**Title** Proximal Humerus Fractures: Epidemiology and trends in surgical management of hospital-admitted patients in Portugal

**Running title** Proximal Humerus Fractures: surgical management trends

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Abstract

Background Proximal humerus fractures (PHF) are frequent and associated with significant healthcare burden. National epidemiological data is limited. Our objective is to characterize the Portuguese population admitted with PHF and analyze therapeutic management, the impact of associated lesions and mortality rate.

Methods Retrospective, observational study of admissions from mainland public hospitals (2000-2015), with primary or secondary diagnosis of PHF. Incomplete records, pathologic lesions, malunion/nonunion and hardware removal were excluded. Age, gender, admission date, hospitalization period, associated injuries, treatment and mortality were recorded.

Results 19290 patients were included. Through the analyzed period, an increase in the absolute number and incidence of PHF was observed. Mean age at diagnosis was 62.6±21.0 years old (57% elderly; 63,5% female). Mean length of stay was 10.0±14.1 days, higher in patients submitted to arthroplasty (p<0.001) and in those with associated fractures (25%; p<0.001). 14482 patients were operated, most frequently with open reduction and internal fixation (ORIF, 28%). Inpatient mortality rate was 3.2%, significantly higher in patients with associated fractures (odds 2.77 for lower limb versus upper limb).

Conclusion There is a trend towards an increase in surgical management of PHF. The relative proportion of ORIF and arthroplasty (particularly reverse arthroplasty) increased, probably reflecting biomechanical implant properties, fracture pattern and demand for better functionality. Associated fractures are an important comorbidity, associated with increased mortality and length of stay.

Level of evidence Level IV; Case Series; Descriptive Epidemiology Study

Keywords: Shoulder; Humeral Fractures; Epidemiology; Osteosynthesis; Hemarthroplasty; Reverse Arthroplasty
Proximal humerus fractures (PHF) are among the most frequent bone fractures in adults, representing about 5.7% of all cases, and being the third most common non-vertebral fracture in the elderly (>64 years old), after femoral neck and distal radius fractures. PHF have a unimodal distribution, peaking in the aged, typical of osteoporotic injuries. As elderly population continues to rise, the number of PHF is expected to increase. Due to the high prevalence and expected increase in incidence, they are associated with significant health care burden.

The acute treatment of these lesions is challenging, time-consuming, expensive and frequently controversial. Non-operative management is the first line of treatment in up to 85% of patients, with surgical alternatives ranging from fixation to arthroplasty. Precise knowledge on PHF epidemiology and treatment tendencies of these fractures is essential to develop prevention strategies and to project and plan for future management and health care resources allocation. Several studies suggest that there is marked regional variation in the incidence and treatment of PHF. However, nationwide information on the epidemiology of this injury in Southern European countries is very scarce, with one available study from Spain including only elderly subjects (above 65 years old). Our main objective is to characterize the Portuguese population admitted to national healthcare system hospitals from 2000 to 2015 with PHF and analyze their therapeutic management, the impact of associated lesions and mortality rate.

Materials and Methods

A retrospective, observational big data study was conducted. Eligible patients were identified by a national database on admissions from mainland public health service hospitals, provided by the Portuguese Ministry of Health’s Authority for Health Services. We included all patients
admitted, from 2000 to 2015, with primary or secondary diagnosis of PHF, as classified by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) – “closed proximal humeral fractures” and “open proximal humeral fractures”, coded 812.0 and 812.1, respectively. Patients with incomplete records, pathologic lesions, admission for hardware removal or management of malunion/nonunion and patients treated conservatively in outpatient care were excluded. Also, patients treated in private facilities were not included in our database. Recorded data included age (subsequently categorized in three subgroups – young: <18 years old; adult: 18-64 years old and elderly: >64 years old), gender, admission date, length of stay (from admission to discharge, including both preoperative and postoperative periods), associated injuries, treatment received and mortality rate.

A retrospective chart review (according to diagnosis and procedure) was performed due to very large size database and limited access to data from all the hospitals. For validation purposes, convenience sampling from a single hospital database (in this case, a Portuguese level III trauma hospital) was used, as described in previous studies. Medical records, including clinical reports, physician assessments information and/or surgical reports, from 65% (n=623) of all patients admitted in this hospital were analyzed and compared with database codification, in order to evaluate matching and error rates and to validate the study results.

Statistical analysis was performed using IBM SPSS statistics, version 25 (IBM Corp., Armonk, NY, USA). Data were summarized using descriptive statistics (mean, standard deviation, frequency, percentage). Odds Ratio were used to evaluate the epidemiological trends, using a 95% confidence interval. Significance level was set at 0.05.

**Results**

19290 patients with PHF admitted to Portuguese public health service hospitals were included. From 2000 to 2015, there was a significant and consistent increase in the absolute number of
patients admitted with PHF (977 patients in 2000 versus 1600 patients in 2015; p<0.001; Fig. 1). Simultaneously, there was an increase in the incidence from 9.49/100.000 person-year in 2000 to 15.45/100.000 person-year in 2015. The average age at diagnosis was 62.6±21.0 years old, with a predominance of elderly patients (57%; p<0.001) and a gradual increase of the mean age at diagnosis over the period studied (Fig. 2). Women were more frequently affected (63.5%; p<0.001; Fig. 1) and typically at older age (69.0±17.3 years versus 51.5±22.2 years old; p<0.001).

Most patients suffered closed fractures (97.4%). Open fractures tended to occur in younger patients, with an odds for open fractures of 1.5 in young and 1.3 in adult patients, when compared to elderly (p<0.05). Associated fractures were diagnosed in about a quarter of patients, most frequently in lower limb (12.6%) and upper limb (8.2%), followed by spine injuries (2%).

The mean length of stay was 10.0±14.1 days, significantly higher in patients submitted to shoulder arthroplasty (11.6 days; p<0.001) and in those with associated fractures (16.9 days; p<0.001). Each associated fracture led to an increase of 6.8 days and each added year of age to an increase of 0.8 days in hospital stay.

Overall, 75% (n=14482) of inpatients with PHF were surgically treated, with a lower rate of procedures in the elderly (71.6%) versus adult and young patients (with 78.8% and 85.3%, respectively; p<0.001). From 2000 to 2015, there was an increase in the absolute number of surgically treated patients (Fig. 3), with an increase in the relative percentage of interventions in the elderly after 2010.

The surgical management of PHF is depicted in figures 4 to 6. The most widely used surgical treatment was open reduction and internal fixation (ORIF; 28%), followed by closed reduction and internal fixation (CRIF; 21%). While the relative percentage of ORIF performed during the study period increased, there was a declining use of CRIF (Fig. 5).
Overall, only 7% of surgically treated patients were submitted to arthroplasty. However, its relative percentage raised steeply after 2010 (Fig. 5), similarly to ORIF. Hemiarthroplasty (HA) was the most widely used technique of replacement (70%), followed by total (TSA; 19.3%) and reverse shoulder arthroplasty (RSA; 10.7% - please note that RSA coding on ICD-9 is only available since 2011). Patients submitted to HA were significantly younger than those submitted to TSA or RSA (70.3±11.0 versus 74.4±9.0 or 76.7±6.5 years old, p<0.001 in both). No significant differences were found between TSA and RSA patients (p=0.093). In the study period, there was a declining use of HA, with a correspondent increase in RSA, the latter after 2011 (Fig. 6). Arthroplasty was mainly performed in the elderly (p<0.001), with 95.6% of RSAs, 87.9% of TSAs and 72.5% of HAs being performed in this group. Moreover, patients with associated fractures were less frequently submitted to shoulder replacement.

The inpatient mortality rate was 3.2%, with increased mortality in patients with associated lower limb injuries (odds 2.77; CI95% 2.3-3.2) when compared with upper limb fractures (p<0.001).

Validation analysis revealed an overall sensitivity between codification and medical records of 86% (error rate of 14%). Among surgically treated patients, the sensitivity was 87% (13% error rate).

Discussion

With the global shift towards an aged population (even if age-adjusted incidence of fracture remains stable), the burden of osteoporotic fractures will be tremendous. Therefore, PHF have gained importance, since this type of osteoporotic injury is associated with significant morbidity, functional disability and socio-economic impact. Consequently, national epidemiological studies may help healthcare providers to plan preventive and therapeutic interventions, directed to a particular injury.
Between 2000 and 2015, the number of inpatients with PHF increased in Portugal, predominantly in elderly women, what is consistent with current literature.\(^2\); \(^5\); \(^15\); \(^18\); \(^25\); \(^35\) Although there are no clear guidelines for decision on conservative or surgical treatment, in our study there is a trend towards an increase in surgical management of PHF. As suggested by Khatib et al\(^16\), this may represent a more aggressive approach, supported by the continuous development of new techniques and implants associated with better outcomes.\(^1\); \(^11\); \(^34\) In the past, conventional plate fixation was associated with inadequate anchorage in osteoporotic bone. However, the current disseminated usage of locking plates has demonstrated better biomechanical characteristics and increased stability.\(^22\); \(^34\) Therefore, the relative proportion of ORIF has increased as opposed to CRIF. Besides, the role of shoulder replacement in the acute treatment of PHF suffered substantial changes, as noted by the increase in the relative proportion of shoulder replacement (fig. 5). These findings may represent a change in fracture pattern complexity, increased surgical differentiation, insights on the importance of accurate reduction of the greater tuberosity for shoulder function and/or increased demand for better functionality among elderly.\(^2\); \(^37\) In the elderly, poorer bone quality often precludes osteossynthesis, which may be associated with unsatisfying functional outcomes. This partly explains the increased use of arthroplasty, particularly RSA. As depicted in figure 6, since 2011 there was a noteworthy decline in HA as opposed to RSA, potentially associated with unpredictable motion and unsatisfactory outcomes of HA.\(^9\); \(^11\); \(^13\); \(^16\); \(^18\); \(^28\); \(^37\) Moreover, the ICD-9 code for RSA was only introduced in 2011. Before that time, RSA were probably codified as TSA, as found in our validation sample. And even afterwards, some physicians probably did not updated their ICD-9 surgical coding, thereby justifying the constant percentage of TSA procedures in the study sample (with no significant differences found between TSA and RSA patients; p=0.093).
However, the tendency for increased surgical management of PHF in our population is conflicting with other studies, such as reported by McLean et al in a study on operative management of PHF among hospitalized patients in Australia.\textsuperscript{25}

Associated fractures are an important risk factor, as they are frequent (about 25%) and associated with increased mortality (especially lower limb lesions) and length of stay. These may represent a non-despicable proportion of polytraumatized patients and, as suggested in previous studies, illustrates that PHF are an indirect sign of patients’ frailty.\textsuperscript{4; 26; 29}

The mean hospitalization period was surprisingly high. Whether conditioned by the type of injury, comorbidities or complications, such long admission is associated with significant risk of nosocomial infections and increased health care costs.\textsuperscript{20} Although we have no data to justify this extended length of stay, it may be partially due to a preoperative delay (related with patient optimization, availability of operative rooms, surgical hardware or specialized shoulder surgeons – which may also explain why arthroplasty patients stayed longer in the hospital) or increased pain.\textsuperscript{6; 17; 32} Therefore, future studies may address the reasons for high hospitalization periods and strategies may be defined to optimize care and reduce length of stay.

The retrospective nature of the study is a limitation. We only considered patients admitted with PHF, excluding those treated in outpatient care and those treated in private facilities, underestimating the total incidence of PHF. Also, since only a small percentage of PHF patients deemed for conservative treatment are admitted for hospital stay, we have a high percentage of surgical treatment, biased by the lack of those treated in outpatient basis.

The accuracy of our estimates is conditioned by proper coding. ICD-9 does not allow for fracture classification and collected data does not indicate complications, revision surgery, patient-reported and functional outcomes, implant survival or other factors that may affect treatment decision making. Secondly, analysis of treatment options (Fig. 4) shows a surprisingly high rate of “other” procedures, other than ORIF, CRIF and arthroplasty. We
believe this is due to separate coding of surgical procedures for pediatric patients and those with fracturé dislocations in ICD-9. Thirdly, TSA coding was probably overused. As is defined in the manuscript, during part of the study period, the RSA could not be coded as such and it was coded elsewhere, probably as another type of arthroplasty. Since there was no RSA code before 2011, data on its use can only be proper interpreted after this year. Future works may prospectively collect data and bring new insights on PHF management.

The limitations of big data analysis (such as missing or duplicate data, poor coding, among others) render large datasets inherently inaccurate.\textsuperscript{10; 14; 31} Although our study validation was restricted to a retrospective chart review, our overall sensitivity was estimated at 86%. This value is consistent with error rates reported in other studies with large databases, suggesting that these results may closely represent the Portuguese standard of care for PHF.\textsuperscript{10; 14; 31}

To the best of our knowledge, this is the first study on the epidemiology of inpatients with PHF and on their surgical management regarding the Portuguese population and in general Southern European population. We believe the data depicted should be deeper studied in future longitudinal studies, with more information on type of fracture and factors that might influence surgical decisions. Data on this topic is of upmost importance to the development of healthcare policies and of treatment algorithms for adequate management of PHF.

\textbf{Conclusion}

This study found a temporal tendency towards an increase in the number of patients admitted with PHF in Portuguese public health service hospitals. Alongside, there was an increase in the number of surgeries due to PHF and in the relative proportion of patients who were submitted to ORIF and arthroplasty. It was also found an important mortality rate of about 3%, mainly influenced by the presence of associated fractures.


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Figure Legends

**Figure 1.** Absolute number of patients hospitalized with proximal humerus fractures, between 2000 and 2015, by gender

**Figure 2.** Mean age of hospitalized patients, diagnosed with proximal humerus fracture, by year

**Figure 3.** Absolute number of surgeries for PHF performed between 2000 and 2015

**Figure 4.** Relative distribution of surgical treatment of PHF. CRIF – Closed reduction, internal fixation; CR no IF – Closed reduction, no internal fixation; ORIF – Open reduction, internal fixation.

**Figure 5.** Relative distribution of surgical main procedures, by year. CRIF – Closed reduction, internal fixation; ORIF – Open reduction, internal fixation

**Figure 6.** Relative distribution of shoulder arthroplasty procedures, by year. Hemiarthro – Hemiarthroplasty; TSA – total shoulder arthroplasty; RSA – Reverse shoulder arthroplasty. Note that the ICD-9 coding for RSA was only introduced in 2021 (before this year, RSA might have been codified elsewhere)