Impact of the MEESSI-AHF tool to guide disposition decision-making in patients with acute heart failure in the Emergency Department: A before and after study

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ABSTRACT

Objectives: To determine the impact of risk stratification using the MEESSI-AHF scale to guide disposition decision-making on the outcomes of emergency department (ED) patients with acute heart failure (AHF), and assess the adherence of emergency physicians to risk stratification recommendations.

Methods: This was a prospective quasi-experimental study (before/after design) conducted in 8 Spanish EDs which consecutively enrolled adult AHF patients. In the pre-implementation stage, the admit/discharge decision was performed entirely based on emergency physician judgment. During the post-implementation phase, emergency physicians were advised to "discharge" patients classified by the MEESSI-AHF scale as low-risk and "admit" patients classified as increased risk. Nonetheless, the final decision was left to treating emergency physicians. The primary outcome was 30-day all-cause mortality. Secondary outcomes were days alive and out of hospital (DAOH), in-hospital mortality and 30-day post-discharge combined adverse event (ED revisit, hospitalization or death).

Results: The pre- and post-implementation cohorts included 1,589 and 1,575 patients, respectively (median age 85 years, 56% females) with similar characteristics, and 30-day all-cause mortality was 9.4% and 9.7%, respectively (post-implementation HR=1.03, 95%CI=0.82-1.29). There were no differences in secondary outcomes or in the percentage of patients entirely managed in the ED without hospitalization (direct discharge from the ED, 23.5% versus 24.4%, OR=1.05, 95%CI=0.89-1.24). Adjusted models did not change these results. Emergency physicians followed the MEESSI-AHF-based recommendation on patient disposition in 70.9% of cases (recommendation overruling: 29.1%). Physicians were more likely to overrule the recommendation when "discharge" was recommended (56.4%; main reason: need for hospitalization for a second diagnosis) than when "admit" was recommended (12.8%; main reason: no appreciation of severity of AHF decompensation by emergency physician), with an OR for overruling the "discharge" compared to the "admit" recommendation of 8.78 (95%CI=6.84-11.3).

Conclusions: Implementing the MEESSI-AHF risk stratification tool in the ED to guide disposition decision-making did not improve patient outcomes.

Key words: Acute heart failure; risk stratification; outcome; mortality; emergency department.

Key messages:

- What is already known on this topic: The MEESSI-AHF score was derived and validated in Emergency Departments. It has a good capacity to predict 30-day mortality in patients with acute heart failure; therefore, it can be used for prognostication of patients with acute heart failure presenting to the Emergency Department. However, whether using this score affects disposition decisions and outcomes is unclear.
- What this study adds*:* This before and after study investigated the potential influence of risk stratification of AHF patients in the ED using the MEESSI-AHF score to guide disposition decision-making on patient outcomes. We found that MEESSI-AHF scale recommendations are frequently overruled (in about 3 out of 10 patients) by emergency physicians and integrating this rule in practice had no impact on 30-day mortality and secondary outcomes.
- How this study might affect research, practice or policy: Risk stratification by itself did not improve patient outcomes in the present study. However, we cannot conclude if the reason for these neutral results is because the physicians ignored the rule or if the rule is wrong. Additional studies evaluating the effects of this strategy on outcomes are needed.

INTRODUCTION

Heart failure (HF) is a syndrome caused by several cardiomyopathies and is highly prevalent in people over the age of 65. Decompensations, also known as acute HF (AHF), are frequent, and led to 1.9% of all hospitalizations of this population in Spain in 2021 **(1)**, have high rates of mortality and rehospitalization **(2)** and around 90% of the economic burden of HF is due to AHF episodes **(3)**. About 90% of AHF patients attend an emergency department (ED) and about 15-35% of AHF patients are discharged **(2,4).** Risk scores aimed at helping in decision-making of patient discharge or hospitalization have recently been developed **(5,6)**, although none are currently widely used in the ED or explicitly recommended in the current European Society of Cardiology (ESC) guidelines **(7)**. Therefore, the decision to discharge patients directly from the ED without hospitalization is still empirically-driven by the subjective assessment of emergency physicians **(8-10)**.

We recently derived the MEESSI-AHF (Multiple Estimation of risk based on the Emergency department Spanish Score In patients with AHF) scale in Spanish EDs for use in AHF patients **(11)**. This risk score uses 13 available items to reliably estimate the 30-day risk of mortality of AHF patients admitted to the ED. This tool, which is freely accessible online **(12)**, showed excellent risk discrimination in derivation and validation cohorts (C-statistic of 0.836/0.828), and was further validated in a new Spanish cohort and a Swiss cohort of AHF patients obtaining similar good results (c-statistics of 0.81 and 0.80, respectively) **(13,14)**. The MEESSI-AHF scale stratifies patients into four clinical categories corresponding to low, intermediate, high and very high. Patients classified as low risk are selected for direct discharge (provided that no other particular circumstance precludes this decision), whilst those classified into any higher risk category (i.e., intermediate, high or very-high risk) should be hospitalized **(8,12,15)**. Nonetheless, the clinical effectiveness of the MEESSI-AHF scale for AHF patients has never been tested in the real world of emergency medicine clinical practice. We therefore undertook this quasi-experimental pre/post clinical trial with the main objectives of determining whether risk stratification guiding decision-making has an impact on mortality, days alive and out of hospital (DAOH) and post-discharge adverse events in AHF patients, and also assess the adherence of emergency physicians to risk stratification recommendations.

METHODS

Study design, objectives and setting

We conducted a prospective quasi-experimental study to assess the impact of risk stratification based on the MEESSI-AHF scale in patients diagnosed with AHF in the ED during decision-making about whether the patient should be hospitalized or discharged home after ED care. **Supplementary Table 1** shows the variables included in the MEESSI-AHF scale. We adhered to the SPIRIT (Standard Protocol Items: Recommendations for Interventional Trials) guideline for clinical trial protocols **(16)**. The study comprised two cohort studies (pre-implementation, and post-implementation) that were compared in relation to pre-defined primary and secondary outcomes. The study was conducted in 8 Spanish EDs (4 located in tertiary centers and 4 in large community centers, located in Barcelona, Madrid, Burgos and Salamanca).

Patients

The pre-intervention cohort included all patients diagnosed with AHF during a 2-month period (January-February 2018) during which decisions regarding patient discharge or hospitalization was performed entirely based on subjective emergency physician criteria, with no support from any tool or risk stratification scale. The MEESSI-AHF scale was published in 2017 and although the use of the scale was minimal during the pre-implementation period, physicians were specifically advised not to use the scale during this period.

The post-intervention cohort included all patients diagnosed with AHF during the 2-month period of January-February 2019 during which decisions related to patient discharge or hospitalization were performed after patient risk stratification with the MEESSI-AHF scale and after MEESSI-guided advice with respect to discharge/admit was given to emergency physicians.

In both periods, the diagnosis of AHF in the EDs was based on the 2016 European Society of Cardiology (ESC) guidelines, that includes clinical symptoms and elevation of natriuretic peptides and/or confirmation of HF using echocardiography **(17)**. Diagnosis of AHF was first suspected by the treating physician and confirmed by the principal investigator of each center. Non-invasive ventilation was available and protocolized in all EDs in both periods as well.

Consecutive AHF patients were asked to participate in the study by treating physician and provide written consent to include their data in the main database and to be further contacted for follow-up. Patients with rapid atrial fibrillation as the trigger of the AHF episode were included in the present study if they fulfilled ESC criteria. The only exclusion criterion was the development of AHF during ST-elevation myocardial infarction.

The study protocol was approved by the Ethical Committee of the Hospital Clinic of Barcelona (Spain), with reference number HCB/2018/0233.

Planned intervention

At the end of the two-month pre-implementation period, two to four online and offline training sessions on how to apply and interpret the MEESSI-AHF scale were provided to all the emergency physicians at the participating centers. Prior to commencing recruitment, each participating center had a run-in period of at least two months (with no patient inclusion) to allow emergency physicians to be trained with the tool and

become familiar with its use in clinical practice. Implementing the MEESSI-AHF tool and providing training in its use was the only intervention. The intervention in the second cohort consisted in calculating the risk score of every patient diagnosed with AHF. The treating physician was responsible for obtaining the MEESSI-AHF score using an online calculator freely accessible at http://meessi-ahf.risk.score-calculator-ica-semes.portalsemes.org/calc.html, as soon as data for score calculation were available (generally during the first 4 hours after patient arrival to the ED). Every risk category had an associated recommendation as follows: for patients classified as low-risk the recommendation was "Discharge", while for patients classified as increased risk (any other risk category), the recommendation was "Admit". The risk score and recommendations provided by the calculator were obtained before the final decision was firm and were recorded in the clinical report in order to be taken into account for the final decision of discharge or admit. Remarkably, this recommendation was established at the beginning of patient care and response to treatment provided during patient stay in the ED was not considered by the tool. Nonetheless, the final decision about patient disposition was left to the treating emergency physician. Similarly, treatment decisions and consultation to cardiologists were left to emergency physician discretion following the usual care of each ED**.** For discharged patients, recommendations about treatments and subsequent follow-up were given as usual. In Spain most patients discharged after an episode of AHF are followed by family doctors, although few patients are seen within the following 7 days. The present study did not record if the follow-up was carried out or the time elapsed from discharge to the follow-up visit.

As we were interested in investigating the level of implementation and agreement of emergency physicians with the risk stratification tool in the ED to help decision-making in patients with AHF, we recorded the agreement or disagreement between the MEESSI-guided recommendations and final physician decisions. For cases of disagreement, we listed potential causes driving the disagreement to be answered by physicians after their final decision had been taken.

Data collection

Forty-five independent variables were collected by the treating physician in a specific datasheet during ED stay (definitions are included in **Supplemental Table 2**). Further checking for errors was made by the principal investigator of each participating center.

Outcomes

The primary outcome was all-cause death during the 30 days following the AHF index event (ED consultation). Secondary outcomes were days alive and out of hospital (DAOH) during the 30 days following the index event (each of these 30 days was computed as at home –including nursing home- or other - comprising ED stay, hospital stay, or death- as considered in a previous study by our group) **(18)**, in-hospital all-cause mortality and 30-day all-cause mortality and for patients surviving the AHF index event (i.e., patients discharged alive from either ED or hospital wards), the 30-day post-discharge combined adverse event (ED revisit due to AHF, hospitalization due to AHF or all-cause mortality). Each of these events included in the combined outcome were also investigated individually as secondary outcomes. Finally, we calculated the percentage of patients entirely managed in the ED during the AHF index event and directly

discharged home without hospitalization in order to know if risk stratification changed the number of patients fully managed in the ED without hospitalization.

All outcomes were adjudicated at the local level by the principal investigator of each center after contacting patients or relatives by phone, after reviewing all the data from the patients' electronic medical reports, and after consultation of the death registry. Additionally, to capture any hospitalization outside the public system (that would affect DAOH counting), we also asked about this possibility during the phone interview.

Sample size calculation

We estimated the sample size taking the primary endpoint as the reference. We based our calculations on the 30-day all-cause mortality of 12% found in our EAHFE (Epidemiology of AHF in EDs) registry, which included nearly 14,000 patients at the time of this calculation. With an alpha error of 0.05 and a beta-error of 0.20, the number of patients needed to detect a relative difference (bilateral) of 25% in mortality (absolute difference 3%) in the primary endpoint was 1,638. As the number of AHF diagnoses in EDs per day is around 4, we decided to include 8 EDs and the length of time for recruitment in each phase was set at 2 months (8 EDs per 60 days per 4 patients equals 1920 patients) to assure the requested size even in the event that around 20% patients failed to be included.

Statistical analysis

Continuous variables are expressed as median and interquartile range (IQR) or mean (SD) and categorical variables as absolute values and percentages. Comparison between pre-intervention and post-intervention groups was performed using the Mann-Whitney rank-sum test for quantitative variables and the chi-square test for categorical variables. Primary and secondary outcomes were explored using survival tables and Kaplan-Meier curves, and comparison between curves was made using the log-rank test.

Unadjusted associations between intervention and outcomes were calculated using Cox regression models **(Supplementary Table 3)** or logistic regression models and expressed as hazard ratios (HR) or odds ratios (OR), respectively, with 95% confidence interval (CI). For DAOH, we estimated absolute differences between means with 95% CI using a linear regression model. In order to adjust for imbalances in the characteristics of patients included in the pre- and post-implementation periods, we also calculated adjusted outcomes. As most of the 45 variables recorded could hypothetically impact any of the outcomes, and in order to limit the number of covariates included in the multivariate model (and avoid a highly unstable model), we decided to only include age, sex, Barthel index and variables for which the distribution was significantly different between the two groups (these were neoplasia as comorbidity, chronic treatment with renin-angiotensin system inhibitors, pulse-oximetry and creatinine at ED arrival, and use of intravenous diuretics in the ED). Finally, the level of agreement (and reasons for disagreement) between emergency physician decisions and MEESSI-AHF recommendations was investigated in the post-implementation cohort, and we conducted a qualitative process evaluation to explore the potential underlying mechanisms of our results **(19)**. This included a number of predefined causes for overruling the recommendation and also leave open boxes to add other causes of overruling aside from the predefined causes.

Statistical significance was accepted if the p value was less than 0.05 or if the 95%CI of the HR or OR excluded the value 1, or if 95% CI of the means difference excluded the value 0. All calculations were made using SPSS v24.0 software (IBM, Armonk, NY, USA).

Patient and Public Involvement

No patient involved.

RESULTS

Characteristics of patients included in the study

From January 1st to February 28th, 2018, 1,669 out of the 134,106 patients attending the 8 participating EDs were diagnosed with AHF (1.2%), and 1,589 formed the pre-implementation cohort. Of these, 373 (23.5%) were discharged home and 1,216 (76.5%) were hospitalized (22 in intensive care units [ICUs]). For the post-implementation cohort from January 1st to February 28th, 2019, 1,967 out of 145,688 patients were diagnosed with AHF (1.4%), and 1,575 were included. Of these, 385 (24.4%) were discharged home and 1178 (75.6%) were hospitalized (14 in ICUs) (**Figure 1**). Patients were of advanced age (median: 85 years), 56% were females and comorbidities were very frequent, the most frequent being hypertension (82%), chronic HF (64%), atrial fibrillation (51%) and diabetes mellitus (37%). The median NT-proBNP was 4,164 pg/mL. The remaining descriptive data of the patients are shown in **Table 1**. Echocardiography was not available in more than one third of patients (in these patients, AHF was based on clinical findings and natriuretic peptides) and, for those in whom echocardiography was available (10% performed during index event and 90% during the 6 previous months), three quarters had a preserved ejection fraction (≥50%).

The characteristics of the patients included in the pre- and post-intervention groups had a very similar distribution, and significant differences were only observed in 5 out of the 45 variables examined: neoplasia and chronic treatment with renin-angiotensin system inhibitors were less frequent in the post-implementation period, and oxygen saturation, creatinine and use of intravenous diuretics in the ED were lower in this period (**Table 1**).

Outcomes

For the primary endpoint of30-day all-cause mortality there were no differences between cohorts; 9.4% pre-intervention and 9.7% post-intervention (HR=1.03, 95%CI=0.82-1.29) **(Table 2, Figure 2)**. For secondary outcomes, the mean DAOH during the first 30 days after the AHF index episode was 19.1 (95%CI=18.6-19.5) and 19.3 (95%CI=19.0-19.5), respectively (difference of -0.2 days, 95%CI from -0.4 to 0.8). We found no significant differences for the remaining secondary endpoints, with the exception of 30-day ED revisit due to AHF which was significantly higher in the post-intervention cohort (HR=1.24, 95%CI=1.04-1.47, **Table 2**). The percentage of patients with AHF directly discharged from the ED home did not change between periods (23.5% versus 24.4% in the pre- and post-intervention cohorts, respectively; OR=1.05, 95%CI=0.89-1.24; **Table 2**). Adjustment for age, sex, Barthel index and the 5 variables unequally distributed between both groups (neoplasia, chronic treatment with renin-angiotensin system inhibitors, pulse-oximetry, creatinine and use of intravenous diuretics) confirmed the results of the unadjusted analysis (**Table 2**).

Adherence of emergency physicians to MEESSI-AHF recommendations

Among the 1,575 patients included in the post-implementation cohort, risk stratification with the MEESSI-AHF scale was performed in 1,567 (98.9%). Of these, 582 patients (37.4%) were classified as low-risk (and "Discharge" was recommended to the attending physician) and 985 (62.6%) as increased risk (and "Admit" was recommended to the attending physician). The physicians' final decisions were congruent with the recommendation provided by the MEESSI-AHF scale in 1,104 cases (70.9%) and overruled in the remaining 453 (29.1%) (**Table 3**, **Figure 3**). The recommendation of "Discharge" was more frequently overruled than

"Admit" (56.4 and 12.8%, respectively), with an OR for overruling the discharge recommendation compared to the admit recommendation of 8.78, 95%CI=6.84-11.3 (**Table 3**, **Figure 3**). The main reasons for overruling the "Discharge" recommendation were the need for hospitalization for causes other than AHF (38.4% of cases) and appreciation of severity by physicians (29.3%), while the main reasons for overruling the "Admit" recommendation were no appreciation of severity by physicians (50.4%) and possible palliative (end of life) care at home (28.8%) (**Table 3**).

DISCUSSION

This study evaluated the impact of decision-making guided by patient risk stratification of the prognosis of patients diagnosed with AHF in the ED. The main conclusions were that no difference in clinical effectiveness endpoints were found and that emergency physicians had poor adherence to recommendations generated after risk stratification as their decisions were not aligned with the recommendations in nearly 30% of cases. On theoretical grounds, prompt risk stratification of AHF patients should help to better decide treatment intensity and patient allocation according to individualized risk **(9,20)** and this would improve outcomes. One potential cause of failure in obtaining these theoretical benefits of risk stratification is that recommendations by the risk stratification tool were not followed in nearly 30% of patients. In clinical practice, the lack of physicians' adherence to recommendations or even to evidence-based guidelines is a well-recognized issue **(21,22)**. In the design of this trial, the final decision about disposition was left to the treating emergency physicians, and this allowed protocol overruling. Notably, there was more overruling of the discharge recommendation (56% were finally hospitalized) than the hospitalization recommendations (only 13% were finally discharged). Clearly, physicians are more cautious than the rule takes into consideration, perhaps because they are hesitant about whether prompt and proper follow-up will be carried out. In addition, the need for hospitalization due to medical conditions other than the AHF decompensation was a common reason for overruling the recommendation, and these situations are not taken into consideration by the MEESSI-AHF scale. Moreover, failure in improving other outcomes aside from mortality could be related to the fact that the MEESSI-AHF scale and its recommendations are based on the risk of 30-day mortality, and it is not as accurate in predicting ED revisit or rehospitalization as it is in predicting mortality **(23)**. On this subject, machine-learning algorithms have shown to obtain better discrimination than conventional scales **(24)**.

Finally, it is also plausible that isolated intervention on disposition decisions is not enough to modify outcomes, especially when it only affects disposition decisions for a small group of patients. Our findings reflect previous work on the implementation of the CodeHF pathway in Canadian EDs, which was followed in only 13.5% of patients, and failed to reduce readmissions or in-hospital or 30-day mortality **(25)**. In addition to risk stratification, close follow-up and intervention after discharge, especially from the ED and in older patients, is crucial to improve outcomes **(26)**. However, we made intervention after discharge and did not determine the time between discharge and follow-up visit. Therefore, the potential for such an intervention remains to be tested, particularly for patients directly discharged from the ED. An ongoing trial is evaluating the impact of a multilevel guided discharge plan (including a checklist of clinical recommendations and resource activations, schedule of early follow-up visits, transfer of information to the primary care doctor, and written instructions for patients) for frail older patients diagnosed with acute AHF and discharged home from the ED **(27)**. Noteworthy, the implementation of early follow-up strategies after patient discharge can have additive effects to risk stratification and help to achieve improved outcomes. Lee *et al.* recently demonstrated that risk stratification of ED patients with AHF using the EHMRG (Emergency Heart failure Mortality Risk Grade) scale for prediction of 7-day mortality **(28)** to support clinical decisions together with rapid follow-up of discharged patients led to a 12% reduction in the risk of a

composite outcome of all-cause death or hospitalization for cardiovascular causes within 30 days compared to usual care **(29)**. Finally, implementation of programs of hospital at home for patients with AHF, which may even be directly used for patients discharged from the ED, can favorably impact some outcomes, quality of life and economic costs **(30-32)**.

Limitations

First, this study was carried out in a single country. Spain has a universal public health care system and caution must be taken when extrapolating the results to other countries, especially those with other health care organizations**.** On the other hand, hospitalization rates in Spain (around 75%, as in the present study) are ranked among those reported in Canada (around 65%) and the US (around 85%) and the generalizability of our results to other countries and health care systems should be made with caution **(8)**. Second, patients were of advanced age (median of 85 years) and predominantly had a preserved left ventricular ejection fraction (LVEF, median 55%). Thus, results in younger cohorts could differ from those obtained in this trial. Third, while recommendations were based on risk stratification calculated at patient arrival to the ED, response to treatment provided during patient stay in the ED was not considered by the tool. Significant improvement with diuretics and ensuring treatment with disease-modifying drugs for patients with reduced LVEF before ED discharge may allow discharge and prevent ED revisits and other adverse outcomes **(33)**. Fourth, we measured DAOH during the 30 days following the index event while other similar studies have used longer follow-up periods (60 or 90 days) **(34,35)**. Nonetheless, as the difference found between the pre- and post-intervention period was minimal for this outcome (medians differed by only 0.2 days), we believe that a longer follow-up would not have changed our findings. Fifth, this is a before and after study, and although no gross relevant changes were recorded between the two periods in the participating hospitals and EDs, we cannot rule out residual confounding due to slight changes in working physicians, waiting times in EDs, cardiologist consultation by emergency physicians, or follow-up strategies. Finally, as the MEESSI-AHF scale was published in 2017, some physicians may have used it in some patients to stratify risk during the pre-implementation phase (January-February 2018). However, we believe this factor barely influenced our results, as use of the MEESSI-AHF scale was minimal at that time and physicians were specifically advised not to use the MEESSI scale.

Conclusions

Implementation of a risk stratification tool to guide decisions in the ED did not improve outcomes in patients with AHF. The reasons for these neutral results are unclear but could be due to lack of effectiveness of the tool or low adherence of emergency physicians to recommendations provided by the tool.

Contributors: OM conceived and designed the study. PLL, XR, VG, CS, JJ, PHP, MPLD, LLLL, RR, MF, JT, CB, AAA, EM, HB, FP, FJMS and SP conducted the data analysis. All authors contributed to the implementation, data acquisition, manuscript preparation and subsequent revisions.

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Ethics approval: Ethics approval for this protocol was granted by the Ethical Committee of the Hospital Clinic, Barcelona, Catalonia (Spain) with the protocol number HCB/2018/0233. The study was conducted with strict adherence to the ethical principles for medical research involving human subjects stated in the Declaration of Helsinki.

Data sharing statement: Unpublished data are available by email request from the corresponding author.

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Table 1: Baseline characteristics corresponding to patients included in the present study and comparison between the pre-implementation (before-MEESSI) and post-implementation (after-MEESSI) cohorts.

	Total N=3,164 n (%)	**Before-MEESSI N=1,589 n (%)**	**After-MEESSI N= 1,575 n(%)**	**p value**	**Missing values** n (%)
Demographic data					
Age (years) [median (IQR)]	85 (78-89)	85 (79-89)	85 (78-89)	0.051	0
Female	1,755 (55.7)	911 (57.3)	844 (54.0)	0.062	13 (0.4)
Comorbidities					
Hypertension	2,582 (81.7)	1,290 (81.3)	1,292 (82.0)	0.613	3 (0.1)
Diabetes mellitus	1,186 (37.5)	587 (37.0)	599 (38.0)	0.554	3 (0.1)
Coronary artery disease	782 (24.7)	393 (24.8)	389 (24.7)	0.958	3 (0.1)
Chronic kidney failure (creatinine >2 mg/mL)	929 (29.4)	457 (28.8)	472 (30.0)	0.477	3 (0.1)
Cerebrovascular disease	371 (11.7)	196 (12.4)	175 (11.1)	0.276	3 (0.1)
Atrial fibrillation	1,629 (51.5)	835 (52.6)	794 (50.4)	0.209	3 (0.1)
Peripheral artery disease	296 (9.4)	158 (10.0)	138 (8.8)	0.249	2 (0.1)
Heart valve disease	756 (23.9)	402 (25.3)	354 (22.5)	0.060	2 (0.1)
Prior episodes of acute heart failure	2,035 (64.3)	1,036 (65.2)	999 (63.4)	0.299	0
Chronic obstructive pulmonary disease	739 (23.4)	375 (23.6)	364 (23.1)	0.731	2 (0.1)
Dementia	318 (10.1)	175 (11.0)	143 (9.1)	0.069	2 (0.1)
Active neoplasia	458 (14.5)	254 (16.0)	204 (13.0)	**0.015**	2 (0.1)
Baseline status					
Barthel Index (points) [median (IQR)]	90 (70-100)	90 (70-100)	90 (70-100)	0.396	63 (2.0)
NYHA class III-IV	759 (24.7)	373 (24.0)	386 (25.5)	0.359	96 (3.0)
Left ventricular ejection fraction (%) [median (IQR)]	55 (49-63)	55 (50-64)	55 (49-62)	0.193	1,091 (34,5)
Left ventricular ejection fraction <50%	523 (25.2)	251 (25.0)	272 (25.5)	0.796	
Chronic treatments at home					
Diuretics (any)	2,280 (72.2)	1,132 (71.6)	1,148 (72.9)	0.419	8 (0.3)
RAS inhibitors	1,649 (52.2)	866 (54.8)	783 (49.7)	**0.004**	8 (0.3)
Neprilysin inhibitor	44 (1.4)	19 (1.2)	25 (1.6)	0.356	8 (0.3)
Beta-blocker	1,467 (46.5)	712 (45.1)	755 (47.9)	0.106	9 (0.3)
Mineralocorticoid-receptor antagonist	390 (12.4)	198 (12.5)	192 (12.2)	0.776	8 (0.3)
Triggering factor for the current AHF episode					
Infection	1,448 (45.9)	739 (46.8)	709 (45.0)	0.314	10 (0.3)
Rapid atrial fibrillation	452 (14.3)	223 (14.1)	229 (14.5)	0.738	10 (0.3)
Anemia	215 (6.8)	102 (6.5)	113 (7.2)	0.426	10 (0.3)
Hypertensive emergency	122 (3.4)	53 (3.4)	69 (4.4)	0.143	10 (0.3)
Dietetic or therapeutic transgression	102 (3.2)	55 (3.5)	47 (3.0)	0.428	10 (0.3)
Acute coronary syndrome	84 (2.7)	44 (2.8)	40 (2.5)	0.667	10 (0.3)
Vitals at ED during acute episode [median (IQR)]					
SBP (mmHg)	138 (120-156)	139 (120-157)	138 (120-155)	0.257	14 (0.4)
Heart rate (bpm)	84 (70-100)	83 (70-100)	85 (71-101)	0.159	115 (3.6)
Respiratory rate (bpm)	22 (18-27)	22 (18-28)	22 (18-28)	0.666	631 (19.9)
Room air oxygen saturation (%)	94 (90-96)	93 (90-96)	94 (90-96)	**0.043**	52 (1.6)
Results of blood tests at ED					
Glucose (mg/dL) [median (IQR)]	128 (106-168)	128 (106-167)	129 (106-168)	0.640	75 (2.4)
Creatinine (mg/dL) [median (IQR)]	1.2 (0.6-1.6)	1,1 (0,9-1,5)	1,2 (0,9-1,6)	**0.004**	45 (1.4)
Hemoglobin (g/L) [median (IQR)]	122 (109-135)	122 (109-135)	121 (109-135)	0.611	28 (0.9)
Anemia (<110 g/L)	835 (26.6)	415 (26.3)	420 (27.0)	0.677	-
Potassium (mmol/L) [median (IQR)]	4.4 (4.0-4.8)	4.4 (4.0-4.8)	4.4 (4.1-4.8)	0.336	191 (6.0)
Hyperpotassemia (>5.5 mmol/L)	166 (5.6)	73 (5.0)	93 (6.1)	0.191	-
Sodium (mmol/L) [median (IQR)]	140 (137-142)	140 (137-142)	140 (137-142)	0.651	127 (4.0)
Raised troponin (>99th percentile)	685 (36.7)	314 (35.0)	371 (38.3)	0.137	1,297 (41.0)
NT-proBNP (pg/mL) [median (IQR)]	4,164 (2,064-8,705)	3,941 (2,031-8,537)	4,320 (2,102-8,898)	0.160	746 (23.6)
Management in ED					
Need for intravenous diuretics	2,472 (78.3)	1,209 (76.4)	1,263 (80.2)	**0.010**	7 (0.2)
Need for intravenous/subcutaneous morphine	136 (4.3)	78 (4.9)	58 (3.7)	0.084	7 (0.2)
Need for intravenous nitrates	95 (3.0)	54 (3.4)	41 (2.6)	0.183	7 (0.2)
Need for inotropics/vasopressors	14 (0.4)	7 (0.4)	7 (0.4)	0.993	7 (0.2)
Need for non-invasive ventilation	152 (4.8)	80 (5.1)	72 (4.6)	0.524	7 (0.2)
Need for mechanical ventilation	19 (0.6)	9 (0.6)	10 (0.6)	0.810	7 (0.2)

ACE: angiotensin-converting enzyme; ARB: angiotensin receptor blocker; ED: emergency department; AHF: acute heart failure.
Bold p values denote statistical significance, and red p values correspond to those which, despite not being statistically significant, were included in the multivariate analysis for adjustments.

Table 2: Unadjusted and adjusted primary and secondary outcomes for patients included during the post-implementation period.

	Pre-implementation period N=1,589	**Post-implementation period N= 1,575**	**Unadjusted ratio** (95% CI)	**Adjusted ratio*** (95% CI)
Primary outcomes				
30-day all-cause mortality	9.4%	9.7%	HR = 1.03 (0.82-1.29)	HR = 1.14 (0.97-1.34)
Secondary outcomes				
In-hospital all-cause mortality	6.8%	7.4%	OR = 1.09 (0.83-1.43)	OR = 1.07 (0.80-1.43)
Days alive and out of hospital (mean (SD))	19.1 (8.8)	19.3 (8.6)	MD = 0.2 (-0.4 to 0.8)	MD = 0.1 (-0.5 to 0.8)
30-day post-discharge combined event	22.3%	23.3%	HR=1.12 (0.96-1.31)	HR=1.14 (0.97-1.34)
30-day ED revisit due to AHF	18.1%	20.7%	**HR=1.24 (1.04-1.47)**	**HR=1.26 (1.05-1.49)**
30-day hospitalization due to AHF	13.1%	13.8%	HR=1.05 (0.86-1.29)	HR=1.08 (0.88-1.33)
30-day post-discharge all-cause death	1.4%	1.6%	HR=1.19 (0.64-2.20)	HR=1.18 (0.63-2.18)
Patients fully managed in the ED				
Direct discharge home	23.5%	24.4%	OR = 1.05 (0.89-1.24)	OR = 1.01 (0.85-1.20)

**Covariates included in the adjusted model were the following: age, sex, Barthel Index, active neoplasia, chronic treatment with renin-angiotensin system inhibitors, pulse oxymetry and creatinine at emergency department arrival, and use of intravenous furosemide during emergency department stay as covariates.*

Ratios in bold numbers denote statistical significance (p<0.05)

ED: emergency department; SD: standard deviation; HR: hazard ratio; MD: means difference; OR: odds ratio.

Table 3: Severity of decompensation of patients included in the post-implementation period of the bM/aM trial and distribution according to whether final emergency physician decisions about discharge or admit were congruent with the recommendations based on the patient risk category assessed using the MEESSI-AHF scale.

	Post-implementation period N= 1,557
Severity of decompensation	
Risk stratification based on MEESSI-AHF (recommendation based on MEESSI-AHF)	
Low-risk (discharge home)	582 (37.4)
Increased risk (admit)	975 (62.6)
Intermediate risk (increased risk, hospitalization)	631
High risk (increased risk, hospitalization)	171
Very high risk (increased risk, hospitalization)	173
Final decision-making congruence with MEESSI-based recommendation	
All patients considered together (irrespective of the recommendation)	
Congruent	1,104 (70.9)
Non-congruent (overruling)	453 (29.1)
Patients for whom recommendation was "Discharge"	
Congruent (i.e., patient discharged)	254 (43.6)
Non-congruent (overruling) (i.e., patient hospitalized)	328 (56.4)
Reasons for overruling	
-Need for hospitalization for causes other than HF itself	*126 (38.4)*
-Appreciation of severity by physician	*96 (29.3)*
-Difficulty of management at home due to medical reasons	*32 (9.8)*
-First episode of HF	*15 (4.6)*
-Difficulty of management at home due to social reasons	*7 (2.1)*
-Very recent discharge from ED or hospitalization	*2 (0.6)*
-Cardiologist decision	*1 (0.3)*
-Palliative care initiation	*1 (0.3)*
-Patient/Family disconformity	*1 (0.3)*
-Not reported	*47 (14.3)*
Patients for whom counseling was "Admit"	
Congruent (i.e., patient hospitalized)	850 (87.2)
Non-congruent (overruling) (i.e., patients discharged)	125 (12.8)
Reasons for overruling	
-No appreciation of severity by physician	*63 (50.4)*
-Palliative care at home	*36 (28.8)*
-Cardiologist decision with walk-in clinic follow-up	*9 (7.2)*
-Patient/Family disconformity (discharged against medical advice)	*4 (3.2)*
-Dying in the ED while awaiting in-hospital bed	*3 (2.4)*
-Symptoms control and patient improvement during ED stay	*2 (1.6)*
-Unknown	*8 (6.4)*

ED: emergency department; HF: heart failure.

LEGENDS FOR FIGURES

Figure 1: Flow chart for patient inclusion

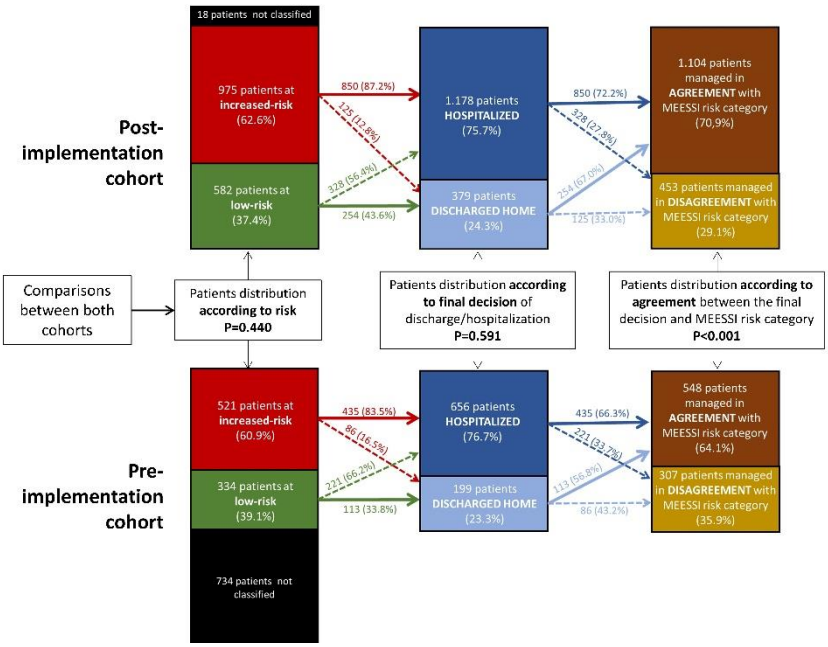

Figure 2: Unadjusted primary outcome in the pre-intervention (before MEESSI) and post-intervention (after MEESSI) cohorts.

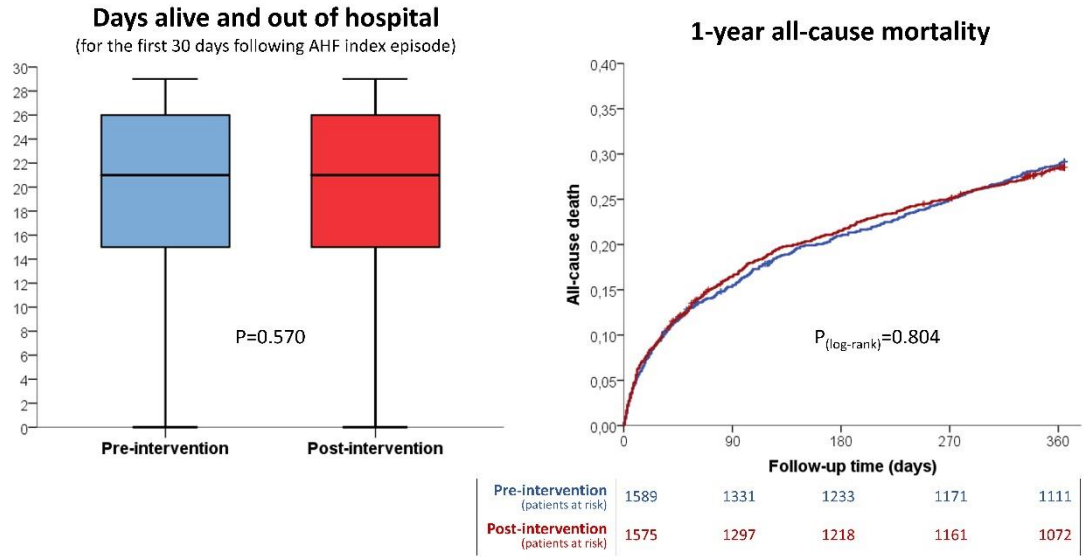

Figure 3: Classification of patients included in the post-implementation period according to whether the final decision was or was not in agreement with the recommendation proposed by MEESSI-AHF scale.