

# BMJ Open One-year rehospitalisations for congestive heart failure in Portuguese NHS hospitals: a multilevel approach on patterns of use and contributing factors

Bruno Moita,<sup>1,2</sup> Ana Patricia Marques,<sup>3,4</sup> Ana Maria Camacho,<sup>2</sup> Pedro Leão Neves,<sup>2,5</sup> Rui Santana<sup>3,4</sup>

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<sup>1</sup>Escola Nacional de Saúde Pública, Universidade Nova de Lisboa, Lisboa, Portugal

<sup>2</sup>Centro Hospitalar Universitário do Algarve, Faro, Portugal

<sup>3</sup>Departamento de Políticas e Gestão dos Sistemas de Saúde, Escola Nacional de Saúde Pública, Universidade Nova de Lisboa, Lisboa, Portugal

<sup>4</sup>Centro de Investigação em Saúde Pública, Universidade Nova de Lisboa, Lisboa, Portugal

<sup>5</sup>Departamento de Ciências Biomédicas e Medicina, Universidade do Algarve, Faro, Portugal

## Correspondence to

Bruno Moita;  
[b.moita@ensp.unl.pt](mailto:b.moita@ensp.unl.pt)

## ABSTRACT

**Objectives** Identification of rehospitalisations for heart failure and contributing factors flags health policy intervention opportunities designed to deliver care at a most effective and efficient level. Recognising that heart failure is a condition for which timely and appropriate outpatient care can potentially prevent the use of inpatient services, we aimed to determine to what extent comorbidities and material deprivation were predictive of 1 year heart failure specific rehospitalisation.

**Setting** All Portuguese mainland National Health Service (NHS) hospitals.

**Participants** A total of 68 565 hospitalisations for heart failure principal cause of admission, from 2011 to 2015, associated to 45 882 distinct patients aged 18 years old or over.

**Outcome measures** We defined 1 year specific heart failure rehospitalisation and time to rehospitalisation as outcome measures.

**Results** Heart failure principal diagnosis admissions accounted for 1.6% of total hospital NHS budget, and over 40% of this burden is associated to patients rehospitalised at least once in the 365-day follow-up period. 22.1% of the patients hospitalised for a principal diagnosis of heart failure were rehospitalised for the same cause at least once within 365 days after previous discharge. Nearly 55% of rehospitalised patients were readmitted within 3 months. Results suggest a mediation effect between material deprivation and the chance of 1 year rehospitalisation through the effect that material deprivation has on the prevalence of comorbidities. Heart failure combined with chronic kidney disease or chronic obstructive pulmonary disease increases by 2.8 and 2.2 times, respectively, the chance of the patient becoming a frequent user of inpatient services for heart failure principal cause of admission.

**Conclusions** One-fifth of patients admitted for heart failure are rehospitalised due to heart failure exacerbation. While the role of material deprivation remained unclear, comorbidities considered increased the chance of 1 year heart failure specific rehospitalisation, in particular, chronic kidney disease and chronic obstructive pulmonary disease.

## Strengths and limitations of this study

- Study focus on heart failure, a condition presenting growing incidence and prevalence trends in ageing populations, with significant burden to society, yet, a condition for which timely and appropriate outpatient care can potentially prevent inpatient admissions.
- A unique analysis of patterns of use, comorbidity and material deprivation association with 1 year specific rehospitalisation for heart failure, adopting a multilevel approach, allowing repeated observations per patient, covering a 5-year follow-up period and all admissions from an entire National Health Service public hospitals population.
- To authors' best knowledge, the first study for the Portuguese setting addressing specific comorbidity and socio-economic association with the risk of 1 year specific rehospitalisation for heart-failure.
- Study relied on administrative discharge data source, with International Classification of Diseases, Ninth Revision, Clinical Modification classification, as granular clinical parameters and serum markers results were not available.
- The assessment of socioeconomic status (SES) was made at municipality level, using Carstairs Index methodology, as no individual SES measures were available.

## INTRODUCTION

Symptomatic heart failure affected 37.7 million patients worldwide in 2010, led to 4.2 million years lived with disability<sup>1</sup> and was the leading cause of hospitalisation for older adult population in Europe and in the USA.<sup>2</sup> In Europe, the prevalence of symptomatic heart failure in general population is estimated to range from 0.4% to 2.0%.<sup>3</sup> Recent projections show that, in the USA, more than 8 million inhabitants, aged 18 or over, are likely to be diagnosed with heart failure by 2030, representing a 46% prevalence increase compared with 2014.<sup>4</sup>

Heart failure (HF) is widely recognised as an ambulatory care sensitive condition (ACSC),<sup>5-9</sup> meaning that a timely and effective outpatient care can help reduce the risk of hospitalisation by either preventing the onset of an illness or condition, controlling an acute episodic illness or condition or managing a chronic disease or condition.<sup>10</sup> However, potential preventability of heart failure related hospitalisations should be interpreted with caution since the disease is a chronic progressive disorder and its preventability is expected to decrease with the progression of the condition.<sup>11</sup>

Hospitalisations for HF are strongly associated to age, sex, to a set of clinical parameters and to the presence of other chronic conditions. Among these, ischaemic heart disease (IHD), hypertension, diabetes, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD) and previous myocardial infarction are conditions frequently referenced.<sup>2 3 12</sup> Patients' attitudes and preferences towards treatment and disease management,<sup>13-15</sup> as well as socioeconomic status, are factors also associated with the incidence and prevalence of HF, the outcomes of care and healthcare use.<sup>16-18</sup>

Systematic use of inpatient services, apart from flagging potential deficits of hospital previous effectiveness, lack of transitional-care strategies and quality of follow-up outpatient care, is associated with inefficient use of scarce resources and increased risk of adverse events.<sup>19-22</sup>

Several underlying measures have been used to capture systematic use of inpatient services. Depending on the focus of the analysis, either frequency, intensity of use or the combination of both are reported.<sup>23-26</sup> In that related to frequency of use, 30-day readmission rates are widely referenced. The assessment of longer time intervals between hospitalisations, addressing the concept of patients with multiple admissions,<sup>13 27-29</sup> may reveal patterns not apparent within 30 days after previous discharge<sup>30</sup> and increase the probability that rehospitalisations captured are related to outpatient quality of care.<sup>31</sup> Therefore it is apparently aligned with the premises of HF as ACSC.

The purpose of the present study was to describe frequent use of inpatient services for HF principal cause of admission, at national level in a universal and free healthcare service, and to determine to what extent comorbidities and material deprivation were predictive of 1 year HF specific rehospitalisations. To authors' present and best knowledge little evidence has been produced adopting a multilevel approach and scarce literature has been found for the Portuguese context.

## METHODS

### Data sources and study population

Inpatient discharge minimum data set containing data from all mainland Portuguese National Health Service (NHS) public hospitals (n=51) was used. Raw data set contained information on 4 922 330 inpatient discharges

from 1 January 2011 until 31 December 2015 associated to 2 574 887 unique patients.

A unique patient identifier, irreversibly encrypted by data provider, was available and used to follow each patient throughout the period. For each inpatient entry, the data set contains information on patients' age, gender, place of residence and on discharge diagnosis (up to 75), procedures (up to 75), discharge status of the patient, institutional hospital provider, admission and discharge dates and length of stay. Diagnosis and procedures were coded according to International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

### Data preparation and outcome measures

A set of validation routines were applied to the raw data set. We excluded all observations with missing unique patient identifier, missing gender, missing municipality of residence or not living in mainland Portuguese municipalities, duplicate entries and entries with errors. The second step excluded observations with no HF principal diagnosis and observations associated to patients aged under 18 years old at date of admission.

Panel data, allowing repeated observation per patient in different years, with summary measures of all included hospitalisations was defined as our working database, containing a total of 51 310 observations, associated to 45 882 distinct patients and 68 565 hospitalisations.

HF was identified according to Agency for Healthcare Research and Quality (AHRQ) prevention quality indicator on heart failure admission rate.<sup>5</sup>

A binary variable indicating 1 year specific heart failure frequent use was defined as our primary outcome measure. This variable indicates whether a patient was associated to two or more admissions with a principal diagnosis of HF in a 365-day look-back period. Similarly, it can also be read as an indicator on whether the patient was rehospitalised at least once for HF specific cause in a 365-day period.

Identification of systematic use of inpatient services was made adapting Canadian Institute for Healthcare Information methodology<sup>25 32</sup> to exclusively capture frequency of use. Index admission was defined as the most recent admission in each civil year, and the assessed year and 365-day look-back period were defined based on index admission date. This approach requires data from three civil years to assess frequent use over a 365-day look-back period. Consequently, initial data from 2011 until 2015 allowed us to assess frequent use in 2012, 2013 and 2014.

Ischaemic heart disease, diabetes, hypertension, chronic obstructive pulmonary disease, previous myocardial infarction and chronic kidney disease were identified as comorbidities, based on literature review,<sup>33-36</sup> from the set of diagnosis present in each discharge (see online supplementary data 1). The enhanced ICD-9-CM version of Charlson Comorbidity Index was computed as defined by Quan *et al* to assess aggregate differences in severity of comorbidities other than HF.<sup>37</sup>

To assess small-area, municipality-level material deprivation Carstairs Index was computed based on methodological notes by Brown *et al*,<sup>38</sup> with adaptations related to data availability. A 2011 Portuguese census data<sup>39</sup> on male unemployment, overcrowded households, population not using individual transport in commuting and households with low social class active head were normalised and summed to construct the composite index (see online supplementary data 2). The index was stratified in population-weighted quintiles, in ascending order of material deprivation, each municipality classified accordingly, and matched to each patient municipality of residence.

### Statistical analysis

Baseline characteristics are presented as percentages or mean. Distributional tests were performed and differences in baseline characteristics were tested using chi-squared, Mann-Whitney and proportion z-tests.

To assess municipality-level geographical variation, population-weighted age standardised yearly heart failure use rate and frequent use rate per 10 000 inhabitants, aged 20 years or older, were computed considering the number of patients verifying use or frequent use in each year. Direct standardisation approach was used assuming 2013 European standard population.<sup>40</sup>

To predict 1 year specific HF frequent use chance, logistic regression analysis assuming hierarchical multi-level modelling with random effects was adopted. Our baseline assumed a three-level random-intercept logistic regression model with year observations *i* nested in patients *j* in turn nested in municipalities *k*. As we allowed repeated observations per patient in different years, the lowest level of aggregation was specific patient year data. The underlying motivation for multilevel modelling resides in the fact that higher-level factors might influence lower-level outcomes<sup>41 42</sup> and consequently, coefficients are corrected for attenuation due to unobserved heterogeneity at different levels.<sup>43</sup> Preliminary analysis of residual intraclass correlation have shown no association between latent measurements of frequent use ( $\approx 1\%$ ) in the same municipality. This suggest that dropping municipality level would produce similar estimates and, consequently, a parsimonious approach was adopted and analysis was conducted with two levels (see online supplementary data 3).

As estimations were made over a sample of users of inpatient services for HF, each coefficient must be interpreted as the increased chance of becoming frequent user among patients that already use inpatient services

**Table 1** Sociodemographic and morbidity characteristics of heart failure patients with inpatient admissions in NHS Portuguese public hospitals from 2012 to 2014

	Occasional users*		Frequent users†		Tests on mean or proportions differences	
	n=39 994 patients		n=11 316 patients		Test	P value
	Mean or %	SD	Mean or %	SD		
Age (years)	79.0	10.9	78.9	10.3	Mann-Whitney	<0.001
Female (%)	56.5		55.8		Proportions z-test	0.1847
Discharge status (%)						
Alive	85.5		81.0		Proportions z-test	<0.001
Death	14.5		19.0			
Charlson comorbidity index (ungrouped score)	2.7	1.6	3.0	1.5	Mann-Whitney	<0.001
Ischaemic heart disease (%)	22.6		37.4		Proportions z-test	<0.001
Diabetes (%)	35.0		46.5		Proportions z-test	<0.001
COPD (%)	15.9		25.9		Proportions z-test	<0.001
Hypertension (%)	67.4		81.2		Proportions z-test	<0.001
Previous myocardial infarction (%)	7.0		14.7		Proportions z-test	<0.001
Chronic kidney disease (%)	25.0		46.5		Proportions z-test	<0.001
Material deprived municipality (%)					$\chi^2$	<0.001
Quintile 1 - least deprived	21.2		19.2			
Quintile 2	20.4		20.1			
Quintile 3	18.0		16.2			
Quintile 4	22.6		25.9			
Quintile 5 - most deprived	17.8		18.6			

\*One heart failure principal diagnosis admission within 365-day look-back period

†Two or more heart failure principal diagnosis admissions within 365-day look-back period.

COPD, chronic obstructive pulmonary disease; NHS, National Health Service.

for HF. For instance, despite a given covariate might be associated with a higher chance of inpatient use for HF, it might not be significant to differentiate frequent from occasional users.

Sensitivity analysis was performed to test for the hypothesis of biased results due to the inclusion of patients that died in any of the admissions included.

All statistical analyses were performed using Stata (StataCorp, Texas, USA) V.14.2 and assuming a 5% level of significance.

## RESULTS

From 2012 to 2014, 51 310 patients with a principal diagnosis of heart failure were hospitalised in NHS Portuguese public hospitals. These patients had 68 565 admissions corresponding to 665 000 bed-days occupied and costing, in inpatient hospital services, up to EUR 193 million, around 1.6% of total Portuguese hospital NHS budget.

Baseline characteristics of the patients at first admission (see online supplementary data 4) show prevalence of females (56.3%), advanced age of patients (78.4 years old) and an average ungrouped Charlson Comorbidity Score of 2.7. The most prevalent comorbidities associated to patients admitted for HF were hypertension (69.6%), diabetes (36.5%), CKD (28.2%) and ischaemic heart disease (24.7%).

We found that 22.1% (n=11 316) of the patients were classified as frequent users. These patients were rehospitalised for HF principal cause of admission at least once within 365 days after previous discharge for the same condition, accounted for 41.6% (EUR 80 million) of total HF inpatient costs in the period considered and represented an average annual cost of EUR 27 million.

Table 1 summarises sociodemographic and clinical characteristics of HF patients by inpatient type of use: occasional users and frequent users.

Except for gender, all covariates were associated with frequent use and differences found statistically significant.

Patients aged 65 years or older represented 89.6% (n=45 980) of observations. Despite significant, arguably by sample size, age difference between occasional and frequent users is small. Frequent users are 0.1 years younger than occasional users.

Frequent users had higher Charlson Comorbidity Scores revealing increased severity of comorbidities other than HF and 19% died in hospital following an inpatient admission for HF principal diagnosis. Patients who died during an inpatient stay were significantly older (82.6 years vs 78.2 years), 55.8% were females and had a higher Charlson Comorbidity Score (2.96 vs 2.71). Prevalence of comorbidities was higher among rehospitalised patients and larger relative differences were found for previous myocardial infarction, ischaemic heart disease, chronic kidney disease and COPD.

Despite tenuous, compared with HF occasional users, HF frequent users present lower relative frequency in

**Table 2** Association between municipality material deprivation index and Charlson comorbidity score among patients hospitalised for heart failure in Portuguese National Health Service hospitals, 2012 to 2014 (n=51 310)

Material deprivation	Average Charlson score		
	Occasional users*	Frequent users†	Total
Quintile 1 - least deprived	2.43 (1.45)	2.71 (1.29)	2.49 (1.42)
Quintile 2	2.62 (1.59)	2.88 (1.40)	2.68 (1.56)
Quintile 3	2.64 (1.57)	2.94 (1.48)	2.70 (1.56)
Quintile 4	2.83 (1.71)	3.22 (1.58)	2.93 (1.69)
Quintile 5 - most deprived	2.89 (1.76)	3.27 (1.65)	2.98 (1.74)

\*One heart failure principal diagnosis admission within 365-day look-back period.

†Two or more heart failure principal diagnosis admissions within 365-day look-back period; population-weighted quintiles; SD in parentheses.

less deprived municipalities and higher concentration on more deprived municipalities.

Table 2 shows that average Charlson Comorbidity Score increase with municipality material deprivation quintile. Moreover, also confirm the same trend stratifying results by type of inpatient use and show that, on average, patients rehospitalised within 1 year for HF have higher Charlson Comorbidity Scores than those who were not rehospitalised.

Table 3 summarises inpatient use characteristics by type of inpatient user.

On average, HF frequent users had 2.5 inpatient admissions ( $\sigma=1.0$ ) in a given year and 52% of these patients occupied an hospital bed for at least 20 days. HF specific rehospitalisation rate at 30 days was 4.9%, at 90 days 12.1%, at 180 days 17.8% and at 1 year 22.1%.

Frequent users amounting to 68.2% were rehospitalised for HF once within 1 year after previous discharge for HF (n=7715), 20.2% two times (n=2292) and 11.6% were rehospitalised three or more times (n=1309). Average time to rehospitalisation was 108 days ( $\sigma=93.3$ ) and 50% of rehospitalised patients were so within 78 days after previous discharge. Among 11 316 rehospitalised patients, 21.8% were so within 30 days and 54.9% within 90 days after previous discharge.

Average HF age standardised inpatient services use rate, for 2012 to 2014 period, was 21.2 per 10 000 adult inhabitants ( $\sigma=5.08$ ). Additionally, average HF age standardised inpatient services frequent use rate, for 2012 to 2014 period, was 4.67 per 10 000 adult inhabitants ( $\sigma=1.77$ ). Differences in proportions of HF frequent users at municipality level were assessed with chi-squared test and the null hypothesis for equal proportions was rejected ( $p<0.001$ ) suggesting an association between municipality and frequent user variable.

**Table 3** Inpatient use characteristics of heart failure patients with inpatient admissions in National Health Service Portuguese public hospitals from 2012 to 2014

	Occasional users*		Frequent users†		Tests on mean or proportions differences	
	n=39 994 patients		n=11 316 patients		Test	P value
	Mean or %	SD	Mean or %	SD		
Admissions per patient (nr.)	1.0	0.0	2.5	1.0	Mann-Whitney	<0.001
Bed-days occupied (%)					$\chi^2$	<0.001
0–2 days	12.9		0.5			
3–9 days	51.4		12.2			
10–19 days	26.5		35.4			
20–29 days	5.9		24.5			
30–44 days	2.3		16.4			
≥45 days	1.0		11.1			
Average time to rehospitalisation (%)					--	--
0–30 days			21.8			
31–90 days			33.1			
91–180 days			25.7			
180–365 days			19.4			

\*One heart failure principal diagnosis admission within 365-day look-back period.

†Two or more heart failure principal diagnosis admissions within 365-day look-back period.

Bivariate analyses presented, despite relevant, fall short to estimate the association with the probability of becoming a frequent user for HF once other covariates are not controlled for. Even geographical rates were computed only controlling for age and omitting the fact that other covariates might play a significant role on explaining differences, as suggested by the results presented.

Table 4 summarises the logistic regression results for 1 year heart failure specific rehospitalisation assuming a two-level structure.

The first model considers material deprivation as the unique individual fixed effect and assumes patient level random effects. The second model adds to the first variables that does not vary with socioeconomic variations, that is, age and gender. The third one is the full model, which adds comorbidity covariates.

Model 1 material deprivation ORs show that, not taking into account other covariates, patients hospitalised for HF living in more deprived municipalities (quintiles 4 and 5) are more likely to become frequent users for HF than those who live in least deprived municipalities. In particular, those who had been hospitalised for heart failure and live in quintile 4 and quintile 5 material deprived municipalities are 1.29 and 1.17 times more likely to be rehospitalised for HF than those who live in quintile 1 material deprived municipalities. These estimates do not vary significantly after adjusting for age and sex (Model 2). However, material deprivation estimates are significantly reduced after comorbidity adjustment suggesting that material deprivation is indirectly associated with 1

year HF rehospitalisation through association it may have on the prevalence of comorbidities.

All comorbidities considered increase the chance of 1 year rehospitalisation and, in particular, chronic kidney disease and COPD have ORs of 2.8 and 2.2, respectively. Females are 1.15 times more likely to become HF frequent users than males; besides, age does not increase the chance of a HF inpatient user becoming frequent user when the prevalence of comorbidities is controlled for.

Sensitivity analysis was performed excluding patients with death discharge status. Results did not differ significantly from our baseline analysis and the hypothesis of biased estimates due to inclusion of patients who died was not confirmed (see online supplementary data 5).

## DISCUSSION

Heart failure admissions account for roughly 1.6% of total annual Portuguese hospital NHS budget, representing over EUR 65 million direct inpatient costs. Over 40% of this financial burden is attributable to patients that are admitted more than once for HF in a 365-day look-back period.

From 51 310 patients admitted due to HF, 22.1% were frequent users. HF frequent users had, on average, 2.5 inpatient admissions per year, 21.8% were rehospitalised within 30 days while 54.9% were rehospitalised within 90 days after previous discharge. Compared with patients with a single admission for HF, females and patients with CKD, COPD, hypertension, diabetes or IHD were more likely to become HF frequent users. Age was not associated

**Table 4** Two-level logistic regression results for the latent probability of becoming heart failure inpatient frequent user (n=51 310)

	Model 1 OR	Model 2 OR	Model 3 OR
<b>Fixed-effects parameters</b>			
Gender			
Female		0.968 (0.0266)	1.151*** (0.0287)
Age			
(65;74)		1.285*** (0.0512)	1.031 (0.0542)
(75;84)		1.256*** (0.0463)	1.010 (0.0490)
(85+)		1.075 (0.0483)	0.917 (0.0514)
Diabetes			1.345*** (0.0289)
Hypertension			1.904*** (0.0343)
COPD			2.181*** (0.0348)
Ischaemic heart disease			1.803*** (0.0358)
Previous myocardial infarction			1.537*** (0.0509)
Chronic kidney disease			2.804*** (0.0317)
Material deprivation			
Quintile 2	1.085* (0.0409)	1.084* (0.0408)	0.974 (0.0431)
Quintile 3	0.991 (0.0428)	0.988 (0.0428)	0.844*** (0.0453)
Quintile 4	1.299*** (0.0391)	1.303*** (0.0391)	0.968 (0.0418)
Quintile 5	1.169*** (0.0419)	1.173*** (0.0419)	0.833*** (0.0451)
Constant	0.180*** (0.0371)	0.156*** (0.0562)	0.0526*** (0.0725)
<b>Random-effects parameters</b>			
Patient			
SD (constant)	1.086* (0.0377)	1.079* (0.0380)	1.135** (0.0411)
LR test versus logistic model: chibar2(01)	354.73***	346.61***	306.79***
Aikaie information criteria	53 723.3	53 679.4	49 981.0
Residual intraclass correlation			
Patient	0.2639 (0.0146)	0.2614 (0.0147)	0.2814 (0.0166)
C-statistic (AUC)			
Without random-effects	0.5255	0.5351	0.6829

Note: Standard errors in parentheses; \*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

AUC, area under the curve; COPD, chronic obstructive pulmonary disease; LR, logistic regression.

with rehospitalisation increased probability. Our results also suggest a potential mediation effect between small-area material deprivation and the chance of 1 year rehospitalisation through the effect that material deprivation has on the prevalence of comorbidities.

We found that 22.1% of the patients (n=11 316) were rehospitalised for HF principal diagnosis at least once within 365 days after previous discharge. Similar 1 year specific HF rehospitalisation rates were found by Philbin for USA (21.3%), although lower than those found by Robertson *et al* (32%) and Al-Omary *et al* (27%) for Australia.<sup>44–46</sup> Other than potential differences on the prevalence and incidence of the disease and provider practices, both Australian studies present methodological options which can, in part, explain the higher rehospitalisation rate found. One year HF specific rehospitalisation

rates are significantly lower comparing to all-cause rehospitalisation rates among patients with HF and literature reports, for the latter, values consistently over 50% and up to 73%.<sup>45–47</sup>

Among patients hospitalised for HF, age was not associated to an increased chance of rehospitalisation for the same cause within 1 year after previous discharge. Philbin heart failure readmission risk model did not retained age as a predictor while Robertson *et al*, using different age stratification, found statistical significant increased ORs, despite small, only for patients aged 75 years or older.

We found that the presence of other comorbidities play a significant role on the probability of 1 year specific HF rehospitalisation. Frequent users present, on average, higher severity of illness and higher likelihood of 1 year post-discharge death, measured by Charlson Comorbidity

Score. HF patients with hypertension, COPD or chronic kidney disease are between 2.8 and 1.9 times more likely to be rehospitalised for HF exacerbation than patients with no comorbidities other than HF. Risk score model developed by Philbin retained renal disease, IHD and respiratory tract chronic diseases as predictors of higher risk of HF specific readmission. European Society of Cardiology HF guidelines also recognise the great importance of comorbidities, not only as contributors to the burden of hospitalisations, but also as constraints to the use of treatment technologies.<sup>33</sup>

Material deprivation association with the probability of the patient to become recurrent inpatient user for HF remained unclear. Living in material deprived municipalities was associated to increased Charlson Comorbidity Scores and higher chance of 1 year HF specific rehospitalisation. However, after adjusting for comorbidities significant lowered probability of rehospitalisation had been found for patients living in Carstairs Index quintile 3 and 5 municipalities. Witte *et al*<sup>18</sup> found no significant association between small area material deprivation and 1 year HF specific readmission. Nevertheless, these authors found evidence for all-cause readmission for HF patients and for total number of bed-days occupied. Eapen *et al*<sup>17</sup> found that county level socioeconomic status data is modestly associated with 30-day heart failure outcomes but do not improve risk adjustment models based on patients characteristics. With results obtained from present study we hypothesise an indirect association between material deprivation and the probability of 1 year specific rehospitalisation for heart failure through the association that material deprivation may have on the prevalence of comorbidities.<sup>48</sup> However, either Akaike information criterion and *c-statistic* variation between models is small, revealing that directed future mediation analysis should be designed to evaluate the hypothesised mediation effect.

### Strengths, limitations and implications

Our study has strengths and limitations. Once it relied exclusively on administrative discharge data sources, no specific inpatient care characteristics other than minimum discharge data set predefined variables were available, as well as information on outpatient care follow-up or granular clinical parameters. Among clinical parameters, evidence of association with all cause rehospitalisation rate has been found for left ventricular ejection fraction (LVEF), New York Heart Association Functional Classification (NYHA) and serum markers. In particular, unavailability of data regarding LVEF hinders the distinction of patients with preserved ejection fraction from those with reduced ejection fraction. Despite frequent inclusion of LVEF and NYHA in analyses as HF severity indicators, no consistent significant statistical association with readmission after hospitalisation for HF has been reported.<sup>34 49</sup>

Despite these limitations, notwithstanding that the availability of complementary information, including granular clinical parameters, would favour the external

validity of results obtained and provide valuable insights on contributing factors for HF rehospitalisations, our model discriminatory and predictive ability, being modest (*c-statistic*=0.68), is aligned with comparable studies.<sup>34</sup> The completeness and validity<sup>50</sup> of administrative national database covering all NHS hospital admissions in Portugal mainland and, consequently, distinct provider differentiation levels, clinical practices and patient characteristics, as well as the hierarchical regression modelling allowing to control for patient level unobserved heterogeneity, is a strength favouring generalisation of our findings.

Geographical aggregation of data was made at municipality level and multilevel modelling suggested no systematic geographical frequent use risk variation. Although our methodological options are supported either by demographic data availability or by a rationale justification, we acknowledge that data aggregation at different levels and different cut-offs might have produced different results.

Nearly 21.8% of patients (n=2466) were rehospitalised, on average, within 30 days and 54.9% (n=6207) within 90 days after previous discharge. This result is suggestive of potential opportunities for ambulatory care follow-up, disease management programmes and transitional care strategies, as a significant proportion of rehospitalisations fall outside the traditional 30-day time frame for index admission quality of care assessment. However, advanced age and multimorbidity associated to patients with HF raise the discussion on potential preventability of admissions associated to these patients. The inclusion of information related to outpatient follow-up may provide a valuable insight on potential preventability of inpatient hospitalisations and subsequent readmissions associated to patient with HF. While some authors report that siloed and fragmented care hinders the goal of reducing HF admissions and subsequent rehospitalisations<sup>14 51</sup> others suggest that early follow-up after discharge, multidisciplinary disease management, promotion of patient self-care literacy and same-day access clinics for outpatient intravenous diuresis are effective in reducing admissions for HF.<sup>33 52-55</sup>

Multiple hospitalisations for patients with HF are common but less than one half are due to cardiovascular causes and only roughly 30% of rehospitalisations are for a HF specific cause.<sup>45 56</sup> Our study focused, exclusively, on the latter. Hence, the positive externalities of successful health policy interventions and disease programme management might be highly leveraged by the potential impacts on preventing hospitalisations in patients with HF but due to other causes than HF.

### CONCLUSION

Heart failure hospitalisations represent a significant burden for health systems with growing trends in developed countries. Assessing patterns of 1 year rehospitalisations due to heart failure exacerbation allowed us to describe, for the first time for the Portuguese context and at national level, the extent of the phenomena and

provided useful insights on contributive factors. The presence of comorbidities was associated with an increased probability of 1 year rehospitalisation for heart failure exacerbation, confirming for this context previous reported associations. Our findings also suggest that the effect of living in material deprived municipalities was indirectly associated with the probability of rehospitalisation by the effect material deprivation has on the prevalence of comorbidities. Thus, successfully managing heart failure in outpatient setting, and consequently potentially preventing rehospitalisations, requires integrative and multidisciplinary approaches on care continuum.

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