



Influence of hospital adverse events and previous diagnoses on hospital care cost of patients with hip fracture

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Received: 16 January 2019 / Accepted: 28 July 2019

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Abstract

Summary Previous diagnoses of patients with hip fracture influence the hospitalization cost of these patients, either directly or by increasing the risk of in-hospital adverse events associated with increased costs.

Purpose To investigate how previous diagnoses influence the occurrence of in-hospital adverse events and how both factors impact on hospital costs.

Methods This is a retrospective analysis of the hospital Minimum Basic Data Set. Patients aged 70 years or older admitted for hip fracture (HF) at a single University Hospital between January 2012 and December 2016. Both, previous diagnoses and adverse events, were defined according to the International Classification of Diseases (ICD-9/ICD-10). The anticipated cost of each admission was calculated based on diagnosis-related groups and using the “all patients refined” method (APR-DRG). The occurrence of adverse events during hospital stay was assessed by excluding all diagnoses present on admission.

Results The record included 1571 patients with a mean (SD) age of 84 years. The most frequent previous diagnoses were diabetes ($n = 432$, 27.5%) and dementia ($n = 251$, 16.0%), and the most frequent adverse events were delirium ($n = 238$, 15.1%) and anemia ($n = 188$, 12.0%). The mean (SD) total acute care costs per patient were €8752.1 (1864.4). The presence of heart failure, COPD, and kidney disease at admission significantly increased the hospitalization cost. In-hospital adverse events of delirium, cardiac events, anemia, urinary tract infection, and digestive events significantly increased costs. The multivariate analyses identified kidney disease as a previous diagnosis significantly contributing to explain an increase in hospitalization costs, and delirium, cardiac disease, anemia, urinary infection, respiratory event, and respiratory infection as in-hospital adverse events significantly contributing to an increase of hospitalization costs.

Conclusions Although few baseline comorbidities have a direct impact on hospitalization costs, most previous diagnoses increase the risk of in-hospital adverse events, which ultimately influence the hospitalization cost.

Keywords Hip fracture · Hospitalization cost · Previous diagnoses · Hospital adverse events · Older patients

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s11657-019-0638-6>) contains supplementary material, which is available to authorized users.

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Introduction

Hip fractures have become a worldwide public health problem due to their associated high mortality and hospital costs. Although there is substantial variation in hip fracture incidence between populations [1–3], these fractures account for a small percentage of incidence of all injuries, although require hospitalization in more than 90% of cases [4, 5]. As a consequence, hip fractures are associated with an increased health care costs, mostly attributable to the index hospitalization (79.6% of the total inpatients' costs in the first year) [4–6].

Owing to the older age of patients with hip fracture (the prevalence peak ranges between 75 and 84 years old [7]), these patients present to the hospital with a history of previous diagnoses that may increase the risk of in-hospital adverse events. In these patients, the presence of three or more comorbidities has been identified as the strongest preoperative risk factor [8]. Both the severity and type of comorbidities and the number and type of perioperative complications are important factors associated with a mortality increase, either in-hospital or during follow-up after discharge [9–11]. Heart failure, chronic obstructive pulmonary disease, diabetes, kidney disease, and dementia are the most frequent comorbidities and those more frequently associated with longer hospital stay and increased death risk [7, 12–14]. Besides previous diagnoses, patients with hip fracture often have to deal with postoperative complications such as cognitive and neurological alterations, chest infection, heart failure, cardiopulmonary affections, gastrointestinal complications, urinary tract infection, and anemia. The appearance of any of these complications has also been associated with a longer hospital stay and an increased death risk [8, 15].

Although the prevalence of comorbidities and the incidence of in-hospital adverse events in these patients have been described, little is known regarding the influence of comorbidities existing at admission on the occurrence of in-hospital adverse events, and how all these factors influence the health care costs in a real-life scenario. To know this influence allows clinicians to intensify the sanitary measures of these patients, improving the management of the care process and reducing the costs of healthcare. In this retrospective study, we analyzed data from an administrative database to investigate how past medical history affects in-hospital adverse events, and how both influence hospitalization costs.

Methods

Study design and patients

This was a retrospective analysis of patients admitted for hip fracture at University Hospital La Ribera from January 2012

to December 2016. All data were obtained from the hospital's "Minimum basic data Set" (MBDS). This database was established in Spain in 1987 for the purpose of managing, planning, and evaluating health care, as well as gathering data for clinical and epidemiological research. Data recorded in the MBDS include information on demographic characteristics, main diagnosis, risk factors, and comorbidities present at admission (secondary diagnoses) and at discharge, relevant diagnostic techniques, and therapeutic interventions used to treat the patient. The MBDS also includes the date of admission and discharge of each patient, as well as the circumstance of admission (urgent, scheduled) and the patient's destination at discharge (e.g., patient's home, death, transfer to another hospital) [16, 17]. Diagnoses and procedures collected are codified according to the International Classification of Diseases in its ninth clinical modification, ICD-9-CM (ICD-10-CM was used since January 2016). Based on the raw data of the MBDS, each admission is classified in a specific Diagnosis Related Group (DRG), which is assigned a relative weight in terms of the "anticipated cost" for that patient [18]. From 2012, the version APR-DRG (All Patients Refined) of DRGs is available. In Spain, the official version from January of 2016 is APR32 [17].

Based on data recorded in the MBDS, all patients aged 70 years or older who had the ICD 820 code (hip fracture) were selected. To capture the real-life scenario of patients admitted because of hip fracture, no further exclusion criteria were established. All patients were assigned to a single analysis group. After the patient had been discharged, a specialized technician reviewed the patient's medical record and generated the corresponding MBDS. This procedure was facilitated by the Electronic Health Records (EHR) which includes all the administrative variables and diagnostic codes (ICD-9/ICD-10) coded by clinicians during the health care process.

The study was approved by the Committee of Ethics and Research of University Hospital La Ribera (Ref approval number PI150715). According to the local regulatory framework—which is compatible with the International Ethical Guidelines for Health-related Research Involving Humans by the Council for International Organizations of Medical Sciences (CIOMS) [19]—the Committee of Ethics considered that the informed consent was not required for this retrospective study. In agreement with the local Personal Data Protection Law (LOPD 15/1999), individual subject records were maintained in the investigator's Sources Documents, and the Case Reports Forms (CRFs) did not include any personal data.

Management of hip fracture patients

The routine practice in our center during the investigated period included a patient's assessment by a geriatrician, an anesthesiologist, and a traumatologist. The geriatrician carried out a

comprehensive geriatric assessment (CGA), including the assessment of the functional, cognitive, and social sphere, and the traumatologist decided on the suitability of the surgical treatment and the technique used. A specialized technician recorded information regarding the patient's comorbidity burden and clinical status from medical records. Both the traumatologist and the geriatrician monitored the patient's progression daily. After the surgical intervention, the rehabilitation service examined the patient and started rehabilitation treatment. Decisions regarding the patient's discharge were made by the traumatologist, the geriatrician, and the rehabilitator.

Variables and endpoints

Retrieved data included demographic characteristics (age and sex), previous diagnoses (diabetes mellitus, dementia, chronic obstructive pulmonary disease, kidney disease, ischemic cardiopathy, heart failure, and cerebrovascular disease), and in-hospital adverse events (delirium, anemia, heart disease, respiratory events, urinary tract infection, respiratory infection, surgical infection, and digestive events). Both, previous diagnoses and adverse events, were defined according to the ICD-9-CM/ICD-10-CM, and the comorbidity burden at admission was estimated based on the Charlson Comorbidity Index [20]. The difference between previous diagnoses and in-hospital adverse events were assessed using the APR32 version of the DRGs which incorporates the concept "present on admission" (POA) [21]. This concept defines whether the diagnosis was present at the time of admission (previous diagnosis) or was acquired during the hospital stay (adverse event). All secondary diagnoses not present at admission were considered adverse events occurred during hospital stay. The hospitalization cost of each patient was estimated based on the patient's APR-DRG. The cost increase due to adverse events experienced during the hospital stay was estimated by the difference between the APR-DRG cost at patient discharge and the anticipated APR-DRG cost at admission.

Statistical analysis

Qualitative variables were described as frequency and percentage and quantitative variables as the mean and standard deviation (SD). Differences in mean age and cost of patients with and without each previous diagnosis/adverse event were assessed using the independent samples *T* test. Differences in the distribution of CCI scores were assessed using the Mann-Whitney *U* test. Patients were grouped according to whether or not their hospitalization cost increased (i.e., the APR-DRG cost at discharge was higher than the anticipated APR-DRG cost at admission). The odds ratio (OR) of age, sex, previous diagnosis, and adverse events to contribute to increasing hospitalization costs were first computed in a univariate analysis.

Subsequently, all the explicative variables were included in stepwise logistic regression models in which the best-fit model was determined by excluding variables with a *p* value ≥ 0.1 . The results were presented as the OR and its 95% confidence interval (CI). For all analyses, the significance threshold was set at a bilateral alpha level of 0.05. All analyses were carried out using the packages *fStats* 1.0 (Biostatistics and Investigation Department Medicine and Odontology, Faculty Catholic University of Valencia San Vicente Mártir, Valencia, Spain) and SPSS (Version 23.0. Armonk, NY: IBM Corp).

Results

Patient characteristics

Between January 2012 and December 2016, 1571 patients aged 70 to 104 years (mean 84; SD 6.1) were admitted to our hospital because of a hip fracture. Of them, 1163 (74%) were female. The mean CCI at admission was 2.4 (SD 2.3). The mean surgical delay was 43 h (SD 30.8), and the mean length of hospital stay was 8 days (SD 3.3). Sixty-six patients died during hospital stay (in-hospital mortality rate 4.2%).

Table 1 summarizes the frequency of each previous diagnosis recorded at admission and each adverse event occurred during the hospital stay. No significant differences in age were

Table 1 Previous diagnoses and adverse events reported in study patients (*N* = 1571)

	No. (%)	Age, years Mean (SD)	<i>p</i> value*
Previous diagnoses			
Diabetes	432 (27.5)	83.4 (5.8)	0.002
Dementia	251 (16.0)	84.7 (6.3)	0.166
COPD ^a	186 (11.8)	83.3 (6.1)	0.056
Kidney disease	179 (11.4)	84.5 (6.5)	0.375
Ischemic cardiopathy	109 (6.9)	84.0 (6.1)	0.772
Heart failure	103 (6.6)	84.2 (6.2)	0.941
Cerebrovascular disease	29 (1.8)	82.7 (8.1)	0.196
Adverse events			
Delirium	238 (15.1)	86.5 (5.6)	< 0.001
Anemia	188 (12.0)	84.2 (6.6)	0.893
Cardiac disease	101 (6.4)	86.1 (6.4)	0.001
Respiratory events	67 (4.3)	85.2 (6.5)	0.147
Urinary tract infection	50 (3.2)	83.3 (6.5)	0.354
Respiratory infection	23 (1.5)	86.2 (7.0)	0.119
Surgical infection	10 (0.6)	84.4 (6.2)	0.899
Digestive events	7 (0.4)	83.9 (9.2)	0.902

^a COPD chronic obstructive pulmonary disease

**p* value was calculated between the mean age of the patients with AE or PD and the age of the patients without that characteristic

found between patients with and without each of the previous diagnoses, except for diabetes: mean (SD) age was 83.4 (5.8) and 84.5 (6.4) years for patients with and without diabetes, respectively ($p = 0.002$). Regarding adverse events occurring during hospital stay, patients experiencing delirium or heart disease were significantly older than those without the effect: mean (SD) age of patients with and without delirium were 86.5 (5.6) and 83.7 (6.3) years, respectively ($p < 0.001$) and those of patients with and without heart disease were 86.1 (6.4) and 84.0 (6.3) years, respectively ($p = 0.001$) (Table 1).

Hospitalization cost

The mean total care cost per patient was €8752.1 (SD 1864.4). Compared with patients without an increase of the hospitalization cost, those with events during hospital stay leading to an increase in cost were more frequently men (37.6% vs 24.5%; $p < 0.001$), older (mean [SD] age 85.6 [6.6] vs. 84.0 [6.2] years; $p = 0.001$), and had a higher comorbidity burden (median scores were 3 vs. 2; patients with cost increase due to in-hospital adverse events had systematically higher scores; $p < 0.001$).

Fig. 1 **a** Mean hospitalization cost and incidence of each previous diagnose. **b** Mean difference cost between the APR-DRG at discharge and the APR-DRG at admission per each adverse effect and incidence of the adverse effect. The dashed red line indicates the mean of the cost variable in each case

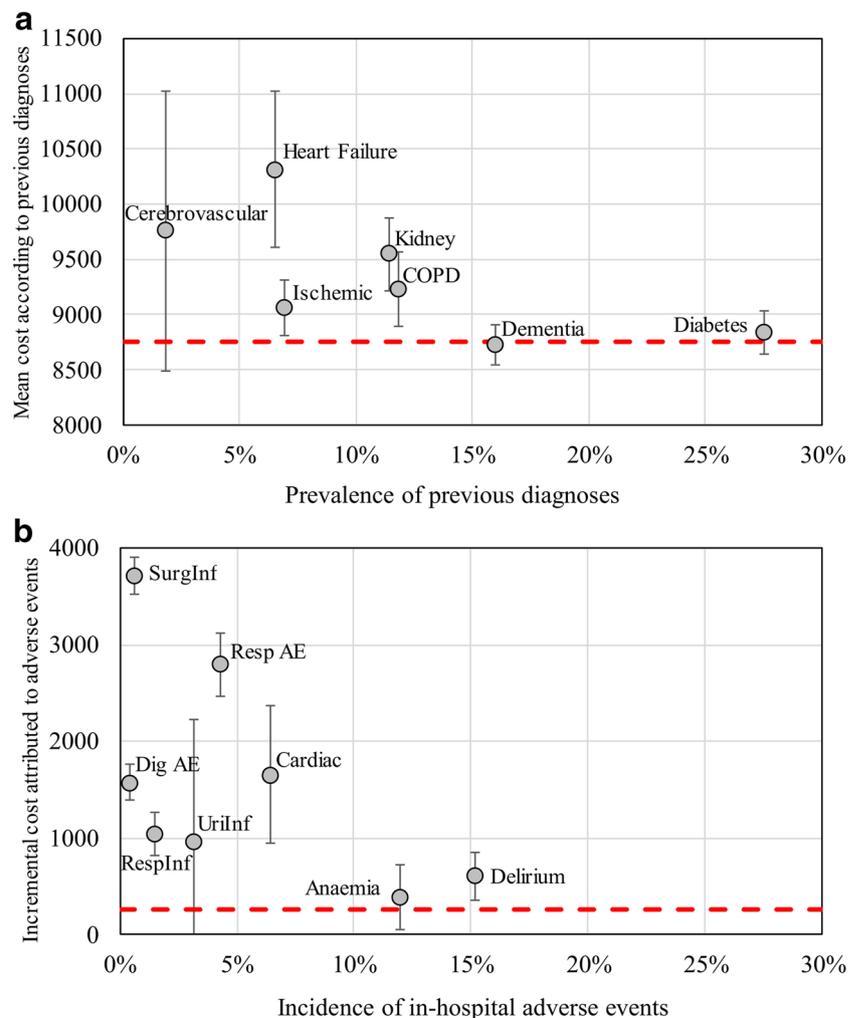


Figure 1 summarizes the hospitalization cost according to the presence of previous diagnoses and the occurrence of in-hospital adverse events. Heart failure was the previous diagnosis with the highest impact on hospitalization cost: mean difference in cost between patients with and without heart failure was €1670.5 ($p < 0.001$) (Fig. 1a). Other previous diagnoses with significant influence on incremental hospital costs were COPD (mean difference €543.6; $p < 0.001$), cerebrovascular disease (mean difference €1022.0; $p = 0.003$), and kidney disease (mean difference 899.3; $p < 0.001$).

The presence of in-hospital adverse events resulted in a significant increase of the hospitalization cost for all events, except for respiratory infection (Fig. 1b). Mean differences between patients with and without the adverse events were €532.8 for delirium ($p < 0.001$), €1764.6 for cardiac event ($p < 0.001$), €357.2 for anemia ($p = 0.014$), €828.8 for urinary tract infection ($p = 0.002$), €1993.4 for digestive event ($p = 0.005$), €2773.3 for respiratory event ($p < 0.001$), and €4717.3 for surgical infection ($p < 0.001$).

Relationship between previous diagnoses and adverse events

The influence of previous diagnoses on the odds of an adverse event during hospital stay was first investigated using univariate logistic regression analyses. The results of each univariate analysis are presented in Table S1

(Supplementary file 1). In summary, the occurrence of delirium was significantly associated with previous diagnoses of dementia and kidney disease; heart disease was associated with ischemic heart disease, heart failure, and kidney disease; anemia with ischemic heart disease and stroke; digestive adverse events with kidney disease; respiratory adverse events to heart failure and kidney disease

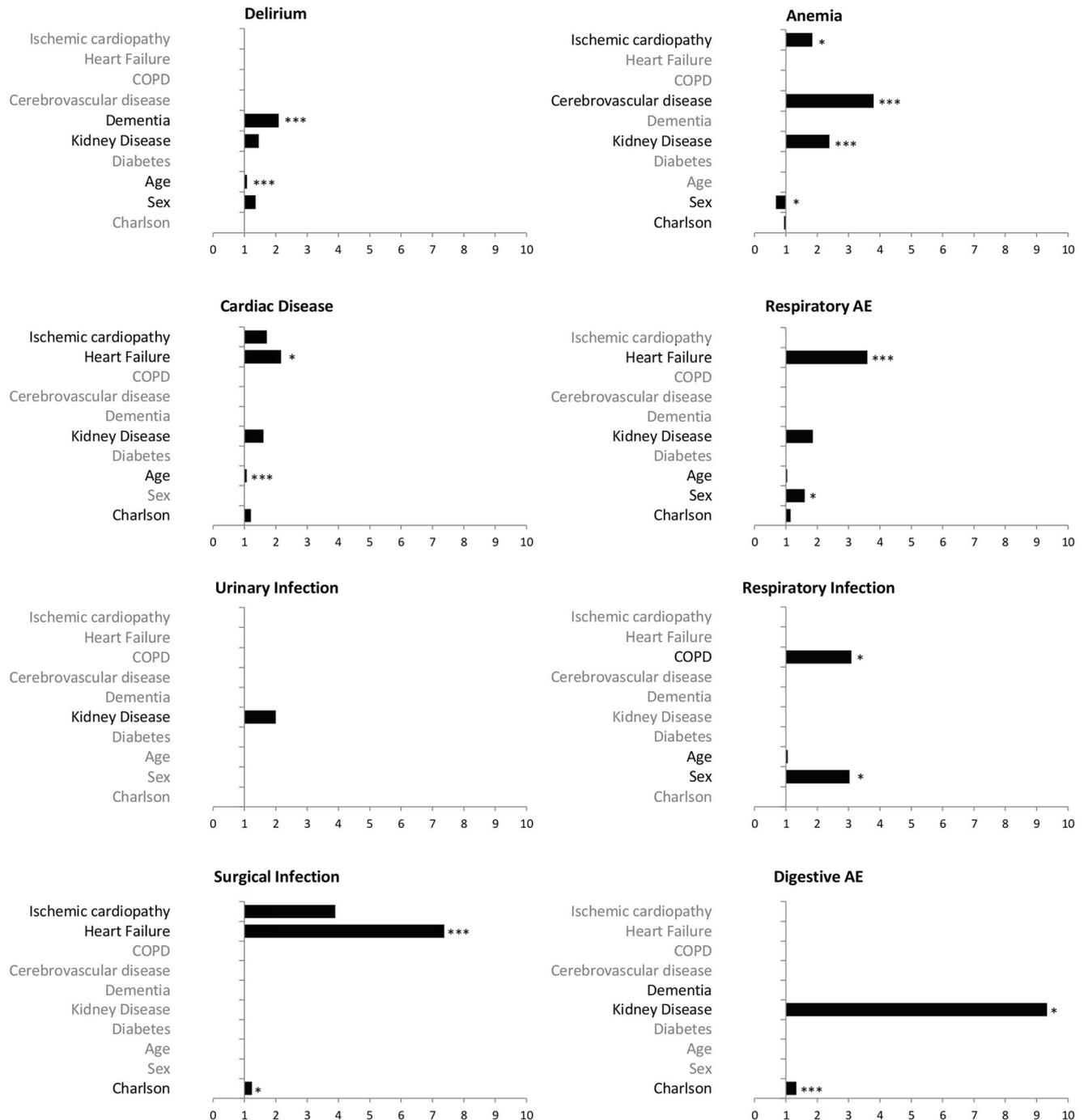


Fig. 2 Predictive model of the influence of previous diagnoses to develop an adverse effect. Graphic representation of the OR: the response variable is the adverse effect and the previous diagnoses are the explanatory

variables. In each graph, the explanatory variables included in that model are written in black, and those not included are written gray

disease; surgical infection to heart failure; and respiratory infection with COPD.

Multiple logistic regressions were performed to predict the occurrence of each in-hospital adverse event based on the presence of previous diagnoses (Fig. 2). All models significantly explained the occurrence of the given adverse event with at least one of the included variables; the detailed results of the multivariate analyses are provided in Table S2 (Supplementary file 1).

Associations with cost increase

The association between previous diagnoses and the increase of hospitalization costs was first investigated using a univariate logistic regression analysis (Table S3, Supplementary file 1). Based on the univariate analysis of each previous diagnosis, the increase of hospital costs was significantly influenced by the previous diagnosis of heart failure (OR 1.93 [95%CI 1.14–3.26]; $p = 0.013$) and kidney disease (OR 2.31 [95%CI 1.54–3.6]; $p < 0.001$).

Finally, two models were built for predicting the increase of hospitalization cost based on (1) previous diagnoses and (2) adverse events occurring during hospital stay (Table 2). The previous diagnoses of kidney disease significantly contributed to explaining the increase in hospitalization cost, although with a moderate influence (ORs < 2 in both cases).

Table 2 Stepwise multiple logistic regressions for predicting a change in the hospitalization cost based on [1] previous diagnoses and [2] in-hospital adverse events. Age, sex, and comorbidities were included in the stepwise process as adjustment variables

	Coefficient	Odds ratio	95% CI	<i>p</i> value
Previous diagnoses (PD)^a				
Constant	- 6.98			
Heart failure	0.51	1.66	0.97–2.86	0.067
Kidney disease	0.47	1.59	1.0–2.49	0.041
Age	0.05	1.05	1.02–1.08	0.000
Sex	0.51	1.67	1.19–2.35	0.003
Charlson	0.12	1.13	1.06–1.21	0.000
Adverse event (AE)^b				
Constant	- 3.50			
Delirium	1.67	5.32	3.46–8.20	0.000
Cardiac disease	2.39	10.90	6.32–18.78	0.000
Anemia	0.71	2.03	1.24–3.33	0.005
Urinary infection	2.42	11.23	5.69–22.20	0.000
Respiratory AE	3.25	25.91	13.12–51.17	0.000
Respiratory infection	3.23	25.21	9.06–70.14	0.000

^a $P(\text{POA cost}) = 1/(1 + \text{Exp}(6.98 - 0.51 \times \text{heart failure} - 0.47 \times \text{kidney disease} - 0.05 \times \text{age} - 0.51 \times \text{sex} - 0.12 \times \text{Charlson}))$

^b $P(\text{POA cost}) = 1/(1 + \text{Exp}(3.5 - 1.67 \times \text{delirium} - 2.39 \times \text{cardiac disease} - 0.71 \times \text{anemia} - 2.42 \times \text{urinary infection} - 3.25 \times \text{respiratory AE} - 3.23 \times \text{respiratory infection}))$

Regarding adverse events, all of them significantly contributed to the model, being respiratory adverse events and respiratory infection those with the greatest contribution to the model (Table 2).

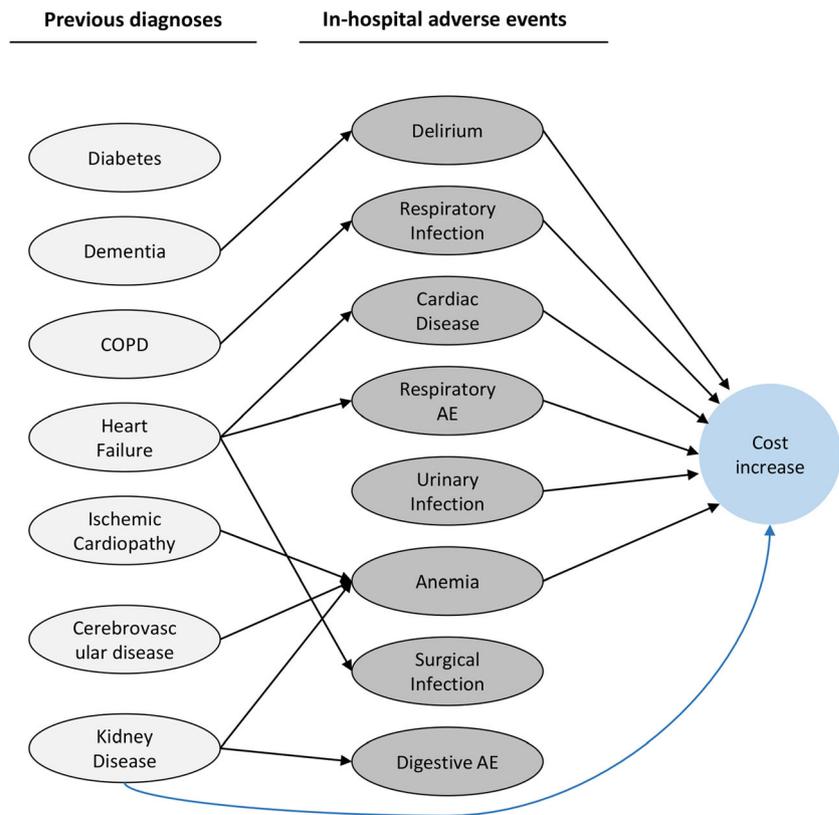
Discussion

In this retrospective analysis of hospitalization costs of patients admitted because of hip fracture, we found that the presence of dementia, COPD, heart failure, ischemic heart disease, kidney disease, and cerebrovascular disease significantly increased the risk of various adverse events during the hospital stay. These adverse events, which included delirium, heart disease, anemia, urinary infection, respiratory events, and respiratory infection, were subsequently associated with a significant increase of hospital costs. Furthermore, the previous diagnosis of kidney disease had a direct influence on costs, regardless of the adverse events occurred. Conversely, the presence of diabetes at admission was not associated with either cost increase or the odds of experiencing any of the investigated adverse events (Fig. 3).

One of the challenges of retrospectively assessing the relationship between previous diagnoses and adverse events, and their ultimate influence on costs is to distinguish between comorbidities recorded in the medical history that occurred during hospitalization and those already present before the index admission. In our analysis, the “present on admission” (POA) feature incorporated in the APR32 allowed us the automated identification of in-hospital adverse events [21]. The MBDS-DRGs system is used as an inter-center billing system in all countries where it is implemented [22–24]. The implementation of the APR32 version of the DRG in Spain, together with the POA concept, allowed us to calculate the DRG both at the time of discharge and at the time of admission, with no need to taking into account all the adverse effects that could appear [25].

Our estimated cost per patient (€8752.1) was very close to that reported in a detailed analysis of HF acute costs in Germany (€8853) [26]. However, the values reported in the literature have extremely wide ranges: €2000 to €25,000 in Europe, \$774–14,198 in Asia, and \$7788–31,310 in the USA [27–29]. Irrespective of the country differences, the events occurring during the hospital stay are likely to influence the hospital cost of patients admitted for any cause [30–33]; hence, the model of care may have a strong influence in the observed cost. In fact, all hospital adverse events investigated in our study significantly increased the hospitalization cost of study patients. The routine practice in our center includes the CGA model, currently considered the gold standard for the care of the elderly in the hospital [34]. The shorter time of hospital stay observed in our study was in line with that

Fig. 3 Diagram of the association of previous diagnoses (light gray circles), adverse effects (dark gray circles), and increase of hospital costs (blue circle)



reported in previous studies using CGA-based models which have ultimately influenced the hospitalization cost [34, 35].

The mean incremental cost associated with each adverse event may strongly vary between centers, and it seems to be independent of the admission cause [17, 30]. Nevertheless, the patient's condition on admission is likely to influence the risk of hospital adverse events in a rather specific manner, thus influencing indirectly the final hospitalization cost of these patients. Indeed, in a previous analysis of hospital costs associated with HF, the comorbidity burden of admitted patients ($CCI \geq 4$) significantly influenced the final cost, although no specific comorbidities with significant influence were identified [26]. Consistently with this finding, in our study sample, the CCI on admission showed a significant—albeit moderate—contribution to the model predicting cost increase. Regarding specific diagnoses on admission, only kidney disease had a direct and independent influence on cost increase. However, most conditions present on admission increased the risk of adverse events with subsequent impact on hospital costs, indicating that these conditions indirectly influence hospital costs. This was the case for dementia, COPD, heart failure, ischemic heart disease, kidney disease, and stroke. As described by other authors, diabetes had no influence on the occurrence of hospital adverse events [36]. Owing to the complexity of the cumulative influence of previous diagnoses on incremental costs via adverse events, we did not attempt to quantify the extent of the indirect risk of cost increase

associated with previous diagnoses. However, Fig. 3 provides an interaction diagram summarizing the sequential influence of previous diagnoses and adverse events on hospital costs.

Our study has the intrinsic limitations of retrospective designs. One of the consequences of this design is the uncontrolled accuracy of diagnoses, which in some cases—such as dementia and delirium—were recorded in the patient's medical record at physician's discretion, without a diagnosis test provided with. Also, as we were constrained by ICD codes and administrative variables recorded in the MBDS, our analysis did not include variables with known influence on hospital cost of hip fracture patients such as waiting time before surgery and the severity of the fracture [26, 37]. Our analysis was focused on the likelihood of cost increase, rather than the quantification of the actual increase. Although various statistical tools are currently available for cost variation analysis, we chose the logistic regression model because we considered useful to provide a more simple and straightforward approach to the influence of events and previous diagnosis on hospitalization costs. Also, we did not perform any multiplicity adjustment; therefore, our results could not be adequately protected from increases in type I error due to multiplicity of testing [38]. Another limitation associated with the data source was the approach to the hospitalization cost, which was established based on pre-defined values assigned to each DRG, as established for our billing system. Cost estimation by DRGs may differ from real costs in certain conditions, and

some studies have suggested micro-costing as a better approach [39, 40]. However, the micro-costing approach also has some limitations, as for instance reflecting only the practice at selected sites with a specific population, thus limiting generalizability compared [41], with the estimations by DRGs, which can be easily extrapolated to other centers. Moreover, we used the APR-DRG (All Patients Refined) version, which was adjusted by the Severity of Illness (SOI) and Risk of Mortality (ROM). This version incorporated the concept “present on admission” (POA), which defines whether the diagnosis was present at the time of admission (previous diagnose) (POA = yes) or was acquired during the hospital stay (adverse event) (POA = No) [21]. However, since not all POA = No (that is, all adverse events or complications) increased the cost, the link between comorbidity, adverse event, and costs was not predetermined. Finally, to reduce variability associated with the trigger condition for admission, our study included only hip fracture patients; however, as no control group was used, we could not distinguish hip fracture-specific associations from those of other conditions. In this regard, future studies shall dissect the factors identified in our work to investigate which are specific of hip fracture patients. Although this work has been carried out in a single center, our hospital has a great capacity for recruitment, and we included all patients who met the inclusion criteria for 4 years, achieving a total of 1571 participants. Future studies will benefit from the MBDS tool checked in this work using a multicentric design.

To summarize, in this study, we show that although few medical conditions present at the moment of admission have a significant influence on hospital cost of hip fracture patients, most of these conditions significantly increase the risk of hospital adverse events with subsequent impact on hospital cost. The sequential association between previous diagnoses, adverse events, and hospital cost increase should be considered when designing healthcare policies for the management of hip fracture patients, since this knowledge may help to improve the care process and reduce the healthcare costs. Moreover, thanks to the use of the CMBD GRDs tool, these results can be systematized and compared with other health centers, allowing to establish benchmarking policies among different organizations.

Acknowledgments The authors would like to thank i2e3 Research Institute for providing medical writing assistance during the preparation of the manuscript.

Author contributions DC-P, FA-M, AB-V, and FJT-S made substantial contributions to the design of the work and to the acquisition, analysis, and interpretation of data. All authors thoroughly revised the various drafts of the manuscript and approved the final version.

Compliance with ethical standards

Conflict of interest None.

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