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Development of a new comprehensive preoperative risk score for predicting 1-year mortality in patients with hip fracture: the HULP-HF score. Comparison with 3 other risk prediction models

Rocío Menéndez-Colino[1,2], Alicia Gutiérrez Misis[2,4], Teresa Alarcon[1,2,3,4], Jesús Díez-Sebastián[5], Macarena Díaz de Bustamante[2,6], Rocío Queipo[2,3,4], Angel Otero[2,3,4] and Juan I González-Montalvo[1,2,3,4]

Abstract

Purpose: The aim of this study was to develop a new comprehensive preoperative risk score for predicting mortality during the first year after hip fracture (HF) and its comparison with 3 other risk prediction models.

Methods: All patients admitted consecutively with a fragility HF during 1 year in a co-managed orthogeriatric unit at a university hospital were assessed and followed for 1 year. Factors independently associated with 1-year mortality were used to create the HULP-HF (Hospital Universitario La Paz – Hip Fracture) score. The predictive validity, discrimination and calibration of the HULP-HF score, the American Society of Anesthesiologists (ASA) scale, the abbreviated Charlson comorbidity index (a-CCI) and the Nottingham Hip Fracture score (NHFS) were compared. Discriminative performance was assessed using the area under the curve (AUC) and calibration by the Hosmer-Lemeshow goodness-of-fit-test.

Results: 509 patients were included. 1-year mortality was 23.2%. The 8 independent mortality risk factors included in the HULP-HF score were age >85 years, baseline functional and cognitive impairment, low body mass index, heart disease, low hand-grip strength, anaemia on admission, and secondary hyperparathyroidism associated with vitamin D deficiency. The AUC was 0.79 in the HULP-HF score, 0.66 in the NHFS, 0.61 in the abbreviated CCI and 0.59 in the ASA scale. The HULP-HF score, the NHFS and the abbreviated CCI all presented good levels of calibration ($p > 0.05$).

Conclusions: The HULP-HF score has a predictive capacity for 1-year mortality in HF patients slightly superior to that of other previously existing scores.

Keywords

Hip fracture, mortality, risk prediction, scoring

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[1]Department of Geriatric Medicine, La Paz University Hospital, Madrid, Spain
[2]Institute for Biomedical Research, La Paz University Hospital (IdiPAZ) Madrid Spain
[3]Thematic Network of Cooperative Research on Aging and Fragility (RETICEF)
[4]Department of Medicine, Autonomous University of Madrid, Spain
[5]Research Unit, La Paz University Hospital, Madrid, Spain
[6]Puerta del Hierro University Hospital of Majadahonda - Geriatric Medicine, Majadahonda, Spain

Rocío Menéndez-Colino and Alicia Gutiérrez Misis are joint first authors.

Corresponding author:
Rocío Menéndez-Colino, Geriatrics Department, Hospital Universitario La Paz, Paseo de la Castellana 261, Madrid, 28046, Spain.
Email: rociocolino@hotmail.com

Introduction

Fragility hip fractures (HF) are frequent in older people. There are 620,000 new cases in the European Union and more than 210,000 new cases per year in the USA.[1,2] Furthermore, HF lead to an enormous burden to patients and to the health services. 1-year mortality after HF varies between 12% and 35%,[3–12] which signifies an excess of mortality of 8% to 18% per year compared to the population of the same age without HF.[13]

It is important to discover the factors associated with mortality in order to identify them in patients and perhaps to act on them, since an accurate prediction of mortality can help in clinical decisions.

The most frequently described factors independently associated with 1-year mortality in HF patients are age and gender,[3,4] functional and cognitive impairment,[3,4] malnutrition and surgical delay.[4,5,14–16]

There are also mortality risk prediction models designed for HF-patients to estimate 1-year mortality. However, some of the studies on which these models are based,[12,17–21] include few variables without making a comprehensive assessment,[12,18,21] or exclude certain patients, such as non-operated patients.[17,19,21,22]

HF patients are clinically complex, and their comprehensive assessment must consider multiple components and assess the weight of each of them in their prognosis and in their probability of dying. We were unable to find studies that simultaneously included features considered important in the older population, such as clinical diagnosis, social factors, functional and cognitive status, nutritional status, lab test results or other factors, such as muscle strength or sarcopenia.

In a previous study that included a wide list of all those variables, we found 9 factors independently associated with 1-year mortality after a HF in a sample of 509 patients.[23] The aim of the current study was to examine the predictive capacity for 1-year mortality of a score created using those factors and to compare it with 3 other risk prediction models.

Methods

Setting and subjects

All patients ⩾65 years consecutively admitted with a fragility HF to a 1300-bed public university hospital from 25 January 2013 to 24 February 2014 (FONDA cohort) were included. This hospital is the only reference centre for HF in a health district with a population of about 520,000. Patients were admitted directly to the Orthogeriatric Unit co-managed by the Orthopaedic Surgery and Geriatric Medicine departments. The activity of this unit has been described previously.[24]

Measures

All patients were exhaustively assessed in the first 72 hours after admission. A clinical interview was administered to collect data on clinical (previous illnesses and treatments), functional (previous Functional Ambulation Category [FAC] and Barthel Index score), and cognitive (Pfeiffer's Short Portable Mental Status Questionnaire, SPMSQ) variables.[25–27] Body mass index (BMI) was estimated, and hand-grip strength in the dominant hand was measured as described in a previous study.[28] Analytical variables were also included. Vitamin D + PTH were combined into a single variable and divided into 2 categories: (1) Vitamin D >20 or Vitamin D ⩽20 and PTH <66); and (2) Vitamin D ⩽20 and PTH ⩾66 (secondary hyperparathyroidism).

We applied the American Society of Anasthesiologists (ASA) scale, the Notthingham Hip Fracture Score (NHFS) and the Abbreviated Charlson Comorbidity Index (a-CCI).[29–31]

1 year after discharge, patients or their relatives were contacted by telephone to ascertain their vital status.

Score system development

The factors independently associated with 1-year mortality after HF were used to create the HULP-HF (Hospital Universitario La Paz – Hip Fracture) score as described in the statistical analysis section below.[23]

Risk prediction models compares

The HULP-HF score was compared with 3 other tools:

(1) The ASA scale was designed to assess anaesthetic risk.[29] Its use in the prognosis of 1-year mortality after HF has been established.[3,4,11,17] In this study, a cut-off point of ⩾III was considered to predict a high risk of 1-year mortality.
(2) The CCI was originally designed to classify prognostic comorbidity in longitudinal studies.[32] The abbreviated version has shown a predictive capacity for mortality similar to the original.[31] A score of ⩾3 was considered to predict a high mortality risk. The CCI was tested as a predictor for 1-year mortality after a HF, showing a sensitivity of 71%, specificity of 64%, positive predictive value (PPV) of 28%, negative predictive value (NPV) of 92% and an area under the curve (AUC) of 0.75.[33]
(3) The NHFS was specifically designed to predict 30-day mortality in a sample of HF patients,[30] and was later validated for 1-year mortality.[20] A score of ⩾4 is considered to predict a high risk of mortality.1-year mortality after HF was higher in the high-risk patients [45.5% vs. 15.9% ($p < 0.001$)]

Statistical analysis

Descriptive analysis. Quantitative variables are described as mean and standard deviation (SD) or median and interquartile range, and qualitative variables as absolute and relative frequencies. Patients were classified into 2 groups according

to whether they were still alive or had died at 1-year post-HF, and all variables were described for both survivors and non-survivors. The statistical significance of the association of each variable with vital status was calculated using bivariate Cox regression (crude hazard ratio [HR]).

Development of the new score. In order to create the HULP-HF score, a logistic regression analysis was performed, including mortality as the dependent variable and each of the 9 factors associated with mortality in a prior study as independent variables.[23] Each factor on the final model was assigned a point value, by multiplying the coefficients obtained during the analysis mentioned by 2 and rounding them to the nearest integer value. Then, a receiver operating characteristics (ROC) analysis was completed to find the best cut-off value for the estimation of the probability of 1-year mortality.

Comparison of the survival (or probability of death) curves across the 4 tools. The probability of death was calculated using the Kaplan-Meier survival analysis.

Study of predictive validity, discrimination and calibration of the tools assessed. A comparison was made of the values for sensitivity, specificity, positive predictive value and negative predictive value for all the scores used.

Discrimination refers to the degree to which the method precisely classifies the individuals who die and those who do not. It was assessed by calculating the standard receiver operating characteristic (ROC) curve. The AUC can be anywhere between 0.5 and 1.0. In mortality prediction models an AUC between 0.70 and 0.79 is considered to represent an acceptable discrimination, and an AUC between 0.80 and 0.89 is considered excellent.[34]

Calibration is the measure of how closely are the predictions to the observed outcome for a cohort of individuals. To evaluate calibration a goodness-of-fit statistics should be used, and the most commonly used is the Hosmer–Lemeshow test. A prediction model is better calibrated if Hosmer–Lemeshow test is not statistically significant ($p > 0.05$).[35,36]

Statistical analysis was performed using SPSS version 24 (SPSS Inc., Chicago, IL, USA).

Ethical approval

The study was approved by the Independent Ethics Committee of Hospital Universitario La Paz (Reference HULP-PI-1334). An informed consent form was obtained from patients or relatives before inclusion in the study.

Results

Descriptive analysis

A total of 509 patients with a mean age of 85.6 ± 6.9 years were included. Clinical, functional, nutritional and analytical characteristics of the cohort have been previously described.[23] A total of 118 (23.2%) patients had died at 12 months post-HF. Table 1 shows patients' baseline characteristics, with the results of the bivariate "1-year vital status" analysis.

Development of the new score

Table 2 shows the results of multivariate logistic regression analysis and the HULP-HF punctuation. There were 9 factors independently related with 1-year mortality and included in the score. The HULP-HF punctuation ranged from 0 to 12. Based on the receiver operating characteristics (ROC) analyses 1-year probability of death, the best cut-off value of HULP-HF score was 4. There were 332 (65.2%) patients with HULP-HF score ⩾4 (high risk of mortality) and 177 (34.8%) patients with HULP-HF score <4 (low risk of mortality).

Comparison of the survivals curves of the four tools assessed

The 4 tools assessed presented statistically significant differences between the scores for survivors and non-survivors after 1 year. The percentage of survival was different depending on being classified as high or low risk surgical patients through the different tools (Table 3)

Figure 1 shows the survival curves obtained from a Kaplan Meier analysis of each tool. All of them showed significant differences between survivors and non-survivors after 1 year ($p < 0.001$).

Study of predictive validity, discrimination and calibration of the tools assessed

Table 4 shows the results for sensitivity, specificity, PPV, NPV, AUC and assessment of calibration using the Hosmer-Lemeshow goodness-of-fit test. NHFS and HULP-HF were the tools with higher sensitivity and negative predictive values (>90%), while the a-CCI had the highest specificity. The HULP-HF was the only tool with an acceptable level of discrimination, very close to Excellent (AUC = 0.791).

The ASA scale score was not included in the Hosmer-Lemeshow test as it is a short-range ordinal variable. The other 3 tools presented values of $p > 0.05$, indicating a good level of calibration.

Discussion

This study was conducted to evaluate the performance of a new score for predicting 1-year mortality following HF. This score was obtained by selecting, among a wide list of clinical, analytical, functional, cognitive and nutritional variables, those associated with 1-year mortality.[23] Finally, the results of the new score were compared with those of 3 other risk prediction models.

Table 1. Characteristics of patients admitted for hip fracture and subgroups of 1-year survivors and non-survivors.

	Total sample ($n=509$)	*n*	Survivors $n=391$ (76.8%)	Non-survivors $n=118$ (23.2%)	*p*
Demographics					
Age (y)	85.6 (6.9)	509	84.8 (6.9)	88.1 (6.5)	<0.001
Women, *n* (%)	403 (79.2)	509	317 (81.1)	86 (72.9)	0.038
Living in residential care, *n* (%)	116 (22.8)	509	84 (21.5)	32 (27.1)	0.225
Extracapsular fracture, *n* (%)	295 (58)	509	225 (57.5)	70 (59.3)	0.713
Geriatric assessment					
Previous FAC ⩽3, *n* (%)	106 (20.8)	509	60 (15.3)	46 (39)	<0.001
Previous FAC 0, *n* (%)	18 (3.5)	509	9 (2.3)	9 (7.6)	<0.001
1,2,3, *n* (%)	88 (17.3)		51 (13)	37 (31.4)	0.326
4,5, *n* (%)	403 (79.2)		331 (84.7)	72 (31.4)	<0.001
Previous BI, (median IQR)	85 (65–95)	509	90 (75–100)	70 (45–85)	<0.001
Previous BI ⩽60, *n* (%)	119 (23.4)	509	68 (17.4)	51 (43.2)	<0.001
SPMSQ at admission >3, *n* (%)	244 (47.9)	509	159 (40.7)	85 (72)	<0.001
SPMSQ, median (IQR)	3 (1–7)	509	2.5 (1–6)	6.7 (3–9)	<0.001
Comorbidities					
Anticoagulant therapy, *n* (%)	240 (47.2)	509	170 (43.5)	70 (59.3)	0.003
Congestive heart failure, *n* (%)	67 (13.2)	509	39 (10)	28 (23.7)	<0.001
Coronary artery disease, *n* (%)	61 (12)	509	39 (10)	22 (18.6)	0.023
Heart disease (any), *n* (%)	195 (38.3)	509	134 (34.3)	61 (51.7)	0.001
Cerebrovascular disease, *n* (%)	73 (14.3)	509	54 (13.8)	19 (16.1)	0.450
Chronic pulmonary disease, *n* (%)	46 (9)	509	29 (7.4)	17 (14.4)	0.008
Kidney disease, *n* (%)	140 (27.5)	509	99 (23.5)	41 (34.7)	0.029
Diabetes, *n* (%)	119 (23.4)	509	90 (23)	29 (24.6)	0.078
Cancer, *n* (%)	65 (12.8)	509	47 (12)	18 (15.3)	0.425
Peripheral vascular disease, *n* (%)	15 (2.9)	509	9 (2.3)	6 (5.1)	0.088

BI, Barthel Index; SPMSQ, Pfeiffer's Short Portable Mental Status Questionnaire; FAC, Functional Ambulation Category scale; *n*, number of patients with data available; IQR, interquartile range.

Table 2. Predictors of mortality in the multivariate analysis and their respective HULP-HF score punctuation.

Risk factor	Coefficient	Adjusted odds ratio (95% confidence interval)	Points
Sex: Male	0.536	1.70 (0.97–3.01)	1
Age >85 years	0.601	1.82 (1.09–3.02)	1
Basal Barthel Index ⩽60	0.585	1.79 (1.03–3.11)	1
Pfeiffer's Short Portable Mental Status Questionnaire >3	0.918	2.50 (1.45–4.31)	2
Grip strength (<23 kg in men; <13 kg in women)	0.762	2.14 (1.13–4.04)	2
Body mass index <21 k/m^2	0.817	2.26 (1.18–4.32)	2
Heart disease	0.551	1.73 (1.08–2.77)	1
Vitamin D <20 ng/ml and Parathyroid hormone ⩾66 pg/ml	0.673	1.96 (1.21–3.17)	1
Haemoglobin (<13 g/l in men and <12 g/l in women)	0.567	1.76 (1.09–2.82)	1

Patients classified as high-risk patients through the 4 tools assessed, presented a significantly higher mortality rate during the first year of follow-up. Among the different tools, NHFS and HULP-HF were the ones with the greatest sensitivity and NPV. a-CCI, NHFS and HULP-HF showed a good level of calibration. The discrimination of HULP-HF was the greatest of all, with an almost Excellent level, and it is among the best or even a little above those described in the HF mortality prediction tools.[18,19,37] A high level of sensitivity is useful for a screening tool, as it allows the detection of the majority of patients at risk and to take risk-reducing measures. A higher discrimination, meanwhile, allows the correct classification of patients into their respective high risk and low risk groups. Consequently, we can conclude that the HULP-HF is a score with greater predictive validity than the rest of those assessed. This may be due to the way it was developed using 9 variables - more than the others - and including some items of recognised importance among the elderly, as well as having been designed

Table 3. Result of bivariate analysis of the 4 scores assessed.

	Total sample ($n = 509$)	*n*	Survivors $n = 391$ (76.8%)	Non-survivors $n = 118$ (23.2%)	*p*
Scores					
Surgical risk: ASA III–IV, *n* (%)	358 (70.3)	509	257 (64.7)	101 (85.6)	<0.001
a-CCI abbreviated >2, *n* (%)	185 (36.3)	509	122 (31.2)	63 (53.4)	<0.001
NHFS >4, *n* (%)	326 (66.1)	508	229 (58.7)	107 (90.7)	<0.001
HULP-HF Score ⩾ 4, *n* (%)	332 (65.2)	509	223 (57.2)	109 (92.37)	<0.001

ASA, American Society of Anesthesiologists; a-CCI, abbreviated Charlson Comorbidity; NHFS, Nottingham Hip Fracture Score; HULP-HF, Hospital Universitario La Paz Hip Fracture.

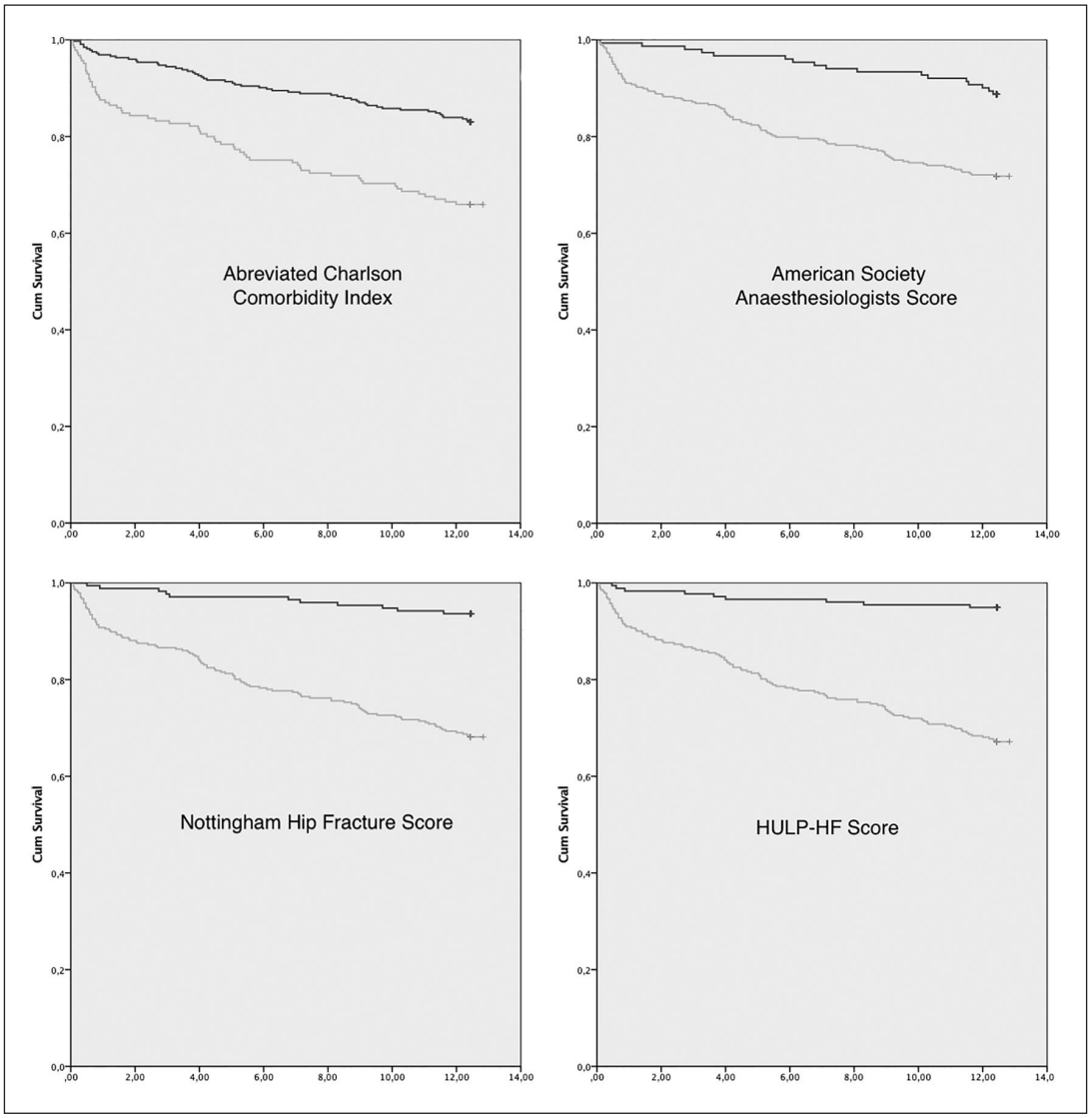

Figure 1. Kaplan-Meier curves showing 1-year mortality after hip fracture. Low- and high-risk groups are represented in base of the predictive capacity of each instrument assessed in this study.
Low-risk, darker line.

specifically for HF patients. There are other scores that have also been expressly created for this purpose, and which are worthy of comment.[17–19,30]

The NHFS is an excellent score designed by Maxwell et al.[30] to predict 30-day mortality after a HF that has also been used for 1 year testing.[20] It includes 7 variables also

Table 4. Statistical measures of the scores analysed in this study: Validity (by sensitivity, specificity, positive predictive (PPV) and negative predictive value (NPV)), discriminative performance (by the area under the curve) and calibration (by the Hosmer-Lemeshow goodness-of-fit test).

	Sensitivity	Specificity	PPV	NPV	AUC	Hosmer-Lemeshow
Risk model						
ASA III–IV	0.856	0.342	0.28	0.89	0.598	NA
a-CCI ⩾2	0.534	0.688	0.30	0.87	0.611	$p = 0.283$
NHFS >4	0.907	0.413	0.31	0.94	0.660	$p = 0.926$
HULP-HF ⩾ 4	0.924	0.430	0.32	0.95	0.791	$p = 0.918$

ASA, American Society of Anaesthesiologists; a-CCI, abbreviated Charlson Comorbidity; NHFS, Nottingham Hip Fracture Score; HULP-HF, Hospital Universitario La Paz, Hip fracture; PPV, positive predictive value; NPV, negative predictive value; AUC, area under curve; NA, not applicable.

obtained from a comprehensive patient assessment (age, sex, haemoglobin, cognitive status, living in residential care, number of comorbidities and a history of malignant disease) of which 4 (age, sex, haemoglobin and cognitive status) are also used in HULP-HF. Others included in HULP-HF, such as functional situation, nutritional status and muscle strength are not included in NHFS.

Bliemel et al.[22] developed a scoring system to assess 1-year survival in HF patients with good discrimination (AUC: 0.74). This score included clusters of variables rather than pure health problems or conditions: ASA scale, health-related quality of life scores (EQ-5D index) Mini-Mental State Examination and 1 individual variable: female gender. Their study did not include non-operated patients.

Jiang et al.[18] published a risk score for 30-day and 1-year mortality mainly based on the comorbidity of patients, with an acceptable predictive capacity for 1-year mortality (AUC: 0.74). The final model included age, sex, living in residential care and 10 different co-morbidities. Over half of the final score (54%) refers to variables also included in the HULP-HF (age, sex, cardiopathies and malnutrition).

Elliott et al.[17] developed a risk score for 1-year mortality including demographic, cognitive deterioration, functional status, high surgical risk and surgical delay variables. It shares variables relating to functional and cognitive assessment with HULP-HF score, and its AUC values are similar to those obtained in our study, although they include a clinical assessment scale (ASA Scale) among the individual variables. Their study did not include non-operated patients.

While our study was underway, Cenzer et al.[19] published a prognostic index for the prediction of 1-year mortality after HF with good discrimination (AUC: 0.73). The 5 variables included in that model were age, sex, heart disease and 2 instrumental activities of daily living (cooking and driving), of which the first 3 are included in HULP-HF. These authors did not include nutritional variables, analytical variables nor muscle mass and strength. Unfortunately, the instrumental activities of daily living were not included in our series. Maybe an instrument compiling components from both scores may achieve a greater predictive capacity than either of them separately.

There are other works that fall outside the field of this study as they assess the prediction of mortality on shorter term (in-hospital, 30 or 120 days post HF), or because they use general surgical prediction tools (O-POSSUM, E-PASS), or they study the impact of individual mortality factors, or because the metric qualities and validity have not been tested.

This study has several strengths. We achieved a highly representational population by consecutively including all HF patients admitted over a period of 1 year to a referral hospital serving a region with a population of 520,000. Another important factor is the high number of variables collected, which include functional, clinical, body-composition and analytical measurements.

Our study also has some limitations. We only collected variables at the first assessment over the first 72 hours after admission; this prevented us from including factors such as complications, surgical delay or length of hospital stay. Our purpose was to develop a model taking account the effect of baseline characteristics. Another limitation was the lack of validation in an external sample, and therefore the same performance of the tool cannot be ensured in other patient populations; still, this should be the object of future research.

In conclusion, this study provides the development of a score with a slightly greater predictive capacity for 1-year mortality in HF patients than that of prior studies, possibly due to the inclusion of other variables that previously were not taken into consideration. Given the complexity of HF patients, the more sophisticated mortality risk scores of the future will probably need to include not only demographic and clinical variables, but also functional ones, for basic, instrumental and based on execution activities, as well as cognitive and nutritional variables.

Declaration of conflicting interest

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