Identifying Performance Outliers for Stroke Care Based on Composite Score of Process Indicators: an Observational Study in China

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BACKGROUND: Variability in the quality of stroke care is widespread. Identifying performance-based outlier hospitals based on quality indicators (QIs) has become a common practice.

OBJECTIVES: To develop a tool for identifying performance-based outlier hospitals based on risk-adjusted adherence rates of process indicators.

DESIGN: Hospitals were classified into five-level outliers based on the observed-to-expected ratio and *P* value. The composite quality score was derived by summation of the points for each indicator for each hospital, and associations between outlier status and outcomes were determined.

PARTICIPANTS: Patients diagnosed with acute ischemic stroke, January 1, 2011–May 31, 2017.

INTERVENTION: N/A

MAIN OUTCOME MEASURES: Independence at discharge (the modified Rankin Scale = 0–2).

KEY RESULTS: A total of 501,132 patients from 519 hospitals were identified. From 0.39 to 19.65% of hospitals were identified as high outliers according to various QIs. Composite quality scores ranged from –20 to 16. Providers that were high outliers based on QI2, QI8, QI9, and QI11 had higher independent rates. For composite quality score, each point increase corresponded to an 8% increase in the odds of independent rate.

CONCLUSION: Nationwide variation in the quality of acute stroke care exists at the hospital level. Variability in the quality of stroke care can be captured by our proposed quality score. Applying this quality score as a benchmarking tool could provide audit-level feedback to policymakers and hospitals to aid quality improvement.

KEY WORDS: stroke; quality of care; composite indicator; performance measures; outliers.

J Gen Intern Med 35(9):2621–8

DOI: 10.1007/s11606-020-05923-x

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Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11606-020-05923-x>) contains supplementary material, which is available to authorized users.

Received November 9, 2019

Accepted May 11, 2020

Published online May 27, 2020

BACKGROUND

Stroke is a global health problem, with 10.3 million new cases of stroke accounting for 113 million disability-adjusted life years (DALYs) per year.¹ Although stroke treatment has evolved, the quality of stroke care varies globally, and inequalities exist between medical facilities even within the same country.^{2, 3} Comparing health care providers and identifying outlier providers simultaneously based on various indicators of performance, such as the rate of occurrence of particular outcome or process-based measures, has become a common practice.^{4–6}

Outcomes-based quality indicators are by far the most common measures in quality performance comparisons and identification of hospital outliers.^{7, 8} Outlier hospitals can be identified simply according to relative rank based on expected mortality (after risk-adjusted) (e.g., top 10%, bottom 10%) or by identifying hospitals that are statistically significantly different from a given benchmark or standard (commonly the overall average mortality in the population being evaluated).⁷ Observed-to-expected (O/E) ratio is a representative method, which consider both the observed and expected rates, and combine the statistical significance to classify hospitals' performance.^{7, 9, 10} However, for outcomes measures, reliability is susceptible to small sample size and low incidence rates, and it can be challenging to obtain granular data allowing adequate risk adjustment that accurately reflects the quality of care a patient actually received.^{11, 12} The challenge of these quality improvement metrics after identifying outliers based on outcome is whether they can be modified by alterations in care processes and consequently improved upon. As a result, outcomes may be less actionable.

Process-based quality indicators are also important part in evaluation of quality of care. The standardization and integrity of clinical therapy has important impacts on patients' outcome. There is evidence that focusing on process measures such as increased adherence to evidence-based guidelines can improve stroke treatment and prognosis in Sweden.¹³ One recent study based on data from global health systems found that improvements in the quality of health services would have a greater overall effect on mortality than expansion of service coverage.¹⁴ In comparison, process-based indicators are

readily modifiable and can potentially offer providers definable targets for improvement.¹⁰ However, discriminating the quality of care using process indicators also involves a number of challenges. Treatment processes are influenced by many factors, including patient-level and provider-level characteristics. It is also necessary to adjust patient case mix for the process measures. Another major hurdle is that the multidisciplinary nature of treatment makes it difficult to use a single process indicator for evaluation. Combining individual indicators into a composite performance measure is a common strategy. There are many approaches to calculate the composite quality score, such as equal-weights, denominator-based weights, numerator-based weights, all-or-none scoring measure, and quality score cutoff measure.^{15, 16} Each method inevitably has some issues.

For acute stroke, previous measures based on outcomes indicator may not be able to well capture the hospital-level quality variation, when it is difficult to acquire the patients' long-term outcomes.^{17, 18} Additionally, some researchers suggested that process measure should also be risk-adjusted.^{19, 20} In this study, we sought to develop a tool for identifying performance-based outlier hospitals based on risk-adjusted adherence rates of stroke process indicators. It helps discover hospitals with higher or lower performance than the expected after case-mix adjustment. The composite performance comprehensively considered the outlier status of hospitals on each indicator, exploring the relationship between a composite quality score and outcomes. Such an analysis method could enable high-performing hospitals to maintain best practices and allow underperformers to understand how much benefit they would receive from quality improvement efforts, providing motivation to critically appraise their multidisciplinary care processes.

METHODS

Data Source and Study Population

We obtained data on patients with acute ischemic stroke from the Medical Care Quality Management and Control System for Specific Disease of China. The system is designed to collect and manage data on quality indicators (QIs) within the health care system. All registered hospitals submitted data by clinical teams via a web-based portal with real-time data validation. To minimize error caused by manual reporting, the information of the front page of inpatient medical records was collected automatically. Data used in the study were fully anonymized. Because the data were collected for administration of quality of care rather than research, ethical approval was not required under China research governance arrangements. The requirement for informed consent was waived as it was determined that this study does not meet the regulatory definition of human subject research.

Hospital-level data and patient-level data were combined according to hospital codes. A cohort of patients with acute

ischemic stroke diagnosed from January 1, 2011, to May 31, 2017, was identified by the International Classification of Diseases, 10th revision (ICD)-10 codes. The exclusion criteria are shown in Figure 1. Patients transferred to another hospital were first excluded, followed by hospitals with fewer than 20 admissions overall and missing information to identify denominators of selected QIs in the study. Finally, the analytical population comprised 501,132 patients who received inpatient treatment from 519 hospitals.

QIs and Outcomes

QIs for stroke care were established by the National Health Commission of the People's Republic of China in 2009, which organized a national multidisciplinary board included the clinical and hospital management experts. The establishing process of indicators was based on a systematic literature review, international and Chinese recommendations. Most of the quality indicators were developed and adapted from the USA. Because medication information after discharge was difficult to obtain, some indicators about drug treatment post-discharge were not included in the study. We used 13 process indicators in this analysis. The indicators are listed in Supplement Table 1.

The functional outcomes at discharge of stroke patients were assessed with the modified Rankin Scale (mRS) score at discharge.²¹ The mRS is a commonly used scale for measuring the degree of disability or dependence in the daily activities of people who have suffered a stroke or other causes of neurological disability. It has become the most widely used clinical outcome measure for stroke.^{7, 22} Patient outcome was classified as independence (mRS score 0–2) or disability/death (mRS score 3–6).^{23, 24} The primary outcome of this study was the independent rate, which was defined as the proportion of patients discharged with mRS score 0 to 2.

Variables

Patient-level covariates included year and age at diagnosis (≤ 55 , 55–65, 65–75, and > 75); primary payer status (socialized medicine, basic medical insurance, commercial medical insurance, and self-paying); pattern of admission (outpatient, emergency); National Institutes of Health Stroke Scale (NIHSS) score on arrival; and comorbidities identified by the ICD-10 codes including diabetes mellitus, myocardial infarction, pneumonia, coronary heart disease, renal failure, chronic obstructive pulmonary disease, arrhythmia, hematological diseases, cerebrovascular diseases, rheumatic valvular heart disease, and congestive heart failure. In China, the insurance reimbursement rates of socialized medicine, basic medical insurance, and commercial medical insurance are 85–95%, 50–65%, and 75%, respectively. We classified the stroke severity into four categories: no stroke symptoms (NIHSS = 0), minor stroke (NIHSS = 1–4), moderate to severe stroke (NIHSS = 16–20), and severe stroke (NIHSS = 21–42).²⁵ In our study, anemia was included in hematological diseases.

Figure 1 The flow chart of the selection of study participants. QI, quality indicator.

Cerebrovascular diseases included cerebral atherosclerosis, aneurysm, vascular malformation, and chronic cerebral circulation insufficiency. Hospital-level covariates included geographic region (east, midland, west), ownership (government owned, private owned), hospital-level (secondary, tertiary), university affiliated status, nurse-to-bed ratio (≤ 0.4 , $0.4-0.6$, $0.6-0.8$, ≥ 0.8), medical personnel-to-bed ratio (≤ 1.03 , $1.03-1.50$, $1.50-2.0$, ≥ 2.0), and annual outpatient volume.

Statistical Analysis

Patient and hospital baseline characteristics of the study population were described in counts and percentages. To assess performance on stroke care of the analytical population, adherence rate for each QI was presented as a proportion in which the sum of patients receiving care (numerator) was divided by the number of patients meeting the eligible definition (denominator). The hospital adherence rate of individual QIs was described in median and interquartile range.

For each indicator, the expected adherence rate was calculated from hierarchical logistic regression models fitted to the entire eligible patient population, adjusting relevant patient-level covariates and setting the hospital level as random intercepts. Based on observed-to-expected (O/E) ratios and its statistical significance, we classified outlier hospitals performing better than expected as superior outliers, and those performing worse than expected as poor outliers.⁹ The performance status of hospital follows the binomial distribution;^{10, 26} we used the exact binomial function to identify the significant O/E outliers:

$$P(m \text{ out of } n) = \frac{n!}{m!(n-m)!} (p^m)(1-p)^{n-m}$$

where n denotes the eligible patients for one indicator in a specific hospital, m denotes the actual patients adhering to one indicator in a specific hospital, and p denotes the model-based estimated adherence rate of one indicator for a specific hospital.^{10, 18} Next, the hospitals were classified into five-level outliers using the following classification: (1)

high outliers: $O/E > 1$ and $P < 0.05$; (2) at-risk high outlier: $O/E > 1$ and $0.05 < P < 0.1$; (3) non-outlier: $O/E < 1$ and $P > 0.1$ and $O/E > 1$ and $P > 0.1$; (4) at-risk low outlier: $O/E < 1$ and $0.05 < P < 0.1$; (5) low outliers: $O/E < 1$ and $P < 0.05$. $O/E > 1$ indicates that observed adherence of hospitals were higher than expected and $O/E < 1$ indicates that observed adherence of hospitals were lower than expected. The five-level outliers were marked as 2, 1, 0, -1, and -2 respectively. A test for trend of relationship between the outliers of hospital with and independent rate was conducted using the hierarchical logistic regression model with hospital outlier status as a continuous variable.

A composite quality measure that composite quality score (QS) was calculated encompassing hospital performance across the 13 indicators, for each indicator a hospital identified as one corresponding point, and the final QS was a summation of the points received across each indicator for an individual hospital. The association between a single indicator (high outlier vs low outlier), QS, and outcomes was investigated using a hierarchical logistic regression model. The correlation between QS and hospital characteristics was analyzed using the *Kruskal-Wallis H* test. The statistical analyses were performed with SAS software version 9.4 (SAS Institute, NC, USA) and a two-sided P value of less than 0.05 was considered to indicate statistical significance.

There also have been numerous discussions about whether process measures should be adjusted for case mix. While outcomes comparisons traditionally accounted for differences in the patient case mix, process measures typically do not.^{19, 20} Therefore, we also repeated the above analysis procedure, but did not adjust for case mix. We also calculated the QS by other two commonly used methods of numerator-based weights and “All-or-None,” respectively.^{15, 16} And we analyzed the relationships between different quality score and outcomes.

RESULTS

Characteristics of Patients and Hospitals

Table 1 shows the characteristics of patients and hospitals. The mean age of patients was 66.28 ± 12.38 , 88.16% of patients were covered by medical insurance, 46.27% were admitted to hospital after emergency, and 44.40% were minor stroke (NIHSS = 1–4). Diabetes mellitus, hematological disease, and cerebrovascular disease were the most common comorbidities. The mean length of stay was 12.93 ± 7.71 days. The mean health technician-to-bed ratio of all hospitals was 1.34 ± 0.40 , and the mean nurse-to-bed ratio was 0.70 ± 0.20 . More than half of the hospitals were in the eastern region, and almost all hospitals were tertiary and public. Meanwhile, 27.17% of patients were treated at university affiliated hospitals.

Table 1 Characteristics of Patients ($n = 501,132$) and Hospitals ($n = 519$)

Characteristic	N	Percentage (%)
Age*		
≤55	101,422	20.24
55–65	130,717	26.08
65–75	140,881	28.11
> 75	128,112	25.56
Medical insurance*		
Public medical insurance	19,272	3.85
Basic medical insurance	386,334	77.09
Commercial medical insurance	36,217	7.23
Self-paying	59,309	11.84
Way of admission*		
Outpatient admission	269,261	53.73
Emergency admission	231,871	46.27
Level of NIHSS score on arrival*		
No stroke symptoms	42,518	8.48
Minor stroke	222,496	44.40
Moderate stroke	216,694	43.24
Moderate to severe stroke	9787	1.95
Severe stroke	9637	1.92
Comorbidity*		
Diabetes mellitus	27,403	5.47
Myocardial infarction	2979	0.59
Pneumonia	5343	1.07
Coronary heart disease	11,529	2.30
Renal failure	1940	0.39
Chronic obstructive pulmonary disease	2875	0.57
Arrhythmia	6145	1.23
Hematological diseases	44,426	8.87
Cerebrovascular disease	27,127	5.41
Rheumatic valvular heart disease	2150	0.43
Congestive heart failure	8177	1.63
Medical personnel-to-bed ratio†		
≤1.03	105	20.23
1.03–1.50	259	49.90
1.50–2.0	125	24.08
> 2.0	30	5.78
Nurse-to-bed ratio†		
≤0.40	20	3.85
0.40–0.60	143	27.55
0.60–0.80	223	42.97
> 0.80	133	25.63
Region†		
East	266	51.25
Midland	99	19.08
West	154	29.67
Ownership†		
Private owned	19	3.66
Government owned	500	96.34
Hospital level†		
Secondary	19	3.66
Tertiary	500	96.34
University affiliated status†		
Non-affiliated hospital	378	72.83
Affiliated hospital	141	27.17

*Patient characteristics

†Hospital characteristics

Adherence Rate of QIs

The overall population eligible for each individual guideline indicator for acute ischemic stroke ranged from 3.49% for anti-coagulant therapy (Q17) to 79.69% for dysphagia screening (Q11), except for two full eligible indicators (Q12 and Q19). Antiplatelet therapy (aspirin or clopidogrel) within 48 h of admission (Q18), evaluation of vascular function within 1 week of hospitalization (Q13), and statins therapy (Q10) occupied the top three adherence rates (98.75%, 94.08%, and 92.06%, respectively). On the contrary, acute thrombolytic therapy of t-PA or urokinase (Q16) had the lowest rate, of only 22.88% (Table 2).

Table 2 Adherence Rates of Quality Indicators and Hospital Variation

Indicator	Eligible rate of patients (%)	Denominator	Numerator	Overall adherence rate (%)	Hospital variation median (IQR) (%)
Q11	25.80	129,292	74,883	57.92	59.88 (41.90–75.00)
Q12	100.00	501,132	207,601	41.43	50.00 (17.93–79.81)
Q13	44.20	221,518	163,200	73.67	78.50 (63.57–88.99)
Q14	45.12	226,096	117,150	51.81	53.80 (28.00–77.87)
Q15	44.24	221,679	114,495	51.65	49.41 (25.19–74.71)
Q16	25.79	129,228	29,569	22.88	22.45 (16.38–32.33)
Q17	3.49	17,488	10,367	59.28	60.00 (42.31–73.33)
Q18	59.02	295,765	292,069	98.75	98.58 (97.50–99.40)
Q19	100.00	501,132	290,809	58.03	73.05 (42.68–90.91)
Q110	37.38	187,309	172,446	92.06	94.59 (89.17–97.23)
Q111	79.69	399,371	188,044	47.09	58.69 (31.25–83.45)
Q112	12.09	60,598	51,103	84.33	85.42 (70.46–92.59)
Q113	54.05	270,841	254,813	94.08	93.80 (89.35–96.79)

QI quality indicator; IQR interquartile range

QS

For each QI, all hospitals were divided into five-level outliers according to observed-to-expected ratios and *P* value. Table 3 shows the number of hospitals in each classification. From 0.39% (Q112) to 19.65% (Q15) of hospitals were identified as high outliers according to different QIs, except for Q17 and Q18, which did not identify any high outliers. For each QI, the higher level of hospital outlier status was associated with a significantly higher independent rate (*P* for trend < 0.05), aside from the indicator Q18, Q110, and Q112. The QS ranged from –20 to 16. Distribution of QS was shown in Figure 2.

Relationship Between Performance and Outcome

The impact of quality variation on patient outcome was assessed using single indicators and composite QS (Fig. 3). After adjusting for patient and hospital characteristics, providers that were high outliers based on Q12, Q18, Q19, and Q111 exhibited better independence rates of treatment compared with low performance outliers, and odds ratios (ORs) were 2.660, 4.344, 4.114, and 3.345, respectively. However, no significant difference in the independent rate was found between high and low outliers in terms of the other nine process indicators. For composite QS,

each point increase predicted an 8% higher odds of independent rate (OR = 1.080, 95% CI = 1.057–1.105) (Table 4).

To better understand the possible structural elements driving quality variations, we evaluated associations between composite quality score and hospital characteristics (Supplement Figure 1). Hospitals with high QS had higher nurse-to-bed ratios and were more likely to be in eastern regions. However, these differences were not statistically significant.

Sensitive Analysis

The results without adjustment for case mix of the process measures were similar to the above analyses. The QS of hospital did not change much (see Supplement Figure 2). The adjusted OR of composite quality score from numerator-based weights and “All-or-None” were similar to the equal-weights method (see Supplement Table 2).

DISCUSSION

Maximizing the quality of care delivered is a promising target for government agencies and medical providers. Therefore, significant efforts have been made to establish hospital-level QIs guiding health policy decision-making, resource

Table 3 Number of 519 Hospitals Stratified by Outlier Classification

Indicator	Number of hospitals stratified by outlier classification					<i>P</i> for trend
	Low outliers	At-risk low outlier	Non-outlier	At-risk high outlier	High outliers	
Q11	71 (13.68%)	90 (17.34%)	216 (41.62%)	89 (17.15%)	53 (10.21%)	< 0.0001
Q12	131 (25.24%)	72 (13.87%)	130 (25.05%)	69 (13.29%)	117 (22.54%)	< 0.0001
Q13	116 (22.35%)	89 (17.15%)	178 (34.30%)	88 (16.96%)	48 (9.25%)	0.0032
Q14	91 (17.53%)	73 (14.07%)	176 (33.91%)	80 (15.41%)	99 (19.08%)	0.0004
Q15	84 (16.18%)	84 (16.18%)	172 (33.14%)	77 (14.84%)	102 (19.65%)	0.0007
Q16	60 (11.56%)	94 (18.11%)	207 (39.88%)	97 (18.69%)	61 (11.75%)	< 0.0001
Q17	2 (0.38%)	39 (7.51%)	455 (87.67%)	23 (4.43%)	0 (0.00%)	0.0269
Q18	4 (0.77%)	59 (11.37%)	450 (86.70%)	6 (1.16%)	0 (0.00%)	0.0693
Q19	168 (32.37%)	65 (12.52%)	120 (23.12%)	83 (15.99%)	83 (15.99%)	< 0.0001
Q110	39 (7.51%)	93 (17.92%)	330 (63.58%)	53 (10.21%)	4 (0.77%)	0.1640
Q111	146 (28.13%)	66 (12.72%)	134 (25.82%)	87 (16.76%)	86 (16.57%)	< 0.0001
Q112	12 (2.31%)	86 (16.57%)	401 (77.26%)	18 (3.47%)	2 (0.39%)	0.7316
Q113	44 (8.48%)	102 (19.65%)	274 (52.79%)	91 (17.53%)	8 (1.54%)	0.0046

QI quality indicator

Figure 2 Distribution of quality score (QS) among hospitals.

allocation, educational initiatives, and patient choice. Moreover, accurately identifying the degree of quality variations and the impact of this variation on patient outcomes according to validated QIs is an important issue. In the current study, we developed a risk-adjusted quality score according to process

indicators to benchmark the quality of acute stroke care at the hospital level. Utilizing this tool, we revealed wide variation in the quality of care that patients received, and demonstrated the positive consequences on important patient outcomes of reducing this variation.

Figure 3 Adjusted association between hospital outlier status (high outlier versus low performance outlier) and patient outcome according to single and composite quality indicators. *The ORs of QI7 and QI8 were calculated by at-risk high outlier vs low outlier because there was no hospital identified as high outlier based on these two indicators.

Table 4 Predictors of Independence Rate by Multivariable Analysis

Characteristic	OR	95% CL
Age* (ref = "> 75")		
≤ 55	1.141	1.117–1.166
55–65	1.106	1.085–1.129
65–75	1.112	1.091–1.134
Medical insurance* (ref = "self-paying")		
Public medical insurance	1.09	1.065–1.115
Basic medical insurance	1.058	1.022–1.095
Commercial medical insurance	0.705	0.675–0.737
Way of admission* (ref = "emergency admission")		
Outpatient admission	0.943	0.929–0.958
Level of NIHSS score on arrival* (ref = "0")		
1	0.822	0.761–0.888
2	0.824	0.774–0.877
3	0.902	0.848–0.96
4	0.948	0.872–1.03
Comorbidity*		
Diabetes mellitus	2.935	2.807–3.069
Myocardial infarction	1.549	1.349–1.779
Pneumonia	0.968	0.887–1.055
Coronary heart disease	2.111	1.968–2.263
Renal failure	0.907	0.78–1.054
Chronic obstructive pulmonary disease	1.644	1.433–1.886
Arrhythmia	1.326	1.22–1.442
Hematological diseases	3.461	3.321–3.607
Cerebrovascular disease	3.045	2.901–3.197
Rheumatic valvular heart disease	2.42	2.073–2.824
Congestive heart failure	1.517	1.37–1.681
Health technician-to-bed ratio† (ref = "≤ 1.03")		
1.03–1.50	1.48	0.971–2.256
1.50–2.0	1.614	0.865–3.011
> 2.0	0.943	0.415–2.143
Nurse-to-bed ratio† (ref = "≤ 0.40")		
0.40–0.60	0.745	0.385–1.445
0.60–0.80	0.632	0.3–1.328
> 0.80	0.626	0.261–1.501
Region† (ref = "west")		
East	0.812	0.611–1.078
Midland	0.683	0.484–0.963
Ownership† (ref = "private owned")		
Government owned	1.285	0.678–2.436
Hospital level† (ref = "secondary")		
Tertiary	0.825	0.627–1.086
University affiliated status† (ref = "non-affiliated hospital")		
Affiliated hospital	0.999	0.998–1.001
Composite quality score	1.080	1.057–1.105

*Patient characteristics

†Hospital characteristics

In the USA and other countries, there were many articles comparing hospital performance of stroke care based on process and outcome indicators.^{2, 8, 13, 15, 16} However, no related studies of identifying performance outliers for stroke care in Chinese population have been carried on thus far. Outcome-based indicators take a longer time to acquire, are more expensive to gather, and may have a very low incidence.¹¹ From the database used in the current study, we collected the mRS scores as in-hospital outcomes, in which patient who died in hospital (mRS = 6) accounted for only 0.56%. Comparing with prior research on quality of care for stroke based on outcomes measured using the Rankin Score,^{21–23} because of the low incidence rate of outcomes, it may be not adequate risk adjustment that accurately reflects the quality of care a patient actually received. In our study, 13 process indicators covering examination, functional assessment, and medication were examined to assess the quality of acute stroke care. This

approach was similar to that used in many previous studies, but with a wider range of indicators.^{27–30} Process indicators can be measured relatively early in the spectrum of care, giving providers a chance to understand their performance and adjust their internal processes to benefit patients entering these hospitals for treatment in future.¹⁰ Literatures indicate that it is more reasonable to use independence to evaluate the prognosis of patients as stroke patients have a high disability rate.^{7, 22} Thus, we used the independence (mRS = 0–2) as in-hospital outcomes and developed a further composite measure of acute stroke quality incorporating all indicators analyzed in this study to resolve the problem of poor consistency of the relationships between different process indicators and outcomes. Moreover, we verified that the QS values were associated with patient outcomes, consistent with the assumptions of the Donabedian model.

The current finding that better health outcomes could be achieved by improving performance in acute stroke care suggests that many undesired outcomes (i.e., dependence or died) could be avoided by implementing clinical practice guidelines and improving patients' adherence to treatment recommendations. This finding also confirmed the practicality and validity of the currently proposed quality score, identifying and improving performance of acute stroke care.

The current study involved several limitations that should be considered. First, although we used a nationwide population-based database, some confounding variables were likely missed. Therefore, these variables may not be included in the multilevel model. Second, we were unable to determine the contribution of better adherence to QIs on long-term outcomes because of the absence of follow-up data. Third, we measured outcome of stroke patients using independence at discharge (mRS = 0–2), but it can only partly explain the quality of stroke care. Fourth, equal-weights is the most common method to create composite QS, and results were similar to other methods. However, the association of different stroke process measures on outcomes may be different. Finally, the results were heavily influenced by the Chinese health-care infrastructure and health system. Thus, these findings may not be generalizable to other countries. Similar quality assessments utilizing population-level databases outside China will be required to confirm the external validity of our results.

CONCLUSION

In China, nationwide variation in the quality of acute stroke care exists at the hospital level. The current results revealed that these variations could be captured by the quality score we constructed, providing a validated specific composite measure of quality. Specifically, we found that patients were likely to receive better outcomes if they received treatment in high outlier hospitals. Our acute stroke quality score may be a

useful quality benchmarking tool for acute stroke care, which can provide audit-level feedback to policymakers and hospitals for quality improvement.

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Funding Information: This work was supported by the National Natural Science Foundation of China (Grant Number 81573255 to Meina Liu), which participated in the design of the study and data collection.

Compliance with Ethical Standards:

Conflict of Interest: The authors declare that they do not have a conflict of interest.

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