International Journal of Research in Orthopaedics
Gass HM et al. Int J Res Orthop. 2024 Jul;10(4):736-740
http://www.ijoro.org

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20241698

Original Research Article

Inferior humeral head subluxation after acute humeral shaft fractures

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Received: 15 May 2024
Accepted: 14 June 2024

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ABSTRACT

Background: Inferior humeral head subluxation (IHHS) is an abnormal inferior translation of the humeral head with respect to the glenoid. While well described for proximal humerus fractures there is little literature regarding IHHS in humeral shaft fractures and the impact of IHHS on fracture healing during non-operative treatment. This study characterized the prevalence and impact of IHHS among patients with acute humeral shaft fractures at a large urban trauma center.

Methods: This retrospective analysis included 62 patients treated conservatively for acute humeral shaft fractures at a single level I trauma center from 2018-2021. Occurrence of IHHS in millimeters was measured radiographically as the distance between the inferior glenoid edge and humeral anatomic neck, a distance greater than 10 mm was considered positive. Demographic data, injury mechanism, AO/OTA fracture classification, risk factors (history of stroke, smoking, diabetes mellitus, radial nerve palsy on presentation, any neurovascular disorder), and failure of conservative management (surgical fixation after a 90-day trial) was recorded. Statistical analyses were performed to evaluate association between risk factors, treatment outcome, and IHHS resolution.

Results: At an average follow-up of 18 weeks, IHHS was noted at any time point in 32.3% patients. All cases of IHHS resolved without formal treatment. No factors were significantly associated with the occurrence of IHHS. 17.7% patients failed conservative treatment, only three had IHHS.

Conclusions: Although IHHS occurred in one third of the study population, it was not significantly correlated with failed conservative management or the need for surgical intervention. This study expands the scope of this phenomenon to include humeral shaft fractures.

Keywords: Glenohumeral subluxation, Humeral shaft fracture, Upper extremity trauma

INTRODUCTION

Inferior humeral head subluxation (IHHS), which is also referred to as pseudo subluxation, is typically considered a benign and commonly asymptomatic condition following proximal humerus fracture, traumatic shoulder injury and surgery violating the shoulder capsule.[1-5] Unlike anterior glenohumeral dislocation which is generally caused by trauma to the glenohumeral joint and is present at the time of injury, IHHS is a radiographic finding either at the time of injury or during subsequent follow up. Ten mm threshold for IHHS was first proposed by Carbone et al and was empirically adopted as there is currently no validated radiographic standard for this phenomenon.[3,4] While exact cause of shoulder pseudo-subluxation is unknown there are multiple theories as to how this radiographic finding develops. IHHS has been theorized to result from muscle fatigue or paralysis.[3] It has also been postulated to result from a loss of the inherent negative intraarticular pressure in the glenohumeral joint. This could be a result of atony of the surrounding musculature and loss of suction effect of the shoulder joint capsule such as from weakness of rotator cuff muscles/ laxity of glenohumeral ligament.[6-8]

Most of the current orthopaedic literature examines IHHS for proximal humerus fractures that were treated surgically.[1-3,7] Due to a relative paucity of overall research regarding IHHS, a lack of accepted and validated radiographic measurements may contribute to the overall low incidence of IHHS reported in the literature.[5] To the best of our knowledge there is no current literature examining the effects of IHHS in acute humeral shaft fractures, and it is unknown how IHHS might affect the potential for secondary bone healing in patients with acute humeral shaft fractures treated without surgery.

Humeral shaft fractures occur at an incidence of 13 per 100,000 per year and commonly occur in a bimodal distribution of males aged 20-30 years and females aged 60-70 years.[9] The current gold standard treatment for acute humeral shaft fractures is nonoperative management with a trial of immobilization, although recent literature has called this into question.[10-13,20] Non-operative treatment for humeral shaft fractures includes closed management using splints, casts, and/or functional bracing. The lack of muscle insertion onto the middle and lower humeral shaft, which would otherwise provide deforming forces, makes these fractures optimal candidates for functional bracing. Functional braces cover the arm from shoulder to elbow while leaving the motion of both joints uninterrupted. The premise of functional bracing as conservative intervention is that it preserves joint function, allowing shoulder and elbow movement, while allowing micromotion at fracture site to encourage osteogenesis.[9,10] Micromotion of fracture is thought to stimulate union through secondary bone healing involving the classic stages of injury, hemorrhage, inflammation, and callus formation. While micromotion is wanted for fracture healing, Driesman et al showed that gross motion of the fracture site at 6 weeks has been showing to be a predictor of eventual nonunion.[18] Humeral shaft fracture have been shown to take up to 12 weeks to achieve bony union, requiring frequent interval outpatient follow up with radiographs.[21] Despite being gold standard there is still a reported nonunion rate of 3-17% for humeral shaft fractures treated with functional bracing.[11]

Although not fully understood, patients with IHHS of the shoulder are likely not activating shoulder joint muscles, causing pseudo-subluxation, and also hypothetically muscles distal to shoulder which may decrease necessary micromotion at fracture site environment, thus rendering functional brace ineffective at eliciting secondary fracture healing. This paper does not aim to solve the current mystery of exact mechanism of IHHS in upper extremity trauma but hopes to add to literature and extend phenomenon to acute humeral shaft fractures. We hypothesized that presence of IHHS in acute humeral shaft fractures and theory of atony of upper arm musculature would decrease effectiveness of functional fracture bracing, therefore increasing failure rate of conservative management and requiring surgical intervention.

METHODS

Subject and demographic data

In this institutional review board-approved retrospective cohort study, a chart review was performed for all patients who underwent initial nonsurgical treatment for acute humeral shaft fracture over a 3-year period (2018 to 2021) at an academic level-I trauma center. Patients eligible for inclusion were skeletally mature, at least 18 years of age, and presented with an isolated acute humeral shaft fracture. An initial cohort of 89 patients were found to meet these criteria. Patients were then excluded if they had previous injury or surgery to the affected upper limb or if they did not have at least 3 months of follow up after initial injury, as this is generally necessary to judge bony union. The follow exclusion yielded a total 62 patients who met the full inclusion criteria. Once eligible patients were identified, a detailed chart review was performed. Demographic data, injury mechanism, location of fracture, AO foundation/ orthopaedic trauma association (AO/OTA) fracture classification, associated patient and injury related risk factors (history of stroke, smoking, osteoporosis, diabetes mellitus, radial nerve palsy on presentation, any neurovascular disorder), and surgical fixation during or after a 90-day nonoperative trial was recorded.

Injury data

The occurrence of IHHS was measured radiographically via the distance between the inferior glenoid edge and humeral anatomic neck. IHHS was considered present if the measured distance was greater than 10 mm on anterior-posterior radiographs of the humerus and shoulder joint (Figure 1). This evaluation was performed on all radiographs by an orthopedic surgeon blinded to patient identifiers.

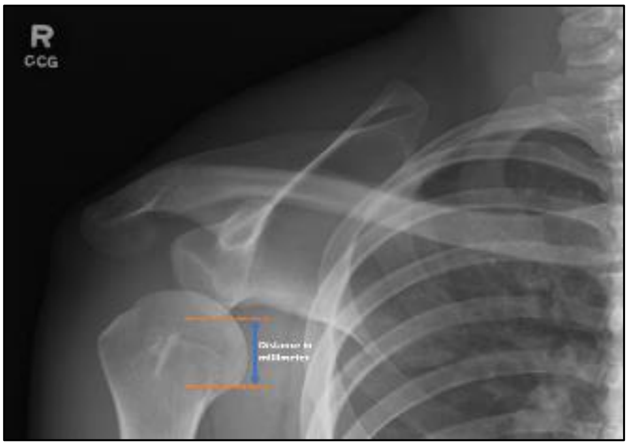

Figure 1: Anterior-posterior radiograph of the right shoulder depicting the measurement protocol for inferior glenohumeral subluxation, with the distance measured between two parallel lines drawn through the inferior border of the glenoid fossa and the anatomic neck of the humerus.

Statistical analysis

Descriptive statistics are displayed as mean (SD; range) for continuous variables and frequency (percentage) for categorical variables. Assessment of normality in the data set was performed using the Shapiro-Wilk test. Chi-squared and binary logistic regression analyses were performed to analyze to evaluate the association between risk factors and IHHS, and between IHHS and treatment outcome, when controlling for potential confounding variables. All statistical analysis were performed in SPSS version 23 (SPSS, Inc).

RESULTS

Patient characteristics

The mean age of our patients was 35.67±18.34 years old and 66.1% were male, 13 of 62 (21.0%) patients also sustained a radial nerve palsy in the injured extremity. Additionally, analysis of injury-related risk factors revealed that 3.2% of patient population had diabetes mellitus and 32.3% had history of smoking as noted in Table 1.

Injury characteristics and treatment

The mechanism of injury for the patients' humeral shaft fracture included gunshot wounds (32.3%), motor vehicle accidents (32.3%), falls (24.19%), and others (18%). The AO/OTA classifications and injury locations were also noted as shown in Table 2.

At our institution acute humeral shaft fractures were initially treated with a coaptation splint that was then converted to a functional fracture brace at close follow up in the outpatient clinic. These patients were then followed with serial radiographs in the outpatient clinic setting at 2 weeks, 6 weeks, and 3 months from injury at which point either fracture healing was noted radiographically or the patient had failed nonoperative management.

The presence of IHHS at any time point after injury was recorded in 20 (32.3%) patients. The distance between the inferior glenoid and the humeral anatomic neck ranged from 0 mm to 34.5 mm in the total cohort. The average follow-up was 18 weeks (126 days).

Patient demographics, injury mechanism, fracture classification, and associated risk factors (including radial nerve palsy) were not significantly associated with the occurrence of IHHS as shown in Table 3. Of the 20 patients who had IHHS at any point during their injury and follow up, only five had evidence of IHHS on the initial injury radiographs obtained in the emergency department. In the subgroup of patients with IHHS present at injury 4 out of the 5 (80%) still had IHHS present at their initial outpatient follow up visit. An additional fifteen patients were found to have IHHS on an upright AP shoulder radiograph at their first follow up visit, which usually occurred approximately 2 weeks after initial injury.

Eleven patients failed conservative treatment and proceeded to surgical fixation after 90 days (mean: 123±66.65 days) after injury. Of this group only 3 patients had IHHS.

Table 1: Patient characteristics.

Variables		N (%)
Age (in years)	35.67±18.34	
Sex	Male	41 (66.1)
	Female	21 (33.9)
Comorbidities	Radial nerve palsy	13 (21.0)
	Smoking	20 (32.3)
	Diabetes mellitus	2 (3.2)

Table 2: Injury characteristics.

Variables		N (%)	IHHS ≥10 mm, (n=20) (%)
Injury mechanism	Gunshot wound	20 (32.3)	7 (35)
	Motor vehicle collision	20 (32.3)	7 (35)
	Fall from height	13 (21)	4 (30.8)
	Ground level fall	2 (3.2)	0
	Other		
	Pedestrian vs. auto collision	4 (6.5)	0
	Assault	2 (3.2)	2 (100)
AO/OTA classification	12A1	7 (11.3)	0
	12A2	3 (4.8)	1 (33.3)
	12A3	12 (19.4)	3 (25)
	12B1	10 (16.1)	4 (40)
	12B2	11 (17.7)	5 (45.5)
	12B3	5 (8.1)	3 (60)
	12C1	4 (6.5)	1 (25)
	12C2	1 (1.6)	0
	12C3	9 (14.5)	4 (44.4)
Fracture location	Proximal 1/3rd	9 (14.5)	3 (33.3)
	Middle 1/3rd	38 (61.3)	11 (28.9)
	Distal 1/3rd	15 (24.2)	7 (46.7)

Table 3: Chi squared analysis for surgical fixation and patient characteristics.

Variables	Total	IHHS ≥10 mm, (%)	P value
Failed conservative treatment	11	3 (27.3)	0.498
Sex			
Male	41	15 (36.6)	0.308
Female	21	5 (23.8)	
Comorbidities			
Radial nerve palsy	13	3 (23.1)	0.329
Smoking	20	8 (40.0)	0.368
Diabetes mellitus	2	0 (0)	0.54

DISCUSSION

IHHS is a relatively common finding after trauma to the shoulder, and is present in 20-42% of proximal humerus fractures.[14,15] Although IHHS is a known phenomenon, there is a paucity of literature evaluating IHHS for humeral shaft fractures or its potential effect on fracture healing.

With or without IHHS a trial of nonsurgical treatment of diaphyseal humeral shaft fractures has been the standard of care in orthopedic trauma since the original description by Augusto Sarmiento in 1977.[12,13] Nonoperative management consists of an initial period of stabilization in either a hanging arm cast or a coaptation splint with a cuff and collar (Figure 2). After an initial period of immobilization the patient is transitioned to a functional fracture brace such as described by Sarmiento in his original series.[12,13,16] This landmark paper also encouraged patients to begin range of motion of the injured extremity as soon as possible and the brace allows for range of motion of the shoulder and elbow. The paper postulated that the brace coupled with motion of the arm allows for a hydraulic effect of the soft tissue to maintain alignment while allowing for osteogenesis through fracture micromotion.[12] While the functional brace provides circumferential compression to the fracture site, the active contraction of the biceps, triceps, and brachialis through normal arm use and motion serves to stabilize the fracture to allow bony healing to begin. If the angulation of the fracture does not exceed 20 degrees, then a functional and cosmetic outcome is usually achieved.[13] Fifty out of 51 patients in Sarmiento's original paper went on to union. Additional studies have shown that in the vast majority of these injuries there is a low complication rate and a nonunion rate of less than 4%.[15]

Figure 2 (a-d): Anterior-posterior radiographs of the left shoulder depicting initial injury, initial nonoperative management in a coaptation splint, IHHS in a functional fracture brace at follow up, and final follow up imaging of resolved IHHS and fracture healing.

Sarmiento, in his follow up paper in 2000 did comment that IHHS was present in 2% of his patients but that early voluntary contractions of the muscles in the arm rapidly restore congruity of the glenohumeral joint.[13] It has been theorized that IHHS occurs due to a number of entities including transient axillary nerve neuropraxia, pain inhibition of the deltoid, or any mechanism that disrupts the physiological negative pressure in the glenohumeral joint.[2] Regardless of the cause of IHHS, if properly identified then there is no need for further reduction of the glenohumeral joint, surgery, or expensive imaging or other diagnostic tests as IHHS is almost always transient and resolves with time and/or the use of a sling.[2]

Our study was designed to examine whether IHHS decreased the effectiveness of fracture bracing in humeral shaft fracture manifesting as nonunion and the need for surgical intervention. If IHHS is caused by atony of the shoulder and arm muscles and loss of negative intra-articular pressure, this might also disturb fracture healing in nonoperative management of humeral shaft fractures causing a failure of conservative management manifesting as humeral shaft nonunion. Nonunion of humeral shaft fractures is defined as failure to heal at 6 months post-fracture with no progress toward healing seen on radiographs.[19] Nonunion in humeral shaft fractures require surgical intervention.

Despite the standard definition of nonunion, if IHHS is used as a marker for atony, then this might be impairing muscular function which is critical to healing humeral shaft fractures that are managed nonoperatively in the early fracture healing period. However, our findings do not support this theory, as IHHS was not found to statistically significant with failure of conservative management requiring surgical intervention.

The 32.3% of patients with acute humeral shaft fractures had IHHS of at least 10 millimeters. Eight percent of patients with IHHS at the time of injury continued to show this radiographic finding at their first follow up visit. Within the study population of acute humeral shaft fractures with sufficient follow up, only 11 of 62 (17.7%) patients went on to operative intervention, and within this failed nonoperative group only 3 of these patients had IHHS at any point during follow up. Although IHHS was observed in more than one-third of humeral shaft fractures in our series, the results from this series suggest that the presence of IHHS does not predict failure of nonsurgical management or the need for surgical management.

There are limitations to this study, many attributable to the fact that it was a retrospective study. Additionally, it is unclear whether the radiographs were obtained in an upright or supine position. Shoulder and humerus films are traditionally obtained in an upright position allowing gravity to affect the arm. In a trauma setting involving a known or suspected fracture this is not always possible and it is likely that at least some of the initial radiographs were obtained with the patient in the supine position. If gravity is not allowed to act on the limb this would potentially mask if IHHS was present. This likely accounts for the large number of IHHS found at follow up that weren't initially present at the time of injury. Additionally, we had neither the power nor the follow up data available to determine whether IHHS truly affected bony union. We used surgery as a failure of non-operative management and a surrogate for bony union. Further investigation is required to look at whether or not IHHS can inhibit fracture union.

CONCLUSION

In conclusion, IHHS is a common finding in upper extremity trauma. While the mechanism underlying IHHS is not fully understood, IHHS appears to include a component of musculature atony, either from shock to the musculature or from pain inhibition. Despite this muscle atony this does not appear to be a risk factor for failure of nonoperative treatment in acute humeral shaft fractures.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Gass HM, Seilern J, Cantu N, Jones CA, Moore TJ. Inferior humeral head subluxation after acute humeral shaft fractures. Int J Res Orthop 2024;10:736-40.