Orthopaedics & Traumatology: Surgery & Research 105 (2019) 301–305

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Original article

Is the Charlson comorbidity index a good predictor of mortality and adverse effects in proximal humerus fractures?

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A R T I C L E   I N F O

Article history:
Received 22 January 2018
Accepted 7 November 2018

Keywords:
Proximal humerus fractures
Comorbidity
Charlson comorbidity index
Adverse effects
Mortality

A B S T R A C T

Introduction: Proximal humerus fractures (PHF) are frequent in elderly patients. This population also suffers from a series of associated comorbidities, and PHF increases morbidity and mortality. The Charlson Comorbidity Index (CCI) is a tool used for calculating comorbidity and therefore the mortality risk.
Hypothesis: Our hypothesis is that CCI is a good predictor of mortality in patients suffering from PHF, and that there is a relationship between CCI and the development of adverse events.
Patients and methods: A retrospective study with prospective data collection of 354 patients who had been diagnosed and treated for a single PHF between August 1st, 2013 and July 31st, 2015 was carried out at our hospital. The minimum follow-up was 24 months (mean 51.1 months). This study included all patients regardless the severity of the fracture, the treatment performed (surgical or conservative treatment) or whether the patient had been admitted to the hospital or was treated as an outpatient. Adverse effects and mortality data were collected and the CCI was calculated.
Results: Patients with high CCI (> 5) had a higher mortality risk 4.6 (95% CI [2.4–9.0]) compared to those with CCI < 5. During follow-up, 40 (11%) patients died, being the mean follow-up of the patients overall 4.3 years 95% CI [4.1–4.4]. Patients suffering from systemic complications had a higher CCI average ($p = 0.001$) compared to those who did not present adverse effects (HR = 6.6; 95% CI [3.5–12.4]). No statistically significant relationship between the type of fracture ($p = 0.473$) and mortality was found.
Conclusion: In our study CCI has proven to be a good predictor of mortality and there is a relationship between CCI and the development of adverse effects in patients suffering from PHF, which maybe should be taken into consideration in our therapeutic decision making.
Level of evidence: IV, retrospective observational study.

1. Introduction

The cause of fractures in elderly patients is mainly due to bone fragility; the most common fractures are located in proximal femur and distal radius, followed by the proximal humerus [1–3].

Based on epidemiological data, an increase in the incidence of proximal humerus fracture (PHF) is expected within the next years due to the increase in life expectancy in developed countries [3,4].

These patients may also have associated comorbidities which makes them a special risk group. Numerous studies have been published about the classification, treatment and functional outcomes of PHF [5–15]. However, only a few papers have focused on how PHF can affect the patient's health status, and, more specifically, how previous comorbidities can influence the complications and mortality rate [1,16,17]. On the other hand, the negative impact of previous illness on morbidity and mortality has been extensively reported on other fragility fractures, such as hip fractures [18–20].

Several comorbidity indices have been described in the medical literature, and Charlson comorbidity index (CCI) is one of the most used [21–25].

The CCI is a method of predicting mortality by classifying or weighting 19 comorbid conditions. Each condition is assigned with

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https://doi.org/10.1016/j.otsr.2018.11.016

Table 1
Weighted index of comorbidity.

Assigned weights for diseases	Conditions
1	Myocardial infarct
	Congestive heart failure
	Peripheral vascular disease
	Cerebrovascular disease
	Dementia
	Chronic pulmonary disease
	Connective tissue disease
	Ulcer disease
	Mild liver disease
	Diabetes
2	Hemiplegia
	Moderate or severe renal disease
	Diabetes with end organ damage
	Any tumor
	Leukemia
	Lymphoma
3	Moderate or severe liver disease
6	Metastatic solic tumor
	AIDS

a score or weight from 1 to 6, based on the adjusted risk of mortality associated with the comorbid conditio [21] (Table 1). The sum of all comorbidities result in a single comorbidity score for a patient. Additionally, age was found to be a significant predicting factor for survival and was considered as an additional comorbidity index. Therefore, age was subsequently incorporated into the CCI to create a single index; one point is added for every additional 10 years to the initial score [23,24]. In spite CCI wasn't initially designed for trauma patients, it has been proved to be useful in orthopaedic surgery like a mortality predictor [19,20,25].

Although CCI has never been validated as a predictor of adverse events, many studies have been found relationship between some items (diabetes mellitus, cardiac disease, age, etc.) included in CCI and the development of these events. This is why we have asked this question.

Our hypothesis is that CCI is a good predictor of mortality in patients suffering from proximal humeral fractures (PHF), and that there is a relationship between CCI and the development of adverse events.

2. Materials and methods

A retrospective study with prospective data collection was performed, considering all patients who had been treated for a single PHF between August 1st, 2013 and July 31st, 2015 in our institution. This hospital is the reference one for trauma patients in our region with a population of 314,853 habitants.

2.1. Inclusion criteria

Patients suffering from an isolated PHF were treated and had their follow up in our hospital.

2.2. Exclusion criteria

Patients who had a concomitant fracture, pregnant women, polytrauma patients, underage patients and those who did not have follow up at our hospital.

All patients have received surgical or conservative treatment in accordance with the protocol and criteria made by 3 orthopaedic surgeons belonging to the shoulder unit.

2.2.1. Surgical treatment

Indicated when fractures are displaced more than 50% and when the difference between the normal physiological head-shaft angle of 130° and the fracture one ranges more than 20° to 45°. This treatment included open reduction and osteosuture, open reduction and internal fixation with angular plate, close reduction with intramedullary nail, hemiarthroplasty or reverse total shoulder arthroplasty.

2.2.2. Non-surgical treatment

Consisted of sling immobilization for 3 weeks. Most of these patients have been treated like outpatients.

Both treatments (surgical and conservative one) were followed by a rehabilitation treatment program.

Pre-fracture comorbidities were collected from all patients and the age-adapted CCI was calculated. Sex, affected side, haemoglobin level (Hb) measured at the emergency department and posteriorly in the immediate postoperative period (24 hours after de intervention), transfusion requirements, addiction habits, and anticoagulants and antiplatelet drugs were collected using data from the electronic patient record. All patients were followed for a minimum of 24 months (mean, 51.1 months). During follow up, the date of death was noted, as well as the local and systemic complications. A new hospital readmission due to complication was also recorded, related to fracture, surgery or other etiology.

Fractures were classified according to the Neer classification [26].

Anesthetic risk, measured with ASA, was only recorded on patients who underwent surgery [27].

Our collection data is based on a digitalised patient history (Ianus), which registers any event that happens to patient anywhere regardless of the hospital or emergency care center where they go.

2.3. Estimated sample size

For a difference in CCI score estimated between alive and exitus patients of 1.4 points, and a standard deviation of 1.9 and 2.1 respectively for a ratio between samples of 0.1. With a 95% confidence interval and a statistical power of 97% the necessary simple size would be 354 patients.

2.4. Statistical analysis

Initially a descriptive analysis where the qualitative variables were expressed as frequency and percentage and continuous variables were expressed as mean ± standard deviation.

Parametric/non-parametric tests were performed in order to determine the potential association between the variables of the study (Chi^2, Student's *t*-test, Anova).

Global and specific survival studies were performed, expressed as hazard ratio and confidence interval (CI) 95%. In continuous variables, univariate COX regression models were executed using p-spline smoothing. The objective of this analysis was to determine, in those non-linear variables, the different strata or categories, to be introduced in the multivariate analysis. Significant variables in this first analysis (when we studied the mortality risk) and those that proved to be of clinical interest were introduced in the multivariate COX analysis (regardless of those that presented collinearity or were a linear combination of others).

A logistic regression model was used to determine association between CCI and presence/absence of systemic complications. In all analyses we considered statistically significant differences with $p < 0.05$. All analyses were performed using SPSS 22.0, Epidat 4.1 and free software R (http://www.r-project.org) – library survival, library smoothHR, library mgcv.

Table 2
Sociodemographic characteristics, personal history, comorbidities and treatment in patients with proximal humerus fractures according to the mortality.

	Global*n* = 354	Alive*n* = 314	Éxitus*n* = 40	*p*-value	HR[CI 95%]
Gender					
Female	279(78.8%)	250(79.6%)	29(72.5%)	0.200	0,72[0,36–1.44]
Age					
≥ 70 years	219(61.9%)	188(59,9%)	31(77,5%)	0.021	2,39[1.13–5,04]
Fractures					
≥ 3 fragments	232(65,5%)	204(65,0%)	28(70,0%)	0.528	1,28[0,65–2,52]
Laterality					
Left	180(50,8%)	158(50,3%)	22(55,0%)	0.577	1.20[0.64–2.24]
Cardiac Pathologies	82(23.2%)	65(20,7%)	17(42,5%)	0.002	2.73[1.46–5.12]
Diabetes Mellitus	63(17.8%)	56(17,8%)	7(17,5%)	0.958	0,96[0.43–2.18]
Previous Neoplasia	52(14.7%)	34(10,8%)	18(45,0%)	< 0,001	5,58[2,99–10,72]
Neurological Disease	47(13.3%)	39(12,4%)	8(20,0%)	0.183	1.66[0.77–3.61]
Alcoholism	22(6.2%)	17(5,4%)	5(12,5%)	0.080	2.10[0.82–5.36]
Charlson					
Mean(sd)	4.41(+2.61)	4.05(+2.13)	7.24(+3.96)	< 0.001+	–
≥ 5	117(33,1%)	90(28,7%)	27(67,5%)	< 0.001	4,64[2,39–9,00]

Number and percentage (%). *p-value: Chi^2 test + Student's t-test .HR: Hazard Ratio Univariate Survival Cox Model and CI 95% Confidence Interval 95%.

2.5. Ethics

The study was conducted in accordance with Good Clinical Practice and the Declaration of Helsinki and was approved by The Ethical Committee of Reference (Autonomous committee of research ethics in Galicia. No. 2016/125).

3. Results

A total of 371 patients were selected, however only 354 met the inclusion criteria (7 of them were excluded because they have been suffering from another fracture, 1 were a pregnant woman, 2 were polytrauma patients and 7 were patients from another country who could not be able to have follow up).

3.1. Description of global population

A total of 251 (71%) were older than 65 years, the mean age was 71.4 (± 14.8) years and most of them were female 279 (79%). Overall 150 patients required hospital admission and 114 of them were finally operated.

A total of 232 (65%) patients had a fracture in 3 or more fragments. Fractures of the left shoulder 180 (51%) were slightly more common than of the right shoulder. The most frequent comorbidities were cardiac pathologies (82 [23%]), and diabetes mellitus 63 (18%), being the global CCI 4.4 CI 95% [4.1–4.7].

3.2. Mortality study

Patients' characteristics according to mortality are showed in Table 2.

During follow-up, overall survival rate was 89% CI 95% [85.3–92.1], and the mean follow-up 4.3 years 95% CI [4.1–4.4]. When we performed the regression analysis in function to the CCI, we found a Hazard ratio (HR) = 4.6;95%CI [2.4–9.0] in patients with CCI > 5 (p < 0.001) (Fig. 1).

We also found that mortality risk increased with age being in patients over 70 years the risk 2.4 times greater 95% CI [1.1–5.0] (Fig. 2).

Hospitalization duration HR = 1.0 95% CI [1.0–1.1], hospital readmission HR = 8.6 [4.5–16.3], presence of complications HR = 6.6 95% CI [3.5–12.4] and the need of blood transfusions HR = 4.2; 95% CI [1.8–9.4] were predictors of mortality too. There was also a significant relationship between the diagnosis of dementia, neoplasia, and heart disease, with an increase in the mortality rate.

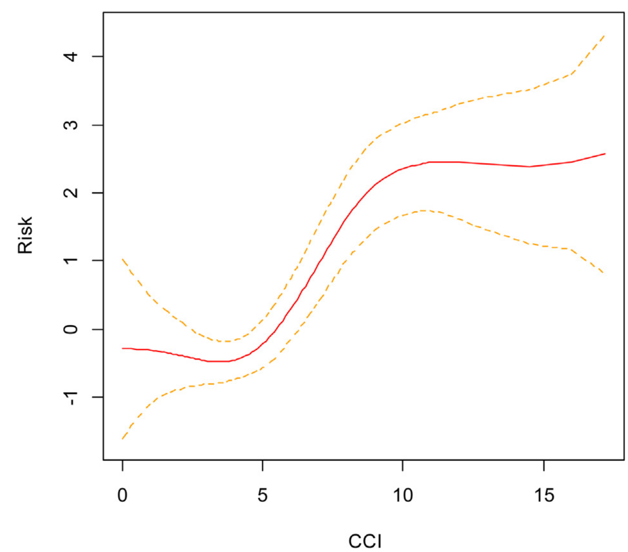

Fig. 1. Univariate Survival Univariate Cox Survival Model with p-spline smoothing for the Charlson comorbidity index variable. Risk of Mortality in function to Charlson comorbidity index.

In multivariate analysis, only the presence of complications HR 6.0; 95% CI [3.2–8.0] and the CCI > 5 HR = 4.1; 95% CI [2.1–8.0] were found as mortality predictors.

3.3. Adverse events

When we studied the relationship between CCI and the presence of complications, we found that patients with local complications had CCI values similar to those with no complications. Nevertheless, patients with systemic complications (mean = 5.9 95% CI [4.5–7.2]) presented statistically superior CCI values to those without complications (mean = 4.3 95% CI [4.0–4.6] or with local complications (mean = 3.6 95% CI [2.7–4.6]) (p = 0.003) (Fig. 3).

When we studied the risk of systemic complications in patients, according to the Charlson score obtained, we found a superior risk 2.4 (95% CI: 1.2–5.0) in patients with ICC > 5.

4. Discussion

Our study showed that CCI is a suitable predictor of mortality and there is a relationship between CCI and the development of adverse effects in patients suffering from isolated PHF, regardless of

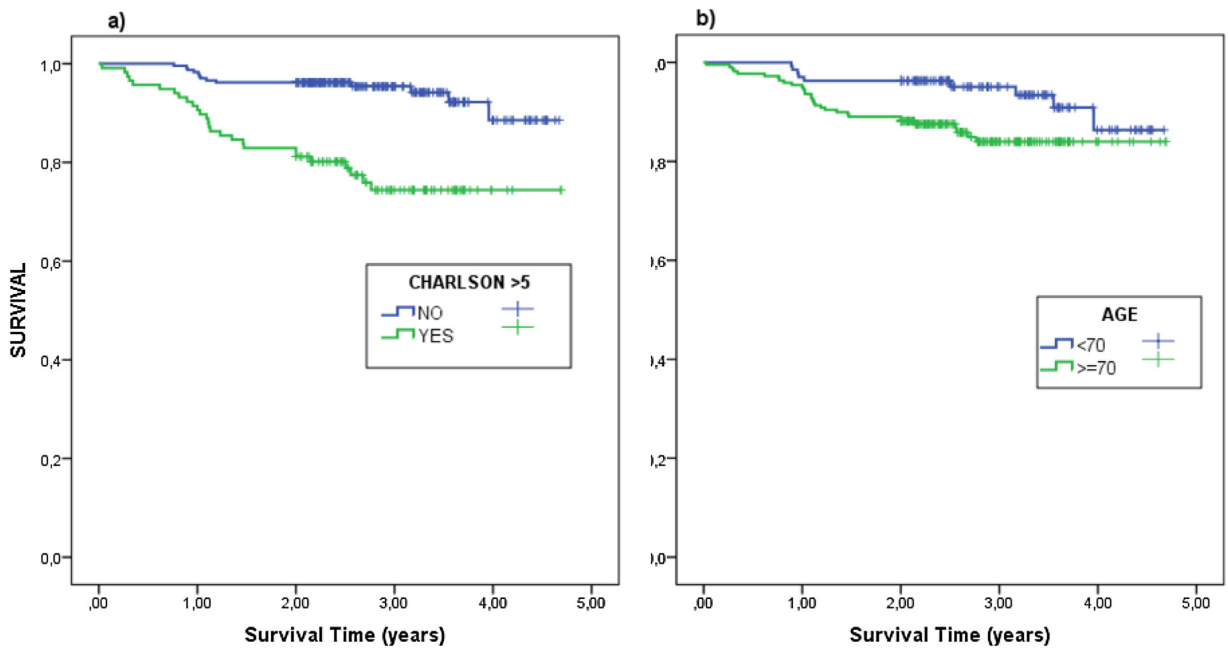

Fig. 2. Kaplan-Meier plot of survival. a: as a function of the two strata of Charlson comorbidity Index: ≤ 5 and > 5; b: as a function of the two strata of age < 70 and ≥ 70.

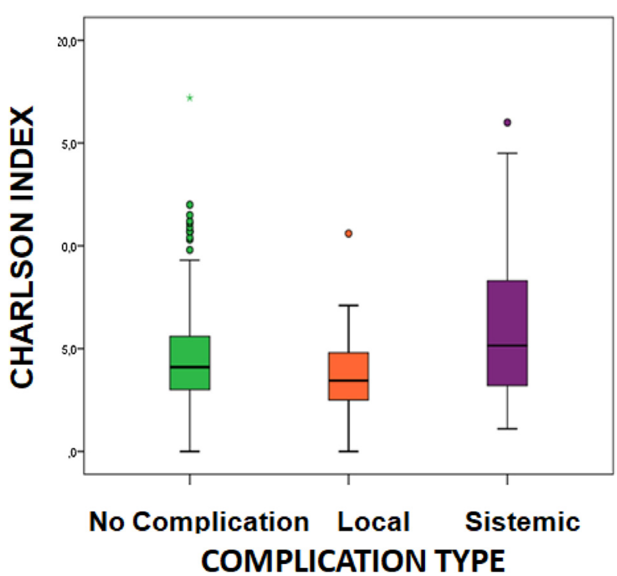

Fig. 3. Boxplot: Charlson comorbidity Index in function of complication type (No complication, Local complication or systemic complication).

the treatment performed (surgical or conservative treatment) and whether they were admitted to hospital or treated as an outpatient. The CCI was proved to be a better predictive factor compared to others such as age, heart diseases, dementia, neoplasia, haemoglobin levels, transfusion requirements or days of admission because it has more discriminating power.

The majority of PHF is minimally displaced and can be successfully managed non-operatively. Conservative treatment is generally indicated in those, which have two fragments with minimal displacement or are impacted in valgus [4–8,10,11,26]. Despite these criteria are widely accepted, the treatment of PHF still remains controversial [3,28–32].

Functional results in patients suffering from PHF have been widely studied [9–15]. In contrast, only a few studies have described the effect of previous morbidity on mortality and adverse events in these patients [16,17,33,34]. Fewer studies include the full range of therapeutic possibilities, patients treated surgically or conservatively, as well as those admitted or outpatients. Olsson et al. studied prospectively the influence that previous comorbidities had on mortality [33]. They concluded that comorbidity has little influence on the functional results, except in severe illness patients who follow up were not carried out at one year.

Multiple studies have been performed on hip fractures regarding the influence of previous morbidity in mortality rate [18–20]. Different scores have been used for this purpose and CCI is one of them [18–21,25]. Regarding PHF, Menendez et al. detected that increasing age and CCI were associated with hospital admission, as well as other non-clinical factors such as the type of insurance [34].

Over the last few years, mortality rate in patients admitted to hospital with PHF have been published [16,17,32,35]. Maravic et al. studied in-patient mortality and further hospitalizations in the French National Hospital Database. They noted that the frequency of comorbidity is higher in rehospitalized patients [35]. Somersalo et al. observed that PHF increase mortality in men as much as hip fractures. These authors included patients of all age ranges with upper limb fractures who were admitted to hospital. They did not have patient comorbidities data therefore they could not study the influence of comorbidity on mortality [17]. Neuhaus et al. considered that internal fixation of PHF is an independent risk factor of mortality and adverse effects [16,32]. Although the studies of Somersalo et al. and Neuhas et al. included a large number of patients, they exclude the majority of patients who were treated conservatively, because around 80–90% of these patients are treated as outpatients [16,17,32]. In addition, they did no not have data of the causes of admission, nor the type of fracture, nor the choice of treatment nor the failure of previous conservative treatment. They did not include data on patient comorbidities. Although the sample size of our study is much smaller, we do have this information for each patient.

One of the strengths of our study is that the follow-up of each patient has been exhaustive because any adverse event was recorded in a digitized medical history by medical staff, regardless of the specialty, center and city in which he has been treated. This is possible because 100% of our reference population enjoys complete health coverage. Other studies have a large sample size but the data of each patient and the follow-up is in general scarce. Most of these data being collected from state registries of admitted patients, so patients who are treated ambulatory are not taken into account, and most of conservative fractures are treated like outpatient (up to 80% of FHP) [4,5,6,10]. Neither the adverse events nor mortality rate of patients once discharged [16,17,32,34]. In our study, we have taken into account this population and the medical follow-up of outpatients has been equally exhaustive.

Our study has as limitations the sample size and its retrospective design.

In our opinion comorbidity scored with CCI could be another factor to take into account on therapeutic decision-making.

Future studies should focus on prospective evaluation of specific medical condition patient to assess which specific patient benefit most from surgical intervention.

5. Conclusion

The CCI is a suitable predictor of mortality and there is a relationship between CCI and the development of adverse effects in patients suffering from PHF, which maybe should be taken into consideration in our therapeutic decision-making.

Disclosure of interest

The authors declare that they have no competing interest.

Funding sources

No external funding source was used for this study.

Authors' contributions

Jesús Vidal-Campos and Xavier Paredes-Carnero have worked collected an analyzed data and Fernando Marco Matinez was de director.

Acknowledgements

We thank Roman García-de-la-Infanta MD for his assistance with data collection, Maria-Teresa Álves-Pérez for her assistance with the statistical analyses, and Ana-Pastor-Zapata for her help during the writing process.

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