Effect of Obliquity on Metaphyseal-Diaphyseal Ratio and Anterior Humeral Line Alignment in Pediatric Supracondylar Fractures: A 3D Radiographic Study

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Disclosures: No relevant disclosures.

INTRODUCTION: Supracondylar humerus fractures are among the most common pediatric fractures, typically affecting boys ages 3–10. Management is guided by the modified Gartland classification: type I fractures are treated nonoperatively, type II with closed reduction and percutaneous pinning (CRPP), and types III–IV with CRPP or open reduction internal fixation as needed. Diagnosis relies heavily on AP and lateral radiographs. On a true lateral, the anterior humeral line (AHL) intersects the capitellum in type I fractures, while posterior displacement indicates type II. However, obtaining high-quality lateral images is challenging due to pain, swelling, and difficulty positioning children, often leading to rotationally oblique films. Such suboptimal radiographs may cause delays, repeat imaging, unnecessary radiation, or misclassification of fractures. Although prior work described how to achieve a true lateral view, no study has quantitatively assessed how rotation alters AHL-capitellum alignment and the lateral distal humeral metaphyseal-diaphyseal (LDHMD) ratio, measures critical for accurate classification.

METHODS: After obtaining approval through IRB, a retrospective study was conducted that included skeletally immature pediatric patients (males/females ages 7–15) with upper extremity CT scans demonstrating no distal humeral injury. Eleven elbow CTs met inclusion criteria. Using Materialise Mimics, 3D reconstructions were generated and fluoroscopy images obtained. The ideal lateral view was defined by the "hourglass" sign, overlapping supracondylar ridges, and an LDHMD ratio near 1. Because Mimics could not directly calculate LDHMD, a 20-mm calibration sphere was created in Materialise 3-Matic, imported into Mimics, and measured in ImageJ (Figure 1). Metaphyseal and diaphyseal widths were recorded, and radiographs were modeled in 5° increments up to ±40° of internal (RAO) or external (LAO) rotation. LDHMD ratios were calculated at each increment. AHL–capitellum distance was measured by drawing a circle around the capitellum in ImageJ and determining the perpendicular distance to the AHL. Methods were validated on two pediatric sawbone models (elbow = SB1, humerus = SB2). Repeated-measures ANOVA with Fisher's PLSD tested differences ($p<0.05$).

RESULTS: LDHMD and AHL-capitellum distance were measured and compared across all eleven pediatric elbow CTs. At 0 degrees, mean LDHMD was 0.99 and AHL distance 0 mm. At 40 degrees RAO, LDHMD was 0.81 and AHL distance 6.35 mm; at 40 degrees LAO, LDHMD was 0.75 and AHL distance 6.16 mm. Threshold analysis showed LDHMD of 0.84 corresponded to ~30 degrees RAO or ~20 degrees LAO, with AHL distances of 5.10 mm and 2.82 mm, respectively. All changes were statistically significant ($p<0.05$). Representations of the rotational trends for LDHMD and AHL can be seen in figures 2 and 3, respectively.

DISCUSSION: Supracondylar humerus fractures are common in children and depend on accurate lateral radiographs for classification and management. This study evaluated how rotational obliquity impacts two key radiographic measures: the anterior humeral line (AHL) to capitellum distance and the lateral distal humeral metaphyseal-diaphyseal (LDHMD) ratio. Simulated rotations demonstrated that even small deviations from a true lateral view significantly altered both metrics. LDHMD values decreased with internal rotation and increased with external rotation, while AHL–capitellum distance consistently widened with greater rotation. These distortions can mislead fracture classification and influence treatment decisions. Clinically, the findings suggest thresholds for acceptable obliquity. Prior work indicated LDHMD of 0.84 as a marker of suboptimal films. In this study, LDHMD of 0.84 corresponded to ~30° internal or ~20° external rotation, associated with AHL–capitellum distances of 5.10 mm and 2.82 mm, respectively. Films within these ranges may still provide adequate diagnostic information, potentially reducing repeat imaging, radiation exposure, and delays in care. Conversely, values outside these limits should prompt further imaging. Limitations include the small sample size (11 patients) and analysis at fixed intervals. Future research should validate these thresholds in larger cohorts and explore correction algorithms to adjust for rotational error in real time, improving accuracy and reliability in clinical decision-making.

SIGNIFICANCE/CLINICAL RELEVANCE: LDHMD >0.84 and AHL ≤5.10 mm (internal) or ≤2.82 mm (external) may still represent acceptable lateral radiographs. These thresholds could reduce unnecessary repeat imaging, decrease radiation exposure, and improve timely treatment decisions in pediatric supracondylar fractures.

IMAGES AND TABLES:

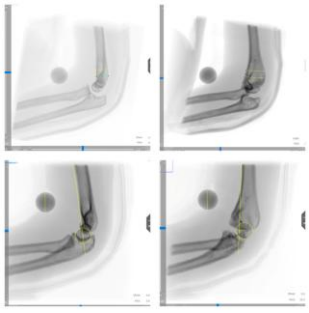

Figure 1. LDHMD and AHL measurement techniques

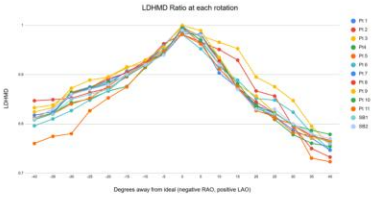

Figure 2. Lateral distal humeral metaphyseal-diaphyseal (LHDMD) ratio at each rotation for each patient

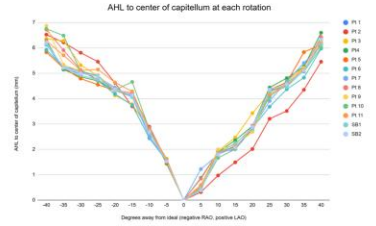

Figure 3. Distance of anterior humeral line to center (AHL) of capitellum (mm) at each rotation for each patient