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## Incidence and risk factors for pseudosubluxation of the humeral head following proximal humerus fracture



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**Background:** Humeral head pseudosubluxation (HHPS) in relation to the glenohumeral joint is a common finding following fractures of the proximal humerus. The temporary inferior subluxation of the humeral head may be secondary to a transient axillary nerve neuropraxia, pain inhibition of the deltoid, or hemiarthrosis or capsular disruption that alters the physiologically negative pressure in the glenohumeral joint. Despite the frequency of this finding, it is not well described in the literature. This study sought to describe the incidence, risk factors, and rate of resolution of HHPS following proximal humerus fracture.

**Methods:** The practice of two fellowship-trained shoulder and elbow surgeons was queried for proximal humerus fractures. Patient radiographs were reviewed at the time of injury and all subsequent follow-ups through one year after injury. Data collection included the presence of HHPS, type of fracture based on the Neer classification, operative vs. nonoperative management, and resolution of HHPS. Exclusion criteria included skeletally immature patients, fracture-dislocations, patients treated with reverse shoulder arthroplasty, inadequate follow-up, or those patients with incorrect International Classification of Diseases coding.

**Results:** The incidence of HHPS was 20.0% (103 out of 515 patients) overall. Patients who required surgical intervention were more likely to develop pseudosubluxation than those who were treated conservatively ( $P < .001$ ). There was an increasing incidence of pseudosubluxation based on the Neer classification, with 0-part fractures demonstrating a 2.56% (2/78) rate, whereas 4-part fractures were found to have HHPS in 35.1% (20/57) of cases ( $P < .001$ ). All patients were found to have resolution of their HHPS at the final follow-up or one year after injury. None of age, sex, obesity, or injury to the dominant arm was associated with the occurrence of HHPS. There was, however, a statistically significant difference in the body mass index of those who developed HHPS ( $28.4, \pm 5.77$ ) vs. those who did not ( $26.2, \pm 5.32, P < .01$ ).

**Conclusion:** This retrospective radiographic study is the largest to date investigating the incidence of HHPS following proximal humerus fracture and first to correlate with Neer classification and operative intervention. We found that HHPS occurs in one-fifth of acute proximal humerus fractures and resolves regardless of intervention. More complex fractures, including those with increasing Neer parts or requiring operative intervention, developed HHPS at higher rates than simpler fracture patterns. This study will help both general orthopedists as well as shoulder surgeons understand the epidemiology of HHPS and provide reassurance to patients that PS is a benign finding with expected spontaneous resolution by one year.

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The study was approved by the Institutional Review Board of the Mount Sinai School of Medicine IRB-19-01564.

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Proximal humerus fractures (PHFs) are common injuries that account for approximately 5% of all fractures in adults.<sup>7,21</sup> These fractures most commonly occur in elderly females as a result of low-energy trauma, representing up to 20% of all fragility fractures, third behind fractures of the hip and wrist.<sup>8</sup> Several options exist for the management of PHFs, with treatment guided by fracture morphology and location, as well as the functional demands of the patient. Common treatment options include

nonoperative management in a sling, closed reduction and percutaneous pinning, intramedullary nailing, plate osteosynthesis, and arthroplasty.<sup>13</sup>

PHFs can occur alone or in conjunction with injuries to nerves, vessels, or soft tissues such as the rotator cuff or biceps tendon. Neurological injury after shoulder trauma is a well-described complication, occurring in as many as two-thirds of patients with PHFs, with damage to the axillary nerve being the most common.<sup>4,27</sup> Peripheral nerve injuries may occur during the initial trauma or during subsequent operative intervention and are usually neuropraxic in nature, resulting from focal compression or traction on the nerve. Neuropraxic injuries sustained during the traumatic event carry an excellent prognosis, with full or near-full resolution of symptoms achieved in most patients.<sup>22</sup> Nerve injuries that occur during surgical fixation are associated with prolonged recovery periods and worse restoration of shoulder function.<sup>29</sup>

Humeral head pseudosubluxation (HHPS) in relation to the glenohumeral joint is a common radiographic finding following fractures of the proximal humerus.<sup>3,5,10,20,23</sup> First described in 1921 after uncomplicated nonoperative treatment of humeral neck fractures, HHPS was poorly understood, with muscle fatigue proposed as the primary mechanism.<sup>6</sup> More recently, the temporary inferior subluxation of the humeral head has been theorized to be an indication of deltoid muscle dysfunction secondary to injury to the axillary nerve.<sup>19</sup> HHPS in the setting of trauma has been associated with obesity, female sex, increasing age, and osteoporosis.<sup>9,16</sup> In fewer cases, it has also been described following atraumatic hemarthrosis, cerebrovascular accident, and sepsis.<sup>2,3,24,26</sup>

Despite the relative frequency of HHPS, its clinical significance and associated risk factors are not well described in the literature and are poorly understood. The authors of this study sought to examine the epidemiology of HHPS, including the incidence, risk factors, and rate of resolution.

## Methods

This retrospective case series investigated patients who sustained PHFs to assess the incidence of, and pertinent risk factors for, HHPS. The study was approved by the institutional review board (IRB-19-01564). The practice of two fellowship-trained shoulder and elbow surgeons who treat patients with this injury was queried based on the appropriate International Classification of Diseases (ICD)-9 and ICD-10 codes (812.01, 812.03, S42.232D, S42.231D, S42.211D, S42.251A, and S42.254A). This generated a sample of 686 patients who sustained PHFs between 2009 and 2015. Exclusion criteria included the following: incorrect ICD coding, inadequate or unclear imaging, incomplete follow-up, subacute, chronic, or recurrent fractures, skeletal immaturity, fracture-dislocations of the shoulder, fractures with excessive displacement that obscured measurement of HHPS, and treatment with reverse shoulder arthroplasty. Subacute or chronic fractures were defined as those which occurred two or more weeks prior to presentation.

The following data were collected for each patient: demographic factors including age, sex, body mass index (BMI), and handedness; the presence of HHPS on plain radiographs of the shoulder; the type of fracture based on the Neer classification system; operative vs. nonoperative management; and resolution of HHPS by one year after injury or lack thereof. All radiographs of these patients were obtained at the same institution, taken by the same group of radiology technicians, and adhered to the same institutional protocol for a multiview shoulder series. The radiographs were subsequently reviewed by two independent orthopedic surgery senior

resident physicians at the time of injury and at all subsequent follow-up visits through one year of follow-up.

HHPS was determined by the integrity of the “gothic arch” of the shoulder.<sup>15</sup> Sometimes referred to as Shenton’s line of the shoulder, as the curvature mimics the continuity of the medial femoral neck with the inferior border of the superior pubic ramus, the shoulder’s gothic arch is a sharp, inverse U-shaped radiographic line formed by the medial aspect of the proximal humeral metaphysis and inferolateral border of the scapula. It is a focal point of anatomic restoration in shoulder arthroplasty for fracture.<sup>15</sup> Using the congruity of this line as the criteria for determining HHPS is similar to the method used in previously published literature documenting humeral head HHPS after trauma or surgery.<sup>23</sup> Pritchett et al (1997) classified HHPS as the center of the humeral head being at or below the inferior rim of the glenoid on a standard AP radiograph of the shoulder.<sup>23</sup> When the midpoint of the humeral head translates below the inferior rim of the glenoid, the gothic arch is inherently violated. In a previous study analyzing a large sample of patients with PHFs, the intraobserver and interobserver reliabilities of physicians recognizing humeral head inferior subluxation, among other radiographic characteristics, on plain radiographs were excellent (83% and 82%, respectively).<sup>2</sup> The review of radiographs in this study should be considered similarly reliable. The gothic arch of the shoulder and an example of HHPS are demonstrated in [Figure 1](#).

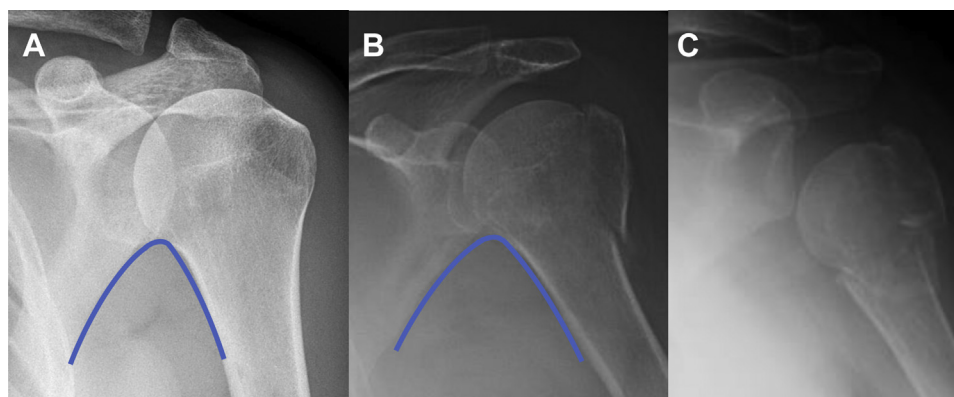
Statistical analysis of all collected data was performed using SPSS (IBM, Armonk, NY, USA). Statistical significance was determined using a 2-tailed Student *t*-test when testing the means of two groups of continuous data and a chi-squared test to compare across categorical variables. Statistical significance was set at  $P < .05$ .

## Results

After the application of exclusion criteria, a final sample of 515 subjects was achieved from the initial group of 686 patients who sustained PHFs between 2009 and 2015 ([Figure 2](#)).

Demographic data were collected for all 515 patients included in the study. Among the group of patients with radiographically confirmed humeral head PS, the mean age was 61.6 ( $\pm 15.6$ ) years, the mean BMI was 28.4 ( $\pm 5.77$ ), the percentage of females was 73, and the percentage of patients who injured their dominant arm was 46. In the group of patients without humeral head PS, the mean age was 65.2 ( $\pm 16.7$ ) years, the mean BMI was 26.2 ( $\pm 5.32$ ), the percentage of females was 66.5, and the percentage of patients who injured their dominant arm was 55.6. The only statistically significant difference between the two cohorts of patients was the BMI, though the difference in means (2.2) is not clinically significant ([Table 1](#)). When analyzing between BMIs considered obese ( $>30$ ) and nonobese ( $<30$ ), there was no statistical difference (16.7% vs. 14.5%,  $P = .56$ ).

Among 515 patients with PHFs who met the aforementioned inclusion criteria, 103 (20.0%) were found to have HHPS on plain radiographs. Patients requiring surgical intervention were more likely to have had humeral head PS than those who were able to be treated conservatively (35.5% vs. 17.1%,  $P < .0001$ ). There was also a correlation between the incidence of HHPS and an increasing number of parts based on the Neer classification. 0-part fractures demonstrated a 2.6% (2/78) rate of PS, 2-part fractures demonstrated a rate of 18.4% (32/174), 3-part fractures demonstrated 24.3% (50/206), and 4-part fractures demonstrated 35.1% (20/57), corresponding to a correlation coefficient of  $r = 0.996$  ( $r^2 = 0.97$ ,  $P < .0001$ ). In regard to resolution of HHPS, all patients were found to have resolution of the HHPS at the final follow-up or one year after injury. These results are summarized in [Table II](#).



**Figure 1** Three AP radiographs of the left shoulder are shown. (A) The unviolated gothic arch of the shoulder is seen, indicated with the blue line, in a normal shoulder. (B) The unviolated gothic arch of the shoulder is seen with a minimally displaced greater tuberosity fracture. (C) Humeral head pseudosubluxation is observed in a 3-part proximal humerus fracture.

Patients with ICD codes for proximal humerus fractures between 2009 and 2015	686
Incorrect ICD coding	58
Inadequate or unclear imaging	47
Chronic or recurrent fractures	22
Incomplete follow-up	28
Treatment with reverse TSA	10
Fracture-dislocation or excessive displacement	6
Included in study	515

**Figure 2** CONSORT (Consolidated Standards of Reporting Trials) flow diagram of inclusion and exclusion criteria for patients with proximal humerus fractures as identified by ICD codes. ICD, International Classification of Diseases.

**Discussion**

Pseudosubluxation of the humeral head in relation to the glenohumeral joint is a common finding following PHF; however, the orthopedic literature lacks in research on the subject. The phenomenon was first noted by Frederic Cotton in 1921, who hypothesized that a “gradual stretching” of the shoulder girdle musculature contributed to the finding.<sup>6</sup> Over time, our understanding of shoulder biomechanics and deltoid function has improved, but only small case series and reports have investigated the finding of HHPS.<sup>2,5,6,9,11,23,30</sup> Trauma is the most common etiology of HHPS; however, other causes include brachial plexopathies,<sup>16,19,28</sup> stroke,<sup>24</sup> sepsis,<sup>26</sup> hemophilia,<sup>17</sup> and iatrogenic<sup>14,18</sup> and oncologic<sup>16</sup> conditions involving the shoulder. In this large retrospective case series, we examined the epidemiology of HHPS following PHFs in the practice of two fellowship-trained shoulder and elbow surgeons, including the incidence, risk factors, and resolution over time.

The overall incidence of HHPS following acute fracture of the proximal humerus was found to be 20.0% (103/515), with a statistically greater percentage of patients requiring surgical

intervention demonstrating HHPS (35.5%) than patients who were treated conservatively (17.1%,  $P > .0001$ ). Similarly, when comparing fractures based upon the Neer classification,<sup>20</sup> fractures with a greater number of parts were associated with a higher risk of HHPS ( $P < .0001$ ). Surgical intervention is generally indicated based upon increasing fracture displacement, which may result in greater trauma to the axillary nerve or the surrounding tissues than fractures which are less displaced. All patients with HHPS demonstrated resolution with regard to motor, sensation, and radiographic examination by one-year follow-up, though the majority of patients recovered by six months. The BMI was the only demographic with a statistically significant difference between cohorts; however, the difference between BMIs of those with HHPS (28.4) and without (26.2) is likely clinically insignificant. No difference was seen when stratifying patients based on obesity with a BMI cutoff of 30.0 ( $P = .56$ ).

The mechanism underlying HHPS following trauma is not well understood. Trauma to the shoulder girdler may result in deltoid atony via transient axillary nerve neuropraxia or pain inhibition of deltoid function. Anterior dislocations of the glenohumeral joint have a known association with axillary nerve injury and may therefore demonstrate HHPS after reduction via this same pathophysiology. Many of the patients with HHPS in this study demonstrated intact deltoid strength and sensation, which would suggest mechanisms other than axillary nerve dysfunction alone. It is possible that HHPS following PHF could be secondary to a traumatic hemarthrosis that increases the standardly negative pressure in the glenohumeral joint, thus pushing the HH inferiorly. A third hypothesis suggests that PHFs can result in rupture of the capsule, removing the negative pressure vacuum effect that typically maintains the congruity of the glenohumeral joint.<sup>12</sup>

Carbone et al recently studied the impact of osteoporosis on radiographic findings following PHFs and found an increased incidence of HHPS in the osteoporotic group (36%) compared to the nonosteoporotic group (16%,  $P = .029$ ).<sup>2</sup> In their series of 225 patients, the overall incidence of HHPS was 30.7% (69/225) as defined by  $> 1$  cm inferior displacement of the humeral head in relation to the inferior edge of the glenoid. These results are slightly greater than the reported incidence of 20.0% in this study, but consistent with a high prevalence following fracture. By comparison, an injury to the axillary nerve was noted in 15.8% (38/240) of patients who sustained an isolated anterior shoulder dislocation.<sup>1</sup> The authors also found an association between obesity and HHPS ( $P = .019$ )—a finding that this study does not corroborate. They did not comment on resolution but suggested it as a point of future research.

**Table I**  
Demographics of patients with proximal humerus fractures included in the final sample.

Demographic	Pseudosubluxation	No pseudosubluxation	P value (* indicates statistical significance)
Age (avg yr)	61.6 (±15.6)	65.2 (±16.7)	0.05
Sex (% female)	73.00%	66.50%	0.35
BMI (avg)	28.4 (±5.77)	26.2 (±5.32)	0.01*
Injured dominant side (%)	46.00%	55.60%	0.16

BMI, body mass index.  
\*Indicates statistical significance,  $P < .05$ .

**Table II**  
Incidence and risk factors of humeral head PS.

Overall incidence of humeral head PS: 20.0% (103/515)				P value < .0001*
Not requiring surgery:		Requiring surgery:		
17.1% (66/385)		35.5% (44/124)		R = 0.996 P value < .0001*
0-part fracture: 2.6% (2/78)	2-part fracture: 18.4% (32/174)	3-part fracture: 24.3% (50/206)	4-part fracture: 35.1% (20/57)	

PS, pseudosubluxation.  
\*Indicates statistical significance,  $P < .05$ .

Two smaller series have investigated HHPS resolution following PHF. Yosipovitch et al reported on 20 patients who developed HHPS, 17 of which recovered by eight weeks after injury and the remaining three patients by six months.<sup>30</sup> EMG was performed on ten of these patients, yet only three patients revealed a peripheral nerve injury. This supports the consensus that EMG for the diagnosis of axillary nerve injury in a patient with HHPS following PHF is not necessary in the acute or subacute period as most are neuropraxias that self-resolve over the course of weeks to months. Pritchett subsequently reported on humeral head inferior subluxation following fracture, rotator cuff repair, and prosthetic replacement.<sup>23</sup> In 100 cases of shoulder injury or surgery, HHPS occurred following PHF at a rate of 42%. Hundred percent of patients achieved radiographic recovery of HHPS by two-year follow-up, corroborating the transient nature of this injury as demonstrated in our study.

HHPS represents an important radiographic finding to be recognized by orthopedic surgeons, radiologists, emergency medicine physicians, and physician extenders involved in the care of acute shoulder injuries. Misdiagnosis of HHPS for a true fracture-dislocation can result in painful reduction attempts and the potential for further iatrogenic injury. In the subacute or chronic phases of care, additional expensive or invasive testing may be performed to diagnose a benign, transient finding. While EMG for the axillary nerve is not necessary, patients with HHPS should undergo a thorough neurovascular exam to determine if any additional motor or sensory deficits are present. Further workup may be warranted depending on such findings.

This study represents the largest series to date examining HHPS and associated risk factors. It demonstrates that increasing fracture severity is positively correlated with the rate of HHPS. It further reinforces that HHPS is a transient condition that resolves spontaneously over time. There are, however, several limitations to our study. This is a retrospective study that was reliant upon proper ICD coding and data collection. Approximately 30% of patients did not have the BMI or hand dominance reported in the electronic medical record and could not be contacted for information. The Neer classification, which was used to quantify fracture severity, confers a degree of variability in data collection as it is shown to have an interobserver reliability of 73% when applied to plain radiographs.<sup>25</sup> Additionally, this study represents the practice of two fellowship-trained shoulder and elbow surgeons at a tertiary care referral center. The possibility exists that patients with more complicated pathology were referred or presented to

the office owing to expertise. Finally, the shoulder radiographs used to determine the presence of HHPS were not all taken by the same technician, and the position of the arm varied patient to patient in regard to being supported by the contralateral hand, in a sling, or unsupported. These factors were unlikely to meaningfully impact our detection of HHPS, however, given that the integrity of the gothic arch is an obvious and categorical dependent variable.

**Conclusion**

This retrospective radiographic study is the largest to investigate the incidence of HHPS following PHF, as well as the first to correlate the rate of HHPS with increasing Neer classification and operative intervention. We found that HHPS occurs in one-fifth of patients following acute fractures of the proximal humerus and spontaneously resolves regardless of intervention. More complex fractures, including those requiring operative intervention and those with higher Neer classification scores, developed HHPS at higher rates than simpler fracture patterns. This study will help both general practitioners as well as shoulder surgeons understand the epidemiology of HHPS and provide appropriate care to patients, reassuring them that it is a benign condition with spontaneous resolution by one year in most cases.

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