Characteristics and management of iatrogenic proximal humeral fracture during manual reduction of shoulder dislocation

CURRENT STATUS: POSTED

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DOI: 10.21203/rs.2.12548/v1

SUBJECT AREAS
Orthopedics

KEYWORDS
Proximal humerus, Iatrogenic injury, Open reduction, Internal fixation, Outcome
Abstract

Purpose

This study aimed to investigate the characteristics, management and patient outcomes of iatrogenic proximal humeral fracture during manual reduction of shoulder dislocation.

Methods

A retrospective chart review from January 2014 to June 2017 identified 10 patients of iatrogenic proximal humeral fracture during shoulder dislocation reduction. The sex and age of patients, associated injuries and location, first-time or habitual shoulder dislocation, the type of anesthesia, the time from injury to revision surgery as well as functional outcomes were analyzed.

Results

There were 1 male and 9 females (female/male ratio 9:1) with an average age of 66.9 years (range, 50-77 years). All patients presented with first-time anterior shoulder dislocation, and 7 patients (70%) associated with greater tuberosity fractures (GTF). Four patients (40%) underwent reduction under general anesthesia and 6 reduction (60%) under propofol sedation. The revision surgery was performed by open reduction and internal fixation. The mean follow-up period was 18.2 months (range, 12-36 months). The mean visual analog score (VAS) was 3.0 ± 1.6 (range, 1-6), and the mean Neer scores were 82.1 ± 6.5 (range, 71-93). Significant differences were observed in the Neer score and VAS with the time (more or less 8 h) from injury to revision surgery (P < 0.05).

Conclusion

A high risk of iatrogenic proximal humeral fracture is present in first-time anterior shoulder dislocation with GTF in senile female. Effective reduction and internal fixation performed timely may help to improve functional outcomes in case of iatrogenic injury.

Background

Shoulder dislocation, which accounts for more than 50% of joint dislocations in the body, is the most common and orthopedic emergency work that requires immediate treatment [1]. Given the incomplete examination before reduction or improper manual reduction by junior residents of the orthopedic department, original occult fractures are displaced. When effective anesthesia is not
properly given during reduction, especially in elderly patients with osteoporosis, forced reduction likely causes new fractures or displacement of existing occult fractures, and eventually iatrogenic proximal humeral fractures occur [2, 3]. At present, most scholars believe that the causes of such complications are closely related to repeated rough manual reduction without pain relief and muscle relaxation [4, 5]. During manual reduction under general anesthesia (GA) in an ideal state of muscle relaxation, iatrogenic injuries are difficult to avoid, even by a senior orthopedic surgeon. Proximal humerus fracture-dislocations are serious injuries of shoulder joints, and related iatrogenic injuries are not uncommon in the clinic. Management of these injuries may cause obvious damage to the blood supply of the head of humerus and avascular necrosis of humeral head easily occur; the consequence can seriously hinder the function of the shoulder joint and easily incur medical disputes [6]. The doctor performing emergency management of patients with shoulder dislocation must be meticulous during inspection and run CT and MRI examinations of shoulder joints before the reduction to further ensure the absence of occult fracture [7, 8].

In this study, the clinical data of 10 patients with iatrogenic proximal humeral fracture during emergency manual reduction of shoulder dislocation were analyzed retrospectively. The characteristics and relationship between iatrogenic factors and possible complications associated with treatment were investigated. The corresponding countermeasures in the treatment of iatrogenic proximal humeral fractures and functional outcomes were discussed, and the clinicians, especially junior doctors, were reminded to avoid iatrogenic injury as far as possible.

Methods

Participants

This study is a retrospective case series with prospectively gathered data from January 2014 to June 2017 in our institution, and the inclusion criteria were as follows: (1) eighteen years or older; (2) diagnosis of simple shoulder dislocation or shoulder dislocation with greater tuberosity fracture (GTF), and radiographs of GTF were classified Type 11-A1 according to the Orthopaedic Trauma Association (OTA) classification, and as 1-part or 2-part GTF with shoulder dislocation according to the Neer classification [9] (Fig. 1a, b); (3) iatrogenic proximal humerus fracture of 3-part or 4-part fracture-
dislocations occurred during attempted closed reduction of shoulder dislocation; (4) treatment with surgical open reduction with internal fixation (ORIF); and (5) radiologic examination and functional outcome assessment for a minimum of 12 months following surgery. The study excluded patients with associated brain injury, open abdominal injury, multiple fractures, vascular injuries, and inadequate preoperative or postoperative films. There were 10 patients included for evaluation. Data collected included the sex and age of patients, associated injuries and location, first-time or habitual shoulder dislocation, the type of anesthesia, the time from injury to revision surgery, and functional outcomes of ORIF. The indication for each operation was based on the Neer description of a displaced fracture and dislocation (Fig. 1a, b, d). Fracture classification was based on plain radiographs and determined by two experienced surgeons. The study was approved by the ethics committee of Renmin Hospital of Wuhan University.

**Surgical technique**

All patients underwent surgery with ORIF after iatrogenic proximal humerus fracture occurred (Fig. 1c, d). The surgical procedures were performed under standardized routine and GA. An anterior deltopectoral approach was used and a skin incisions was approximately 15-20 cm long; the deltopectoral approach was completed through an incision from the coracoid process, via the anterior axillary fold, and to the deltoid tuberosity (Fig. 1e). By detaching the lateral half of the conjoined tendon, a large exposure can be achieved and the articular fragment can be managed extracapsularly without vigorous retraction of the conjoined tendon. Next, the biceps long head was recognized, and the fracture configuration was checked. After thorough removal of scar tissue, the glenoid articular cartilage was considered to be in good form, and the humeral head was reduced (Fig. 1f). Then, the head to the shaft fragment was reduced, and temporary K-wires were inserted to sustain the reduction (Fig. 1g). The location of the locking compression plate was 5–10 mm lateral to the bicipital groove and 15–20 mm inferior to the vertex of the humerus (Fig. 1h). After checking the plate location, we primarily implanted a cortical screw through the oval shaft hole, followed by one or two head-locking screws positioned through the top holes of the plate (Fig. 1i). The insertion of the inferior
head screws supporting the medial column was simplified by proximal or distal mobilization. We confirmed the position of the screw tip within the humeral head with an image intensifier (Fig. 1j, k). We constantly used a tie-down suture of the rotator cuff to the plate; this suture is necessary for avoiding tuberosity migration and varus collapse of the humeral head.

**Rehabilitation**

The arm was restrained for 6 weeks in an abduction brace after operation. The drain was removed by the second postoperative day. Shrugging of the shoulder and active motion of the elbow, wrist, and hand with the brace applied were encouraged gradually after the operation. However, shoulder joint movement, including pendulum exercise, was not permitted. At 6 weeks, self-assisted forward elevation and external rotation using a stick was began. Internal rotation exercises using the sleeper’s stretch were increasingly performed depending on the patients’ arm elevation level. Active, assisted range of motion (ROM) exercises were encouraged 8 weeks postoperatively.

**Postoperative evaluation and management**

Images in the standard anteroposterior, lateral, axillary, and scapular Y views were obtained instantaneously following surgery and during the follow-up evaluation at 4, 8 and 12 weeks postoperatively; at 6 and 12 months following surgery; and during followed up yearly. Patients were evaluated for the time to bone union and for radiologic complications (screw penetration, tuberosity malunion or nonunion, varus collapse, and avascular necrosis). The neck-shaft angle of the humerus was measured. Functional outcomes were assessed at the final follow up in accordance with Neer’s criteria, which included pain (none to totally disabled), function (strength, reach, and stability), ROM (flexion, abduction, extension, external rotation, and internal rotation), and anatomy (rotation, angulation, joint congruity, retracted tuberosities, metal failure, myositis, nonunion, and avascular necrosis) [10]. The degree of patient satisfaction was evaluated using the visual analog score (VAS) (0 = very satisfied, 10 = no satisfaction) at the final follow up [11]. Postoperative axillary nerve function was noted while examining the sensory territories of the axillary nerve and testing the weakness or
atrophy of the anterior deltoid muscle. Implant removal was not suggested unless hardware-related complications or symptoms were present.

**Statistical analysis**

Data were statistically analyzed using the SPSS 13.0 statistical software. Continuous variables, expressed as the mean ± standard deviation (SD) and categorical variables as number (n) and percentage (%) were compared by the Student t test to detect group differences. The qualitative data of groups were compared by the χ² test.

**Results**

There were 1 male and 9 females (female/male ratio 9:1) with an average age of 66.9 years (range, 50-77 years) (Table 1). All patients presented with first-time anterior shoulder dislocation, and 7 patients (70%) associated with GTF. Four patients (40%) underwent reduction attempt under GA and six reduction (60%) under unconscious sedation by propofol, which all were performed by Hippocratic manual reduction. Six (60%) were on the left side and 4 (40%) were right side dislocations. Low-energy falls (from a standing position) caused in 5 (50%) patients; high falling injury (from a considerable height or down-stairs) caused in 2 (20%) patients; motor vehicle accidents caused in 3 (30%) patients. Average time from injury to revision surgery (ORIF) was 9.8 ± 5.7 h (range, 4–21 h). The mean follow-up period was 18.2 months (range, 12–36 months). Fracture union was achieved in all cases. The mean time to union was 8.5 weeks (range, 7-12 weeks). The mean neck-shaft angle at the final follow up was 129.8° ± 8.7° (range, 115°-142°) (Fig. 1l, m). The majority of patients showed good or excellent results in accordance with the Neer score (Fig. 1n, o, p, q). The mean Neer score was 82.1 ± 6.5 (range, 71-93). The mean VAS for patient satisfaction was 3.0 ± 1.6 (range, 1-6) (Table 2). The Neer score and VAS were significantly influenced by the time from injury to revision surgery. There were 4 patients with treatment waiting time more than 8 h (range, 12-21 h), and the Neer score and VAS were 76.8 ± 4.8 (range, 71-82) and 4.5 ± 1.3 (range, 3-6), respectively. There were 6 patients with treatment waiting time less than 8 h (range, 4-7 h), and the Neer score and VAS were 85.7 ± 5.0 (range, 80-93) and 2.0 ± 0.9 (range, 1-3), respectively. Significant differences were
observed in the Neer score (P = 0.023) and VAS (P = 0.007) with treatment waiting time. One patient with brachial plexus nerve injury recovered 3 months after surgery. One patient presented superficial infection of the wound, which healed after debridement and perfusion drainage. Avascular necrosis of the humeral head occurred in one case. Major complications, such as internal fixation failure and varus collapse at the fracture site, were not observed. None of the patients showed any clinically detectable sensory deficits in the axillary nerve distribution or anterior deltoid muscle weakness or atrophy.

Discussion
The purpose of this study was to assess the characteristics, management and patient outcomes of iatrogenic proximal humeral fracture during manual reduction of shoulder dislocation. We understood the characteristics of high-risk groups and high-risk factors for iatrogenic proximal humeral fracture, and were guided in preliminary screening and targeted treatment during emergency work. Besides young individuals, elderly women over the age of 50 years are prone to primary shoulder dislocation; this observation is highly consistent with the elderly population of osteoporotic proximal humerus fractures [12]. The risk of primary shoulder dislocation combined with proximal humerus fracture in elderly patients is much higher than that in young and habitually dislocated patients. Research shows that iatrogenic fractures occur in about 80% of elderly women due to age-related elements such as postmenopausal osteoporosis [2, 13]. In the course of diagnosis and treatment, the neglect of these characteristics of senile shoulder dislocation will lead to serious complications [14]. In this study, we found that the vast majority (90%) of these patients were elderly women with primary shoulder anterior dislocation, and the highest priority for prevention should be given to elderly women for their bone fragility.

The high-risk population of iatrogenic injury includes patients with anterior shoulder dislocation who are prone to proximal humeral fracture or with GTF during manual reduction. Considering our experience and literature review, we believe that the characteristics of high-risk groups are as follows: (1) elderly women over 50 years of age, (2) first-time anterior shoulder dislocation, (3) concurrent GTF [15], and (4) displaced humerus head located below or medial to the coracoid
process. Based on our observations, about 70% of the original dislocation types belong to the Neer 1-part or 2-part of GTF with shoulder dislocation type. The fragment size, shape, and location of GTF may reveal diverse mechanisms and rapidity of injury, and the size of GTF is proportional to the incidence of iatrogenic humeral neck fractures [16, 17]. Compared with habitual dislocation, the muscles around the shoulder joint are obviously tense at first-time shoulder dislocation, which requires greater traction during reduction and is more prone to iatrogenic injury. As to the type of analgesia/anesthesia adopted for the shoulder reduction, there are several options available, such as intramuscular analgesics, intraarticular anesthesia, conscious or unconscious sedation, and GA. Some scholars recommended closed reduction under GA with full relaxation of shoulder muscles. In present study, we recommend unconscious sedation and GA during closed reduction, which could reduce traction strength, facilitate reduction, and decrease iatrogenic fractures. We believe that the causes of iatrogenic injuries in these patients are mainly related to the following factors: (1) the doctors lacked sufficient understanding of the high-risk population of anterior shoulder dislocation, (2) inadequate imaging examination resulted in the failure to determine the presence of occult anatomical neck fracture before reduction, (3) improper treatment (i.e., without any anesthetic measures, hastily manual reduction without diagnosis, or rough manipulations).

Currently, most scholars believe that the causes of such complications are related to repeated rough manipulations in patients without pain relief and muscle relaxation [18]. However, many scholars have reported that during manual reduction under GA in an ideal state of muscle relaxation, iatrogenic injuries are difficult to avoid, even by a senior orthopedic surgeon [6, 19]. These scholars propose that the cause of iatrogenic injuries is related to the omission of the combined undisplaced humerus anatomical neck before reduction [20]. Given the lack of additional pre-reduction imaging data in most of the cases, we were unable to understand whether humeral anatomic neck fracture existed at the time. However, by carefully reading the pre-reductive X-rays, some of the patients were highly suspicious for occult proximal humerus fracture. Whether the anatomical neck fracture was caused by improper manual reduction or inadvertent accompanying reduction, inappropriate treatment aggravated the displacement between the humeral head and the humeral shaft. The
common consequence is worsening of the fracture and dislocation type of the proximal humerus. The causes of iatrogenic proximal humerus fracture are associated with errors in diagnosis and/or treatment and should be classified as iatrogenic complications. Identifying the characteristics of iatrogenic injuries will help prevent similar mistakes in future work.

The overall incidence of iatrogenic proximal humeral fracture was 5.4 %, but the incidence of GTF can increase to 26 % [15]. We found that the affected patients were basically elderly women with primary anterior shoulder dislocation, and most of the primitive dislocation types belonged to the Neer 2-part of GTF with shoulder dislocation type. A weak bone area may be present in the junction of the humeral head and shaft, even with occult humerus anatomic neck fracture. Guo et al. [17] found that a positive relationship exists between the size of the greater tuberosity fragment and the occurrence of iatrogenic humeral neck fractures during the reduction of shoulder dislocation. In the absence of relevant preventive measures for gimmick reset, the original lack of displacement or slight shift anatomic neck fracture displacement will inevitably lead to separation between the humerus head and shaft. Even under anesthesia, such complications are difficult to avoid during reduction. In the case of elderly patients with primary shoulder dislocation, especially those together with GTF or occult anatomical neck fracture, the patients and their families should be informed of the potential risks in the course of reduction. Multiple Kirschner needles may also be used to temporarily fix the humeral head and shaft under anesthesia before manual reduction.

For the choice of salvage operation for iatrogenic injuries occur, individualized treatment should be carried out depending on the patient’s age, fracture severity and patient’s requirement of shoulder joint function [21, 22]. After failure of manual reduction and iatrogenic proximal humeral fracture occurs, ORIF, even artificial shoulder arthroplasty and other rescue measures should be prepared [23]. In our study, we all chose the rescue measures of ORIF, and obtained clinical effects with different degrees of satisfaction. This result was attained partially because of the relatively young age of the patients, the complete mass fractures, the ideal reduction quality and the reasonable functional rehabilitation after operation. In this group, the anterior deltopectoral approach, which is beneficial for full exposure, restoration, and fixation, was adopted [24]. We also analyzed the relationship
between the time from injury to revision surgery and functional outcomes of ORIF. Unsurprisingly, those patients who had treatment waiting time less than 8 h had a better functional outcomes than those more than 8 h (P < 0.05). This significant difference demonstrates the importance of timely and effective ORIF for functional recovery. First, the blood supply of anterior circumflex brachial artery branches has been destroyed after iatrogenic injury, and early operation to protect the posterior medial branch of posterior circumflex brachial artery is the key to the protection of humeral head from ischemic necrosis. Second, the humerus head is in a non-physiological state for a long time, which increases the contact wear between the cartilage of humeral head and the fracture section. In addition, delayed ORIF aggravated soft tissue edema and hemorrhage around the shoulder joint, followed by postoperative adhesions around the shoulder joint. Therefore, early (within 8 h) ORIF after iatrogenic injury could save the residual blood supply of humerus head and improve functional outcomes.

Additionally, the brachial plexus nerve injury occurred in 1 case during reduction. It may be related to the humerus head shifting to anterior part of shoulder capsule and pressing brachial plexus nerve during the retraction and reduction, which can recover spontaneously. One patient suffered from ischemic necrosis of humerus head, which may be associated with long follow-up time for 3 years and seriously impaired blood supply to the head. The morphology of humerus head in this patient was changed, but no severe collapse of the head occurred and did not cause serious dysfunction. Longer follow-up and more case summaries are needed to illustrate this point.

Conclusions
The high risk group of first-time anterior shoulder dislocation with GTF in senile female should be managed carefully. The risks in the course of reduction must be paid with close attention, and the patients and their families should be informed of the complexity and underlying complications of reduction in the high-risk group. Effective reduction and internal fixation performed timely may help to improve functional outcomes in case of iatrogenic injury.

Abbreviations
VAS: Visual analog score; GTF: Greater tuberosity fractures; GA: General anesthesia; OTA:
Orthopaedic Trauma Association; ORIF: Open reduction with internal fixation; ROM: Range of motion; SD: Standard deviation; LEF: Low-energy falls; HFI: High falling injury; MVA: Motor vehicle accidents

Declarations

Acknowledgements

The authors thank Lu Xia, study nurse, for her efforts in contacting and questioning all patients. They also thank Shihao Wu for the excellent copy-editing of this manuscript.

Funding

The study was supported by the Fundamental Research Funds for the Central Universities (No. 2042018kf0123), the National Natural Science Foundation of China (No. 81802203), and the Guidance Fund of Renmin Hospital of Wuhan University (No. RMYD2018M43). These grands only covered the publication charges. These funds were not used for any of the following: design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request. All data generated or analysed during this study are included in this published article. The manuscript, including related data, figures and tables have not been previously published and are not under consideration elsewhere.

Authors’ contributions

ZY conceived and designed the study and drafted the manuscript. MJH and LSQ put forward the concept of the study and reviewed the manuscript. ZY collected the data and analyzed them. ZY and MJH interpreted the data. ZY and LSQ revised the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The study was approved by the ethics committee of Renmin Hospital of Wuhan University. The study was conducted in compliance with the Declaration of Helsinki. All the individuals were participating in this study with written informed consent.

**Consent for publication**

Not applicable.

**Competing Interests**

The authors declare that they have no conflict of interest.

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**Tables**

**Table 1** Basic information for patients included in this study

| Number | Age | Injury cause | Original injury     | Primary treatment     |
|--------|-----|--------------|---------------------|----------------------|
| 1      | 60  | LEF          | Anterior dislocation| Closed reduction Under sedation |
| 2      | 77  | HFI          | Anterior dislocation| Closed reduction Under GA |
| 3      | 68  | MVA          | Anterior dislocation| Closed reduction Under GA |
| # | Age | Gender | Diagnosis       | Treatment          |
|---|-----|--------|-----------------|--------------------|
| 4 | 70  | LEF    | Anterior dislocation | Closed reduction Under sedation |
| 5 | 65  | LEF    | Anterior dislocation GTF | Closed reduction Under sedation |
| 6 | 68  | LEF    | Anterior dislocation GTF | Closed reduction Under sedation |
| 7 | 50  | HFI    | Anterior dislocation GTF | Closed reduction Under GA |
| 8 | 69  | LEF    | Anterior dislocation GTF | Closed reduction Under sedation |
| 9 | 70  | MVA    | Anterior dislocation GTF | Closed reduction Under sedation |
| 10| 72  | MVA    | Anterior dislocation | Closed reduction Under GA |

**Table 2** Clinical evaluations at the last follow up
| Number | treatment waiting time (hours) | Follow-up (months) | Neck-shaft angle (degree) | Neer scores | visual analog score | Complication |
|--------|-------------------------------|--------------------|--------------------------|-------------|-------------------|---------------|
| 1      | 6                             | 12                 | 115                      | 93          | 3                 |               |
| 2      | 7                             | 15                 | 140                      | 82          | 3                 |               |
| 3      | 14                            | 18                 | 135                      | 75          | 5                 |               |
| 4      | 4                             | 36                 | 130                      | 80          | 3                 | Avascular     |
| 5      | 5                             | 20                 | 125                      | 85          | 3                 | Brachioplex    |
| 6      | 12                            | 12                 | 137                      | 82          | 3                 |               |
| 7      | 16                            | 17                 | 128                      | 79          | 4                 |               |
| 8      | 7                             | 14                 | 142                      | 90          | 1                 |               |
| 9      | 6                             | 24                 | 126                      | 84          | 2                 |               |
| 10     | 21                            | 14                 | 120                      | 71          | 6                 | Superficial   |

Figures
The patients with iatrogenic proximal humeral fracture during manual reduction of shoulder dislocation treated with ORIF. a,b A patient of shoulder dislocation with GTF as seen on the preoperative anteroposterior and oblique radiographs; c The general appearance of the damage; d The iatrogenic humerus anatomical neck fracture occurred after reduction; e,f Right shoulder anterior deltopectoral approach was utilized, and the biceps long head was removed and the humerus head was exposed; g,h Provisional fixation with one K-wire and fixed with plate; i The general appearance after internal fixation; j,k C-arm fluoroscopy in orthotopic and abductor position of the shoulder confirmed the appropriate length of the screw; l,m The postoperative radiograph at 12 months after operation with neck-shaft angle of 125°; n,o,p,q The ROM at 12 months follow up were shown.