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Comparison of two electronic medical record-based frailty assessment tools and their association with adverse outcomes in older hospitalized patients with urgent admissions

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Abstract

Background Frailty assessment is crucial for predicting outcomes in acute care settings; however, its application remains challenging. Therefore, this study aims to evaluate and compare two electronic medical record-based tools—the Canadian Institute for Health Information Hospital Frailty Risk Measure (CIHI-HFRM) and the United Kingdom Hospital Frailty Risk Score (UK-HFRS)—in older patients requiring urgent admission.

Methods In this retrospective cohort study, we analyzed 35,564 patients aged 65 or older from the MIMIC-IV 2.0 database. Frailty was assessed using CIHI-HFRM and UK-HFRS. Primary outcomes included in-hospital mortality, one-year post-discharge mortality, post-discharge care needs, timely hospital discharge, and one-year readmission rates. Logistic regression, Cox regression, and competing risk models were used for analysis.

Results The CIHI-HFRM and UK-HFRS were significantly associated with in-hospital mortality [odds ratio (OR) per point: CIHI-HFRM 1.10 (95% confidence interval (CI) 1.07–1.13); UK-HFRS 1.06 (95% CI 1.05–1.07)] and one-year post-discharge mortality [hazard ratio (HR) per point: CIHI-HFRM 1.08 (95% CI 1.06–1.09); UK-HFRS 1.05 (95% CI 1.04–1.05)]. Both measures were associated with prolonged hospital stays and post-discharge care needs, while only CIHI-HFRM was linked to one-year readmission risk.

Conclusion The CIHI-HFRM and UK-HFRS effectively stratify adverse outcomes risk in older patients requiring urgent admission. They may be considered alongside traditional measures as part of a pragmatic multimodal pathway, which represents a potential direction for clinical application.

Keywords Canadian Institute for Health Information-Hospital Frailty Risk Measure, United Kingdom-Hospital Frailty Risk Score, Urgent admission, Older, Adverse outcome

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Introduction

Frailty is a multifaceted geriatric syndrome characterized by reduced physiological reserve and increased vulnerability to stressors [1]. It significantly contributes to adverse health outcomes in older adults. Emerging evidence underscores its intricate pathophysiology, driven by chronic inflammation, sarcopenia, endocrine dysregulation, and psychosocial stress [2–5]. Beyond physical decline, frailty encompasses cognitive impairment, nutritional deficits, and social isolation, all of which increase the risk of disability [6–8]. Epidemiological studies indicate that frailty is common among older adults, with prevalence of approximately 12–24% in community-dwelling populations and about 47% in hospital settings [9, 10]. Frailty is linked to prolonged hospitalizations, higher infection rates, and increased mortality [11]. Acute hospitalizations can further worsen frailty in older adults by causing immobility, acute physiological stress, and new functional dependence, which accelerates functional decline, increases the likelihood of requiring institutional care, and ultimately raises healthcare costs [12, 13].

Although frailty is a key prognostic factor, its assessment in acute care settings remains challenging [14]. Bedside frailty tools such as the Fried frailty phenotype [15] and the Clinical Frailty Scale [16] (CFS) are widely used but each has practical limitations in the acute setting. The Fried phenotype requires performance-based physical testing and structured patient-reported information, which can be time- and resource-intensive. The CFS can be scored more quickly but relies largely on global clinical judgment and reported functional history, and therefore offers limited objective standardization. These limitations are more pronounced in urgent admissions, where cognitive impairment or critical illness compromises assessment reliability and increases the workload of the clinician and nursing staff. Electronic medical record (EMR)-based tools offer a promising alternative by using routinely collected clinical data for automated risk stratification. Several frailty assessment tools originally developed using administrative data, including the Canadian Institute for Health Information–Hospital Frailty Risk Measure [17] (CIHI-HFRM) and the United Kingdom–Hospital Frailty Risk Score [18] (UK-HFRS), have raised the question of whether they can be operationalized earlier at clinical frontline—i.e., applied directly to EMR data before administrative aggregation—to enable frailty screening in the emergency or inpatient setting. Additionally, these tools differ in both design and predictive performance, underscoring the need to explore and comparatively evaluate their applicability across diverse patient populations.

Among emerging administrative data-based frailty assessment tools, the CIHI-HFRM and the UK-HFRS offer distinct advantages, as both have been shown to identify older inpatients at increased risk of mortality, prolonged hospitalization, and readmission [17, 18]. Both are developed using International Classification of Diseases (ICD) codes to assess frailty in patients who are hospitalized in acute care settings. The CIHI-HFRM categorizes frailty into 36 unweighted frailty-related condition categories based on 595 ICD-10 codes, while the UK-HFRS applies weighted scores to 109 ICD-10 codes. However, the CIHI-HFRM lacks external validation and it has not been directly compared with the UK-HFRS in an external cohort.

Therefore, this cohort study aims to evaluate and compare the CIHI-HFRM and UK-HFRS in older patients requiring urgent hospitalization using the MIMIC-IV database, by applying EMR-based versions of these tools in place of the administrative data on which they were originally developed. We hypothesize that these tools differ in prognostic performance. By externally validating the CIHI-HFRM and comparing it to the UK-HFRS, this study addresses key evidence gaps regarding their generalizability and clinical utility in acute care. Understanding these differences could help develop tailored frailty screening protocols, ultimately improving risk stratification and resource allocation in time-sensitive settings.

Methods

Study design and population

In this retrospective observational study, we employed the MIMIC-IV 2.0 database [19, 20], a publicly accessible dataset that includes comprehensive EMR of 315,460 patients admitted to the emergency department or intensive care unit for urgent care at Beth Israel Deaconess Medical Center between 2008 and 2019. The Institutional Review Board of the medical center approved the use of this database, and access was granted upon completion of the human research participant protection course offered by the National Institutes of Health (Certification number: 11153471).

This study included the first urgent admission records from patients with prior admissions, ensuring sufficient data for frailty score calculation. The following exclusion criteria were applied: (1) patients with only one hospitalization; (2) individuals under 65 years old; (3) patients admitted for non-urgent reasons; (4) patients with a survival time less than zero or those identified as organ donors; and (5) patients with missing essential data, such as demographic information, diagnoses, Charlson Comorbidity Index (CCI), or survival status during hospitalization.

Data collection

The extracted data included demographic variables (age, gender, ethnicity), medical history (cerebrovascular

disease, chronic pulmonary disease, congestive heart failure, dementia, diabetes mellitus, malignancy, myocardial infarction, and kidney disease), CCI, discharge location, hospital length of stay (LOS), in-hospital survival status, one-year post-discharge survival, and one-year readmission.

Frailty assessment

CIHI-HFRM

The CIHI-HFRM was developed using diagnoses from the most recent hospitalization, following established protocols [17]. It classified 36 frailty-related condition categories based on ICD codes, encompassing a total of 595 individual ICD codes. The supplementary materials provide detailed information on CIHI-HFRM development, including the specific ICD codes used and the prevalence of each frailty category (see "Methods for Constructing Frailty Measures" and Table S1). Patients were categorized into two groups: low frailty risk (CIHI-HFRM < 6) and high frailty risk (CIHI-HFRM ≥ 6) [17].

UK-HFRS

The UK-HFRS, derived from 109 ICD codes, was also developed using diagnoses from the most recent hospitalization, following established protocols [18]. Table S2 shows details for 109 ICD codes. Patients were categorized into two groups: low frailty risk (UK-HFRS < 5) and high frailty risk (UK-HFRS ≥ 5). This binary classification, which follows previously published work, was also applied to facilitate comparison with the CIHI-HFRM [18, 21–23].

Outcomes

The primary outcomes were in-hospital mortality and one-year post-discharge mortality. Secondary outcomes included post-discharge care needs (post-discharge care needs including hospice, home care, and other healthcare facilities versus discharge home without further need for nursing care) [12], timely hospital discharge, and readmission within 1-year post-discharge. Timely discharge was defined as LOS below the 75th percentile, corresponding to a hospital stay of ≤ 5.91 days [24].

Statistical analysis

Continuous variables were presented as either mean ± standard deviation or median with interquartile range (IQR), depending on the data distribution. Categorical variables were summarized as counts and percentages. Group comparisons were performed using Student's t-test, Mann–Whitney U test, or χ^2 test, as appropriate. Spearman's rank correlation and kappa statistics were employed to evaluate the correlation and diagnostic concordance between the two frailty assessment tools.

Logistic regression analysis was conducted to explore the relationship between frailty, in-hospital mortality, and post-discharge care needs. To further examine the effect of frailty on one-year post-discharge mortality, Kaplan–Meier survival curves and Cox proportional hazards models were applied. Competing risk models were used to evaluate the association between frailty and outcomes, including timely hospital discharge and one-year readmission while considering death as a competing risk for both events. Fully adjusted models controlled for age group, gender, ethnicity, and CCI as confounding factors. Restricted cubic spline curves with three knots were employed to examine the association between frailty (as a continuous variable) and outcomes, such as mortality and post-discharge care needs, with formal nonlinearity testing.

Frailty (CIHI-HFRM or UK-HFRS) was entered as a continuous predictor. For discrimination, we fitted separate univariable models for each score and calculated the C-index with 95% CIs. The C-indices of the two frailty scores were then compared.

All statistical analyses were conducted using Stata version 18.0 and R version 4.4.2. Statistical significance was set as a two-tailed p-value < 0.05.

Results

Patient characteristics

In total, 35,564 patient records met the inclusion criteria of the study (Fig. 1). Table 1 provides a comprehensive summary of patient characteristics by survival status at hospital discharge. The cohort had a mean age of 77.7 ± 8.2 years, and 48.1% were male. The median CCI was 6.0 (IQR: 4.0–7.0). CIHI-HFRM scores ranged from 0 to 16, with a median of 4.0 (IQR: 3.0–6.0), while UK-HFRS scores ranged from 0 to 38.7, with a median of 3.1 (IQR: 1.1–6.4). High frailty risk was observed in 11,332 patients (31.9%) using CIHI-HFRM and in 12,087 patients (34.0%) according to UK-HFRS. The median LOS was 3.1 days (IQR: 1.5–5.9), and in-hospital mortality occurred in 1,072 patients (3.0%). Nonsurvivors were older, had a higher proportion of males, and showed a greater frequency of nearly all comorbid conditions, leading to a higher CCI. Both frailty scoring systems identified a higher rate of high frailty risk among nonsurvivors who had longer hospital stays (all $p < 0.05$). Supplement (Tables S3 and S4) provide additional data on frailty risk stratification.

A correlation analysis comparing the two frailty assessment tools revealed a robust association (Spearman's rho = 0.715, $p < 0.001$). We also observed moderate agreement between the two tools in identifying patients as high frailty risk (kappa = 0.535, $p < 0.001$) (Figure S1).

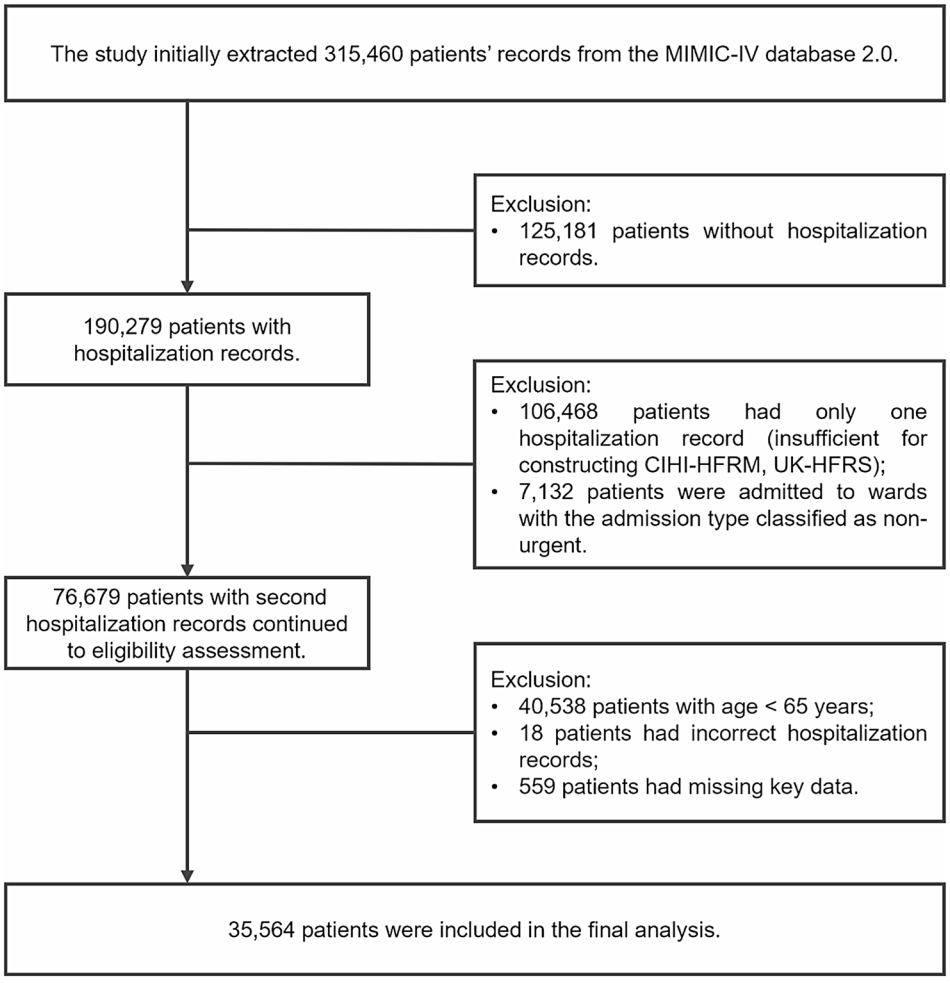

Fig. 1 Flowchart of the study population selection process. MIMIC, Medical Information Mart for Intensive Care; CIHI-HFRM, Canadian Institute for Health Information-Hospital Frailty Risk Measure; UK-HFRS, United Kingdom-Hospital Frailty Risk Score

Mortality analysis

Table 2 shows that the overall in-hospital mortality occurred in 1,072 of 35,564 patients, resulting in a rate of 0.03. CIHI-HFRM and UK-HFRS identified that patients in the high frailty risk group had significantly higher in-hospital mortality than those in the low frailty risk group. For CIHI-HFRM, patients in the high frailty risk group had more than twice the risk of in-hospital mortality compared with those in the low frailty risk group in the crude model [Odds Ratio (OR) = 2.21, 95% Confidence Interval (CI): 1.96–2.50]. This association remained significant in the fully adjusted model, after adjustment for all covariates, with an OR of 1.44 (95% CI, 1.27–1.64). Similarly, for UK-HFRS, the high-risk group showed significantly elevated in-hospital mortality risk, with ORs of 2.26 (95% CI: 2.00–2.55) in the crude model and 1.78 (95% CI: 1.57–2.02) in the fully adjusted model. When analyzed as continuous measures (Fig. 2a and b), each one-point increment in CIHI-HFRM score correlated with a 20.3% increased risk of in-hospital mortality in the crude model (OR = 1.20, 95% CI: 1.18–1.23) and 9.7% increased risk in the fully adjusted model (OR = 1.10, 95% CI: 1.07–1.13). Correspondingly, each one-point increase in UK-HFRS score corresponded to higher risks of 8.1% (OR = 1.08, 95% CI: 1.07–1.09) and 6.0% (OR = 1.06, 95% CI: 1.05–1.07) of in-hospital mortality across the respective models.

For one-year post-discharge mortality (Table 2), the overall incidence occurred in 6,151 among 34,492 patients, resulting in an incidence rate of 201.55 per 1,000 person-years. The frailty assessment tools consistently showed that patients in the high frailty risk group had a significantly higher incidence rate than those in the low frailty risk group. For CIHI-HFRM, in the unadjusted analysis the high-risk group had a higher one-year mortality risk than the low-risk group (HR = 2.10, 95% CI: 1.99–2.20). After adjustment for all covariates in the fully adjusted model, this association remained significant (HR = 1.34, 95% CI: 1.27–1.41). When analyzed as a continuous variable (Fig. 2c), each one-point increase

Table 1 Baseline characteristics of included patients according to survival status at hospital discharge

Variable	All patients (*n* = 35,564)	Survivors (*n* = 34,492)	NonSurvivors (*n* = 1,072)	*p*-value
Age, mean (SD), years	77.7 ± 8.2	77.6 ± 8.1	80.4 ± 8.2	< 0.001
(65, 75)	15,230 (42.8%)	14,923 (43.3%)	307 (28.6%)	< 0.001
(75, 85)	12,480 (35.1%)	12,077 (35.0%)	403 (37.6%)	
85+	7,854 (22.1%)	7,492 (21.7%)	362 (33.8%)	
Men, n (%)	17,116 (48.1%)	16,558 (48.0%)	558 (52.1%)	0.009
Ethnicity, n (%)				
White	27,360 (76.9%)	26,533 (76.9%)	827 (77.1%)	< 0.001
Black	3,971 (11.2%)	3,896 (11.3%)	75 (7.0%)	
Other	4,233 (11.9%)	4,063 (11.8%)	170 (15.9%)	
Medical history, n (%)				
Cerebrovascular disease	3,743 (10.5%)	3,504 (10.2%)	239 (22.3%)	< 0.001
Chronic pulmonary disease	7,747 (21.8%)	7,409 (21.5%)	338 (31.5%)	< 0.001
Congestive heart failure	8,105 (22.8%)	7,679 (22.3%)	426 (39.7%)	< 0.001
Dementia	2,120 (6.0%)	2,008 (5.8%)	112 (10.4%)	< 0.001
Diabetes mellitus	10,718 (30.1%)	10,370 (30.1%)	348 (32.5%)	0.092
Malignancy	5,630 (15.8%)	5,350 (15.5%)	280 (26.1%)	< 0.001
Myocardial infarction	4,483 (12.6%)	4,249 (12.3%)	234 (21.8%)	< 0.001
Kidney disease	7,532 (21.2%)	7,205 (20.9%)	327 (30.5%)	< 0.001
CCI, median (IQR), points	6.0 (4.0–7.0)	6.0 (4.0–7.0)	8.0 (6.0–10.0)	< 0.001
Frailty assessment tools				
CIHI-HFRM, median (IQR), points	4.0 (3.0–6.0)	4.0 (3.0–6.0)	6.0 (4.0–7.0)	< 0.001
Low frailty risk, n (%)	24,232 (68.1%)	23,698 (68.7%)	534 (49.8%)	< 0.001
High frailty risk, n (%)	11,332 (31.9%)	10,794 (31.3%)	538 (50.2%)	
UK-HFRS, median (IQR), points	3.1 (1.1–6.4)	3.0 (1.1–6.3)	5.4 (2.2–9.4)	< 0.001
Low frailty risk, n (%)	23,477 (66.0%)	22,974 (66.6%)	503 (46.9%)	< 0.001
High frailty risk, n (%)	12,087 (34.0%)	11,518 (33.4%)	569 (53.1%)	
Hospital LOS, median (IQR), days	3.1 (1.5–5.9)	3.0 (1.4–5.8)	5.7 (2.3–12.4)	< 0.001

SD, Standard Deviation; CCI, Charlson Comorbidity Index; IQR, Interquartile Range; CIHI-HFRM, Canadian Institute for Health Information-Hospital Frailty Risk Measure; UK-HFRS, United Kingdom-Hospital Frailty Risk Score; LOS, Length of Stay

in the CIHI-HFRM score was associated with an 18.7% higher one-year mortality risk in the unadjusted analysis (HR = 1.19, 95% CI: 1.18–1.20) and a 7.5% higher risk in the fully adjusted model (HR = 1.08, 95% CI: 1.06–1.09). Similarly, for the UK-HFRS, the high-risk group showed a higher one-year mortality risk than the low-risk group in the unadjusted analysis (HR = 1.91, 95% CI: 1.82–2.01), and this association persisted in the fully adjusted model (HR = 1.51, 95% CI: 1.43–1.58). Each one-point increase in the UK-HFRS was associated with a 7.1% higher one-year mortality risk in the unadjusted analysis (HR = 1.07, 95% CI: 1.07–1.08) and a 4.8% higher risk in the fully adjusted model (HR = 1.05, 95% CI: 1.04–1.05) (Fig. 2d). Kaplan–Meier survival curves (Figure S2) further confirmed that patients with high frailty risk, as assessed via CIHI-HFRM and UK-HFRS, had significantly lower one-year survival than those in the low-risk group ($p < 0.001$).

When analyzed as continuous variables (Table 3), CIHI-HFRM and UK-HFRS showed comparable discrimination for in-hospital and one-year mortality. For in-hospital mortality, the C-index was 0.633 (95% CI: 0.616–0.650) and 0.628 (95% CI: 0.610–0.645) for CIHI-HFRM and UK-HFRS, respectively, with similar discriminatory performance (ΔC-index: 0.005, 95% CI: -0.007 to 0.018). For one-year mortality, the C-index was 0.625 (95% CI: 0.618–0.759) and 0.610 (95% CI: 0.603–0.617) for CIHI-HFRM and UK-HFRS, respectively. In long-term mortality assessment, CIHI-HFRM showed only a modestly higher discrimination, with a ΔC-index of 0.015 (95% CI: 0.010–0.020).

Secondary outcomes analysis

In the fully adjusted model, patients with increased frailty risk, measured via CIHI-HFRM, had significantly higher post-discharge care needs. UK-HFRS also showed a significant effect (Table S5, Figure S3). Competing risk models were used to evaluate timely hospital discharge and one-year rehospitalization, with death treated as a competing event. For timely discharge, higher CIHI-HFRM scores were associated with a significantly lower chance of discharge, and patients with high frailty risk had poorer outcomes than those with low risk. The UK-HFRS was also negatively associated with timely discharge. One-year rehospitalization rates were significantly higher

Table 2 Association between frailty and mortality

Outcomes	Events/ sample size; Incidence per 1,000 PYs (95% CI) or Proportion of events (95% CI)	Crude Model	Adjusted Model [a]	Fully adjusted Model [b]
In-hospital mortality	1,072/35,564; 0.03 (0.03–0.03)	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**	**Adjusted OR (95% CI)**
CIHI-HFRM (per point)		1.20 (1.18–1.23)	1.19 (1.16–1.21)	1.10 (1.07–1.13)
Low frailty risk	534/24,232; 0.02 (0.02–0.02)	Ref.	Ref.	Ref.
High frailty risk	538/11,332; 0.05 (0.04–0.05)	2.21 (1.96–2.50)	2.04 (1.80–2.31)	1.44 (1.27–1.64)
UK-HFRS (per point)		1.08 (1.07–1.09)	1.07 (1.06–1.08)	1.06 (1.05–1.07)
Low frailty risk	503/23,477; 0.02 (0.02–0.02)	Ref.	Ref.	Ref.
High frailty risk	569/12,087; 0.05 (0.04–0.05)	2.26 (2.00–2.55)	2.07 (1.83–2.34)	1.78 (1.57–2.02)
One-year mortality	6,151/34,492; 201.55 (196.58–206.65)	**Unadjusted HR (95% CI)**	**Adjusted HR (95% CI)**	**Adjusted HR (95% CI)**
CIHI-HFRM (per point)		1.19 (1.18–1.20)	1.17 (1.16–1.18)	1.08(1.06–1.09)
Low frailty risk	3,269/23,698; 151.23 (146.14–156.51)	Ref.	Ref.	Ref.
High frailty risk	2,882/10,794; 323.72 (312.11–335.76)	2.10 (1.99–2.20)	1.93 (1.84–2.04)	1.34 (1.27–1.41)
UK-HFRS (per point)		1.07 (1.07–1.08)	1.06 (1.06–1.07)	1.05 (1.04–1.05)
Low frailty risk	3,246/22,974; 155.31 (150.06–160.75)	Ref.	Ref.	Ref.
High frailty risk	2,905/11,518; 302.04 (291.25–313.22)	1.91 (1.82–2.01)	1.75 (1.66–1.84)	1.51 (1.43–1.58)

[a] Adjusted Model adjusted for age (65–75, 75–85 and ≥ 85 years) and gender;

[b] Fully adjusted Model adjusted for age (65–75, 75–85 and ≥ 85 years), gender, ethnicity, and CCI

PY, Person-Year; CI, Confidence Interval; OR, Odds Ratio; CIHI-HFRM, Canadian Institute for Health Information-Hospital Frailty Risk Measure; Ref, Reference; UK-HFRS, United Kingdom-Hospital Frailty Risk Score; HR, Hazard Ratio; CCI, Charlson Comorbidity Index

among patients with elevated CIHI-HFRM scores and frailty risk, while the association with UK-HFRS was not significant (Table S5).

Discussion

This study is the first to use the MIMIC-IV 2.0 database to validate CIHI-HFRM and compare it with UK-HFRS, and it also represents an initial attempt to operationalize these administrative-data–derived frailty tools earlier in the care pathway by applying EMR-derived diagnostic information rather than relying solely on finalized administrative data. The findings indicate that in older patients requiring urgent hospitalization, both CIHI-HFRM and UK-HFRS are associated with in-hospital and one-year mortality. Although both tools are associated with post-discharge care needs and the hospital LOS, only CIHI-HFRM effectively predicts one-year readmission risk.

EMR-based frailty tools (such as CIHI-HFRM and UK-HFRS) [17, 18] greatly improve automation in large-scale inpatient assessments compared with that of traditional clinical scales such as the Fried phenotype [15] and CFS [16]. By reducing the need for manual evaluation, they are especially important in urgent care settings with limited resources. However, differences in the frailty dimensions (e.g., acute events vs. chronic deficits), coding weight strategies, and data completeness can lead to inconsistent predictive performance across studies. For example, CIHI-HFRM, developed using a nationwide Canadian cohort of 788,000 patients aged 65 and older [17], uses a deficit accumulation model that integrates 36 groups of ICD codes, incorporating a larger number of ICD-coded diagnoses than the UK-HFRS and offering a broader characterization of chronic health burden. The development cohort included 42.1% of patients aged 65–74, which enhanced its sensitivity to early frailty indicators in younger older adults. In contrast, UK-HFRS, derived from a regional British cohort of patients aged 75 and older, focuses on acute complications and short-term outcomes using 109 weighted ICD codes (such as delirium, hospital-acquired infections, and sepsis). However, its limited coverage of chronic deficits may underestimate long-term risk [18].

Currently, CIHI-HFRM has not been applied outside its development population and it lacks real-world validation, while UK-HFRS has undergone external validation across various countries, regions, and patient groups with promising results. Previous studies have validated UK-HFRS in patients in the hospital with head and neck cancer [25], those undergoing endoscopic retrograde cholangiopancreatography [26], major vascular surgery [27], inflammatory bowel disease [28], heart failure [29, 30], and general admissions [31, 32]. These validations span the United States [25, 26, 28, 30], France [31, 33], Australia [27, 29, 32], and Switzerland [34]. Consistent with previous studies, the frailty prevalence measured via UK-HFRS varied across studies. However, the main findings align with those of this research, indicating that UK-HFRS is significantly associated with both short-term and long-term mortality, hospital LOS, and medical

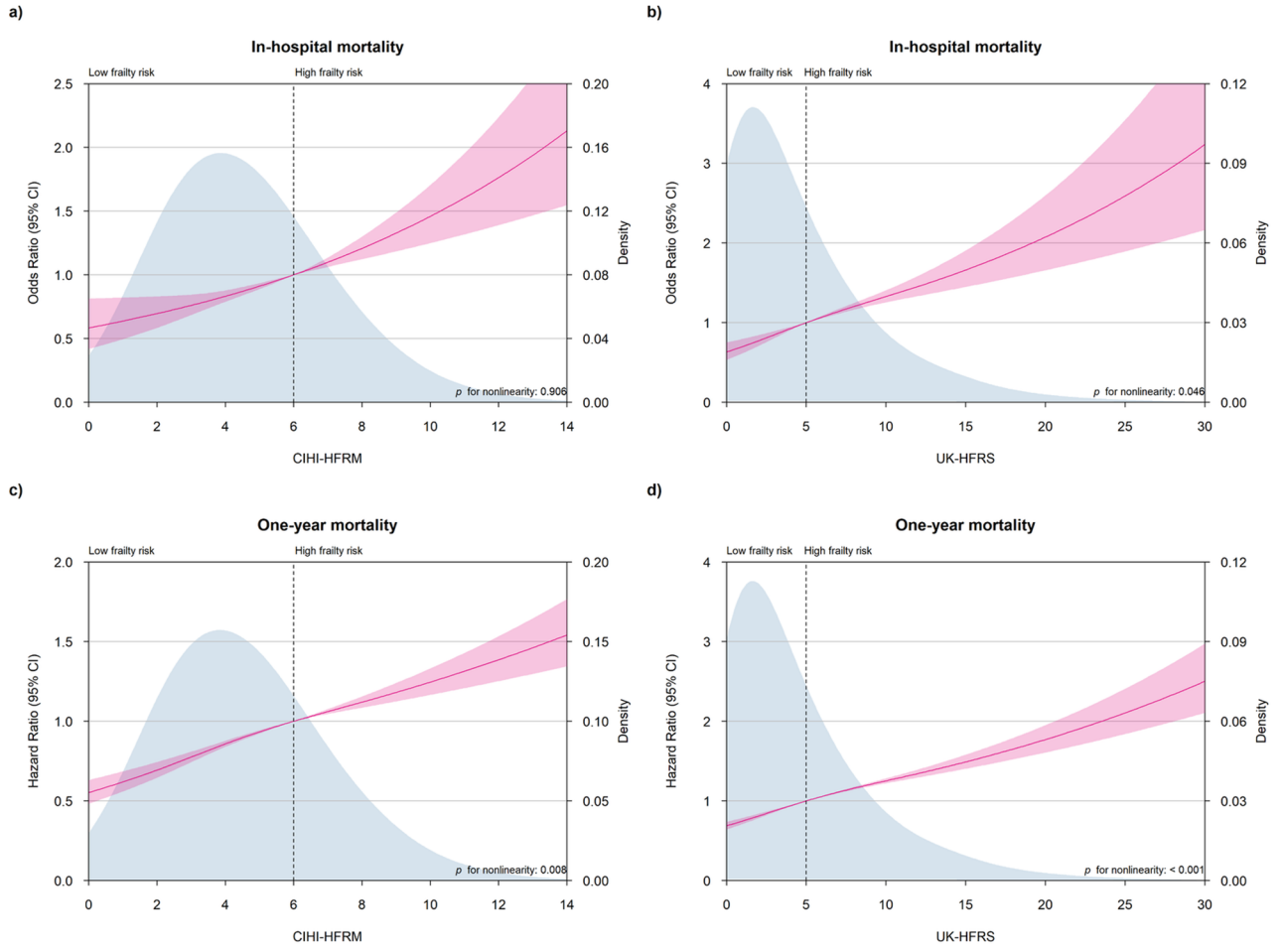

Fig. 2 Distribution of the two frailty measures among the study population and their association with mortality. Spline curves illustrate the relationship between the two frailty measures and in-hospital mortality (**a-b**) as well as one-year mortality (**c-d**). The blue density curve represents the distribution of the frailty measures within the study population. Colored background strips along the curves denote confidence intervals for each spline. Dashed lines indicate the cutoff values for categorizing frailty risk: 6 points for the CIHI-HFRM and 5 points for the UK-HFRS, which serve as reference standards for examining the frailty-associated outcomes. Spline curves were adjusted for age (65–75, 75–85, and ≥ 85 years), gender, ethnicity, and CCI. CIHI-HFRM, Canadian Institute for Health Information-Hospital Frailty Risk Measure; UK-HFRS, United Kingdom-Hospital Frailty Risk Score; CCI, Charlson Comorbidity Index

Table 3 Comparison and evaluation of mortality risk models

Outcomes	C-index (95% CI)	△C-index (95% CI)
In-hospital mortality		
CIHI-HFRM	0.633 (0.616–0.650)	——
UK-HFRS	0.628 (0.610–0.645)	——
CIHI-HFRM vs. UK-HFRS	——	0.005 (-0.007–0.018)
One-year mortality		
CIHI-HFRM	0.625 (0.618–0.759)	——
UK-HFRS	0.610 (0.603–0.617)	——
CIHI-HFRM vs. UK-HFRS	——	0.015 (0.010–0.020)

CIHI-HFRM, Canadian Institute for Health Information-Hospital Frailty Risk Measure; UK-HFRS, United Kingdom-Hospital Frailty Risk Score; CI, Confidence Interval

resource use, although its association with readmission risk remains less robust.

In this cohort of older patients requiring urgent hospitalization, CIHI-HFRM and UK-HFRS showed similar predictive accuracy for in-hospital mortality, and although CIHI-HFRM achieved a statistically significant improvement in predicting long-term mortality, the difference in C-index between the two measures was small. This finding is consistent with that from the CIHI-HFRM development cohort and may be attributed to its comprehensive deficit model [35], which uses a larger set of ICD-coded diagnoses than the UK-HFRS, with especially broader coverage of codes that reflect chronic health burden commonly linked to long-term prognosis, and to its applicability younger older patients, allowing for a more multidimensional assessment of frailty [17]. Although the weighted diagnoses in UK-HFRS effectively identify high-risk inpatients, the tool is less sensitive to the chronic progression of frailty and long-term outcomes, such as one-year readmission [18]. Differences in coding frameworks and weighting strategies may also limit its external use, further widening the disparity in

predictive performance. Spearman correlation analysis showed that the two frailty assessment methods tend to move together overall in this cohort, whereas the kappa analysis indicated that their agreement in identifying patients as high frailty risk is only moderate, suggesting that they capture overlapping frailty features while relying on different core principles and may therefore be complementary in practice. Both CIHI-HFRM and UK-HFRS demonstrated meaningful predictive value in acute care settings and are clinically usable. Our aim is not to replace traditional frailty assessment, but to show that automated, ICD-based approaches are feasible and can serve as a supplement—and, where resources are constrained, an interim alternative—to standard tools. Traditional measures (Fried phenotype, CFS) are particularly appropriate before admission in primary care, outpatient follow-up, or community care, given that patients' physical function and support needs are more readily available than at acute admission; however, rapid tools like the CFS depend on clinical judgment and patient/caregiver reports and thus remain susceptible to subjective bias. Looking ahead, a pragmatic multimodal approach—pre-hospital frailty recognition in the community or clinic, automated risk flags derived from prior coded diagnoses, and, where feasible, bedside assessment using traditional tools at the time of acute admission—represents a promising direction for enabling earlier intervention and more efficient allocation of in-hospital and post-acute resources.

The primary strength of this study is its first external validation of CIHI-HFRM and its systematic comparison with UK-HFRS in older adults requiring urgent hospitalization. The wide age range (65–94 years) and high comorbidity burden (median CCI: 6.0) enhance the clinical applicability of the findings. However, this study has some limitations. First, the single-center, retrospective design may introduce selection bias. Second, the transition from ICD-9 to ICD-10 coding may cause classification inaccuracies. Third, frailty was computed using diagnoses from only the most recent completed prior hospitalization rather than aggregating across multiple prior stays; this conservative choice simplifies implementation but may underestimate the maximum achievable predictive performance. Finally, although UK-HFRS has been consistently validated externally, CIHI-HFRM requires further testing across diverse healthcare systems and populations. Future studies should focus on refining these tools by optimizing dynamic weighting (e.g., stratification by age or comorbidities) and modeling specific subgroups (such as heart failure or trauma). Additionally, studies should explore cost-effectiveness in resource-limited settings.

Conclusion

Both CIHI-HFRM and UK-HFRS demonstrate clinically meaningful prognostic value in older adults requiring urgent hospitalization. Rather than ranking one over the other, they—together with traditional frailty tools—should be viewed as potentially complementary. Looking ahead, a pragmatic multimodal approach—pre-hospital frailty recognition, automated risk flags from prior coded diagnoses, and, where feasible, bedside assessment using traditional tools at acute admission—represents a promising direction for clinical application.

Supplementary Information

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Supplementary Material 1

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Author contributions

Bei Zhao: Conceptualization, Methodology, and Writing–review & editing; Benchuan Hao: Data curation, Methodology, Formal analysis, and Writing–original draft; Yifei Xu: Methodology and Writing–review & editing; Huimin Yang: Software, Formal analysis and Visualization; Liangchen Li: Software, Formal analysis, and Visualization; Zhong Zhang: Data curation and Software; Huihui Xia: Data curation and Software; Dapeng Song: Data curation and Software; Chaosheng Du: Software; Zhenzhen Yang: Data curation.

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Data availability

This study used the de-identified MIMIC-IV v2.0 database hosted on PhysioNet (https://physionet.org/content/mimiciv/2.0/). Access to the raw data analyzed here is available to qualified researchers after registering for a PhysioNet account, completing the required human-subjects training, and agreeing to the data-use agreement. No additional individual-level data beyond the MIMIC-IV v2.0 resource are shared by the authors.

Declarations

Ethics approval and consent to participate

This investigation was conducted in accordance with the ethical principles of the Declaration of Helsinki. The establishment of this de-identified database was approved by the Institutional Review Board at the Beth Israel Deaconess Medical Center. Written informed consent for participation was not required for this project in accordance with the national legislation and the institutional requirements. Data access was granted after completing the National Institutes of Health course on protecting human research participants (Certification number: 11153471).

Consent for publication

Not applicable.

Declaration of generative AI

The author confirms that no generative AI or AI-assisted technologies were used during the writing of this manuscript.

Competing interests

The authors declare no competing interests.

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