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Bone fracture nonunion rate decreases with increasing age: A prospective inception cohort study

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ABSTRACT

Background: Fracture nonunion risk is related to severity of injury and type of treatment, yet fracture healing is not fully explained by these factors alone. We hypothesize that patient demographic factors assessable by the clinician at fracture presentation can predict nonunion.

Methods: A prospective cohort study design was used to examine ~2.5 million Medicare patients nationwide. Patients making fracture claims in the 5% Medicare Standard Analytic Files in 2011 were analyzed; continuous enrollment for 12 months after fracture was required to capture the ICD-9-CM nonunion diagnosis code (733.82) or any procedure codes for nonunion repair. A stepwise regression analysis was used which dropped variables from analysis if they did not contribute sufficient explanatory power. In-sample predictive accuracy was assessed using a receiver operating characteristic (ROC) curve approach, and an out-of-sample comparison was drawn from the 2012 Medicare 5% SAF files.

Results: Overall, 47,437 Medicare patients had 56,492 fractures and 2.5% of fractures were nonunion. Patients with healed fracture (age 75.0 ± 12.7 SD) were older ($p < 0.0001$) than patients with nonunion (age 69.2 ± 13.4 SD). The death rate among all Medicare beneficiaries was 4.8% per year, but fracture patients had an age- and sex-adjusted death rate of 11.0% ($p < 0.0001$). Patients with fracture in 14 of 18 bones were significantly more likely to die within one year of fracture ($p < 0.0001$). Stepwise regression yielded a predictive nonunion model with 26 significant explanatory variables (all, $p \leq 0.003$). Strength of this model was assessed using an area under the curve (AUC) calculation, and out-of-sample AUC = 0.710.

Conclusions: A logistic model predicted nonunion with reasonable accuracy (AUC = 0.725). Within the Medicare population, nonunion patients were younger than patients who healed normally. Fracture was associated with increased risk of death within 1 year of fracture ($p < 0.0001$) in 14 different bones, confirming that geriatric fracture is a major public health issue. Comorbidities associated with increased risk of nonunion include past or current smoking, alcoholism, obesity or morbid obesity, osteoarthritis, rheumatoid arthritis, type II diabetes, and/or open fracture (all, multivariate $p < 0.001$). Nonunion prediction requires knowledge of 26 patient variables but predictive accuracy is currently comparable to the Framingham cardiovascular risk prediction.

1. Background

Fractures are relatively common among patients older than age 65 [1]. The increase in fracture incidence in the elderly may represent a confluence of trends. The number of falls by the elderly correlates positively with increasing age [2]. There is also a rising age-related incidence of illnesses that increase fall risk, including diabetes [2], Alzheimer's

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disease [3], stroke [4], Parkinson's disease [5], and multiple sclerosis [5, 6]. Certain comorbidities which increase in prevalence with age, including diabetes [7,8], osteoporosis [9], osteopenia [10], sarcopenia [11], vitamin D insufficiency [12], and chronic opioid dependency [13] make patients more prone to fracture if they do fall [1]. Finally, certain diseases make elderly patients with fracture more prone to nonunion [14]. People over age 65 are therefore at increased risk for fracture [1] and may also be at increased risk for nonunion.

A better understanding of fracture nonunion in the elderly is important because certain geriatric fractures predispose patients to premature death [15], including fractures of the cervical spine [16], pelvis [17], acetabulum [18,19], hip [1,20,21,22], and distal radius [23]. We seek to develop a predictive algorithm that will alert physicians to elderly patients at risk of fracture nonunion. This may enable clinicians to identify at-risk patients earlier in their course, when intervention could potentially improve clinical outcome.

2. Methods

2.1. Study cohort

The study cohort was derived from the 5% Medicare Standard Analytic Files (SAF) for calendar year 2011, a random sample of the covered lives in Medicare. In 2011, Medicare covered 48.7 million people, including 40.4 million people aged 65 and older, and 8.3 million disabled people. About 25% of all beneficiaries chose to enroll in Part C private health plans, which contract with Medicare to provide Part A and Part B health services. Thus, the traditional fee-for-service Medicare beneficiaries that would have claims in the SAF would be 36.5 million (48.7×0.75). The SAF contains final action claims data submitted by providers for reimbursement. We analyzed all Medicare beneficiaries with ≥1 fracture diagnosis in the 18 bones most frequently fractured.

We excluded beneficiaries who did not have both Medicare Part A and Part B eligibility in all of 2011 and 2012, so that a code for nonunion could be captured. Patients were excluded for a malunion claim or if the 2011 claim was for nonunion of a prior fracture.

2.2. Outcome identification

We identified nonunions in the 2011 and 2012 Medicare SAFs using the ICD-9-CM nonunion diagnosis code (733.82) [24] and also using procedure codes for repair of nonunion, including bone graft and various bone growth stimulators, such as electrical stimulation and low-intensity pulsed ultrasound. We identified physician, hospital inpatient, hospital outpatient, and durable medical equipment claims ≤365 days after the fracture index date. Bone graft codes within 6 months of the index date were considered part of the initial fracture treatment and not necessarily evidence of nonunion.

Roughly 84% of patients in the study had only one fracture. The nonunion diagnosis code and some treatment codes are not bone-specific, so we sought to associate nonunion with an individual fracture. We compared the date of nonunion diagnosis or treatment to the dates of fracture care visits. First, we linked patients with a single fracture and a nonunion code on the same day. For patients with multiple fractures and a nonunion, we associated nonunion with the fracture treated within 14 days of the nonunion diagnosis. For the few remaining cases, the fracture that was treated closest to the claim was accepted as a nonunion. We also identified whether death occurred within 365 days of the index date from denominator files for 2011 and 2012.

2.3. Covariate identification

Conditions and comorbidities that could potentially contribute to nonunion were identified through treatment claims up to 1 year prior to, or 30 days after, the index fracture date. A medical condition was considered present when ≥2 claims indicating the condition were found for a patient. Treatments were categorized as surgical or nonsurgical based on procedure codes. Demographic information on age, gender, original reason for Medicare eligibility, and dual eligibility for Medicaid was obtained from the denominator file.

2.4. Analysis

Patient demographics that are binary are presented as percentages and analyzed with a two-tailed χ^2 test. Continuous variables are presented as mean ± standard deviation (SD) and analyzed with a two-tailed Student *t*-test.

Regression analysis used 60 patient characteristics and comorbidities that might contribute to nonunion. Variables included: 6 categories of age; 18 bones of interest (with 1 bone used as a reference); number of concurrent fractures; gender; 23 comorbidity variables (e.g. hypertension); a variable representing whether surgery was performed; open or closed fracture; and 3 variables representing the reason for Medicare eligibility (disabled vs. aged) and whether the patient was dually eligible for Medicaid. Rib fracture was not represented in the model because it was the reference, chosen because it had the lowest risk of nonunion in our cohort.

The dependent variable in the analysis was nonunion (1 = Present, 0 = Absent), and we used a logistic model [25]. For parsimony, the model was estimated using a stepwise procedure, which dropped variables from analysis if they did not contribute sufficient explanatory power. We specified $p = 0.01$ as the significance level to retain a variable in the model. The out-of-sample predictive accuracy of the model was assessed using a receiver operating characteristic (ROC) curve approach [26]. The out-of-sample comparison sample was drawn from the 2012 Medicare 5% SAF files.

2.5. Patient involvement

Patients were not involved in the design of this study, nor were patients recruited for study involvement; this was a payer reimbursement study.

3. Results

A total of 54,269 patients had fracture in the 2011 Medicare 5% SAF database, but 5018 patients were excluded from consideration because they were not Medicare Part A and B eligible in 2011 and 2012 or because they elected to use a health-maintenance organization (HMO) in 2011 or 2012 (Fig. 1). An additional 79 patients had flaws in the demographic file and could not be analyzed, while fewer than 11 patients were under age 18. A total of 1718 patients with 1754 fractures were excluded because there was treatment in 2010 for the same bone treated in 2011, suggesting that the 2011 fracture actually occurred in 2010.

A total of 47,437 Medicare patients with 56,492 fractures were analyzed, and 2.5% of fractures went to nonunion (Table 1). Patients with fracture but without nonunion (age 75.0 ± 12.7 standard deviation, SD), were significantly older ($p < 0.0001$) than patients with nonunion (age 69.2 ± 13.4 SD). Compared to the average Medicare patient, patients were significantly more likely to develop nonunion under age 75, while patients over age 75 were less likely to go to nonunion (Table 1). Among patients ≥85 years, the nonunion rate was 1.3%, whereas the nonunion rate in patients age 55–59 was 5.5% (Table 1).

Nonunion rate varied by bone, from a low of 0.6% in ribs and trunk to a high of 6.4% in scaphoid (Table 2). The estimate of nonunion rate bone-by-bone is likely to be robust as the smallest sample size was scaphoid ($N = 534$), while the largest sample size was neck of femur ($N = 9426$).

Fracture was associated with premature death in many different bones (Table 2). Death rate in the Medicare population overall was 4.8% per year among 50 million patients. Patients with fracture in any