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Proximal humerus fracture with injury to the axillary artery: A population-based study

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ABSTRACT

Background: The available evidence regarding axillary artery injury as a result of proximal humerus fracture consists of individual case reports or small series. This study used nationally representative data to determine the prevalence and predictors of axillary artery injury secondary to proximal humerus fracture, and to characterise its influence on inpatient mortality, length of stay, cost and discharge disposition.

Methods: An estimated 388,676 inpatients with a proximal humerus fracture were identified in the Nationwide Inpatient Sample between 2002 and 2011, 331 with concomitant axillary artery injury (8.5 per 10,000). Multivariable regression modelling was used to identify independent predictors of axillary artery injury and to assess its relationship with inpatient outcomes.

Results: Factors associated with axillary artery injury were male sex (odds ratio (OR): 1.6, 95% confidence interval (CI): 1.2–2.0), atherosclerosis (OR: 3.7, 95% CI: 2.5–5.4), open fracture (OR: 2.9, 95% CI: 1.9–4.5) and the presence of concomitant injuries, including brachial plexus injury (OR: 109, 95% CI: 79–151), shoulder dislocation (OR: 3.4, 95% CI: 2.0–5.8), scapula fracture (OR: 3.4, 95% CI: 2.1–5.4) and rib fracture (OR: 2.5, 95% CI: 1.6–4.0). Axillary artery injury was associated with increased length of stay, costs and mortality, but it did not affect discharge disposition.

Conclusion: Our study provides important baseline information regarding the epidemiology of axillary artery injury secondary to proximal humerus fracture. Prompt identification of at-risk patients upon admission might lead to improved diagnosis and management of this vascular injury.

Level of Evidence: Prognostic level II.

Introduction

Proximal humerus fractures account for 5% of all fractures, and they are very common in the elderly [1–3]. A fracture in this area may injure the axillary artery and result in substantial morbidity [4–8]. Given the rarity of axillary artery injury secondary to proximal humerus fracture, its prevalence has proved difficult to quantify on a large-scale level. Current evidence is limited to individual case reports or small case series [4–23]. As such, data on its predisposing factors are scarce. Because axillary artery injury is often unrecognised on initial evaluation – particularly when concomitant lesions are present or the patient is in shock [5,7,9,24] – early identification of associated risk factors upon admission can facilitate its diagnosis and management.

Using nationally representative data, we sought to determine the prevalence and predictors of axillary artery injury in the setting of a proximal humerus fracture. Secondarily, we characterised the association of axillary artery injury with inpatient mortality, prolonged hospital stay, increased hospital cost and nonroutine disposition.

Materials and methods

Data source

We carried out a retrospective population-based analysis using discharge records from the Nationwide Inpatient Sample (NIS) for the years 2002–2011. The NIS was created and is maintained by the Agency for Healthcare Research and Quality (AHRQ), and it currently constitutes the largest all-payer inpatient care database in the United States [25]. Each dataset year represents a 20% stratified sample of discharges from >1000 short-term and non-Federal hospitals. Discharges are weighted based on the sampling

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scheme to ensure national representativeness [26]. Besides collecting patient-related and provider-related data, the NIS utilizes the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) codes to standardise the reporting of up to 25 (15 prior to 2009) diagnoses and 15 procedures. Despite being intended for billing purposes, the NIS is one of the most comprehensive national sources of health-care information, and it has been routinely used for comparative health services research since its inception in 1988 [27–30]. This study was exempt from review by our institutional review board because the data contained no personal identifiers.

Identification of sample and definitions

We considered all discharges with a primary diagnosis code (ICD-9-CM) of closed (812.00–812.03, 812.09) or open (812.10–812.13, 812.19) fracture of the proximal humerus (Appendix 1). Patients with an associated axillary artery injury were identified using the ICD-9-CM code 903.01.

Demographic variables consisted of age and sex. We assessed the mechanism of injury (fall, motor vehicle accident, other and unknown), fracture type (closed and open) and the presence of common concomitant injuries including brachial plexus injury (ICD-9-CM code 953.4), shoulder dislocation (ICD-9-CM code 831.x) and fracture of the clavicle (ICD-9-CM code 810.x), rib (ICD-9-CM code 807.0x, 807.1x) and scapula (ICD-9-CM code 811.x). Based on clinical plausibility and available evidence, we considered peripheral vascular disease or atherosclerosis as it could potentially be associated with an increased risk of axillary artery injury [7]. We also collected data on the history of alcohol and drug-use disorders and psychiatric disorders, all of which may be associated with risky behaviours.

Statistical analysis

Multivariable logistic regression modelling was used to determine which factors are independently associated with axillary artery injury in the setting of a proximal humerus fracture. All covariates were entered into the model simultaneously, without further selection. Because proximal humerus fractures are generally isolated and closed, we performed a sensitivity analysis restricted to patients with such fractures. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). The area under the receiver-operating characteristic (ROC) curve was used to evaluate the discriminatory ability of our models. Therefore, to set stricter standards owing to multiple testing, the statistical threshold for type I error was set at < 0.001.

In addition, we constructed four multivariable logistic regression models to assess the association of axillary artery injury with inpatient mortality, prolonged length of stay (>75th percentile) [31], increased hospital cost (>75th percentile) [32] and nonroutine discharge (discharge to location other than home).

Results

Among 388,676 inpatients with a proximal humerus fracture, 331 (0.09%) had an associated axillary artery injury – 65% of which underwent vascular repair (Table 1, Fig. 1).

In multivariable modelling, patient-specific factors associated with axillary artery injury were male sex (OR: 1.6, 95% CI: 1.2–2.0; $p < 0.001$) and peripheral vascular disease (OR: 3.7, 95% CI: 2.5–5.4; $p < 0.001$). Open fractures of the proximal humerus were associated with a threefold higher risk of axillary artery injury (OR: 2.9, 95% CI: 1.9–4.5; $p < 0.001$), compared to closed fractures. There was an increased likelihood of axillary artery injury in the presence of concomitant injuries, including (in decreasing order of magnitude of effect estimate) brachial plexus injury (OR: 109, 95% CI: 79–151; $p < 0.001$), shoulder dislocation (OR: 3.4, 95% CI: 2.0–5.8; $p < 0.001$), scapula fracture (OR: 3.4, 95% CI: 2.1–5.4; $p < 0.001$), rib fracture (OR: 2.5, 95% CI: 1.6–4.0; $p < 0.001$) and other fracture (OR: 2.0, 95% CI: 1.4–2.7; $p < 0.001$; Table 1). In sensitivity analysis restricted to patients with an isolated closed fracture of the proximal humerus, factors associated with an increased risk for axillary artery injury included male sex (OR: 1.7, 95% CI: 1.3–2.3; $p < 0.001$), peripheral vascular disease (OR: 3.5, 95% CI: 2.3–5.4; $p < 0.001$) and brachial plexus injury (OR: 143, 95% CI: 96–212; $p < 0.001$; Table 2).

After adjusting for potential confounders using multivariable modelling, axillary artery injury was associated with higher inpatient mortality (OR: 4.2, 95% CI: 2.2–8.0; $p < 0.001$) prolonged hospital stay (OR: 2.4, 95% CI: 1.9–3.1; $p < 0.001$) and increased hospital cost (OR: 5.6, 95% CI: 4.4–7.2; $p < 0.001$), but it did not affect discharge disposition (OR: 1.4, 95% CI: 0.73–2.4; $p = 0.21$; Table 3). There was no statistically significant difference in outcomes between the patients who underwent a vascular repair and those who did not.

Discussion

This nationwide population-based study determined the prevalence and predictors of axillary artery injury secondary to proximal humerus fracture, and it characterised its influence on inpatient outcomes. The overall prevalence of axillary artery injury was 8.5 per 10,000 inpatients with fracture of the proximal humerus. Factors associated with a greater risk for this injury were male sex, atherosclerosis, open fracture and the presence of concomitant injuries (e.g. brachial plexus injury and shoulder dislocation). Axillary artery injury was associated with increased length of stay, costs and mortality during admission.

Given the limited population-based data available on this topic, our study provides important baseline information regarding the epidemiology of axillary artery injury secondary to proximal humerus fracture. The overall rate of axillary artery injury (0.09%) was lower than the rate of brachial plexus injury (0.14%), confirming assumptions that neurologic injury is more common than vascular injury secondary to proximal humerus fracture [8,33].

Male sex and atherosclerosis were independent predictors of axillary artery injury. It is possible that the loss of arterial elasticity observed in atherosclerosis makes the axillary artery more susceptible to injury [7,34]. Increasing age was not a risk factor for axillary arterial lesion in our study, despite most previously reported cases of vascular injury occurring in patients >50 years. In fact, we found that patients with an axillary artery injury were on average younger than patients without such an injury. Open fractures of the proximal humerus and fracture dislocations were more likely to injure the axillary artery, confirming suspicions that increased fracture severity is linked to greater odds of vascular injury [7,8]. Given that brachial plexus injuries occurred in nearly 20% of axillary artery injuries, a heightened index of suspicion for vascular injury should be maintained in patients presenting with a proximal humerus fracture with associated brachial plexus injury despite a well-perfused limb [35,36]. Injuries to the axillary artery often elude diagnosis on initial evaluation because patients may have palpable pulses and normal capillary refill due to collateral flow through arterial anastomoses around the shoulder [9,37]. The presence of other concomitant fractures increased the risk of axillary arterial lesion. In particular, fractures of the scapula showed the highest risk – most likely a result of the intimate anatomical relationship between the scapula and the axillary artery and its branches [38].