

Intra-Operative Bone Stability Test

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Summary: Fractures of the supracondylar humerus are the most common elbow fracture in pediatrics. Management of this injury would be aided if surgeons could reliably test fracture stability intraoperatively after pinning. A transverse supracondylar humerus fracture model was created using 3 adult cadaver upper-extremity specimens with an intact soft tissue envelope. Using the lateral entry technique, three 2.0 mm pins were then drilled using lateral entry technique to create an “A” pinning. Pins were checked in anteroposterior and lateral views with the C-arm to confirm accurate placement in both planes. The pinning configuration was then tested by holding the proximal fragment steady with one hand and applying stress to the distal fragment with the other hand. The amount of movement of the distal fragment relative to the proximal fragment was recorded for each specimen. Distraction did not produce any substantial displacement of the osteotomy. The most valuable maneuvers were (in order of effectiveness): external rotation, lateral translation, posterior translation, valgus, and apex posterior. The results of this study indicate that external rotation, lateral translation, posterior translation, and valgus stresses created the most temporary deformity to the construct. A combination of these maneuvers should help the surgeon to decide if the fixation is stable. Our study demonstrates a possible technique to determining intraoperatively the stability of fixation of supracondylar humerus fractures, which could prevent the need for postoperative radiographs to assess stability.

Key Words: supracondylar humerus fracture—radiographs—cadaveric study.

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The supracondylar humerus fracture is the most common elbow fracture in the pediatric population.¹ It is also one of the most studied, with > 588 peer-reviewed articles written on the subject in the last 10 years. With the current emphasis on increasing quality, safety, and value in pediatric orthopedics, surgeons are looking for ways to streamline the management of this injury.

Displaced supracondylar humerus fractures are treated with closed or open reduction and pinning. One topic that has been investigated is the need for postoperative radiographs. Recent literature suggests that postoperative radiographs may not be necessary, potentially eliminating the need for the 1-week postoperative visit.^{2–4} However, this concept depends on the surgeon being able to evaluate objectively the stability of the intraoperative pin fixation. If there were an accepted method to

determine that the intraoperative fixation was stable enough to prevent loss of alignment, then surgeons could feel comfortable forgoing clinical and radiographic evaluation until 3 to 4 weeks after surgery. This pilot study used a cadaveric model to determine the most effective series of maneuvers to test the stability of the supracondylar pinning construct in the operating room.


METHODS

Three adult cadaver upper-extremity specimens with an intact soft tissue envelope were used (Fig. 1). Each cadaver upper extremity was complete from the shoulder to the fingertips. A 1 cm lateral incision was made at the level of the olecranon fossa. A percutaneous osteotomy was created using a hand-held osteotome at the mid-level of the olecranon fossa from lateral to medial. This osteotomy was used to produce a transverse supracondylar humerus fracture model. C-arm fluoroscopy was used to confirm complete transverse fracture of the distal humerus. Using the lateral entry technique, three 2.0 mm pins were then drilled until they just exited the medial cortex of the proximal humeral shaft fragment to create an “A” pinning (1 pin traversing the medial, central, and lateral thirds of the distal humerus, respectively).⁵ The pins were then checked in anteroposterior and lateral views with the C-arm to confirm accurate placement in both planes (Fig. 2). With the surgeon holding the specimen, the pinning configuration was then tested by stabilizing the proximal fragment with one hand and applying stress to the distal fragment with the other hand. The following stresses were applied to the elbow and documented with C-arm images: anterior translation, posterior translation, medial translation, lateral translation, varus, valgus, apex anterior, apex posterior, internal rotation, external rotation, and distraction. The amount of movement of the distal fragment relative to the proximal fragment was recorded for each specimen using static images from the C-arm.

RESULTS

The amount of displacement or angulation for each maneuver on each specimen is listed in Table 1. For each paired movement, 1 test was consistently found to cause more displacement/angulation than the other (ie, apex posterior > apex anterior, external rotation



FIGURE 1. One of the 3 adult cadaver upper-extremity specimens used in the study. Each had an intact soft tissue envelope. 

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For reprint requests, or additional information and guidance on the techniques described in the article, please contact Christopher A. Iobst, MD, at christopher.iobst@nationwidechildrens.org or by mail at Department of Orthopedic Surgery, Nationwide Children's Hospital, 700 Children's Drive Suite A2630 Columbus, OH 43205-2696. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

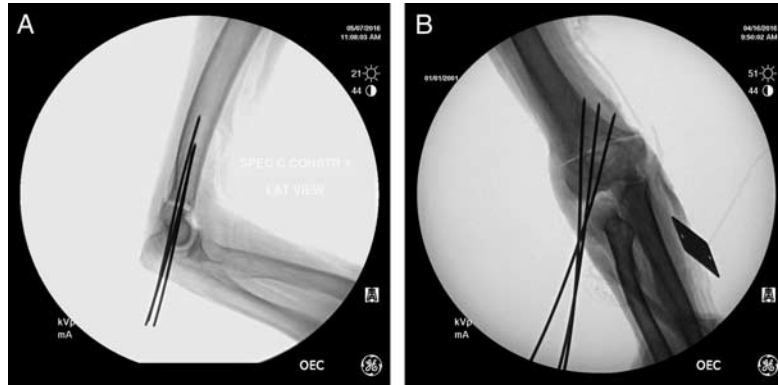


FIGURE 2. C-arm fluoroscopy (lateral, A, anteroposterior, B) was used to confirm that pins were placed accurately in both planes. [full color online](#)

TABLE 1. Displacement or Angulation for Each Specimen

Force Applied	Internal Rotation (mm)	External Rotation (mm)	Distraction (mm)	Apex Posterior (deg.)	Apex Anterior (deg.)	Valgus (deg.)	Varus (deg.)	Anterior Translation (mm)	Posterior Translation (mm)	Lateral Translation (mm)	Medial Translation (mm)
Specimen 1	0	12	3	15	13	6	2	0	4	6	0
Specimen 2	3	16	0	23	15	5	1	0	4	10	1
Specimen 3	0	13	1	20	10	6	3	2	5	5	0
Average	1.0	13.7	1.3	19.3	12.7	5.7	2.0	0.7	4.3	7.0	0.3



FIGURE 3. Intraoperative fluoroscopy demonstrating the displacement from external (A) and internal (B) rotation stress. [full color online](#)

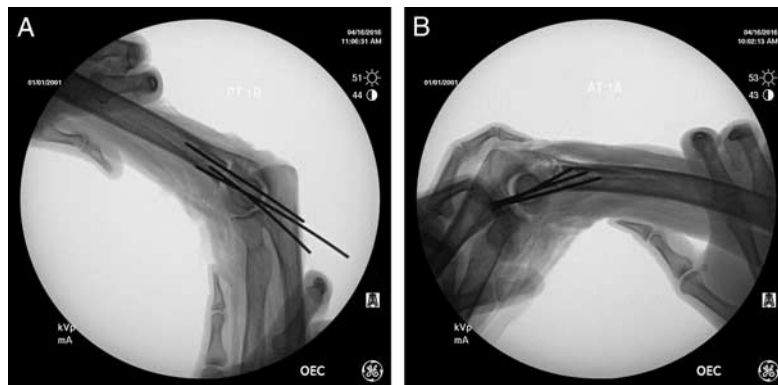


FIGURE 4. Intraoperative fluoroscopy demonstrating the displacement from posterior (A) and anterior (B) translation stress. [full color online](#)

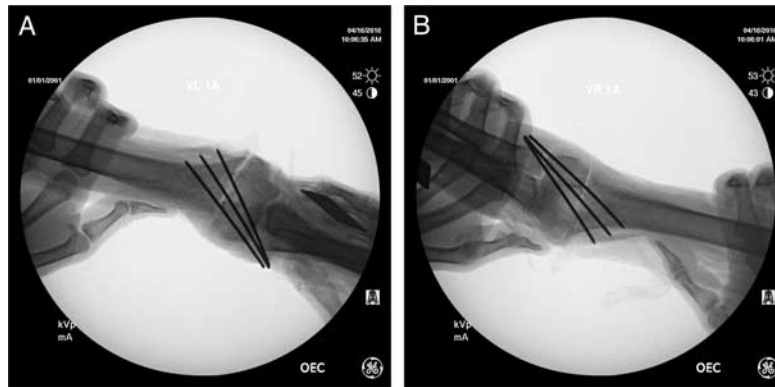


FIGURE 5. Intraoperative fluoroscopy demonstrating displacement from valgus (A) and varus (B) rotation stress. full color
online

> internal rotation, lateral translation > medial translation, posterior translation > anterior translation, valgus > varus) (Figs. 3–5). Distraction did not produce any substantial displacement of the osteotomy. The most valuable maneuvers were (in order of effectiveness): external rotation, lateral translation, posterior translation, valgus, and apex posterior.

DISCUSSION

The rising costs of medicine are forcing health care systems to investigate ways to improve the value of medical care.⁶ This concept has relevant implications in pediatric orthopedics.⁷ Investigators are now looking at methods to improve the health outcome while decreasing costs in various pediatric orthopedic conditions such as supracondylar humerus fractures and forearm fractures.^{8–10}

One of the proposed methods to improve the efficiency of managing supracondylar humerus fractures is to eliminate postoperative radiographs. Several authors have documented that there is little value in routinely obtaining these radiographs.^{2–4} In addition to removing some cost, avoiding a routine radiograph 1 week after surgery will also lower radiation exposure for the patient. The key factor in this proposal is the ability of the surgeon to determine that adequate intraoperative stability has been obtained. If the surgeon is confident that the fracture will not lose alignment, then it seems appropriate to avoid any postoperative radiographs to assess maintenance of reduction, and further imaging can be delayed until needed to assess for fracture union. If an intraoperative stability test deems the fixation to be tenuous, however, then a 1-week radiograph may be necessary.

How does a surgeon make this important determination? It is critically important to determine if the fixation is inadequate before leaving the operating room rather than finding out weeks later. Previous authors have described the need to assess fracture stability after pinning; however, the method of assessing stability is not described.¹¹ The goal of this study was to start the process of developing a reliable intraoperative test that could be used to verify the stability of the supracondylar fracture pin construct. Using a cadaver supracondylar humerus fracture model, a stable lateral entry pin construct was stressed in 11 different directions. Every direction of stress was applied in the coronal, sagittal, and axial planes. The stress was applied by hand by a single investigator in a consistent manner to each specimen (C.A.I.). The goal was to apply enough pressure to create maximum movement at the fracture site and measure the displacement/angulation produced. The results of this study indicate that external rotation, lateral translation, posterior translation, and valgus stresses created the most temporary deformity to the construct. A combination of

these maneuvers should help the surgeon to decide if the fixation is stable. In the cadaver model with an “A” level fixation from 3 lateral entry pins, the fracture maintained a reduced position after the stress was released.⁵ Theoretically, this would indicate that this fixation would be stable enough to maintain alignment in a cast where the potential deforming forces would be much less. Future studies will need to determine if these maneuvers will demonstrate loss of alignment in supracondylar humerus fractures with more tenuous fixation.

This study has many limitations. The cadaver model was chosen to more closely mimic the clinical scenario but the elasticity of the embalmed soft tissue envelope is clearly different than real life. As pediatric cadaver specimens are rare, the study was performed on adult upper extremities and larger pins (2.0 mm) were used to accommodate the larger sized bone. Therefore, this model may not truly represent the findings of a pediatric humerus pinned with 1.6-mm wires. As this was a pilot study, only 3 specimens were studied. Although the data were consistent among the specimens, more tests would have produced more reliable data. Because lateral entry pin constructs are used more commonly in clinical practice, only this construct was studied. Cross-pinning constructs may have produced different results and will need to be investigated in the future. The cadaver model used a transverse osteotomy to simulate the supracondylar humerus fracture. It is recognized that not all supracondylar humerus fracture patterns are transverse and the results may differ with oblique fracture lines.

In summary, we performed a pilot study to develop an intraoperative bone stability test for pediatric supracondylar humerus fractures. We propose that following pin fixation of a pediatric supracondylar humerus fracture, the surgeon should test the construct by applying (1) external rotation, (2) lateral translation, (3) posterior translation, and (4) valgus stresses under fluoroscopic guidance. By doing so, the surgeon should be performing the 4 most effective maneuvers to test the stability of the fracture in this cadaver model. Further clinical testing will need to be performed to verify that fractures undergoing intraoperative bone stability testing in this sequence maintain alignment until fracture union.

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