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Development and validation of a score for evaluating comprehensive stroke care capabilities: J-ASPECT Study

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Abstract

Background: Although the Brain Attack Coalition recommended establishing centers of comprehensive care for stroke and cerebrovascular disease patients, a scoring system for such centers was lacking. We created and validated a comprehensive stroke center (CSC) score, adapted to Japanese circumstances.

Methods: Of the selected 1369 certified training institutions in Japan, 749 completed an acute stroke care capabilities survey. Hospital performance was determined using a 25-item score, evaluating 5 subcategories: personnel, diagnostic techniques, specific expertise, infrastructure, and education. Consistency and validity were examined using correlation coefficients and factorial analysis.

Results: The CSC score (median, 14; interquartile range, 11–18) varied according to hospital volume. The five subcategories showed moderate consistency (Cronbach's $\alpha = 0.765$). A strong correlation existed between types of available personnel and specific expertise. Using the 2011 Japanese Diagnosis Procedure Combination database for patients hospitalized with stroke, four constructs were identified by factorial analysis (neurovascular surgery and intervention, vascular neurology, diagnostic neuroradiology, and neurocritical care and rehabilitation) that affected in-hospital mortality from ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage. The total CSC score was related to in-hospital mortality from ischemic stroke (odds ratio [OR], 0.973; 95% confidence interval [CI], 0.958–0.989), intracerebral hemorrhage (OR, 0.970; 95% CI, 0.950–0.990), and subarachnoid hemorrhage (OR, 0.951; 95% CI, 0.925–0.977), with varying contributions from the four constructs.

Conclusions: The CSC score is a valid measure for assessing CSC capabilities, based on the availability of neurovascular surgery and intervention, vascular neurology, diagnostic neuroradiology, and critical care and rehabilitation services.

Keywords: Ischemia, Stroke, Hemorrhage, Cerebrovascular circulation, Risk factors

Background

Stroke is the fourth leading cause of mortality and the most common cause of permanent morbidity in Japan, causing an enormous socioeconomic burden. The public health implications of stroke care globally, including in Japan, are profound. Despite accelerating progress in stroke therapy, implementation of appropriate acute

treatment remains essential for decreasing the associated mortality and permanent morbidity. In 2000, the Brain Attack Coalition discussed the concept of primary stroke centers and later proposed the design of comprehensive stroke centers (CSCs) [1, 2]. Most stroke patients can be adequately treated at a primary stroke center (PSC), and the Joint Commission established programs for the certification and performance measurement of PSCs [3]. The concept and recommended key components of a CSC enable intensive patient care and the use of specialized techniques that are not available at most PSCs [1, 4]. To continuously monitor the efficiency of care, reliable

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measures of hospital capabilities and performance are needed. Although the Joint Commission and several US states have started certification processes for PSCs and CSCs [5–8], an established, simple scoring system does not exist to evaluate the comprehensive acute stroke care capabilities of CSCs. To this end, a simple tool for assessing CSC capabilities would be useful for monitoring service quality and enabling its improvement [4]. In 2010, we started the J-ASPECT study (Nationwide survey of Acute Stroke care capacity for Proper designation of Comprehensive stroke center in Japan) to establish optimal nationwide implementation of stroke centers to improve acute stroke outcomes. We modified the above recommendations to reflect the specific circumstances in Japan and developed a CSC score; this tool was validated using the nationwide Diagnosis Combination Procedure (DPC) database, created during the first year of this study.

Methods

Content validity

In the first step of the J-ASPECT study, we investigated the current conditions of stroke hospitals in Japan. We created a 49-item questionnaire examining various aspects of stroke care, including medical systems, emergency systems, stroke rehabilitation, education, and medical performance. Some recommended items, such as ventriculostomy availability, were excluded from our questionnaire for the sake of simplicity and to increase the survey response rate since the items seemed identical to the recommendations of board-certified (BC) neurosurgeons in Japan. Other items, such as availability of transesophageal echocardiography, were excluded because of their very low expected usage, which would make an evaluation of their impact on mortality rates difficult. In February 2011, the questionnaire was mailed to 1369 certified training institutions belonging to the Japan Neurosurgical Society, the Japanese Society of Neurology, and the Japan Stroke Society. Based on this questionnaire, the overall organizational and staffing levels of the hospitals, in terms of CSC capacity, were scored following the Brain Attack Coalition recommendations, after reviewing the literature describing CSCs and conducting a thorough discussion with an expert panel [9]. Advanced acute stroke care capabilities were assessed based on 25 items divided into 5 subcategories (listed in Table 1). One point was assigned for each recommended item that the hospital met, resulting in a maximum total score of 25; subcategory scores were also calculated.

Consistency

Cronbach's α was calculated to evaluate the consistency between the 5 CSC score subcategories used for

Table 1 The availability of comprehensive stroke center score components

| Components | Items | Item No | Number | Percent |
|--------------------|---------------------------------------|---------|--------|---------|
| Personnel | Neurologists | 1 | 358 | 47.8 |
| | Neurosurgeons | 2 | 694 | 92.7 |
| | Endovascular physicians | 3 | 272 | 36.3 |
| | Critical care medicine | 4 | 162 | 21.6 |
| | Physical medicine and rehabilitation | 5 | 113 | 15.1 |
| | Rehabilitation therapy | 6 | 742 | 99.1 |
| | Stroke rehabilitation nurses | 7 | 102 | 13.6 |
| Diagnostics (24/7) | CT ^a | 8 | 742 | 99.1 |
| | MRI ^b with diffusion | 9 | 647 | 86.4 |
| | Digital cerebral angiography | 10 | 602 | 80.4 |
| | CT angiography | 11 | 627 | 83.7 |
| | Carotid duplex ultrasound | 12 | 257 | 34.3 |
| | TCD ^c | 13 | 121 | 16.2 |
| Specific expertise | Carotid endarterectomy | 14 | 603 | 80.5 |
| | Clipping of intracranial aneurysm | 15 | 685 | 91.5 |
| | Hematoma removal/drainage | 16 | 689 | 92.0 |
| | Coiling of intracranial aneurysm | 17 | 360 | 48.1 |
| | Intra-arterial reperfusion therapy | 18 | 498 | 66.5 |
| Infrastructure | Stroke unit | 19 | 132 | 17.6 |
| | Intensive care unit | 20 | 445 | 59.4 |
| | Operating room staffed 24/7 | 21 | 451 | 60.2 |
| | Interventional services coverage 24/7 | 22 | 279 | 37.2 |
| | Stroke registry | 23 | 235 | 31.4 |
| Education | Community education | 24 | 369 | 49.3 |
| | Professional education | 25 | 436 | 58.2 |

^acomputed tomography; ^bmagnetic resonance imaging; ^ctranscranial Doppler

assessing CSC capabilities. To determine the influence of each subcategory, α -values were also calculated for all combinations of the four subcategories. Correlations between the 25 CSC score items were determined using tetrachoric correlation coefficients to evaluate individual items measured with different constructs.

Construct validity

Factorial analysis, based on tetrachoric correlation coefficients [10], was performed using principal factor analysis to explore possible potential groupings of the 25 items into a more limited number of components. The selection of the number of components was based on the Eigen values. To understand the meaning of the components, promax rotation was used.

Predictive validity

Using the Japanese DPC database for patients hospitalized with strokes during the 2011 fiscal year, we examined the differential effects of the items on mortality and poor outcomes (modified Rankin Scale: 3–6, at discharge) associated with ischemic stroke (IS), intracerebral hemorrhage (ICH), and subarachnoid hemorrhage (SAH). This cross-sectional survey used the DPC discharge database for the institutions participating in the J-ASPECT study. The DPC database is a mixed-case classification system that is linked with the lump-sum payment system, launched in 2002 by the Ministry of Health, Labor and Welfare of Japan [11]. In 2010, approximately 1388 acute care hospitals, representing about 50% of the total hospital beds, had adopted the DPC data system. Data regarding practices were obtained from the DPC database; the attending physician is responsible for each patient's clinical data entry. The details of this database have been described elsewhere [12].

Of the 749 hospitals that responded to the institutional survey of advanced stroke care capabilities, 256 agreed to participate in the DPC discharge database study. Consecutive patients, hospitalized between April 1, 2010 and March 31, 2011, were identified in the annual discharge database using the International Classification of Diseases (ICD)-10 diagnosis codes related to IS (I63.0-9), nontraumatic ICH (I61.0-9, I62.0-1, I62.9), and SAH (I60.0-9). Patients with scheduled admissions were excluded from analysis. This research was approved by the Institutional Review Board of the National Cerebral and Cardiovascular Center and, if required, by the participating hospitals.

We used hierarchical logistic regression models to determine relationships between hospital CSC scores, reflecting the capacities they were equipped with, and mortality. Each model had two levels of hierarchy (hospital and patient), and considered the random effects of hospital variables as well as the fixed effects of CSC scores, patient age and sex, and Japan Coma Scale (JCS) scores. Interactions such as those between the JCS and CSC scores were not included in the model. The analyses were performed using SAS, version 9.3 (SAS Institute, Cary, NC, USA), and R, version 3.2.0 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the selected 1369 certified training institutions, 749 (55%) responded to the acute stroke care capability survey. Among the surveyed hospitals, 62% had more than 300 beds, and 51% had more than 200 acute patients (Table 2). Clipping of intracranial aneurysms (IAs) was performed more frequently than any other procedure (median/hospital, 15), followed by craniotomy removal

Table 2 Hospital characteristics

| | |
|---|------------|
| Beds per hospital, n (%) | |
| 20–49 | 16 (2.1) |
| 50–99 | 30 (4.0) |
| 100–299 | 232 (31.0) |
| 300–499 | 260 (34.7) |
| > 500 | 207 (27.6) |
| Unknown | 4 (0.5) |
| Acute stroke patients per hospital, n (%) | |
| ≤ 49 | 51 (6.8) |
| 50–99 | 78 (10.4) |
| 100–199 | 199 (26.6) |
| 200–299 | 155 (20.7) |
| > 300 | 228 (30.4) |
| Unknown | 38 (5.1) |
| Treated patients per hospital, median (IQR ^a) | |
| Tissue plasminogen activator | 5 (2–10) |
| Intra-arterial thrombolysis/percutaneous angioplasty | 0 (0–2) |
| Carotid endarterectomy | 1 (0–4) |
| Carotid stenting | 1 (0–7) |
| Extracranial-intracranial bypass surgery | 1 (0–5) |
| Clipping of intracranial aneurysm | 15 (6–27) |
| Coiling of intracranial aneurysm | 3 (0–11) |
| Craniotomy hematoma removal | 6 (2–12) |
| Stereotactic hematoma removal | 0 (0–3) |
| Endoscopic hematoma removal | 0 (0–0) |

^ainterquartile range

of ICH (6), intravenous infusion of recombinant tissue plasminogen activator (5), and coiling of IAs (3). The availability of each item is shown in Table 1. Even within the same component, the availability of each item varied. Low availability values were noted for IA coiling (48.1%) in the specific expertise component and for stroke units (17.6%) in the infrastructure component.

The distribution of CSC score components, by hospital, is shown in Table 3. The median CSC score was 14 (interquartile range, 11–18). These components showed moderate consistency (Cronbach's $\alpha = 0.765$, for the total score). Removal of any one component resulted in Cronbach's α falling in the range of 0.668–0.776, indicating the absence of substantial influence of individual components. High correlations between the survey components pertaining to personnel and specific expertise were observed (Table 4). For example, there were high correlations between neurosurgeon availability and carotid endarterectomy ($r = 0.821$; items 2 and 14), clipping of IAs ($r = 0.936$; items 2 and 15), and hematoma removal/drainage ($r = 0.949$; items 2 and 16). Similarly, endovascular physician availability was strongly correlated with

Table 3 The distribution of comprehensive stroke center score components and their consistency

| Components | Mean | SD | Median | IQR ^a | Cronbach's α |
|--------------------|-------|------|--------|------------------|---------------------|
| Personnel | 3.26 | 1.25 | 3 | 2–4 | 0.724 |
| Diagnostic | 4.00 | 1.28 | 4 | 4–5 | 0.741 |
| Specific expertise | 3.79 | 1.48 | 4 | 3–5 | 0.668 |
| Infrastructure | 2.06 | 1.43 | 2 | 1–3 | 0.674 |
| Education | 1.07 | 0.83 | 1 | 0–2 | 0.776 |
| Total Score | 14.18 | 4.57 | 14 | 11–18 | 0.765 |

^ainterquartile range

coiling of IAs ($r = 0.932$; items 3 and 17) and intra-arterial reperfusion therapy ($r = 0.842$; items 3 and 18). Other relationships regarding diagnostics, infrastructure, and education did not stand out.

Factorial analysis, based on promax rotation, revealed four constructs (Table 5). The first pattern contained items pertaining to neurovascular surgery and intervention, such as endovascular physician availability, coiling of IAs, intra-arterial reperfusion therapy, 24/7 interventional services coverage, carotid endarterectomy, hematoma removal/drainage, clipping of IAs, neurosurgeon availability, rehabilitation therapy, 24/7 operating room staffing, and stroke rehabilitation nurse availability. The first pattern had the largest explained variance (43% of total variance). The second pattern included imaging modalities mainly associated with diagnostic neuroradiology (e.g., computed tomography, computed tomography angiography, digital cerebral angiography, and diffusion-weighted magnetic resonance imaging) and intensive care units. The third pattern contained items related to vascular neurology: transcranial Doppler, carotid duplex ultrasound, professional education, community education, stroke registry, and available stroke units. The fourth pattern represented neurocritical care and rehabilitation, and included the availability of neurologists, physical medicine and rehabilitation, and critical care medicine.

A total of 53,170 patients in the cohort were analyzed; the in-hospital mortality was 7.8% for IS, 16.8% for ICH, and 28.1% for SAH (Table 6). Table 7 shows the impact of hospital capacity for each of the 25 items on mortality. Among the four constructs obtained using factorial analysis, the availability of neurologists in neurocritical care and rehabilitation was significantly associated with reduced mortality of patients with IS ($P < 0.05$). The 24/7 availability of interventional service coverage in neurovascular surgery and intervention ($P < 0.05$), availability of intensive care units in diagnostic neurology, and physical medicine and rehabilitation in neurocritical care and rehabilitation ($P < 0.05$) were related to SAH mortality. The total CSC score was related to the mortality associated with IS (OR, 0.973; 95% CI, 0.958–0.989), ICH (OR,

0.970; 95% CI, 0.950–0.990), and SAH (OR, 0.951; 95% CI, 0.925–0.977).

The proportions of poor outcomes (modified Rankin Scale, 3–6) were 49.2% for IS, 65.3% for ICH, and 56.4% for SAH (Table 6). In contrast to mortality, the total CSC score was not significantly associated with poor outcomes in patients having any type of stroke (Table 8). The impact of hospital capacity for each of the 25 items on poor outcomes differed from that for mortality in some aspects. For example, among patients with IS, stroke unit availability were significantly associated with a reduced proportion of poor outcomes ($P < 0.05$). Among patients with ICH and SAH, no significant association was observed between the availability of any item and poor outcomes.

Discussion

We evaluated the consistency and validity of the CSC score; based on the Cronbach's α value of 0.765, the five components were moderately consistent [13]. The validity of the score was evaluated using factorial analysis, which revealed four major constructs. Although the four constructs were determined by the five components: personnel, diagnostic techniques, specific expertise, infrastructure, and education, this study showed a high correlation between the survey components pertaining to personnel and specific expertise. The unique fact that BC neurosurgeons comprise more than 95% of BC endovascular physicians, in Japan, may explain why personnel, specific expertise, and infrastructure components closely related to these different treatment aspects were grouped into the same construct (neurovascular surgery and intervention). Considering their influence on the variance of the CSC scores, temporal trends and geographical disparities focused on this construct may provide critical information for proper accreditation and implementation of CSCs.

With regard to the predictive validity of the CSC score, the four constructs had different effects on mortality and poor outcomes in patients with IS, ICH, and SAH. The availability of neurologists involved in neurocritical care and rehabilitation was significantly associated with reduced in-hospital mortality in patients with IS. Recently, the treatment paradigm for acute IS has been changing rapidly, such that the critical role of endovascular intervention following tissue plasminogen activator infusion, for acute IS, has been established by several recent randomized controlled trials (MR Clean, ESCAPE, EXTEND-IA) [14–16]. Of note, however, the acute stroke care survey used in this study and the DPC database were both implemented before these evidences were published in 2015. The availability of BC neurosurgeons at more than 90% of the participating hospitals suggests the importance of multidisciplinary acute stroke care [17].

Table 4 Correlation coefficients between the 25 survey items

| Item No ^a | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | |
|----------------------|--------|-------|-------|--------|--------|--------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
| 1 | 1.000 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | -0.071 | 1.000 | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 0.201 | 0.671 | 1.000 | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 0.282 | 0.243 | 0.244 | 1.000 | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 0.520 | 0.063 | 0.259 | 0.476 | 1.000 | | | | | | | | | | | | | | | | | | | | | |
| 6 | 0.334 | 0.282 | 0.239 | -0.190 | 0.140 | 1.000 | | | | | | | | | | | | | | | | | | | | |
| 7 | 0.171 | 0.072 | 0.248 | 0.054 | 0.117 | 0.125 | 1.000 | | | | | | | | | | | | | | | | | | | |
| 8 | 0.300 | 0.451 | 0.265 | 0.202 | 0.037 | 0.392 | 0.007 | 1.000 | | | | | | | | | | | | | | | | | | |
| 9 | -0.018 | 0.500 | 0.325 | 0.054 | -0.025 | 0.043 | 0.047 | 0.636 | 1.000 | | | | | | | | | | | | | | | | | |
| 10 | -0.027 | 0.827 | 0.490 | 0.255 | 0.058 | 0.132 | -0.005 | 0.616 | 0.594 | 1.000 | | | | | | | | | | | | | | | | |
| 11 | -0.132 | 0.701 | 0.264 | 0.201 | -0.050 | 0.017 | 0.055 | 0.632 | 0.614 | 0.830 | 1.000 | | | | | | | | | | | | | | | |
| 12 | 0.120 | 0.215 | 0.118 | 0.198 | 0.016 | -0.196 | 0.158 | 0.306 | 0.357 | 0.332 | 0.295 | 1.000 | | | | | | | | | | | | | | |
| 13 | 0.155 | 0.435 | 0.361 | 0.156 | 0.036 | -0.142 | 0.102 | 0.194 | 0.287 | 0.492 | 0.372 | 0.713 | 1.000 | | | | | | | | | | | | | |
| 14 | 0.095 | 0.821 | 0.639 | 0.238 | 0.155 | 0.234 | 0.138 | 0.281 | 0.363 | 0.694 | 0.492 | 0.196 | 0.305 | 1.000 | | | | | | | | | | | | |
| 15 | 0.029 | 0.936 | 0.669 | 0.208 | 0.073 | 0.253 | 0.123 | 0.414 | 0.405 | 0.840 | 0.675 | 0.253 | 0.521 | 0.885 | 1.000 | | | | | | | | | | | |
| 16 | 0.010 | 0.949 | 0.709 | 0.227 | 0.053 | 0.263 | 0.105 | 0.431 | 0.429 | 0.831 | 0.663 | 0.256 | 0.512 | 0.865 | 0.987 | 1.000 | | | | | | | | | | |
| 17 | 0.215 | 0.648 | 0.932 | 0.283 | 0.270 | 0.228 | 0.373 | 0.262 | 0.288 | 0.486 | 0.243 | 0.220 | 0.386 | 0.648 | 0.695 | 0.729 | 1.000 | | | | | | | | | |
| 18 | 0.092 | 0.784 | 0.842 | 0.209 | 0.226 | 0.215 | 0.289 | 0.234 | 0.407 | 0.646 | 0.391 | 0.247 | 0.418 | 0.754 | 0.793 | 0.821 | 0.874 | 1.000 | | | | | | | | |
| 19 | 0.185 | 0.378 | 0.277 | 0.109 | 0.045 | 0.049 | 0.373 | 0.197 | 0.333 | 0.340 | 0.193 | 0.206 | 0.260 | 0.345 | 0.408 | 0.395 | 0.307 | 0.357 | 1.000 | | | | | | | |
| 20 | 0.154 | 0.358 | 0.256 | 0.237 | 0.086 | -0.230 | 0.012 | 0.451 | 0.197 | 0.416 | 0.374 | 0.187 | 0.229 | 0.325 | 0.403 | 0.416 | 0.265 | 0.243 | 0.291 | 1.000 | | | | | | |
| 21 | 0.291 | 0.599 | 0.603 | 0.205 | 0.155 | 0.314 | 0.180 | 0.484 | 0.287 | 0.583 | 0.429 | 0.193 | 0.386 | 0.714 | 0.756 | 0.718 | 0.564 | 0.515 | 0.443 | 0.382 | 1.000 | | | | | |
| 22 | 0.273 | 0.515 | 0.912 | 0.226 | 0.218 | 0.229 | 0.376 | 0.347 | 0.277 | 0.464 | 0.224 | 0.217 | 0.400 | 0.538 | 0.594 | 0.626 | 0.895 | 0.762 | 0.321 | 0.283 | 0.697 | 1.000 | | | | |
| 23 | 0.203 | 0.314 | 0.360 | 0.145 | 0.210 | 0.014 | 0.213 | 0.059 | 0.342 | 0.357 | 0.253 | 0.287 | 0.406 | 0.373 | 0.425 | 0.451 | 0.385 | 0.405 | 0.381 | 0.165 | 0.369 | 0.362 | 1.000 | | | |
| 24 | 0.193 | 0.346 | 0.298 | 0.080 | 0.134 | 0.188 | 0.104 | 0.179 | 0.219 | 0.234 | 0.079 | 0.249 | 0.414 | 0.266 | 0.337 | 0.334 | 0.293 | 0.314 | 0.408 | 0.174 | 0.303 | 0.344 | 0.315 | 1.000 | | |
| 25 | 0.038 | 0.425 | 0.230 | 0.025 | 0.073 | -0.114 | 0.055 | 0.012 | 0.312 | 0.292 | 0.260 | 0.193 | 0.289 | 0.373 | 0.422 | 0.395 | 0.267 | 0.359 | 0.417 | 0.101 | 0.282 | 0.221 | 0.311 | 0.576 | 1.000 | |

^aItem No in Table 1

Table 5 Factor analysis

| | | Factor 1 Neurovascular surgery and intervention | Factor 2 Diagnostic neuroradiology | Factor 3 Vascular neurology | Factor 4 Neurocritical care and rehabilitation |
|---------|---------------------------------------|---|--|--------------------------------|--|
| | Proportion explained | 0.43 | 0.25 | 0.19 | 0.14 |
| Item No | Items | Standardized loadings (pattern matrix) | | | |
| 3 | Endovascular physicians | 0.91^d | -0.07 | -0.04 | 0.12 |
| 17 | Coiling of intracranial aneurysm | 0.89 | -0.11 | 0.04 | 0.15 |
| 18 | Intra-arterial reperfusion therapy | 0.88 | 0.00 | 0.10 | -0.05 |
| 22 | Interventional services coverage 24/7 | 0.80 | -0.09 | 0.05 | 0.23 |
| 14 | Carotid endarterectomy | 0.76 | 0.24 | -0.01 | -0.10 |
| 16 | Hematoma removal/draining | 0.75 | 0.37 | 0.06 | -0.16 |
| 15 | Clipping of intracranial aneurysm | 0.73 | 0.37 | 0.08 | -0.16 |
| 2 | Neurosurgeons | 0.69 | 0.43 | 0.02 | -0.22 |
| 6 | Rehabilitation therapy | 0.59 | 0.07 | -0.63 | 0.18 |
| 21 | Operating room staffed 24/7 | 0.59 | 0.28 | 0.00 | 0.18 |
| 7 | Stroke rehabilitation nurses | 0.34 | -0.36 | 0.21 | 0.20 |
| 8 | CT ^a | -0.03 | 0.89 | -0.21 | 0.34 |
| 11 | CT angiography | 0.08 | 0.84 | 0.06 | -0.17 |
| 10 | Digital cerebral angiography | 0.36 | 0.70 | 0.08 | -0.10 |
| 9 | MRI ^b with diffusion | 0.03 | 0.59 | 0.23 | -0.06 |
| 20 | Intensive care unit | -0.06 | 0.50 | 0.17 | 0.22 |
| 13 | TCD ^c | 0.02 | 0.15 | 0.71 | 0.04 |
| 12 | Carotid duplex ultrasound | -0.31 | 0.26 | 0.72 | 0.16 |
| 25 | Professional education | 0.23 | -0.15 | 0.63 | -0.23 |
| 24 | Community education | 0.21 | -0.17 | 0.56 | 0.07 |
| 23 | Stroke registry | 0.24 | -0.08 | 0.52 | 0.10 |
| 19 | Stroke unit | 0.23 | -0.05 | 0.49 | 0.06 |
| 1 | Neurologists | -0.02 | -0.02 | 0.02 | 0.85 |
| 5 | Physical medicine and rehabilitation | 0.10 | -0.09 | 0.00 | 0.72 |
| 4 | Critical care medicine | -0.09 | 0.25 | 0.14 | 0.55 |

^acomputed tomography; ^bmagnetic resonance imaging; ^ctranscranial Doppler; ^dvalues > 0.300 are shown in bold font

The association between the availability of a stroke care unit and the increased proportion of favorable outcomes after IS, observed in this study, is consistent with a 2009 Cochrane review conducted by the Stroke Unit Trialists' Collaboration that showed the benefits of stroke unit care in terms of reducing death, dependency, and institutional care [18].

The SAH-associated mortality was higher than that associated with IS or ICH, and the condition of the patients with SAH was also more severe and required more urgent intervention. Accordingly, the availability of items representing SAH treatment, such as 24/7 interventional service coverage, intensive care unit, and BC physical medicine and rehabilitation, showed the greatest effects on mortality. The critical role of endovascular coil embolization for ruptured IAs was previously

established by the International Subarachnoid Aneurysms Trial [19]. Using Nationwide Inpatient Survey data, Qureshi et al. reported a significant increase in endovascular treatment as well as a decrease in in-hospital mortality (2000–2002, 27%; 2004–2006, 24%) in patients with SAH after publication of the International Subarachnoid Trial (ISAT) in 2002 [20]. However, whether the ISAT results can be generalized to all patients with SAH is questionable because most of the patients enrolled in the study were patients with good clinical grades, having small, anterior circulation aneurysms.

The second common cause of SAH-related death and poor functional outcome is rebleeding [21], and early treatment of the ruptured aneurysm is known to lower the incidence of rebleeding. Intensive care unit and 24/7

Table 6 Demographics of the patient cohort at diagnosis, mortality, and severe disability at discharge

| | Total (n = 53170) | | IS ^a (n = 32671) | | ICH ^b (n = 15699) | | SAH ^c (n = 4934) | |
|--|----------------------|------|--------------------------------|------|---------------------------------|------|--------------------------------|------|
| | N | % | N | % | N | % | N | % |
| Male | 29353 | 55.2 | 18816 | 57.6 | 9030 | 57.5 | 1584 | 32.1 |
| Age (years) | | | | | | | | |
| 18–50 | 3515 | 6.6 | 1328 | 4.1 | 1271 | 8.1 | 927 | 18.8 |
| 51–60 | 5824 | 11.0 | 2742 | 8.4 | 2171 | 13.8 | 934 | 18.9 |
| 61–70 | 11744 | 22.1 | 6894 | 21.1 | 3640 | 23.2 | 1242 | 25.2 |
| 71–80 | 15825 | 29.8 | 10342 | 31.7 | 4466 | 28.4 | 1048 | 21.2 |
| 81–106 | 16262 | 30.6 | 11365 | 34.8 | 4151 | 26.4 | 783 | 15.9 |
| Hypertension | 39918 | 75.1 | 22531 | 69.0 | 13281 | 84.6 | 4229 | 85.7 |
| Diabetes mellitus | 13725 | 25.8 | 9318 | 28.5 | 3278 | 20.9 | 1174 | 23.8 |
| Hyperlipidemia | 15015 | 28.2 | 11104 | 34.0 | 2529 | 16.1 | 1412 | 28.6 |
| Smoking (n = 44842) | 12761 | 24.0 | 8188 | 25.1 | 3540 | 22.5 | 1074 | 21.8 |
| Japan Coma Scale | | | | | | | | |
| 0 | 19635 | 36.9 | 15027 | 46.0 | 3620 | 23.1 | 1024 | 20.8 |
| 1-digit code | 19371 | 36.4 | 12375 | 37.9 | 5934 | 37.8 | 1117 | 22.6 |
| 2-digit code | 6937 | 13.0 | 3396 | 10.4 | 2705 | 17.2 | 852 | 17.3 |
| 3 digit code | 7227 | 13.6 | 1873 | 5.7 | 3440 | 21.9 | 1941 | 39.3 |
| Emergency admission by ambulance | 31995 | 60.2 | 17336 | 53.1 | 10909 | 69.5 | 3830 | 77.6 |
| Mortality | 6522 | 12.3 | 2535 | 7.8 | 2630 | 16.8 | 1384 | 28.1 |
| Poor outcome (modified Rankin Scale 3–6) at discharge. (N = 51719) | 28238 | 54.6 | 15566 | 49.2 | 10044 | 65.3 | 2721 | 56.4 |

^aischemic stroke; ^bintracerebral hemorrhage; ^csubarachnoid hemorrhage

interventional coverage availability were significant factors associated with decreasing in-hospital mortality after SAH. These findings are explained by the importance of early obliteration of ruptured aneurysms for preventing rebleeding and by the early detection and appropriate treatment of vasospasms, another important cause of morbidity and mortality in patients with SAH. The study provided additional evidence that the availability of endovascular treatment and surgical clipping may reduce in-hospital mortality in patients with SAH [22]. Another recent study also showed that an early mobilization program for patients with aneurysmal SAH is feasible and safe [23]. In addition, appropriate nutritional care from the acute stage is reported to be essential for improving functional outcomes and reducing post-SAH mortality [24]. Taken together, the significant association between the availability of BC physical medicine and rehabilitation and reduced mortality observed in our study reinforces the importance of comprehensive care capabilities, including early rehabilitation and nutritional care for patients with SAH, to prevent complications. Further investigation is required to understand the role of BC physical medicine and rehabilitation in reducing SAH-associated mortality.

Finally, the total CSC score correlated with reduced mortality for all types of stroke, supporting the usefulness of this score as a comprehensive measure of acute stroke care capabilities. Another study showed that hemorrhagic stroke patients admitted to CSCs were more likely to receive neurosurgical and endovascular treatments and to be alive at 90 days than patients admitted to other hospitals. The authors used certification by the New Jersey Department of Health and Senior Services to identify CSCs. The impacts of CSCs on mortality determined in that study are similar to the results obtained using our simple scoring system [25].

In contrast to its impact on in-hospital mortality, the total CSC score did not show a significant impact on poor functional outcomes in patients with any type of stroke. Similarly, no specific item had a significant impact on poor outcomes in patients with hemorrhagic stroke. In patients with IS, the significant role of the presence of a stroke unit in reducing poor outcomes, observed in the present study, was consistent with the results of a previous report [26]. A validation study investigating functional outcomes using the DPC database may be necessary to explain the disparities between the total CSC scores (and specific items) on mortality and poor functional outcomes.

Table 7 The effect of items on mortality

| Item No | Items | IS ^a (n = 32671) | | | ICH ^b (n = 15699) | | | SAH ^c (n = 4934) | | |
|-----------|---|--------------------------------|---------------------|-------|---------------------------------|--------|-------|--------------------------------|--------|-------|
| | | OR ^d | 95% CI ^e | | OR | 95% CI | | OR | 95% CI | |
| 3 | Endovascular physicians | 0.832 | 0.653 | 1.060 | 0.896 | 0.671 | 1.198 | 1.309 | 0.906 | 1.891 |
| 17 | Coiling of intracranial aneurysm | 1.062 | 0.832 | 1.355 | 1.075 | 0.797 | 1.451 | 0.982 | 0.667 | 1.444 |
| 18 | Intra-arterial reperfusion therapy | 1.155 | 0.931 | 1.434 | 0.919 | 0.706 | 1.194 | 0.854 | 0.608 | 1.201 |
| 22 | Interventional services coverage 24/7 | 1.071 | 0.831 | 1.379 | 1.145 | 0.844 | 1.555 | 0.674 ^j | 0.458 | 0.992 |
| 14 | Carotid endarterectomy | 0.945 | 0.708 | 1.262 | 0.833 | 0.595 | 1.165 | 0.789 | 0.503 | 1.237 |
| 15 and 16 | Clipping of intracranial aneurysm and hematoma removal/drainage | 0.798 | 0.465 | 1.368 | 0.537 | 0.266 | 1.088 | 0.359 | 0.082 | 1.564 |
| 2 | Neurosurgeons | 0.905 | 0.530 | 1.546 | 1.513 | 0.744 | 3.077 | 0.840 | 0.230 | 3.071 |
| 6 | Rehabilitation therapy | 1.000 | | | 1.000 | | | 1.000 | | |
| 21 | Operating room staffed 24/7 | 0.986 | 0.826 | 1.176 | 0.956 | 0.769 | 1.187 | 1.217 | 0.921 | 1.610 |
| 7 | Stroke rehabilitation nurses | 1.021 | 0.831 | 1.253 | 1.019 | 0.803 | 1.293 | 1.074 | 0.803 | 1.436 |
| 8 | CT ^f | 0.963 | 0.208 | 4.462 | 0.515 | 0.035 | 7.590 | 1.000 | | |
| 11 | CT angiography | 1.127 | 0.877 | 1.449 | 0.820 | 0.608 | 1.107 | 0.978 | 0.662 | 1.446 |
| 10 | Digital cerebral angiography | 0.840 | 0.652 | 1.082 | 1.243 | 0.917 | 1.684 | 1.068 | 0.722 | 1.580 |
| 9 | MRI ^g with diffusion | 1.117 | 0.849 | 1.471 | 0.844 | 0.605 | 1.176 | 0.897 | 0.581 | 1.383 |
| 20 | Intensive care unit | 1.032 | 0.897 | 1.188 | 0.964 | 0.813 | 1.144 | 0.795 ^j | 0.640 | 0.988 |
| 13 | TCD ^h | 0.852 | 0.699 | 1.038 | 0.879 | 0.700 | 1.105 | 1.222 | 0.930 | |
| 12 | Carotid duplex ultrasound | 1.039 | 0.889 | 1.215 | 1.021 | 0.849 | 1.228 | 1.119 | 0.891 | 1.406 |
| 25 | Professional education | 0.907 | 0.765 | 1.076 | 1.061 | 0.868 | 1.296 | 0.954 | 0.751 | 1.212 |
| 24 | Community education | 0.948 | 0.810 | 1.109 | 0.908 | 0.753 | 1.094 | 0.800 | 0.636 | 1.006 |
| 23 | Stroke registry | 0.895 | 0.781 | 1.026 | 0.861 | 0.732 | 1.013 | 0.915 | 0.749 | 1.118 |
| 19 | Stroke unit | 0.993 | 0.838 | 1.177 | 0.887 | 0.724 | 1.086 | 0.871 | 0.679 | 1.118 |
| 1 | Neurologists | 0.854 ^j | 0.742 | 0.982 | 1.043 | 0.881 | 1.234 | 1.110 | 0.901 | 1.367 |
| 5 | Physical medicine and rehabilitation | 1.025 | 0.844 | 1.245 | 0.976 | 0.777 | 1.225 | 0.746 ^j | 0.562 | 0.991 |
| 4 | Critical care medicine | 0.967 | 0.825 | 1.134 | 0.993 | 0.823 | 1.200 | 0.895 | 0.712 | 1.126 |
| | Total CSC ⁱ score | 0.973 ^j | 0.958 | 0.989 | 0.970 ^j | 0.950 | 0.990 | 0.951 ^j | 0.925 | 0.977 |

^aischemic stroke; ^bintracerebral hemorrhage; ^csubarachnoid hemorrhage; ^dOR odds ratio adjusted by hierarchical logistic model including patient age, sex, Japan Coma Scale scores, and hospital variables; ^eCI confidence interval; ^fcomputed tomography; ^gmagnetic resonance imaging; ^htranscranial Doppler; ⁱcomprehensive stroke center; ^j $P < 0.05$ (hierarchical logistic model)

Strengths and limitations of the present study

First, this study is limited by a possible selection bias because hospitals actively working to improve stroke care were more likely to respond to the questionnaire. However, the coverage of the J-ASPECT Study group, which collaborates with the Japan Neurosurgical Society and the Japanese Congress of Neurological Surgeons, was broad enough to provide a reliable study sample. Second, information bias might have existed (self-reporting, recall, and nonresponse). Third, the CSC score mainly evaluated structural measures and did not consider their utilization, supported with real data. To assess clinical practice quality, the use of process measures is preferred [27], but process measures, such as electrocardiogram monitoring and pulse oximetry, were not considered in this scoring system [4, 28]. However,

strong correlations between survey components pertaining to personnel and specific expertise (e.g., availability of neurosurgeons and carotid endarterectomy) were observed in this study, suggesting that these items may not be considered as purely structural, but may have characteristics of both structural and process measures. We are planning to develop a new registry system in the J-ASPECT Study to include key metrics required for certification of CSCs in the US, in addition to the DPC database, to study and monitor the association of such quality metrics on mortality and morbidity of acute stroke patients, in Japan. Fourth, in-hospital mortality was selected as an outcome measure to test the validity of the CSC score. A recent systematic review showed that hospital mortality does not necessarily reflect the quality of clinical practice because mortality is affected

Table 8 The effect of items on poor outcome (modified Rankin Scale 3–6)

| Item No | Items | IS ^a (n = 31640) | | | ICH ^b (n = 15391) | | | SAH ^c (n = 4821) | | |
|-----------|---|--------------------------------|---------------------|-------|---------------------------------|--------|-------|--------------------------------|--------|--------|
| | | OR ^d | 95% CI ^e | | OR | 95% CI | | OR | 95% CI | |
| 3 | Endovascular physicians | 1.180 | 0.890 | 1.563 | 0.896 | 0.671 | 1.198 | 1.267 | 0.856 | 1.875 |
| 17 | Coiling of intracranial aneurysm | 0.838 | 0.634 | 1.106 | 1.075 | 0.797 | 1.451 | 0.933 | 0.618 | 1.407 |
| 18 | Intra-arterial reperfusion therapy | 0.990 | 0.777 | 1.261 | 0.919 | 0.706 | 1.194 | 0.704 | 0.487 | 1.017 |
| 22 | Interventional services coverage 24/7 | 0.969 | 0.725 | 1.295 | 1.145 | 0.844 | 1.555 | 0.928 | 0.615 | 1.400 |
| 14 | Carotid endarterectomy | 1.293 | 0.946 | 1.768 | 0.833 | 0.595 | 1.165 | 0.838 | 0.511 | 1.376 |
| 15 and 16 | Clipping of intracranial aneurysm and hematoma removal/draining | 0.763 | 0.427 | 1.364 | 0.537 | 0.266 | 1.088 | 0.553 | 0.065 | 4.693 |
| 2 | Neurosurgeons | 1.026 | 0.582 | 1.807 | 1.513 | 0.744 | 3.077 | 4.449 | 0.987 | 20.041 |
| 6 | Rehabilitation therapy | 1.000 | . | . | 1.000 | . | . | 1.000 | . | . |
| 21 | Operating room staffed 24/7 | 0.883 | 0.723 | 1.078 | 0.956 | 0.769 | 1.187 | 0.959 | 0.712 | 1.290 |
| 7 | Stroke rehabilitation nurses | 0.874 | 0.693 | 1.101 | 1.019 | 0.803 | 1.293 | 0.877 | 0.641 | 1.200 |
| 8 | CT ^f | 1.328 | 0.296 | 5.956 | 0.515 | 0.035 | 7.590 | 1.000 | . | . |
| 11 | CT angiography | 1.227 | 0.931 | 1.617 | 0.820 | 0.608 | 1.107 | 0.877 | 0.579 | 1.329 |
| 10 | Digital cerebral angiography | 0.912 | 0.685 | 1.213 | 1.243 | 0.917 | 1.684 | 1.274 | 0.842 | 1.928 |
| 9 | MRI ^g with diffusion | 0.940 | 0.706 | 1.252 | 0.844 | 0.605 | 1.176 | 0.793 | 0.490 | 1.284 |
| 20 | Intensive care unit | 0.987 | 0.842 | 1.156 | 0.964 | 0.813 | 1.144 | 1.000 | 0.795 | 1.259 |
| 13 | TCD ^h | 0.966 | 0.773 | 1.208 | 0.879 | 0.700 | 1.105 | 1.152 | 0.858 | 1.547 |
| 12 | Carotid duplex ultrasound | 1.183 | 0.988 | 1.415 | 1.021 | 0.849 | 1.228 | 1.206 | 0.945 | 1.538 |
| 25 | Professional education | 0.892 | 0.737 | 1.079 | 1.061 | 0.868 | 1.296 | 1.015 | 0.782 | 1.317 |
| 24 | Community education | 1.144 | 0.957 | 1.368 | 0.908 | 0.753 | 1.094 | 0.871 | 0.680 | 1.116 |
| 23 | Stroke registry | 0.981 | 0.840 | 1.146 | 0.861 | 0.732 | 1.013 | 0.860 | 0.695 | 1.065 |
| 19 | Stroke unit | 0.783 ^j | 0.645 | 0.952 | 0.887 | 0.724 | 1.086 | 0.878 | 0.676 | 1.141 |
| 1 | Neurologists | 1.137 | 0.969 | 1.335 | 1.043 | 0.881 | 1.234 | 1.096 | 0.877 | 1.370 |
| 5 | Physical medicine and rehabilitation | 1.163 | 0.934 | 1.449 | 0.976 | 0.777 | 1.225 | 0.979 | 0.725 | 1.322 |
| 4 | Critical care medicine | 1.113 | 0.929 | 1.334 | 0.993 | 0.823 | 1.200 | 1.062 | 0.830 | 1.360 |
| | Total CSC ⁱ score | 0.995 | 0.977 | 1.014 | 1.007 | 0.984 | 1.030 | 0.978 | 0.950 | 1.008 |

^aischemic stroke; ^bintracerebral hemorrhage; ^csubarachnoid hemorrhage; ^dOR odds ratio adjusted by hierarchical logistic model including patient age, sex, Japan Coma Scale scores, and hospital variables; ^eCI: confidence interval; ^fcomputed tomography; ^gmagnetic resonance imaging; ^htranscranial Doppler; ⁱcomprehensive stroke center; ^j $P < 0.05$ (hierarchical logistic model)

to a greater extent by the patients' condition rather than by the quality of practice [29]. Possible correlations between specific items and mortality in patients with IS may have been missed because of the relatively low in-hospital mortality associated with these patients; a larger study is necessary to resolve this issue. Fifth, the DPC-based payment system contains limited information regarding patient condition severity beyond post-discharge data and the National Institute of Health Stroke (NIHSS) Scale, Glasgow Coma Scale (GCS), ICH-, or Hunt-Hess severity scores, upon admission. Nevertheless, the JCS is a useful tool for evaluating stroke severity. Notably, the importance of the JCS, published in 1974, for predicting stroke outcomes has been recently reconfirmed [9, 30]. Further study is necessary to validate the results of the present study with other

patient-level measurements, such as the NIHSS, GCS, etc. Despite the above limitations, clear correlations were revealed between the CSC score and in-hospital mortality in patients with all types of strokes. In future work, the score's components should be weighted according to stroke type, based on their influence on patient outcomes.

Conclusions

The CSC score is a valid measure for assessing the capabilities of CSCs with regard to the availability of neurovascular surgery and intervention, vascular neurology, diagnostic neuroradiology, and neurocritical care and rehabilitation. The total CSC score was associated with mortality in patients with IS, ICH, and SAH, with varying contributions from the four abovementioned constructs.

Abbreviations

BC: Board-certified; CI: Confidence interval; CSC: Comprehensive stroke center; DPC: Diagnosis combination procedure; GCS: Glasgow coma scale; IA: Intracranial aneurysm; ICH: Intracerebral hemorrhage; IS: Ischemic stroke; ISAT: International subarachnoid trial; JCS: Japan coma scale; NIHSS: National institute of health stroke; OR: Odds ratio; PSC: Primary stroke center; SAH: Subarachnoid hemorrhage

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Availability of data and materials

The datasets for this manuscript will not be shared, based on agreements between the principal investigator and the presidents of the participating hospitals.

Authors' contributions

KI initiated the collaborative project. AK, KN, SK, and KI designed the study, drafted and revised the article. AK, KN, SK monitored data collection and analyzed the data. JN, KO, JO, YS, TA, SM, IN, KT, SM, AS, HK, FN designed the study, and validated the survey questions from the views of physicians and experts. All authors read and approved the final manuscript.

Competing interests

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Consent for publication

Not applicable.

Ethics approval and consent to participate

Ethical approval was provided by National Cerebral and Cardiovascular Center in Japan.

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