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Temporal trends and geographical disparities in comprehensive stroke center capabilities in Japan from 2010 to 2018

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ABSTRACT

Objectives: Comprehensive stroke center (CSC) capabilities are associated with reduced in-hospital mortality due to acute stroke. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement. This study examined whether CSC capabilities changed in Japan between 2010 and 2018, and whether any changes were influenced by hospital characteristics.

Design: A hospital-based cross-sectional study.

Setting: We sent out questionnaires to the training institutions of the Japan Neurosurgical Society and Japan Stroke Society in 2010, 2014 and 2018.

Participants: 749 in 2010, 532 in 2014 and 786 in 2018 hospitals that participate in the J-ASPECT Study.

Main outcome measures: CSC capabilities were assessed using the validated scoring system (CSC score:1-25 points) in 2010, 2014, and 2018 survey. The effect of hospital characteristics was examined using multiple logistic regression analysis.

Results: Among the 323 hospitals that responded to all surveys, the implementation of 14 recommended items increased. The CSC score (median, interquartile range) was 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively (p for trend< 0.001). There was a ≥ 20% increase in six items (e.g. endovascular physicians, stroke unit, and interventional coverage 24/7), and a ≤ 20% decrease in community education. A lower baseline CSC score (odds ratio 0.82, [95% confidence interval] 0.75-0.9), the number of beds ≥ 500 (3.9 [1.2–13.0]), and the number of stroke physicians (7-9) (2.6 [1.1-6.3]) was associated with improved CSC capabilities, independent of geographical location.

Conclusions: There was a significant improvement in CSC capabilities between 2010 and 2018, which was mainly related to the availability of endovascular treatment and multidisciplinary care. Hospital characteristics may be considered to further improve systems of stroke care in light of a limited medical resources in a defined area.

Strengths and limitations of this study:

・A large-scale, representative hospitals of Japan provided data on temporal trends in the CSC capabilities for this cross-sectional study.

・Hospitals actively working to improve stroke care are more likely to respond to the questionnaire, which may lead to information bias.

・ The CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items.

INTRODUCTION

Stroke is the third leading cause of death and a leading cause of long-term disability in Japan. Primary and comprehensive stroke centers (CSCs) were developed to provide optimal implementation of intravenous recombinant tissue plasminogen activator (rt-PA) infusion and more intensive stroke care that includes endovascular and neurosurgical treatment. [1, 2] Organized care in a stroke unit is associated with better quality of care, and reduced death and dependency. [3, 4] Previous studies showed that patient outcomes associated with stroke and cardiovascular diseases are influenced by the hospital case volume, [5, 6] number of physicians, and geographical locations of the facility [7]. Progressive rural-urban disparities in acute stroke care has been reported in the United States, [8] but it is not known whether such disparity exists in other countries.

In 2010, we launched the J-ASPECT Study, a nationwide survey of acute stroke care capacity for proper designation of a comprehensive stroke center in Japan. [9] [10] The J-ASPECT stroke database is a hospital-based, Japan-wide stroke registry. We demonstrated significant geographical differences in CSC capabilities in 2010,[9] and that CSC capabilities of a facility are associated with reduced in-hospital mortality from acute stroke.[10] Thus continuous monitoring of the CSC capabilities may be clinically meaningful to improve stroke outcomes. [10, 11] Since 2010, we have conducted nationwide benchmark analyses to allow participating hospitals to facilitate improvement of stroke care. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement.

AIMS

We aimed to examine whether CSC capabilities in Japan changed from 2010 to 2018 and whether any recorded changes were influenced by hospital characteristics.

METHODS

Institutional survey of CSC capabilities

The J-ASPECT Study was launched in collaboration with the Japan Neurosurgical Society and Japan Stroke Society, and participation was voluntary. In this study, we sent out questionnaires to the training institutions of both Societies in 2010, 2014 and 2018 to assess CSC capabilities. The CSC capabilities of each facility were assessed with a validated scoring system (CSC score), using 25 items recommended by the Brain Attack Coalition. (2, 5-7)

All items were classified into five categories: personnel, diagnostic, specific expertise, infrastructure, and education. A score of 1 was assigned for meeting each item, yielding a total CSC score of up to 25. Content, constructs, and predictive validity of this scoring system have been reported.[10, 11]

Other hospital characteristics

Hospital characteristics including number of beds, annual stroke hospitalizations, stroke physicians, academic status, adoption of the Diagnosis Procedure Combination (DPC)-based payment system [9], and geographic location were obtained from the 2010 survey. The geographic location was classified according to urban employment areas (UEAs) divided into Metropolitan Employment Areas (MEAs) and Micropolitan

Employment Areas (McEAs).[9] The MEAs were further classified into central and outlying areas based on the commuting pattern of their inhabitants.

Statistical analysis

To explore trends in CSC capabilities, we examined implementation of the 25 items and the CSC score in the 323 consecutively participating hospitals that responded to all surveys. To examine the influence of hospital-related factors on the change in CSC capabilities, we divided the hospitals into those with or without a temporal improvement of CSC score (≥1point increase between 2010 and 2018). Hospital characteristics were compared between the two groups with means or medians for continuous variables and proportions for categorical variables, using Chi-square tests for categorical variables and a Student's t-test for continuous variables.

To explore the influence of hospital-related factors on temporal improvement of CSC capabilities, multiple logistic regression models were used. To assess selection bias, we compared hospital characteristics between consecutively participating hospitals with the others. All analyses were performed using the JMP Statistical Version 12 Software (SAS Institute Inc., Cary, NC, USA). P values of <0.05 were considered statistically significant.

Ethics approval

The study was approved by the Kyushu University Institutional Review Board, which waived the requirement for individual informed consent.

RESULTS

Trends in the CSC capabilities from 2010 to 2018

A total of 749, 532 and 786 hospitals responded to the survey in 2010, 2014, and 2018, respectively. The implementation rates of each item are shown in Table 1a. The median (interquartile range) of the CSC scores was 14 (11-18), 17 (13-19), and 17 (12-20.3), for each year, respectively (Table 1a).

Among consecutively participating hospitals, there was an increase in implementation rates of the 14 items, and the CSC scores were (median, interquartile range): 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively (p for trend<0.001) (Table 1b). A marked increase (≥20%) was noted in six items related to endovascular treatment (endovascular physicians and interventional coverage 24/7) and multidisciplinary care (stroke unit, specialists of emergency medicine and physical medicine/rehabilitation, and stroke rehabilitation nurses).

In addition, a moderate increase (≤20%) was noted in eight items: 24/7 availability of diffusion-weighted magnetic resonance imaging, digital and CT angiography, carotid ultrasound, coiling of an intracranial aneurysm, and implementation of stroke registry. In contrast, there was a marked decrease (≤20%) in community education.

Geographical differences in CSC capabilities between 2010 and 2018

Among the seven items with significant geographical differences in 2010, all items in the personal component still showed a gap, despite overall improvement at all locations in 2018 (Table 2). In contrast, geographical differences in all infrastructure items diminished with overall improvement and a marked improvement in the McEA in 2018.

Over the study period, geographical differences emerged in intra-arterial reperfusion therapy and the number of specialists in physical medicine/rehabilitation. The remaining item, coiling of intracranial aneurysms, showed no changes.

Influence of hospital characteristics on change in CSC capabilities

Among consecutively participating hospitals, 23 were excluded due to missing data. Temporal improvement of CSC capabilities between 2010 and 2018 was noted in 198 hospitals (66.0%). As for hospital characteristics, there were significant differences in bed number (p=0.016) and CSC score in 2010 (p=0.032) between the two groups on univariable analysis (Table 3).

In the logistic regression analyses, the following variables had an association with temporal improvement of CSC capabilities (Table 4): a lower baseline CSC score (odds ratio 0.82 [95% Confidence Interval 0.75-0.9]), bed volume ≥500 (3.90, [1.17–13.0]), and moderate (7-9) number of stroke physicians (2.63, [1.10-6.27]). In contrast, geographical location, academic status, DPC-based payment system, and case volume of stroke did not show a significant association.

Selection bias

The response rates in 2010, 2014, and 2018 surveys were 55.0%, 39.7%, and 49.9%, respectively. There were significant differences in the hospital characteristics between hospitals that consecutively participated in all three surveys and the others (supplementary table 1). Consecutively participating hospitals were more likely to be MEA-central, academic, have a larger number of hospital beds, higher annual stroke admission rate, and more stroke physicians.

DISCUSSION

We found an overall improvement in CSC capabilities between 2010 and 2018, and different trends in geographical disparities based on the component of items. Hospitals with a higher number of hospital beds, intermediate number of stroke physicians, and a lower baseline CSC score had a higher likelihood of improving their CSC capabilities.

Temporal Changes to CSC capabilities

In addition to a significant increase in CSC capabilities, there was a marked increase in implementation of the items, mainly related to endovascular treatment and multidisciplinary care. Of note, we previously showed that interventional 24/7 coverage and the presence of physical medicine/rehabilitation specialists were associated with reduced in-hospital mortality for those with subarachnoid hemorrhage, whereas availability of neurologists and stroke units were associated with reduced in-hospital mortality and better functional outcomes, respectively, for those with ischemic stroke.[11]

These findings are consistent with prior studies, which showed admission to a stroke unit with organized stroke care is associated with better quality of care and outcomes in those who experience an acute stroke. [12 3] The use of mechanical thrombectomy for large vessel acute ischemic stroke (AIS) has been rapidly increasing, but only 3.3% out of 15.1% potentially eligible AIS patients received it in 2016. [13] Improvement of CSC capabilities, especially related to endovascular treatment and multidisciplinary care should contribute to improved quality of care and outcomes in patients with acute stroke.

Decreased implementation of community education may be explained by limited availability of stroke physicians for this purpose due to increased burden of stroke care (e.g. emergent endovascular call). [14] Stroke educational campaigns have the potential to improve knowledge and awareness, but public campaigns are usually expensive and short-lived and may not achieve any significant improvement. [15]

Diminished and emerging geographical disparity

Determining rural/urban differences in CSC capabilities may help in the development of targeted interventions to improve stroke care and outcomes in rural areas. We found different trends in implementation of the items between personnel and infrastructure components. Rural areas are associated with reduced access to optimal stroke care and a lower use of acute stroke intervention.[16] Diminished disparities of implementation of stroke units in this study might result in a higher use of rt-PA infusion in rural areas.[17]

Emerging disparities in implementation of intraarterial reperfusion therapy deserves some attention. Since the evidence regarding acute endovascular reperfusion therapy efficacy was established in 2015, [18] relocation of relevant specialists might have occurred from rural to urban areas to meet urgent needs for more widespread use. In addition, a high prevalence of neurointerventional physician burnout may require centralization of acute endovascular reperfusion treatment. [19]

Influence of hospital-related factors on improvement of CSC capabilities

Our study showed the impact of specific hospital-related factors on improvement of CSC capabilities, which may be useful to determine which hospitals to target to improve CSC capabilities in what regions. In rural areas, where medical resources are limited, centralization of acute stroke care in large hospitals may be needed. It is unclear why the highest quartile of physician volumes was not a significant factor for improvement of CSC capabilities; however, the answer may lie in the presence of a ceiling effect for further improvement.

Limitations

There are several limitations to this study. First, this study may have included biased information. Hospitals actively working to improve stroke care are more likely to respond to the questionnaire. Second, the CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items. Third, we did not determine the influence of unmeasured confounders. Further research is required to examine the influence of

CSC capability improvement on outcomes of patients who experience ischemic and hemorrhagic stroke.

Conclusions

The CSC capabilities in Japan improved between 2010 and 2018, especially related to endovascular treatment and multidisciplinary care. Hospital characteristics may be considered to further improve systems of stroke care in light of limited medical resources in a defined area.

Patient consent for publication

Not required

Data availability statement

We have documented the data, methods, and materials used to conduct the research in this report. The individual patient data are not publicly available because of the memorandum signed by the director of the participating hospitals and the principal investigator of the J-ASPECT Study group.

Authors and contributors

A Kurogi and KI drafted the manuscript. AN, KN, A Kada, DO, AH and KI were involved in study concept, design and obtaining funding. A Kada , DO, AH, KO, YS, TK, KA and KI were involved in analysis and of data. KO, YS, TK and KI were involved in acquisition of data. All authors reviewed the study report, made comments or suggestions on the manuscript drafts, and approved the final version.

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Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest related to the submitted work.

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Table 1.

(a) All participating hospitals; (b) Consecutively participating hospitals

Components	Items	(a) 2010 (n=749)	(a) 2014 (n=532)	(a) 2018 (n=786)	(b) 2010 (n=323)	(b) 2014 (n=323)	(b) 2018 (n=323)	P value
Personnel	Neurologists	358 (47.8)	283 (53.2)	452 (57.5)	176 (54.5)	177 (54.8)	210 (65.0)	0.009
	Neurosurgeons	694 (92.7)	515 (96.8)	754 (95.9)	314 (97.2)	317 (98.1)	317 (98.1)	0.645
	Endovascular physicians	272 (36.3)	280 (52.6)	428 (54.4)	146 (45.2)	196 (60.7)	211 (65.3)	<0.001
	Emergency medicine	162 (21.6)	207 (38.9)	427 (54.3)	96 (29.7)	146 (45.2)	205 (63.5)	<0.001
	Physical medicine and rehabilitation	113 (15.1)	143 (26.9)	313 (39.8)	61 (18.9)	95 (29.4)	137 (42.4)	<0.001
	Rehabilitation therapy	742 (99.1)	529 (99.4)	779 (99.1)	321 (99.4)	321 (99.4)	321 (99.4)	1
	Stroke rehabilitation nurses	102 (13.6)	157 (29.5)	285 (36.2)	48 (14.9)	116 (35.9)	146 (45.2)	<0.001

Diagnostic	CT	742 (99.1)	527 (99.1)	763 (97.1)	322 (99.7)	322 (99.7)	322 (99.7)	1
	MRI with diffusion	647 (86.4)	504 (94.7)	732 (93.1)	291 (90.1)	311 (96.3)	314 (97.2)	<0.001
	Digital cerebral angiography	602 (80.3)	476 (89.4)	638 (81.2)	288 (89.2)	305 (94.4)	299 (92.6)	0.043
	CT angiography	627 (83.7)	492 (92.5)	701 (89.2)	289 (89.5)	305 (94.4)	309 (95.7)	0.004
	Carotid duplex ultrasound	257 (34.3)	219 (41.2)	343 (43.6)	126 (39.0)	153 (47.4)	169 (52.3)	0.003
	Transcranial Doppler ultrasound	121 (16.2)	123 (23.1)	162 (20.6)	70 (21.7)	87 (26.9)	95 (29.4)	0.073
Specific Expertise	Carotid endarterectomy	603 (80.5)	458 (86.1)	613 (78.0)	292 (90.4)	288 (89.2)	284 (87.9)	0.599
	Clipping of intracranial aneurysm	685 (91.5)	504 (94.7)	706 (89.8)	314 (97.2)	315 (97.5)	314 (97.2)	0.961
	Hematoma removal/draining	689 (92.0)	505 (95.0)	718 (91.3)	315 (97.5)	315 (97.5)	314 (97.2)	0.96
	Coiling of	3360 (48.1)	332 (62.4)	448 (57.0)	192 (59.4)	223 (69.0)	223 (69.0)	0.001

	intracranial aneurysm							
	Intra-arterial reperfusion therapy	498 (66.5)	398 (74.8)	510 (64.9)	245 (75.9)	261 (80.8)	247 (76.5)	0.257
Infrastructure	Stroke unit	132 (17.6)	202 (38.0)	342 (43.5)	74 (22.9)	136 (42.1)	171 (52.9)	<0.001
	Intensive care unit	445 (59.4)	362 (68.0)	467 (59.4)	214 (66.3)	224 (69.4)	220 (68.1)	0.698
	Operating room staffed 24/7	451 (60.2)	339 (63.7)	487 (62.0)	230 (71.2)	239 (74.0)	243 (75.2)	0.495
	Interventional services coverage 24/7	279 (37.3)	317 (59.6)	452 (57.5)	147 (45.5)	218 (67.5)	219 (67.8)	<0.001
	Stroke registry	235 (31.4)	260 (48.9)	349 (44.4)	133 (41.2)	172 (53.3)	164 (50.8)	0.005
Education	Community education	369 (49.3)	144 (27.1)	204 (26.0)	188 (58.2)	91 (28.2)	98 (30.3)	<0.001
	Professional education	436 (58.2)	326 (61.3)	429 (54.6)	207 (64.1)	208 (64.4)	184 (57.0)	0.089
Total CSC score								

median, (IQR)	14 (11, 18)	17 (13, 19)	17 (12, 20.3)	16 (13, 19)	18 (14, 20)	19 (15, 21)	<0.001

Table 2.

		a) 2010				b) 2018		
		MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)	P value	MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)
Personnel	Neurologists	115 (61.8)	44 (55.7)	10 (28.6)	0.001	133(71.5)	55(69.6)	14 (40.0)
	Neurosurgeons	181 (97.3)	77 (97.5)	34 (97.1)	0.995	183 (98.4)	78 (98.7)	34 (97.1)
	Endovascular physicians	101 (54.3)	31 (39.2)	8 (22.9)	<0.001	136 (73.1)	49 (62.0)	14 (40.0)
	Emergency medicine	57 (30.7)	25 (31.7)	7 (20.0)	0.406	122 (65.6)	54 (68.4)	16 (45.7)
	Physical medicine and rehabilitation	36 (19.4)	16 (20.3)	5 (14.3)	0.740	83 (44.6)	42 (53.2)	3 (8.6)
	Rehabilitation therapy	185 (99.5)	78 (98.7)	35 (100)	0.701	185 (99.5)	78 (98.7)	35 (100)
	Stroke	33 (17.8)	9 (11.4)	1 (2.9)	0.049	90 (48.4)	41 (51.9)	9 (25.7)

	rehabilitation nurses							
Diagnostic	CT	185 (99.5)	79 (100.0)	35 (100.0)	0.735	185 (100)	79 (100)	35 (100)
	MRI with diffusion	167 (89.8)	69 (87.3)	33 (94.3)	0.530	179 (96.2)	78 (98.7)	35 (100)
	Digital cerebral angiography	165 (88.7)	70 (88.6)	34 (97.1)	0.303	168 (90.3)	76 (96.2)	33 (94.3)
	CT angiography	163 (87.6)	72 (91.1)	32 (91.4)	0.627	176 (94.6)	77 (97.5)	34 (97.1)
	Carotid duplex ultrasound	71 (38.1)	30 (38.0)	14 (40.0)	0.977	95 (51.1)	48 (60.8)	15 (42.9)
	TCD	43 (23.1)	18 (22.8)	3 (8.6)	0.146	54 (29.0)	29 (36.7)	5 (14.3)
Specific Expertise	Carotid endarterectomy	173 (93.0)	68 (86.1)	32 (91.4)	0.196	166 (89.3)	71 (89.9)	28 (80)
	Clipping of intracranial aneurysm	183 (98.4)	75 (94.9)	34 (97.1)	0.280	181 (97.3)	77 (97.5)	34 (97.1)
	Hematoma removal/draining	183 (98.4)	76 (96.2)	34 (97.1)	0.546	182 (97,9)	77 (97.5)	35 (94.3)

	Coiling of intracranial aneurysm	119 (64.0)	46 (58.2)	13 (37.1)	0.012	143 (76.9)	49 (62.0)	17 (48.6)
	Intra-arterial reperfusion therapy	142 (76.3)	58 (73.4)	27 (77.1)	0.859	153 (82.3)	57 (72.2)	22 (62.9)
Infrastructure	Stroke unit	50 (26.9)	17 (21.5)	2 (5.7)	0.023	106 (57.0)	44 (55.7)	13 (37.1)
	Intensive care unit	123 (66.1)	54 (68.4)	21 (60.0)	0.685	134 (72.0)	54 (68.4)	18 (51.4)
	Operating room staffed 24/7	143 (76.9)	59 (74.7)	15 (42.9)	<0.001	148 (79.6)	56 (70.9)	22 (62.9)
	Interventional services coverage 24/7	103 (55.4)	30 (38.0)	6 (17.1)	<0.001	133 (71.5)	54 (68.4)	18 (51.4)
	Stroke registry	81 (43.6)	31 (29.1)	15 (42.9)	0.808	93 (50.0)	47 (59.5)	15 (42.9)
Education	Community education	110 (59.1)	53 (67.1)	17 (48.6)	0.164	55 (29.6)	28 (35.4)	8 (22.9)

	Professional education	125 (67.2)	53 (67.1)	17 (48.6)	0.095	105 (56.5)	47 (59.5)	17 (48.6)

*MEA metropolitan, McEA microplitan

Table 3.

Hospital-related factors in 2010	All Hsps. (n=300)	Improvement Hsps. (n=198)	No improvement Hsps. (n=102)	p value[#]
Hospital locations				0.478
MEA central	186 (62.0)	121 (61.1)	65 (63.7)	
MEA outlying	79 (26.3)	56 (28.3)	23 (22.6)	
McEA	35 (11.7)	21 (10.6)	14 (13.7)	
CSC score in 2010				
median (IQR)	16 (13, 19)	16 (13, 18)	17 (13, 20)	0.032
Academic hospital	58 (19.3)	42 (21.2)	16 (15.7)	0.251
DPC* hospital	225 (75.0)	145 (73.2)	80 (78.4)	0.325
Number of hospital beds				0.016

1-99	17 (5.7)	9 (4.6)	8 (7.8)	
100-299	68 (22.7)	37 (18.7)	31 (30.4)	
300-499	96 (32.0)	62 (31.1)	34 (33.3)	
≧500	119 (39.7)	90 (45.5)	29 (28.4)	
Annual stroke case volume				0.915
0-99	34 (11.3)	21 (10.6)	13 (12.8)	
100-199	73 (24.3)	47 (23.7)	26 (25.5)	
200-299	67 (22.3)	45 (22.7)	22 (21.6)	
≧300	126 (42.0)	85 (42.9)	41 (40.2)	
Number of stroke physicians				0.139
median (IQR)	6 (3, 9)	6 (3.8, 9)	5 (3, 9.3)	
0-3	82 (27.3)	49 (24.8)	33 (32.4)	
4-6	68 (22.7)	43 (21.7)	25 (24.5)	
7-9	80 (26.7)	61 (30.8)	19 (18.6)	

≧10	70 (23.3)	45 (22.7)	25 (24.5)

*DPC: Diagnostic Procedure Combination, Hsp: hospital, # p value: Improvement vs. No improvement hospitals, MEA: metropolitan, McEA: micropolitan

Table 4.

Hospital-related factors in 2010	Odds	95%CI	P value
Hospital locations			
MEA central	1.00		
MEA outlying	1.42	0.76-2.65	0.269
McEA	0.82	0.36-1.86	0.632
CSC score in 2010	0.82	0.75-0.90	<0.001
Academic hospital	1.37	0.54-3.48	0.506
DPC hospital	0.77	0.41-1.42	0.397
Number of beds			
1-99	1.00		
100-299	1.16	0.37-3.66	0.794
300-499	1.68	0.56-5.10	0.358

≥500	3.90	1.17-13.00	0.027
Annual stroke case volume			
1-99	1.00		
100-199	1.62	0.64-4.07	0.305
200-299	2.41	0.89-6.49	0.083
≥300	2.74	0.99-7.54	0.051
Number of stroke physicians			
0-3	1.00		
4-6	1.77	0.81-3.88	0.153
7-9	2.63	1.10-6.27	0.030
≥10	1.58	0.57-4.38	0.380

Supplemental material

eTable 1. Univariable analysis of association between consecutively participating hospitals in all three surveies and the others eTable 1

	All Hsps. in 2010 (n=749)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=426)	p value
Hospital location				<0.001
MEA central	381 (50.9)	193 (59.8)	188 (44.1)	
MEA outlying	239 (31.9)	83 (25.7)	156(36.6)	
McEA	102 (13.6)	38 (11.8)	64 (15.0)	
Unclassified	27 (3.6)	9 (2.8)	18 (4.2)	
CSC score at 2010				
median (IQR)	14 (11, 18)	16 (13, 19)	13 (10, 17)	<0.001
Academic hospital	90 (12.1)	61 (18.9)	29 (6.8)	<0.001
DPC hospital	553 (73.8)	237 (73.4)	316 (74.2)	0.804
Number of beds				<0.001
-99	50 (6.7)	19 (5.9)	31 (7.3)	
100-299	232 (31.0)	75 (23.2)	157 (36.9)	
300-499	260 (34.7)	105 (32.5)	155 (36.4)	
≥500	207 (27.6)	124 (38.4)	83 (19.5)	
Annual stroke volume				<0.001
-99	129 (17.2)	36 (11.2)	93 (21.8)	

100-199	199 (26.5)	76 (23.5)	123 (28.9)	
200-299	155 (20.7)	70 (21.7)	85 (20.0)	
≥300	228 (30.4)	127 (39.3)	101 (23.7)	
N/A	38 (5.1)	14 (4.3)	24 (5.6)	
Stroke physician				<0.001
median (IQR)	4 (3, 7)	5 (3, 9)	4 (2, 6)	

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Temporal trends and geographical disparities in comprehensive stroke centre capabilities in Japan from 2010 to 2018

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ABSTRACT

Objectives: Comprehensive stroke centre (CSC) capabilities are associated with reduced in-hospital mortality due to acute stroke. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement. This study examined whether CSC capabilities changed in Japan between 2010 and 2018, and whether any changes were influenced by hospital characteristics.

Design: A hospital-based cross-sectional study.

Setting: We sent out questionnaires to the training institutions of the Japan Neurosurgical Society and Japan Stroke Society in 2010, 2014 and 2018.

Participants: 749 in 2010, 532 in 2014 and 786 in 2018 hospitals that participate in the J-ASPECT study.

Main outcome measures: CSC capabilities were assessed using the validated scoring system (CSC score:1-25 points) in 2010, 2014, and 2018 survey. The effect of hospital characteristics was examined using multiple logistic regression analysis.

Results: Among the 323 hospitals that responded to all surveys, the implementation of 14 recommended items increased. The CSC score (median, interquartile range) was 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively ($p < 0.001$). There was a ≥ 20% increase in six items (e.g. endovascular physicians, stroke unit, and interventional coverage 24/7), and a ≤ 20% decrease in community education. A lower baseline CSC score (odds ratio 0.82, [95% confidence interval] 0.75-0.9), the number of beds ≥ 500 (3.9 [1.2–13.0]), and the number of stroke physicians (7-9) (2.6 [1.1-6.3]) was associated with improved CSC capabilities, independent of geographical location.

Conclusions: There was a significant improvement in CSC capabilities between 2010 and 2018, which was mainly related to the availability of endovascular treatment and multidisciplinary care. Our findings may be useful to determine which hospitals should be targeted to improve CSC capabilities in a defined area.

Strengths and limitations of this study:

・A large-scale, representative hospitals of Japan provided data on temporal trends in the CSC capabilities for this cross-sectional study.

- Hospitals actively working to improve stroke care are more likely to respond to the questionnaire, which may lead to information bias.
- The CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items.

INTRODUCTION

Stroke is the third leading cause of death and a leading cause of long-term disability in Japan. Primary and comprehensive stroke centres (CSCs) were developed to provide optimal implementation of intravenous recombinant tissue plasminogen activator (rt-PA) infusion and more intensive stroke care that includes endovascular and neurosurgical treatment. [1, 2] Organised care in a stroke unit is associated with better quality of care and reduced death and dependency. [3, 4] In addition to the influence of this process, previous studies have shown that patient outcomes associated with stroke and cardiovascular diseases are influenced by the hospital case volume, [5, 6] number of physicians, and geographical locations of the facility [7]. Progressive rural-urban disparities in acute stroke care have been reported in the United States, [8] but it is not known whether such disparity exists in other countries.

In 2010, we launched the J-ASPECT study, a nationwide survey of acute stroke care capacity for proper designation of a comprehensive stroke centre in Japan. [9 10] The J-ASPECT stroke database is a hospital-based, Japan-wide stroke registry. We demonstrated significant geographical differences in CSC capabilities in 2010,[9] and that CSC capabilities of a facility are associated with reduced in-hospital mortality from acute stroke.[10] Thus continuous monitoring of the CSC capabilities may be clinically meaningful to improve stroke outcomes. [10, 11] Since 2010, we have conducted nationwide benchmark analyses to allow participating hospitals to facilitate improvement of stroke care. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement.

AIMS

We aimed to examine whether CSC capabilities in Japan changed from 2010 to 2018 and whether any recorded changes were influenced by hospital characteristics.

METHODS

Institutional survey of CSC capabilities

This cross-sectional survey used the DPC discharge database from participating institutions in the J-ASPECT study. Participation in the J-ASPECT study was voluntary. Of the 1369 training institutions certified by the Japan Neurosurgical Society, the Japanese Society of Neurology, and the Japan Stroke Society, 621 agreed to participate in this study. The J-ASPECT study group analysed the Diagnosis Procedure Combination (DPC) database to gain new clinical insights on ischaemic and haemorrhagic stroke, an approach we applied again for this cross-sectional survey. In this study, we sent out questionnaires to the training institutions of all three societies in 2010, 2014, and 2018 to assess CSC capabilities. The CSC capabilities of each facility were assessed with a validated scoring system (CSC score), using 25 items recommended by the Brain Attack Coalition [2, 5-7].

All items were classified into five categories: personnel, diagnostic, specific expertise, infrastructure, and education. A score of 1 was assigned for meeting each item, yielding a total CSC score of up to 25. Content, constructs, and predictive validity of this scoring system have been previously reported.[12, 13]

Other hospital characteristics

Hospital characteristics including number of beds, annual stroke hospitalisations, stroke physicians, academic status, adoption of the Diagnosis Procedure Combination (DPC)-based payment system [9], and geographic location were obtained from the 2010 survey. The geographic location was classified according to urban employment areas (UEAs) divided into Metropolitan Employment Areas (MEAs) and Micropolitan Employment Areas (McEAs).[9] The MEAs were further classified into central and outlying areas based on the commuting pattern of their inhabitants. Details of UEAs, such as total population or total land area, have been previously described.[10]

Statistical analysis

To explore trends in CSC capabilities, we examined implementation of the 25 items and the CSC score in the 323 consecutively participating hospitals that responded to all surveys. To examine the influence of hospital-related factors on the change in CSC capabilities, we divided the hospitals into those with or without a temporal improvement of CSC score (≥1-point increase between 2010 and 2018). The increase of "One point" was set based on our previous report on the CSC score.[11] In that study, we showed that even a small preceding improvement of the CSC score was associated with reduced in-hospital mortality, reduced poor outcomes, and higher use of acute reperfusion therapy in AIS patients; our findings also suggested the difficulty in improving the CSC score in a relatively short time period.

We used a chi-squared test to detect differences between consecutively participating hospitals and other hospitals in the number of each hospital item. We did not perform multiple tests. Wilcoxon rank sum test was used to compare total CSC scores between consecutively participating hospitals and other hospitals.

To explore the influence of hospital-related factors on temporal improvement of CSC capabilities, multiple logistic regression models were used. To assess selection bias, we compared hospital characteristics between consecutively participating hospitals with the others. We also examined the relationship between "number of physicians" and "hospital size" and the relationship between "number of physicians" and "CSC score" using chi-squared tests. All analyses were performed using the JMP Statistical Version 12 Software (SAS Institute Inc., Cary, NC, USA). P values of <0.05 were considered statistically significant.

Patient and public involvement

Data for this study are based on information collected by the J-ASPECT study. Patients and the public were not involved in the development of this study.

RESULTS

Trends in the CSC capabilities from 2010 to 2018

A total of 749, 532, and 786 hospitals responded to the survey in 2010, 2014, and 2018, respectively. The implementation rates of each item are shown in Table 1. The median (interquartile range) of the CSC scores was 14 (11-18), 17 (13-19), and 17 (12-20.3), for each year, respectively (Table 1).

Among consecutively participating hospitals, there was an increase in implementation rates of the 14 items, and the CSC scores were (median, interquartile range): 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively ($p < 0.001$) (Table 1). A marked increase (≥20%) was noted in six items related to endovascular treatment (endovascular physicians and interventional coverage 24/7) and multidisciplinary care (stroke unit, specialists of emergency medicine and physical medicine/rehabilitation, and stroke rehabilitation nurses).

In addition, a moderate increase (≤20%) was noted in eight items: 24/7 availability of diffusion-weighted magnetic resonance imaging, digital and CT angiography, carotid ultrasound, coiling of an intracranial aneurysm, and implementation of stroke registry. In contrast, there was a marked decrease (≤20%) in community education.

Geographical differences in CSC capabilities between 2010 and 2018

Among the seven items with significant geographical differences in 2010, all items in the personal component still showed a gap, despite overall improvement at all locations in 2018 (Table 2). In contrast, geographical differences in all infrastructure items diminished with overall improvement and a marked improvement in the McEA in 2018.

Over the study period, geographical differences emerged in intra-arterial reperfusion therapy and the number of specialists in physical medicine/rehabilitation. The remaining item, coiling of intracranial aneurysms, showed no changes.

Influence of hospital characteristics on change in CSC capabilities

Among consecutively participating hospitals, 23 were excluded due to missing data. Temporal improvement of CSC capabilities between 2010 and 2018 was noted in 198 hospitals (66.0%). As for hospital characteristics, there were weakly significant differences in bed number (p=0.016) and CSC score in 2010 (p=0.032) between the two groups on univariable analysis (Table 3).

In the logistic regression analyses, the following variables had an association with temporal improvement of CSC capabilities (Table 4): a lower baseline CSC score (odds ratio 0.82 [95% confidence interval 0.75-0.9]), bed volume ≥500 (3.90, [1.17–13.0]), and moderate (7-9) number of stroke physicians (2.63, [1.10-6.27]). In contrast, geographical location, academic status, DPC-based payment system, and case volume of stroke did not show a significant association. We also performed the logistic regression analysis adjusting tertile, instead of quartile, of stroke physician volume in addition to the other adjusting factors. Except for Q3 of stroke physician volume, we found very similar results (Supplementary Table 1). Additionally, there was a significant relationship between hospital size and number of physicians (P<0.001), and between CSC score and number of physicians (P<0.001).

Selection bias

The response rates of the 2010, 2014, and 2018 surveys were 55.0%, 39.7%, and 49.9%, respectively. We found that a selection bias did exist; in fact, the total CSC scores and most of the implementation rates of each item were significantly higher for the consecutively participating hospitals than for the others in all three surveys (Table 1). Consecutively participating hospitals were more likely to be MEA-central, academic, have a larger number of hospital beds, higher annual stroke admission rate, and more stroke physicians (Supplementary Table 2).

DISCUSSION

We found an overall improvement in CSC capabilities between 2010 and 2018, and different trends in geographical disparities for different items. Hospitals with a higher number of hospital beds, intermediate number of stroke physicians, and a lower baseline CSC score had a higher likelihood of improving their CSC capabilities.

Temporal Changes to CSC capabilities

In addition to a significant increase in CSC capabilities, there was a marked increase in implementation of the items, mainly related to endovascular treatment and multidisciplinary care. Of note, we previously showed that interventional 24/7 coverage and the presence of physical medicine/rehabilitation specialists were associated with reduced in-hospital mortality for patients with subarachnoid haemorrhage, whereas availability of neurologists and stroke units were associated with reduced in-hospital mortality and better functional outcomes, respectively, for those with ischaemic stroke.[13]

These findings are consistent with those of prior studies, which have shown that admission to a stroke unit with organised stroke care is associated with better quality of care and outcomes in those who experience an acute stroke. [14 3] Although the use of mechanical thrombectomy for large vessel acute ischaemic stroke (AIS) has been rapidly increasing, only 3.3% of 15.1% potentially eligible AIS patients received it in 2016. [15] Improvement of CSC capabilities, especially related to endovascular treatment and multidisciplinary care, should contribute to improved quality of care and outcomes in patients with acute stroke.

The decreased implementation of community education observed in this study may be explained by the limited number of stroke physicians available for this purpose due to an increased burden of stroke care (e.g. emergent endovascular calls). [16] Stroke educational campaigns have the potential to improve knowledge and awareness, but public campaigns are usually expensive and short-lived and may not achieve any significant improvement. [17]

Diminished and emerging geographical disparities

Determining rural/urban differences in CSC capabilities may support the development of targeted interventions to improve stroke care and outcomes in rural areas. We found differing trends in implementation of the items according to personnel and infrastructure components. Rural areas are associated with reduced access to optimal stroke care and a lower use of acute stroke intervention.[18] The diminished disparities in implementation of stroke units in this study might result in a higher use of rt-PA infusion in rural areas.[19]

The emerging disparities in implementation of intraarterial reperfusion therapy deserve some attention. Since the evidence regarding the efficacy of acute endovascular reperfusion therapy was established in 2015,[20] relocation of relevant specialists might have occurred from rural to urban areas to meet the urgent need created by more widespread use. In addition, a high prevalence of neurointerventional physician burnout may require centralisation of acute endovascular reperfusion treatment.[21]

Influence of hospital-related factors on improvement of CSC capabilities

Our study showed the impact of specific hospital-related factors on improvement of CSC capabilities, which may be useful to determine which hospitals should be targeted to improve CSC capabilities, and in what regions. In rural areas, where medical resources are limited, centralisation of acute stroke care in large hospitals may be needed. We also found a significant relationship between CSC score and number of physicians. This means that, in 2010, institutions with more physicians tended to have higher baseline CSC scores. The reason that a physician volume of more than 10 did not affect the improvement of the CSC score may be explained by the ceiling effect of a high baseline CSC score in 2010.

Limitations

There are several limitations of this study. First, this findings may have included biased information. Hospitals actively working to improve stroke care would be more likely to respond to the questionnaire. Second, the CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items. Third, we did not determine the influence of unmeasured confounders. Fourth, the CSC score is a self-reported questionnaire rather than the result of any formal certification process. In Japan, the official certification process for PSCs (primary stroke centres) just began in 2019. The criteria for CSC certification is now under discussion by the Japan Stroke Society. The results of this study could have a significant impact on the recommended items and criteria for the designation of official CSCs in Japan. After the official certification process for CSCs is implemented, we plan to reassess the effect of CSC capabilities on AIS patients. Finally, the 2014 data did not factor into this analysis because of the small number of participants in that year. Further research is required to examine the effect of 2014 data on the analysis.

Conclusions

The CSC capabilities in Japan improved between 2010 and 2018, especially related to endovascular treatment and multidisciplinary care. Our findings may be useful to determine which hospitals should be targeted to improve CSC capabilities in a defined area.

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Competing interests statement

None declared.

Ethics approval

The study was approved by the Kyushu University Institutional Review Board, which waived the requirement for individual informed consent (No. 28-335)

Data availability statement

We have documented the data, methods, and materials used to conduct the research in this report. The individual patient data are not publicly available because of the memorandum signed by the director of the participating hospitals and the principal investigator of the J-ASPECT Study group.

Authors and contributors

A Kurogi and KI drafted the manuscript. AN, KN, A Kada, DO, AH and KI were involved in study concept, design and obtaining funding. A Kada , DO, AH, KO, YS, TK, KA and KI were involved in analysis and of data. KO, YS, TK and KI were involved in acquisition of data. All authors reviewed the study report, made comments or suggestions on the manuscript drafts, and approved the final version.

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Patient consent for publication

Not required.

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Table 1. Number (percentage) of the responding hospitals fulfilling the recommended items of comprehensive stroke care capabilities

Components	Items	2010				2014		
		All participating Hsps. (n=749)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=426)	p value	All participating Hsps. (n=532)	Consecutively participating Hsps. (n=323)	C
Personnel	Neurologists	358 (47.8)	176 (54.5)	182 (42.7)	0.001	283 (53.2)	177 (54.8)	10
	Neurosurgeons	694 (92.7)	314 (97.2)	380 (89.2)	<0.001	515 (96.8)	317 (98.1)	19
	Endovascular physicians	272 (36.3)	146 (45.2)	126 (29.6)	<0.001	280 (52.6)	196 (60.7)	84
	Emergency medicine	162 (21.6)	96 (29.7)	66 (15.5)	<0.001	207 (38.9)	146 (45.2)	61

	Physical medicine and rehabilitation	113 (15.1)	61 (18.9)	52 (12.2)	0.011	143 (26.9)	95 (29.4)	48
	Rehabilitation therapy	742 (99.1)	321 (99.4)	421 (98.8)	0.435	529 (99.4)	321 (99.4)	20
	Stroke rehabilitation nurses	102 (13.6)	48 (14.9)	54 (12.7)	0.388	157 (29.5)	116 (35.9)	41
Diagnostic	CT	742 (99.1)	322 (99.7)	420 (98.6)	0.122	527 (99.1)	322 (99.7)	20
	MRI with diffusion	647 (86.4)	291 (90.1)	356 (83.6)	0.01	504 (94.7)	311 (96.3)	19
	Digital cerebral angiography	602 (80.3)	288 (89.2)	314 (73.7)	<0.001	476 (89.4)	305 (94.4)	17
	CT angiography	627 (83.7)	289 (89.5)	338 (79.3)	<0.001	492 (92.5)	305 (94.4)	18
	Carotid duplex ultrasound	257 (34.3)	126 (39.0)	131 (30.8)	0.018	219 (41.2)	153 (47.4)	66

	TCD	121 (16.2)	70 (21.7)	51 (12.0)	<0.001	123 (23.1)	87 (26.9)	36
Specific Expertise	Carotid endarterectomy	603 (80.5)	292 (90.4)	311 (73.0)	<0.001	458 (86.1)	288 (89.2)	17
	Clipping of intracranial aneurysm	685 (91.5)	314 (97.2)	371 (87.1)	<0.001	504 (94.7)	315 (97.5)	18
	Hematoma removal/draining	689 (92.0)	315 (97.5)	374 (87.8)	<0.001	505 (95.0)	315 (97.5)	19
	Coiling of intracranial aneurysm	360 (48.1)	192 (59.4)	168 (39.4)	<0.001	332 (62.4)	223 (69.0)	10
	Intra-arterial reperfusion	498 (66.5)	245 (75.9)	253 (59.4)	<0.001	398 (74.8)	261 (80.8)	13

	therapy							
Infrastructure	Stroke unit	132 (17.6)	74 (22.9)	58 (13.6)	<0.001	202 (38.0)	136 (42.1)	66
	Intensive care unit	445 (59.4)	214 (66.3)	231 (54.2)	<0.001	362 (68.0)	224 (69.4)	13
	Operating room staffed 24/7	451 (60.2)	230 (71.2)	221 (51.9)	<0.001	339 (63.7)	239 (74.0)	10
	Interventional services coverage 24/7	279 (37.3)	147 (45.5)	132 (31.0)	<0.001	317 (59.6)	218 (67.5)	99
	Stroke registry	235 (31.4)	133 (41.2)	102 (23.9)	<0.001	260 (48.9)	172 (53.3)	88
Education	Community education	369 (49.3)	188 (58.2)	181 (42.5)	<0.001	144 (27.1)	91 (28.2)	53
	Professional education	436 (58.2)	207 (64.1)	229 (53.8)	0.005	326 (61.3)	208 (64.4)	11
Total CSC score								

median, (IQR)	14 (11, 18)	16 (13, 19)	13 (10, 17)	<0.001	17 (13, 19)	18 (14, 20)	15

Hsp, hospital; CT, computed tomography; MRI, magnetic resonance imaging; TCD, transcranial Doppler.

Table 2. Characteristics of comprehensive stroke care capabilities according to the geographical differences

		a) 2010				b) 2018		
		MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)	P value	MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)
Personnel	Neurologists	115 (61.8)	44 (55.7)	10 (28.6)	0.001	133(71.5)	55(69.6)	14 (40.0)
	Neurosurgeons	181 (97.3)	77 (97.5)	34 (97.1)	0.995	183 (98.4)	78 (98.7)	34 (97.1)
	Endovascular physicians	101 (54.3)	31 (39.2)	8 (22.9)	<0.001	136 (73.1)	49 (62.0)	14 (40.0)
	Emergency medicine	57 (30.7)	25 (31.7)	7 (20.0)	0.406	122 (65.6)	54 (68.4)	16 (45.7)
	Physical medicine and rehabilitation	36 (19.4)	16 (20.3)	5 (14.3)	0.740	83 (44.6)	42 (53.2)	3 (8.6)
	Rehabilitation therapy	185 (99.5)	78 (98.7)	35 (100)	0.701	185 (99.5)	78 (98.7)	35 (100)

	Stroke rehabilitation nurses	33 (17.8)	9 (11.4)	1 (2.9)	0.049	90 (48.4)	41 (51.9)	9 (25.7)
Diagnostic	CT	185 (99.5)	79 (100.0)	35 (100.0)	0.735	185 (100)	79 (100)	35 (100)
	MRI with diffusion	167 (89.8)	69 (87.3)	33 (94.3)	0.530	179 (96.2)	78 (98.7)	35 (100)
	Digital cerebral angiography	165 (88.7)	70 (88.6)	34 (97.1)	0.303	168 (90.3)	76 (96.2)	33 (94.3)
	CT angiography	163 (87.6)	72 (91.1)	32 (91.4)	0.627	176 (94.6)	77 (97.5)	34 (97.1)
	Carotid duplex ultrasound	71 (38.1)	30 (38.0)	14 (40.0)	0.977	95 (51.1)	48 (60.8)	15 (42.9)
	TCD	43 (23.1)	18 (22.8)	3 (8.6)	0.146	54 (29.0)	29 (36.7)	5 (14.3)
Specific Expertise	Carotid endarterectomy	173 (93.0)	68 (86.1)	32 (91.4)	0.196	166 (89.3)	71 (89.9)	28 (80)
	Clipping of intracranial aneurysm	183 (98.4)	75 (94.9)	34 (97.1)	0.280	181 (97.3)	77 (97.5)	34 (97.1)
	Hematoma removal/draining	183 (98.4)	76 (96.2)	34 (97.1)	0.546	182 (97,9)	77 (97.5)	35 (94.3)
	Coiling of intracranial aneurysm	119 (64.0)	46 (58.2)	13 (37.1)	0.012	143 (76.9)	49 (62.0)	17 (48.6)

	Intra-arterial reperfusion therapy	142 (76.3)	58 (73.4)	27 (77.1)	0.859	153 (82.3)	57 (72.2)	22 (62.9)
Infrastructure	Stroke unit	50 (26.9)	17 (21.5)	2 (5.7)	0.023	106 (57.0)	44 (55.7)	13 (37.1)
	Intensive care unit	123 (66.1)	54 (68.4)	21 (60.0)	0.685	134 (72.0)	54 (68.4)	18 (51.4)
	Operating room staffed 24/7	143 (76.9)	59 (74.7)	15 (42.9)	<0.001	148 (79.6)	56 (70.9)	22 (62.9)
	Interventional services coverage 24/7	103 (55.4)	30 (38.0)	6 (17.1)	<0.001	133 (71.5)	54 (68.4)	18 (51.4)
	Stroke registry	81 (43.6)	31 (29.1)	15 (42.9)	0.808	93 (50.0)	47 (59.5)	15 (42.9)
Education	Community education	110 (59.1)	53 (67.1)	17 (48.6)	0.164	55 (29.6)	28 (35.4)	8 (22.9)
	Professional education	125 (67.2)	53 (67.1)	17 (48.6)	0.095	105 (56.5)	47 (59.5)	17 (48.6)

*MEA

metropolitan,

McEA

microplitan

Table 3. Hospital characteristics those with/without temporal improvement of the CSC capabilities

Hospital-related factors in 2010	all Consecutively participating Hsps. (n=300)	Improvement Hsps. (n=198)	No improvement Hsps. (n=102)	p value#
Hospital locations				0.478
MEA central	186 (62.0)	121 (61.1)	65 (63.7)	
MEA outlying	79 (26.3)	56 (28.3)	23 (22.6)	
McEA	35 (11.7)	21 (10.6)	14 (13.7)	
CSC score in 2010				
median (IQR)	16 (13, 19)	16 (13, 18)	17 (13, 20)	0.032
Academic hospital	58 (19.3)	42 (21.2)	16 (15.7)	0.251
DPC* hospital	225 (75.0)	145 (73.2)	80 (78.4)	0.325
Number of hospital beds				0.016
1-99	17 (5.7)	9 (4.6)	8 (7.8)	
100-299	68 (22.7)	37 (18.7)	31 (30.4)	
300-499	96 (32.0)	62 (31.1)	34 (33.3)	

≥500	119 (39.7)	90 (45.5)	29 (28.4)	
Annual stroke case volume				0.915
0-99	34 (11.3)	21 (10.6)	13 (12.8)	
100-199	73 (24.3)	47 (23.7)	26 (25.5)	
200-299	67 (22.3)	45 (22.7)	22 (21.6)	
≥300	126 (42.0)	85 (42.9)	41 (40.2)	
Number of stroke physician volume				
median (IQR)	6 (3, 9)	6 (3.8, 9)	5 (3, 9.3)	0.139
Number of stroke physicians, quartile				
Q1 (0-3)	82 (27.3)	49 (24.8)	33 (32.4)	
Q2 (4-6)	68 (22.7)	43 (21.7)	25 (24.5)	
Q3 (7-9)	80 (26.7)	61 (30.8)	19 (18.6)	
Q4 (≥10)	70 (23.3)	45 (22.7)	25 (24.5)	
Number of stroke physicians, tertile				
T1 (0-4)	114 (38.0)	72 (36.4)	42 (41.2)	
T2 (4-8)	96 (32.0)	63 (31.8)	33 (32.4)	
T3 (≥9)	90 (30.0)	63 (31.8)	27 (26.5)	

*DPC: Diagnostic Procedure Combination, Hsp: hospital, # p value: Improvement vs. No improvement hospitals, MEA: metropolitan, McEA: micropolitan

Table 4. Multivariable analysis of the impact of hospital characteristics on one-point increases of the CSC score

Hospital-related factors in 2010	Odds	95%CI	P value
Hospital locations			
MEA central	ref.		
MEA outlying	1.42	0.76-2.65	0.269
McEA	0.82	0.36-1.86	0.632
CSC score in 2010	0.82	0.75-0.90	**<0.001**

Academic hospital	1.37	0.54-3.48	0.506
DPC hospital	0.77	0.41-1.42	0.397
Number of beds			
1-99	ref.		
100-299	1.16	0.37-3.66	0.794
300-499	1.68	0.56-5.10	0.358
≥500	3.9	1.17-13.00	**0.027**

Annual stroke case volume			
1-99	ref.		
100-199	1.62	0.64-4.07	0.305
200-299	2.41	0.89-6.49	0.083
≥300	2.74	0.99-7.54	0.051
Number of stroke physician volume quartile			
Q1 (0-3)	ref.		
Q2 (4-6)	1.77	0.81-3.88	0.153

Q3 (7-9)	2.63	1.10-6.27	**0.030**
Q4 (≥10)	1.58	0.57-4.38	0.380

*DPC: Diagnostic Procedure Combination, Hsp: hospital, # p value: Improvement vs. No improvement hospitals, MEA: metropolitan, McEA: micropolitan

Supplemental material

eTable 1. Multivariable analysis of the impact of the hospital characteristics on one-point increase of the CSC score

eTable 2. Univariable analysis of association between consecutively participating hospitals in all three surveies and the others

Supplemental Appendix 1. List of the J-ASPECT Study Collaborators.

eTable 1 Multivariable analysis of the impact of the hospital characteristics on one-point increase of the CSC score

Hospital-related factors in 2010	Odds	95%CI	P value
Hospital locations			
MEA central	ref.		
MEA outlying	1.35	0.36-2.48	0.339
McEA	0.78	0.35-1.75	0.549
CSC score in 2010	0.83	0.76-0.91	**<0.001**
Academic hospital	1.29	0.52-3.24	0.582
DPC hospital	0.72	0.39-1.34	0.302
Number of beds			
1-99	ref.		
100-299	1.1	0.36-3.41	0.868
300-499	1.82	0.60-5.48	0.285
≥500	3.81	1.16-12.54	**0.028**
Annual stroke case volume			

1-99	ref.		
100-199	1.68	0.67-4.18	0.267
200-299	2.47	0.92-6.61	0.072
≥300	3.17	1.16-8.66	**0.024**
Number of stroke physicians, tertile			
T1 (0-4)	ref.		
T2 (4-8)	1.12	0.58-2.16	0.745
T3 (≥9)	1.35	0.57-3.21	0.492

eTable 2 Univariable analysis of association between consecutively participating hospitals in all three surveies and the others

	All Hsps. in 2010 (n=749)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=426)	p value
Hospital location				<0.001
MEA central	381 (50.9)	193 (59.8)	188 (44.1)	
MEA outlying	239 (31.9)	83 (25.7)	156(36.6)	
McEA	102 (13.6)	38 (11.8)	64 (15.0)	
Unclassified	27 (3.6)	9 (2.8)	18 (4.2)	
CSC score at 2010				
median (IQR)	14 (11, 18)	16 (13, 19)	13 (10, 17)	<0.001
Academic hospital	90 (12.1)	61 (18.9)	29 (6.8)	<0.001
DPC hospital	553 (73.8)	237 (73.4)	316 (74.2)	0.804
Number of beds				<0.001
-99	50 (6.7)	19 (5.9)	31 (7.3)	
100-299	232 (31.0)	75 (23.2)	157 (36.9)	
300-499	260 (34.7)	105 (32.5)	155 (36.4)	
≥500	207 (27.6)	124 (38.4)	83 (19.5)	
Annual stroke volume				<0.001
-99	129 (17.2)	36 (11.2)	93 (21.8)	

100-199	199 (26.5)	76 (23.5)	123 (28.9)	
200-299	155 (20.7)	70 (21.7)	85 (20.0)	
≥300	228 (30.4)	127 (39.3)	101 (23.7)	
N/A	38 (5.1)	14 (4.3)	24 (5.6)	
Number of stroke physicians, median (IQR)	4 (3, 7)	5 (3, 9)	4 (2, 6)	<0.001

*DPC: Diagnostic Procedure Combination, Hsp: hospital, MEA: metropolitan, McEA: micropolitan

Supplemental Appendix 1. List of the J-ASPECT Study Collaborators.

All Contributors were involved in collection of data.

Hospitals	Responsible persons
Ainomiyako Neurosurgery Hospital	Isao Sasaki
Aizawa Hospital	Takao Hasimoto
Akita University Hospital	Hiroaki Shimizu
Akocity Hospital	Minoru Asahi
Almeida Memorial Hospital	Makoto Goda
Aomori City Hospital	Atsuhito Takemura
Aomori Prefectural Central Hospital	Tatsuya Sasaki
Asahi General Hospital	Saburo Watanabe
Ashiya Municipal Hospital	Seiko Kataoka
Atsuchi Neurosurgical Hospital	Kouji Takasaki
Ayabe City Hospital	Kouji Shiga
Baba Memorial Hospital	Hidehuku Gi
Bellland General Hospital	Ryunosuke Uranishi
Beppu Medical Center	Yasuyuki Nagai
Chiba Cancer Center	Toshihiko Iuchi
Chiba Cerebral and Cardiovascular Center	Toshio Machida, Junichiro Shimada
Chiba Neurosurgical Clinic	Kenji Wakui
Chiba Rosai Hospital	Takashi Saegusa

Chiba Tokushukai Hospital	Isao Kitahara
Chidoribashi Hospital	Yasushi Ejima
Chigasaki Municipal Hospital	Takaakira Yokoyama
Chikamori Hospital (Chikamori Health Care Group)	Satoru Hayashi
Chutoen General Medical Center	Toshikazu Ichihashi
Corporate Medical Association Shoikai Kasai Shoikai Hospital	Junichi Harashina
Daiichitowakaihospital	Tsugumichi Ichioka
Daiyukai General Hospital	Takayuki Kato, Shinichi Shirakami
Date Red Cross Hospital	Takeshi Matsuoka
Department of Neurosurgery Shiroyama Hospital	Kenichi Murao
Dokkyo Medical University Koshigaya Hospital	Akio Hyodo, Tomoyuki Miyamoto
Doutounoushinnkeigekabyouinn	Teruo Kimura
Ebina General Hospital	Tomonori Kobayashi
Ehime Prefectural Central Hospital	Shinji Iwata
Faculty of Medicine, Saga University	Tatsuya Abe
Faculty of Medicine, University of Miyazaki	Hideo Takeshima
Fuchu Hospital	Kazunori Yamanaka
Fuji City General Hospital	Satoru Morooka
Fujii Neurosurgical Hospital	Hideo Kunimine
Fujita General Hospital	Satoshi Taira
Fujita Health University Hospital	Ichiro Nakahara, Yuichi Hirose

Fujiyoshida Municipal Hospital	Syougo Imae
Fukaya Red Cross Hospital	Hirochiyo Wada
Fukuchiyama City Hospital	Mamoru Murakami
Fukui Katsuyama General Hospital	Masanori Kabuto
Fukuoka Seisyukai Hospital	Masaharu Tani, Isao Inoue
Fukuoka Tokushukai Medical Center	Hidenori Yoshida
Fukuoka University Chikushi Hospital	Kiyoshi Kazekawa
Fukuoka University Hospital	Tooru Inoue
Fukuoka Wajiro Hospital	Kouzou Fukuyama
Fukuokashinmizumaki Hospiral	Shigenari Kin
Fukushima Medical University Hospital	Taku Sato
Fukushima Red Cross Hospital	Yoichi Watanabe
Gifu Municipal Hospital	Tetsuya Tanigawara
Gifu Prefectural Tajimi Hospital	Junki Ito
Gifu University Hospital	Toru Iwama
Hachisuga Hospital	Yoshihisa Maeda
Hakodate Central General Hospital	Makoto Takeda
Hakodate Municipal Hospital	Jun Niwa
Hakodate Neurosurgical Hospital	Mikio Nishiya
Hakujyuji Hospital	Shuji Hayasi
Hamamatsu Medical Center	Teiji Nakayama

Hamanomachi Hospital	Koichirou Matsukado
Harasanshin Hospital	Tadahisa Shono
Hata Kenmin Hospital	Hiroyuki Nishimura
Higashiosaka City Medical Center	Takatoshi Fujimoto, Ryo Tamaki
Higashitotsuka Memorial Hospital	Satoshi Utsuki
Higashiyamato Hospital	Ikuo Kobayashi, Hirotoshi Ohtaka
Hirosaki Stroke and Rehabilitation Center	Takamitsu Uchizawa
Hirosaki University Hospital	Hiroki Ohkuma
Hiroshima City Hiroshima Citizens Hospital	Shigeki Nishino
Hiroshima Prefectural Hospital	Atsushi Tominaga
Hiroshima Red Cross Hospital & Atomic Bomb Survivors Hospital	Masayuki Sumida
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Hokuto Hospital	Kimito Kondo, Kazumi Nitta
Hospital	Toshiki Ikeda, Hidetoshi Ooigawa
Hospital Nanbu Tokushukai	Tutomu Kadekaru
Hukuoka City Hospital	Katsuyuki Hirakawa
Hyogo College of Medicine	Shinichi Yoshimura

Hyogo Prefectural Awaji Medical Center	Yoshio Sakagami
Hyogo Prefectural Kakogawa Medical Center	Hideo Aihara
Hyogokenritu_Nishinomiya_Hospital	Takayuki Sakaki
Ibaraki Prefectural Central Hospital	Hiroko Oyama, Yuuji Kujiraoka
Ibaraki Seinan Medical Center Hospital	Keishi Fujita
Iida Municipal Hospital	Sumio Kobayashi
Imari Arita Kyoritsu Hospital	Nobuaki Momozaki
Ina Central Hospital	Atsushi Sato
Inagi Municipal Hospital	Hideki Murakami, Tatsuo Iwasita
Institute of Brain and Blood Vessels Mihara Memorial Hospital	Akazi Kazunori, Takao Kanzawa
Irixyouhoujin Okinawatokushuukai Uwajimatokushukai Hospital	Hiromichi Sadashima
Iryohojin Seiwakai Wada Hospital	Shiro Miyata
Iryouhoujinsyadanjinmeikai Akiyamanousinnkeigeka	Takekazu Akiyama
Iryouhouzinsyadan Meihoukai Yokohamashintoshinoushinkeigekabyouin	Akihiro Nemoto, Masafumi Morimoto
Isahaya General Hospital	Yoshihiro Nishiura
Ise Red Cross Hospital	Fumitaka Miya, Masunari Sibata
Ishikawa Prefectural Central Hospital	Yutaka Hayashi
Ishinomaki Red Cross Hospital	Syuichi Ishikawa
Itabashi Chuo Medical Center	Miura Naohisa
Itami Kousei Neurosurgical Hospital	Shinya Noda

Iwaki　Kyoritsu General Hospital	Yasuhiro Suzuki
Iwata Municipal General Hospital	Shinji Amano
Iwate Medical University	Kuniaki Ogasawara
Iwate Prefectural Central Hospital	Takayuki Sugawara
Iwate Prefectural Iwai Hospital	Keiichi Saitou
Iwate Prefectural Kuji Hospital	Kazuyuki Miura
Iwate Prefectural Ninohe Hospital	Akinori Yabuta
Izumi Hospital	Makoto Hasebe
Izumino Hospital	Masato Seike
Japan Community Health Care Organization Chukyo Hospital	Akira Ikeda
Japan Community Health Care Organization Kyushu Hospital	Satoshi Inoha
Japan Community Health Care Organization Tokyo Takanawa Hospital	Hirofumi Hiyama
Japan Organization of Occupational Health and Safety Kumamoto Rousai Hospital	Hiromasa Tsuiki, Shigeo Yamashiro
Japanese Red Cross Akita Hospital	Keiichi Nishimaki
Japanese Red Cross Asahikawa Hospital	Katsumi Takizawa, Kenichi Makino
Japanese Red Cross Fukuoka Hospital	Hitoshi Tsugu, Jiro　Kitayama
Japanese Red Cross Kitami Hospital	Nozomi Suzuki
Japanese Red Cross Kumamoto Hospital	Shu Hasegawa, Tadashi Terasaki
Japanese Red Cross Maebashi Hospital	Ken Asakura

Japanese Red Cross Medical Center	Ichiro Suzuki
Japanese Red Cross Society Hachinohe Hospital	Hiromu Konno
Japanese Red Cross Takayama Hospital	Katsunobu Takenaka
Japanese Redcross Fukui Hospital	Hiroki Toda, Taketo Hatano
Jcho Hitoyoshi Medical Center	Keizou Yamamoto
Jcho Kobe Central Hospital	Keigo Matsumoto
Jcho Kumamoto General Hospital	Kazunari Koga
Jcho Nankai Medical Center	Takamitu Hikawa
Juntendo Universty Hospital	Hajime Arai
Kaetsu Hospital	Kazuaki Awamori
Kaga Medical Center	Naoki Shirasaki
Kagawa Rosai Hospital	Kimihiro Yoshino
Kagawa University Hospital	Takashi Tamiya
Kagoshima City Hospital	Kazuho Hirahara
Kagoshima Prefectural Kanoya Medical Center	Shunichi Tanaka
Kagoshima Tokushukai Hospital	Teruaki Kawano
Kagoshima University Hospital	Sei Sugata, Kazunori Arita
Kan-Etsu Hospital	Masahiko Tanaka
Kanazawa Medical Univercity	Shunsuke Shiraga
Kanazawa Neurosurgical Hospital	Syuji Sato
Kanazawa University Hospital	Mitsutoshi Nakada

Kaneda Hospital	Kimihisa Kinoshita
Kanmon Medical Center	Katsuhiro Yamashita
Kano Hospital	Nakazawa Kazutomo
Kansai Electric Power Hospital	Yasuhiro Fujimoto
Kansai Medical University Hospital	Kunikazu Yoshimura
Kanto Rosai Hospital	Takayuki Tachizawa
Kasaoka Daiichi Hospital	Akira Watanabe
Kashiwaba Nourosagical Hospital	Tetsuyuki Yoshimoto
Kasugai Municipal Hospital	Naoto Kuwayama
Kawasaki Medical School Hospital	Masaaki Uno
Kazuno Kosei Hospital	Masayuki Sasou
Keiju Medical Center	Sotaro Higashi
Keishunkai Medical Corporation Kobari General Hospital	Naoaki Sato
Kenwakai Hospital	Masakazu Kitahara
Kenwakai Otemati Hospital	Hiroshi Yoneda
Kieikai Hospital	Satoshi Suzuki
Kindai University Hospital	Toshiho Ohtsuki, Amami Kato
Kindai University Sakai Hospital	Yusaku Nakamura
Kiryu Kosei General Hospital	Satoshi Magarisawa
Kishiwada City Hospital	Kenji Hashimoto
Kishiwada Tokushukai Hospital	Hiroyuki Matsumoto

Kita-Harima Medical Center	Hirotoshi Hamaguchi, Shigeru Miyake
Kitakami Saiseikai Hospital	Tomohiko Satou
Kitakyusyu General Hospital	Masaru Idei
Kitakyusyu Municipal Medical Center	Masahiro Mizoguchi
Kitamurayama Hospital	Eiichiro Kamatsuka
Kitasato University School of Medicine	Toshihiro Kumabe
Kobe City Medical Center General Hospital	Nobuyuki Sakai
Kobe Ekisaikai Hospital	Takashi Tominaga
Kobe Red Cross Hospital	Haruo Yamashita
Kobe University Hospital	Eiji Kohmura, Tatsushi Toda
Kochi Health Sciences Center	Tsuyoshi Oota, Masanori Morimoto
Kochi Medical School Hospital	Tetsuya Ueba
Kohka Public Hospital	Kazuyoshi Watanabe
Kohnan Hospital	Hidenori Endo
Kohsei General Hospital	Kenjirou Hujiwara, Minoru Nakagawa
Kokura Memorial Hospital	Taketo Hatano, Akira Ishii
Komaki City Hospital	Toshinori Hasegawa
Komatsu Municipal Hospital	Hisashi Nitta
Komoro Kosei General Hospital	Takayuki Kuroyanagi
Koshigaya Municipal Hospital	Akira Tunoda
Koto Memorial Hospital	Hisao Hirai

Koyama Memorial Hospital	Takuya Kawai
Kugayama Hospital	Mitsuyuki Fujitsuka
Kumamoto City Hospital	Akira Takada, Seiji Tajiri
Kurashiki Central Hospital	Masaki Chin
Kurashiki Heisei Hospital	Hidemiti Sasayama
Kurosawa Hospital	Sigehiro Ohmori
Kurosishi General Hospital	Seiko Hasegawa
Kurosu Hospital	Kazuhiro Kikuchi, Mikio Teduka
Kurume University Hospital	Motohiro Morioka
Kyorin University Hospital	Yoshiko Unno, Hiroki Yoshida , Teruyuki Hirano
Kyoritsu Hospital	Masayuki Yokota
Kyoto Okamoto Memorial Hospital	Minoru Kidooka
Kyoto Second Red Cross Hospital	Hiroshi Tenjin
Kyoto Univerisity Hospital	Susumu Miyamoto
Kyoto Yamashiro General Medical Center	Yoshihiro Iwamoto
Kyotokatsura Hospital	Yasumasa Yamamoto
Kyotomin-Iren Chuohospital	Yuko Shikata
Kyushu Central Hospital of The Mutual Aid Association of Public School Teachers	Hitonori Takaba
Kyushu Rosai Hospital	Sei Haga

Kyushu University Hospital	Koji Iihara
Local Incorporated Administrative Agency Tokushima Prefecture Naruto Hospital	Masahito Agawa
Makita General Hospital	Yoshinori Arai
Maruko Central Hospital	Toshiyuki Tsukada
Matsushita Memorial Hospital	Nozomu Murai
Matsuyama Shimin Hospital	Masakazu Suga
Mazda Hospital	Kawamoto Yukihiko
Medical Corporation Ijinkai Nakamura Memorial Hospital	Kenji Kamiyama
Medical Corporation Meiseikai Abashiri Neurosurgicalrehabilitation Hospital	Naoto Izumi
Meitetsu Hospital	Youtarou Takeuchi
Midorigaoka Hospital	Motohiro Arai
Mie University Hospital	Hidenori Suzuki
Mimihara General Hospital	Shinji Okumura
Minamata City General Hospital and Medical Center	Makoto Yoshikawa
Minami Wakayama Medical Center	Yoshinari Nakamura
Minato Medical Coop-Kyoritsu General Hospital	Hisashi Tanaka
Mito Kyodo General Hospital	Yasusi Sibata
Mitoyogeneralhospital	Tetsuya Masaoka
Mitsugi General Hospital	Takashi Matsuoka

Miyakonojo Medical Association Hospital	Hajime Ohta
Miyoshi Central Hospital	Osamu Hamasaki
Moriguchi-Ikuno Memorial Hospital	Misao Nishikawa
Morioka Red Cross Hospital	Naohiko Kubo
Munakata Suikokai General Hospital	Yosimasa Kinosita
Muroran City General Hospital	Hiroshi Ooyama
Nagahama City Hospital	Taro Komuro
Nagano Municipal Hospital	Yoshikazu Kusano
Nagaoka Chuo General Hospital	Shigekazu Takeuchi
Nagasaki Kawatana Medical Center	Ei-Ichirou Urasaki
Nagasaki University Hospital	Takayuki Matsuo
Nagasakiken Shimabara Hospital	Yoshiharu Tokunaga
Nagoya City University	Mitsuhito Mase
Nagoya Daini Red Cross Hospital	Yukio Seki, Keizo Yasui
Nagoya University Hospital	Yoshio Araki
Naha City Hospital	Naoki Tomiyama
Nakamura Memorial South Hospital	Taiichiro Watanabe, Koji Oka
Nakatsu Municipal Hospital	Hiromichi Koga
Nara Medical University	Hiroyuki Nakase
Narita Red Cross Hospital	Michio Nakamura
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Nho Sendai Medical Center	Masayuki Ezura
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Nihon University Itabashi Hospital	Atsuo Yoshino
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Niigata Tokamachi Hospital	Mitsuo Kouno
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Niigatanougekabyouin	Kiyoshi Onda
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Nishitokyo Central General Hospital	Tatsuya Nakamura
Nissan Tamagawa Hospital	Takayuki Kubodera
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Obara Hospital	Souichi Obara
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Saiseikai Nagasaki Hospital	Wataru Haraguchi
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Osaka Saiseikai Ibaraki Hospital	Yasunobu Gotou
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Takarazuka Daiichi Hospital	-
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Yoshida Hospital	Yasuhisa Yoshida
Yuaikaihospital	Yoshihumi Teramoto

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	11
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(b) Give reasons for non-participation at each stage	14
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-14
		(b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	11-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	11-13

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	11-13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Temporal trends and geographical disparities in comprehensive stroke centre capabilities in Japan from 2010 to 2018

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Temporal trends and geographical disparities in comprehensive stroke centre capabilities in Japan from 2010 to 2018

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Keywords: stroke, comprehensive stroke centre, care quality

Word count: 2,209

ABSTRACT

Objectives: Comprehensive stroke centre (CSC) capabilities are associated with reduced in-hospital mortality due to acute stroke. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement. This study examined whether CSC capabilities changed in Japan between 2010 and 2018, and whether any changes were influenced by hospital characteristics.

Design: A hospital-based cross-sectional study.

Setting: We sent out questionnaires to the training institutions of the Japan Neurosurgical Society and Japan Stroke Society in 2010, 2014 and 2018.

Participants: 749 in 2010, 532 in 2014 and 786 in 2018 hospitals that participate in the J-ASPECT study.

Main outcome measures: CSC capabilities were assessed using the validated scoring system (CSC score:1-25 points) in 2010, 2014, and 2018 survey. The effect of hospital characteristics was examined using multiple logistic regression analysis.

Results: Among the 323 hospitals that responded to all surveys, the implementation of 14 recommended items increased. The CSC score (median, interquartile range) was 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively ($p< 0.001$). There was a ≥ 20% increase in six items (e.g. endovascular physicians, stroke unit, and interventional coverage 24/7), and a ≤ 20% decrease in community education. A lower baseline CSC score (odds ratio 0.82, [95% confidence interval] 0.75-0.9), the number of beds ≥ 500 (3.9 [1.2–13.0]), and the number of stroke physicians (7-9) (2.6 [1.1-6.3]) was associated with improved CSC capabilities, independent of geographical location.

Conclusions: There was a significant improvement in CSC capabilities between 2010 and 2018, which was mainly related to the availability of endovascular treatment and multidisciplinary care. Our findings may be useful to determine which hospitals should be targeted to improve CSC capabilities in a defined area.

Strengths and limitations of this study:

- A large-scale, representative hospitals of Japan provided data on temporal trends in the CSC capabilities for this cross-sectional study.
- Hospitals actively working to improve stroke care are more likely to respond to the questionnaire, which may lead to information bias.
- The CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items.

INTRODUCTION

Stroke is the third leading cause of death and a leading cause of long-term disability in Japan. Primary and comprehensive stroke centres (CSCs) were developed to provide optimal implementation of intravenous recombinant tissue plasminogen activator (rt-PA) infusion and more intensive stroke care that includes endovascular and neurosurgical treatment. [1, 2] Organised care in a stroke unit is associated with better quality of care and reduced death and dependency. [3, 4] In addition to the influence of this process, previous studies have shown that patient outcomes associated with stroke and cardiovascular diseases are influenced by the hospital case volume, [5, 6] number of physicians, and geographical locations of the facility [7]. Progressive rural-urban disparities in acute stroke care have been reported in the United States, [8] but it is not known whether such disparity exists in other countries.

In 2010, we launched the J-ASPECT study, a nationwide survey of acute stroke care capacity for proper designation of a comprehensive stroke centre in Japan. [9 10] The J-ASPECT stroke database is a hospital-based, Japan-wide stroke registry. We demonstrated significant geographical differences in CSC capabilities in 2010,[9] and that CSC capabilities of a facility are associated with reduced in-hospital mortality from acute stroke.[10] Thus continuous monitoring of the CSC capabilities may be clinically meaningful to improve stroke outcomes. [10, 11] Since 2010, we have conducted nationwide benchmark analyses to allow participating hospitals to facilitate improvement of stroke care. However, it remains unclear whether there are improving trends in the CSC capabilities, or how hospital-related factors determine quality improvement.

AIMS

We aimed to examine whether CSC capabilities in Japan changed from 2010 to 2018 and whether any recorded changes were influenced by hospital characteristics.

METHODS

Institutional survey of CSC capabilities

This cross-sectional survey used the DPC discharge database from participating institutions in the J-ASPECT study. Participation in the J-ASPECT study was voluntary. Of the 1369 training institutions certified by the Japan Neurosurgical Society, the Japanese Society of Neurology, and the Japan Stroke Society, 621 agreed to participate in this study. The J-ASPECT study group analysed the Diagnosis Procedure Combination (DPC) database to gain new clinical insights on ischaemic and haemorrhagic stroke, an approach we applied again for this cross-sectional survey. In this study, we sent out questionnaires to the training institutions of all three societies in 2010, 2014, and 2018 to assess CSC capabilities. The CSC capabilities of each facility were assessed with a validated scoring system (CSC score), using 25 items recommended by the Brain Attack Coalition [2, 5-7].

All items were classified into five categories: personnel, diagnostic, specific expertise, infrastructure, and education. A score of 1 was assigned for meeting each item, yielding a total CSC score of up to 25. Content, constructs, and predictive validity of this scoring system have been previously reported.[12, 13]

Other hospital characteristics

Hospital characteristics including number of beds, annual stroke hospitalisations, stroke physicians, academic status, adoption of the Diagnosis Procedure Combination (DPC)-based payment system [9], and geographic location were obtained from the 2010 survey. The geographic location was classified according to urban employment areas (UEAs) divided into Metropolitan Employment Areas (MEAs) and Micropolitan Employment Areas (McEAs).[9] The MEAs were further classified into central and outlying areas based on the commuting pattern of their inhabitants. Details of UEAs, such as total population or total land area, have been previously described.[10]

Statistical analysis

To explore trends in CSC capabilities, we examined implementation of the 25 items and the CSC score in the 323 consecutively participating hospitals that responded to all surveys. To examine the influence of hospital-related factors on the change in CSC capabilities, we divided the hospitals into those with or without a temporal improvement of CSC score (≥1-point increase between 2010 and 2018). The increase of "One point" was set based on our previous report on the CSC score.[11] In that study, we showed that even a small preceding improvement of the CSC score was associated with reduced in-hospital mortality, reduced poor outcomes, and higher use of acute reperfusion therapy in AIS patients; our findings also suggested the difficulty in improving the CSC score in a relatively short time period.

We used a chi-squared test to detect differences between consecutively participating hospitals and other hospitals in the number of each hospital item. We did not perform multiple tests. Wilcoxon rank sum test was used to compare total CSC scores between consecutively participating hospitals and other hospitals.

To explore the influence of hospital-related factors on temporal improvement of CSC capabilities, multiple logistic regression models were used. To assess selection bias, we compared hospital characteristics between consecutively participating hospitals with the others. We also examined the relationship between "number of physicians" and "hospital size" and the relationship between "number of physicians" and "CSC score" using chi-squared tests. All analyses were performed using the JMP Statistical Version 12 Software (SAS Institute Inc., Cary, NC, USA). P values of <0.05 were considered statistically significant.

Patient and public involvement

Data for this study are based on information collected by the J-ASPECT study. Patients and the public were not involved in the development of this study.

RESULTS

Trends in the CSC capabilities from 2010 to 2018

A total of 749, 532, and 786 hospitals responded to the survey in 2010, 2014, and 2018, respectively. The implementation rates of each item are shown in Table 1. The median (interquartile range) of the CSC scores was 14 (11-18), 17 (13-19), and 17 (12-20.3), for each year, respectively (Table 1).

Among consecutively participating hospitals, there was an increase in implementation rates of the 14 items, and the CSC scores were (median, interquartile range): 16 (13-19), 18 (14-20), 19 (15-21), for 2010, 2014, and 2018, respectively ($p < 0.001$) (Table 1). A marked increase (≥20%) was noted in six items related to endovascular treatment (endovascular physicians and interventional coverage 24/7) and multidisciplinary care (stroke unit, specialists of emergency medicine and physical medicine/rehabilitation, and stroke rehabilitation nurses).

In addition, a moderate increase (≤20%) was noted in eight items: 24/7 availability of diffusion-weighted magnetic resonance imaging, digital and CT angiography, carotid ultrasound, coiling of an intracranial aneurysm, and implementation of stroke registry. In contrast, there was a marked decrease (≤20%) in community education.

Geographical differences in CSC capabilities between 2010 and 2018

Among the seven items with significant geographical differences in 2010, all items in the personal component still showed a gap, despite overall improvement at all locations in 2018 (Table 2). In contrast, geographical differences in all infrastructure items diminished with overall improvement and a marked improvement in the McEA in 2018.

Over the study period, geographical differences emerged in intra-arterial reperfusion therapy and the number of specialists in physical medicine/rehabilitation. The remaining item, coiling of intracranial aneurysms, showed no changes.

Influence of hospital characteristics on change in CSC capabilities

Among consecutively participating hospitals, 23 were excluded due to missing data. Temporal improvement of CSC capabilities between 2010 and 2018 was noted in 198 hospitals (66.0%). As for hospital characteristics, there were weakly significant differences in bed number (p=0.016) and CSC score in 2010 (p=0.032) between the two groups on univariable analysis (Table 3).

In the logistic regression analyses, the following variables had an association with temporal improvement of CSC capabilities (Table 4): a lower baseline CSC score (odds ratio 0.82 [95% confidence interval 0.75-0.9]), bed volume ≥500 (3.90, [1.17–13.0]), and moderate (7-9) number of stroke physicians (2.63, [1.10-6.27]). In contrast, geographical location, academic status, DPC-based payment system, and case volume of stroke did not show a significant association. We also performed the logistic regression analysis adjusting tertile, instead of quartile, of stroke physician volume in addition to the other adjusting factors. Except for Q3 of stroke physician volume, we found very similar results (Supplementary Table 1). Additionally, there was a significant relationship between hospital size and number of physicians ($P<0.001$), and between CSC score and number of physicians ($P<0.001$).

Selection bias

The response rates of the 2010, 2014, and 2018 surveys were 55.0%, 39.7%, and 49.9%, respectively. We found that a selection bias did exist; in fact, the total CSC scores and most of the implementation rates of each item were significantly higher for the consecutively participating hospitals than for the others in all three surveys (Table 1). Consecutively participating hospitals were more likely to be MEA-central, academic, have a larger number of hospital beds, higher annual stroke admission rate, and more stroke physicians (Supplementary Table 2).

DISCUSSION

We found an overall improvement in CSC capabilities between 2010 and 2018, and different trends in geographical disparities for different items. Hospitals with a higher number of hospital beds, intermediate number of stroke physicians, and a lower baseline CSC score had a higher likelihood of improving their CSC capabilities.

Temporal Changes to CSC capabilities

In addition to a significant increase in CSC capabilities, there was a marked increase in implementation of the items, mainly related to endovascular treatment and multidisciplinary care. Of note, we previously showed that interventional 24/7 coverage and the presence of physical medicine/rehabilitation specialists were associated with reduced in-hospital mortality for patients with subarachnoid haemorrhage, whereas availability of neurologists and stroke units were associated with reduced in-hospital mortality and better functional outcomes, respectively, for those with ischaemic stroke.[13]

These findings are consistent with those of prior studies, which have shown that admission to a stroke unit with organised stroke care is associated with better quality of care and outcomes in those who experience an acute stroke. [14 3] Although the use of mechanical thrombectomy for large vessel acute ischaemic stroke (AIS) has been rapidly increasing, only 3.3% of 15.1% potentially eligible AIS patients received it in 2016. [15] Improvement of CSC capabilities, especially related to endovascular treatment and multidisciplinary care, should contribute to improved quality of care and outcomes in patients with acute stroke.

The decreased implementation of community education observed in this study may be explained by the limited number of stroke physicians available for this purpose due to an increased burden of stroke care (e.g. emergent endovascular calls). [16] Stroke educational campaigns have the potential to improve knowledge and awareness, but public campaigns are usually expensive and short-lived and may not achieve any significant improvement. [17]

Diminished and emerging geographical disparities

Determining rural/urban differences in CSC capabilities may support the development of targeted interventions to improve stroke care and outcomes in rural areas. We found differing trends in implementation of the items according to personnel and infrastructure components. Rural areas are associated with reduced access to optimal stroke care and a lower use of acute stroke intervention.[18] The diminished disparities in implementation of stroke units in this study might result in a higher use of rt-PA infusion in rural areas.[19]

The emerging disparities in implementation of intraarterial reperfusion therapy deserve some attention. Since the evidence regarding the efficacy of acute endovascular reperfusion therapy was established in 2015,[20] relocation of relevant specialists might have occurred from rural to urban areas to meet the urgent need created by more widespread use. In addition, a high prevalence of neurointerventional physician burnout may require centralisation of acute endovascular reperfusion treatment.[21]

Influence of hospital-related factors on improvement of CSC capabilities

Our study showed the impact of specific hospital-related factors on improvement of CSC capabilities, which may be useful to determine which hospitals should be targeted to improve CSC capabilities, and in what regions. In rural areas, where medical resources are limited, centralisation of acute stroke care in large hospitals may be needed. We also found a significant relationship between CSC score and number of physicians. This means that, in 2010, institutions with more physicians tended to have higher baseline CSC scores. The reason that a physician volume of more than 10 did not affect the improvement of the CSC score may be explained by the ceiling effect of a high baseline CSC score in 2010.

Limitations

There are several limitations of this study. First, since the total CSC scores and most of the implementation rates of each item were significantly higher for the consecutively participating hospitals than for the others in all three surveys, our findings may have included biased information. Second, the CSC score was a significant composite measure to influence in-hospital mortality of acute stroke, but little information was established on the influence of specific items. Third, we did not determine the influence of unmeasured confounders. Fourth, the CSC score is a self-reported questionnaire rather than the result of any formal certification process. In Japan, the official certification process for PSCs (primary stroke centres) just began in 2019. The criteria for CSC certification is now under discussion by the Japan Stroke Society. The results of this study could have a significant impact on the recommended items and criteria for the designation of official CSCs in Japan. After the official certification process for CSCs is implemented, we plan to reassess the effect of CSC capabilities on AIS patients. Finally, the 2014 data did not factor into this analysis because of the small number of participants in that year. Further research is required to examine the effect of 2014 data on the analysis.

Conclusions

The CSC capabilities in Japan improved between 2010 and 2018, especially related to endovascular treatment and multidisciplinary care. Our findings may be useful to determine which hospitals should be targeted to improve CSC capabilities in a defined area.

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Competing interests statement

None declared.

Ethics approval

The study was approved by the Kyushu University Institutional Review Board, which waived the requirement for individual informed consent (No. 28-335)

Data availability statement

We have documented the data, methods, and materials used to conduct the research in this report. The individual patient data are not publicly available because of the memorandum signed by the director of the participating hospitals and the principal investigator of the J-ASPECT Study group.

Authors and contributors

A Kurogi and KI drafted the manuscript. AN, KN, A Kada, DO, AH and KI were involved in study concept, design and obtaining funding. A Kada, DO, AH, KO, YS, TK, KA and KI were involved in analysis and of data. KO, YS, TK and KI were involved in acquisition of data. All authors reviewed the study report, made comments or suggestions on the manuscript drafts, and approved the final version.

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Patient consent for publication

Not required.

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Table 1. Number (percentage) of the responding hospitals fulfilling the recommended items of comprehensive stroke care capabilities.

Components	Items	2010				2014				2018			
		All participating Hsps. (n=749)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=426)	p value	All participating Hsps. (n=532)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=209)	p value	All participating Hsps. (n=786)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=464)	p value
Personnel	Neurologists	358 (47.8)	176 (54.5)	182 (42.7)	0.001	283 (53.2)	177 (54.8)	106 (50.7)	0.357	452 (57.5)	210 (65.0)	242 (52.2)	<0.001
	Neurosurgeons	694 (92.7)	314 (97.2)	380 (89.2)	<0.001	515 (96.8)	317 (98.1)	198 (94.7)	0.03	754 (95.9)	317 (98.1)	437 (94.2)	0.006
	Endovascular physicians	272 (36.3)	146 (45.2)	126 (29.6)	<0.001	280 (52.6)	196 (60.7)	84 (40.2)	<0.001	428 (54.4)	211 (65.3)	217 (46.8)	<0.001
	Emergency medicine	162 (21.6)	96 (29.7)	66 (15.5)	<0.001	207 (38.9)	146 (45.2)	61 (29.2)	<0.001	427 (54.3)	205 (63.5)	222 (63.5)	<0.001
	Physical medicine and rehabilitation	113 (15.1)	61 (18.9)	52 (12.2)	0.011	143 (26.9)	95 (29.4)	48 (23.0)	0.102	313 (39.8)	137 (42.4)	176 (37.9)	0.206
	Rehabilitation therapy	742 (99.1)	321 (99.4)	421 (98.8)	0.435	529 (99.4)	321 (99.4)	208 (99.5)	0.832	779 (99.1)	321 (99.4)	458 (98.7)	0.354
	Stroke rehabilitation nurses	102 (13.6)	48 (14.9)	54 (12.7)	0.388	157 (29.5)	116 (35.9)	41 (19.6)	<0.001	285 (36.2)	146 (45.2)	139 (30.0)	<0.001
Diagnostic	CT	742 (99.1)	322 (99.7)	420 (98.6)	0.122	527 (99.1)	322 (99.7)	205 (98.1)	0.061	763 (97.1)	322 (99.7)	441 (85.0)	<0.001
	MRI with diffusion	647 (86.4)	291 (90.1)	356 (83.6)	0.01	504 (94.7)	311 (96.3)	193 (92.3)	0.047	732 (93.1)	314 (97.2)	418 (90.1)	<0.001
	Digital cerebral angiography	602 (80.3)	288 (89.2)	314 (73.7)	<0.001	476 (89.4)	305 (94.4)	171 (81.8)	<0.001	638 (81.2)	299 (92.6)	399 (73.1)	<0.001
	CT angiography	627 (83.7)	289 (89.5)	338 (79.3)	<0.001	492 (92.5)	305 (94.4)	187 (89.5)	0.034	701 (89.2)	309 (95.7)	392 (84.5)	<0.001
	Carotid duplex ultrasound	257 (34.3)	126 (39.0)	131 (30.8)	0.018	219 (41.2)	153 (47.4)	66 (31.6)	<0.001	343 (43.6)	169 (52.3)	174 (37.5)	<0.001
	TCD	121 (16.2)	70 (21.7)	51 (12.0)	<0.001	123 (23.1)	87 (26.9)	36 (17.2)	<0.010	162 (20.6)	95 (29.4)	67 (14.4)	<0.001
Specific	Carotid endarterectomy	603 (80.5)	292 (90.4)	311 (73.0)	<0.001	458 (86.1)	288 (89.2)	170 (81.3)	0.011	613 (78.0)	284 (87.9)	329 (70.9)	<0.001

Expertise													
	Clipping of intracranial aneurysm	685 (91.5)	314 (97.2)	371 (87.1)	<0.001	504 (94.7)	315 (97.5)	189 (90.4)	<0.001	706 (89.8)	314 (97.2)	392 (84.5)	<0.001
	Hematoma removal/draining	689 (92.0)	315 (97.5)	374 (87.8)	<0.001	505 (95.0)	315 (97.5)	190 (90.9)	<0.001	718 (91.3)	314 (97.2)	404 (87.1)	<0.001
	Coiling of intracranial aneurysm	360 (48.1)	192 (59.4)	168 (39.4)	<0.001	332 (62.4)	223 (69.0)	109 (52.2)	<0.001	448 (57.0)	223 (69.0)	225 (48.5)	<0.001
	Intra-arterial reperfusion therapy	498 (66.5)	245 (75.9)	253 (59.4)	<0.001	398 (74.8)	261 (80.8)	137 (65.6)	<0.001	510 (64.9)	247 (76.5)	263 (56.7)	<0.001
Infrastructure	Stroke unit	132 (17.6)	74 (22.9)	58 (13.6)	<0.001	202 (38.0)	136 (42.1)	66 (31.6)	0.015	342 (43.5)	171 (52.9)	171 (36.9)	<0.001
	Intensive care unit	445 (59.4)	214 (66.3)	231 (54.2)	<0.001	362 (68.0)	224 (69.4)	138 (66.0)	0.422	467 (59.4)	220 (68.1)	247 (53.2)	<0.001
	Operating room staffed 24/7	451 (60.2)	230 (71.2)	221 (51.9)	<0.001	339 (63.7)	239 (74.0)	100 (47.9)	<0.001	487 (62.0)	243 (75.2)	244 (52.6)	<0.001
	Interventional services coverage 24/7	279 (37.3)	147 (45.5)	132 (31.0)	<0.001	317 (59.6)	218 (67.5)	99 (47.4)	<0.001	452 (57.5)	219 (67.8)	233 (50.2)	<0.001
	Stroke registry	235 (31.4)	133 (41.2)	102 (23.9)	<0.001	260 (48.9)	172 (53.3)	88 (42.1)	0.012	349 (44.4)	164 (50.8)	185 (39.9)	0.003
Education	Community education	369 (49.3)	188 (58.2)	181 (42.5)	<0.001	144 (27.1)	91 (28.2)	53 (25.4)	0.476	204 (26.0)	98 (30.3)	106 (22.8)	0.018
	Professional education	436 (58.2)	207 (64.1)	229 (53.8)	0.005	326 (61.3)	208 (64.4)	118 (56.5)	0.066	429 (54.6)	184 (57.0)	245 (52.8)	0.249
Total CSC score median, (IQR)		14 (11, 18)	16 (13, 19)	13 (10, 17)	<0.001	17 (13, 19)	18 (14, 20)	15 (12, 18)	<0.001	17 (12, 20)	19 (15, 21)	15 (10, 19)	<0.001

Hsp, hospital; CT, computed tomography; MRI, magnetic resonance imaging; TCD, transcranial Doppler.

Table 2. Characteristics of comprehensive stroke care capabilities according to the geographical differences

		a) 2010				b) 2018			
		MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)	P value	MEA central (n=186)	MEA outlying (n=79)	McEA (n=35)	P value
Personnel	Neurologists	115 (61.8)	44 (55.7)	10 (28.6)	0.001	133(71.5)	55(69.6)	14 (40.0)	0.001
	Neurosurgeons	181 (97.3)	77 (97.5)	34 (97.1)	0.995	183 (98.4)	78 (98.7)	34 (97.1)	0.826
	Endovascular physicians	101 (54.3)	31 (39.2)	8 (22.9)	<0.001	136 (73.1)	49 (62.0)	14 (40.0)	<0.001
	Emergency medicine	57 (30.7)	25 (31.7)	7 (20.0)	0.406	122 (65.6)	54 (68.4)	16 (45.7)	0.052
	Physical medicine and rehabilitation	36 (19.4)	16 (20.3)	5 (14.3)	0.740	83 (44.6)	42 (53.2)	3 (8.6)	<0.001
	Rehabilitation therapy	185 (99.5)	78 (98.7)	35 (100)	0.701	185 (99.5)	78 (98.7)	35 (100)	0.701
	Stroke rehabilitation nurses	33 (17.8)	9 (11.4)	1 (2.9)	0.049	90 (48.4)	41 (51.9)	9 (25.7)	0.027
Diagnostic	CT	185 (99.5)	79 (100.0)	35 (100.0)	0.735	185 (100)	79 (100)	35 (100)	0.735
	MRI with diffusion	167 (89.8)	69 (87.3)	33 (94.3)	0.530	179 (96.2)	78 (98.7)	35 (100)	0.299
	Digital cerebral angiography	165 (88.7)	70 (88.6)	34 (97.1)	0.303	168 (90.3)	76 (96.2)	33 (94.3)	0.232
	CT angiography	163 (87.6)	72 (91.1)	32 (91.4)	0.627	176 (94.6)	77 (97.5)	34 (97.1)	0.525
	Carotid duplex ultrasound	71 (38.1)	30 (38.0)	14 (40.0)	0.977	95 (51.1)	48 (60.8)	15 (42.9)	0.164
	TCD	43 (23.1)	18 (22.8)	3 (8.6)	0.146	54 (29.0)	29 (36.7)	5 (14.3)	0.052
Specific Expertise	Carotid endarterectomy	173 (93.0)	68 (86.1)	32 (91.4)	0.196	166 (89.3)	71 (89.9)	28 (80)	0.260
	Clipping of intracranial aneurysm	183 (98.4)	75 (94.9)	34 (97.1)	0.280	181 (97.3)	77 (97.5)	34 (97.1)	0.995

	Hematoma removal/draining	183 (98.4)	76 (96.2)	34 (97.1)	0.546	182 (97,9)	77 (97.5)	35 (94.3)	0.485
	Coiling of intracranial aneurysm	119 (64.0)	46 (58.2)	13 (37.1)	0.012	143 (76.9)	49 (62.0)	17 (48.6)	<0.001
	Intra-arterial reperfusion therapy	142 (76.3)	58 (73.4)	27 (77.1)	0.859	153 (82.3)	57 (72.2)	22 (62.9)	0.019
Infrastructure	Stroke unit	50 (26.9)	17 (21.5)	2 (5.7)	0.023	106 (57.0)	44 (55.7)	13 (37.1)	0.093
	Intensive care unit	123 (66.1)	54 (68.4)	21 (60.0)	0.685	134 (72.0)	54 (68.4)	18 (51.4)	0.054
	Operating room staffed 24/7	143 (76.9)	59 (74.7)	15 (42.9)	<0.001	148 (79.6)	56 (70.9)	22 (62.9)	0.062
	Interventional services coverage 24/7	103 (55.4)	30 (38.0)	6 (17.1)	<0.001	133 (71.5)	54 (68.4)	18 (51.4)	0.064
	Stroke registry	81 (43.6)	31 (29.1)	15 (42.9)	0.808	93 (50.0)	47 (59.5)	15 (42.9)	0.199
Education	Community education	110 (59.1)	53 (67.1)	17 (48.6)	0.164	55 (29.6)	28 (35.4)	8 (22.9)	0.377
	Professional education	125 (67.2)	53 (67.1)	17 (48.6)	0.095	105 (56.5)	47 (59.5)	17 (48.6)	0.555

*MEA metropolitan, McEA microplitan.

Table 3. Hospital characteristics those with/without temporal improvement of the CSC capabilities.

Hospital-related factors in 2010	all Consecutively participating Hsps. (n=300)	Improvement Hsps. (n=198)	No improvement Hsps. (n=102)	p value#
Hospital locations				0.478
MEA central	186 (62.0)	121 (61.1)	65 (63.7)	
MEA outlying	79 (26.3)	56 (28.3)	23 (22.6)	
McEA	35 (11.7)	21 (10.6)	14 (13.7)	
CSC score in 2010				
median (IQR)	16 (13, 19)	16 (13, 18)	17 (13, 20)	0.032
Academic hospital	58 (19.3)	42 (21.2)	16 (15.7)	0.251
DPC* hospital	225 (75.0)	145 (73.2)	80 (78.4)	0.325
Number of hospital beds				0.016
1-99	17 (5.7)	9 (4.6)	8 (7.8)	
100-299	68 (22.7)	37 (18.7)	31 (30.4)	
300-499	96 (32.0)	62 (31.1)	34 (33.3)	
≥500	119 (39.7)	90 (45.5)	29 (28.4)	

Annual stroke case volume				0.915
0-99	34 (11.3)	21 (10.6)	13 (12.8)	
100-199	73 (24.3)	47 (23.7)	26 (25.5)	
200-299	67 (22.3)	45 (22.7)	22 (21.6)	
≥300	126 (42.0)	85 (42.9)	41 (40.2)	
Number of stroke physician volume				
median (IQR)	6 (3, 9)	6 (3.8, 9)	5 (3, 9.3)	0.139
Number of stroke physician volume quartile				
Q1 (0-3)	82 (27.3)	49 (24.8)	33 (32.4)	
Q2 (4-6)	68 (22.7)	43 (21.7)	25 (24.5)	
Q3 (7-9)	80 (26.7)	61 (30.8)	19 (18.6)	
Q4 (≥10)	70 (23.3)	45 (22.7)	25 (24.5)	
Number of stroke physician volume tertile				
T1 (0-4)	114 (38.0)	72 (36.4)	42 (41.2)	
T2 (4-8)	96 (32.0)	63 (31.8)	33 (32.4)	
T3 (≥9)	90 (30.0)	63 (31.8)	27 (26.5)	

*DPC: Diagnostic Procedure Combination, Hsp: hospital, # p value: Improvement vs. No improvement hospitals, MEA:

metropolitan, McEA: micropolitan

Table 4. Multivariable analysis of the impact of hospital characteristics on one-point increases of the CSC score

Hospital-related factors in 2010	Odds ratio	95%CI	P value
Hospital locations			
MEA central	ref.		
MEA outlying	1.42	0.76-2.65	0.269
McEA	0.82	0.36-1.86	0.632
CSC score in 2010	0.82	0.75-0.90	<0.001
Academic hospital	1.37	0.54-3.48	0.506
DPC hospital	0.77	0.41-1.42	0.397
Number of beds			
1-99	ref.		
100-299	1.16	0.37-3.66	0.794

300-499	1.68	0.56-5.10	0.358
≥500	3.9	1.17-13.00	0.027
Annual stroke case volume			
1-99	ref.		
100-199	1.62	0.64-4.07	0.305
200-299	2.41	0.89-6.49	0.083
≥300	2.74	0.99-7.54	0.051
Number of stroke physician volume quartile			
Q1 (0-3)	ref.		
Q2 (4-6)	1.77	0.81-3.88	0.153
Q3 (7-9)	2.63	1.10-6.27	**0.030**
Q4 (≥10)	1.58	0.57-4.38	0.380

*DPC: Diagnostic Procedure Combination, Hsp: hospital, # p value: Improvement vs. No improvement hospitals, MEA: metropolitan, McEA: micropolitan.

Supplemental material

eTable 1 Multivariable analysis of the impact of the hospital characteristics on one-point increase of the CSC score

Hospital-related factors in 2010	Odds	95%CI	P value
Hospital locations			
MEA central	ref.		
MEA outlying	1.35	0.36-2.48	0.339
McEA	0.78	0.35-1.75	0.549
CSC score in 2010	0.83	0.76-0.91	**<0.001**
Academic hospital	1.29	0.52-3.24	0.582
DPC hospital	0.72	0.39-1.34	0.302
Number of beds			
1-99	ref.		
100-299	1.1	0.36-3.41	0.868
300-499	1.82	0.60-5.48	0.285
≥500	3.81	1.16-12.54	**0.028**
Annual stroke case volume			

1-99	ref.		
100-199	1.68	0.67-4.18	0.267
200-299	2.47	0.92-6.61	0.072
≥300	3.17	1.16-8.66	**0.024**
Number of stroke physicians, tertile			
T1 (0-4)	ref.		
T2 (4-8)	1.12	0.58-2.16	0.745
T3 (≥9)	1.35	0.57-3.21	0.492

eTable 2 Univariable analysis of association between consecutively participating hospitals in all three surveies and the others

	All Hsps. in 2010 (n=749)	Consecutively participating Hsps. (n=323)	Other Hsps. (n=426)	p value
Hospital location				<0.001
MEA central	381 (50.9)	193 (59.8)	188 (44.1)	
MEA outlying	239 (31.9)	83 (25.7)	156(36.6)	
McEA	102 (13.6)	38 (11.8)	64 (15.0)	
Unclassified	27 (3.6)	9 (2.8)	18 (4.2)	
CSC score at 2010				
median (IQR)	14 (11, 18)	16 (13, 19)	13 (10, 17)	<0.001
Academic hospital	90 (12.1)	61 (18.9)	29 (6.8)	<0.001
DPC hospital	553 (73.8)	237 (73.4)	316 (74.2)	0.804
Number of beds				<0.001
-99	50 (6.7)	19 (5.9)	31 (7.3)	
100-299	232 (31.0)	75 (23.2)	157 (36.9)	
300-499	260 (34.7)	105 (32.5)	155 (36.4)	
≥500	207 (27.6)	124 (38.4)	83 (19.5)	
Annual stroke volume				<0.001
-99	129 (17.2)	36 (11.2)	93 (21.8)	

100-199	199 (26.5)	76 (23.5)	123 (28.9)	
200-299	155 (20.7)	70 (21.7)	85 (20.0)	
≥300	228 (30.4)	127 (39.3)	101 (23.7)	
N/A	38 (5.1)	14 (4.3)	24 (5.6)	
Number of stroke physicians, median (IQR)	4 (3, 7)	5 (3, 9)	4 (2, 6)	<0.001

*DPC: Diagnostic Procedure Combination, Hsp: hospital, MEA: metropolitan, McEA: micropolitan

Supplemental Appendix 1. List of the J-ASPECT Study Collaborators.

All Contributors were involved in collection of data.

Hospitals	Responsible persons
Ainomiyako Neurosurgery Hospital	Isao Sasaki
Aizawa Hospital	Takao Hasimoto
Akita University Hospital	Hiroaki Shimizu
Akocity Hospital	Minoru Asahi
Almeida Memorial Hospital	Makoto Goda
Aomori City Hospital	Atsuhito Takemura
Aomori Prefectural Central Hospital	Tatsuya Sasaki
Asahi General Hospital	Saburo Watanabe
Ashiya Municipal Hospital	Seiko Kataoka
Atsuchi Neurosurgical Hospital	Kouji Takasaki
Ayabe City Hospital	Kouji Shiga
Baba Memorial Hospital	Hidehuku Gi
Bellland General Hospital	Ryunosuke Uranishi
Beppu Medical Center	Yasuyuki Nagai
Chiba Cancer Center	Toshihiko Iuchi
Chiba Cerebral and Cardiovascular Center	Toshio Machida, Junichiro Shimada
Chiba Neurosurgical Clinic	Kenji Wakui
Chiba Rosai Hospital	Takashi Saegusa

Chiba Tokushukai Hospital	Isao Kitahara
Chidoribashi Hospital	Yasushi Ejima
Chigasaki Municipal Hospital	Takaakira Yokoyama
Chikamori Hospital (Chikamori Health Care Group)	Satoru Hayashi
Chutoen General Medical Center	Toshikazu Ichihashi
Corporate Medical Association Shoikai Kasai Shoikai Hospital	Junichi Harashina
Daiichitowakaihospital	Tsugumichi Ichioka
Daiyukai General Hospital	Takayuki Kato, Shinichi Shirakami
Date Red Cross Hospital	Takeshi Matsuoka
Department of Neurosurgery Shiroyama Hospital	Kenichi Murao
Dokkyo Medical University Koshigaya Hospital	Akio Hyodo, Tomoyuki Miyamoto
Doutounoushinnkeigekabyouinn	Teruo Kimura
Ebina General Hospital	Tomonori Kobayashi
Ehime Prefectural Central Hospital	Shinji Iwata
Faculty of Medicine, Saga University	Tatsuya Abe
Faculty of Medicine, University of Miyazaki	Hideo Takeshima
Fuchu Hospital	Kazunori Yamanaka
Fuji City General Hospital	Satoru Morooka
Fujii Neurosurgical Hospital	Hideo Kunimine
Fujita General Hospital	Satoshi Taira
Fujita Health University Hospital	Ichiro Nakahara, Yuichi Hirose

Fujiyoshida Municipal Hospital	Syougo Imae
Fukaya Red Cross Hospital	Hirochiyo Wada
Fukuchiyama City Hospital	Mamoru Murakami
Fukui Katsuyama General Hospital	Masanori Kabuto
Fukuoka Seisyukai Hospital	Masaharu Tani, Isao Inoue
Fukuoka Tokushukai Medical Center	Hidenori Yoshida
Fukuoka University Chikushi Hospital	Kiyoshi Kazekawa
Fukuoka University Hospital	Tooru Inoue
Fukuoka Wajiro Hospital	Kouzou Fukuyama
Fukuokashinmizumaki Hospiral	Shigenari Kin
Fukushima Medical University Hospital	Taku Sato
Fukushima Red Cross Hospital	Yoichi Watanabe
Gifu Municipal Hospital	Tetsuya Tanigawara
Gifu Prefectural Tajimi Hospital	Junki Ito
Gifu University Hospital	Toru Iwama
Hachisuga Hospital	Yoshihisa Maeda
Hakodate Central General Hospital	Makoto Takeda
Hakodate Municipal Hospital	Jun Niwa
Hakodate Neurosurgical Hospital	Mikio Nishiya
Hakujyuji Hospital	Shuji Hayasi
Hamamatsu Medical Center	Teiji Nakayama

Hamanomachi Hospital	Koichirou Matsukado
Harasanshin Hospital	Tadahisa Shono
Hata Kenmin Hospital	Hiroyuki Nishimura
Higashiosaka City Medical Center	Takatoshi Fujimoto, Ryo Tamaki
Higashitotsuka Memorial Hospital	Satoshi Utsuki
Higashiyamato Hospital	Ikuo Kobayashi, Hirotoshi Ohtaka
Hirosaki Stroke and Rehabilitation Center	Takamitsu Uchizawa
Hirosaki University Hospital	Hiroki Ohkuma
Hiroshima City Hiroshima Citizens Hospital	Shigeki Nishino
Hiroshima Prefectural Hospital	Atsushi Tominaga
Hiroshima Red Cross Hospital & Atomic Bomb Survivors Hospital	Masayuki Sumida
Hiroshima University Hospital	Takahito Okazaki, Shirou Aoki
Hito Medical Center	Naoki Shinohara
Hokkaido Medical Center	Satoshi Ushikoshi
Hokkaido University Dept. Neurosurgery	Syunsuke Terasaka, Kiyohiro Houkin
Hokushikai Megumino Hospital	Mitsunobu Kaijima
Hokuto Hospital	Kimito Kondo, Kazumi Nitta
Hospital	Toshiki Ikeda, Hidetoshi Ooigawa
Hospital Nanbu Tokushukai	Tutomu Kadekaru
Hukuoka City Hospital	Katsuyuki Hirakawa
Hyogo College of Medicine	Shinichi Yoshimura

Hyogo Prefectural Awaji Medical Center	Yoshio Sakagami
Hyogo Prefectural Kakogawa Medical Center	Hideo Aihara
Hyogokenritu_Nishinomiya_Hospital	Takayuki Sakaki
Ibaraki Prefectural Central Hospital	Hiroko Oyama, Yuuji Kujiraoka
Ibaraki Seinan Medical Center Hospital	Keishi Fujita
Iida Municipal Hospital	Sumio Kobayashi
Imari Arita Kyoritsu Hospital	Nobuaki Momozaki
Ina Central Hospital	Atsushi Sato
Inagi Municipal Hospital	Hideki Murakami, Tatsuo Iwasita
Institute of Brain and Blood Vessels Mihara Memorial Hospital	Akazi Kazunori, Takao Kanzawa
Irixyouhoujin Okinawatokushuukai Uwajimatokushukai Hospital	Hiromichi Sadashima
Iryohojin Seiwakai Wada Hospital	Shiro Miyata
Iryouhoujinsyadanjinmeikai Akiyamanousinnkeigeka	Takekazu Akiyama
Iryouhouzinsyadan Meihoukai Yokohamashintoshinoushinkeigekabyouin	Akihiro Nemoto, Masafumi Morimoto
Isahaya General Hospital	Yoshihiro Nishiura
Ise Red Cross Hospital	Fumitaka Miya, Masunari Sibata
Ishikawa Prefectural Central Hospital	Yutaka Hayashi
Ishinomaki Red Cross Hospital	Syuichi Ishikawa
Itabashi Chuo Medical Center	Miura Naohisa
Itami Kousei Neurosurgical Hospital	Shinya Noda

Iwaki Kyoritsu General Hospital	Yasuhiro Suzuki
Iwata Municipal General Hospital	Shinji Amano
Iwate Medical University	Kuniaki Ogasawara
Iwate Prefectural Central Hospital	Takayuki Sugawara
Iwate Prefectural Iwai Hospital	Keiichi Saitou
Iwate Prefectural Kuji Hospital	Kazuyuki Miura
Iwate Prefectural Ninohe Hospital	Akinori Yabuta
Izumi Hospital	Makoto Hasebe
Izumino Hospital	Masato Seike
Japan Community Health Care Organization Chukyo Hospital	Akira Ikeda
Japan Community Health Care Organization Kyushu Hospital	Satoshi Inoha
Japan Community Health Care Organization Tokyo Takanawa Hospital	Hirofumi Hiyama
Japan Organization of Occupational Health and Safety Kumamoto Rousai Hospital	Hiromasa Tsuiki, Shigeo Yamashiro
Japanese Red Cross Akita Hospital	Keiichi Nishimaki
Japanese Red Cross Asahikawa Hospital	Katsumi Takizawa, Kenichi Makino
Japanese Red Cross Fukuoka Hospital	Hitoshi Tsugu, Jiro Kitayama
Japanese Red Cross Kitami Hospital	Nozomi Suzuki
Japanese Red Cross Kumamoto Hospital	Shu Hasegawa, Tadashi Terasaki
Japanese Red Cross Maebashi Hospital	Ken Asakura

Japanese Red Cross Medical Center	Ichiro Suzuki
Japanese Red Cross Society Hachinohe Hospital	Hiromu Konno
Japanese Red Cross Takayama Hospital	Katsunobu Takenaka
Japanese Redcross Fukui Hospital	Hiroki Toda, Taketo Hatano
Jcho Hitoyoshi Medical Center	Keizou Yamamoto
Jcho Kobe Central Hospital	Keigo Matsumoto
Jcho Kumamoto General Hospital	Kazunari Koga
Jcho Nankai Medical Center	Takamitu Hikawa
Juntendo Universty Hospital	Hajime Arai
Kaetsu Hospital	Kazuaki Awamori
Kaga Medical Center	Naoki Shirasaki
Kagawa Rosai Hospital	Kimihiro Yoshino
Kagawa University Hospital	Takashi Tamiya
Kagoshima City Hospital	Kazuho Hirahara
Kagoshima Prefectural Kanoya Medical Center	Shunichi Tanaka
Kagoshima Tokushukai Hospital	Teruaki Kawano
Kagoshima University Hospital	Sei Sugata, Kazunori Arita
Kan-Etsu Hospital	Masahiko Tanaka
Kanazawa Medical Univercity	Shunsuke Shiraga
Kanazawa Neurosurgical Hospital	Syuji Sato
Kanazawa University Hospital	Mitsutoshi Nakada

Kaneda Hospital	Kimihisa Kinoshita
Kanmon Medical Center	Katsuhiro Yamashita
Kano Hospital	Nakazawa Kazutomo
Kansai Electric Power Hospital	Yasuhiro Fujimoto
Kansai Medical University Hospital	Kunikazu Yoshimura
Kanto Rosai Hospital	Takayuki Tachizawa
Kasaoka Daiichi Hospital	Akira Watanabe
Kashiwaba Nourosagical Hospital	Tetsuyuki Yoshimoto
Kasugai Municipal Hospital	Naoto Kuwayama
Kawasaki Medical School Hospital	Masaaki Uno
Kazuno Kosei Hospital	Masayuki Sasou
Keiju Medical Center	Sotaro Higashi
Keishunkai Medical Corporation Kobari General Hospital	Naoaki Sato
Kenwakai Hospital	Masakazu Kitahara
Kenwakai Otemati Hospital	Hiroshi Yoneda
Kieikai Hospital	Satoshi Suzuki
Kindai University Hospital	Toshiho Ohtsuki, Amami Kato
Kindai University Sakai Hospital	Yusaku Nakamura
Kiryu Kosei General Hospital	Satoshi Magarisawa
Kishiwada City Hospital	Kenji Hashimoto
Kishiwada Tokushukai Hospital	Hiroyuki Matsumoto

Kita-Harima Medical Center	Hirotoshi Hamaguchi, Shigeru Miyake
Kitakami Saiseikai Hospital	Tomohiko Satou
Kitakyusyu General Hospital	Masaru Idei
Kitakyusyu Municipal Medical Center	Masahiro Mizoguchi
Kitamurayama Hospital	Eiichiro Kamatsuka
Kitasato University School of Medicine	Toshihiro Kumabe
Kobe City Medical Center General Hospital	Nobuyuki Sakai
Kobe Ekisaikai Hospital	Takashi Tominaga
Kobe Red Cross Hospital	Haruo Yamashita
Kobe University Hospital	Eiji Kohmura, Tatsushi Toda
Kochi Health Sciences Center	Tsuyoshi Oota, Masanori Morimoto
Kochi Medical School Hospital	Tetsuya Ueba
Kohka Public Hospital	Kazuyoshi Watanabe
Kohnan Hospital	Hidenori Endo
Kohsei General Hospital	Kenjirou Hujiwara, Minoru Nakagawa
Kokura Memorial Hospital	Taketo Hatano, Akira Ishii
Komaki City Hospital	Toshinori Hasegawa
Komatsu Municipal Hospital	Hisashi Nitta
Komoro Kosei General Hospital	Takayuki Kuroyanagi
Koshigaya Municipal Hospital	Akira Tunoda
Koto Memorial Hospital	Hisao Hirai

Koyama Memorial Hospital	Takuya Kawai
Kugayama Hospital	Mitsuyuki Fujitsuka
Kumamoto City Hospital	Akira Takada, Seiji Tajiri
Kurashiki Central Hospital	Masaki Chin
Kurashiki Heisei Hospital	Hidemiti Sasayama
Kurosawa Hospital	Sigehiro Ohmori
Kurosishi General Hospital	Seiko Hasegawa
Kurosu Hospital	Kazuhiro Kikuchi, Mikio Teduka
Kurume University Hospital	Motohiro Morioka
Kyorin University Hospital	Yoshiko Unno, Hiroki Yoshida , Teruyuki Hirano
Kyoritsu Hospital	Masayuki Yokota
Kyoto Okamoto Memorial Hospital	Minoru Kidooka
Kyoto Second Red Cross Hospital	Hiroshi Tenjin
Kyoto Univerisity Hospital	Susumu Miyamoto
Kyoto Yamashiro General Medical Center	Yoshihiro Iwamoto
Kyotokatsura Hospital	Yasumasa Yamamoto
Kyotomin-Iren Chuohospital	Yuko Shikata
Kyushu Central Hospital of The Mutual Aid Association of Public School Teachers	Hitonori Takaba
Kyushu Rosai Hospital	Sei Haga

Kyushu University Hospital	Koji Iihara
Local Incorporated Administrative Agency Tokushima Prefecture Naruto Hospital	Masahito Agawa
Makita General Hospital	Yoshinori Arai
Maruko Central Hospital	Toshiyuki Tsukada
Matsushita Memorial Hospital	Nozomu Murai
Matsuyama Shimin Hospital	Masakazu Suga
Mazda Hospital	Kawamoto Yukihiko
Medical Corporation Ijinkai Nakamura Memorial Hospital	Kenji Kamiyama
Medical Corporation Meiseikai Abashiri Neurosurgicalrehabilitation Hospital	Naoto Izumi
Meitetsu Hospital	Youtarou Takeuchi
Midorigaoka Hospital	Motohiro Arai
Mie University Hospital	Hidenori Suzuki
Mimihara General Hospital	Shinji Okumura
Minamata City General Hospital and Medical Center	Makoto Yoshikawa
Minami Wakayama Medical Center	Yoshinari Nakamura
Minato Medical Coop-Kyoritsu General Hospital	Hisashi Tanaka
Mito Kyodo General Hospital	Yasusi Sibata
Mitoyogeneralhospital	Tetsuya Masaoka
Mitsugi General Hospital	Takashi Matsuoka

Miyakonojo Medical Association Hospital	Hajime Ohta
Miyoshi Central Hospital	Osamu Hamasaki
Moriguchi-Ikuno Memorial Hospital	Misao Nishikawa
Morioka Red Cross Hospital	Naohiko Kubo
Munakata Suikokai General Hospital	Yosimasa Kinosita
Muroran City General Hospital	Hiroshi Ooyama
Nagahama City Hospital	Taro Komuro
Nagano Municipal Hospital	Yoshikazu Kusano
Nagaoka Chuo General Hospital	Shigekazu Takeuchi
Nagasaki Kawatana Medical Center	Ei-Ichirou Urasaki
Nagasaki University Hospital	Takayuki Matsuo
Nagasakiken Shimabara Hospital	Yoshiharu Tokunaga
Nagoya City University	Mitsuhito Mase
Nagoya Daini Red Cross Hospital	Yukio Seki, Keizo Yasui
Nagoya University Hospital	Yoshio Araki
Naha City Hospital	Naoki Tomiyama
Nakamura Memorial South Hospital	Taiichiro Watanabe, Koji Oka
Nakatsu Municipal Hospital	Hiromichi Koga
Nara Medical University	Hiroyuki Nakase
Narita Red Cross Hospital	Michio Nakamura
National Cerebral and Cardiovascular Center	Jun Takahashi

National Hospital Organization Chiba Medical Center	Hirokazu Tanno
National Hospital Organization Hamada Medical Center	Takato Kagawa
National Hospital Organization Himeji Medical Center	Osamu Narumi
National Hospital Organization Kyushu Medical Center	Akira Nakamizo, Shinji Nagata
National Hospital Organization Nagoya Medical Center	Noriyuki Suzaki
National Hospital Organization Okayama Medical Center	Yoichiro Namba
National Hospital Organization Osakaminami Medidcal Center	Tomonori Yamada
National Hospital Organization Tochigi Medical Center	Masayuki Ishihara
National Hospital Organization Toyohashi Medical Center	Hideki Sakai
National Hospital Organization Ureshino Medical Center	Masayuki Miyazono
National Hospital Organization, Iwakuni Clinical Center	Kotaro Ogihara
Nayoro City Hospital	Naoki Tokumitsu
Nho Sendai Medical Center	Masayuki Ezura
Nho Shinshu Ueda Medical Center	Keiichi Sakai
Nihon University　Itabashi Hospital	Atsuo Yoshino
Niigata City General Hospital	Kenichi Morita, Akihiko Saito
Niigata Prefectural Central Hospital	Igarashi Michitoku
Niigata Tokamachi Hospital	Mitsuo Kouno
Niigata University Medical and Dental Hospital	Yukihiko Fujii, Osamu Onodera
Niigatanougekabyouin	Kiyoshi Onda
Nishikobe Medical Center	Naoya Takeda

Nishinomiya Kyoritsu Neurosurgical Hospital	Hiroji Miyake
Nishio Municipal Hospital	Toshio Yokoe
Nishitokyo Central General Hospital	Tatsuya Nakamura
Nissan Tamagawa Hospital	Takayuki Kubodera
Nitobe Memorial Nakano General Hospital	Mitsuhiko Hokari
Noshiro Kosei Medical Center	Yasunari Otawara
Noto General Hospital	Cheho Park
Nozaki Tokushukai Hospital	Hidemitu Nakagawa
Obara Hospital	Souichi Obara
Obase Hospital	Haruki Takahashi
Obihiro Kosei General Hospital	Masafumi Ohtaki
Odate Municipal General Hospital	Atsuya Okubo
Ogaki Tokushukai Hospital	Katsuhiko Hayashi
Ohnishi Neurological Center	Hideyuki Ohnishi, Yoshihiro Kuga
Ohta Nishinouchi Hospital	Masahisa Kawakami
Oita Prefectural Hospital	Yu Takeda
Oitaken Koseiren Tsurumi Hospital	Akihiko Kaga
Okaya City Hospital	Ryoichi Hayashi
Okayama City Hospital	Koji Tokunaga
Okayama Kyokuto Hospital	Hiroyuki Nakashima
Okayama University Hospital	Isao Date

Okinawa Kyodo Hospital	Koji Idomari, Nobuyuki Kaneko
Okinawa Prefectural Nanbu Medical Center and Children's Medical Center	Tomoaki Naganine
Okitama Public General Hospital	Toshihiko Kinjo
Ome Municipal General Hospital	Yoshiaki Takada, Osamu Tao
Omihachiman Community Medical Center	Masayuki Nakajima
Omori Red Cross Hospital	Akira Isoshima
Omuta City Hospital	Terukazu Kuramoto
Onomichi Municipal Hospital	Shigeru Daido
Osaka Medical College	Toshihiko Kuroiwa
Osaka National Hospital	Kazuo Hashikawa
Osaka Neurological Institute	Akatsuki Wakayama
Osaka Neurosurgical Hospital	Naoki Hayashi
Osaka University Hospital	Kouich Iwatsuki, Toshiki Yoshimine
Osaki Citizen Hospital	Masahiro Yoshida
Otaru General Hospital	Yoshimasa Niiya
Otsu City Hospital	Motohiro Takayama
Otsu Red Cross Hospital	Masaaki Saiki
Rakuwakaiotowa Hospital	Kazuo Yamamoto
Research Institute For Brain and Blood Vessels-Akita	Junta Moroi, Taizen Nakase, Tatsuya Ishikawa
Saga-Ken Medical Centre Koseikan	Shuji Sakata, Hiroshi Sugimori

Saiseikai Futsukaichi Hospital	Naoko Fujimura
Saiseikai Imabari Hospital	Osamu Nishizaki
Saiseikai Kumamoto Hospital	Toru Nishi
Saiseikai Kurihashi Hospital	Hiroshi Wanihuti
Saiseikai Kyouto Hospital	Nobukuni Murakami
Saiseikai Matsusaka General Hospital	Hiroto Murata
Saiseikai Nagasaki Hospital	Wataru Haraguchi
Saiseikai Toyama Hospital	Yukio Horie
Saiseikai Yahata General Hospital	Yuji Okamoto
Saiseikai Yokohamashi Tobu Hospital	Makoto Inaba
Saiseikaiustunomiya Hospital	Masashi Nakatsukasa
Saitama City Hospital	Atsuhiro Kojima
Saitama Medical Center	Kyoichi Nomura
Saitama Red Cross Hosoital	Toshie, Yamamoto Kenji Takahashi
Sakai City Medical Center	Yoshikazu Nakajima
Saku Central Hospital Advanced Care Center	Takaaki Yoshida
Sanyudohospital	Yohei Kudoh
Sapporo Azabu Neurosurgical Hospital	Toshitaka Nakamura
Sapporo Medical University Hospital	Nobuhiro Mikuni
Sapporo Shiroishi Memorial Hospital	Akira Takahashi
Sapporoteishinkaihospital	Rokuya Tanikawa

Sasebo Chuo Hospital	Seisaburo Sakamoto
Secomedic Hospital	Seiichiro Hoshi
Seikeikai Hospital	Yoshinari Okumura
Seirei Memorial Hospital	Sinichi Okabe
Seirei Mikatahara General Hospital	Haruhiko Sato
Sendai City Hospital	Hirosi Karibe
Shakaiiryouhoujinzaidanshinwakaiyachiyobyouin	Takashi Inoue
Shikoku Medical Center For Children and Adults	Kazuyuki Kuwayama
Shimane Prefectural Central Hospital	Tatsuya Mizoue
Shimizu Hospital	Takashi Yoshida
Shimonoseki City Hospital	Takaharu Nakamura
Shin Koga Hospital	Tsutomu Hitotsumatsu
Shin-Oyama City Hospital	Tomoaki Kameda
Shingu Municipal Medical Center	Mitsukazu Nakai, Hiroshi Ishiguchi
Shinonoi General Hosapital	Masanobu Hokama
Shinsapporo Neurosurgical Hospital	Akinori Yamamura
Shinshu University Hospital	Kazuhiro Hongo
Shinsuma General Hospital	Takeshi Kondoh
Shintakeohospital	Makoto Ichinose
Shizuoka Children's Hospital	Yuzuru Tashiro
Shizuoka City Shizuoka Hospital	Seiji Fukazawa

Shonan Kamakura General Hospital	Takahisa Mori
Showa Inan General Hospital	Shinsuke Muraoka
Showa University Fujigaoka Hospital	Tomoaki Terada
Shuuwa General Hospital	Tsuneo Shishido
Social Welfare Organization Saiseikai Imperial Gift Foundation Inc.	
Osaka Saiseikai Ibaraki Hospital	Yasunobu Gotou
Social Welfare Organization Saiseikai Imperial Gift Foundation	
Inc.Yamagata Saisei	Sunao Takemura
South Miyagi Medical Center	Hiroaki Arai
Southern Tohoku Hospital	Zenichiro Watanabe
St. Marianna University School of Medicine	Yuichiro Tanaka
St.Luke's International Hospital	Yasunari Niimi
Steel Memorial Yawata Hospital	Shinya Yamaguchi, Akira Nakamizo
Suiseikai Kajikawa Hospital	Shinichi Wakabayashi
Suwa Central Hospital	Hiroki Sato
Suwa Red Cross Hospital	Yukinari Kakizawa
Syakaiiryouhouzin Kouseikai Takai Hospital	Tetsuya Morimoto
Tachibana Medical Corporation Higashisumiyoshi Morimoto Hospital	Naofumi Isono
Tachikawa General Hospital	Hiroki Takano, Hiroshi Abe
Takamatsu Municipal Hospital	Norihito Shirakawa
Takamatsu Red Cross Hospital	Masahiro Kagawa

Takarazuka City Hospital	Eiichiro Mabuchi
Takarazuka Daiichi Hospital	-
Takatsuki General Hospital	Kazusige Maeno
Takeda General Hospital Organization	Takayuki Koizmi
Takeda Hospital	Waro Taki
Takikawa Neurosurgical Hospital	Yusuke Nakagaki
Tanushimaru Central Hospital	Yoshihisa Matumoto
Teinekeijinkai Hospital	Katuyuki Asaoka
Tenri Hospital	Yoshinori Akiyama
Tenshindo Hetsugi Hospital	Tadao Kawamura
Teraoka Memorial Hospital	Atumi Takenobu
The Veritas Hospital	Masayuki Yokota
Tobata Kyoritu Hospital	Taketoshi Tuji
Tohoku University Hospital	Teiji Tominaga
Tokai University Hachioji Hospital	Shigeru Nogawa, Masami Shimoda
Toki General Hospital	Sinji Noda
Tokushima Red Cross Hospital	Hajimu Miyake
Tokushima University Hospital	Shinji Nagahiro, Junichiro Satomi
Tokuyama Central Hospital	Kunihiko Harada
Tokyo Dental College Ichikawa General Hospital	Sadao Suga
Tokyo General Hospital	Shinichi Numazawa

Tokyo Medical and Dental University	Taketoshi Maehara
Tokyo Medical University Hachioji Medical Center	Hiroyuki Jimbo, Jyunya Tsurukiri
Tokyo Medical University Hospital	Michihiro Kohno
Tokyo Metropilitan Hiroo Hospital	Kensaku Yoshida
Tokyo Metropolitan Geriatric Hospital and Institute of Gerontology	Koji Matuoka
Tokyo Metropolitan Tama Medical Center	Takahiro Ota
Tokyo Saiseikai Central Hospital	Haruhiko Hoshino
Tokyo Teisin Hospital	Makoto Noguchi
Tokyo Women's Medical University	Takakazu Kawamata
Tokyo Yamate Medical Center	Yasuaki Takeda
Tomakomaihigashi Hospital	Youichi Hashimoto
Tomei Atsugi Hopital	Keiichirou Onitsuka
Tominaga Hospital	Masahiko Kitano
Tomishiro Central Hospital	Jae-Hyun Son
Tottori Municipal Hospital	Keiichi Akatsuka
Tottori University	Masamichi Kurosaki, Takashi Watanabe
Toyama City Hospital	Miyamori Tadao
Toyama Prefectural Central Hospital	Hiroaki Hondo
Toyama Red Cross Hospital	Kazumasa Yamatani, Kotaro Tsumura
Toyama University Hospital	Satoshi Kuroda
Toyohashi Municipal Hospital	Hirofumi Oyama

Toyokawa City Hospital	Takayuki Watanabe
Toyooka Hospital	Kazuhiro Tanaka
Tsuchiura Kyodo General Hospital	Shinji Yamamoto
Tsukuba Medical Center Hospital	Kazuya Uemura
Tsuruoka Municipal Shonai Hospital	Hirosi Maruya, Kazuhiko Sato
Tsutiura Kyodo Hospital Namegata District Medical Center	Hitoshi Tabata
Tsuyama Chuo Hospital	Hideyuki Yoshida
Tyuubu Rousai Hospital	Noriaki Matubara
Ube Kohsan Industries Hospital	Takafumi Nishizaki
Uki General Hospital	Hiroshi Egami
University of Fukui Hospital	Osamu Yamamura
University of Occupational and Environmental Health	Junkoh Yamamoto
University of The Ryukyus Hospital	Shogo Ishiuchi
University of Tsukuba Hospital	Yuji Matsumaru, Akira Matsumura, Tetsuya Yamamoto
University of Yamanashi	Hiroyuki Kinouchi
Urasoe General Hospital	Susumu Mekaru
Ushioda General Hospital	Hitoshi Ozawa
Uwajima City Hospital	Kiichiro Zenke
Wakayama Medical University Hospital	Naoyuki Nakao
Wakayama Rosai Hospital	Toshikazu Kuwata

Wakayama-Seikyo Hospital	Teruyuki Habu
Yaizu City Hospital	Seiya Takehara
Yamagata City Hospital Saiseikan	Rei Kondo
Yamagata Prefectural Central Hospital	Takashi Kumagai
Yamagata Prefectural Shinjo Hospital	Keiten So
Yamagata University Hospital	Yukihiko Sonoda
Yamaguchi Prefectural Grand Medical Center	Manabu Urakawa
Yamaguchi Red Cross Hospital	Yasuhiro Hamada
Yamaguchi University Hospital	Michiyasu Suzuki
Yamanashi Prefectural Central Hospital	Shin Nakano, Hidehito Koizumi
Yamanashi Redcross Hospital	Hiroshi Ozawa
Yamanashikouseibyouin	Mikito Uchida
Yamato Municipal Hospital	Masaru Yamada
Yao Tokushukai General Hospital	Takashi Turuno
Yatsuo General Hospital	Ryouichi Masuda
Yawata Medical Center	Makoto Kimura
Yayoigaoka Kage Hospital	Shin-Ichiro Ishihara
Yodogawa Christian Hospital	Masashi Morikawa
Yokohama City Minato Red Cross Hospital	Yasunori Takemoto, Hiroaki Tanaka
Yokohama City University Hospital	Hidetoshi Murata, Nobutaka Kawahara
Yokohama City University Medical Center	Katsumi Sakata

Yokohamasinmidorihospital	Endo Sumio
Yonezawa City Hospital	Tooru Sasaki
Yoshida Hospital	Yasuhisa Yoshida
Yuaikaihospital	Yoshihumi Teramoto

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	11
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	10
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(b) Give reasons for non-participation at each stage	14
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-14
		(b) Indicate number of participants with missing data for each variable of interest	14
Outcome data	15*	Report numbers of outcome events or summary measures	11-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	11-13

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	11-13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.