Shoulder and Elbow Tips & Tricks: A Case Study in Shoulder Hemiarthroplasty for Proximal Humerus Fractures: The Importance of Accurate Humeral Head Length Measurements

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Background

Proximal humerus fractures are commonly seen after low energy mechanisms in elderly populations with osteoporotic bone and high energy mechanisms in younger patients.[1] The large majority of these fractures are minimally displaced and can be managed non-operatively with good functional outcomes.[1, 2] Surgical indications for these fractures include multi-fragmentary head-splitting fractures, fracture dislocations, and neurovascular injuries.[1] Surgical management is determined based on patient characteristics, fracture pattern, and how fixation will drive functional outcomes.[1]

For operative treatment of proximal humerus fractures, two broad categories of operative treatment are available: those which preserve the humeral head and those that are humeral-head sacrificing. Preservation of the humeral head includes osteosynthesis techniques using plates or nails, while humeral-head sacrificing arthroplasty refers to reverse total shoulder arthroplasty (RSA) or hemiarthroplasty.[2] Prior to the development of RSA, hemiarthroplasty was the "gold standard" option for proximal humerus fractures in which fracture fixation was unachievable. However, hemiarthroplasty, particularly in older patients with osteoporotic bone and rotator cuff deficiency, showed poor functional outcomes and early re-operation rates.[1] Recently, RSA has become the arthroplasty option of choice for severe proximal humerus fractures[3,4] due to their more reliable and reproducible outcomes. This trend is largely because outcomes of reverse total shoulder arthroplasty are much less dependent on the function of the rotator cuff and therefore less limited by factors such as nonhealing tuberosities or prosthesis height.[5] However, despite the rise in use of RSA, there remains a need for shoulder hemiarthroplasty in the treating surgeon's repertoire.

In current practice, hemiarthroplasty for proximal humerus fractures is reserved for younger or higher demand patients with proximal humerus fractures that are unable to be fixed with osteosynthesis. Patients typically demonstrate adequate bone quality to support healing around the prosthesis, minimal comminution of the tuberosity fragments, and have adequate rotator cuff functions to enable post-operative rehabilitation.[2]

Adequate humeral height, version, and anatomic tuberosity reduction have important implications for success following hemiarthroplasty. Tuberosity reduction correlates with functional results, particularly native shoulder kinematics. Humeral height and version, similarly, correlate to functional outcomes, where improper measurements can lead to persistent pain and stiffness post-operatively.[2]

In order to ensure proper tuberosity reduction, humeral height and version require specific calculations during preoperative planning to restore proper humeral length.[6] Without proper restoration, inadequate humeral height can lead to non-anatomic reconstruction and poor clinical outcomes.

This case study provides an example of the use of hemiarthroplasty in a young female patient after a gun-shot wound to the left upper extremity and demonstrates the importance of accurate measurement of humeral head length when completing the operation.

Case Presentation

A 44-year-old female presents to the Trauma Center with multiple gun-shot wounds, including to the left upper extremity. Radiographs of the left shoulder demonstrated a comminuted left proximal humerus fracture with humeral head displacement and dispersed osseous fragments (Figure 1). The patient was Glascow Coma Scale 3 at the time of arrival and initial physical examination was limited due to her disposition. On examination, there was an entry wound over the lateral shoulder with exit wound near the acromion and clavicle. No motor or sensory examination was possible because the patient was intubated and sedated at this time.

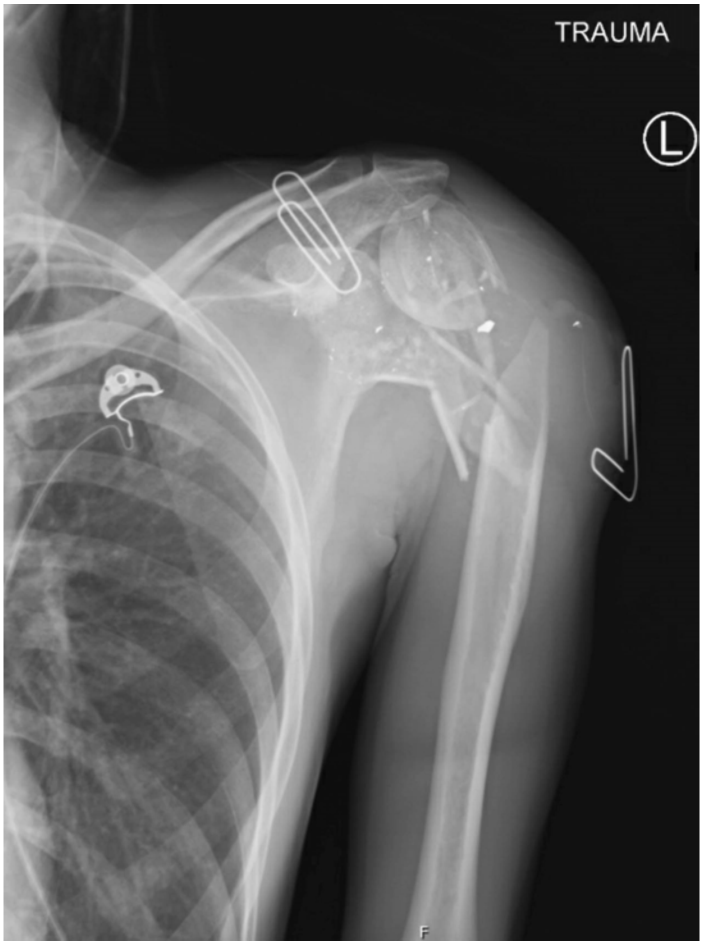

Figure 1. Shoulder x-ray upon arrival to the Trauma Center illustrating a comminuted left proximal humerus fracture with humeral head displacement and dispersed osseous fragments.

The patient was taken emergently to the operating room for a formal irrigation and debridement because of fracture-dislocation of the left glenohumeral joint with joint space violation from her gun-shot wound and concern for possible arterial injury. No arterial injury was identified at the time of surgical exploration.

The patient was extubated post-operatively and able to participate in a neurovascular examination at this time. She was neurovascularly intact in the ulnar, median and radial distributions with overall weakness and diminished sensation. Her axillary nerve was nonfunctioning with no deltoid motor functioning and limited sensation. Definitive operative planning was pending patient stabilization for further surgical intervention.

A post-operative CT scan was performed to better understand the injury pattern and demonstrated a severely comminuted proximal humerus fracture involving multiple portions of the humeral head and medial calcar with significant comminution of the tuberosities (Figure 2). Due to the extensive comminution of the articular surface, open reduction internal fixation was deemed an inadequate option and the decision was made to proceed with a hemiarthroplasty. The indications for hemiarthroplasty included the comminution of the articular surface, the patient's young age, and the concern for deltoid dysfunction in the setting of an axillary nerve injury which would compromise the function of a reverse total shoulder arthroplasty.

Tips and Tricks

The patient was positioned in the modified beach chair position at a 45-degree angle.[6] All areas of bony prominence and possible sites of nerve compression were well-padded and offloaded. At the time of prepping and draping, electrodiagnostic needles were placed for neuromonitoring of the left upper extremity. Due to the patient's symptomatic nerve injury, neuromonitoring was performed to confirm the preoperative status of her nerve function. Neuromonitoring confirmed no signals in the axillary nerve distribution and

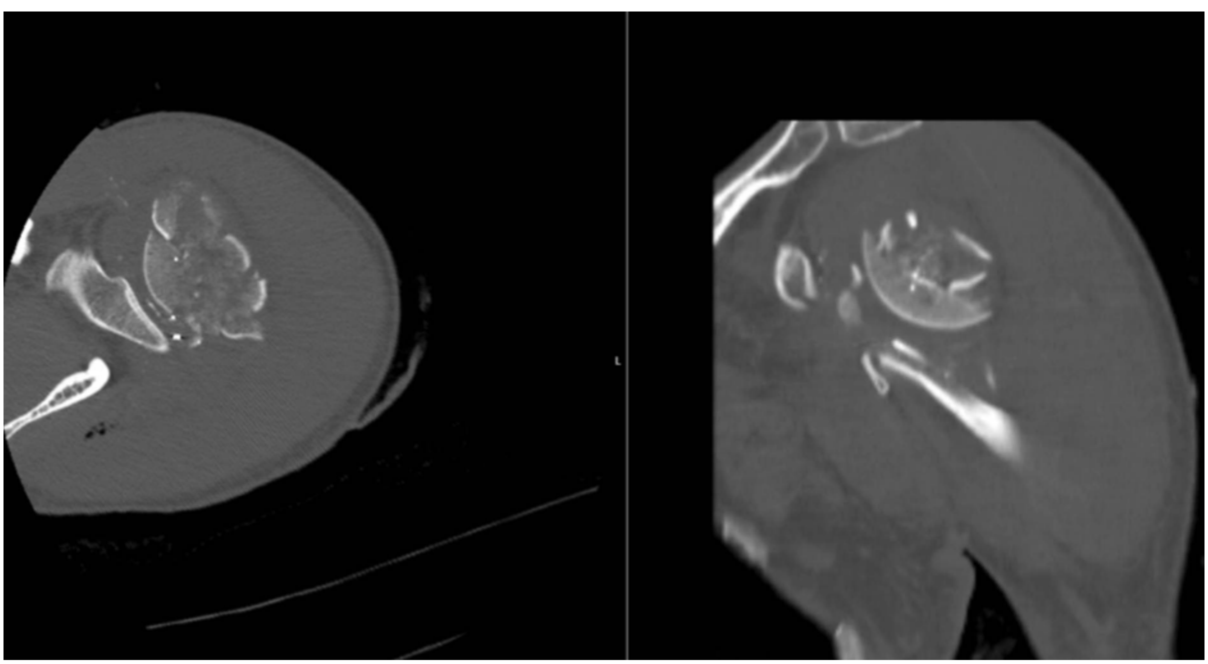

Figure 2. Post-operative CT scan of the left shoulder illustrating severely comminuted proximal humerus fracture.

also demonstrated significant decrease in signals in the other peripheral nerve distributions.

In order to properly restore the humeral length with the hemiarthroplasty, proper preoperative films are obtained of both the injured and contralateral humerus. The films are calibrated using a radiologic marker ball for calibration. In this case, the marker is 30mm in diameter (Figure 3 A-C).

The length of the humerus on the contralateral arm is measured from the superior apex of the articular surface to a fixed point distally. In the case of the AP radiograph, the center of the olecranon fossa is selected. In this particular case, the length of the contralateral (non-injured) humerus for those endpoints measured 299.8mm (Figure 3, A). On the injured full-length humerus film, the measurement is recreated starting from the center of the olecranon fossa distally and measured proximally to the superior-most aspect of the humeral shaft (which in this case was the lateral aspect of the humeral shaft). This distance measured 253.3mm (Figure 3, B). This measurement is repeated but now using the proximal-most aspect of the medial portion of the humeral shaft to the center of the olecranon fossa which measures 216.2mm (Figure 3, C). These two measures from the injured humerus are then subtracted from the length measured on the contralateral uninjured humerus (delta) to help determine how much the humeral prosthesis should be proud from the medial and lateral aspects of the fractured humeral shaft fragment to restore the humeral height appropriately. For the medial aspect, this measured 83.6mm and for the lateral aspect, this measured 46.5mm. A marking pen is then used to mark these delta lengths on the trial and final humeral prostheses as they are measured from the superior aspect of the hemiarthroplasty down the stem. Of note, the large medial calcar fragment that was initially displaced medially included the attachment of the pectoralis major tendon. At the time of surgery, this medial calcar fragment was reduced around the trial humeral stem and cabled into place. Once this was performed, the defect medially was near equivalent to the defect laterally with about 5cm of height needed to be restored. This correlated with the known distance of the pectoralis insertion from the superior aspect of the humeral articular surface.

Cadaveric studies have demonstrated that the average distance of the superior aspect of the humeral head to the superior border of the pectoralis major tendon insertion is 56mm. Murachovsky et. al.[7] described this distance (the PMT) using 20 cadavers (40 shoulders) and showed this measurement with a 95% confidence interval. There was no difference based on patient size and thus, the PMT is a method for accurate humeral length restoration intraoperatively with comminuted fracture patterns when other landmarks are absent. This measure was also used intraoperatively as another check that the humeral height was appropriately restored (Figure 4). Using this anatomical landmark and the preoperative radiographic measurements, a height defect of about 5cm was necessary for restoration of proper humeral length.

Finally, as the trial implant is placed, heavy sutures in the tuberosity fragments were used to reduce to the proximal aspect of the humeral stem. Restoration of the tuberosities to the implant and their relation to each other area also used to judge the height of the prosthesis. In particular, the greater tuberosity should not be proximal to the most superior aspect of the humeral head surface. Intraoperative fluoroscopy was performed at the time of trial reduction to confirm adequate tuberosity reduction with the humeral stem placed at the appropriate height and 30 degrees of retroversion.

Individually or separately, errors in humeral length or version during hemiarthroplasty are associated with non-anatomical reconstruction.[6] Shortening of the humerus can shorten the deltoid causing contracture leading to compromised anterior elevation of the shoulder. This change can decrease the level arm in the operative extremity. Lengthening compared to the contralateral extremity leads to pain and limited range of motion secondary to superior humeral migration and abnormal joint compression forces that may cause anterosuperior impingement.[6] Improper version can place excess tension on the rotator cuff, which can lead to either suture release or posterior migration of the greater tuberosity.

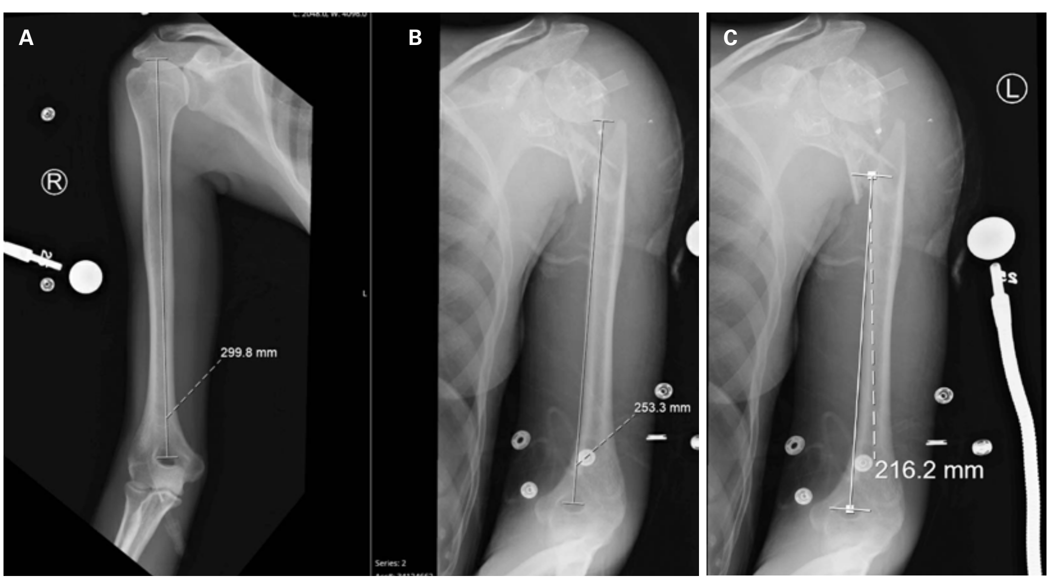

Figure 3. Humerus x-ray measurements. **(A)** Contralateral right humerus measurement with marker ball; **(B)** Left comminuted proximal humerus fracture with lateral measurement; **(C)** Left comminuted proximal humerus fracture with medial measurement.

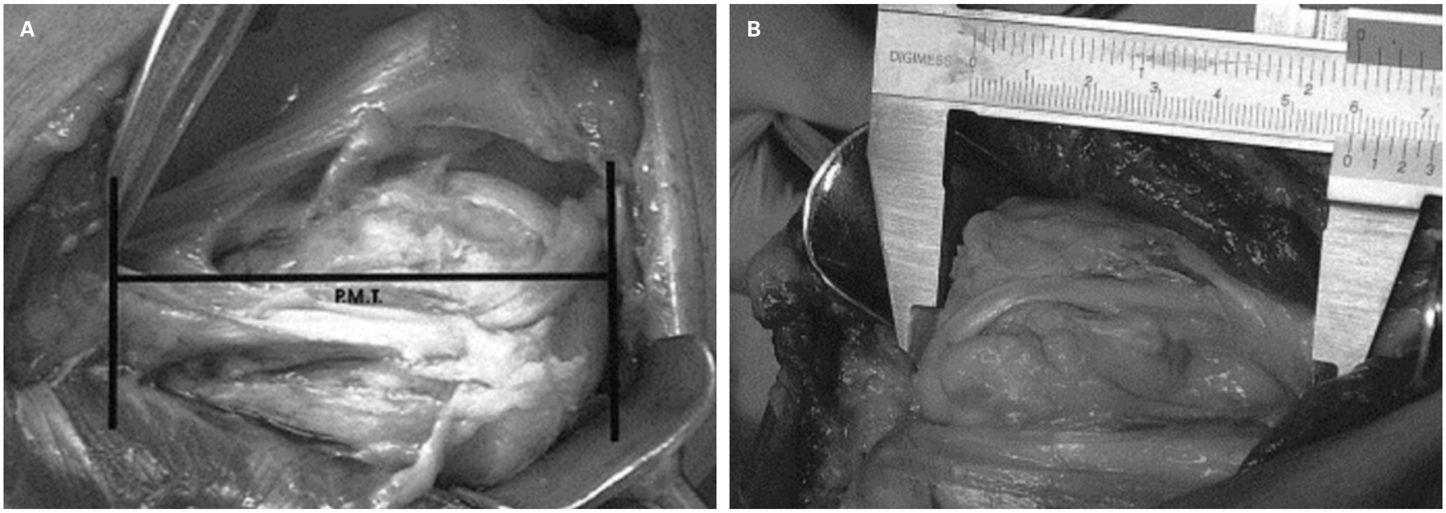

Figure 4. (A) PMT distance showing superior aspect of the humeral head to the superior border of the pectoralis major tendon insertion; **(B)** Intraoperative measurement of PMT of 5cm [images courtesy of Murachovsky et. al.[7]]

Outcome

Following left shoulder hemiarthroplasty with cable fixation and repair of the rotator cuff (Figure 5), the patient was placed in a sling and was started on early passive and active assisted range of motion exercises. However, the patient had increasing pain postoperatively with limited participation in examinations and physical and occupational therapy which delayed discharge.

Three months post-operatively, the patient developed significant deltoid atrophy and persistent axillary nerve dysfunction which was confirmed by MRI. She also had continued weakness in her radial, median, and ulnar nerve distributions. Most recent x-rays of the left shoulder show a well-fixated hemiarthroplasty with some anterior subluxation on the axillary view unchanged from previous x-rays. The implant height is appropriate and well-fixated.

Figure 5. Post-operative x-ray of the left humerus hemiarthroplasty with cerclage wires.

Conclusion

This case demonstrates an example of the continued value in hemiarthroplasty and the need for proper humeral height assessment. Unfortunately, the patient's axillary nerve injury at the time of her trauma resulted in poor deltoid function. However, this was an important thing to consider at the time of her surgical management as a reverse total shoulder would have not been functional and likely would have remained grossly unstable with the deltoid atony.

As with any surgical method, hemiarthroplasty complications occur. These include infection, fracture, nerve injury, and tuberosity malunion/nonunion.[2] However, similar concerns exist with other operative fixation techniques. Thus, with consideration of proper humeral length, version, and anatomic tuberosity reduction in appropriate candidates, hemiarthroplasty is a good surgical option for proximal humerus fractures.[1,2,5] Preoperative radiographic planning and intraoperative measurements using established methods provide good surgical fixation for better patient functional outcomes in younger patients.

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