




A Nomogram for Predicting 30-day Mortality in Elderly Patients Undergoing Hemiarthroplasty for Femoral Neck Fractures

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Abstract

Introduction: Femoral neck fractures in the elderly are increasingly common as a result of a growing geriatric population with 1-year mortality rates approaching 35%. While preoperative medical optimization and early time to surgery have reduced morbidity and mortality, patients with numerous medical comorbidities remain high risk for death in the perioperative period. Identifying those with greatest risk with a scoring system or nomogram may assist multidisciplinary teams in reducing mortality following hemiarthroplasty. **Purpose:** Identify predictors of 30-day mortality in elderly patients who underwent hemiarthroplasty for a femoral neck fracture to generate a predictive nomogram to determine the probability of post-operative mortality. **Methods:** Retrospective evaluation using data from the ACS-NSQIP database from 2005 to 2014 with CPT code 27125 for hip hemiarthroplasty. Multiple factors including demographics and comorbidities were compared in patients who experienced 30-day mortality and those who did not. T-test and chi-square tests were used to analyze data and a multivariate model was generated using logistic regression. **Results:** Advanced age (odds ratio (OR) 1.04), underweight BMI (OR 1.55), male sex (OR 1.80), reduced functional status (OR 2.04), heart failure within 30 days prior to surgery (OR 2.22), American Society of Anesthesiologists grade > 2 (OR > 2.50), disseminated cancer (OR 3.43) were all found to have statistically significant odds ratios for 30-day mortality following hemiarthroplasty. **Conclusion:** A tool based on easily identifiable risk factors, demographics, and comorbidities was developed that can help predict elderly patients who will experience mortality within 30 days of following hemiarthroplasty. In addition to identifying high risk patients, the nomogram can serve as a counseling tool for physicians to use with patients and their families to assist with better understanding of perioperative mortality risk.

Keywords

adult reconstructive surgery, biostatistics, economics of medicine, geriatric medicine, anesthesia, fragility fractures

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Introduction

Femoral neck fractures are a major clinical and financial impact on the health care system with approximately over 250,000 hip fractures occurring annually with over 30% undergoing hemiarthroplasty.¹⁻⁴ Current treatment for hip fractures can include internal fixation, hemiarthroplasty, or total hip arthroplasty, however hemiarthroplasty remains prevalent treatment of choice.⁴⁻⁸ A growing geriatric population, with those greater than 65 years old expected to account for 25% of the population by 2030, will further increase rates of displaced femoral neck fractures observed in elderly patients.^{9,10} Despite attempts to reduce modifiable risk factors and improve

medical co-management of patients, femoral neck fractures in elderly patients have high rates of in-hospital and 30-day morbidity and mortality with 1-year mortality rates approaching 35%.¹⁰⁻¹⁵

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Previous studies have shown decreased mortality and improved functional outcomes by reducing time to operating room for patients with femoral neck fractures.^{12,13,15-17} As patients with multiple medical comorbidities need pre-operative optimization for efficient time to surgery; understanding risk factors may assist multidisciplinary teams in facilitating pre-operative management. Male gender, age > 80, non-ambulatory status, and American Society of Anesthesiologists (ASA) grade 4 or 5 have been shown to be predictors of mortality in patients with femoral neck fractures.^{11,18} Additionally, patients with 3 or more comorbidities, respiratory disease, or malignancy were more likely to experience death.¹⁰

While preliminary literature has identified risk factors for morbidity and mortality, there is little information on the impact of these risk factors on predicting 30-day mortality. The purpose of this study is to evaluate predictors of 30-day mortality in elderly patients who underwent hemiarthroplasty for a femoral neck fracture to generate a predictive nomogram which can easily be used by clinicians to determine the probability of mortality and assist in informed discussions with patients and family regarding risks and clinical outcomes following hemiarthroplasty for displaced femoral neck fractures.

Methods

This study is a retrospective evaluation using data collected from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP). The registry was queried using the Current Procedural Terminology (CPT) code, 27125, for hip hemiarthroplasties conducted from 2005 through 2014. All patients with CPT 27125 were included.

Patient characteristics including demographics, comorbidities, pre-operative lab values, ASA classification, pre-operative functional status, and surgical variables were then compared for patients who experienced 30-day mortality and those who did not. Comorbid conditions captured in the ACS-NSQIP database included ascites, pneumonia, cerebrovascular accident with and without neurological deficit, diabetes, pre-operative dialysis, dyspnea at rest or with moderate exertion, disseminated cancer, drinking greater than 2 drinks of alcohol per day, hemiplegia, history of angina 1 month prior to surgery, heart failure 30 days prior to surgery, history of revascularization or amputation or peripheral vascular disease, hypertension requiring medication, impaired sensorium, smoking, paraplegia, blood transfusion of greater than 4 units less than 72 hours prior to surgery, urinary tract infection, and whether the patient was ventilator dependent. For the remaining available comorbid conditions which were prevalent in less than 1% of the patient sample, a composite variable was created. Pre-operative laboratory assessments in the database included serum albumin, alkaline phosphate, bilirubin, blood urea nitrogen, serum creatinine, hematocrit, international normalized ratio (INR), platelet count, prothrombin time, partial thromboplastin time, serum sodium, serum glutamic oxaloacetic transaminase, and white blood count.

Table 1. Baseline Demographics of Patients Undergoing Hip Hemiarthroplasty for Femoral Neck Fractures Between 2005 and 2014 in NSQIP.

| Demographics | Survived | | | P value |
|-------------------------------|----------|-------|---------|----------|
| | 30 days | Death | Overall | |
| Overall | 5,650 | 269 | 5,919 | |
| Age (year) | 79.5 | 81.7 | 79.8 | <0.0001* |
| Race | | | | 0.11 |
| American Indian | 16 | 0 | 16 | |
| Asian/Pacific | 150 | 4 | 154 | |
| Black/African American | 218 | 5 | 223 | |
| White | 4,078 | 191 | 4,269 | |
| Unknown | 1,188 | 69 | 1,257 | |
| Hispanic | 255 | 11 | 266 | |
| BMI | 24.9 | 23.8 | 24.8 | 0.01* |
| Weight loss > 10% in 6 months | 73 | 9 | 82 | 0.005* |
| Male Sex | 1,751 | 126 | 1,877 | <0.0001* |

Patients were evaluated based on survival versus death within 30 days after undergoing hip hemiarthroplasty. Categorical variables were analyzed using a chi square test. Continuous variables were examined for normality and the need for appropriate transformation or comparison methods. Means with standard deviations were compared between the 2 study groups using a t-test or a Wilcoxon signed rank test. Variables that were identified as statistically significantly ($\alpha \leq 0.05$) were retained for prediction modeling. Logistic regression models were employed to determine the odds of death within 30 days following surgery accounting for each of the predictors from the bivariate analyses.

A nomogram was created to facilitate the interpretation and utility of the logistic regression model. To generate the nomogram, we used a point system to assign each predictor from the logistic regression model with point ranges from 0 to 100 in a graphic interface. Based on the estimated regression coefficients, we ranked the estimated effects based on the positive beta values (disregarding direction). We then determined which predictor variable had the largest impact in the model, then worked sequentially to assign other predictors based on their proportions to the points assigned to the largest impact predictor. Statistical analyses were conducted using SAS version 9.2 for bivariate and logistic regression modeling and Stata version 14 for the generation of the nomogram.

Results

The ACS-NSQIP database identified 5,918 elderly patients age 60 or older who underwent a hip hemiarthroplasty in the included time period. No patients were excluded from the study. There were 269 patients who experienced a 30-day mortality event for an overall mortality rate of 4.5% in this cohort. Patient demographics found to be statistically significant for mortality included advanced age (>75 years), male sex, and underweight BMI (<18.5 kg/m²) (Table 1). Weight loss > 10% of body weight in 6 months prior to surgery

Table 2. Comorbidities of Patients Undergoing Hip Hemiarthroplasty for Femoral Neck Fractures between 2005 and 2014 in NSQIP.

| Comorbidities | Survived 30 days | Death | Overall | P Value |
|--|------------------|-------|---------|----------|
| CVA with Neurologic Deficit | 95 | 9 | 104 | 0.12 |
| Diabetes | 1,065 | 54 | 1,119 | 0.39 |
| Dialysis | 127 | 12 | 139 | 0.02* |
| Dyspnea | | | | <0.0001* |
| At Rest | 74 | 12 | 96 | |
| With Moderate Exertion | 352 | 26 | 378 | |
| Disseminated Cancer | 199 | 24 | 223 | <0.0001* |
| Heart Failure 30 Days Prior | 190 | 30 | 220 | <0.0001* |
| Hypertension | 3,887 | 189 | 4,076 | 0.61 |
| Smoker | 186 | 8 | 194 | 0.77 |
| Pulmonary Embolism (Post-op) | 33 | 8 | 41 | <0.0001* |
| Transfusion > 4 units PRBC 72 hours prior to surgery | 187 | 17 | 206 | 0.009* |
| Urinary Tract Infection | 382 | 22 | 404 | 0.37 |
| Any Rare Comorbidity ¹ | 187 | 20 | 207 | 0.0003* |

¹Rare comorbidities: ascites, pneumonia, alcohol >2 drinks/day, hemiplegia, history angina, history revascularization, amputation or pvd, impaired sensorium, pulmonary embolism, paraplegia, ventilator dependent. CVA = cerebrovascular accident, pRBC = packed red blood cells.

Table 3. Pre-Operative Laboratory Results of Patients \geq 60 Years Old Undergoing Hemiarthroplasty for Femoral Neck Fractures (CPT 27125) Between 2005 and 2014 in NSQIP (n = 5,918).

| Pre-operative Labs | Survived 30 days | Death | Overall | P Value |
|--|------------------|-------|---------|----------|
| Serum albumin Ref: 3.5-5.5 g/dL | 3.5 | 3.3 | 3.5 | <0.0001* |
| Alkaline phosphate Ref: 20-70 U/L | 93.6 | 101.6 | 94.0 | 0.08 |
| Total bilirubin Ref: 1-1.0 mg/dL | 0.7 | 0.9 | 0.75 | 0.002* |
| Blood urea nitrogen Ref: 7-18 mg/DL | 21.1 | 27.2 | 21.4 | <0.0001* |
| Serum Creatinine Ref: 6-1.2 mg/dL | 1.1 | 1.3 | 1.1 | <0.0001* |
| International Normalized Ratio | 1.1 | 1.2 | 1.1 | <0.0001* |
| Platelet Count Ref: 150,000-400,000/mL | 212.1 | 197.7 | 211.5 | 0.005* |
| Prothrombin time Ref: 11-15 secs | 13.0 | 13.1 | 13.0 | 0.72 |
| Partial thromboplastin time (n = 3,829) Ref: 25-40 seconds | 29.8 | 32.4 | 29.9 | 0.002* |
| White blood count Ref: 4.5-11 kcells/mL | 9.8 | 10.3 | 9.8 | 0.07 |

(p = 0.07) was approaching significance and was included in the nomogram due to its clinical significance and ease of clinical assessment.

Patient comorbidities including disseminated cancer (OR 3.43, 95% CI 2.14-5.50) and heart failure within 30 days prior to surgery (OR 2.22, 95% CI 1.44-3.42) were found to be

Table 4. Patient Characteristics of Patients \geq 60 Years Old Undergoing Hemiarthroplasty for Femoral Neck Fractures (CPT 27125) Between 2005 and 2014 in NSQIP (n = 5,918).

| Patient characteristics | survived 30 days | Death | Overall | P Value |
|---|------------------|-------|---------|----------|
| Prior Operation within 30 days | 17 | 0 | 17 | 0.66 |
| ASA Classification | | | | <0.0001* |
| Healthy | 37 | 0 | 37 | |
| Mild Systemic Disease | 1,055 | 13 | 1,068 | |
| Severe Systemic Disease | 3,547 | 148 | 3,695 | |
| Life Threatening Disease | 993 | 107 | 1,100 | |
| Moribund | 7 | 1 | 8 | |
| None assigned | 10 | 0 | 10 | |
| Functional Status Before Surgery | | | | <0.0001* |
| Independent | 4,260 | 146 | 4,406 | |
| Partially Dependent | 1,098 | 93 | 1,191 | |
| Totally Dependent | 239 | 26 | 265 | |
| Unknown | 53 | 4 | 57 | |
| Surgery related variables | | | | |
| Elective Surgery | 694 | 23 | 717 | 0.17 |
| Emergency Surgery | 1,744 | 88 | 1,832 | 0.52 |
| Days from Hospital Admission to Operation | 1.8 | 2.5 | 1.8 | 0.001* |

statistically significant (Table 2). Patients who were partially or functionally dependent, or ASA grade 3, 4 and 5 (severe/life threatening/moribund) were found to have increased risk of 30-day mortality following hemiarthroplasty (Table 3). Additionally, numerous preoperative laboratory values including serum albumin, blood urea nitrogen, serum creatinine and international normalized ratio were found to differ significantly between those with and those without 30-day mortality events (Table 4). However, these preoperative laboratory values were not found to have clinical significance as the values did not differ widely enough between groups to be useful.

A nomogram to predict 30-day mortality in patients 60 years or older following hemiarthroplasty for femoral neck fractures was generated with overall score correlating probability of 30-day mortality (Figure 1). The relative contribution of each predictor is represented visually based on the length of the variable axis. ASA classification, history of disseminated cancer and a history of heart failure contributed the most points to the model if present. Certain comorbidities that were statistically significant predictors of mortality such as dyspnea, preoperative need for dialysis or transfusion > 4 units pack red blood cells 72 hours prior to surgery were not included in the nomogram based on their decreased relative predictive strength in relation to the included comorbidities (Table 2).

Discussion

Ground level falls remain the most common mechanism of injury in elderly patients with a significant number resulting in hip fractures including over 50% of femoral neck

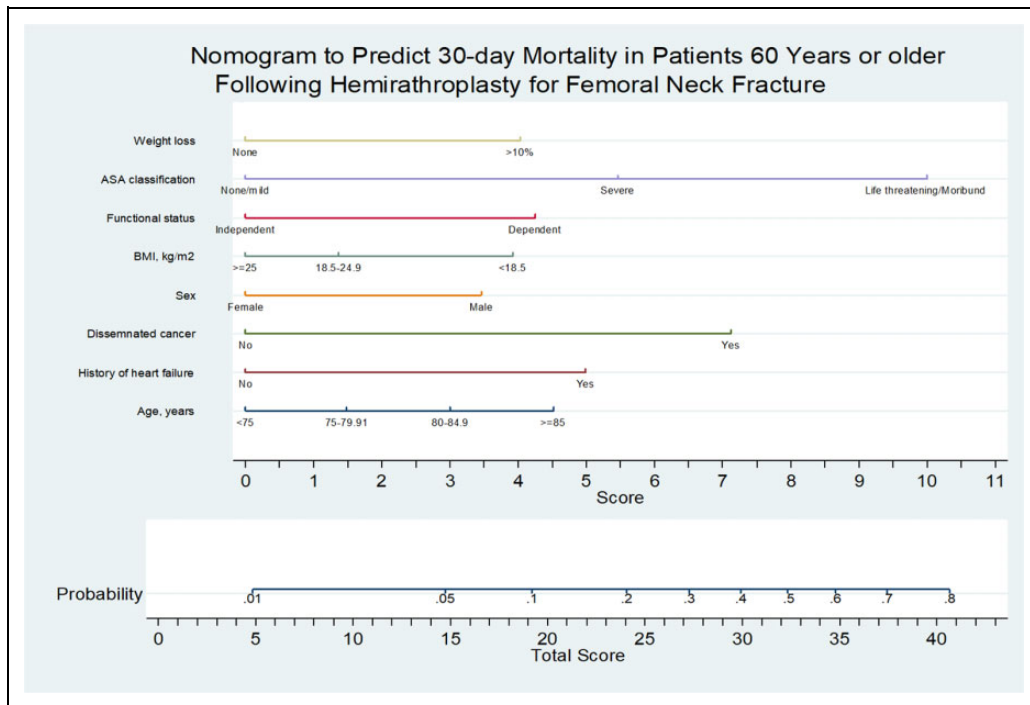


Figure 1. Nomogram to Predict 30-day Mortality in Patients 60 years or Older Following Hemiarthroplasty for Femoral Neck Fractures. Instruction for provider: For each predictor variable on the nomogram, based on the patient characteristics, draw a line straight downward to the Score axis to determine how many points toward 30-day mortality the patient has. Repeat this process for each of the remaining axes and sum the points achieved for each predictor to determine the Total Score. Draw a line straight upward from the Total Score line to find the patient's probability of 30-day mortality following the procedure.

fractures.^{4,9} As the population continues to age, the number of displaced femoral neck fractures requiring hemiarthroplasty will continue to increase.^{10,11,16,17} While interventions and increased knowledge on the risk factors contributing to 30-day mortality have improved outcomes, an understanding of the relative impact of specific risk factors on mortality remains unknown.^{10,11,13-16} This study evaluated elderly patients undergoing hemiarthroplasty for femoral neck fractures to compare risk factors and generate a nomogram for understanding their mortality risk.

Patients with an increased risk of mortality after 30 days were found to be older, male, or have an underweight BMI. These results are similar to studies published by Major and North, and Novoa-Parra et al.^{11,18} While age and gender are non-modifiable risk factors, underweight BMI can be targeted post-operatively to improve nutritional status and possibly reduce mortality.^{19,20} While these findings did not contribute to the development of the nomogram, data from the NSQIP database demonstrated that patients with a reduced serum albumin had an increased risk of mortality (3.3 g/dL vs. 3.5 g/dL, $P < 0.0001$). This could suggest that assessment of nutritional status, especially in patients with underweight BMI or weight loss $> 10\%$ prior to injury is an important factor in reducing mortality.

When evaluating patients with major comorbidities, patients on dialysis pre-operatively, dyspnea, disseminated cancer, and

heart failure within 30 days prior to fracture all had increased risk of 30-day mortality. These results correlated with a previous prospective observational cohort evaluation on over 2,000 consecutive patients with hip fractures undergoing operative fixation.¹⁰ Their study found patients with 3 or more comorbidities were associated with increased mortality compared to those with none (HR 2.5, 95% CI 1.6-3.9). These results suggest patients with complicated medical histories have an increased risk of mortality compared to those who do not.

The creation of the nomogram in this study is intended to help counsel patients and their families in regard to the risk for mortality associated with operative treatment of displaced femoral neck fractures in elderly patients. Nomograms have previously been widely utilized in the oncology literature to help patients understand the risk of disease progression and mortality risk.²¹⁻²³ Similarly, by providing a graphical representation of a patient's individualized risk, we hope to give patients a better understanding of the high rates of mortality associated with these injuries. It is important for patients to understand that not all patients with a high predicted mortality will die and that all patients with a low predicted mortality will survive, particularly as this tool only specifically focuses on 30 day mortality. It should also be noted, this nomogram is not intended to influence treatment, as surgical treatment of these fractures is nearly universally indicated except in extraordinary cases where patients are too ill to undergo surgery.

Limitations

The predictors used to generate the nomogram described were limited to variables measured in the NSQIP database and likely do not reflect all variables necessary to develop a comprehensive nomogram. The ACS NSQIP database is retrospective and reliant on each system providing accurate information and may not be as reliable compared to single center databases with consistent data collection. Additionally, NSQIP data is limited to 30-day mortality and thus we were unable to further evaluate for 1-year mortality. This study was focused on hemiarthroplasty and may not be generalizable to other treatment methods for all types of hip fractures. Lastly, this nomogram still requires external validation with a prospective cohort which is an area of planned future study.

Conclusion

We have generated a tool based on easily identifiable risk factors, demographics, and comorbidities that can help predict elderly patients who will experience mortality within 30 days of surgery. This nomogram was developed to serve as a counseling tool for physicians to use with patients and their families to better assist them in understanding perioperative mortality risk.

Declaration of Conflicting Interests


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