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ACUTE HF score, a multiparametric prognostic tool for acute heart failure: A real-life study

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ABSTRACT

Background: Acute heart failure (AHF) is the first cause of hospitalization for over-65 individuals, associated with high mortality and readmission rate. The aim of this study was to assess the prognostic value of a multiparametric score combining clinical, biochemical and echocardiographic indexes in AHF for clinical practice.
Methods: 830 patients hospitalized for AHF were enrolled. Exclusion criteria were: active neoplasms; previous heart transplantation or left ventricular assist device implantation. Different variables were analyzed: etiology of AHF, clinical and biochemical data, lung congestion on chest-X ray, echocardiographic parameters and administered therapy. The endpoints were: all-cause mortality at 30 days, 6 months and 5 years and the duration of hospitalization.
Results: 771 patients met eligibility criteria. Using the univariate and multivariate analysis the indexes with the best correlation with outcome were discretized and used to create the ACUTE HF score, computed as: 1.4*[serum creatinine>2 mg/dl] + 0.8*[ejection fraction<30] + 0.7*[age > 76] + 0.7*[prior hospitalization for AHF] + 0.9*[prior stroke/transient ischemic attack] + 0.5*[more than moderate mitral regurgitation] + 0.8*[use of non-invasive ventilation] and used to divide patients into 3 groups according to the risk of 6-months mortality. With the receiver operating curves and Kaplan-Meier analysis, this score proved to have a high predictive power for mortality at 30 days, 6 months and 5 years from hospitalization, and for event-free survival rates, providing a risk stratification capability superior to that of single variables.
Conclusions: The ACUTE HF score could be a complete and useful tool for assessing prognosis of AHF patients. It could represent a step in the long standardization pathway of prognostic protocols for AHF.

1. Introduction

Acute heart failure (AHF) is the most common cause of hospitalization in the elderly [1] and is associated with high mortality [2] and readmission rates [3]. Based on the Italian National Health Service reports, hospitalizations for AHF represent the highest total direct cost for heart failure (HF) management [4]. HF could be described as a heterogeneous syndrome in which patients show several phenotypic presentations, comorbidities, precipitating factors, in addition to different management strategies [5]. The incidence of AHF syndrome has increased in the last decades parallel to the well documented longevity [6], a fact that created a significant clinical and economic challenge.

Clinical and biochemical determinants of AHF prognosis have been extensively studied, but less interest has been paid to the application of echocardiographic measures of cardiac structure and function. Being universally available as a prime investigation for cardiac assessment, Doppler echocardiography carries a pivotal importance in daily practice, particularly in managing AHF patients. The aim of this study was to find the best predictors of prognosis in patients hospitalized for AHF, and to describe the predictive role of echocardiographic parameters, individually or in combination, in AHF, investigating the additive value their use could provide in daily clinical practice.

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2. Methods

2.1. Data source

A retrospective study was conducted in a cohort of 771 patients hospitalized for signs and symptoms (i.e. rapid worsening of dyspnoea or peripheric oedema, cardiogenic shock, lung congestion at chest-X-ray) of AHF in the coronary care unit (CCU) of Santa Maria delle Scotte Hospital in Siena, between 2011 and 2013.

The inclusion criteria were: signs and symptoms of AHF at the time of hospital admission; signs of pulmonary congestion at hospitalization, or confirmed diagnosis of AHF at patient discharge. Patients with left ventricular assist device (LVAD) implantation, previous heart transplantation or history of active neoplasms were excluded. All work complied with the Declaration of Helsinki and its protocol was approved by the local ethics committee.

AHF etiology was carefully ascertained: ischemic heart disease including ST elevation myocardial infarction (STEMI) or non-STEMI; anterior, lateral and inferior acute myocardial infarction (AMI) and non-ischemic etiology including valvular heart disease, dilated cardiomyopathy, post-ischemic dilated cardiomyopathy, and restrictive cardiomyopathy. In addition, at the time of admission, the presence of malignant arrhythmias (ventricular tachycardia and fibrillation) and cardiovascular arrest were recorded. For each patient anamnestic and clinical data was assessed: the degree of lung congestion by chest X ray, biochemical tests, including blood count, kidney function, electrolytes, renal and liver function; as well as any previous invasive intervention required e.g. intra-aortic balloon pump (IABP) and mechanical ventilation. Data regarding the outcome of each patient was collected through the analysis of hospital database and patient interview. The endpoints considered were: all-cause mortality at 30 days, 6 months and 5 years and the duration of hospitalization.

2.2. Echocardiographic examination

The echocardiographic examination was performed according to the American Society of Echocardiography/European Association of Cardiovascular Imaging recommendations [7]. It was carried out by an experienced cardiologist the same day of admission or, in exceptional cases, within 48 h from admission, using a high definition cardiovascular ultrasound machine (PHILIPS, IE33, USA), equipped with a 2.5 MHz probe. Several standard two-dimensional echocardiographic parameters were made from the short-axis view, such as left ventricular (LV) end-diastolic and end-systolic diameters (EDD, ESD), interventricular septum (IVS) and posterior wall thickness (PW), whereas the apical 4-chamber view was used to measure LV volumes and ejection fraction (EF), calculated using the Simpson method, and left atrial (LA) area and volume. The end-diastolic diameter of the right ventricle was also measured from a dedicated apical 4 chamber view. Using M-mode echocardiography and placing the sample volume at the level of tricuspid annulus, tricuspid annular plane systolic excursion (TAPSE) was assessed. Finally, valvular diseases (aortic and mitral stenosis and regurgitation) were evaluated using conventional spectral Doppler measurements according to the European guidelines [7]. Systolic pulmonary artery pressure (sPAP) was estimated from tricuspid regurgitation retrograde velocities using the equation $4V^2$. Finally, inferior vena cava (IVC) diameter was measured and wall motion score index (WMSI) evaluated on the basis of LV kinetic regional and global features.

2.3. Statistical analysis

Analyses were performed using the SPSS (Statistical Package for the Social Sciences, Chicago, Illinois) software release 12.0. Binary variables are presented as counts and percentages, while numerical variables are presented as mean ± SD or, in the case of high skewness and/or non-normality, as median [1st quartile, 3rd quartile].

Basic univariate comparisons were performed using standard Chi-square test in the case of categorical comparisons, Student *t*-test in case of normal comparisons and Mann-Whitney U non-parametric test for non-normal comparisons. Normality of numerical variables was determined by the Kolmogorov-Smirnov test. For each variable, the relationship with the length of stay in CCU and in ordinary regimen was evaluated using univariate and multivariate analyses.

Multivariate fit for hospitalization days was performed via a generalized linear model (GLM) with Poisson response. Variables with >100 missing values were excluded from the model. When the Pearson correlation between variables was >0.50, only the variable with the best fit was left in the model. Significance level was set at 0.05 before performing a standard Bonferroni correction.

The predictive power of the variables for mortality at 30 days, 6 months and 5 years was analyzed using the univariate and multivariate analysis. The multivariate analysis, as for the duration of hospitalization, was applied in a first phase only to the variables that presented missing data in <100 patients. In a second phase, the analysis was also extended to some variables previously excluded (glucose, urea, EDD, ESD, LA area, TAPSE, right EDD and sPAP).

The most significant variables according to the 3 mortality multivariate models (beta values between 0,5 and 1,5; $p < 0.005$) and the variables with high univariate prediction power ($p < 0.00001$) and few missing values (<100) were the selected variables to produce the predictive score. Among this group of selected variables, the numerical predictors were discretized using a univariate Youden index for balancing sensitivity and specificity (applied on the binary 6-months mortality). The discretized variables were then used to compute the score using a simple binomial GLM. Linear estimators from this model were used as weights for each of the discretized variables, to create the new score as the weighted sum of the discretized variables. Receiver operating characteristics (ROC) and area under curve (AUC) were composed to assess the score's predictive power for 30-day, 6-month and 5-year mortality rates and to find optimal cut-off values for each variable. The score was used to classify patients into 3 groups and Kaplan-Meier survival curves were computed for these groups and compared with the survival curves of the score's numerical components. All analyses included age, sex, BMI, BP, HR and smoker indicators as confounding variables.

3. Results

3.1. Population characteristics

Of the 830 patients enrolled, 771 were eligible for the analysis (Fig. 1). Mean age was 72.3 (±13.5) years, 65% were male and 35% female (Fig. 2).

Only 3% had a body mass index above 30 kg/m^2. Systolic blood pressure was 125.3 ± 32.2 mmHg and heart rate 86.2 ± 30.5 beats/min. 26% of patients had previous hospitalization for HF, 7% had history of stroke or transient ischemic attack (TIA), and 22% had chronic renal failure. 46% patients had AHF of ischemic etiology and 33% had a non-ischemic etiology. 13% of patients received non-invasive ventilation (NIV) at the time of admission.

3.2. Correlation of variables with the duration of ordinary hospitalization

On univariate analysis, the following parameters significantly correlated with the duration of ordinary hospitalization: age; ischemic etiology, non-ischemic etiology, previous ICD implantation, and the use of dopamine. Among the echocardiographic variables, IVS, PW, LV EDD, ESD, left atrial area and LV EF.

3.3. The relationship of variables with the length of stay in CCU

On the univariate analysis the following parameters correlated with the CCU stay (days): the use of IABP, NIV, and continuous veno-venous hemofiltration (CVVH); pre admission cardiac arrest, LV EF and WMSI.

3.4. Multivariate analysis

Multivariate analysis showed a few variables which maintained a correlation with the length of hospitalization (Table 1). Hospitalization duration directly correlated with non-ischemic etiology, the presence of valvular heart disease, permanent atrial fibrillation, a prior stroke or TIA, and negatively with prior hospitalization for HF, the use of NIV in CCU, LV EF and WMSI. The following parameters correlated with the duration of CCU stay: late presentation of AMI, cardiac arrest, the use of NIV, IABP, or CVVH, prior stroke or TIA and LV EF.

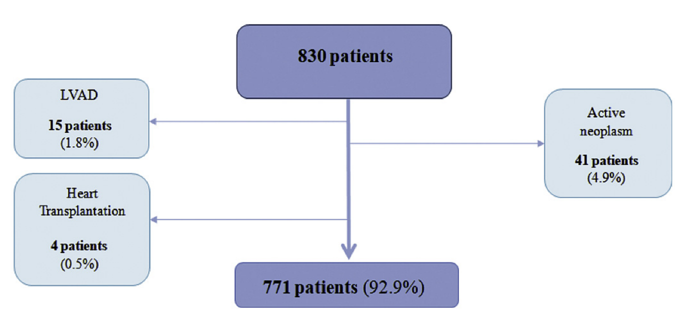

Fig. 1. Patients selection process.

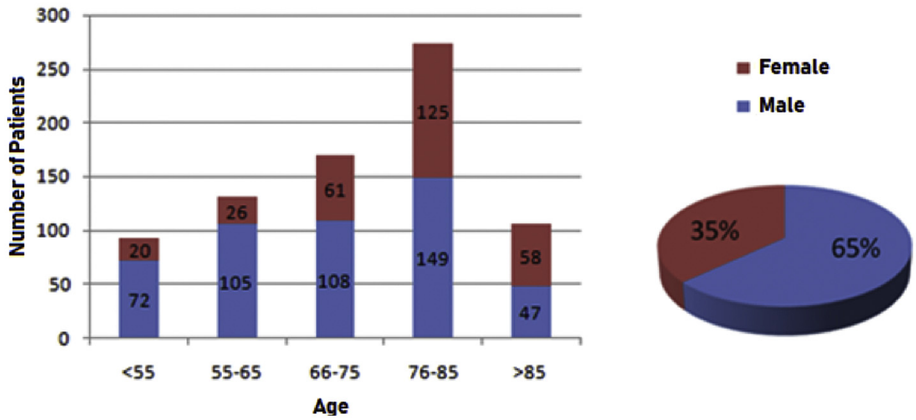

Fig. 2. Age and sex distribution in our study population.

Table 1
Correlation of each variable with the length of stay (in CCU and ordinary ward) at multivariate analysis.

	Beta value for ordinary length of stay	p-Value	Beta value for CCU length of stay	p-Value
Precipitating factor				
Late presentation of AMI	–		0,26	0,0001
Cardiac arrest	–		0,73	<0,0001
Non-ischemic etiology	0,38	<0,0001	–	
Valvular heart disease	−0,34	<0,0001	–	
Anamnestic data				
Stroke or TIA	0,17	<0,0001	0,26	<0,0001
Permanent AF	0,2	<0,0001	–	
Prior hospitalization for heart failure	−0,17	<0,0001	–	
Laboratory data				
Creatinine serum level (mg/dl)	0,5	<0,0001	0,54	<0,0001
Therapy in CCU				
NIV	–		0,41	<0,0001
IABP	–		0,4	<0,0001
CVVH	–		0,65	<0,0001
Echocardiographic data				
EF	−0,01	<0,0001	−0,02	<0,0001
WMSI	−0,29	<0,0001	–	

AMI = acute myocardial infarction; TIA = transient ischemic attack; AF = atrial fibrillation; CCU = coronary care unit; NIV = non-invasive ventilation; IABP = intra-aortic balloon pump; CVVH = continuous veno-venous hemofiltration; EF = ejection fraction; WMSI = wall motion score index.

3.5. Correlation with mortality

Mortality at 30 day after hospital discharge correlated, on univariate analysis, with: age, hypercholesterolemia, use of NIV, blood glucose, C-reactive protein (CRP) ($p < 0{,}001$); AMI not receiving coronary angiography, WMSI ($p = 0{,}0001$); CVVH ($p < 0{,}01$); LV EF, use of dopamine therapy in CCU, hypertension, Blood Urea Nitrogen (BUN) ($p < 0{,}0001$); and PAPS ($p = 0{,}0028$).

Table 2
Variables with a positive correlation with discretized mortality at multivariate analysis.

	Beta value			p-Value
	30 days	6 months	5 years	
Precipitating factors				
AMI not studied by coronarography	1,86	–	–	0,047
Valvular heart disease	3,81	–	–	0,002
Clinical history				
Severe carotid stenosis	–	–	0,78	0,027
Stroke/TIA	–	1,18	1,33	0,004
Prior hospitalization for AHF	1,07	0,78	1,37	0,03
Laboratory data				
Creatininemia (mg/dl)	0,5	0,54	0,62	<0,0001
Therapy in CCU				
NIV	–	1,05	–	0,003
Echocardiographic data				
Severe or mild-to-severe mitral regurgitation	–	–	0,63	0,012

AMI = acute myocardial infarction; TIA = transient ischemic attack; AHF = acute heart failure; CCU = coronary care unit; NIV = non-invasive ventilation.

Mortality at 6 months after hospitalization correlated with age, prior hospitalization for HF, hypertension, LV EF, more than moderate mitral regurgitation (MR), history of coronary artery disease, BUN, creatinine level, PAPS ($p < 0{,}0001$); ischemic etiology ($p = 0{,}006$); AMI not studied by angiography ($p = 0{,}01$); chronic kidney disease ($p < 0{,}001$); CRP ($p = 0{,}0005$); LV ESD ($p = 0{,}004$); EDD ($p = 0{,}001$); TAPSE ($p = 0{,}0001$); IVC diameter ($p < 0{,}005$).

5-years mortality was predicted by: age, ischemic etiology, STEMI, LV EF, PAPS, more than moderate MR, prior hospitalization for HF, chronic kidney disease, hemoglobin, LA area ($p < 0{,}0001$); inferior AMI, undefined AMI, severe carotid artery stenosis, TAPSE ($p = 0{,}0001$); prior stroke or TIA ($p = 0{,}007$); pacemaker implantation, familiar history of cardiovascular disease, LV EDD ($p < 0{,}001$); smoking ($p < 0{,}005$); ESD ($p = 0{,}003$); WMSI ($p < 0{,}0002$); right EDD ($p < 0{,}0005$); IVC diameter ($p = 0{,}0005$).

3.6. Multivariate predictors of mortality

By multivariate analysis different variables show correlation with mortality (Table 2). 30-days mortality was predicted by valvular heart disease, AMI not receiving coronary angiography, prior hospitalization for AHF and serum creatinine, and negatively

Table 3
Variables with a negative correlation with discretized mortality at multivariate analysis.

	Beta value			p-Value
	30 days	6 months	5 years	
Precipitating factors				
Non-ischemic etiology	−3,13	–	–	0,025
VT/VF	–	−1,54	–	0,023
Echocardiographic data				
EF	–	–	−0,03	0,037

VT = ventricular tachycardia; VF = ventricular fibrillation; EF = ejection fraction.

correlated with non-ischemic etiology. 6-months mortality correlated with: prior hospitalization for AHF, prior stroke or TIA, use of NIV, serum creatinine level, and negatively to history of arrhythmic storm and history of CAD (Table 3).

5-years mortality correlated with: hospitalization for AHF ($\beta = 1{,}37$; $p < 0{,}0001$), prior Stroke or TIA ($\beta = 1{,}33$; $p = 0{,}001$), severe carotid artery stenosis ($\beta = 0{,}78$; $p = 0{,}02$) serum creatinine ($\beta = 0{,}62$; $p < 0{,}0001$), more than moderate MR ($\beta = 0{,}63$; $p = 0{,}01$) and LV EF ($\beta = -0{,}03$; $p = 0{,}03$).

3.7. ACUTE HF score

Based on the 3 mortality multivariate models, variables were selected to produce a predictive score, together with a few variables of univariate high predictive power. These variables were discretized and were then used to create the ACUTE-HF score.

The new ACUTE HF score can be calculated as the weighted sum of the following 7 variables (Table 4):

$$\begin{aligned}1.4\ [\text{creatinine} > 2\ \text{mg/dl}] &+ 0.8\ [\text{LV EF} < 30\%] + 0.7\ [\text{age} > 76]\\ &+ 0.7\ [\text{prior hospitalization for AHF}]\\ &+ 0.9\ [\text{prior Stroke or TIA}]\\ &+ 0.5\ [\text{more than moderate MR}] + 0.8\ [\text{use of NIV}]\end{aligned}$$

The ACUTE HF score was then used to classify patients into 3 groups according to the risk of 6 months mortality:

- *Group 1* if ACUTE HF score < 1,5 (13% estimated mortality at 6 months) = low risk;
- *Group 2* if ACUTE HF score > 1,5 e < 3 (33,5% estimated mortality at 6 months) = intermediate risk;
- *Group 3* if ACUTE HF score > 3 (62,9% of estimated mortality at 6 months) = high risk.

Receiver Operating Characteristic (ROC) curves with area under the curves (AUC) were calculated to assess the predictive power of the new score for 30-day, 6-months and 5-years mortality. The AUC value was 0,78; 0,79; and 0,76 respectively. The ACUTE HF score proved to have better prognostic value than each variable included in the score (age, creatinine, NIV, stroke/TIA, LV EF, hospitalization, MR) individually (Fig. 3). Moreover, ACUTE HF score proved to be superior than the ADHERE score, previously applied in AHF, based on the ROC produced sensitivity and specificity for mortality prediction (Fig. 4).

Finally, Kaplan-Meier survival curves showed that the ACUTE HF score risk stratification was superior than single variables, e.g. LV EF (Fig. 5) and creatinine, showing clear differences in free events survival rates between the three risk groups (Fig. 6).

Table 4
Calculation of the ACUTE HF score.

ACUTE HF score	Points
Age > 76	0.7
Creatinine > 2 mg/dl	1.4
Use of NIV	0.8
TIA or stroke	0.9
EF < 30	0.8
Prior hospitalization for AHF	0.7
Mitral dysfunction	0.5
Max.	5,8 pt.

NIV = non-invasive ventilation; TIA = transient ischemic attack; EF = ejection fraction; AHF = acute heart failure.

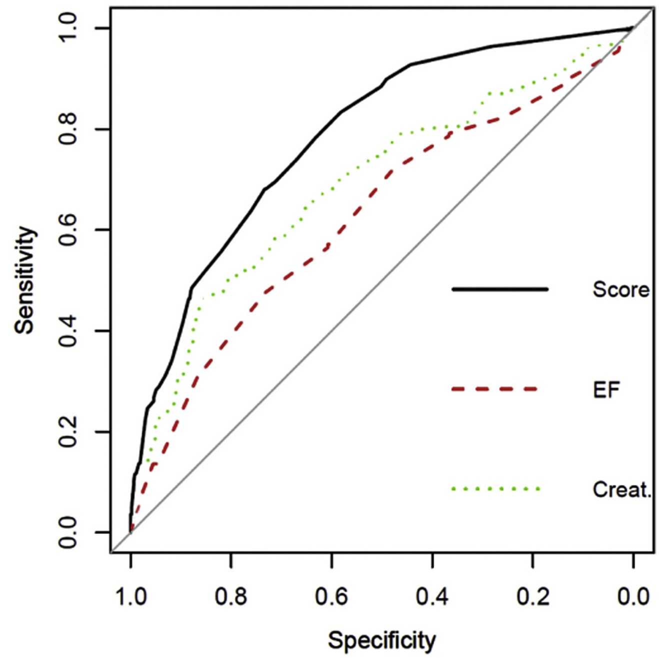

Fig. 3. Comparison between ACUTE HF, EF and creatinine receiver operating characteristic (ROC) curves for the prediction of 6-months mortality.

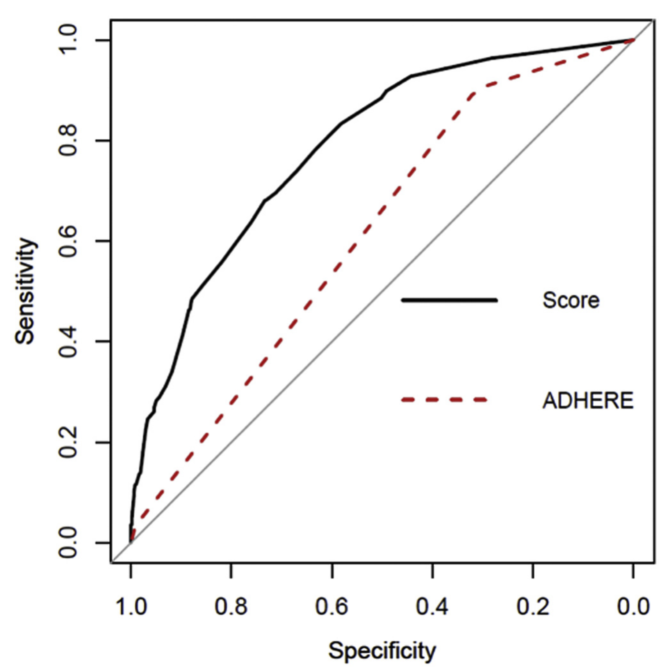

Fig. 4. Comparison between ACUTE HF and ADHERE receiver operating characteristic (ROC) curves for the prediction of 6-months mortality.

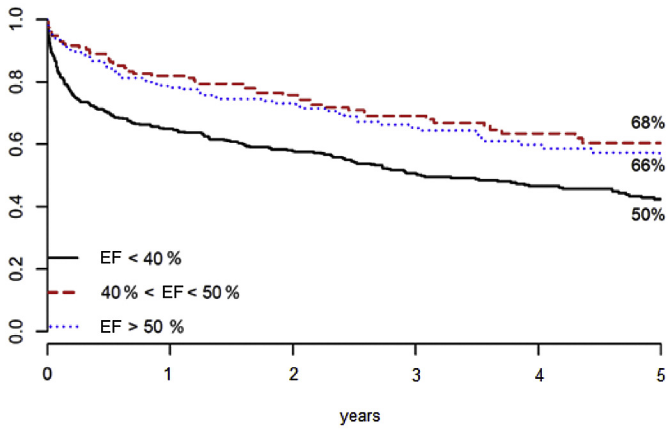

Fig. 5. Kaplan-Meier cumulative event-free survival curves of the three risk groups of patients based on EF.

4. Discussion

The prognostic evaluation of patients with AHF is a major challenge for clinicians. Our results show that the presence of valvular heart disease including more than moderate mitral regurgitation, previous hospitalization for HF, history of stroke or TIA, raised serum creatinine, the use of NIV, non-ischemic AHF and low LV EF was independently correlated with mortality. These findings could have significant impact on clinical practice in general and management of heart failure in particular.

4.1. The new and the old elements

Ischaemic heart disease is a well-established cause for HF hence our finding of negative relationship between non-ischaemic etiology and AHF mortality at 30 days concurs with that finding. This relationship has been also supported by similar results in AHF patients [8] as well as those presenting with acute coronary syndrome associated with AHF [9–11]. This persuaded us to study the two groups of patients, according to the underlying pathology, separately. Our analysis showed slight decrease in mortality, 6 months after hospitalization in the subgroup with history of coronary heart disease.

Cerebrovascular syndromes, stroke and TIA, proved to be another strong predictor of mortality, both in uni- and multivariable analysis, in keeping with the fact that it is another manifestation of atherosclerosis, irrespective of additional coronary artery disease. Cerebrovascular disease may lead to disruption of the quality of life, a compromised self-independence and adherence to therapy [12]. The clinical importance of this has previously been considered and prognostic scores for AHF, such as EFFECT and PREMIER have been created [13]. However, only the 30-day mortality was evaluated by the EFFECT, while the PREMIER score was not applicable during the hospital stay but could only be calculated at the time of discharge through a complex algorithm. Significant valvular heart disease was the third important etiological factor that predicted mortality in our AHF cohort.

In addition to etiology, history of previous hospitalization for AHF correlated with mortality, a factor which was previously investigated [3,8,14] and considered in the PROTECT score developed by Lara et al. [13]. However, it is based on a selected cohort for a clinical trial, which may not necessarily represent patients commonly seen in daily clinical practice. Moreover, their findings that lower survival parallels the perpetual increase in hospitalizations, are supported by our findings which showed that previous hospitalization for AHF was an independent predictor of 30 days, 6 months, and 5 years mortality. A rather new finding of our study was the increase in 6-months mortality for patients treated with NIV when admitted to CCU. Although not previously established, this relationship reflects the worse clinical status of those patients.

Finally, among laboratory tests, raised serum creatinine, as a marker of renal impairment, was a lone predictor of mortality, as shown by many previous studies. Irrespective of chronic HF [15] or AHF [16,17] renal function has been shown to carry a high prognostic value. Serum creatinine levels have also been included in the ADHERE [18] and the GWTG scores [19], but their results were limited to intra-hospital mortality.

In addition to the above clinical and laboratory results, echocardiography played an important role in our analysis, despite having only a modest role in AHF according to literature. The latest European Society of Cardiology (ESC) guidelines [12] for AHF recommends echocardiographic examination within 48 h from admission or immediately if the patient is hemodynamically unstable. However, the precise echocardiographic indices to evaluate have not been stated yet. Harjola et al. [20], in the statement from the Acute Heart Failure Committee of the Heart Failure Association (HFA) of the ESC, suggest some echocardiographic parameters to systematically evaluate, but their prognostic value was not assessed. In our study, we evaluated the echocardiographic parameters simultaneously with many other data. LV EF and more than moderate mitral regurgitation showed a good correlation with mortality in multivariate analysis, irrespective of the etiology of regurgitation. The role of LV EF in predicting mortality in AHF is controversial. While Chun et al. [8] reported a greater event-free survival in HFpEF compared to HFrEF patients, no difference was found in other studies [21,22], and Kim et al. [23] claimed that the LV EF was incapable of providing prognostic information. A stratification of the AHF patients according to LV EF was not performed in this study, however we believe that considering LV EF evaluation along with other variables in AHF patients allows a better estimation of prognosis.

4.2. The unique potential value of the ACUTE HF score

There are several strength points of the present investigation which deserve specific emphasis: firstly, it was carried out in a cohort of patients representing those commonly seen in clinical practice, due to the lack of strict exclusion criteria often seen in other studies conducted in ultra-selected cohorts. Also, we avoided any focus on the evaluation of individual tools, hence made a comprehensive analysis of clinical, anamnestic, biochemical, therapeutic and echocardiographic parameters, to reach the point of a

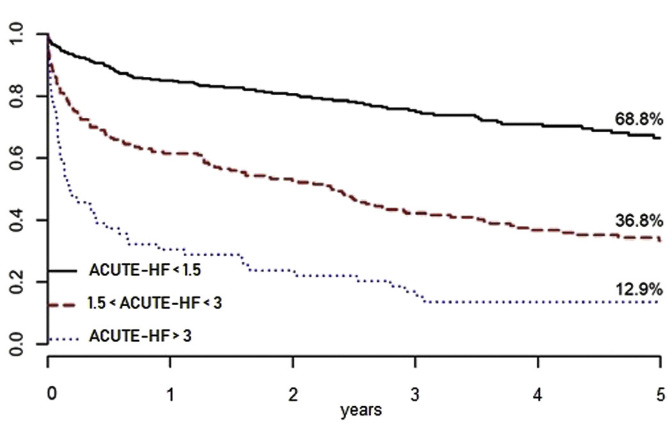

Fig. 6. Kaplan-Meier cumulative event-free survival curves of the three risk groups of patients based on ACUTE HF score.

real-life study. Then, we have demonstrated that the inclusion of echocardiographic parameters would provide an additive value to the risk models currently used for the risk prediction in HF. A detailed analysis of HF etiology and outcome was undertaken, having considered both hospitalization and mortality as endpoints, to ensure the selection of the actual best variables for the prognostic evaluation. Finally, the indexes included in the score are easy-to-obtain and standardized. For these reasons ACUTE HF score could represent a simple and complete approach to the patient commonly hospitalized for AHF.

4.3. Clinical perspectives

The use of ACUTE HF score may allow thorough evaluation of patients with AHF, including clinical findings, blood tests and imaging data, and proved a good prognostic indicator for these patients. It could be useful to focus clinical attention on factors of greatest prognostic value, to guide clinicians in selecting the most appropriate therapy and to guide future researches towards new therapeutic strategies depending on the different grades of risk.

4.4. Study limitations

This study presents a potential tool for predicting prognosis of patients hospitalized for AHF reflecting those seen in clinical daily practice. Also, it provides new evidence for the impact of echocardiography in the prognosis of AHF. However, the analyzed database had missing data for many patients and this allowed us to apply the multivariate model only to a restricted part of the analyzed variables. Moreover, it was a single center study conducted in a relatively small cohort, therefore our results need to be validated in further researches. In general, the use of scores tends to simplify the management of HF patients, but it cannot be applied without an accurate clinical evaluation of individual patients. Another limitation is the lack of an advanced echocardiographic analysis of these patients, with new techniques, such as speckle tracking echocardiography, which has been shown to provide additive information [24,25] to basic echocardiographic parameters for a complete and precise evaluation of HF patients.

5. Conclusions

AHF is a heterogeneous and complex pathological condition. The use of ACUTE HF score represents a simple applicable tool that allows physicians, using a multiparametric approach, to focus the attention on variables with greater prognostic value. The score also has a higher predictive capacity than single variables. Furthermore, the score has a good feasibility for every day clinical application since it is made of easy-to-obtain parameters and is fast to calculate. Thus, it could represent a step in the long standardization pathway of prognostic protocols for AHF. The ACUTE-HF score could be used for daily risk stratification of patients with AHF, irrespective of its etiology.

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Declaration of interest

None.

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