(JCS) scores, Barthel activities of daily living (ADL) index scores, and modified Rankin Scale (mRS) scores on admission; these variables have been included in DPC data from July 2010 onward. These scores are measured according to the respective standardized criteria of each of the 3 variables by clinicians and transcribed to the claims data by administrative staff. The JCS is the most widely used clinical tool for evaluating consciousness level in Japanese emergency care, and consists of a scale of ten levels categorised into four groups: (i) JCS level 0, indicating a completely alert state; (ii) JCS levels 1–3 (disoriented: awake without stimulation); (iii) JCS levels 10– 30 (somnolent: arousable only in the presence of stimulation); and (iv) JCS levels 100–300 (comatose: unarousable despite stimulation) [29]. For this analysis, we utilized JCS level 0 as the referent, with the remaining class groups as binary variables. Next, during the model construction process, we decided to use a cut-off point for Barthel ADL index score of 20 (out of a possible 100); an index score that was less than 20 was included as the independent variable, and scores that were 20 or more were used as the referent. The cut-off of 20 was selected due to as patients with scores below this value represent low functional ability, and accounted for approximately half of our sample. In the case of mRS, scores of 0 to 3 were used as the referent, as patients with these scores generally require little assistance in their daily activities; mRS scores of 4 and 5 were included as dummy variables to indicate patients with severe disabilities.

Factors concerning the arrival period included whether a patient was admitted after hours (defined as the period between 6pm and 8am), and on weekends and public holidays.

The predictive abilities of the models were assessed using the C-statistic.

The patients were randomly assigned into derivation and validation subgroups, with each group comprising approximately 50% of the overall sample. Prediction models for the three mortality outcomes were constructed using the derivation dataset and evaluated using the validation dataset. We conducted this validation by applying the regression coefficients from each independent variable obtained from the test subgroup to the validation subgroup, and calculated the C-statistic from the resulting analysis. Calibration of each model was evaluated using the Hosmer-Lemeshow chi-squared test (with $P>0.05$ considered favourable). All statistical analyses were conducted using SPSS software, version 17.0.0 (SPSS Inc.,Chicago,IL,USA). A two-tailed *P*-value below 0.05 indicated statistical significance.

RESULTS

After exclusions, overall sample size for the analysis was 21 445 patients from 176 hospitals. The derivation subgroup consisted of 10 774 patients, and the validation subgroup consisted of 10 671 patients. Table 1 shows the demographics of the overall sample, and the derivation and validation subgroups. The derivation and validation subgroups were statistically similar to each

other insofar as the independent variables were concerned: a two-sided *t*-test for age (given as a continuous variable in years) as well as chi-squared tests for the other variables (given as binary variables) showed non-significant *P*-values between the two subgroups for all the variables used, as well as in all three outcomes.

Patients were approximately 75 years of age upon admission, and there were more men than women represented in the sample. There were higher incidences of atrial fibrillation, dyslipidemia and hypertension when compared to the other comorbidities. Approximately 50% of the patients were alert according to the JCS levels, with decreasing incidence in the higher JCS levels (indicating less alert states). On the other hand, there was increasing incidence in the higher mRS scores, and more than half of the patients had low functional activity (Barthel index <20).

The results of the prediction models developed in the derivation subgroup are shown in Table 2. All three models showed good calibration, with *P*-values from the Hosmer-Lemeshow tests for the 7-day mortality model, 30-day mortality model, and in-hospital mortality model being 0.716, 0.280, and 0.119, respectively. Although age did not have significant association with short-term mortality indicator of 7-day mortality, this factor gained significance when the time-line for mortality was extended to 30 days and to overall in-hospital mortality. Atrial fibrillation was significantly associated with increased mortality for all three

timespans. Peripheral vascular disease was significantly associated with increased in-hospital mortality, and marginally non-significant in 30-day mortality (*P*-value: 0.051). Although renal disease and cancer had no significant association with 7-day mortality, they were associated with increased 30-day mortality and in-hospital mortality. On the other hand, dyslipidemia and hypertension were both significantly associated with reduced mortality for all three timespans.

Reduced patient consciousness was significantly associated with increased mortality: the JCS levels showed that even mild disorientation (levels 1 to 3) was associated with increased mortality. However, the adjusted ORs for JCS levels 10 to 30 and 100 to 300 were highest in 7-day mortality, but decreased with longer timespans. Disability and dependence levels were also significantly associated with increased mortality, with Barthel index scores of less than 20 and an mRS score of 5 significantly associated with all three mortality indicators. The mRS score of 4 was significantly associated in 30-day mortality and in-hospital mortality, but not in 7-day mortality.

The Figure shows the predictive ability of the models for the three mortality outcomes in the derivation subgroup and the validation subgroup. The C-statistics were highest in 7-day mortality, and were all higher than 0.872 for the various measures.

DISCUSSION

The accuracy of predicting in-hospital mortality in ischaemic stroke patients using administrative claims has been limited by the lack of information reflecting disease severity of patients upon admission. However, administrative data in Japan have recently included information on patient consciousness and disability levels. In this study, we have derived and validated in-hospital mortality prediction models for three timespans based on administrative data, and shed light on predictors of in-hospital mortality in patients admitted for ischaemic stroke.

Predictive ability was highest in the short-term 7-day mortality indicator, with the C-statistic reaching 0.906 in the derivation subgroup. This predictive ability is similar to or higher than existing mortality prediction models, whether in chart review analyses or administrative data complemented with clinical information [8–11,19]. Although predictive ability was observed to be reduced as the timespans increased, the C-statistics for both 30-day mortality and in-hospital mortality were still noticeably higher than previous attempts to predict mortality using administrative data [26,27]. Validation of all three prediction models showed a high degree of consistency between the discriminatory ability of the models in both the derivation and validation subgroups.

By analysing different mortality rates at various timespans in the same population, we were able to observe the shift in predictors that influence mortality. Age was not observed to

have a significant association with 7-day mortality, but was associated with mortality in the longer timespans. Furthermore, short-term mortality was found to be most influenced by low levels of patient consciousness, which is similar to the results found using clinical information [17]. Atrial fibrillation was consistently associated with increased mortality across all three timespans, a result corroborated by previous studies [30–32]. Higher mRS and Barthel index scores, in addition to JCS levels, were significantly associated with mortality in general; however, only the highest mRS score of 5 was significantly associated with 7-day mortality. Although we did not have access to a stroke severity scale, such as the National Institutes of Health Stroke Scale (NIHSS), the combination of patient consciousness levels (which is a component of the NIHSS) and patient disability and dependency scales accorded a high level of discrimination to in-hospital mortality prediction.

Renal disease and cancer were associated in 30-day mortality and in-hospital mortality, indicating that these diseases had less impact on short-term mortality when compared to patient consciousness and disability levels, which was congruent with results found in a previous study [9,33]. Hypertension and dyslipidemia were consistently associated with lowered mortality for all three timespans. Although hypertension is associated with an increased risk of stroke [34–36], the link between hypertension and stroke mortality may be similar to the results seen in heart failure, in which higher blood pressure has been shown to be associated with reduced risk of

dying [37–38]. Furthermore, another study has shown that hypertension was not an important predictor of death in stroke patients [39]. In the case of dyslipidemia, these results may be an indication of reverse epidemiology, which has been previously observed in stroke patients [40–41].

Whether patients had been admitted during office hours or after hours had no bearing on survivability, but admissions on weekends and public holidays were associated with increased 7-day mortality. This may indicate that a decreased availability of resources—possibly that of manpower—during weekends and public holidays may have resulted in poorer processes of care leading to increased short-term mortality. However, if a patient should survive past the first seven days, weekend and public holiday admissions ceased to be a significant predictor of in-hospital mortality.

Although accurately predicting mortality and its predictors in ischaemic stroke patients is unlikely to substantially improve the survivability of patients, it can strengthen the attributional validity of hospital level evaluations. Fairer evaluations of outcome measures such as mortality would then have more meaningful applications in incentive systems or contributing to payment system reform.

In addition to random categorisation at the patient level, we also conducted an additional analysis with randomisation conducted at the hospital level (data not shown). Here,

hospitals were randomly divided into 2 groups and tested with the same mortality prediction models. Each of the random groups comprised of 88 hospitals, with 11,314 patients in 1 group and 10,131 patients in the other. The model produced similar results to patient-level randomized groups: in 7-day in-hospital mortality, the C-statistics were 0.894 and 0.911; in 30-day in-hospital mortality, the C-statistics were 0.885 and 0.879; and in overall in-hospital mortality, the C-statistics were 0.874 and 0.871. This showed that the models had comparable predictive abilities in different groups of hospitals.

The limitations of this study are as follows: 7-day mortality and 30-day mortality were both indicators of in-hospital mortality on stipulated timespans in this study. We were unable to track mortality that occurred post-discharge, but the acute nature of stroke would generally preclude the transfer or discharge of patients who had not been stabilized; we do not expect this limitation to have a substantial impact on our analysis. Next, the hospitals included in this analysis were all volunteer participants in the QIP, and therefore represent a group of hospitals that have an active aim to improve the quality of the health care that they provide. However, the wide variations in size, ownership and geographic location of the hospitals, as well as the large sample size may make a substantial bias unlikely.

Administrative databases are a product of hospital reimbursement systems, and not designed for the purposes of health outcomes research. As such, disease severity information

has been relatively less important from a hospital's perspective when compared to information on health services and goods consumed. The novelty of this study shows that the recent addition of the JCS, Barthel ADL Index, and mRS scores to ischaemic stroke patients to the DPC database in Japan has allowed the use of this administrative database to be applied effectively to predict in-hospital mortality Our results have implications in the use of administrative data in future mortality prediction analyses, as well as to provide fairer risk-adjusted mortality rate evaluations. As the quality of administrative claims data improves, health care researchers must endeavour to make the most of this resource.

Funding: This study was supported in part by a Health Sciences Research Grant from the Ministry of Health, Labour and Welfare of Japan, and a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science

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Table 1 Demographics of all patients (given in percentages) in the sample, derivation subgroup and validation subgroup

Variables	Overall (n = 21,445)	Derivation Subgroup (n = 10,774)	Validation Subgroup (n = 10,671)	*P*
Age (years)	74.8	74.9	74.8	0.423
Female	42.0	42.4	41.6	0.234
Acute myocardial infarction	1.7	1.6	1.8	0.224
Atrial Fibrillation	16.6	16.6	16.5	0.956
Dyslipidemia	22.3	22.5	22.1	0.512
Hypertension	49.1	49.2	49.0	0.722
Peripheral vascular disease	0.5	0.4	0.6	0.076
Chronic pulmonary disease	2.4	2.5	2.2	0.106
Connective tissue disease	0.8	0.8	0.8	0.703
Liver disease	0.3	0.3	0.4	0.554
Renal disease	3.5	3.6	3.4	0.333
Metastatic cancer	0.5	0.5	0.5	0.847
JCS Levels 1 to 3	36.4	36.3	36.4	0.921
JCS Levels 10 to 30	9.2	9.2	9.2	0.962
JCS Levels 100 to 300	4.7	4.8	4.6	0.520
Barthel ADL Index <20	54.2	54.6	53.7	0.179
mRS 0	2.8	2.8	2.9	0.902
mRS 1	11.9	11.7	12.1	0.411
mRS 2	17.3	17.4	17.1	0.588
mRS 3	15.2	15.1	15.4	0.582
mRS 4	28.8	28.9	28.6	0.608
mRS 5	24.0	24.0	24.0	0.898
After Hours	21.2	21.0	21.4	0.547
Weekends/Public Holidays	8.9	9.2	8.5	0.093
7-day Mortality	2.5	2.6	2.4	0.355
30-day Mortality	4.4	4.5	4.4	0.765

In-hospital Mortality	6.3	6.2	6.3	0.779

All values are percentages except for age, which is in years. JCS, Japan Coma Scale; ADL, activities of daily living; mRS, modified Rankin Scale. *P* values are calculated using either a two-sided *t*-test (for age) or a chi-squared test (for all other variables) between the derivation and validation subgroups.

Table 2 Prediction model results for 7-day, 30-day and Overall in-hospital mortality in the derivation subgroup

Variables	Prediction Models for In-Hospital Mortality the Derivation Subgroup								
	7-day			30-day			Overall		
	Adjusted Odds Ratio	95% Confidence Intervals	*P*	Adjusted Odds Ratio	95% Confidence Intervals	*P*	Adjusted Odds Ratio	95% Confidence Intervals	*P*
Age	1.00	(0.98,1.01)	0.662	1.01	(1.00,1.02)	0.013	1.03	(1.02,1.04)	<0.001
Female	1.04	(0.79,1.38)	0.762	0.85	(0.68,1.05)	0.135	0.88	(0.73,1.06)	0.176
Acute myocardial infarction	1.25	(0.51,3.02)	0.625	1.34	(0.66,2.70)	0.414	1.01	(0.52,1.98)	0.977
Atrial Fibrillation	1.60	(1.22,2.10)	0.001	1.55	(1.24,1.93)	<0.001	1.42	(1.17,1.72)	<0.001
Dyslipidemia	0.51	(0.30,0.88)	0.014	0.43	(0.28,0.66)	<0.001	0.44	(0.31,0.62)	<0.001
Hypertension	0.60	(0.45,0.79)	<0.001	0.60	(0.48,0.75)	<0.001	0.62	(0.51,0.74)	<0.001
Peripheral vascular disease	2.66	(0.69,10.25)	0.156	2.89	(0.99,8.41)	0.051	3.97	(1.62,9.73)	0.003
Chronic pulmonary disease	0.82	(0.35,1.96)	0.662	1.28	(0.72,2.30)	0.402	1.09	(0.65,1.84)	0.751
Connective tissue disease	1.38	(0.31,6.24)	0.676	1.18	(0.34,4.07)	0.792	1.00	(0.34,2.92)	0.992
Liver disease	1.72	(0.20,14.68)	0.622	3.10	(0.82,11.71)	0.095	1.86	(0.49,7.06)	0.360
Renal disease	1.69	(0.89,3.19)	0.108	2.20	(1.40,3.47)	0.001	2.27	(1.54,3.35)	<0.001
Metastatic cancer	2.82	(0.89,8.95)	0.079	14.32	(7.12,28.82)	<0.001	13.18	(6.81,25.53)	<0.001
JCS Level 0	1.00	Referent	NA	1.00	Referent	NA	1.00	Referent	NA
JCS Levels 1 to 3	2.03	(1.16,3.55)	0.014	2.29	(1.56,3.35)	<0.001	1.71	(1.29,2.28)	<0.001
JCS Levels 10 to 30	5.59	(3.13,10.01)	<0.001	5.17	(3.42,7.82)	<0.001	3.36	(2.43,4.63)	<0.001
JCS Levels 100 to 300	15.59	(8.72,27.87)	<0.001	15.44	(10.15,23.49)	<0.001	9.91	(7.10,13.83)	<0.001