

Admission triage for hospital-associated disability in older inpatients: a multicenter clinical decision rule

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Abstract

Hospital-associated disability (HAD) is a frequent complication in hospitalized older adults and is associated with unfavorable outcomes. Because preventive interventions require substantial resources, efficient identification of high-risk patients at admission is required. We developed a simple admission clinical decision rule for triage using routinely available admission information.

Methods: In a multicenter retrospective cohort study, adults aged ≥ 65 years admitted to acute care hospitals between October 2019 and March 2025 were included. HAD was defined as a ≥ 5 -point decline in the Barthel Index from admission to discharge. Candidate predictors included age, admission type, Clinical Frailty Scale (CFS), and Mini-Mental State Examination (MMSE). A multivariable logistic regression model derived a simplified point-based score; discrimination was assessed by AUC, calibration by bootstrap-corrected calibration, and clinical utility by decision curve analysis with 2,000 bootstrap resamples.

Results: Among 1,292 patients, 26.2% developed HAD. The final score (0–8 points) included emergency admission, frailty (CFS ≥ 5), cognitive impairment (MMSE ≤ 23), and age ≥ 80 years. Discrimination was good (AUC 0.796; 95% CI 0.771–0.820) with adequate calibration. HAD incidence increased from $<5\%$ in the lowest-risk group to $\sim 50\%$ in the highest-risk group, and decision curve analysis showed net clinical benefit across relevant thresholds.

Conclusions: This admission triage rule identifies patients who may require early geriatric co-management and supports targeted preventive care and efficient allocation of limited geriatric resources.

Key summary points

Aim

To develop a simple admission triage rule to identify older inpatients at risk of hospital-associated disability (HAD).

Findings

A four-item rule (age ≥ 80 , CFS ≥ 5 , MMSE ≤ 23 , emergency admission) stratified HAD risk effectively (AUC 0.80). Low scores identified patients with very low risk, whereas high scores identified those at markedly increased risk.

Message

This bedside rule supports early geriatric co-management and targeted use of comprehensive geriatric assessment while avoiding unnecessary intervention in low-risk patients.

Introduction

Hospital-associated disability (HAD), defined as a decline in activities of daily living during hospitalization, is a common and serious complication among older adults. Up to one-third of hospitalized older patients experience new functional decline that cannot be fully explained by their acute illness alone [1]. HAD is associated with prolonged hospital stay, institutionalization, and increased mortality [2,3]. Preventing HAD has therefore become a central goal of geriatric inpatient care [4].

Frailty and cognitive impairment are consistently identified as major risk factors for HAD, reflecting diminished physiological reserve and impaired resilience to hospital-related stressors [5–8]. However, preventive interventions for HAD, such as early mobilization and comprehensive geriatric assessment, require substantial clinical resources and cannot feasibly be applied to all hospitalized older adults. Effective prevention therefore depends on early identification of patients who are most vulnerable at the time of admission.

A central unresolved issue in acute geriatric care is not whether preventive interventions are effective, but whom they should be applied to. Comprehensive geriatric assessment and structured mobilization programs are resource-intensive and cannot realistically be delivered to all hospitalized older adults. As a result, clinicians currently rely on unstructured clinical judgment, leading to both under-treatment of vulnerable patients and unnecessary interventions in low-risk patients.

Although several prediction models for functional decline have been proposed, most require numerous variables, laboratory data, or information unavailable at the time of admission [9–12]. Consequently, these tools are rarely incorporated into real-time clinical decision-making and have had limited impact on routine inpatient care. There remains a need for a simple bedside approach that can be used immediately after admission to support targeted preventive strategies. To address this gap, we aimed to establish an admission triage rule to guide early geriatric intervention to prevent HAD using routinely available information.

Previous studies have demonstrated that frailty is independently associated with functional decline, prolonged hospitalization, and increased healthcare utilization [13,14], while cognitive dysfunction further amplifies the risk of in-hospital and post-discharge disability [15,16]. Rather than representing redundant predictors, frailty and cognitive impairment capture distinct but complementary dimensions of vulnerability—physiological reserve and neurocognitive resilience—that together influence functional recovery during acute illness.

We therefore focused on a parsimonious set of routinely available admission variables—age, pre-admission frailty assessed by the Clinical Frailty Scale, cognitive function assessed by the Mini-Mental State Examination, and admission type—to enable early risk stratification and to support targeted preventive interventions in routine clinical practice.

Methods

Study design and participants

This multicenter retrospective cohort study was conducted using data from hospitalized older adults admitted to participating acute care hospitals (Japan Hospital-Associated Complications Study, [J-HAC study]) between October 2019 and March 2025. Patients aged 65 years or older who were admitted to medical or surgical wards were eligible for inclusion [17, 18].

Patients were excluded if they had severe pre-existing disability that precluded reliable assessment of functional decline (defined as Barthel Index = 0 or Clinical Frailty Scale = 9), were transferred from other acute care hospitals, were admitted primarily for palliative care, died during hospitalization, or had missing outcome data.

The study protocol was approved by the institutional review boards of all participating institutions (approval no. 2019-0260). Written informed consent was obtained from all participants or their representatives, in accordance with the Declaration of Helsinki.

Data collection and baseline assessment

Baseline demographic and clinical data were extracted from electronic medical records and standardized assessment forms. Data were collected within 48 hours of admission by trained healthcare professionals.

Collected variables included age, sex, admission type, length of hospital stay, and baseline functional status using the Barthel Index [19].

Frailty was assessed using the Clinical Frailty Scale (CFS) based on pre-admission functional status [20, 21]. Cognitive function was evaluated using the Mini-Mental State Examination when patients were clinically stable [22]. Functional status at admission and discharge was assessed.

Outcome definition

The primary outcome was hospital-associated disability (HAD), defined as a decline of at least 5 points in the Barthel Index between admission and discharge.

Barthel Index scores were measured within 48 hours of admission and within 48 hours prior to discharge.

Candidate predictors

Candidate predictors were selected a priori based on clinical relevance and previous literature [15]. These included age, admission type, CFS, and MMSE.

Development of the HAD risk score

A multivariable logistic regression model using continuous predictors (age, CFS, and MMSE) and binary admission type was fitted to identify independent associations with HAD. For bedside implementation,

continuous predictors were subsequently dichotomized using prespecified clinically interpretable thresholds (age ≥ 80 years, CFS ≥ 5 , and MMSE ≤ 23), and regression coefficients were translated into an integer point-based score (0–8 points). The risk score was developed using regression coefficients as a guide while prioritizing clinical interpretability and bedside usability.

Model performance

Discrimination was evaluated using receiver operating characteristic analysis and quantified by the area under the curve. Calibration was assessed using bootstrap-corrected calibration curves comparing predicted and observed probabilities. Observed incidence of HAD was calculated for each score category to evaluate clinical risk stratification.

Decision curve analysis

Because the primary objective of the score was to guide preventive decision-making, decision curve analysis was performed to evaluate its potential clinical utility across plausible intervention thresholds. Net benefit was calculated across a range of threshold probabilities using standard methods, comparing the risk score with default strategies of treating all patients and treating none. Threshold probability was defined as the minimum predicted risk at which preventive interventions would be considered.

Net benefit was calculated by weighting true-positive against false-positive classifications. Decision curves were generated using predicted probabilities from the logistic model, and results were interpreted in relation to corresponding risk score categories to support clinical application.

Handling of missing data

Missing data were handled using multiple imputation by chained equations with 20 imputed datasets including all candidate predictors and outcomes. Estimates were pooled using Rubin's rules.

Internal validation

Internal validation was performed using bootstrap resampling with 2,000 iterations to estimate optimism-corrected model performance.

Statistical analysis

Continuous variables are presented as means $\pm$ standard deviations or medians with interquartile ranges, as appropriate. Categorical variables are presented as numbers and percentages. Between-group comparisons were performed using independent-samples t tests or Mann–Whitney U tests for continuous variables and χ^2 tests for categorical variables.

All statistical analyses were conducted using R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria) and IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA). Two-sided p values < 0.05 were considered statistically significant.

Results

Patient characteristics

Among 1,599 hospitalized older adults assessed for eligibility, 241 were excluded due to missing data required for score calculation and outcome ascertainment. Among the remaining 1,358 patients with complete data, 19 patients who died during hospitalization (disposition = 3), 46 patients with a Barthel Index of 0 at admission, and 1 patient with CFS = 9 were excluded (Supplementary figure S1).

Among 1,292 eligible participants, 339 patients (26.2%) developed hospital-associated disability (HAD). Patients with HAD were significantly older than those without HAD (85.8 ± 6.0 vs 81.8 ± 6.6 years, $p < 0.001$). They had poorer baseline functional status, reflected by lower Barthel Index and instrumental ADL scores, were more frail (higher Clinical Frailty Scale), and had worse cognitive performance (lower MMSE). Body mass index was also lower in the HAD group. Emergency admission was substantially more frequent in patients who developed HAD (80.5% vs 35.4%, $p < 0.001$), whereas sex distribution did not differ between groups (Table 1).

Univariable and multivariable associations

All admission variables were first evaluated using univariable logistic regression (Supplementary Table S1). Older age, lower functional status, greater frailty, worse cognitive function, lower body mass index, and emergency admission were significantly associated with HAD.

In multivariable analysis (Table 2), emergency admission was the strongest independent predictor (OR 4.48, 95% CI 3.20–6.28, $p < 0.001$). Frailty and cognitive impairment also remained independently associated with HAD, while age showed a modest but significant association.

Regression coefficients from the multivariable logistic model were converted into a simplified integer score to facilitate bedside use. Continuous predictors were categorized using clinically interpretable thresholds (age ≥ 80 years, CFS ≥ 5 , and MMSE ≤ 23). Emergency admission was retained as a binary variable. Point values were assigned according to the relative magnitude of regression coefficients and simplified to maintain clinical usability.

Development of the risk score

Regression coefficients were translated into a simplified bedside score (range 0–8 points) (Supplementary Table S2). The score incorporated:

- age ≥ 80 years (+1)
- Clinical Frailty Scale ≥ 5 (+2)
- MMSE ≤ 23 (+2)
- emergency admission (+3)

The observed incidence of HAD demonstrated clear clinical risk stratification across score categories (Figure 1). Patients with scores 0–2 had a low probability of functional decline (<10%), those with scores 3–5 had an intermediate risk (approximately 10–30%), and those with scores ≥ 6 had a markedly increased risk exceeding 40%.

Discrimination and calibration

The risk score demonstrated acceptable discrimination with an AUC of 0.796 (95% CI 0.771–0.820) (Supplementary figure S2). Internal validation using bootstrap resampling showed minimal optimism (≈ 0.003), indicating negligible overfitting. Multiple imputation analyses yielded similar results, with only slight attenuation of discrimination (AUC 0.766), indicating that missing data did not materially influence model performance.

Calibration analysis showed good agreement between predicted and observed risk across the range of probabilities, with minimal deviation after bootstrap correction (Figure 2). Importantly, the model did not systematically overestimate risk in low-risk patients.

At a threshold of ≥ 3 points, the score demonstrated high sensitivity (0.96) and a negative predictive value of 0.97, indicating strong ability to rule out HAD (Table 3).

Using a higher threshold (≥ 6 points) improved specificity (0.75) and yielded a positive predictive value of 0.51, identifying a subgroup at substantially increased risk of functional decline suitable for targeted intervention.

Decision curve analysis

Decision curve analysis demonstrated a consistent net clinical benefit across threshold probabilities relevant to preventive decision-making (Supplementary Figure S3). Within plausible intervention thresholds, the risk score outperformed both treat-all and treat-none strategies, indicating that its use could reduce unnecessary preventive interventions while still identifying patients at high risk of functional decline.

Sensitivity Analysis Using Multiple Imputation

To address potential bias due to missing baseline assessments, multiple imputation using chained equations was performed (20 datasets, predictive mean matching). The HAD score was recalculated in each imputed dataset without modification of the scoring rules. AUC values after imputation were slightly attenuated but remained within a comparable range, supporting robustness of model performance.

Discussion

The principal contribution of this study is not the development of another prognostic model, but the provision of a practical admission-level triage tool for hospitalized older adults. In routine care, clinicians

must decide shortly after admission whether to initiate structured mobilization or comprehensive geriatric assessment, yet objective criteria to guide this decision have been lacking. The present score translates routinely available admission information into actionable risk categories that directly correspond to levels of preventive care. Low-risk patients can safely receive standard management, whereas high-risk patients can be identified immediately for targeted intervention.

Frailty assessed by the CFS was strongly associated with HAD, supporting the concept that reduced physiological reserve increases susceptibility to hospitalization-related stressors such as immobility, environmental change, and inflammatory responses. Cognitive impairment further amplified this risk, likely through impaired participation in rehabilitation, increased risk of delirium, and difficulties in maintaining mobility and self-care behaviors during hospitalization [23, 24]. Emergency admission emerged as the most influential predictor, suggesting that the abrupt onset of illness and lack of pre-admission preparation substantially contribute to functional deterioration [25, 26]. Unplanned hospitalization often involves bed rest, diagnostic procedures, and environmental disorientation, all of which can accelerate functional decline. These findings support consideration of early mobilization and geriatric assessment soon after admission, particularly in high-risk patients. Age alone was a weaker determinant than frailty or cognitive impairment. This observation is consistent with the concept that biological vulnerability, rather than chronological age, primarily governs resilience to acute hospitalization. The inclusion of age in the score therefore reflects cumulative risk rather than an independent mechanistic effect.

Previous studies have consistently identified advanced age, impaired baseline function, and cognitive impairment as risk factors for functional decline during hospitalization [15,16]. Several prediction tools have been proposed; however, many require multiple clinical or laboratory variables or information not readily available at the time of admission, which limits their routine use in acute care settings.

In contrast, the present score uses only routinely collected admission data and can be calculated immediately at the bedside without additional testing. By combining age, frailty, cognitive status, and admission type, the score provides clinically interpretable risk stratification while maintaining acceptable predictive performance. Its simplicity may facilitate integration into routine workflows and support early targeting of preventive interventions.

Patients with low scores (<3 points) have a very low probability of hospital-associated disability and can generally be managed with standard care. Those with intermediate scores (3–5 points) may benefit from structured mobility monitoring and early preventive measures, whereas patients with high scores (≥ 6 points) represent a subgroup at substantially elevated risk who should be considered for comprehensive geriatric assessment and multidisciplinary intervention (supplementary figure S4). The lower threshold therefore functions as a practical rule-out criterion, while the higher threshold identifies patients in whom early intensive intervention is justified. Decision curve analysis supported the clinical usefulness of this approach across a range of plausible intervention thresholds. By enabling rapid admission-level stratification using routinely available information, the score provides a pragmatic method for allocating

limited geriatric care resources. In addition, the score may serve as a standardized stratification framework for future interventional studies aimed at preventing HAD.

The predictors included in the score suggest that HAD may reflect the interaction between baseline vulnerability and acute illness stress. The four components of the score—age, frailty, cognitive impairment, and emergency admission—represent complementary domains of risk: biological reserve, functional reserve, cognitive resilience, and acute illness burden. Together, they provide a clinically coherent framework for identifying patients susceptible to functional decline at the time of admission.

This study has several strengths. First, the multicenter design and large sample size enhance the applicability of the findings across diverse acute care settings. Second, candidate predictors were prespecified based on clinical relevance, and the final score relies only on routinely available admission information, supporting practical bedside implementation. Third, internal validation using bootstrap resampling demonstrated stable model performance with minimal optimism.

Future studies should externally validate the HAD risk score in independent healthcare systems and diverse clinical settings to confirm its generalizability. Implementation research is warranted to examine how integration into electronic health records can enable automated calculation and real-time clinical decision support at admission. Importantly, prospective interventional studies are needed to determine whether risk-guided preventive strategies—such as early mobilization or comprehensive geriatric assessment targeted to high-risk patients—can reduce the incidence of hospital-associated disability and improve patient-centered outcomes.

Finally, although the present score is based on admission data to maximize practicality, future research may explore dynamic prediction approaches incorporating in-hospital trajectory data to refine risk estimation over time.

We established a clinically interpretable admission triage rule that enables early identification of older patients who may benefit from structured mobility support or comprehensive geriatric assessment. Using routinely available admission data—age, frailty, cognitive status, and admission type—the rule enables early identification of patients who may benefit from targeted preventive interventions. This tool may support efficient allocation of geriatric care resources and provides a practical framework for future interventional studies aimed at preventing HAD.

Declarations

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coauthors were informed of the manuscript submission, reviewed all revised versions, approved the final manuscript, and agreed to the order of authorship and the accuracy of author affiliations.

Author Contributions

Study concept and design: H.U.

Acquisition of data: H.N., Y.Y., K. W., C.F., H.K., T.T., S.S., Y.T., M.Y.

Analysis and interpretation of data: H.U.

Drafting of the manuscript: H.U.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: H.U.

Administrative, technical, or material support: H.U.

Study supervision: H.U.

Conflict of Interest

All authors declare no conflicts of interest.

Sponsor's Role

The funding sources had no role in the design and conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication.

Artificial intelligence–based language model use

The authors used an AI-assisted language editing tool for grammatical refinement. The authors take full responsibility for the content.

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Tables

Table 1. Baseline characteristics according to hospital-associated disability

Characteristic	Total (n=1292)	No HAD (n=953)	HAD (n=339)	p value
Age, years	82.9 ± 6.7	81.8 ± 6.6	85.8 ± 6.0	<0.001
Female sex, n (%)	752 (58.2)	554 (58.2)	198 (58.3)	1.00
Barthel Index at admission	79.1 ± 27.2	83.0 ± 26.4	68.6 ± 28.1	<0.001
Clinical Frailty Scale	4.60 ± 1.74	4.28 ± 1.73	5.57 ± 1.33	<0.001
MMSE score	21.0 ± 7.3	22.4 ± 6.8	16.6 ± 8.0	<0.001
Instrumental ADL	4.25 ± 2.91	4.76 ± 2.77	2.72 ± 2.79	<0.001
Body mass index, kg/m²	21.6 ± 4.0	21.9 ± 3.9	20.7 ± 4.0	<0.001
Emergency admission, n (%)	610 (47.2%)	337 (35.4%)	273 (80.5%)	<0.001

Abbreviations: HAD, hospital-associated disability; MMSE, Mini-Mental State Examination; ADL, activities of daily living; IADL, instrumental activities of daily living; BMI, body mass index.

Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.

HAD was defined as a decline of ≥5 points in the Barthel Index between admission and discharge.

Between-group comparisons were performed using the independent-samples *t* test or Mann–Whitney U test for continuous variables and the χ^2 test for categorical variables.

All tests were two-sided, and *p* < 0.05 was considered statistically significant

Table 2. Multivariable logistic regression model for development of the HAD score

Variable	β coefficient	Odds ratio (95% CI)	p value
Age (per year)	0.033	1.03 (1.01–1.06)	0.008
Clinical Frailty Scale (per point)	0.124	1.13 (1.01–1.28)	0.036
MMSE (per point)	–0.053	0.95 (0.93–0.97)	<0.001
Emergency admission	1.500	4.48 (3.20–6.28)	<0.001

Abbreviations: HAD, hospital-associated disability; CI, confidence interval; MMSE, Mini-Mental State Examination.

Results are from a multivariable logistic regression model with HAD as the dependent variable.

Age, Clinical Frailty Scale, and MMSE were entered as continuous variables. Emergency admission was entered as a binary variable (emergency vs elective admission).

β coefficients represent log-odds. Odds ratios correspond to the change in odds of HAD per 1-unit increase in each variable (per year for age, per point for Clinical Frailty Scale and MMSE).

All variables were prespecified based on clinical relevance.

Two-sided p values <0.05 were considered statistically significant.

Table 3. Diagnostic performance of the admission HAD risk score at clinically relevant thresholds

Cutoff	Sensitivity	Specificity	PPV	NPV	LR+	LR–
≥3	0.96	0.42	0.37	0.97	1.64	0.10
≥6	0.72	0.75	0.51	0.88	2.91	0.3

Abbreviations: PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR–, negative likelihood ratio; HAD, hospital-associated disability.

Diagnostic indices were calculated using observed HAD status at discharge as the reference standard.

PPV and NPV were calculated based on the observed prevalence of HAD in the study cohort.

Positive likelihood ratio (LR+) was defined as sensitivity / (1 – specificity), and negative likelihood ratio (LR–) as (1 – sensitivity) / specificity.

Cutoff values were prespecified to represent clinically relevant decision thresholds for screening (≥ 3 points) and targeted intervention (≥ 6 points).

All estimates were derived from the original cohort without external validation.

Figures

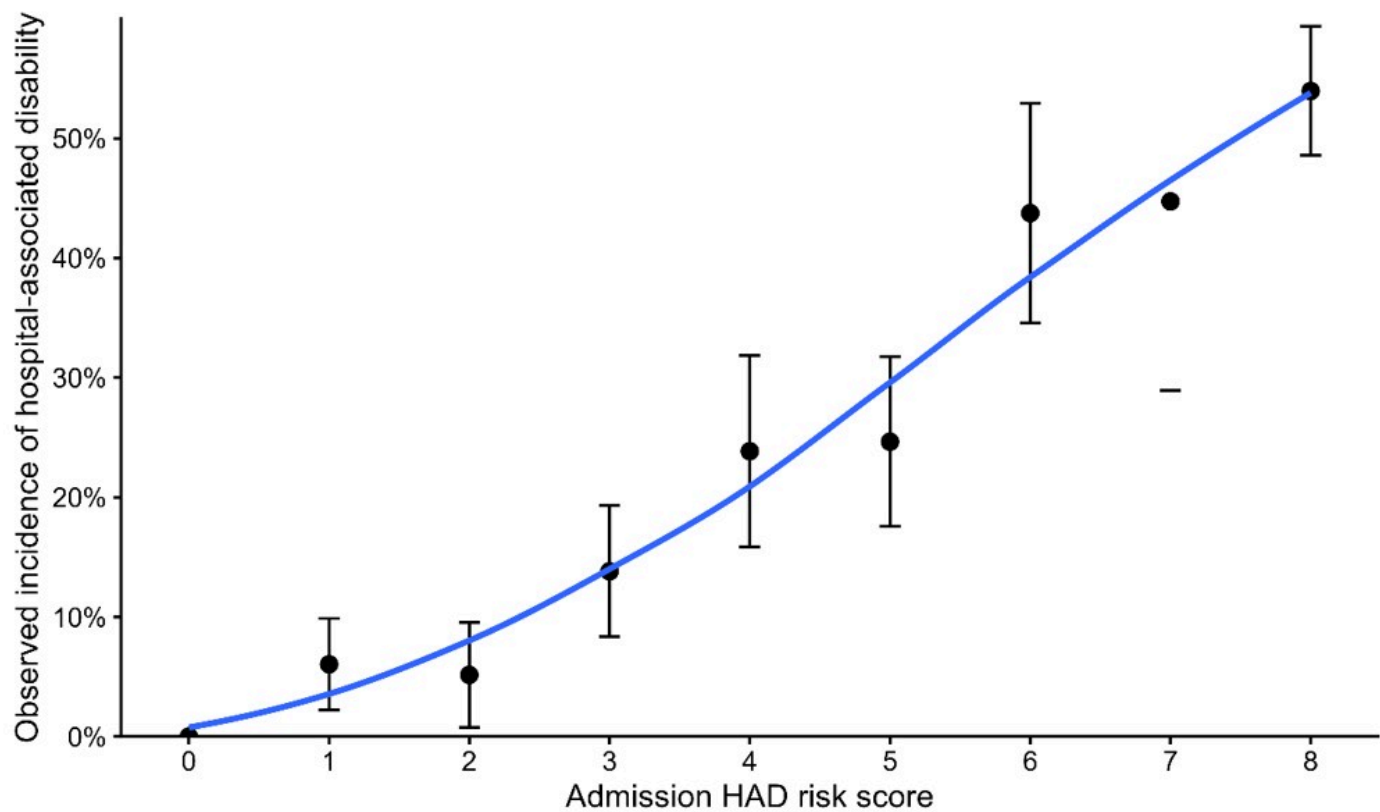


Figure 1

The observed incidence of HAD across risk scores

Observed incidence of hospital-associated disability according to admission HAD risk score categories. The incidence of HAD increased progressively across score levels, demonstrating effective clinical risk stratification.

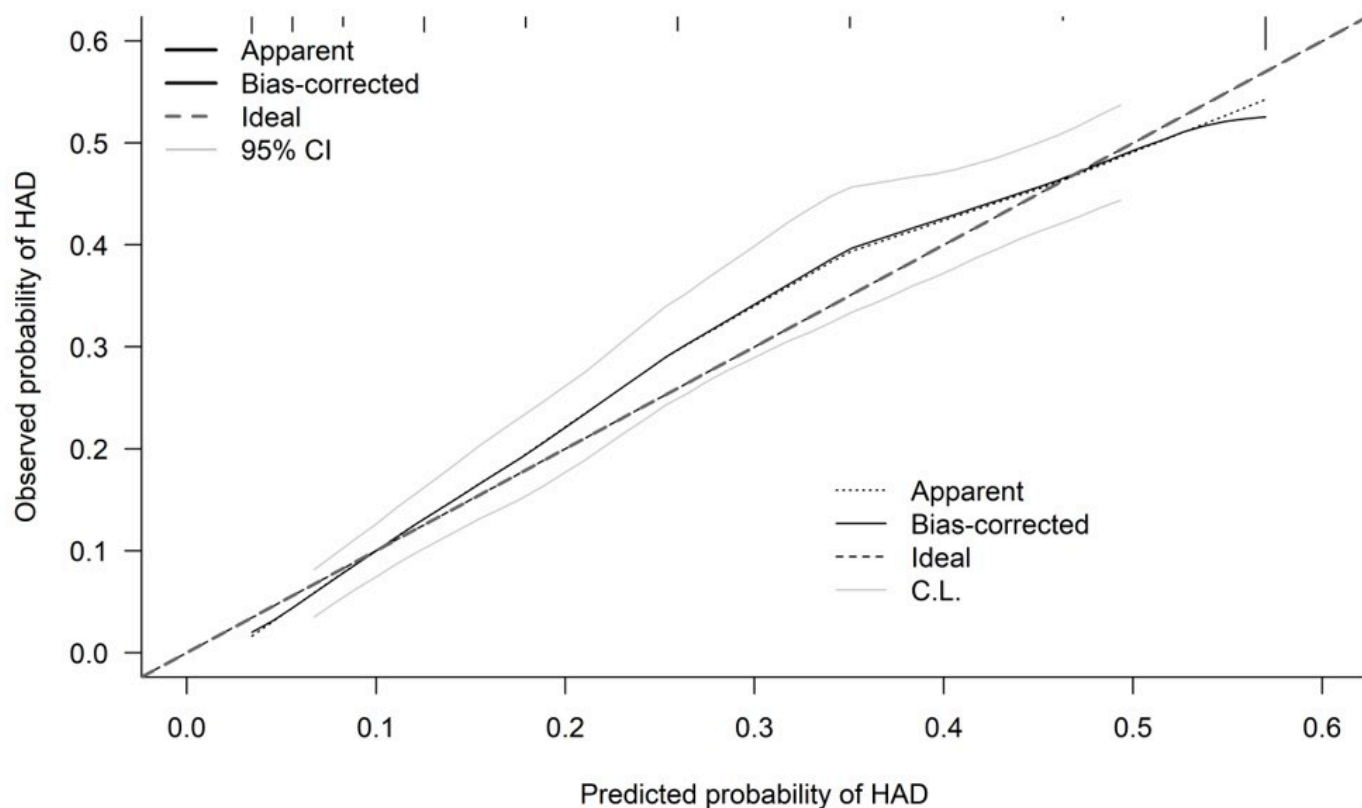


Figure 2

Bootstrap-corrected calibration plot comparing predicted and observed probabilities

Bootstrap-corrected calibration plot comparing predicted and observed probabilities of hospital-associated disability. The model demonstrated good calibration across the range of predicted risks.

Image not available with this version

Figure 3

Decision curve analysis showing net benefit of the HAD risk score across a range of threshold probabilities compared with treat-all and treat-none strategies.

Supplementary Files

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