9750
Dysphagia screening	0.93(0.67,1.29)	0.6693	0.95(0.68,1.32)	0.7466
Rehabilitation assessment	1.18(0.98,1.44)	0.0869	1.27(0.96,1.66)	0.0887
Antihypertensive medicines at discharge	1.13(0.86,1.49)	0.3818	1.23(0.97,1.55)	0.0861
Performance measures of SAH				
Neurosurgical procedures of SAH	2.04(1.46,2.83)	<0.0001	1.23(0.85,1.78)	0.2774
DVT prophylaxis	0.82(0.32,2.11)	0.6831	1.40(0.59,3.32)	0.4405
Dysphagia screening	0.78(0.49,1.24)	0.2938	0.63(0.41,0.98)	0.0421
Rehabilitation assessment	1.28(0.91,1.80)	0.1570	1.24(0.80,1.93)	0.3389
Antihypertensive medicines at discharge	0.92(0.56,1.51)	0.7391	1.08(0.68,1.72)	0.7485
All-or-none measure	1.15(0.64,2.08)	0.6323	1.29(0.75,2.22)	0.3530

Fig. 2: Adjusted odds ratio for adherence to performance measures in CSCs compared to PSCs. [a]For all types of stroke or AIS: Adjusted for age, sex, smoking status, NIHSS score, medical history, hospital grade, region distribution. For ICH or SAH: Adjusted for age, sex, smoking status, GCS score, medical history, hospital grade, region distribution.

the United States.[17] This indicated that there was still a large gap compared with developed countries and that additional efforts are required to overcome this discrepancy.

Insufficient discharge medication after stroke could lead to insufficient secondary medical prevention. There is evidence that if patients are discharged from hospital on prevention medications that they will tend to continue using them over the longer term.[21] For most components of the stroke care-performance measures at discharge for patients with AIS, such as the administration of antihypertensive drugs, antiplatelet drugs, and anticoagulants for AF, the performance between the two center types was largely similar. However, a significant disparity was observed between PSCs and CSCs in terms of the administration of hypoglycemic drugs and statins upon discharge. We speculate that the level of awareness of the recommended guidelines and medical resource allocation might be the reasons for the significant differences between PSCs and CSCs. To reduce the differences between PSCs and CSCs, we suggest increasing the awareness on guideline-recommended treatments.

We further noted that CSCs preferred to develop neurosurgical procedures of ICH or SAH for eligible patients compared with PSCs (Table 2), which might be the real cause of longer hospital stay for ICH or SAH patients in CSCs. This was in accordance with what is recommended in guidelines. While the target population of stroke centers should be acute stroke patients, direct admission or transfer to a CSC is recommended for massive ischemic or hemorrhagic stroke, stroke of unknown etiology, stroke requiring special examination or multidisciplinary treatment. However, on the other hand, our data failed to support our impression that ICH patients in CSCs tended to have more severe neurological deficits as measured by the GCS score. This is at odds with the CSC target population proposed in the guidelines for the construction of stroke centers in China.

Prevalent data of stroke showed that the leading risk factor for stroke was hypertension (57.3% for AIS, 69.9% for ICH, and 44.1% for SAH).[22] Those who received antihypertensive drugs on discharge after a stroke tended to achieve better cardiovascular and all-cause survival.[23] Our study revealed that adherence to antihypertensive drug prescriptions at discharge was comparable between PSCs and CSCs. These findings suggest that PSCs and CSCs have the potential to provide similar levels of healthcare quality for stroke in terms of antihypertensive drug management at discharge.

Variants	Overall (n = 750,594)	CSC (n = 229,173)	PSC (n = 521,421)	ASD (%)
Stroke				
In-hospital mortality	4971 (0.7)	1991 (0.9)	2980 (0.6)	3.5
DAMA	37,535 (5.0)	10,643 (4.6)	26,892 (5.2)	2.8
In-hospital stroke recurrence	49,077 (6.5)	13,869 (6.1)	35,208 (6.8)	2.8
LOS, median (IQR)	11 (8–14)	11 (8–15)	11 (8–14)	9.4
N miss (%)	2690 (0.4)	935 (0.4)	1755 (0.3)	
Discharge home	672,650 (89.6)	200,305 (87.4)	472,345 (90.6)	10.2
AIS				
In-hospital mortality	3065 (0.5)	1270 (0.6)	1795 (0.4)	2.8
DAMA	29,689 (4.4)	8444 (4.1)	21,245 (4.5)	2.0
LOS, days, median (IQR)	11 (8–14)	11 (8–14)	11 (8–14)	9.1
N miss (%)	2233 (0.3)	768 (0.4)	1465 (0.3)	
Discharge home	614,939 (90.7)	182,873 (88.6)	432,066 (91.6)	10.1
ICH				
In-hospital mortality	1647 (2.6)	621 (3.1)	1026 (2.3)	4.9
DAMA	6781 (10.5)	1897 (9.6)	4884 (10.9)	4.3
LOS, days, median (IQR)	15 (10–21)	15 (10–22)	14 (9–20)	10.2
N miss (%)	414 (0.6)	150 (0.8)	264 (0.6)	
Discharge home	52,074 (80.9)	15,133 (76.7)	36,941 (82.7)	15.0
SAH				
In-hospital mortality	259 (3.3)	100 (3.3)	159 (3.3)	0.0
DAMA	1065 (13.5)	302 (10.0)	763 (15.7)	17.1
LOS, days, median (IQR)	14 (6–20)	15 (8–22)	13 (4–20)	21.9
N miss (%)	43 (0.5)	17 (0.6)	26 (0.5)	
Discharge home	5637 (71.4)	2299 (76.2)	3338 (68.5)	17.3

Abbreviations: CSC, comprehensive stroke center; PSC, primary stroke center; ASD, absolute standardized differences; DAMA, discharge against medical advice; LOS, length of stay; IQR, inter quartile range; AIS, acute ischemic stroke; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage. [a]Data are presented as number (percentage) unless otherwise indicated.

***Table 3:* In-hospital outcomes by stroke center level division.**[a]

Prevalent data of stroke also identified that the leading comorbidity was pneumonia or pulmonary infection for stroke (10.4% for IS, 34.6% for ICH, and 29.7% for SAH).[22] Pneumonia causes the highest attributable mortality of all medical complications following stroke. Most available data suggested post-stroke pneumonia is often due to aspiration and dysphagia.[24,25] Previous studies demonstrated that dysphagia screening performance was associated with a lower risk of pneumonia.[26,27] The findings of our study demonstrated that the rate of dysphagia screening among patients with SAH or ICH was higher in PSCs than those in CSCs. A likely explanation would be that mild stroke patients in CSCs (with lower GCS scores) were substantially less likely to have dysphagia screening, consistent with findings from previous studies. Joundi et al. have reported an increase in dysphagia screening omission with decreasing stroke severity.[28] Likewise, a previous study using the Get with the Guidelines–Stroke database reported the same results.[29] Follow-up studies are needed to test this hypothesis. Nonetheless, regardless of the severity of the stroke, dysphagia screening is essential for stroke patients.

Compared with previous reports, the proportion of stroke patients who received in-hospital rehabilitation increased significantly.[2] However, compared with developed western countries, there was still a large gap.[17] We observed that patients in CSCs had higher odds of getting rehabilitation for AIS than those in PSCs. A possible explanation for the differences is that most CSCs were tertiary hospitals, enjoying better medical resources. Data from China National Stroke Registry II (CNSR II) indicated that larger hospitals with a higher number of hospital beds were more likely to assess AIS patients for rehabilitation.[30] The current study also revealed that acute stroke patients receiving care in PSCs exhibited a greater probability of being discharged directly to home, as opposed to being discharged to in-patient rehabilitation facilities or alternative health facilities, than their counterparts receiving care in CSCs. While the present study did not provide information on patient prognosis postdischarge, prior research has demonstrated that patients discharged to in-patient rehabilitation facilities, despite presenting with more severe stroke markers, demonstrated fewer mobility problems and a decreased likelihood of hospital readmission during the 1st poststroke year than those

Variants		OR (95% CI)	*p* value
Stroke			
In-hospital mortality	Unadjusted	1.52 (1.16,2.00)	0.0022
	Adjusted	1.33 (1.01,1.73)	0.0398
In-hospital stroke recurrence	Unadjusted	0.89 (0.75,1.06)	0.1880
	Adjusted	1.01 (0.84,1.22)	0.8867
DAMA	Unadjusted	0.90 (0.73,1.10)	0.2949
	Adjusted	1.01 (0.79,1.29)	0.9636
Discharge home	Unadjusted	0.72 (0.62,0.84)	<0.0001
	Adjusted	0.74 (0.61,0.88)	0.00080
AIS			
In-hospital mortality	Unadjusted	1.62 (1.31,2.01)	<0.0001
	Adjusted	1.27 (1.00,1.63)	0.0533
DAMA	Unadjusted	0.90 (0.73,1.12)	0.3483
	Adjusted	0.99 (0.78,1.27)	0.9417
Discharge home	Unadjusted	0.72 (0.60,0.85)	<0.0001
	Adjusted	0.73 (0.61,0.88)	0.00090
ICH			
In-hospital mortality	Unadjusted	1.38 (0.85,2.24)	0.1897
	Adjusted	1.53 (0.91,2.57)	0.1105
DAMA	Unadjusted	0.87 (0.65,1.16)	0.3325
	Adjusted	1.17 (0.84,1.63)	0.3386
Discharge home	Unadjusted	0.69 (0.56,0.85)	0.00060
	Adjusted	0.69 (0.52,0.92)	0.0110
SAH			
In-hospital mortality	Unadjusted	1.02 (0.59,1.76)	0.9531
	Adjusted	1.21 (0.64,2.27)	0.5561
DAMA	Unadjusted	0.60 (0.43,0.83)	0.0023
	Adjusted [b]	0.85 (0.55,1.31)	0.4715
Discharge home	Unadjusted	1.47 (1.16,1.87)	0.0015
	Adjusted	1.33 (0.88,2.01)	0.1803

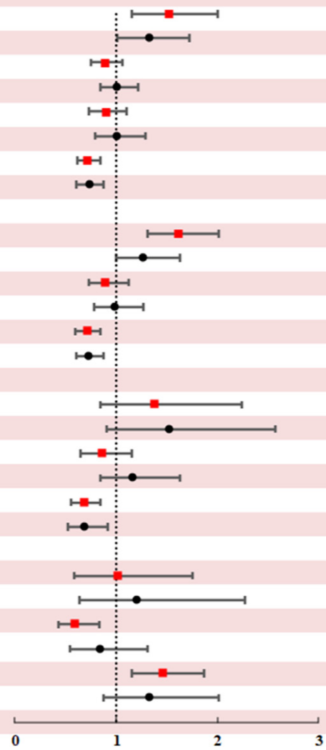


Fig. 3: Adjusted odds ratio for in-hospital outcomes in CSCs compared to PSCs. [a]For all types of stroke or AIS: Adjusted for age, sex, smoking status, NIHSS score, medical history, hospital grade, region distribution. For ICH or SAH: Adjusted for age, sex, smoking status, GCS score, medical history, hospital grade, region distribution. [b]Unadjusted for carotid stenosis due to a limited sample size.

who were directly discharged to their homes.[31] It is recommended that medical personnel in PSCs augment their attention towards rehabilitation treatment and strengthen their efforts in this area.

Interestingly, we observed that patients in CSCs had a higher in-hospital mortality due to stroke than those in PSCs. Furthermore, the mortality rate in our study was much lower than those reported in previous studies conducted in other countries.[13,17] As previous studies describe, the low mortality rate observed in our study is partly due to cultural differences and economic reasons.[7] In mainland China, many patients are discharged from hospitals against medical advice at the end stage of the disease.[32] Indeed, the rate of DAMA among patients with stroke in CSCs was found to be marginally lower than that in PSCs, with recorded rates of 4.6% and 5.2%, respectively. Potential discrepancies in patient discharged against medical advice during the terminal stage of the disease between the two center types may have caused bias in mortality. Therefore, using the composite outcomes of in-hospital mortality and DAMA instead of in-hospital mortality alone in future studies may better reflect the poor outcomes. Moreover, survivor bias could potentially contribute to the observed lower mortality rate, as critically ill patients who were unable to reach the hospital or died prior to admission were not included in the data. Future studies should clarify the pre-admission mortality rates at various stroke centers or hospitals.

In-hospital stroke recurrence may also lead to an extended hospitalisation period and an increased mortality rate during the hospital stay.[33,34] Nonetheless, the current investigation has demonstrated that the rates of in-hospital stroke recurrence were comparatively similar between CSC and PSC, with an ASD of 2.8 and an aOR of 1.01 (95% CI: 0.84–1.22; P = 0.8867). Consequently, it is plausible that stroke recurrence is not the primary factor contributing to the discrepancy in mortality between the two center types. Furthermore, the in-hospital stroke recurrence rate of 6.5% observed in our study is broadly consistent with previous relevant researches.[33,34] However, it is noteworthy that this percentage was significantly higher than the reported rate in developed countries, which stands at 0.8%.[35] Future research on the risk factors associated with stroke recurrence using data from the CSCA holds significant importance in mitigating the recurrence of stroke in hospitalised patients and bridging the gap between developing and developed nations.

Additionally, as mentioned above, the rate of DAMA in patients with stroke in CSCs was somewhat lower than that in PSCs. A plausible explanation for this difference is that CSCs are more likely to be teaching hospitals and can provide highly specialised tertiary care for referrals from other peripheral hospitals. Patients may fear the lack of better healthcare elsewhere.[36,37]

For the first time, our study quantified the disparities in stroke care quality for PSCs and CSCs in China. These results can be used to identify areas of stroke care that have room for improvement, leading to targeted interventions and improvements in care at PSCs and CSCs. Our research firmly supports the idea that balancing the distribution of medical staff, upgrading the carrying capacity of medical staff, and facilitating compliance or adherence to recommended treatment regimens are greatly warranted.

This study has a few limitations that need to be addressed. First, it was noted that hospital participation in the CSCA is voluntary. As a result, the current participating hospitals are larger centers with a myriad of resources, while smaller hospitals do not have access to such resources. However, the participating hospitals in this study covered 31 provinces, autonomous regions, and municipalities in mainland China, and the clinical and demographic characteristics in our study were similar to those of other large stroke studies. Hence, we believe that potential bias is therefore not of major concern to the study. Additionally, data concerning patient characteristics and guideline-recommended performance measures were self-reported by participating hospitals. However, prior quality audits of CSCA data revealed high degree of consistency with source documentation. Second, we excluded a large proportion of patients with missing data for neurological function scores. To fully understand the effect of the high missing rate, selection bias was studied in a comparison of baseline characteristics between the patients with neurological function score and those with missing NIHSS and GCS scores. The results suggested that they are comparable. The robustness of our primary analysis is also confirmed by the results of the sensitivity analysis with median-imputed GCS scores (Supplement Tables S3–S7). Third, previous studies have detected variances in adherence to performance measures for stroke care at both the regional and hospital levels.[7,38] Consequently, the regression analysis incorporated regional allocation and hospital classification. Additionally, age, sex, smoking habits, stroke severity (measured using NIHSS or GCS scores), and various medical histories are linked to stroke outcomes and may potentially influence in-hospital management. Therefore, these factors were considered potential confounders in the regression model. However, the lack of pertinent information limited our ability to adjust for other possible confounding factors, such as socioeconomic status and education level, which may impact in-hospital outcomes and management. Furthermore, another limitation arises from the lack of a multiple comparison adjustment for the P values derived from the logistic models, potentially leading to a misinterpretation of the findings. Finally, a major limitation of this study lies in its inability to provide post-discharge outcomes, which poses challenges for measuring long-term effects. Inpatient data in the CSCA lack follow-up information, and whether gaps would exist between CSCs and PSCs in post discharge follow-up remains to be ascertained.

Conclusions

In general, PSCs in China demonstrated comparable levels of care to CSCs across many quality measures, with the exception of thrombolysis, rehabilitation access, and medication at discharge for AIS, which require targeted enhancements. Additionally, in-hospital mortality rates were lower and direct discharge to home was greater in PSCs. The results might be instructive in improving the care quality in PSCs and CSCs in China. It is imperative to balance the distribution of medical care, upgrade the capacity of the medical staff, and facilitate compliance with recommended treatments.

Contributors

Dr XY and Dr ZXL had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Dr ZYL contributed to the conception and design of the study, methodology, writing-up of the original draft and revision of the manuscript. Dr XY contributed to the conception of the study, the project administration, resources, software, data curation, and validation of the underlying data. Dr JX contributed to the conception of the study, data interpretation, and critical revisions to the manuscript for important intellectual content. Dr HQG contributed to the analysis or interpretation of the data. Dr ZXL contributed to the project administration, resources, software, data curation, and validation of the underlying data. MPW, XJF, FY, and JF contributed to data acquisition and manuscript revision. All authors have reviewed and approved the manuscript.

Data sharing statement

The data that support the findings of this study are available from the CSCA project but are not publicly available. Our data will be shared by request from any qualified investigator for the purposes of replicating procedures and results.

Declaration of interests

All authors declare that they have no competing interests.

Acknowledgements

The authors thank all participating centers in the Chinese Stroke Center Alliance program for their hard work in data collection. This work was supported by the National Key Research and Development Projects of China (2022YFC3602400, 2022YFC3602401), the National Natural Science Foundation of China (82271369).

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2023.100863.

References

1 Zhou M, Wang H, Zeng X, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990-2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2019;394(10204): 1145–1158.

2 Wu S, Wu B, Liu M, et al. Stroke in China: advances and challenges in epidemiology, prevention, and management. *Lancet Neurol*. 2019;18(4):394–405.

3 Tu WJ, Zhao Z, Yin P, et al. Estimated burden of stroke in China in 2020. *JAMA Netw Open*. 2023;6(3):e231455.

4 Liu L, Wang D, Wong KS, Wang Y. Stroke and stroke care in China: huge burden, significant workload, and a national priority. *Stroke*. 2011;42(12):3651–3654.

5 Wang Y, Li Z, Zhao X, et al. Stroke care quality in China: substantial improvement, and a huge challenge and opportunity. *Int J Stroke*. 2017;12(3):229–235.

6 Lou M, Wang YL, Li ZX, et al. Guidelines for the construction of stroke centers in China. *Chin J Stroke*. 2015;10(6):499–507 (in Chinese).

7 Gu HQ, Yang X, Wang CJ, et al. Clinical characteristics, management, and in-hospital outcomes in patients with stroke or transient ischemic attack in China. *JAMA Netw Open*. 2021;4(8):e2120745.

8 Wang Y, Li Z, Wang Y, et al. Chinese Stroke Center Alliance: a national effort to improve healthcare quality for acute stroke and transient ischaemic attack: rationale, design and preliminary findings. *Stroke Vasc Neurol*. 2018;3(4):256–262.

9 Gu HQ, Rao ZZ, Yang X, et al. Use of emergency medical services and timely treatment among ischemic stroke. *Stroke*. 2019;50(4):1013–1016.

10 Association NboCM. Guidelines for the diagnosis and treatment of acute ischemic stroke in China 2014. *Chin J Neurol*. 2015;48: 246–257 (in Chinese).

11 Association NboCM. Chinese guidelines for diagnosis and treatment of acute intracerebral hemorrhage 2014. *Chin J Neurol*. 2015;48(6):435–444 (in Chinese).

12 Association NboCM. Chinese guidelines for diagnosis and treatment of subarachnoid hemorrhage 2015. *Chin J Neurol*. 2016;49(3):182–191 (in Chinese).

13 Fonarow GC, Reeves MJ, Smith EE, et al. Characteristics, performance measures, and in-hospital outcomes of the first one million stroke and transient ischemic attack admissions in get with the guidelines-stroke. *Circ Cardiovasc Qual Outcomes*. 2010;3(3):291–302.

14 Wang Y, Li Z, Zhao X, et al. Effect of a multifaceted quality improvement intervention on hospital personnel adherence to performance measures in patients with acute ischemic stroke in China: a randomized clinical trial. *JAMA*. 2018;320(3):245–254.

15 Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083–3107.

16 Smith EE, Shobha N, Dai D, et al. Risk score for in-hospital ischemic stroke mortality derived and validated within the get with the guidelines-stroke program. *Circulation*. 2010;122(15): 1496–1504.

17 Man S, Zhao X, Uchino K, et al. Comparison of acute ischemic stroke care and outcomes between comprehensive stroke centers and primary stroke centers in the United States. *Circ Cardiovasc Qual Outcomes*. 2018;11(6):e004512.

18 Saver JL, Fonarow GC, Smith EE, et al. Time to treatment with intravenous tissue plasminogen activator and outcome from acute ischemic stroke. *JAMA*. 2013;309(23):2480–2488.

19 Saver JL, Goyal M, van der Lugt A, et al. Time to treatment with endovascular thrombectomy and outcomes from ischemic stroke: a meta-analysis. *JAMA*. 2016;316(12):1279–1288.

20 Xian Y, Xu H, Smith EE, et al. Achieving more rapid door-to-needle times and improved outcomes in acute ischemic stroke in a nationwide quality improvement intervention. *Stroke*. 2022;53(4): 1328–1338.

21 Thrift AG, Kim J, Douzmanian V, et al. Discharge is a critical time to influence 10-year use of secondary prevention therapies for stroke. *Stroke*. 2014;45(2):539–544.

22 Wang YJ, Li ZX, Gu HQ, et al. China stroke statistics: an update on the 2019 report from the National Center for Healthcare Quality Management in Neurological Diseases, China National Clinical Research Center for Neurological Diseases, the Chinese Stroke Association, National Center for Chronic and Non-communicable disease Control and Prevention, Chinese Center for Disease Control and Prevention and Institute for Global Neuroscience and Stroke Collaborations. *Stroke Vasc Neurol*. 2022;7(5):415–450.

23 Andrew NE, Kim J, Thrift AG, et al. Prescription of antihypertensive medication at discharge influences survival following stroke. *Neurology*. 2018;90(9):e745–e753.

24 Martino R, Foley N, Bhogal S, Diamant N, Speechley M, Teasell R. Dysphagia after stroke: incidence, diagnosis, and pulmonary complications. *Stroke*. 2005;36(12):2756–2763.

25 Armstrong JR, Mosher BD. Aspiration pneumonia after stroke: intervention and prevention. *Neurohospitalist*. 2011;1(2):85–93.

26 Wu MR, Chen YT, Li ZX, et al. Dysphagia screening and pneumonia after subarachnoid hemorrhage: findings from the Chinese stroke center alliance. *CNS Neurosci Ther*. 2022;28(6): 913–921.

27 Ouyang M, Boaden E, Arima H, et al. Dysphagia screening and risks of pneumonia and adverse outcomes after acute stroke: an international multicenter study. *Int J Stroke*. 2020;15(2):206–215.

28 Joundi RA, Martino R, Saposnik G, Giannakeas V, Fang J, Kapral MK. Predictors and outcomes of dysphagia screening after acute ischemic stroke. *Stroke*. 2017;48(4):900–906.

29 Masrur S, Smith EE, Saver JL, et al. Dysphagia screening and hospital-acquired pneumonia in patients with acute ischemic stroke: findings from get with the guidelines–Stroke. *J Stroke Cerebrovasc Dis*. 2013;22(8):e301–e309.

30 Bettger JP, Li Z, Xian Y, et al. Assessment and provision of rehabilitation among patients hospitalized with acute ischemic stroke in China: findings from the China National Stroke Registry II. *Int J Stroke*. 2017;12(3):254–263.

31 Lynch EA, Labberton AS, Kim J, et al. Out of sight, out of mind: long-term outcomes for people discharged home, to inpatient rehabilitation and to residential aged care after stroke. *Disabil Rehabil*. 2022;44(12):2608–2614.

32 Li Z, Li Z, Zhou Q, Gu H, Wang Y, Zhao X. Effects of estimated glomerular filtration rate on clinical outcomes in patients with intracerebral hemorrhage. *BMC Neurol*. 2022;22(1):19.

33 Yu F, Liu X, Yang Q, Fu Y, Fan D. In-hospital recurrence in a Chinese large cohort with acute ischemic stroke. *Sci Rep*. 2019;9(1): 14945.

34 Zhang G, Yang Q, Zhang H, Huang X, Fu Y, Fan D. The clinical features of in-hospital recurrence in acute ischaemic stroke patients over time: a real-world observation at a single center. *Brain Sci*. 2022;12(2):123.

35 Erdur H, Scheitz JF, Ebinger M, et al. In-hospital stroke recurrence and stroke after transient ischemic attack: frequency and risk factors. *Stroke*. 2015;46(4):1031–1037.

36 Ibrahim SA, Kwoh CK, Krishnan E. Factors associated with patients who leave acute-care hospitals against medical advice. *Am J Public Health*. 2007;97(12):2204–2208.

37 Lin Z, Han H, Wu C, et al. Discharge against medical advice in acute ischemic stroke: the risk of 30-day unplanned readmission. *J Gen Intern Med*. 2021;36(5):1206–1213.

38 Zheng S, Zhang T, Gu HQ, et al. Adherence to stroke care performance measures in different regions in China, 2015-2019: evidence from the Chinese Stroke Center Alliance. *Neurology*. 2022;99(16):e1767–e1778.