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Hospital Frailty Risk Score (HFRS) in ischemic stroke

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Abstract

Background & Objective: Frailty results from an age-associated decline in physiological reserve and function and is prevalent in older adults. In this retrospective cohort study, we aimed to validate the Hospital Frailty Risk Score (HFRS) in predicting adverse events and hospitalisation utilisation in older patients hospitalised with ischemic stroke and hypothesise that frailty is a comparable predictor of adverse outcomes in stroke. *Methods:* Older patients aged 65 years and above with ischemic stroke admitted to a tertiary hospital in Singapore from 1st January 2019 to 31st December 2019 were identified and categorised into high risk (>15), intermediate risk (5-15) and low risk (<5) of frailty using HFRS. *Results:* A total of 1,023 patients with ischemic stroke were included in this study. HFRS was categorised as high risk in 271 patients (26.5%), intermediate risk in 544 patients (53.2%) and low risk in 208 patients (20.3%). Patients with higher HFRS scores were older, more likely female, have lower BMI and more comorbidities. Higher HFRS scores was also associated with increased length of stay, 90 day and 1 year mortality, but not 30-day readmission and inpatient mortality. Predictive models which incorporated HFRS and other relevant variables showed good predictive value for long length of stay and 1 year mortality with AUC of 0.811 (0.744 – 0.878) and 0.749 (0.619 – 0.878) respectively.
Conclusion: Our study has shown that patients with high risk of frailty have higher healthcare utilisation than low risk patients. Identification of frailty can help stratify care for older frail patients.

Keywords: Frailty, stroke, Hospital frailty risk score, geriatrics

INTRODUCTION

Frailty as defined by the World Health Organisation (WHO), is a clinically recognizable state in older people who have increased vulnerability, resulting from age-associated decline in physiological reserve and function across multiple organ systems, such that the ability to cope with every day or acute stressors is compromised.[1] Frailty is prevalent amongst community-dwelling older adults with a weighted prevalence of 10.7%[2] but progresses at different rates in different people. It is associated with higher rates of utilisation across different healthcare services[3] and has predictive risk for a range of adverse health outcomes[4], including increased emergency admissions[5], increased hospital length of stay (LOS)[6], functional decline at discharge in hospitalised older adults[7], as well as 30-day mortality.[8]

Singapore is a rapidly ageing population, with an estimated 40% of the population being at least 60 years old by 2050.[9] Hence, the proportion and number of frail individuals will rise, and implementation of frailty assessment tools to aid identification of those at higher risk of adverse outcomes has never been more crucial.[10] Frailty risk stratification systems within healthcare services allow targeted strategies for delivery of integrated care[11] and thereby reduces costs that are typically required for those at increased risk of 'frailty crises'.[12] Identifying high-risk patients at the start of their hospitalisation episode offers

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the opportunity to initiate early interventions to reduce future risk of adverse outcomes.

Stroke is considered one of the most neurologically debilitating diseases, often prevalent in an older population as stroke risk increases with age.[13] In Singapore, stroke episodes have increased from 6,367 to 9,702 episodes per year over the span of a decade (2012-2022), with cerebrovascular disease being the fourth most common cause of death, accounting for 6.0% of all deaths in Singapore.[14] Amongst the various frailty assessment tools, the Hospital Frailty Risk Score (HFRS) is a low-cost risk stratification tool[15] that does not require clinical assessment but uses routinely collected electronic health records. It has been shown to identify a distinct patient group with higher non-elective hospitalisation rates, increased 30-day readmission, length of stay (LOS) and 30-day mortality.[15] HFRS is non-operator dependent[16] and has been validated against the two widely used clinical frailty screening tools, the Fried phenotype and the Rockwood Clinical Frailty Scale which both require more manpower resources and knowledge of baseline function. Currently, HFRS has been validated in multiple cohorts of patients including a Singaporean study of delirium[17], heart failure[18] and community acquired pneumonia.[19]

The study aims to validate the use of HFRS in predicting adverse events and hospitalisation utilisation in patients with ischemic stroke admitted to a tertiary Hospital in Singapore from 1st January 2019 to 31st December 2019. We postulate that patients with higher HFRS will have poorer health outcomes and higher health care utilisation and anticipate that frailty is a comparable predictor of stroke adverse outcomes. We also hypothesise that frailty is a comparable predictor of outcome in stroke compared to National Institute of Health Stroke Score (NIHSS), modified Rankin Scale (mRS) or Charlson Co-morbidity index (CCI).

The primary outcome was to compare and validate HFRS in predicting adverse events and hospitalisation utilisation in older patients hospitalised for ischaemic stroke; and the secondary outcome was to compare to traditional severity indices such as the NIHSS, modified Rankin scale (mRS) and Charlson Co-morbidity index (CCI) to the HFRS and test the predictive value of HFRS in predicting adverse events and hospitalisation utilisation

METHODS

Study design and oversight

The study involves a retrospective review of electronic medical records undertaken in hospitalised patients discharged with a diagnosis of ischemic stroke from 1st January 2019 to 31st December 2019. The patients were identified using ICD codes for stroke. The analysis excluded any patients who had absconded or discharged against medical advice, elective admissions including day surgery and discharges from the Short Stay Unit or Emergency Department Treatment Unit or equivalent.

Data extraction was performed by the Data Science Intelligence (DSI) team and was analysed by the Health Systems Intelligence (HSI) team. Only anonymised data was provided to the study team, and this was password protected and held within hospital secured shared folders.

Ethics review

Consent was not required as this study utilised only anonymised and aggregated data.

Methodology

Data collection included demographic data for age, sex, race and BMI where available. HFRS for each patient was calculated based on 109 three-character ICD diagnostic codes that were recoded as a primary or secondary diagnosis following their index hospitalisation and the previous 2 emergency admissions within the preceding 2 years, and their associated weights. The 109 ICD codes can be found in Supplementary Information. Patients were categorised into three frailty risk groups: high risk (>15), intermediate risk (5-15) and low risk (<5) of frailty, as described by Gilbert *et al*.[15] Hospitalisation utilisation included length of stay (LOS), where long LOS was defined as >= 13 days and 30-day emergency hospital re-admissions. The duration of 13 days was derived from the average length of stay of all stroke patients admitted in 2019. Mortality was reviewed inpatient and at 30 days, 90 days and one year from date of hospital admission.

Functional status was assessed using mRS, which is a clinician-rated scale of global disability widely utilised in evaluating post-stroke functional outcomes[20] and a common end point in randomised controlled studies evaluating efficacy of stroke treatment.[21] Stroke severity was quantified with the 1st NIHSS score where available, which is a score commonly applied in clinical settings to quantify stroke severity. The presence of comorbidities was assessed retrospectively using CCI[22], which was calculated based on the discharge diagnoses, as coded by the 10th version of the World Health Organisation (WHO) International Classification of Diseases (ICD-10) for each discharged case.

Statistical analysis

Data was analysed using R statistical software (v3.6.1; R Core Team 2019). Continuous variables are presented as means with their corresponding standard deviations (SD), while categorical variables are summarized as frequencies and percentages. HFRS was analysed as a categorical variable, classified into high, intermediate and low risk groups. To compare association of the HFRS categories with various variables and outcomes, we conducted the analysis of Variance (ANOVA), Kruskal-Wallis and Pearson Chi-square test as appropriate. Statistical analyses were selected based on the respective variable and outcome characteristics and distributional properties. ANOVA was used for continuous outcomes that met assumptions of normality (Shapiro-Wilk test, $p > 0.05$) and homogeneity of variance (Levene's test, $p > 0.05$). For continuous variables that did not meet normality or homogeneity assumptions, the non-parametric Kruskal-Wallis test was employed as the appropriate alternative. Chi-square tests of independence were used to examine associations between categorical variables when assumptions of independence of observations, mutually exclusive categories, and expected cell frequencies ≥5 were met. Fisher's exact test was used when expected cell frequencies ≥5 was not met. In our analysis of 30-day readmission, cases which died inpatient were excluded from analysis.

The multivariate model was adjusted for the covariates of age, BMI, CCI, stroke severity (using NIHSS and mRS as proxies). Odd Ratios (ORs) with 95% Confidence Intervals (CIs) are provided as appropriate. Model development employed Akaike Information Criterion (AIC) based selection to ensure optimal balance between fit and complexity. Final model selection was based on lower AIC scores, significant odds ratios, and good discrimination ability to determine the predictive potential of HFRS. The discriminative ability of the respective model was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC-ROC). To evaluate the selected model's reliability, we assessed calibration using the Hosmer-Lemeshow goodness-of-fit test, which examines the agreement between predicted probabilities and observed outcomes across different risk levels. Statistical significance was set at $p<0.05$ using two-tailed tests for all analyses.

RESULTS

Baseline characteristics

A total of 1,023 patients were admitted with ischemic stroke between 1st January 2019 and 31st December 2019, with a mean age of 68.6 years (SD 13.8; Table 1), of whom 419 (41%) were female. The racial distribution was representative of Singapore, with a larger proportion of Chinese (64.3%) in comparison to Malay (17.5%), Indian (7.0%) and other races (11.1%). Using the HFRS, 79.7% patients overall were at high or intermediate risk of frailty. HFRS was categorised as high risk in 271 patients (26.5%), intermediate risk in 544 patients (53.2%) and low risk in 208 patients (20.3%). Patients at high risk of frailty were older than those at low risk (mean age 77.2 years versus 62.8 years, respectively; $p <0.001$), with more females in the high-risk group (56.1% versus 35.6%; $p<0.001$). BMI was also lower in those at higher risk of frailty (23.1 versus 25.7; $p<0.001$). Those at higher risk of frailty had more comorbidities than those at lower risk (CCI 3-4, 34.3% versus 15.9% respectively), with the converse holding true as well. (CCI 0, 2.2% versus 44.2% respectively). Patients at higher risk of frailty also presented more frequently with higher initial NIHSS score (NIHSS > 15, 27.7% versus 3.8%, $p< 0.001$) and mRS score (mRS 5, 19.6% versus 1.9%, $p<0.001$).

Primary outcomes

Average hospital Length of Stay (LOS) was significantly longer in those at high risk of frailty (23.5 vs 5.8 days respectively, $p<0.001$;*Table 2*) and long LOS (> 13 days) was much more likely in high risk patients (72% vs 8.2%, $p<0.001$). 30-day emergency re-admissions were similar (7% vs 9.1% $p=0.125$). Mortality was significantly higher in high risk compared to low risk patients at 90 days (14.0% vs 5.3%, $p<0.001$) and one year (30.3% vs 6.3%, $p<0.001$) but not during inpatient (6.6% vs 2.4%, $p=0.077$) nor at 30-days (5.5% vs 3.4%, $p=0.497$).

Table 1: Baseline characteristics

	HFRS Low Risk (N=208)	HFRS Intermediate Risk (N=544)	HFRS High Risk (N=271)	Overall (N=1023)	p-value
Age in years (SD)					<0.001
Mean (SD)	62.8 (13.3)	66.6 (13.0)	77.2 (11.8)	68.6 (13.8)	
Median [Min, Max]	61.0 [31.0, 100]	67.0 [18.0, 98.0]	79.0 [39.0, 102]	68.0 [18.0, 102]	
Gender					<0.001
Female	74 (35.6%)	193 (35.3%)	152 (56.1%)	419 (41.0%)	
Race					<0.05
Chinese	134 (64.4%)	332 (61.0%)	192 (70.8%)	658 (64.3%)	
Indian	19 (9.1%)	47 (8.6%)	6 (2.2%)	72 (7.0%)	
Malay	34 (16.3%)	101 (18.6%)	44 (16.2%)	179 (17.5%)	
Other Races	21 (10.1%)	64 (11.8%)	29 (10.7%)	114 (11.1%)	
BMI					<0.01
Mean (SD)	25.7 (4.67)	24.8 (4.41)	23.1 (4.54)	24.5 (4.59)	
Median [Min, Max]	25.5 [13.7,43.1]	24.4 [15.5, 42.7]	22.6 [14.1, 46.2]	24.1 [13.7, 46.2]	
Missing	18 (8.7%)	41 (7.5%)	17 (6.3%)	76 (7.4%)	
CCI Category					< 0.001
0	92 (44.2%)	45 (8.3%)	6 (2.2%)	143 (14.0%)	
1 to 2	80 (38.5%)	213 (39.2%)	65 (24.0%)	358 (35%)	
3 to 4	33 (15.9%)	196 (36.0%)	93 (34.3%)	322 (31.5%)	
>4	0	0	0	0	
Missing	3 (1.4%)	90 (16.5%)	107 (39.5%)	200 (19.6%)	
Modified Rankin Scale score					< 0.001
0	56 (26.9%)	108 (19.9%)	11 (4.1%)	175 (17.1%)	
1	47 (22.6%)	52 (9.6%)	4 (1.5%)	103 (10.1%)	
2	25 (12.0%)	28 (5.1%)	4 (1.5%)	57 (5.6%)	
3	22 (10.6%)	92 (16.9%)	26 (9.6%)	140 (13.7%)	
4	12 (5.8%)	162 (29.8%)	119 (43.9%)	293 (28.6%)	
5	4 (1.9%)	28 (5.1%)	53 (19.6%)	85 (8.3%)	
Missing	42 (20.2%)	74 (13.6%)	54 (19.9%)	170 (16.6%)	
1st NIHSS Cat					< 0.001
Minor (<5)	162 (77.9%)	264 (48.5%)	45 (16.6%)	471 (46.0%)	
Moderate (5-15)	19 (9.1%)	196 (36.0%)	104 (38.4%)	319 (31.2%)	
Severe (>15)	8 (3.8%)	51 (9.4%)	75 (27.7%)	134 (13.1%)	
Missing	19.1% (9.1%)	33 (6.1%)	47 (17.3%)	99 (9.7%)	

Chi square test used on categorical variables. Kruskal-Willis test used on Age and BMI.
Abbreviation: SD, Standard Deviation; CCI, Charlson Comorbidity Index; 1st NIHSS Cat, Initial National Institute of Health Stroke Score Category; HFRS, Hospital Frailty Risk Score

Table 2: Primary outcomes in ischemic stroke cohort

	Low Risk (N=208)	Intermediate risk (N=544)	High risk (N=271)	Overall (N=1023)	p-value
LOS					<0.001
Mean (SD)	5.8 (6.37)	12.2 (12.8)	23.5 (17.4)	13.9 (14.7)	
Median [Min, Max]	4.0 [0, 58.0]	10.0 [0, 192]	19.0 [3.0, 114]	10.0 [0, 192]	
Long LOS	17 (8.2%)	195 (35.8%)	195 (72.0%)	407 (39.8%)	< 0.001
30-day readmission	19 (9.1%)	28 (5.1%)	19 (7.0%)	66 (6.5%)	0.125
Inpatient mortality	5 (2.4%)	23 (4.2%)	18 (6.6%)	46 (4.5%)	0.077
30-day mortality	7 (3.4%)	23 (4.2%)	15 (5.5%)	45 (4.4%)	0.497
90-day mortality	11 (5.3%)	32 (5.9%)	38 (14.0%)	81 (7.9%)	<0.001
1Y mortality	13 (6.3%)	47 (8.6%)	82 (30.3%)	142 (13.9%)	<0.001

Chi square test used on categorical variables. Kruskal-Willis test used on LOS.
Abbreviation: LOS, Length of Stay
Long LOS defined as LOS > 13 days
**excludes cases who died inpatient*

In multivariate analysis, patients defined as high risk by HFRS (>15) had significantly higher odds ratio for long LOS (aOR 18.440, 7.538-49.664; p <0.001), 90 day mortality (aOR 3.935, 1.677- 10.833; p < 0.01) as well as 1 year mortality (aOR 3.365, 1.085 – 11.923; p<0.050) *(Tables 3 -5)*

Predictive value

HFRS demonstrated strong associations with long LOS (*Table 3)* and moderate associations with 1-year mortality (*Table 4)*, as indicated by the regression analyses. HFRS exhibited strong predictive performance for long LOS (AUC-ROC of 0.811 (0.744 – 0.878), *Figure 1*) and moderate predictive performance for 1-year mortality (AUC-ROC of 0.749 (0.619 – 0.878), *Figure 2*), as indicated by the discrimination analyses. However, CCI and mRS were superior to HFRS in predicting 90-day mortality as compared to CCI and mRS scores. *(Table 5)* Model calibration was assessed for long LOS and 1 year mortality using the Hosmer-Lemeshow goodness of fit test, which showed good calibration for both outcomes (LOS: $\chi^2 = 6.52$, df = 8, p = 0.589) and (1-year mortality: $\chi^2 = 9.88$, df = 8, p = 0.273) respectively.

DISCUSSION

Frailty is increasingly recognised as a major determinant of outcomes in older adults with stroke. In a recent scientific statement published by the World Stroke Organisation (WSO), the need for research focusing on frailty and its impact on stroke prevention, treatment, recovery and rehabilitation were highlighted.[23] Our validation study involving patients 65 years old and above admitted to a tertiary hospital in Singapore with ischemic stroke showed that HFRS is a robust independent predictor of adverse clinical outcomes in our patient cohort. The association with LOS (aOR = 18.44, 95% CI: 7.54–49.66, p < 0.001) represents a strong predictive indicator and HFRS also demonstrated statistically significant associations with 90day mortality and 1 year mortality (aOR = 3.94 and 3.37, respectively), indicating its broader prognostic utility across multiple clinically meaningful endpoints.

These findings are consistent with existing literature. A meta-analysis by Burton *et al.*[24] reported a pooled frailty prevalence of 24.6% among acute stroke patients, with frailty strongly associated with poorer functional recovery and survival. Similarly, in a retrospective analysis of data from US National Inpatient Sample (NIS) database including adult patients 45 years and older with a primary diagnosis of stroke, Baker *et al*. demonstrated that frail stroke patients (HFRS > 15) had nearly threefold higher mortality (aOR 2.82, 95% CI: 2.63 – 3.04).[25] and greater complication rates compared to their non-frail counterparts.[26] For patients who underwent endovascular stroke treatment, Pinho et. al demonstrated that high frailty risk was independently associated with decreased likelihood of favourable 3-month outcome as

Table 3: Binomial GLM for independent variable (HFRS), covariates and association of frailty for LOS > 13 days

	LOS > 13 days			
	Univariate		Adjusted*	
	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	1.027 (1.018-1.037)	<0.001	0.977 (0.960 – 0.993)	< 0.010
Male	*Ref*			
Female	1.455 (1.129-1.877)	<0.010		
Race (Chinese)	*Ref*			
Race (Indian)	0.456 (0.255-0.779)	<0.010		
Race (Malay)	1.032 (0.738-1.439)	0.853		
Race (Other races)	0.581 (0.374-0.886)	<0.050		
BMI	0.942 (0.914-0.970)	<0.001	0.961 (0.916 – 1.008)	0.100
CCI	1.381 (1.287-1.486)	<0.001	1.120 (1.001 – 1.256)	<0.050
mRS 0	*Ref*		*Ref*	
mRS 1	0.168 (0.063-0.382)	<0.001	0.258 (0.082 – 0.676)	<0.050
mRS 2	0.511 (0.220-1.079)	0.094	0.713 (0.242 – 1.886)	0.513
mRS 3	1.089 (0.662-1.789)	0.735	0.872 (0.454- 1.657)	0.676
mRS 4	5.766 (3.833-8.793)	<0.001	2.770 (1.597 – 4.852)	<0.001
mRS 5	8.300 (4.645-15.340)	<0.001	1.889 (0.782 – 4.599)	0.157
1st NIHSS score (<5)	*Ref*		*Ref*	
1st NIHSS score (5-15)	5.123 (3.749-7.044)	<0.001	1.844 (1.170 – 2.904)	<0.010
1st NIHSS score (>15)	8.861 (5.802-13.743)	<0.001	4.213 (1.987 – 9.297)	<0.001
HFRS (low)	*Ref*		*Ref*	
HFRS (intermediate)	6.278 (3.813-10.988)	<0.001	4.931 (2.310 – 11.845)	<0.001
HFRS (high)	28.827 (16.848-52.173)	<0.001	18.440 (7.538 – 49.664)	<0.001

**Models adjusted for patient's age, body mass index, Charlson Comorbidity group, modified Rankin Scale, National Institute of Health Stroke Score.*

Abbreviation: GLM, Generalized Linear Model; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; mRS, modified Rankin Scale; 1st NIHSS, Initial National Institute of Health Stroke Score; HFRS, Hospital Frailty Risk Score; OR, Odds Ratio; aOR, Adjusted Odds Ratio.

defined by mRS of 0-2 for older adults with acute ischemic stroke.[26] In a cohort study performed in Vietnam, there was a high prevalence of pre-stroke frailty of 30.6%, with pre stroke very frail status identified as an independent predictor of poor functional outcomes at 30 days.[27]

Our results corroborate these observations, reinforcing frailty as a critical prognostic factor in older adults with stroke. Importantly, we observed that nearly 80% of our cohort were classified as intermediate or high risk of frailty, underscoring the substantial burden of frailty in Singapore's greying landscape.

It is also imperative to consider how the relationship between frailty and stroke outcomes compares with other cardiovascular phenotypes. In Balamrit *et al.*'s work examining association of frailty status on causes and outcomes of patients admitted with cardiovascular disease, while atrial fibrillation and heart failure carried the strongest relative associations with mortality in highly frail patients, ischemic stroke emerged as the commonest presentation in this group.[28] While this may be partially explained by inclusion of stroke sequelae in HFRS, this observation suggests that frailty not only worsens prognosis in stroke but also highlights how stroke may act as a frequent clinical manifestation of frailty. Shared mechanisms such as systemic inflammation[29], pro-thrombotic states and multi-morbidity[30] may partially account for this overlap. This is especially relevant in our Asian

Table 4: Binomial GLM for independent variable (HFRS), covariates and association of frailty for 1 year mortality

	1 year Mortality			
	Univariate		Adjusted*	
	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	1.084 (1.066-1.102)	<0.001		
Male	*Ref*			
Female	2.206 (1.543-3.171)	<0.001	1.241 (0.683 – 2.246)	0.475
Race (Chinese)	*Ref*			
Race (Indian)	0.750 (0.323-1.528)	<0.001	1.602 (0.407 – 5.041)	0.454
Race (Malay)	1.113 (0.693-1.740)	0.730		
Race (Other races)	0.706 (0.356-1.287)	0.055		
BMI	0.902 (0.861-0.944)	<0.001	0.875 (0.806 – 0.941)	<0.001
CCI	1.334 (1.219-1.462)	<0.001		
mRS 0	*Ref*			
mRS 1	0.626 (0.135-2.221)	<0.001	0.624 (0.088 – 2.843)	0.575
mRS 2	0.759 (0.112-3.141)	0.729	0.967 (0.132 – 4.584)	0.969
mRS 3	0.935 (0.301-2.752)	0.055	0.931 (0.272 – 3.071)	0.906
mRS 4	2.740 (1.299-6.497)	0.403	0.960 (0.359 – 2.787)	0.936
mRS 5	19.452 (8.922-47.515)	0.058	5.861 (1.960 – 19.120)	<0.010
1st NIHSS score (<5)	*Ref*			
1st NIHSS score (5-15)	3.002 (1.684-5.525)	<0.001	1.491 (0.627 – 3.676)	0.373
1st NIHSS score (>15)	19.798 (11.281-36.294)	0.729	2.862 (1.072 – 7.882)	<0.050
HFRS (low)	*Ref*			
HFRS (intermediate)	1.419 (0.772-2.785)	<0.001	0.908 (0.307 – 3.072)	0.867
HFRS (high)	6.508 (3.624-12.599)	0.729	3.365 (1.085 – 11.923)	<0.050

**Models adjusted for patient's race, gender, body mass index, Charlson Comorbidity group, modified Rankin Scale, National Institute of Health Stroke Score.*

Abbreviation: GLM, Generalized Linear Model; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; mRS, modified Rankin Scale; 1st NIHSS, Initial National Institute of Health Stroke Score; HFRS, Hospital Frailty Risk Score; OR, Odds Ratio; aOR, Adjusted Odds Ratio.

demographic, where there is a higher prevalence of stroke, specifically lacunar ischemic strokes, compared to our Western counterparts.[31]

While frailty worsens outcomes for stroke patients, stroke itself may also accelerate the trajectory of frailty. The diagnosis of stroke may inadvertently unearth underlying medical comorbidities like atrial fibrillation, ischemic heart disease or valvular heart disease[32] and lead to complications like delirium, immobility or pressure ulcers[33], further compounding the state of frailty. The bidirectional relationship between stroke and frailty highlights the importance of timely identification and management.[34] From a predictive standpoint, HFRS demonstrated strong discriminative performance for prolonged length of stay (AUC = 0.811, 95% CI: 0.744–0.878), surpassing thresholds typically considered clinically meaningful for risk stratification. Although discrimination was more modest for 90-day mortality (AUC = 0.634), the fair performance for 1 year mortality (AUC = 0.749) indicates sustained prognostic value across different temporal outcomes. Combined with the excellent calibration demonstrated across all three models (Hosmer-Lemeshow p-values ranging from 0.273 to 0.609), the predictive models highlight the ability of HFRS to provide

Table 5: Binomial GLM for independent variable (HFRS), covariates and association of frailty for 90-day mortality

	90-day Mortality			
	Univariate		Adjusted*	
	OR (95% CI)	P-value	aOR (95% CI)	P-value
Age	1.066 (1.046-1.087)	<0.001		
Male	*Ref*			
Female	2.505 (1.579-4.031)	<0.001	1.907 (1.096 – 3.360)	<0.050
Race (Chinese)	*Ref*			
Race (Indian)	0.870 (0.295-2.060)	0.774		
Race (Malay)	0.989 (0.516-1.781)	0.971		
Race (Other races)	1.121 (0.523-2.185)	0.753		
BMI	0.957 (0.905-1.009)	0.115	0.983 (0.923 – 1.042)	0.574
CCI	1.280 (1.147-1.431)	<0.001		
mRS 0	*Ref*			
mRS 1	0.000 (0.000-1.25×10[11#])	0.988		
mRS 2	0.763 (0.039-5.293)	0.811		
mRS 3	0.936 (0.182-4.314)	0.931		
mRS 4	1.826 (0.625-6.612)	0.304		
mRS 5	14.929 (5.460-52.553)	<0.001		
1st NIHSS score (<5)	*Ref*			
1st NIHSS score (5-15)	2.591 (1.030-7.030)	<0.050		
1st NIHSS score (>15)	28.207 (13.017-70.569)	<0.001		
HFRS (low)	*Ref*			
HFRS (intermediate)	1.119 (0.570-2.365)	0.754	1.355 (0.566 – 3.761)	0.522
HFRS (high)	2.921 (1.502-6.139)	<0.010	3.935 (1.677 – 10.833)	<0.010

Odds ratio not estimable due to quasi-complete separation in the data
*Models adjusted for patient's gender, body mass index.
GLM, Generalized Linear Model; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; mRS, modified Rankin Scale; 1st NIHSS, Initial National Institute of Health Stroke Score; HFRS, Hospital Frailty Risk Score; OR, Odds Ratio; aOR, Adjusted Odds Ratio..

both strong discriminative ability and accurate probability estimation, supporting its utility as a valuable adjunct to established indices such as NIHSS, mRS and CCI. Beyond prognostication, these findings raise the possibility of dynamic frailty monitoring during inpatient rehabilitation to guide care transitions and resource allocation. In Baker *et al.*'s study, majority of pre-frail and frail patients were discharged to skilled nursing or intermediate care facilities whereas the majority of non-frail patients were discharged to their homes, reflecting the stark differences in discharge dispositions for stroke patients across the frailty spectrum.[25]

Our study has a few strengths. Firstly, we were able to analyse a large group of older patients from Asia across multiple ethnicities admitted with ischaemic stroke, of which significant proportion were at high (20.3%) or intermediate (53.1%) risk of frailty. Secondly, we were able to validate models incorporating common variables measured in stroke like the mRS and NIHSS scores with HFRS in predicting adverse outcomes. Lastly, the HFRS is a practical, non-operator dependent tool derived from routinely collected administrative data, which is particularly advantageous in acute stroke care where time and manpower are limited.

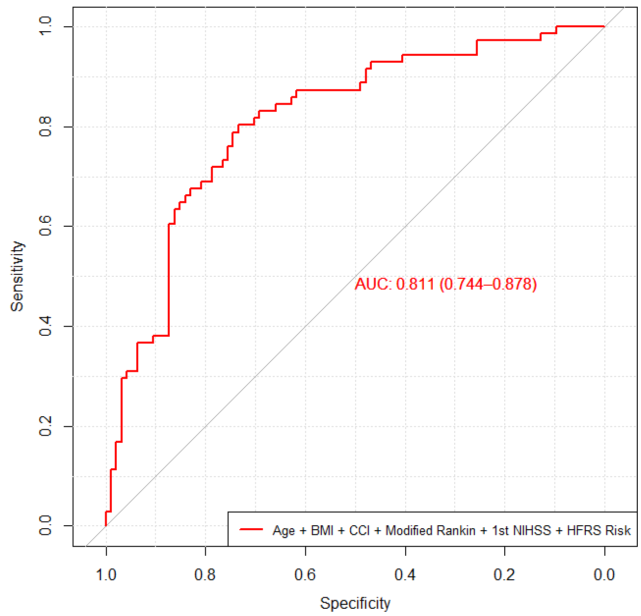

Figure 1. AUC-ROC curve for long LOS

Several limitations should be highlighted. Firstly, the retrospective design and reliance on administrative coding may have introduced misclassification bias, and HFRS can only be applied after sufficient coding is available, limiting real-time clinical use. Since HFRS can only be calculated after coding is performed following the index admission, it may not accurately capture the degree of frailty of the current admission. An alternative practical assessment that can be considered in clinical practice to assess pre-stroke frailty is the Clinical Frailty Scale (CFS) version 2. In a retrospective analysis of patients with stroke admitted to the Geriatric Medicine unit of a urban teaching hospital in Malaysia, frail patients were more

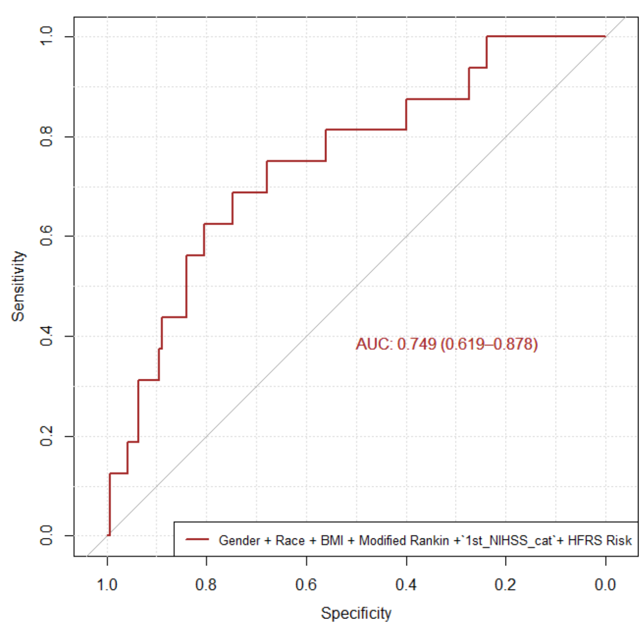

Figure 2. AUC-ROC curve for 1-year mortality

likely to have to a mRS score of 3 to 5, higher rates of inpatient infection as well as remained an independent predictor of inpatient and 1-year mortality.(35) Secondly, ICD-based coding may overlook frailty domains such as polypharmacy, sarcopenia or psychosocial vulnerabilities and does not adjust for the severity of comorbidities or place heavy emphasis on the functional status of the patient, which are important aspects of frailty assessment. Thirdly, missing data for CCI and mRS (16.6% and 19.6% respectively) may have affected the precision of our models. The lower odds ratios observed for mRS 1-2 should be interpreted with caution. The relatively small number of patients achieving mRS 1-2, together with a high proportion of missing mRS data, likely limited statistical power and contributed to unstable effect estimates, instead of representing a true absence of association between frailty and functional recovery. In contrast, mRS 5 was associated with a statistically significant and substantially higher odds ratio, consistent with a strong association between frailty and severe functional dependence.

To our knowledge, this is the first locally validated study looking at the HFRS in older patients with ischemic stroke in a tertiary hospital in Singapore. Our study has validated the HFRS in an older population of stroke patients and has shown that patients with higher scores on HFRS have poorer health outcomes (90 day and 1 year mortality), higher health care utilisation and is predictive of long LOS. Integration of frailty assessment into routine stroke evaluation could facilitate risk stratification, inform rehabilitation planning and discharge disposition, and support the design of targeted interventions to mitigate poor outcomes in this high-risk population.

DISCLOSURE

Data availability: The anonymised datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Conflict of interest: None

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