

Frailty-aware surgical care: Validation of Hospital Frailty Risk Score (HFRS) in older surgical patients

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ABSTRACT

Introduction: Frailty has an important impact on the health outcomes of older patients, and frailty screening is recommended as part of perioperative evaluation. The Hospital Frailty Risk Score (HFRS) is a validated tool that highlights frailty risk using 109 International Classification of Diseases, 10th revision (ICD-10) codes. In this study, we aim to compare HFRS to the Charlson Comorbidity Index (CCI) and validate HFRS as a predictor of adverse outcomes in Asian patients admitted to surgical services.

Method: A retrospective study of electronic health records (EHR) was undertaken in patients aged 65 years and above who were discharged from surgical services between 1 April 2022 to 31 July 2022. Patients were stratified into low (HFRS <5), intermediate (HFRS 5–15) and high (HFRS >15) risk of frailty.

Results: Those at high risk of frailty were older and more likely to be men. They were also likely to have more comorbidities and a higher CCI than those at low risk of frailty. High HFRS scores were associated with an increased risk of adverse outcomes, such as mortality, hospital length of stay (LOS) and 30-day readmission. When used in combination with CCI, there was better prediction of mortality at 90 and 270 days, and 30-day readmission.

Conclusion: To our knowledge, this is the first validation of HFRS in Singapore in surgical patients and confirms that high-risk HFRS predicts long LOS (≥ 7 days), increased unplanned hospital readmissions (both 30-day and 270-day) and increased mortality (inpatient, 10-day, 30-day, 90-day, 270-day) compared with those at low risk of frailty.

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CLINICAL IMPACT

What is New

- Hospital Frailty Risk Score (HFRS) can identify frail older surgical patients, and has greater accuracy if combined with Charlson Comorbidity Index for 90-day and 270-day mortality and 30-day readmission.

Clinical Implications

- HFRS does not require a clinical assessment, and can predict those at risk of longer length of stay, unplanned hospital readmissions and mortality.
- HFRS is currently being adapted into an easy and low-cost tool to screen and identify patients at higher risk of adverse outcomes in an older surgical population in Singapore.

INTRODUCTION

Frailty is a clinically recognisable state of vulnerability in older people, resulting from age-associated decline in physiological reserves and function across multiple organ systems, such that the ability to cope with acute stressors is compromised.¹ Frailty is prevalent among older people² and is associated with higher rates of utilisation of various healthcare services,³ increased emergency admissions⁴ and a higher predictive risk for adverse health outcomes.⁵ With the increasing proportion of residents aged 60 and above in Singapore,⁶ the number of frail individuals attending hospital is expected to increase, and

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this highlights the need for suitable tools to stratify patients⁸ and identify those at highest risk for frailty.

Studies on older surgical patients have consistently shown an association between frailty and adverse outcomes, such as postoperative complications,⁹ increased length of stay (LOS)¹⁰ and higher readmissions.¹¹ Identifying high-risk frailty patients preoperatively allows for identification of those who may benefit from early intervention and rehabilitation.¹² The presence of frailty may alter treatment plans as well as contribute to the informed discussion of operative risk with older patients.¹³

Currently, frailty can be identified through 3 main approaches: the Rockwood and Mitniski deficit accumulation model, Fried physical phenotype model, and mixed physical and psychosocial model.¹⁴ These screening tools require manpower and training for face-to-face assessment and may also be associated with inaccuracies or paucity of documentation. A study performed in an emergency department setting showed significant missing Clinical Frailty Scale scores in manual data collection with up to 50% of patients being missed, highlighting the need for a systematised tool that is accurate and easy to implement.¹⁵

The Hospital Frailty Risk Score (HFRS) is a low-cost screening tool¹⁶ that uses routinely collected electronic health records and removes the need for clinical assessment. It has been shown to identify a distinct patient group with higher non-elective hospitalisations, increased 30-day mortality, LOS and 30-day readmissions.^{16,17} It highlights at-risk frailty patients and triggers in-depth assessment of the patient, such as a Comprehensive Geriatric Assessment (CGA). HFRS is non-operator dependent¹⁸ and has also been validated against the 2 widely used clinical frailty screening tools, the Fried phenotype and Rockwood Frailty Index. HFRS has also been validated in multiple cohorts of patients in several countries across the world.¹⁸⁻²⁰ While there have been studies in Singapore that have evaluated the association of HFRS with delirium in patients admitted to the Division of Geriatric Medicine,²¹ there has yet to be any validation or implementation of HFRS for surgical patients in Singapore.

In this study, we sought to validate HFRS in a cohort of older surgical patients in Singapore and assess the score as an independent risk factor for adverse outcomes after surgery. We postulate that patients with higher HFRS scores will have poorer health outcomes and higher healthcare utilisation, thus supporting the utility of early frailty identification in surgical patients to reduce adverse outcomes.

METHOD

Study design

The study involves a retrospective review of electronic medical records of patients 65 years old and above who were discharged from surgical service in Changi General Hospital (CGH), in Singapore between 1 April 2022 and 31 July 2022. This is a single-site study that included data from the patients' acute hospitalisation episode. Data extraction was performed by the Data Management and Information team, anonymised and analysed by the Health Systems Intelligence team at CGH. Data were analysed using Python version 3.6.4 (Python Software Foundation) and R statistical software version 3.6.1 (R Core Team 2019, Vienna, Austria). Python was used for data pre-processing, while R was used for statistical analysis.

Data collected included demographic data for age, sex and race. HFRS was calculated using an algorithm based on the methodology outlined in literature.¹⁶ Body mass index (BMI) was included if available within the 12 months prior to admission. For cases with no BMI recorded within this time, imputation was performed to replace missing values (14%) with the median BMI of each age group (65–74, 75–84, 85–94, ≥95 years) to avoid skewing data due to outliers.⁴⁰ Sensitivity analysis showed that this method of imputation yielded the same conclusions compared to imputation using sample mean in multivariate regression. Comorbidity was assessed using the Charlson Comorbidity Index (CCI) and was calculated based on the coding of the index admission. Hospitalisation data included LOS, 30-day emergency hospital readmissions and mortality at 10 days, 30 days, 90 days and 270 days from the date of hospital admission. In the analysis of 30-day readmissions, patients who died inpatient were excluded but deaths within 30 days of discharge were included. Table of Surgical Procedure (TOSP), number of TOSP procedures and American Society of Anesthesiologists (ASA) scoring were used to determine complexity of surgical cases. TOSP is an exhaustive list of procedures ranked from 1A to 7C. Generally, higher category and/or higher number of TOSP procedures is presumed to suggest increased complexity. TOSP table number was only available for patients who underwent a surgical procedure and those who did not undergo surgery were scored with a TOSP table number of 0. ASA scoring is a subjective assessment of a patient's overall health that is based on 5 classes. Class I comprises healthy patients, class II patients have mild systemic disease, class III patients have severe systemic disease that is not incapacitating, class IV patients have incapacitating disease that

is a constant threat to life, and class V patients are moribund and not expected to live 24 hours without surgery. Patients were categorised into high risk (>15), intermediate risk ($5-15$) and low risk (<5) of frailty based on HFRS.¹⁶ The 109 ICD-10 codes used to calculate the HFRS for each patient can be found in Supplementary Appendix S1. The analysis excludes day surgery and 23-hour ward admissions, and discharges from the Short Stay Unit or Emergency Department Treatment Unit or equivalent. Elective admissions that were discharged within 24 hours were also excluded. The cohort is representative of patients undergoing acute surgical admissions to a tertiary hospital in Singapore.

Informed consent was not required as the study team had no direct contact with patients and no access to patient-identifiable data, as all data collected were anonymised. SingHealth Centralised Institutional Review Board provided ethics approval (IRB number 2022/2645). All methods included in this study are in accordance with the Declaration of Helsinki.

The primary aim of this study is to compare HFRS with CCI and validate HFRS as a predictor of adverse outcomes, such as hospitalisation utilisation and mortality in older surgical patients. The secondary aim is to determine whether HFRS is associated with severity and complexity of surgery in older patients, and any other contributory factors that predict adverse outcomes.

Statistical analysis

Continuous variables are presented as means and standard deviations (SD), while categorical variables are presented as counts and percentages. HFRS was analysed as a categorical variable (high, intermediate and low risk). To compare the association of HFRS categories with various variables and outcomes, we conducted the Pearson chi-square test, Fisher's Exact test, analysis of variance, and Kruskal-Wallis test as appropriate. For our analysis of 30-day readmissions, inpatients who died were excluded from analysis. The number of TOSP procedures was presented and analysed as a categorical variable in hypothesis testing, where those with ≥ 5 TOSP procedures were grouped into 1 category to fulfil the assumptions of the Pearson chi-square test.

Univariate and multivariate logistic regressions were fitted to evaluate the association between HFRS (as a continuous variable) and the relevant outcomes. The multivariate model was adjusted for age, sex, race, BMI, CCI, maximum TOSP table number and number of TOSP procedures. Maximum TOSP table number and number of

TOSP procedures were analysed as a continuous variable in logistic regression. Data are presented as odds ratios (ORs) with 95% confidence intervals (CIs). An unadjusted model was used to compare HFRS, CCI and HFRS in combination with CCI as predictors of outcomes. The area under the receiver operator characteristic curve (AUROC) was used to assess model discrimination. All statistical analyses were performed using a two-tailed test with a significance level of $P < 0.05$.

RESULTS

Baseline characteristics

A total of 1829 patients were discharged from surgical service in CGH between 1 April 2022 and 31 July 2022. Mean age was 76 years (SD 7.91), with a range of 65 to 103 years (Table 1). Those at high risk of frailty were significantly older compared to those at low risk of frailty (mean: 81.1 versus 73.4, $P < 0.001$) (Table 1). There was a higher prevalence of men in the study population (53.9% vs 46.1%), although the proportion of men and women were similar among those at high risk of frailty (49.3% vs 50.7%, respectively) (Table 1). There were no significant differences in race across the frailty risk groups.

Hospitalisation usage

Hospital LOS was significantly longer in those at higher risk of frailty compared with those at lower risk (60.5% vs 15.6%, $P < 0.001$) (Table 2). In both univariate and multivariate analyses, women were more likely to have longer LOS (adjusted OR [aOR] 1.676, CI 1.318–2.134, $P < 0.001$) (Table 3A). HFRS was associated with long LOS, in both univariate (OR 1.106, CI 1.092–1.122, $P < 0.001$) and multivariate analyses (aOR 1.106, CI 1.088–1.125, $P < 0.001$) (Table 3A). CCI was also associated with long LOS in both univariate (OR 1.338, CI 1.271–1.411, $P < 0.001$) and multivariate analyses (aOR 1.231, CI 1.157–1.310, $P < 0.001$) (Table 3A). Complexity of surgical procedures defined as higher TOSP (aOR 1.248, CI 1.170–1.333, $P < 0.001$) and higher number of surgical procedures (aOR 1.680, CI 1.441–1.970, $P < 0.001$) were associated with longer LOS (Table 3A).

Hospital readmission (excluding inpatients who died but including patients who died within 30 days of discharge) within 30 days was significantly higher in those at higher risk of frailty (20.3% vs 7.2%, $P < 0.001$) and this remained significant for readmission within 270 days (46.1% vs 19.5%) (Table 2). Age, high risk of frailty (aOR 1.047, CI 1.030–1.065, $P < 0.001$) and CCI (aOR 1.124, CI 1.042–1.211, $P < 0.01$) were associated with

Table 1. Baseline characteristics.

	Low risk (n=923)	Intermediate risk (n=600)	High risk (n=306)	Overall (N=1829)	P value
Age, mean (SD), years	73.4 (6.74)	77.2 (7.68)	81.1 (8.51)	76.0 (7.91)	<0.001
Men, no. (%)	532 (57.6)	302 (50.3)	151 (49.3)	985 (53.9)	<0.001
BMI, mean (SD)	24.9 (4.43)	24.3 (5.00)	23.3 (4.82)	24.4 (4.72)	<0.001
Race, no. (%)					
Chinese	704 (76.3)	425 (70.8)	239 (78.1)	1368 (74.8)	0.23
Indian	47 (5.1)	35 (5.8)	14 (4.6)	96 (5.2)	
Malay	117 (12.7)	94 (15.7)	37 (12.1)	248 (13.6)	
Other races	55 (6.0)	46 (7.7)	16 (5.2)	117 (6.4)	
CCI, mean (SD)	1.09 (1.71)	1.75 (1.88)	2.66 (2.26)	1.57 (1.95)	<0.001
CCI category, no. (%)					
0	560 (60.7)	255 (42.5)	60 (19.6)	875 (47.8)	<0.001
1	47 (5.1)	39 (6.5)	51 (16.7)	137 (7.5)	
2	187 (20.3)	130 (21.7)	54 (17.6)	371 (20.3)	
≥3	129 (14.0)	176 (29.3)	141 (46.1)	446 (24.4)	

BMI: body mass index; CCI: Charlson Comorbidity Index

Table 2. Hospital outcomes.

	Low risk (n=923)	Intermediate risk (n=600)	High risk (n=306)	Overall (N=1829)	P value
LOS ≥7 days, no. (%)	144 (15.6)	257 (42.8)	185 (60.5)	586 (32.0)	<0.001
Inpatient mortality, no. (%)	4 (0.4)	22 (3.7)	12 (3.9)	38 (2.1)	<0.001
10-day mortality, no. (%)	6 (0.7)	15 (2.5)	8 (2.6)	29 (1.6)	<0.01
30-day mortality, no. (%)	13 (1.4)	26 (4.3)	14 (4.6)	53 (2.9)	<0.001
90-day mortality, no. (%)	24 (2.6)	41 (6.8)	39 (12.7)	104 (5.7)	<0.001
270-day mortality, no. (%)	50 (5.4)	78 (13.0)	70 (22.9)	198 (10.8)	<0.001
30-day readmission (emergency), no. (%) ^a	66 (7.2)	71 (11.8)	62 (20.3)	199 (10.9)	<0.001
270-day readmission (emergency), no. (%) ^a	180 (19.5)	211 (35.2)	141 (46.1)	532 (29.1)	<0.001

^a Excludes cases who died inpatient but not patients who died within 30 days of hospital discharge.

30-day emergency readmissions (Table 2 and Table 3F). Women had lower likelihood of 30-day emergency hospital readmission (aOR 0.704, CI 0.511–0.965, $P<0.05$) (Table 3F).

TOSP and ASA scores

The most common admitting surgical specialty was general surgery (50.7%) followed by orthopaedic surgery (33.8%) (Table 4). Surgical

procedures (TOSP) were performed in 64.3% of patients and among them, majority underwent 1 procedure (70.5%). There were more patients of high risk versus low risk (23.2% vs 17.4%) for frailty who underwent 2 or more TOSP procedures. The number of surgical procedures was associated with higher risk of frailty ($P<0.001$) as was the complexity of surgical procedure ($P<0.001$) (Table 1). Higher TOSP table number was taken

Table 3A. Multivariable logistic regression analyses results: long length of stay.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.038 (1.025–1.051)	<0.001	1.015 (0.998–1.032)	0.07
Women	1.668 (1.369–2.033)	<0.001	1.676 (1.318–2.134)	<0.001
HFRS	1.106 (1.092–1.122)	<0.001	1.106 (1.088–1.125)	<0.001
Race				
Indian	1.264 (0.815–1.935)	0.29	1.287 (0.758–2.150)	0.34
Malay	1.191 (0.893–1.579)	0.23	1.182 (0.831–1.672)	0.35
Other	1.019 (0.672–1.519)	0.93	1.204 (0.732–1.945)	0.46
CCI	1.338 (1.271–1.411)	<0.001	1.231 (1.157–1.310)	<0.001
BMI	0.994 (0.973–1.015)	0.57	1.004 (0.979–1.030)	0.74
Maximum TOSP table no.	1.298 (1.240–1.359)	<0.001	1.248 (1.170–1.333)	<0.001
No. of TOSP procedures	1.965 (1.755–2.210)	<0.001	1.680 (1.441–1.970)	<0.001

Table 3B. Multivariable logistic regression analyses results: 10-day mortality.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.090 (1.045–1.137)	<0.001	1.071 (1.019–1.125)	<0.01
Women	1.255 (0.599–2.644)	0.54	1.133 (0.522–2.469)	0.75
HFRS	1.046 (1.010–1.079)	<0.01	1.009 (0.967–1.049)	0.67
Race				
Indian	0.000 (NA)	0.98	0.000 (NA)	0.99
Malay	0.749 (0.176–2.183)	0.64	0.871 (0.201–2.631)	0.83
Other	2.166 (0.625–5.777)	0.16	2.363 (0.662–6.637)	0.13
CCI	1.212 (1.034–1.401)	<0.05	1.230 (1.032–1.447)	<0.05
BMI	0.921 (0.839–1.004)	0.08	0.957 (0.869–1.043)	0.35
Maximum TOSP table no.	0.701 (0.546–0.862)	<0.01	0.652 (0.470–0.862)	<0.01
No. of TOSP procedures	0.727 (0.438–1.088)	0.18	1.249 (0.793–1.623)	0.18

BMI: body mass index; CCI: Charlson Comorbidity Index; CI: confidence interval; HFRS: Hospitality Frailty Risk Score; NA: not available; OR: odds ratio; TOSP: Table of Surgical Procedure

as a proxy for surgical complexity. ASA scores were only available for 48.6% of the cohort and hence was not used as a variable in logistic regression. However, higher risk of frailty correlated with a higher ASA score ($P<0.001$) (Table 1).

Charlson Comorbidity Index (CCI)

CCI is shown in Table 1 where more than half (52.2%) of the cohort had 1 or more comorbidity,

20.3% had CCI of 2, and 24.4% had CCI of 3 or higher. Mean CCI was higher in those at high risk compared to those at low risk of frailty (2.66 vs 1.09, $P<0.001$). There was a statistically significant association between HFRS and CCI ($P<0.001$)—a higher proportion of patients with CCI 3 or more were those at high risk of frailty compared with those at low risk of frailty (Table 1). There was low collinearity between HFRS and CCI (correlation coefficient=0.32, $P<0.05$).

Table 3C. Multivariable logistic regression analyses results: 30-day mortality.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.075 (1.042–1.110)	<0.001	1.055 (1.017–1.095)	<0.01
Women	1.425 (0.824–2.486)	0.21	1.352 (0.761–2.421)	0.3
HFRS	1.043 (1.017–1.069)	<0.001	1.010 (0.979–1.041)	0.5
Race				
Indian	0.368 (0.021–1.727)	0.33	0.421 (0.023–2.038)	0.4
Malay	1.017 (0.412–2.166)	0.97	1.146 (0.454–2.520)	0.75
Other	2.227 (0.894–4.811)	0.06	2.320 (0.904–5.226)	0.06
CCI	1.223 (1.088–1.365)	<0.001	1.234 (1.083–1.396)	<0.01
BMI	0.927 (0.865–0.989)	<0.05	0.951 (0.887–1.014)	0.14
Maximum TOSP table no.	0.737 (0.624–0.855)	<0.001	0.701 (0.564–0.856)	<0.001
No. of TOSP procedures	0.734 (0.509–1.002)	0.08	1.176 (0.832–1.473)	0.25

Table 3D. Multivariable logistic regression analyses results: 90-day mortality.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.074 (1.049–1.099)	<0.001	1.045 (1.016–1.074)	<0.01
Women	1.086 (0.729–1.614)	0.68	1.034 (0.673–1.585)	0.88
HFRS	1.065 (1.046–1.084)	<0.001	1.033 (1.012–1.055)	<0.01
Race				
Indian	0.357 (0.058–1.157)	0.15	0.420 (0.068–1.405)	0.24
Malay	0.927 (0.485–1.640)	0.81	1.042 (0.529–1.912)	0.9
Other	1.916 (0.965–3.508)	<0.05	2.122 (1.031–4.066)	<0.05
CCI	1.305 (1.201–1.416)	<0.001	1.295 (1.179–1.419)	<0.001
BMI	0.900 (0.854–0.945)	<0.001	0.926 (0.878–0.974)	<0.01
Maximum TOSP table no.	0.799 (0.718–0.883)	<0.001	0.791 (0.685–0.909)	<0.01
No. of TOSP procedures	0.778 (0.606–0.969)	<0.05	1.024 (0.780–1.255)	0.84

BMI: body mass index; CCI: Charlson Comorbidity Index; CI: confidence interval; HFRS: Hospitality Frailty Risk Score; OR: odds ratio; TOSP: Table of Surgical Procedure

Mortality

Older age was associated with mortality in both univariate and multivariate analyses at 10 days (aOR 1.071, CI 1.019–1.125, $P<0.01$), 30 days (aOR 1.055, CI 1.017–1.095, $P<0.01$), 90 days (aOR 1.045, CI 1.016–1.074, $P<0.01$) and 270 days (aOR 1.058, CI 1.035–1.081, $P<0.001$) (Tables 3B to 3E). Women had lower mortality at 270 days only (aOR 0.653, CI 0.465–0.911, $P=0.01$).

Mortality was higher in those at high risk of frailty at 10 days (2.6% vs 0.7%, $P<0.01$), 30 days (4.6% vs 1.4%, $P<0.001$), 90 days (12.7% vs 2.6%, $P<0.001$), and 270 days (22.9% vs 5.4%, $P<0.001$). Inpatient mortality was higher in frail patients (3.9% vs 0.4%, $P<0.001$) (Table 2). However, in adjusted multivariate analyses, HFRS was only associated with mortality at 90-day (aOR 1.033, CI 1.012–1.055, $P<0.01$) and 270-day (aOR

Table 3E. Multivariable logistic regression analyses results: 270-day mortality.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.077 (1.059–1.097)	<0.001	1.058 (1.035–1.081)	<0.001
Women	0.752 (0.555–1.013)	0.06	0.653 (0.465–0.911)	<0.05
HFRS	1.068 (1.053–1.083)	<0.001	1.032 (1.015–1.050)	<0.001
Race				
Indian	0.453 (0.158–1.025)	0.09	0.527 (0.179–1.236)	0.18
Malay	0.883 (0.549–1.366)	0.59	0.975 (0.583–1.577)	0.92
Other	1.803 (1.066–2.925)	<0.05	2.038 (1.156–3.470)	<0.05
CCI	1.340 (1.256–1.431)	<0.001	1.339 (1.243–1.444)	<0.001
BMI	0.903 (0.869–0.937)	<0.001	0.932 (0.895–0.969)	<0.001
Maximum TOSP table no.	0.819 (0.760–0.881)	<0.001	0.807 (0.727–0.892)	<0.001
No. of TOSP procedures	0.865 (0.733–1.003)	0.07	1.052 (0.881–1.221)	0.54

Table 3F. Multivariable logistic regression analyses results: 30-day readmission.

	Univariate		Adjusted	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.023 (1.004–1.041)	<0.05	1.009 (0.987–1.031)	0.42
Women	0.766 (0.566–1.032)	0.08	0.704 (0.511–0.965)	<0.05
HFRS	1.055 (1.040–1.071)	<0.001	1.047 (1.030–1.065)	<0.001
Race				
Indian	1.449 (0.770–2.545)	0.22	1.332 (0.693–2.397)	0.36
Malay	1.131 (0.727–1.706)	0.57	1.018 (0.639–1.574)	0.94
Other	1.124 (0.588–1.987)	0.71	1.077 (0.554–1.940)	0.82
CCI	1.205 (1.127–1.288)	<0.001	1.124 (1.042–1.211)	<0.01
BMI	1.017 (0.986–1.047)	0.28	1.029 (0.997–1.062)	0.07
Maximum TOSP table no.	0.959 (0.897–1.025)	0.22	0.962 (0.885–1.045)	0.36
No. of TOSP procedures	1.031 (0.904–1.155)	0.63	1.003 (0.861–1.145)	0.96

BMI: body mass index; CCI: Charlson Comorbidity Index; CI: confidence interval; HFRS: Hospital Frailty Risk Score; OR: odds ratio; TOSP: Table of Surgical Procedure

1.032, CI 1.015–1.050, $P<0.001$) mortality but not 10-day ($P=0.67$) or 30-day ($P=0.50$) mortality (Tables 3B to 3E). CCI was associated with mortality at all time points whereas surgical complexity, defined as higher TOSP, was less likely to result in mortality at all time points (Tables 3B to 3E).

Comparing HFRS with CCI, we observed that HFRS is a better predictor of long LOS (AUROC

0.757 vs 0.631), 90-day mortality (AUROC 0.663 vs 0.611) and 270-day mortality (AUROC 0.686 vs 0.684). When used in combination, HFRS and CCI were better predictors of 90-day mortality (AUROC 0.670), 270-day mortality (AUROC 0.724) and 30-day readmission (AUROC 0.679 vs 0.646 for HFRS) (Table 5).

Table 4. Surgical characteristics.

	Low risk (n=923)	Intermediate risk (n=600)	High risk (n=306)	Overall (N=1829)	P value
Admitting specialty, no. (%)					
Ear Nose & Throat	29 (3.1)	7 (1.2)	4 (1.3)	40 (2.2)	<0.001
Ophthalmology	6 (0.7)	5 (0.8)	2 (0.7)	13 (0.7)	
Neurosurgical	19 (2.1)	36 (6.0)	20 (6.5%)	75 (4.1)	
Oro-maxillary surgery	1 (0.1)	0	1 (0.3)	2 (0.1)	
Orthopaedic surgery	287 (31.1)	234 (39.0)	98 (32.0)	619 (33.8)	
General surgery	493 (53.4)	278 (46.3)	156 (51.0)	927 (50.7)	
Urology	88 (9.5)	40 (6.7)	25 (8.2)	153 (8.4)	
TOSP procedure performed, no. (%)	610 (66.1)	378 (63.0)	188 (61.4)	1176 (64.3)	0.24
TOSP table (maximum), no. (%)					
1	98 (10.6)	55 (9.2)	34 (11.1)	187 (10.2)	<0.001
2	71 (7.7)	46 (7.7)	22 (7.2)	139 (7.6)	
3	113 (12.2)	55 (9.2)	16 (5.2)	184 (10.1)	
4	124 (13.4)	57 (9.5)	43 (14.1)	224 (12.2)	
5	86 (9.3)	128 (21.3)	59 (19.3)	273 (14.9)	
6	94 (10.2)	27 (4.5)	8 (2.6)	129 (7.1)	
7	24 (2.6)	10 (1.7)	6 (2.0)	40 (2.2)	
No procedure	313 (33.9)	222 (37.0)	118 (38.6)	653 (35.7)	
No. of TOSP procedures, (%)					
0 ^a	313 (33.9)	222 (37.0)	118 (38.6)	653 (35.7)	<0.001
1	449 (48.6)	263 (43.8)	117 (38.2)	829 (45.3)	
2	109 (11.8)	79 (13.2)	41 (13.4)	229 (12.5)	
3	40 (4.3)	16 (2.7)	14 (4.6)	70 (3.8)	
4	10 (1.1)	10 (1.7)	8 (2.6)	28 (1.5)	
≥5	2 (0.2)	10 (1.7)	8 (2.6)	20 (1.1)	
ASA status (maximum), no. (%)					
1	7 (0.8)	2 (0.3)	1 (0.3)	10 (0.5)	<0.001
2	217 (23.5)	59 (9.8)	11 (3.6)	287 (15.7)	
3	233 (25.2)	204 (34.0)	100 (32.7)	537 (29.4)	
4	14 (1.5)	20 (3.3)	18 (5.9)	52 (2.8)	
5	0	2 (0.3)	0	2 (0.1)	
No ASA	452 (49.0)	313 (52.2)	176 (57.5)	941 (51.4)	

ASA: American Society of Anaesthesiologists; TOSP: Table of Surgical Procedure

^a TOSP of 0 indicates no surgical procedure was undertaken.

Table 5. Comparing Hospital Frailty Risk Score (HFRS) and Charlson Comorbidity Index (CCI) as a predictor of outcomes.

	AUROC		
	HFRS	CCI	HFRS and CCI
Long LOS	0.757	0.631	0.755
10-day mortality	0.512	0.492	0.508
30-day mortality	0.450	0.481	0.450
90-day mortality	0.663	0.611	0.670
270-day mortality	0.686	0.684	0.724
30-day readmission	0.646	0.646	0.679

AUROC: area under the receiver operator characteristic curve; CCI: Charlson Comorbidity Index; HFRS: Hospitality Frailty Risk Score; LOS: length of stay

DISCUSSION

Frailty is associated with poorer health outcomes, increased healthcare utilisation and cost.^{5,9-11} The HFRS is promising and has been shown to predict negative outcomes and increased healthcare utilisation and costs.¹⁹ High HFRS scores have been associated with major adverse cardiovascular events,²² postoperative sepsis,²³ LOS,^{24,25} postoperative complications,²⁴ time to surgery²⁴ and mortality.²⁵⁻²⁷

This retrospective analysis of 1829 patients aged 65 years old and above has shown that high HFRS scores were associated with longer hospital LOS, increased 30-day hospital readmissions, and higher risk of short and longer-term mortality. Frail patients undergoing surgery are not only at risk of adverse outcomes in the immediate perioperative period, but also have an increased risk of mortality at 90 days and at 270 days, which is consistent with other studies in surgical cohorts showing increased risk of mortality up to 2 years.^{25,26} This has implications in prognostication which may influence decision making for surgery.

Early and timely assessment can guide interventions in frail patients who require in-depth assessment and/or prehabilitation to reduce the risk of adverse outcomes.³⁴ This maximises the benefit while minimising the harm of surgical interventions as well as healthcare cost.³⁵ HFRS and its association with adverse outcomes has been shown in multiple inpatient and procedural settings.^{18,20,36,37} In a cohort of 487,197 patients over the age of 50 undergoing surgery, higher HFRS was associated with prolonged LOS, readmission and 30-day mortality. Notably, the addition of HFRS to CCI did not significantly improve model performance possibly due to lack of CCI and HFRS data, which was calculated in only 17% and 32% of the patients, respectively.³⁸ Importantly, in our cohort, the use of both HFRS

and CCI increased the prediction of mortality and readmissions, and shows that HFRS may be useful when combined with other conventional morbidity assessments. The low collinearity between the HFRS and CCI (correlation coefficient=0.32, $P<0.05$) in our cohort suggests that the HFRS and CCI are not strongly correlated and might be capturing different and unique information. This is consistent with the intent and computation method of both scores. Overall, CCI was developed as a predictor of mortality, while HFRS is meant to identify more broad “adverse outcomes”, which includes outcomes like LOS and readmissions. Although both scores do overlap in the conditions they utilise for scoring (e.g. renal disease, dementia and cerebrovascular diseases), the weights assigned within these models are different. To illustrate this point, dementia from Alzheimer’s disease is the highest weighted code for HFRS (7.1, where weights range from 0.1 to 7.1), but is the lowest weighted in the CCI (1, where weights range from 1 to 6). Additionally, HFRS includes conditions like falls, cellulitis and electrolyte imbalance, which are not featured in CCI, while CCI includes cancers and diabetes, which are not featured in HFRS.

The largest study assessing the effects of frailty on perioperative outcomes utilised the Johns Hopkins Adjusted Clinical groups frailty-defining diagnoses indicator, which is not easily available nor utilised by clinicians on a day-to-day basis for large populations.³⁹ This further highlights the role of HFRS as a practical tool to trigger in-depth frailty assessment and interventions in those who will most benefit.

There are some limitations of our study. The HFRS is based on available administrative data, which were not primarily intended for research purposes, and relies on accurate coding and documentation of information to define frailty and other conditions. Coding inaccuracies may create

bias. Furthermore, ICD coding typically takes 6 to 8 weeks from the index admission, which means that the HFRS can only be used retrospectively and does not allow access to frailty risk during the patient's index admission. Using ICD-10 codes may miss important aspects of frailty that may not be covered by coding, such as polypharmacy, fatigue, severity of comorbidities and functional abilities. Finally, while the AUROC of our predictive models suggest that HFRS or a combination of HFRS and CCI might be a better predictor of selected outcomes, the AUROC indicates only moderate to good model discrimination, which might limit its use as a bedside risk prediction tool. An unexpected finding is the lower mortality in those with higher TOSP, which may be skewed by the small numbers of patients at high frailty risk or impacted by selection of patients needing complex surgery. Hence, no inference can be assumed about direct or inverse associations between frailty risk and complexity of surgery. Despite these limitations, we propose that HFRS may still be useful as a simple, low-cost screening tool to identify frailty in older surgical patients.

CONCLUSION

To our knowledge, this is the first validated study in Singapore looking at HFRS in older surgical patients in Singapore. This study has shown that HFRS predicts long LOS, higher unplanned hospital readmissions and increased mortality when compared to those at low risk of frailty and is currently being adapted to provide an easy, rapid, low-cost tool for screening and identifying patients at higher risk of adverse outcomes in an older surgical population in Singapore.

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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Disclosure

The authors declare no conflict of interest and have no relationships and activities to disclose.

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