Radiographic Predictors of Repeat Surgery and Post-Operative Complications in Proximal Humerus Fractures Treated with 3rd Generation Intramedullary Nail

Hayden B. Schuette[1], B. Gage Griswold[2], Libby Mauter[1], Mallory Boyd[1], Benjamin W. Sears[1], Armodios M. Hatzidakis[1]
[1]Western Orthopaedics, Denver, CO, USA
[2]Medstar Georgetown/Washington Hospital Center, Washington, DC

Introduction:
Intramedullary nail (IMN) fixation for proximal humerus fractures has been shown to provide satisfactory results. However, the impact of reduction quality on clinical outcomes, and postoperative complications has not been objectively described. The purpose of this study was to objectively evaluate the quality of reduction and determine if any parameter was predictive for subsequent complications or need for additional surgery.

Methods:
A single-center retrospective review was conducted on patients who underwent IMN for a proximal humerus fracture by one of three surgeons between 2009 and 2022. Minimum radiographic follow-up of 12 months was required. Neck shaft angle measurement, humeral shaft position in relationship to the center of rotation of the humeral head, nail height measured from the top of the nail to the zenith of the humeral head, calcar overhang measured from the intact humeral head fracture fragment to the intact shaft fragment, calcar length measured from the margin of articular cartilage to the intact calcar and reduction grade on the anterior posterior and axillary lateral radiographs were measured (Figure 1A-E). Clinical outcomes included the American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE) score, patient satisfaction, pain score (0-10 scale), and range of motion (ROM). The need for additional surgery was also recorded.

Results:
Seventy-three patients with a mean clinical follow-up of 36.8 months and a mean radiographic follow-up of 42.5 months were eligible for inclusion. According to the Neer classification, the cohort included 32 (44%) two-part, 26 (36%) three-part, and 15 (20%) 4-part fractures. Additional surgical intervention was required in 21.9% of patients; 11underwent arthroscopic debridement, with or without proximal interlocking screw removal and 4 required conversion to arthroplasty. One patient underwent revision open reduction and internal fixation with a proximal humeral plate. Among the recorded radiographic parameters, intraoperative medialization of the humeral shaft relative to the humeral head (Figure 2A) was associated with an increased need for additional surgery, including conversion to arthroplasty ($p=0.039$), and a higher rate of avascular necrosis (AVN) ($p=0.018$). Univariate regression demonstrated that the medialization of the humeral shaft related to the humeral head was significant for predicting need for revision (OR = 0.87, (CI 0.76, 0.99), $p = 0.039$). Poor reduction on the axillary lateral image (Figure 2B) was associated with the development of glenohumeral arthritis (GHOA) ($p=0.018$) and decreased external rotation. No other parameters were associated with complications following IMN placement. Patients who developed AVN or GHOA had inferior ROM, SANE, ASES, pain, and satisfaction scores compared to those who did not. Prior to conversion to arthroplasty, patients exhibited decreased external rotation, ASES, SANE, and satisfaction scores compared to those who did not require additional surgery.

Conclusion:
This study demonstrates that medialization of the humeral shaft relative to the humeral head is associated with a higher incidence of additional surgery (major and minor revision) and the occurrence of AVN. Additionally, poor reduction on the axillary lateral image is associated with the development of GHOA and decreased external rotation, which emphasizes the importance of tuberosity reduction.

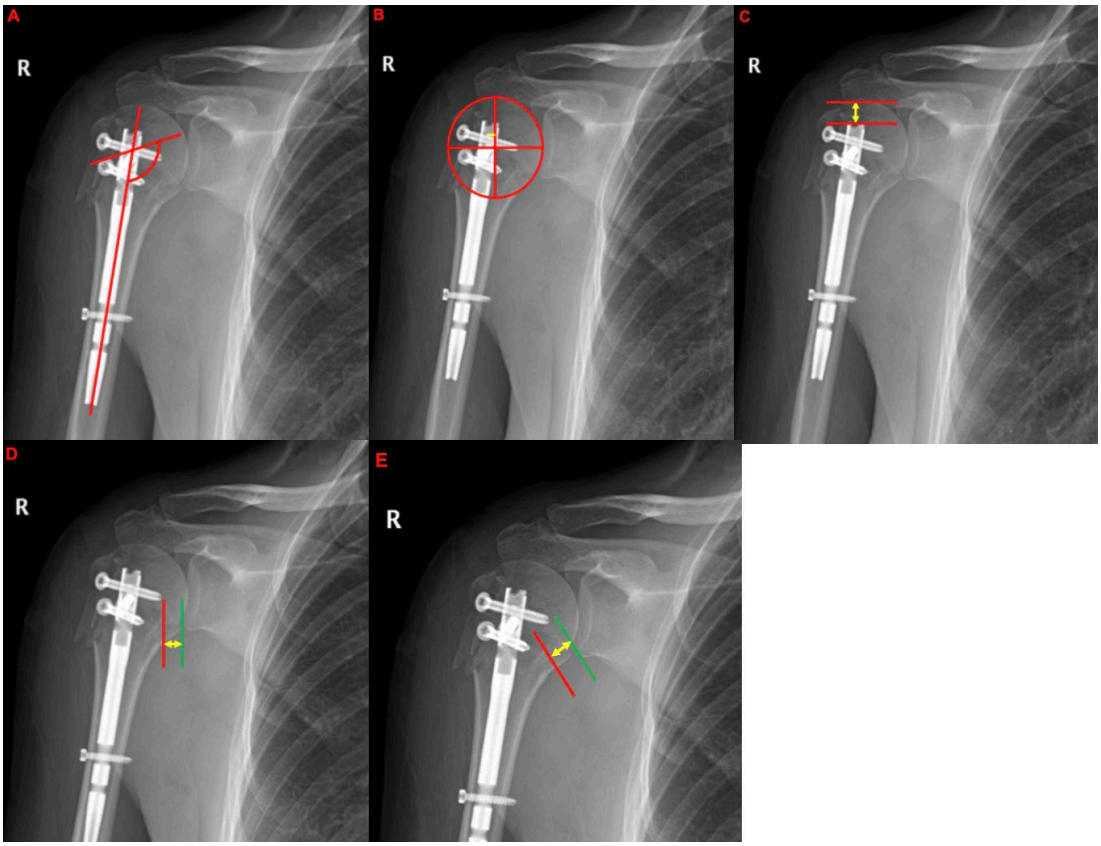

Figure 1A: Neck shaft angle measurement. Figure 1B: Intramedullary nail position in relationship to the center of rotation of the humeral head. Figure 1C: Nail height measured from the top of the nail to the zenith of the humeral head. Figure 1D: Calcar overhang measured from the intact humeral head fracture fragment (red line) to the intact shaft fragment (green line). Figure 1E: Calcar length measured from the margin of articular cartilage to the intact calcar.

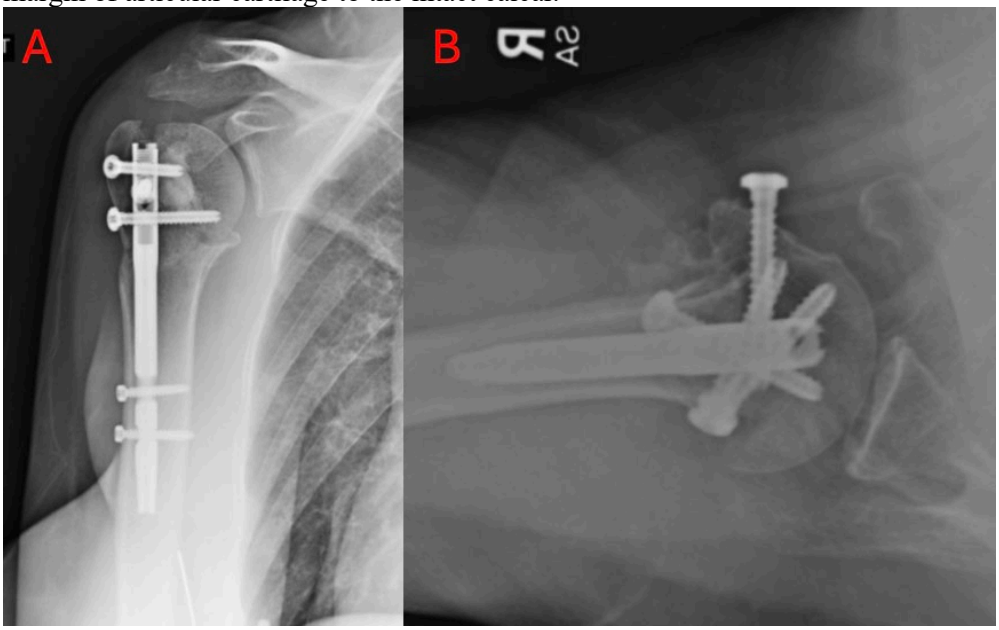

Figure 2A. Example of intraoperative medialization of the humeral shaft relative to the humeral head. Figure 2B. Example of poor reduction on the axillary lateral image with 5–10 mm of displacement between fragments and 20–40 residual angular displacement.