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Title: Trends in hospital standardized mortality ratios for Stroke in Japan between 2012 and 2016: A retrospective observational study

Running Title: Variation in HSMRs of Stroke

Abstract

Objective

Stroke is one of the leading cause of death and disability, imposes a major healthcare burden. Aim of this study was to determine the characteristics of hospital standardized mortality ratios (HSMRs) for stroke in Japan for the year 2012-2016 to describe the trend.

Design

Retrospective observational study.

Setting

Data from the Japanese administrative database.

Participants

All hospital admissions for stroke were identified from DPC database from 2012 to 2016.

Main Outcome Measures

HSMR was calculated using the actual number of in-hospital deaths and expected deaths. To obtain the expected death number, a logistic regression model was developed to get the coefficient with a number of explanatory variables. Predictive accuracy of the logistic models were assessed using c-index and calibration was evaluated using the Hosmer-Lemeshow test.

Results

Total 63,084 patients admitted for stroke from January 2012 to December 2016, were analyzed. HSMRs showed declining tendency over these 5 years, suggesting stroke-related mortality has been improving. While the HSMRs varied from year to year, a wide variation was also seen among the different hospitals in Japan. The proportion of hospitals with HSMR less than 100, increased from 41.0% in 2012 to 59.0% in 2016.

Conclusion

This study demonstrated that HSMR can be calculated using DPC data and found wide variation in HSMR of stroke among hospitals in Japan and enabled us to image the trend. By examining these trends, facilities, authorities and provinces can initiate designs that will ultimately lead to an upgraded healthcare delivery system.

Keywords: stroke, Japan, in-hospital mortality, quality indicator, health care/ standards, benchmarking

Introduction:

Worldwide, about 6.5 million people die from stroke each year [1]. According to the 2013 Global Burden of Disease study, stroke is the second largest contributor to disability adjusted life years (113 million disability adjusted life years) in the world and is the second highest cause of dementia [1]. In 2017, cerebrovascular disease (CVD) was the third leading cause of death in Japan despite improvements in acute care over the last few decades, and the crude mortality rate from stroke was 49.8 per 100,000 population [2]. Results from the Hisayama study have shown that despite mortality from stroke decreasing over time owing to the improved management of hypertension [3], four individuals still die every hour on an average from stroke in Japan [2]. Stroke fatality rates are now used for hospital benchmarking among member countries of the Organization for Economic Co-operation and Development (OECD), as stroke survival partly reflects the quality of acute care delivered [4].

The quality of care in hospitals has been the subject of growing attention from regulators and physicians in the past few decades, and it is a critical prerequisite for making improvements. Hospital standardized mortality ratio (HSMR) is a representative risk-adjusted tool for quality improvement in hospitals. It measures mortality by taking account of factors known to affect the underlying risk of death. When tracked over time, the HSMR indicates how successful hospitals or health regions have been in reducing inpatient deaths and improving care. HSMRs have been used in the USA, Canada, Sweden, Wales, Australia, France, Singapore and Hong Kong, and can be used to assess mortality, identify areas for possible improvement and monitor performance over time [5].

Recently, hospital administrative data have been used widely for research and quality improvement efforts [6]. DPC (Diagnostic Procedures Combination)/ PDPS (Per-Diem Payment System) is a reimbursement method for acute care hospitals introduced in 2003, and DPC database is a national administrative claims and discharge abstract database for acute care inpatients in Japan [7, 8]. Several HSMR studies have been conducted in Japan [9-11], and the single-year HSMR model has already been created using the DPC data for stroke [12]. However, the trend of the Japanese HSMRs for stroke has not yet been monitored, and studies regarding this are sparse in the international literature. We believe that diagnosis-specific HSMR is potentially a more fruitful method for monitoring mortality over time, which allows earlier identification of care deficiencies.

Aim of this study was to establish the calculation method of HSMR using the DPC data; and determine the characteristics of HSMR for stroke in Japan for the year 2012-2016 to capture and describe the trend. To the best of our knowledge, this is the first HSMR study of stroke revealing a 5-year trend using administrative data.

Methods:

HSMR method, originally developed by Jarman, B. and the Dr. Foster unit, was used for this retrospective observational study [5, 13].

Data Sources

DPC data of the Medi-Target benchmarking project managed by the All Japan Hospital Association (AJHA) were used. The data contain unique hospital identifiers; demographics of the patients; diagnoses coded according to the International Classification of Diseases, 10th revision (ICD 10); diagnoses that led to hospitalization; their most resource consuming disease; in-hospital death; length of stay (LOS); disease specific conditions such as the Japan coma scale (JCS), modified Rankin score (mRS); comorbidities, complications, and treatment procedures etc. The AJHA is one of the largest nation-wide hospital associations comprising of 2,500 hospitals, which manages the administration of the Medi-Target project, a benchmark project using clinical indicators based on DPC/PDPS data. Participation in the Medi-Target project was optional, and there were 182 participating hospitals in 2010, submitting about 500,000 claims data in a year [8].

Nature of the used data is anonymous; therefore no IRB (Institutional Review Board) approval is necessary for this kind of study in Japan [14].

Study population

All hospital admissions for cerebral infarction were identified from DPC database for the year 2012 to 2016. ICD-10 code (I63-I64) was used to determine the major diagnoses. Hospitals which had ≤ 10 patients per year and those that lacked continuity of monthly data submission were excluded from the study.

Data Characteristics

Patient and hospital-level data were collected as covariates for case mix adjustment. Patient-level data included sex, age, type of admission (emergency or elective), mode of transportation (ambulance use), comorbidities on admission and during hospital stay, JCS score on admission, LOS, operative status (surgery done or not) and in-hospital death. JCS is the most widely used clinical tool to assess the consciousness level in Japanese emergency care [12]. It consists of a scale of ten levels categorized into four groups: (i) JCS score 0 (complete alert state); (ii) JCS score 1-3 (disoriented: awake without stimulation); (iii) JCS score 10-30 (somnolent: responds only with stimulation), and (iv) JCS score 100-300 (comatose: unarousable despite stimulation). Recoding of JCS for the analysis purpose was done as following: JCS level 1-3 as 1, JCS level 10-30 as 2, and JCS level 100-300 as 3. JCS and Glasgow Coma Scale assessments are well correlated [12]. Later, Charlson comorbidity Index (CCI; range 0-6), which is derived from secondary ICD-10 diagnoses codes, was calculated. The CCI is a weighted score based on the number and type of diagnoses reported in the hospital summary data [15, 16]. Hospital-level data included patient volume per month. Outcome variable was in-hospital mortality, which was defined as death during hospital stay in the given period of time (2012-2016).

Calculation of HSMR

HSMR is defined as the ratio of the actual number of in-hospital deaths to the expected number of such deaths multiplied by 100 [17].

$$\text{HSMR} = \left(\frac{\text{Observed number of deaths}}{\text{Expected number of deaths}}\right) \times 100$$

The observed number of death is the sum of the actual number of deaths in that hospital. The expected number of death for a hospital is based on the sum of the probabilities of in-hospital deaths. An HSMR above and below 100 means the mortality rate is higher and lower than the overall average, respectively.

For a standard population during a baseline period of the risk of dying for a particular patient subgroup (e.g. age, sex, primary diagnosis, type of admission, number and severity of illness etc.) was calculated. This risk was then applied to the corresponding subgroups in different hospitals to calculate how many deaths would be predicted to occur in that hospital if the standard level of risk was applied.

At first, a multivariable logistic regression model was constructed to assume the likelihood of in-hospital death for each patient with patient-level and hospital-level factors. Logistic regression analyses were performed to calculate the intercept of co-variates i.e. sex, age, type of admission, mode of transportation, patient volume per month in each hospital, JCS score, and CCI. CCI was calculated based on Quan's methodology [15, 16]. All variables were categorical except age, CCI and patient volume, which are continuous variable. All independent variables were entered into the equation in one step (forced entry method). The predicted probability of death for each patient (ranging from 0-1) was calculated using this model. Then summation of the predicted probabilities of deaths of patients in each hospital was done to get the expected number of in-hospital deaths. This predicted figure was then compared with the actual observed number of deaths that occurred within the hospital to obtain the standardized ratio.

Single-year analysis

This model included the hospitals, which submitted complete data for 12 months; therefore, this number is different for each year.

5-year trend analysis

To assess the trend over time, a 5-year prediction model was created by including hospitals which had complete data for 5 years. Fitting one model to the data from all 5 years combined allowed us to make valid comparisons over time.

Statistical analysis

Following variables were examined for their association with in-hospital mortality: sex, age, type of admission, mode of transportation, LOS, operative status, JCS score at admission, and CCI. Summary statistics of categorical patient characteristics were presented as percentages, while the continuous variables were presented as mean and SD. Patient characteristics of the dead and alive groups were compared using either Chi-square tests for categorical variables and t-tests for continuous variables. P values <0.05 were considered statistically significant.

Predictive accuracy of the logistic model was assessed using c-index [11-12]. The c-index is derived by calculating the proportion of concordant pairs and is equal to area under receiver operating curve. Accuracy of the prediction models in each year was calculated to assess the stability of the models for all individual years. A c-index value of 0.5 suggests that the model is no better than random chance in predicting death; a value 1.0 indicates perfect discrimination. Calibration of each model was evaluated using the Hosmer-Lemeshow test (with $p > 0.05$ considered favorable). ROC curve was drawn to show the discriminative ability of the models.

The association between each year's HSMRs were evaluated by using spearman's correlation coefficient. All statistical analyses were performed by using the Statistical Package for Social Science (SPSS) version 17.0.0. 95% (CIs) of the HSMRs of 2012-2016 were calculated using Byar's approximation.

Results:

Patient demographics

Patients admitted from January 2012 to December 2016 with primary diagnosis of stroke were included. After exclusions, the overall sample size for the analysis was 63,084 patients over the 5-year study period. **Table 1** shows the demographics of the overall sample. Of the 63,084 patients, 94.2% were discharged alive. Essential hypertension was the single most commonly occurring (12,263 patients) comorbidity among stroke patients at admission. Other associated comorbidities at admission included type 2 diabetes mellitus (6,625), atrial fibrillation (3,797), and hyperlipidemia (2,279). The top five comorbidities after admission were aphasia and dysphagia (2,299), gastro-esophageal reflux (1,565), constipation (1,418), pneumonitis (1,189), and insomnia (999).

Patient characteristics of each year in the single-year model showed similar trend like 5-year model, which increases the robustness of the results.

HSMR

Supp. Table 1 shows the details of logistic regression models that was used to calculate the expected death rates in both models.

Single-year model

The HSMR widely varied across the hospitals included in this study. **Figure 1** shows the variation and distribution of the mean and SD of HSMRs for each year. HSMR ranged from 21-382% in 2012, 16-288% in 2013, 29-325% in 2014, 19-287% in 2015 and 34-302% in 2016. Of the hospitals evaluated, 48 (54%), 52 (63%), 30 (48%), 42

(55%), and 33 (48%) had higher mortality rate than expected in 2012, 2013, 2014, 2015 and 2016, respectively.

5-year trend

For this time series analysis, total 39 hospitals were included. The percentage of hospitals with mortality lower than the expected rates increased from 41.0% in 2012 to 59.0% in 2016, indicating a positive linear relationship **(Figure 2)**. The percent change in the HSMR during this 5-year period ranged from -0.24 to 0.28.

Mean and 95% CIs in each hospital have been graphed in **Figure 3**. While the lower limit varied from 20.3 to 135.2, the upper limit varied from 65.8 to 235.9. The mean HSMR was 102.9.

Statistical analysis

C-index showed strong predictive ability for both model; i.e. 0.816 for 5-year model, and no less than 0.804 in single year model. Results are shown in the supporting figure **(Supp. Figure 1)**. Both models showed good calibration, with P values from the Hosmer-Lemeshow test for the 5-year model being 0.002; and for single year model being 0.201, 0.701, 0.846, 0.214 and 0.374 in 2012, 2013, 2014, 2015 and 2016, respectively.

Table 1 compares the patient characteristics with mortality for statistical significance. All the analyzed variables showed a statistically significant relationship with mortality (P value < 0.05).

To check the change in each year's HSMR, the Spearman's non-parametric correlation between each consecutive year was calculated. The correlation analysis revealed a positive significant relationship between changes in the HSMR each year **(Table 2)**.

Discussion:

This study demonstrates that HSMRs can be calculated using DPC data. Findings of this study revealed HSMRs of stroke varied significantly among hospitals in Japan. While the HSMR was >1.50 in approximately 15 - 20% of the hospitals, it was < 0.50 in 10 - 16% of them.

Taking into account several factors, such as sex, age, type of admission, mode of transportation, patient volume per month in each hospital, JCS score on admission, and the CCI, some hospitals were found to have a higher mortality rate.

The 5-year HSMR trend reveals that though advancements in secondary prevention, improvements in medical care, therapeutic procedures like the endovascular therapy, and use of IV recombinant tissue plasminogen activator (rt-PA) therapy since 2004 [18], have all led to a decrease in deaths from stroke, some hospitals are still struggling in this area. Overall, the HSMRs showed a downward trend, which is consistent with previous studies from Japan and other countries [19, 10]. While some countries require public reporting of HSMR, there are no such requirements yet in Japan [10]. Considering there are no incentives for lowering the HSMRs in Japan, it is encouraging to see this downward trend.

The most notable findings in this study are the results of correlation analysis, which states that hospitals with lower HSMRs were likely to continue in doing so in next year; on the other hand, institutions with higher HSMR also continued to be in the same position, which warrants further detailed investigations.

Healthcare has become more complex than it was when there were fewer treatment options. Hospital death rates depend on many factors aside from quality and safety of care, including admission and discharge practices, coding definitions, and long-term care (LTC) resources. Part of the reduction in HSMRs could be due to by chance, better coding, regression to the mean, different discharge policies, or referral of more complicated patients to other hospitals. A study by Van Den Bosch et al. suggested that coding of main diagnoses, urgency of admission and comorbidities largely influenced HSMR outcomes [20]. Recently, hospitals have been encouraged to shorten the LOS as a part of the health sector reform implemented by the Ministry of Health, Labor and Welfare, Japan [21]. However, to shorten LOS, discharge policies of each facility might differ. If patients die after being discharged to community services/ LTC facilities, they are not included in the HSMR calculation.

The present study has several strengths. Firstly, the administrative database enabled us to conduct a study with large sample size and several variables. Secondly, this study developed a risk-adjusted model, which exhibited the variation in stroke mortality among hospitals in a period of 5 years.

Several limitations of this study are undeniable. Firstly, due to the retrospective and observational nature of this study, it was not possible to control the collection or reporting of several variables. Second, 30-day mortality has been argued to have better validity than in-hospital mortality [22]. To minimize the so-called "discharge bias," including post-discharge mortality in the HSMR calculation would be attractive. However, it is difficult to do so due to data unavailability. Third, tests for statistical significance were not done, so cautious interpretation is needed. Also, prediction model based on hospitals that voluntarily provided data may reduce the generalizability of the model. Fourth, ICD-10 codes didn't take into account the severity of stroke. Though we used JCS score, but JCS score evaluates consciousness level. Fifth, detail treatment history (medicines taken) data were not analyzed, which is our future study scope.

Additionally, this study used CCI score which is the overall severity. On the other hand, there is also a model that considers the presence or absence of CCI component diseases individually, and we'll carry it out as a matter for future study. Another often heard query is whether facilities with missing data could have had higher mortality rates than those whose data are reported. A legitimate concern is that the HSMR focuses entirely on mortality as an outcome, which is an incomplete measure of quality of care [23]. It has, therefore, been suggested to combine outcome indicators with process indicators. Furthermore, this study didn't analyze the relationship between hospital-level factors and HSMRs. Future studies can focus on structural characteristics of hospitals such as teaching status, location, presence of specialized stroke care unit, number of physicians, ICU performance and resource utilization [24, 25]. Another contradictory fact is, due to the lack of a clear relationship between the system level hospital changes and reductions in mortality, the utility of HSMR as a tool for measuring the performance of a hospital over time is debatable [23, 26]. We believe, HSMR is a relatively simple, macro-level measurement of institutional performance, and its true validity will be evident when institutions will conduct analyses of their own data to yield a true insight; admitting the effectiveness in reducing deaths are yet to be determined [27-29].

We also should keep in mind that HSMR is not intended for inter-hospital comparisons, rather, to provide hospitals and providers the trends in mortality rates over time to track their own progress, and if a hospital has high HSMR than others then further investigation is merited to exclude or identify quality of care issues.

Hospitals that have adopted this approach in the USA, UK, and Canada, have gained a thoughtful insight regarding mortality at their institution, which has been related with documented decline in mortality rates; and seemed to act as a powerful catalyst for initiating change [28, 30]. Therefore, if we look beyond the strict use of the HSMR; measurement and reporting of the issues that impact quality will drive improvements in practice, quality and patients' experience.

Conclusion:

This study enabled us to calculate HSMR using DPC data and found wide variation in HSMRs of stroke among hospitals; and this methodology can be applied in other disease category to visualize their trends. Although it is not easy to explain downward HSMR trend, further efforts are warranted for proper evaluation of the hospital performances. In addition to determining the quality of care, such assessments would provide benchmarking opportunities that can be used as an incentive for system reform.

Competing interests

The authors declare that they have no competing interests.

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Table 1. Patient characteristics

	2012				*2013*			
Characteristics	**All(n)**	**Alive**	**Dead**	**P value**	**All(n)**	**Alive**	**Dead**	**P value**
Age	74.0±12.7	73.6±12.7	82.3±10.0	**	73.7±13.1	73.3±13.1	82.3±10.0	**
Sex				**				**
Male	10086(57.2)	9629(57.7)	457(48.3)		8833(57.5)	8460(57.9)	373(48.9)	
Female	7550(42.8)	7060(42.3)	490(51.7)		6535(42.5)	6145(42.1)	390(51.1)	
CCI	3.9±1.6	3.9±1.6	4.9±1.7	**	3.9±1.7	3.9±1.7	4.9±1.7	**
LOS	27.3±41.5	26.4±34.9	42.6±101.7	**	26.8±38.8	26.0±35.9	41.6±74.2	**
Type of admission				**				**
Elective	1797(10.2)	1725(10.4)	72(7.4)		1875(12.2)	1830(12.5)	45(5.9)	
Emergency	15828(89.8)	14931(89.6)	897(92.6)		13488(87.8)	12770(87.5)	718(94.1)	
Ambulance use				**				**
Yes	7982(45.3)	7325(43.9)	657(69.4)		7027(45.7)	6482(44.4)	545(71.4)	
No	9654(54.7)	9364(56.1)	290(30.6)		8337(54.3)	8119(55.6)	218(28.6)	
Operative status				**				**
Surgery	1908(10.8)	1759(10.5)	149(15.7)		1706(11.1)	1570(10.7)	136(17.8)	
No surgery	15728(89.2)	14930(89.5)	798(84.3)		13662(88.9)	13035(89.3)	627(82.2)	
Severity status				**				**
JCS 0	10379(58.9)	10191(61.1)	188(19.9)		9114(59.3)	8965(61.4)	149(19.5)	
JCS 1	5924(30.0)	4988(29.9)	306(32.3)		4764(30.4)	4411(30.2)	263(34.5)	
JCS 2	1271(7.2)	1047(6.3)	224(23.7)		1049(6.8)	884(6.1)	165(21.6)	
JCS 3	692(3.9)	463(2.8)	229(24.2)		531(3.5)	345(2.4)	186(24.4)	

Table 1. Continued

	2014				*2015*			
Characteristics	**All(n)**	**Alive**	**Dead**	**P value**	**All(n)**	**Alive**	**Dead**	**P value**
Age	74.4±12.8	74.0±12.8	82.4±9.8	**	73.7±13.1	73.3±13.1	82.3±10.0	**
Sex				**				**
Male	6350(57.7)	6110(58.3)	240(45.3)		5638(56.2)	5400(56.9)	238(44.1)	
Female	4653(42.3)	4363(41.7)	290(54.7)		4393(43.8)	4091(43.1)	302(55.9)	
CCI	4.0±1.6	4.0±1.6	5.0±1.7	**	4.2±1.7	4.1±1.7	5.2±1.9	**
LOS	27.9±34.0	27.5±30.8	37.3±72.0	**	30.9±34.5	30.5±32.6	38.2±58.3	**
Type of admission				**				**
Elective	793(7.2)	772(7.4)	21(4.0)		696(6.9)	662(7.0)	34(6.3)	
Emergency	10197(92.8)	9689(92.6)	508(96.0)		9327(93.1)	8821(93.0)	506(93.7)	
Ambulance use				**				**
Yes	5309(48.3)	4928(47.1)	381(72.0)		4759(47.5)	4415(46.5)	344(63.7)	
No	5683(51.7)	5535(52.9)	148(28.0)		5266(52.5)	5070(53.5)	196(36.3)	
Operative status				**				**
Surgery	1056(9.6)	972(9.3)	84(15.8)		933(9.3)	841(8.9)	92(17.0)	
No surgery	9947(90.4)	9501(90.7)	446(84.2)		9098(90.7)	8650(91.1)	448(83.0)	
Severity status				**				**
JCS 0	6002(54.5)	5911(56.4)	91(17.2)		5376(53.6)	5270(55.5)	106(19.6)	
JCS 1	3791(34.5)	3622(34.6)	169(31.9)		3581(35.7)	3384(35.7)	197(36.5)	
JCS 2	787(7.2)	667(6.4)	120(22.6)		723(7.2)	602(6.3)	121(22.4)	
JCS 3	423(3.8)	273(2.6)	150(28.3)		351(3.5)	235(2.5)	116(21.5)	

Table1. Continued

	2016				*2012-2016*			
Characteristics	**All(n)**	**Alive**	**Dead**	**P value**	**All(n)**	**Alive**	**Dead**	**P value**
Age	75.2±12.4	74.8±12.3	82.6±11.0	**	74.4±12.7	74.0±12.7	82.5±10.1	**
Sex				**				**
Male	5243(58.0)	5016(58.6)	227(46.2)		36150(57.3)	34615(57.9)	1535(46.9)	
Female	3803(42.0)	3539(41.4)	264(53.8)		26934(42.7)	25198(42.1)	1736(53.1)	
CCI	4.1±1.7	4.0±1.6	5.2±2.2	**	4.0±1.7	3.9±1.6	5.0±1.8	**
LOS	30.6±33.5	30.1±32.0	39.9±52.4	*	28.3±37.5	27.7±33.8	40.2±78.0	**
Type of admission				*				*
Elective	615(6.8)	585(6.8)	30(6.1)		9104(14.4)	8744(14.6)	360(11.0)	
Emergency	8421(93.2)	8960(93.2)	461(93.9)		53934(85.6)	51027(85.4)	2907(89.0)	
Ambulance use				**				**
Yes	4324(47.9)	3979(46.6)	345(70.3)		29401(46.6)	27129(45.4)	998(30.5)	
No	4712(52.1)	4566(53.4)	146(29.7)		33652(53.4)	32654(54.6)	2272(69.5)	
Operative status				**				**
Surgery	835(9.2)	744(8.7)	91(18.5)		6438(10.2)	5886(9.8)	552(16.9)	
No surgery	8211(90.8)	7811(91.3)	400(81.5)		56646(89.8)	53927(90.2)	2719(83.1)	
Severity status				**				**
JCS 0	4716(52.1)	4632(54.2)	84(17.1)		35587(56.4)	34969(58.5)	618(18.9)	
JCS 1	3311(36.6)	3139(36.7)	172(35.0)		20651(32.7)	19544(32.7)	1107(33.8)	
JCS 2	689(7.6)	576(6.7)	113(23.0)		4519(7.2)	3776(6.3)	743(22.7)	
JCS 3	329(3.6)	207(2.4)	122(24.8)		2326(3.7)	1523(2.5)	803(24.5)	

** = P value < 0.001, * = P value < 0.5. Plus-minus values are means ± SD, () values are %

CCI= Charlson comorbidity index, LOS= length of stay, JCS= Japan coma scale

Table 2. Relationship between HSMRs of each consecutive year (single-year model)

Year	R	P	N
2012 & 2013	0.389	0.001	73
2013 & 2014	0.348	0.006	61
2014 & 2015	0.416	0.002	55
2015 & 2016	0.399	0.001	66

R = correlation coefficient (Spearman's non-parametric correlation), P = two tailed significance, N = number of hospitals

Positive correlation coefficient means hospitals with lower/ higher HSMRs are likely to get same results in next year

Supporting **Table 1.** Logistic regression models used to calculate the expected death rates

	2012		2013		2014		2015		2016		2012-2016	
	OR	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**	**OR**	**P value**
Age	1.04	< 0.001	1.04	< 0.001	1.03	< 0.001	1.04	< 0.001	1.02	< 0.001	1.03	< 0.001
Sex	0.78	< 0.05	0.85	0.05	0.95	0.61	0.93	0.47	0.95	0.62	0.87	0.001
Type of admission	0.91	0.25	1.10	0.57	0.98	0.92	0.75	0.16	0.62	< 0.05	0.85	0.01
Ambulance usage	1.64	< 0.001	1.71	< 0.001	1.51	< 0.001	1.21	0.08	1.67	< 0.001	1.55	< 0.001
CCI	1.23	< 0.001	1.20	< 0.001	1.23	< 0.001	1.21	< 0.001	1.28	< 0.001	1.23	< 0.001
JCS score	2.53	< 0.001	2.57	< 0.001	2.81	< 0.001	2.54	< 0.001	2.73	< 0.001	2.62	< 0.001
Patient vol./month	1.00	0.001	0.99	< 0.001	0.99	< 0.001	0.98	< 0.001	0.98	< 0.001	0.99	< 0.001
Negelkerke R^2	0.23		0.23		0.24		0.21		0.24		0.22	

OR= odds ratio, CCI= Charlson comorbidity Index, JCS= Japan coma scale

Figure Legends

Figure 1. Mean and SD of the HSMR for stroke for each year (single year model)

Abbreviation: HSMR= Hospital standardized mortality ratio

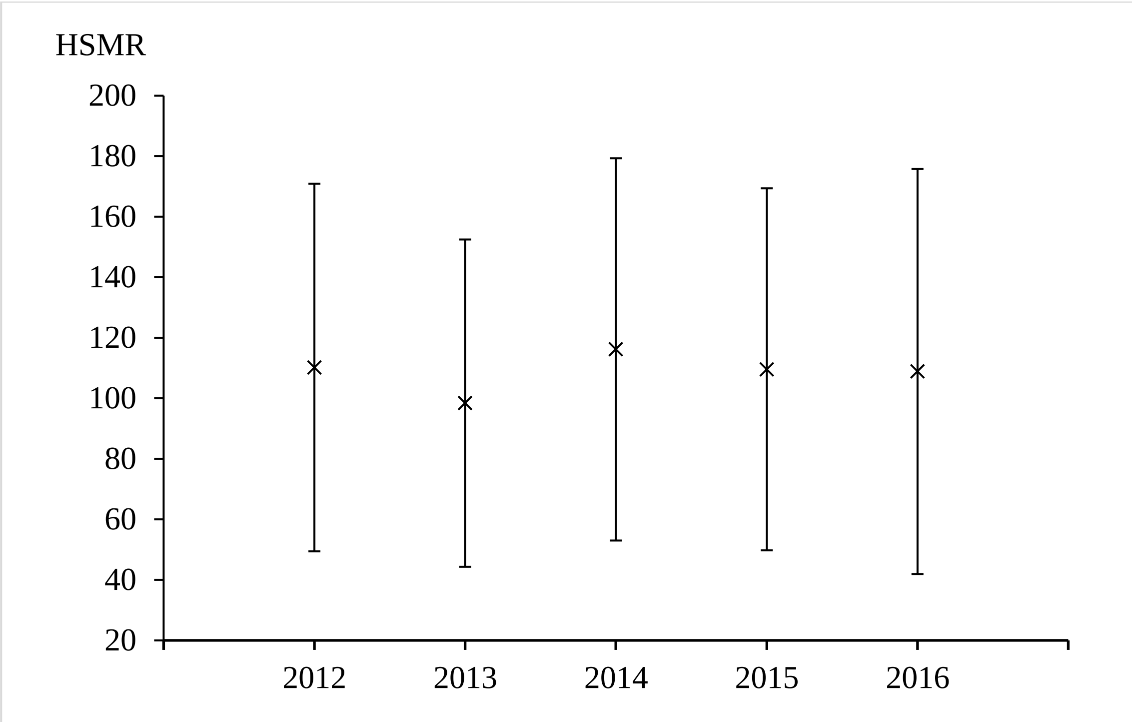
Figure 2. Changes in the trend of hospitals with HSMR ≤ 100 from 2012 to 2016 (n = 39)

Abbreviation: HSMR= Hospital standardized mortality ratio

Figure 3. Caterpillar plot of the HSMR for stroke (2012-2016, n=39) for each hospital. The HSMR is graphed as the upper and lower 95% confidence limits

Abbreviation: HSMR= Hospital standardized mortality ratio

Supporting **Figure 1.** Predictive ability of the models (single year model and 5-year model)



HSMR
200
180
160
140
120
100
80
60
40
20
2012
2013
2014
2015
2016

Figure 1

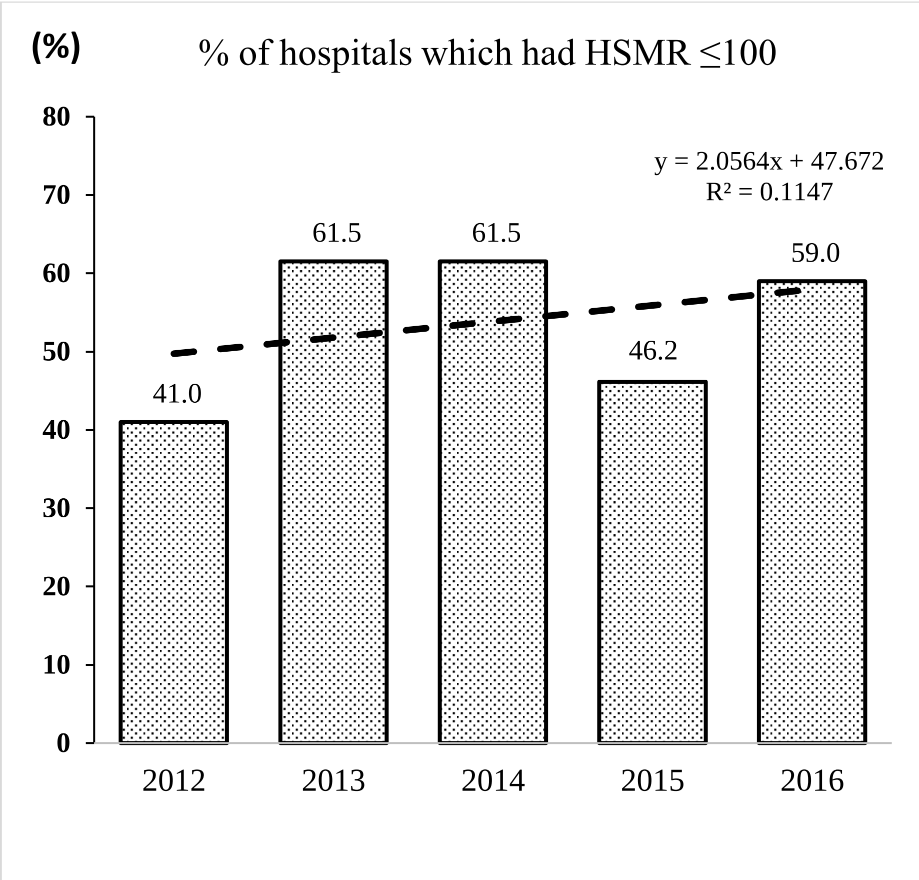

(%)
% of hospitals which had HSMR ≤100
80
70
60
50
40
30
20
10
0
y = 2.0564x + 47.672
R² = 0.1147
41.0
61.5
61.5
46.2
59.0
2012
2013
2014
2015
2016

Figure 2

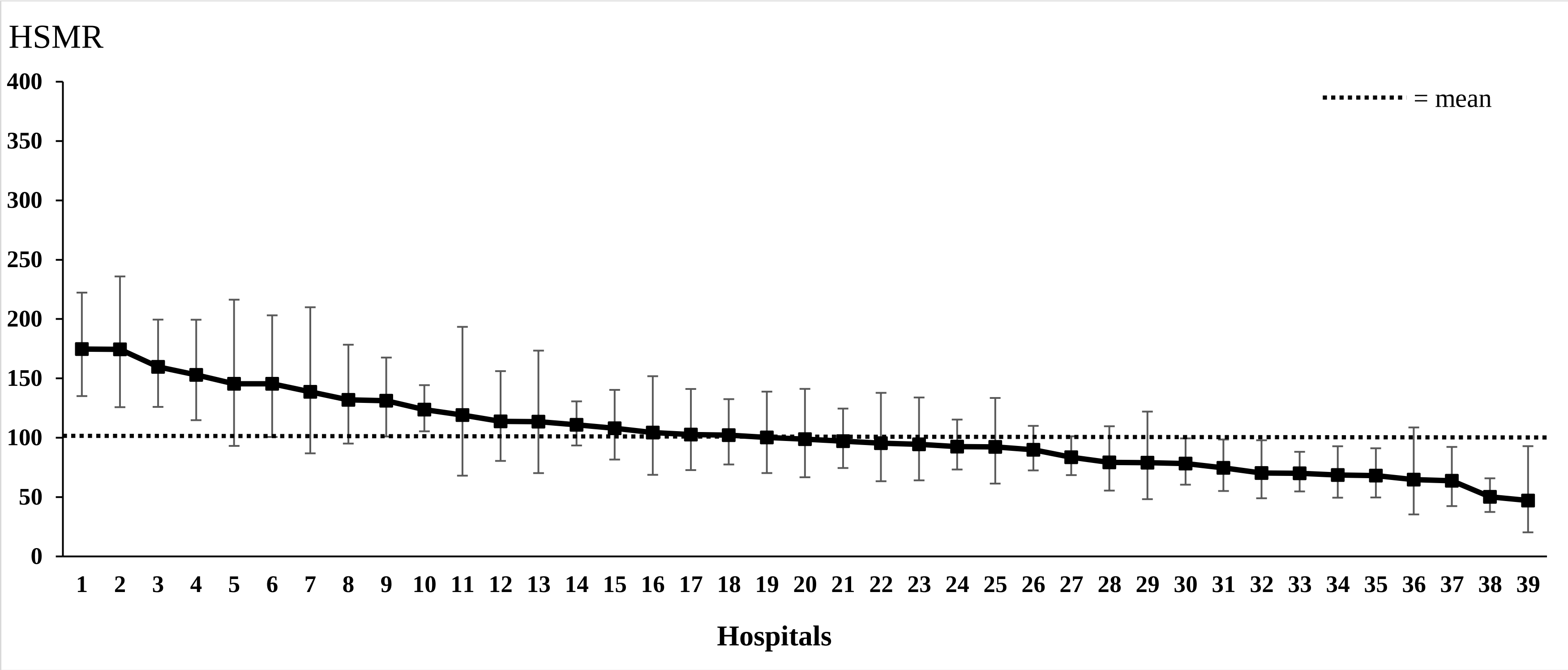
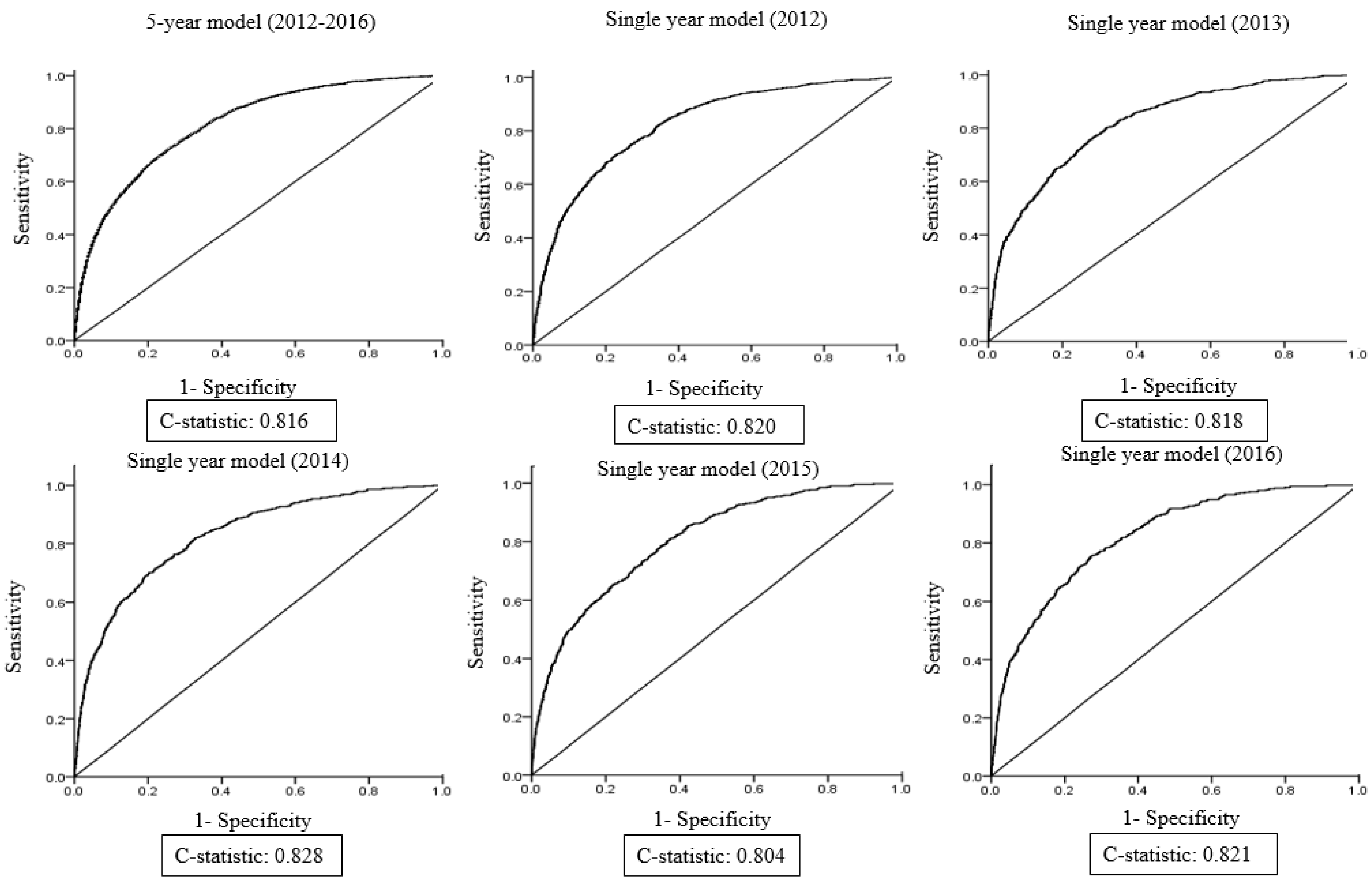

HSMR
400
350
300
250
200
150
100
50
0
= mean
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
Hospitals

Figure 3



Supporting Figure 1