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UPPER LIMB

# Proximal humerus fractures – epidemiology, comparison of mortality rates after surgical versus non-surgical treatment, and analysis of risk factors based on Medicare registry data

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## Aims

The optimal choice of management for proximal humerus fractures (PHFs) has been increasingly discussed in the literature, and this work aimed to answer the following questions: 1) what are the incidence rates of PHF in the geriatric population in the USA; 2) what is the mortality rate after PHF in the elderly population, specifically for distinct treatment procedures; and 3) what factors influence the mortality rate?

## Methods

PHFs occurring between 1 January 2009 and 31 December 2019 were identified from the Medicare physician service records. Incidence rates were determined, mortality rates were calculated, and semiparametric Cox regression was applied, incorporating 23 demographic, clinical, and socioeconomic covariates, to compare the mortality risk between treatments.

## Results

From 2009 to 2019, the incidence decreased by 11.85% from 300.4 cases/100,000 enrollees to 266.3 cases/100,000 enrollees, although this was not statistically significant ($z = -1.47$, $p = 0.142$). In comparison to matched Medicare patients without a PHF, but of the same five-year age group and sex, a mean survival difference of -17.3% was observed. The one-year mortality rate was higher after nonoperative treatment with 16.4% compared to surgical treatment with 9.3% (hazard ratio (HR) = 1.29, 95% confidence interval (CI) 1.23 to 1.36; $p < 0.001$) and to shoulder arthroplasty with 7.4% (HR = 1.45, 95% CI 1.33 to 1.58; $p < 0.001$). Statistically significant mortality risk factors after operative treatment included age older than 75 years, male sex, chronic obstructive pulmonary disease (COPD), cerebrovascular disease, chronic kidney disease, a concomitant fracture, congestive heart failure, and osteoporotic fracture.

## Conclusion

Mortality risk factors for distinct treatment modes after PHF in elderly patients could be identified, which may guide clinical decision-making.

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**Keywords:** Proximal humerus fracture, Epidemiology, Management, Mortality

## Article focus

- Determination of the epidemiology and mortality rates depending on the choice of treatment for proximal humerus fractures (PHF) in the elderly USA population.

## Key messages

- Findings from Medicare registry data identified a one-year mortality rate of 15.4% after PHF in the elderly USA population.

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- Mortality rates differ statistically significantly between nonoperative treatment, fracture fixation surgery, and shoulder arthroplasty.
- An early assessment of individual risk factors accessible for therapeutical treatment is crucial.

## Strengths and limitations

- The study is based on nationwide registry data including records from approximately 2.5 million enrollees.
- The analysis relies on correct coding and data management, which cannot be ensured.

## Introduction

With increasing life expectancy in the general population and demographic changes in industrialized countries, trauma-related injuries are expected to increase, especially among geriatric patients.[1,2] Of all fractures, 5% to 6% are sustained at the proximal humerus with a bimodal distribution representing high-energy trauma in young patients and low-energy falls in the elderly.[3] Proximal humerus fractures (PHFs) mainly occur in patients older than 65 years of age, and account for 10% of fractures in this population.[4,5] Also, PHFs are the third most common type of osteoporotic fractures with a lifetime risk of 13% for women aged 50 years and above.[6,7] Whereas some studies have provided insights into the epidemiology of PHF, most rely on data from a single institution.[5,8-11] To evaluate potential future incidence and demand for treatment, as well as potentially optimal treatment, analyses using registry data are required.

Different treatment options exist for PHF, ranging from conservative treatment to surgical procedures such as fracture reduction and osteosynthesis, as well as joint arthroplasty surgery. The choice of treatment is complex, as risks and benefits of surgical treatment have been shown to be heterogeneous across PHF patients.[4,12] Over the past decade, PHFs were reported to be increasingly managed with non-surgical treatment.[13] Studies comparing mortality after surgical and non-surgical treatment of PHF are scarce and the findings are inconsistent. For instance, higher rates of surgery were statistically significantly associated with a lower one-year mortality risk,[12] and higher mortality rates in patients treated nonoperatively were reported.[14] However, a meta-analysis of randomized controlled trials found little difference in mortality between participants treated surgically and non-surgically (17/248 vs 12/248; risk ratio (RR) 1.40 favouring non-surgical treatment, 95% confidence interval (CI) 0.69 to 2.83; $p = 0.35$; six trials).[15] Among these studies, the ProFHER trial, the largest randomized trial on PHFs, found that surgical treatment does not result in a better outcome for most patients with a displaced PHF, suggesting that non-surgical management could be a better standard of care.[16] Also, it has been shown that timing of surgery does not affect patient-reported outcomes.[17] Such findings resulted in divided opinion, sparking criticism and debates on the optimal PHF treatment.[18]

Thus, we aimed to answer the following questions based on broad nationwide data: 1) what is the overall incidence rate, as well as the age- and sex-specific incidence rates of PHFs in the elderly population in the USA; 2) what is the mortality rate after fracture of the proximal humerus in the elderly population in general and specifically for distinct treatment procedures; and 3) what clinical, demographic, and community-level socioeconomic factors influence the post-fracture mortality rate?

## Methods

PHFs occurring between 1 January 2009 and 31 December 2019 were identified from the Medicare physician claims records. These records encompassed physicians' diagnoses and services rendered in medical offices, outpatient clinics, hospitals, emergency departments, skilled nursing homes, and other healthcare facilities. The records were compiled by the Centers for Medicare and Medicaid Services (CMS), and after deidentification were made available for researchers, known as the Limited Data Set (LDS). Specifically, physician records associated with a 5% sample of Medicare beneficiaries, equivalent to the records from approximately 2.5 million enrollees, formed the basis of this study. Since the Medicare programme is nationwide and enrolment in Medicare is near-universal among the elderly in the USA with virtually no one lost to follow-up or un-enrolment, it can be thought of as a registry-like system that systematically captures medical services rendered nationwide and from across the social economic spectrum. For the LDS dataset, CMS replaced the beneficiary's identity with a synthetic and unique ID, which allowed patients to be followed longitudinally for survivorship and outcomes analyses. The population of interest included elderly Medicare patients (aged 65 years and above) who experienced a traumatic PHF during the study period. Since these LDS datasets were generated from the Medicare fee-for-service enrollees, those enrolled in a Medicare health maintenance organization (HMO), those younger than 65 years, or those residing outside of the 50 USA states were excluded. Since the CMS LDS data were deidentified, they were exempt from review by the Institutional Review Board.

The International Classification of Diseases (ICD), Ninth and Tenth Revisions,[19,20] were used to identify PHFs from these physician records. Diagnosis in claims submitted before 1 October 2015 were recorded in ICD-9-CM and later in ICD-10-CM. The ICD-9 codes used to identify PHFs were 812.0 and 812.1, and the ICD-10 codes used were S42.2xxA and S42.2xxB. Several steps were implemented to ensure that the identified fracture was true and was a new fracture. First, only records

**Table I.** Historic development of proximal humerus fracture diagnoses between 2009 and 2019.

| Year | Total, n | Medicare enrollees, n | Incidence/100,000 | IRR | p-value* |
|---|---|---|---|---|---|
| 2009 | 4,321 | 1,438,222 | 300.4 | N/A | N/A |
| 2010 | 4,316 | 1,458,043 | 296.0 | 0.99 | 0.857 |
| 2011 | 4,261 | 1,477,801 | 288.3 | 0.97 | 0.750 |
| 2012 | 4,285 | 1,509,564 | 283.9 | 0.98 | 0.854 |
| 2013 | 4,470 | 1,531,684 | 291.8 | 1.03 | 0.742 |
| 2014 | 4,549 | 1,546,499 | 294.1 | 1.01 | 0.924 |
| 2015 | 4,527 | 1,565,215 | 289.2 | 0.98 | 0.839 |
| 2016 | 4,258 | 1,602,680 | 265.7 | 0.92 | 0.319 |
| 2017 | 4,349 | 1,609,249 | 270.3 | 1.02 | 0.842 |
| 2018 | 4,314 | 1,619,824 | 266.3 | 0.99 | 0.863 |
| 2019 | 4,329 | 1,631,332 | 265.4 | 1.00 | 0.969 |

*Two-sample z-test.
IRR, incidence rate ratio; N/A, not applicable.

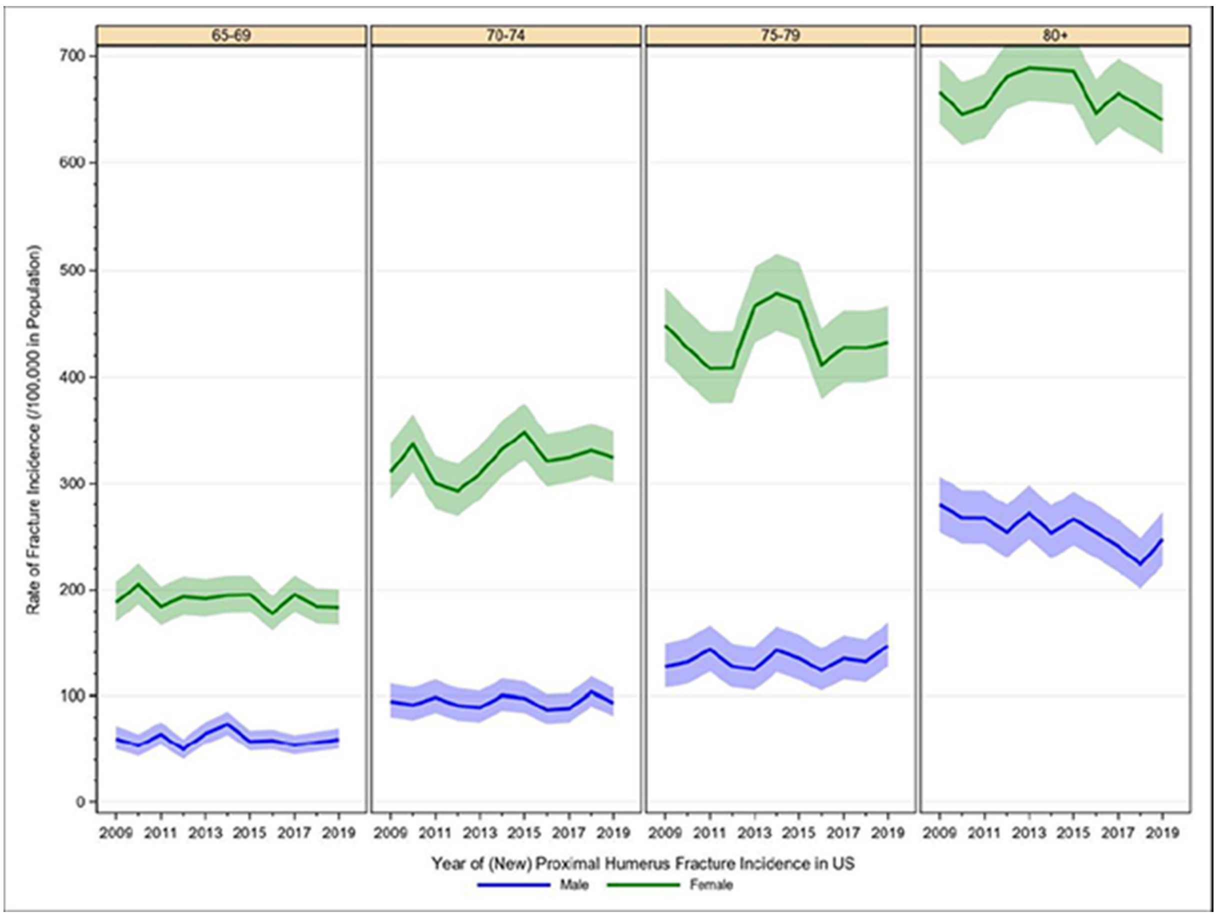


**Fig. 1**

Historic development of age- and sex-specific incidence rates of proximal humerus fractures.

with fracture diagnosis listed as the primary diagnosis were retained. Second, there could be no PHF record in the previous single year. Some patients did experience the PHF more than once during the ten-year study period, however from one PHF to the next a minimal interval of one year was required to ensure that the next PHF was not associated with continued care for the previous PHF. Third, for fractures coded using ICD-10, the seventh digit had to be 'A' or 'B' indicating a new encounter with that condition. Fractures with diagnosis code indicating postoperative care for healing of fracture or codes that indicated malunion or nonunion would not be counted because these conditions were consistent only with pre-existing fractures.

**Table II.** Total numbers and percentages of patients with comorbidities based on all cases with the respective morbidity type in association with the treatment procedure.

| Morbidity type | Treatment type | Total number | Percentage |
|---|---|---|---|
| Anticoagulant use | Nonoperative treatment | 2,650 | 90.82 |
| | Operative treatment | 187 | 6.41 |
| | Shoulder arthroplasty | 81 | 2.78 |
| COPD | Nonoperative treatment | 6,063 | 89.35 |
| | Operative treatment | 540 | 7.96 |
| | Shoulder arthroplasty | 183 | 2.70 |
| Chronic kidney disease | Nonoperative treatment | 5,019 | 89.96 |
| | Operative treatment | 381 | 6.83 |
| | Shoulder arthroplasty | 179 | 3.21 |
| Congestive heart failure | Nonoperative treatment | 5,450 | 91.50 |
| | Operative treatment | 364 | 6.11 |
| | Shoulder arthroplasty | 142 | 2.38 |
| Diabetic | Nonoperative treatment | 11,886 | 88.37 |
| | Operative treatment | 1,073 | 7.98 |
| | Shoulder arthroplasty | 492 | 3.66 |
| Hypertensive disease | Nonoperative treatment | 27,119 | 87.78 |
| | Operative treatment | 2,599 | 8.41 |
| | Shoulder arthroplasty | 1,177 | 3.81 |
| Insulin use | Nonoperative treatment | 595 | 88.81 |
| | Operative treatment | 45 | 6.72 |
| | Shoulder arthroplasty | 30 | 4.48 |
| Ischaemic heart disease | Nonoperative treatment | 8,742 | 89.49 |
| | Operative treatment | 745 | 7.63 |
| | Shoulder arthroplasty | 282 | 2.89 |
| Morbid obesity | Nonoperative treatment | 536 | 84.41 |
| | Operative treatment | 50 | 7.87 |
| | Shoulder arthroplasty | 49 | 7.72 |
| NSAID use | Nonoperative treatment | 32 | 82.05 |
| | Operative treatment | 4 | 10.26 |
| | Shoulder arthroplasty | 3 | 7.69 |
| Opioid use | Nonoperative treatment | 181 | 92.35 |
| | Operative treatment | 10 | 5.10 |
| | Shoulder arthroplasty | 5 | 2.55 |
| Osteoporosis | Nonoperative treatment | 4,248 | 87.61 |
| | Operative treatment | 427 | 8.81 |
| | Shoulder arthroplasty | 174 | 3.59 |
| Rheumatoid disease | Nonoperative treatment | 1,167 | 87.74 |
| | Operative treatment | 113 | 8.50 |
| | Shoulder arthroplasty | 50 | 3.76 |
| Tobacco dependence | Nonoperative treatment | 751 | 86.62 |
| | Operative treatment | 90 | 10.38 |
| | Shoulder arthroplasty | 26 | 3.00 |

COPD, chronic obstructive pulmonary disease; NSAID, non-steroidal anti-inflammatory drug.

The incidence of PHF was calculated by year and the rate of fracture was estimated by dividing the fracture frequency with the corresponding Medicare enrolments. The overall incidence rate and age- and sex-specific incidence rates were calculated. Incidence rate ratios (IRRs) with the corresponding 95% CIs were calculated by dividing the incidence in 2019 by the incidence of the preceding year. Incidence rates were compared using the two-sample z-test.

Treatments for the fracture were grouped into three categories: shoulder arthroplasty; other operational treatments; and nonoperational treatments. The operational and nonoperational treatments used a set of Common Procedural Terminology (CPT) codes identified by Bell et al.[21] Patients without these CPT treatment codes, but who could be fitted with a sling or immobilization devices, were grouped under the 'nonoperational' treatment group. We investigated the propensity of these treatments for PHF over the ten-year study period.

We also conducted a post-fracture mortality risk analysis in this study. Mortality was identified from the Medicare enrolment data provided by the CMS, which

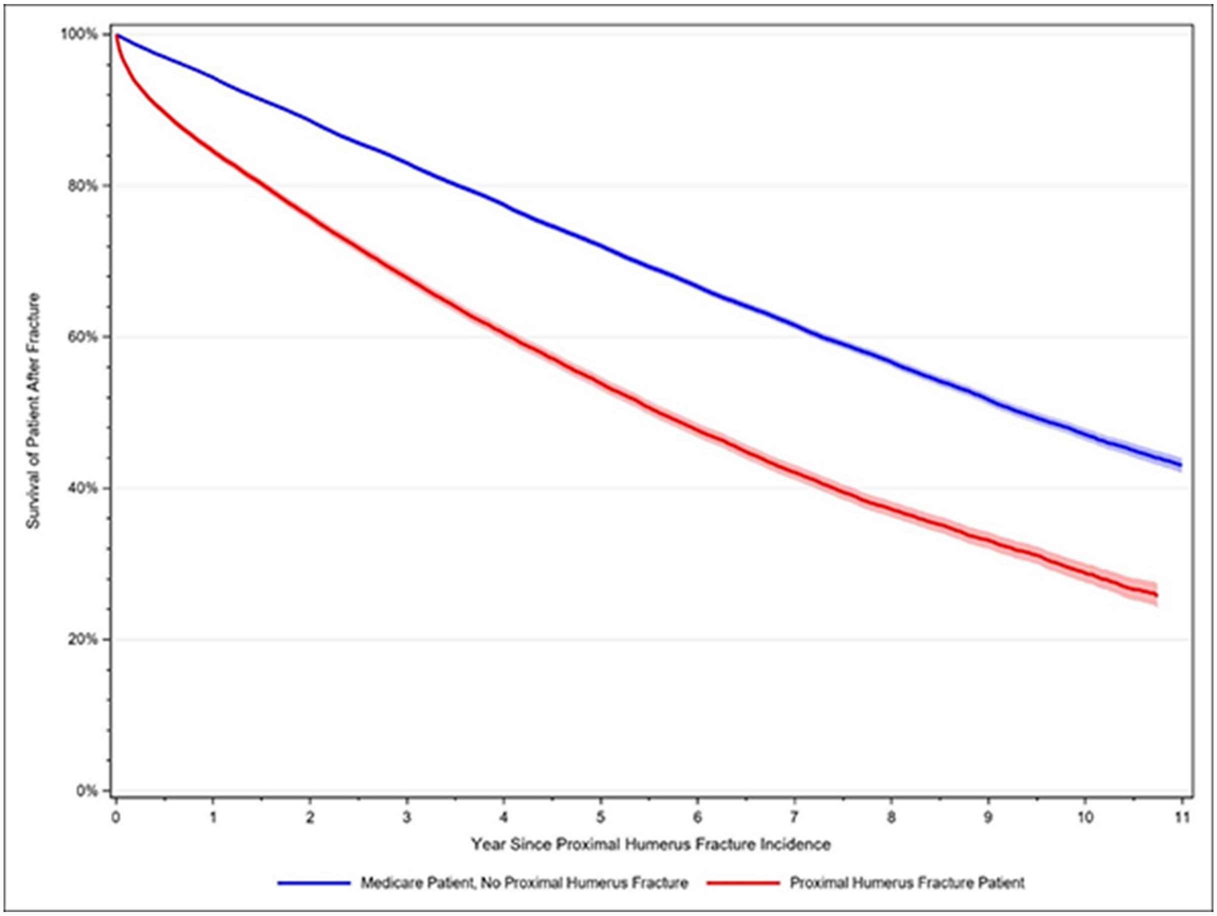


Fig. 2

Survival of patient after proximal humerus fracture (PHF) in comparison to age- and sex-matched Medicare enrollee without PHF.

included the date of death. We took advantage of the unique patient ID to track mortalities after the humerus fracture. Individuals were tracked from the PHF incidence date until the occurrence of the outcome, or until death, end of enrolment, or end of the study on 31 December 2019, whichever came first.

Since each PHF patient was tracked for different durations, we used survival analysis techniques to analyze these outcomes and to account for censoring in the observation period. We used the semiparametric Cox regression to compare mortality risk among patients receiving different types of treatment, after adjusting for a number of potential confounding factors. The Cox models incorporated demographic, clinical, and several community-level socioeconomic measures as covariates. The demographic factors included age, sex, race, resident region, and Medicare buy-in (as a surrogate for patient's economic status). Clinical factors included osteoporosis, obesity, diabetes mellitus, rheumatoid disease, chronic kidney disease, tobacco dependence, regular use of anticoagulant, regular non-steroidal anti-inflammatory drug (NSAID) use, prior osteoporotic fracture, hypertensive disease, ischaemic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), and congestive heart failure. These conditions were identified from the same type of physician claims records in a one-year period prior to the PHF; they could appear as either primary or secondary diagnosis, but at least two mentions of such condition in the prior year were required to reduce false or suspected-only conditions. Supplementary Table i documents the codes used to identify these conditions. The socioeconomic measures for the patients' resident county included were population, median household income, percentage of population with at least college education, percentage of population in poverty, percentage of unemployment, and a measure of the urban-rural character of the county. These measures were obtained from the USA Census, the Census Bureau's American Community Survey (ACS) programme,[22] and the Economic Research Service of the United States Department of Agriculture (USDA).[23] These measures helped to characterize the resident county of the patient and shed light on the association between socioeconomic effects and health outcomes among elderly PHF patients. For the fractures themselves, we characterized them as open or closed, and whether there was another bone fracture involved in a concomitant fracture incidence. We also checked to see if the fracture was

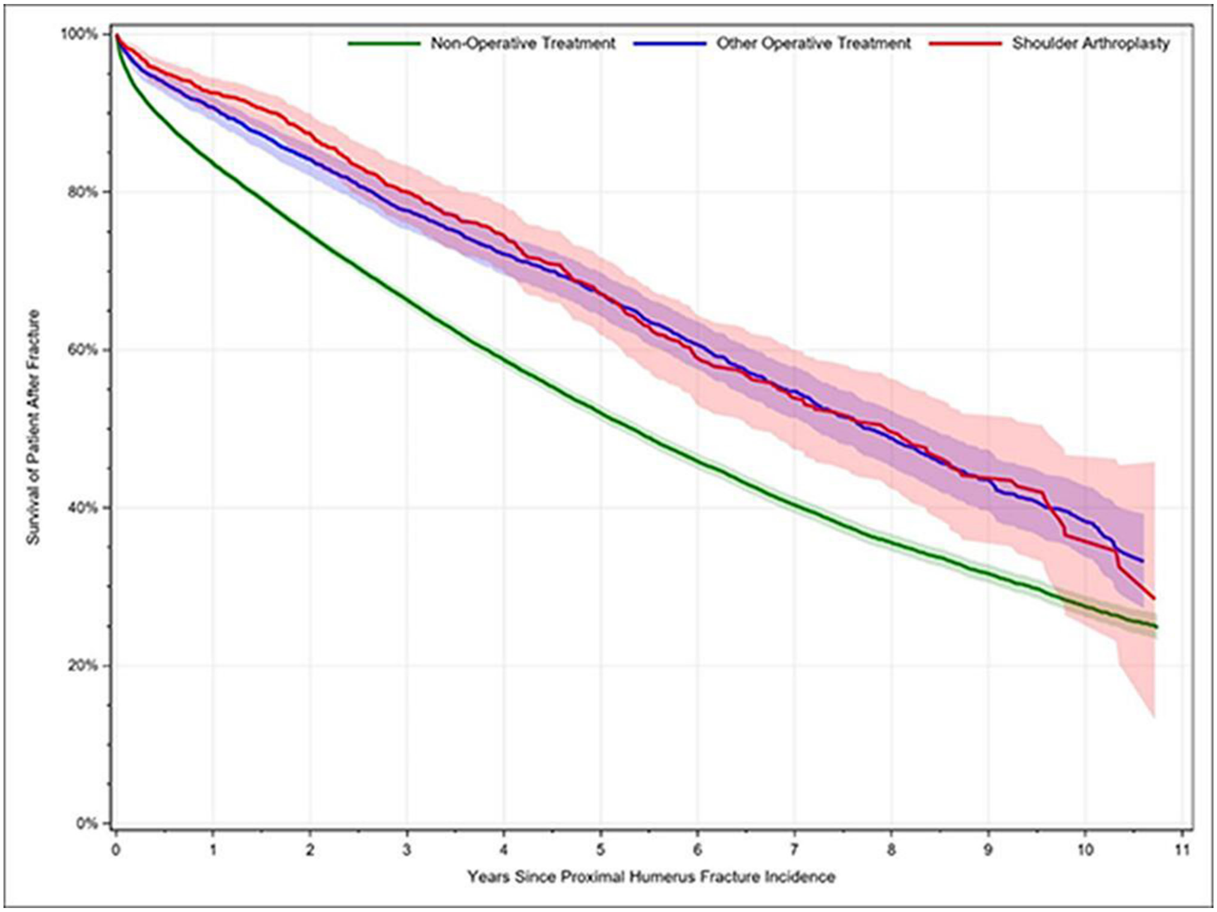


Fig. 3

Survival of patient after proximal humerus fracture dependent on the treatment procedure.

related to a fall or a vehicle crash, as those high-energy injuries could affect the outcomes.

Cox regression models and two-sample z-test were calculated using SAS statistical software version 9.4 (SAS Institute, USA), and statistical significance was determined at $p < 0.05$.

## Results

**Fracture incidence.** Based on the 5% of Medicare enrollees between 2009 and 2019, 47,979 PHFs were identified. In 2019, this resulted in 4,329 PHFs. Comparing the rates between 2009 and 2019, the incidence decreased by 11.85% from 300.4 cases per 100,000 Medicare enrollees to 266.3 cases per 100,000 Medicare enrollees, although this was not statistically significant ($z = -1.47$, $p = 0.142$, two-sample z-test) (Table I). PHFs occurred more often in women than in men (n = 38,367 (80%) vs n = 9,612 (20%)). The fracture incidence increased with age for both sexes, whereby 49.4% (n = 23,704) of all PHFs affected patients older than 80 years of age. The highest age- and sex-specific incidence was recorded for women aged 80 years or older, with 1,534 cases per 100,000 Medicare enrollees in 2019 (Figure 1). Out of all PHFs, 19.4% (n = 9,328) were fall-related, 0.3% (n = 125) vehicle-related, and 0.6% (n = 266) constituted open fractures. Over the considered time period, the percentage of cases managed conservatively changed from 88.5% (95% CI 87.5 to 89.4) to 87.6% (95% CI 86.6 to 88.5). Surgical treatment decreased from 9.5% (95% CI 8.7 to 10.4) to 7.0% (95% CI 6.2 to 7.7), whereas shoulder arthroplasties after PHF increased from 2.0% (95% CI 1.6 to 2.4) to 5.5% (95% CI 4.8 to 6.2). The mean age of patients treated non-surgically was 79.9 years (standard deviation (SD) 8.5), patients in the operative treatment group were aged 77.0 years (SD 7.5), and patients receiving a shoulder arthroplasty had a mean age of 77.9 years (SD 7.1). Further, more patients receiving nonoperative treatment had comorbidities (Table II).

**Mortality.** Regardless of the treatment procedure, 84.6% (95% CI 84.0 to 85.1) of PHF patients survived after one year, whereas after 11 years 25.7% (95% CI 24.1 to 27.3) of patients were still alive. In comparison to matched Medicare patients without a PHF, but of the same five-year age group and sex and who resided in the same county, a mean survival difference of -17.3% was observed (Figure 2). The one-year mortality rate was higher after nonoperative treatment with 16.4% compared to surgical treatment with 9.3% (hazard ratio (HR) = 1.29, 95% CI

**Table III.** Comparison of treatment procedure associated with mortality risk.

| Treatment | Reference treatment | HR | Lower HR | Upper HR | p-value* |
|---|---|---|---|---|---|
| Nonoperative treatment | Other operative treatment | 1.29 | 1.23 | 1.36 | < 0.001 |
| | Shoulder arthroplasty | 1.45 | 1.33 | 1.58 | < 0.001 |
| Other operative treatment | Nonoperative treatment | 0.78 | 0.74 | 0.82 | < 0.001 |
| | Shoulder arthroplasty | 1.13 | 1.02 | 1.24 | 0.018 |
| Shoulder arthroplasty | Nonoperative treatment | 0.69 | 0.63 | 0.75 | < 0.001 |
| | Other operative treatment | 0.89 | 0.80 | 0.98 | 0.018 |

Statistical significance set at p < 0.05.
*Semiparametric Cox regression.
HR, hazard ratio.

1.23 to 1.36; p < 0.001) and to shoulder arthroplasty with 7.4% (HR = 1.45, 95% CI 1.33 to 1.58; p < 0.001, both semiparametric Cox regression) (Figure 3, Table III).

Statistically significant mortality risk factors after operative treatment included age older than 75 years, male sex, COPD, cerebrovascular disease, chronic kidney disease, a concomitant fracture, congestive heart failure, and osteoporotic fracture (Table IV).

## Discussion

The present study investigated age- and sex-specific incidence rates of PHFs as well as mortality risk as a function of the treatment procedure, and also explored associated risk factors in the elderly Medicare population.

**Age- and sex-dependent incidence rates in the elderly population.** We found a decreased incidence of PHFs in the elderly USA population from 2009 to 2019. The incidence declined by 11.85% from 300.4 cases per 100,000 to 266.3 cases per 100,000 Medicare enrollees.

Between 1990 and 2010, the incidence was shown to increase from 78.9/100,000 to 101.0/100,000 patients aged 65 years or older in the state of New York.[24] The subsequent decrease over the past decade might reflect advances in the risk assessment, prevention, and treatment of osteoporosis.[25] This is in contrast to other European countries, where a steadily increased incidence of PHF has been reported.[26–30]

In line with our findings of increasing age-specific incidences for both sexes, an analysis based on a Nationwide Emergency Department Sample in the USA in 2008 revealed an increase in PHF rates until the age of 89 years, which was also more pronounced among women.[5] The higher incidence in older females might be explainable by a higher osteoporosis prevalence.[31] In addition, differences in the trauma mechanisms play a role in that women are more prone to low-energy trauma, whereas high-energy trauma occurs more frequently in men.[9] The low rate of coded osteoporotic fractures in the PHF dataset analyzed in the present study might be due to low coding accuracy. This could mirror the neglect of osteoporosis diagnostics in treatment even in typical osteoporotic fractures, whereby injuries involving the proximal- and middle-thirds of the humeral diaphysis should be considered as fragility fractures.[32]

**Mortality.** The data from this study show a one-year mortality rate of 15.4%. When comparing this to Medicare patients without a PHF, a mean survival difference of -17.3% was observed. The one-year mortality rate was significantly higher after nonoperative treatment with 16.4% compared to surgical treatment with 9.3% (HR = 1.29, 95% CI 1.23 to 1.36; p < 0.001), as well as in comparison to shoulder arthroplasty procedure with a mortality rate of 7.4% (HR = 1.45, 95% CI 1.33 to 1.58; p < 0.001, both semiparametric Cox regression).

A study similar to ours by Clement et al[33] revealed a one-year mortality rate of 10% in PHF patients older than 65 years. The authors found that the only predictor of improved survival in these patients was living at home when the PHF occurred (p = 0.025). In another study involving patients with a complex, displaced PHF who were older than 75 years, one-year mortality was determined as 8.1% after reverse shoulder arthroplasty and as 10.8% without surgical treatment.[34]

Our results show that the higher mortality in patients with nonoperative management could be explained by a selection bias, such that these patients could be sicker and carry a greater operative risk, leading the treating physician to choose nonoperative treatment in this group for this reason. Non-surgical management has also been found to be a predictor for five-year mortality in other studies.[35] Additionally, Lander et al[14] analyzed 42,511 PHFs in patients older than 60 years, associating operative treatment with lower mortality at seven days, 30 days, and one year (9.1% vs 19.1%; p < 0.01). Another comparative effectiveness study on PHF among Medicare beneficiaries with PHF in 2011 showed that a one-percentage point increase in the surgery rate was associated with a 0.01-percentage point decrease in the one-year mortality rate ($\beta = -0.01$; 95% CI -0.015 to -0.005; p < 0.001). However, increased costs and adverse events were statistically significantly higher with the increased surgery rate.[12] To illustrate the financial burden, mean costs of a reverse shoulder arthroplasty procedure were determined to be €8,027.[36]

In our current study, statistically significant mortality risk factors after operative treatment included age older than 75 years, male sex, COPD, cerebrovascular disease, chronic kidney disease, a concomitant fracture,

**Table IV.** Mortality risk factors after nonoperative treatment of proximal humerus fracture.

| Factor | Nonoperative treatment | | | | | Other operative treatment | | | | | Shoulder arthroplasty | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HR | Lower HR | Upper HR | Chi-square | p-value* | HR | Lower HR | Upper HR | Chi-square | p-value* | HR | Lower HR | Upper HR | Chi-square | p-value* |
| **Age at fracture (yrs)** | | | | | | | | | | | | | | | |
| 70 to 74 vs 65 to 69 | 1.18 | 1.11 | 1.26 | 24.66 | < 0.001 | 1.16 | 0.95 | 1.42 | 2.07 | 0.150 | 0.98 | 0.64 | 1.48 | 0.01 | 0.912 |
| 75 to 79 vs 65 to 69 | 1.62 | 1.52 | 1.73 | 221.87 | < 0.001 | 1.82 | 1.50 | 2.20 | 38.33 | < 0.001 | 1.55 | 1.04 | 2.31 | 4.67 | 0.031 |
| 80+ vs 65 to 69 | 3.58 | 3.39 | 3.79 | 2011.76 | < 0.001 | 3.98 | 3.36 | 4.73 | 248.23 | < 0.001 | 2.90 | 2.01 | 4.17 | 32.76 | < 0.001 |
| **Race** | | | | | | | | | | | | | | | |
| Black vs White | 1.03 | 0.94 | 1.12 | 0.37 | 0.543 | 0.87 | 0.56 | 1.34 | 0.40 | 0.527 | 1.08 | 0.58 | 2.00 | 0.06 | 0.808 |
| Other vs White | 0.78 | 0.72 | 0.86 | 29.78 | < 0.001 | 0.74 | 0.55 | 1.01 | 3.63 | 0.057 | 1.51 | 0.97 | 2.35 | 3.30 | 0.069 |
| **Resident region** | | | | | | | | | | | | | | | |
| Midwest vs South | 1.03 | 0.99 | 1.07 | 1.85 | 0.174 | 1.12 | 0.98 | 1.28 | 2.86 | 0.091 | 0.98 | 0.77 | 1.25 | 0.03 | 0.871 |
| Northeast vs South | 0.93 | 0.89 | 0.97 | 10.07 | 0.002 | 0.92 | 0.78 | 1.10 | 0.84 | 0.360 | 1.01 | 0.74 | 1.38 | 0.01 | 0.939 |
| West vs South | 0.95 | 0.91 | 1.00 | 4.36 | 0.037 | 1.08 | 0.92 | 1.26 | 0.85 | 0.356 | 1.22 | 0.93 | 1.61 | 2.03 | 0.154 |
| Female sex | 0.67 | 0.65 | 0.70 | 474.53 | < 0.001 | 0.61 | 0.54 | 0.70 | 52.55 | < 0.001 | 0.73 | 0.57 | 0.93 | 6.60 | 0.010 |
| Anticoagulant use | 1.13 | 1.07 | 1.20 | 18.88 | < 0.001 | 1.22 | 0.99 | 1.51 | 3.32 | 0.069 | 1.15 | 0.78 | 1.69 | 0.50 | 0.482 |
| COPD | 1.52 | 1.46 | 1.59 | 397.65 | < 0.001 | 1.72 | 1.49 | 1.99 | 52.62 | < 0.001 | 1.50 | 1.13 | 2.00 | 7.78 | 0.005 |
| Cerebrovascular disease | 1.26 | 1.21 | 1.32 | 120.06 | < 0.001 | 1.25 | 1.06 | 1.47 | 7.21 | 0.007 | 1.60 | 1.21 | 2.11 | 10.92 | < 0.001 |
| Chronic kidney disease | 1.43 | 1.37 | 1.50 | 243.04 | < 0.001 | 1.45 | 1.22 | 1.72 | 17.68 | < 0.001 | 1.45 | 1.08 | 1.95 | 5.96 | 0.015 |
| Concomitant fracture | 1.23 | 1.18 | 1.29 | 81.73 | < 0.001 | 1.24 | 1.09 | 1.41 | 10.04 | 0.002 | 1.50 | 1.16 | 1.95 | 9.31 | 0.002 |
| Congestive heart failure | 1.75 | 1.67 | 1.82 | 635.98 | < 0.001 | 1.76 | 1.47 | 2.10 | 38.08 | < 0.001 | 1.97 | 1.44 | 2.71 | 17.72 | < 0.001 |
| Diabetes mellitus | 1.09 | 1.05 | 1.13 | 24.51 | < 0.001 | 1.11 | 0.99 | 1.25 | 2.94 | 0.086 | 1.09 | 0.88 | 1.34 | 0.58 | 0.446 |
| Fall related fracture | 1.00 | 0.96 | 1.04 | 0.01 | 0.926 | 0.98 | 0.86 | 1.11 | 0.15 | 0.700 | 1.05 | 0.84 | 1.31 | 0.19 | 0.665 |
| Hypertensive disease | 0.94 | 0.91 | 0.97 | 12.97 | < 0.001 | 0.95 | 0.85 | 1.07 | 0.69 | 0.406 | 0.92 | 0.74 | 1.13 | 0.64 | 0.423 |
| Ischaemic heart disease | 1.03 | 1.00 | 1.07 | 3.04 | 0.081 | 1.01 | 0.88 | 1.16 | 0.01 | 0.914 | 1.12 | 0.88 | 1.41 | 0.85 | 0.356 |
| Morbid obesity | 0.89 | 0.76 | 1.04 | 2.29 | 0.130 | 0.83 | 0.39 | 1.75 | 0.24 | 0.624 | 0.91 | 0.50 | 1.66 | 0.09 | 0.762 |
| Open fracture | 1.11 | 0.94 | 1.30 | 1.46 | 0.226 | 1.08 | 0.69 | 1.71 | 0.11 | 0.736 | 0.93 | 0.34 | 2.57 | 0.02 | 0.889 |
| Osteoporotic fracture | 1.61 | 1.46 | 1.78 | 89.47 | < 0.001 | 2.07 | 1.51 | 2.84 | 20.62 | < 0.001 | 0.93 | 0.48 | 1.82 | 0.04 | 0.837 |
| Osteoporosis | 0.91 | 0.87 | 0.96 | 13.25 | < 0.001 | 0.99 | 0.83 | 1.18 | 0.01 | 0.905 | 1.34 | 1.01 | 1.77 | 4.08 | 0.043 |
| Rheumatoid disease | 1.07 | 0.98 | 1.17 | 2.54 | 0.111 | 0.83 | 0.60 | 1.15 | 1.23 | 0.267 | 0.78 | 0.47 | 1.31 | 0.86 | 0.354 |
| Tobacco dependence | 1.30 | 1.16 | 1.46 | 19.86 | < 0.001 | 1.55 | 1.08 | 2.20 | 5.81 | 0.016 | 2.12 | 1.04 | 4.32 | 4.27 | 0.039 |
| % college degree | 1.00 | 0.99 | 1.00 | 4.25 | 0.039 | 1.00 | 0.99 | 1.01 | 0.45 | 0.503 | 0.98 | 0.97 | 1.00 | 4.45 | 0.035 |
| % poverty | 1.00 | 1.00 | 1.00 | 0.09 | 0.769 | 1.01 | 1.00 | 1.03 | 1.79 | 0.181 | 0.99 | 0.97 | 1.02 | 0.49 | 0.484 |

Statistical significance set at p < 0.05.
*Semiparametric Cox regression.
COPD, chronic obstructive pulmonary disease; HR, hazard ratio.

congestive heart failure, and osteoporotic fracture. For conservative management these incorporated age older than 70 years, male sex, anticoagulant use, COPD, cerebrovascular disease, chronic kidney disease, a concomitant fracture, congestive heart failure, diabetes mellitus, hypertensive disease, osteoporosis, and tobacco dependence. Given the high mortality rate after nonoperative treatment in the investigated cohort of elderly patients, modifiable factors should be optimized.

Increasing age, male sex, and non-surgical treatment were also identified as independent factors associated with an increased risk of mortality in a recent study.[37] Further, a higher Charlson Comorbidity Index and pulmonary embolism were associated with increased risk odds ratios

(ORs) in a mortality risk analysis.[38] Other retrospective studies also investigated risk factors for other complications after surgical treatment such as heterotopic ossification. Here, higher ORs were found for male sex (OR 3.57) and dislocation during initial injury (OR 5.01).[39] In addition, risk factors such as alcohol abuse, severe osteoarthritis, and osteoporosis were determined for secondary fracture displacement after conservative treatment.[40] Our analysis further revealed a lower number of risk factors for mortality after shoulder arthroplasty for PHF management. In line with this, other studies also reported that hemiarthroplasty in particular offers a valid alternative, with a 14-year cumulative revision rate of 5.7%.[41]

This study had a number of limitations. First of all, the underlying analysis is based on a 5% sample of Medicare beneficiaries, equivalent to the records from approximately 1.6 million enrollees aged older than 65 years. As these represent only a small proportion of the overall USA population, the generalizability of the results is limited. The Medicare data used in this study are fundamentally a set of administrative claims records, with all the attendant limitations for this type of data for orthopaedic outcomes research.[42,43] We do not have access to the underlying clinical records of these patients, and the analysis relies on correct coding and data management, which cannot be independently validated beyond Medicare's checking and validation process in their claim processing system. Additionally, many important clinical measures (e.g. radiological imaging findings) and other indicators (e.g. blood chemistry, organ function test) are not captured by the diagnosis or procedure codes in these data. Whereas an individual record could include errors of omission or commission, systematic error permeating throughout millions of such records in the entire Medicare system is unlikely. In this regard, the broad range of facilities submitting these claims and the hundreds of millions of such records processed by Medicare are its unique strength. It can be assumed that the extensive information on patient characteristics and complications has a high level of quality, due to its relevance for the billing of costs and the insertion of the data by appropriate specialists. In terms of the range of available parameters, the Medicare dataset is characterized by a richness of relevant parameters that is incomparable to other registry data. In addition, as PHFs included in the analysis were identified based on ICD-10 codes, no subgroup analyses according to a classification of the fractures (e.g. AO, Neer) were feasible. Thus, the lack of information on the fracture pattern limits the content of the study.

In conclusion, PHFs represent a clinical challenge associated with a one-year mortality rate of 15.4%. Mortality rates differ statistically significantly between nonoperative treatment, fracture fixation surgery, and shoulder arthroplasty. Conservative management was a statistically significant risk factor for death. Mortality risk factors for distinct treatment procedures after PHF in elderly patients could be identified, which may guide clinical decision-making.

## Supplementary material

ë Table showing used International Classification of Diseases (ICD)-9 and ICD-10 diagnosis codes for the semiparametric Cox regression models.

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