Pediatrics Tips and Tricks: Appropriate Use of Medial Pinning for Pediatric Supracondylar Humerus Fractures

Cody H. Hansen, MD[1]
J. Todd R. Lawrence, MD, PhD[2]

[1]Department of Orthopaedic Surgery
Univeristy of Pennsylvania

[2]Department of Orthopaedic Surgery
Children's Hospital of Philadelphia

Introduction

Supracondylar humerus fractures are the most common type of elbow fracture in children. The vast majority of these fractures are extension-type injuries that occur in children ages 5-7 years old. Non-displaced (Type I) fractures can be managed without surgery in a cast. However, displaced, angulated or unstable fractures usually require surgical fixation. Closed reduction and percutaneous pinning (CRPP) is the mainstay of treatment in the majority of Type II, III and IV fractures[1,], with open reduction used if there is an inadequate alignment with closed reduction. Classically, CRPP of supracondylar humerus fractures has been accomplished using pins in a crossed configuration. In this method, at least one pin is percutaneously inserted laterally into the capitellar ossification center and another pin is placed medially anterior to the medial epicondyle and the ulnar nerve. The pins are directed to cross proximal to the fracture site and penetrate through the respective far cortex. A medial pin confers additional torsional strength and leads to a more stable construct. However, it also introduces the risk of iatrogenic ulnar nerve injury, leading many to attempt to stabilize these fractures with laterally based pin constructs only. The appropriate indications for use of a medial pin are controversial[13], but understanding the risks and benefits of medial pinning in stabilizing pediatric supracondylar humerus fractures will help clinicians utilize this technique only when necessary.

Biomechanics

Supracondylar humerus fractures tend to fail in extension and/or rotation, and both deforming forces must be accounted for when designing a pin construct. For any transverse fracture pattern stabilized with a smooth pin construct of a given pin size, total pin purchase in each fragment tends to be the most important factor in limiting bending, while pin spread at the fracture site tends to be the most important factor limiting rotation. An ideal pin configuration biomechanically is one that engages as much of each fracture fragment as possible and has as much pin spread as possible at the fracture site. A balance must be struck between maximizing bony purchase and maximizing pin spread, as each will come at the cost of the other.

Consider a fracture fixed with two pins. If the pins are placed with maximal pin spread, they will achieve maximal rotational stability. However, they will engage the fracture fragments so peripherally that they engage minimal bone, and they will sacrifice resistance to extension. The inverse is true if the pins are directed to engage as much bone as possible (Figure 1A-B). In lateral-only pinning, the lateral pins have limited ability to engage the fracture site medially due to their entry site and trajectory, and a more medial trajectory comes at the cost of decreased bony purchase in the proximal segment medially. Crossed pins have traditionally solved this problem because a medial pin's trajectory allows it to cross the fracture site medially while still achieving excellent bony purchase (Figure 1C). It should be noted, however, that even crossed pins can confer minimal rotational stability if they cross at the fracture site (Figure 1D).

Crossed pinning, then, is biomechanically advantageous because the increased resistance to rotational deformity will reduce the likelihood of fixation failure. Historically, clinical outcomes of crossed pinning have been very good[2, 3], and biomechanical studies have supported the idea that a medial pin is required for optimal fixation.[4, 5] Zoints at al. used adult cadaveric models to demonstrate that a medial and lateral crossed pin construct is stronger than both 2-pin and 3-pin lateral pin constructs.[4] Lee et al. examined this question usng using a pediatric synthetic bone model and demonstrated that while 2 divergent lateral pins are superior to 2 parallel lateral pins, the crossed medial and lateral pin configuration still outperformed both lateral pin configurations.[5] Based on these data, they recommended crossed pinning when there is concern for instability with lateral pins alone. Notably, however, the fixation techniques used in early biomechanical studies don't reflect modern techniques. The lateral pins placed by Zoints et al. were placed in parallel rather than divergently and Lee et al. did not assess 3-lateral pin configurations of any kind.[4, 5]

Larson et al. were the first to compare three divergent lateral pins, a medial pin with 2 divergent lateral pins (3-crossed pins), and a standard medial and lateral crossed pin (2-crossed pins) configuration (Figure 2). They compared the constructs in two synthetic humerus models: a standard fracture model and a model with a medial wedge cut out to simulate medial comminution. The medial wedge model demonstrated less torsional stability across all pin configurations. The 3-crossed pin configuration was the strongest construct in both models. The three divergent lateral pin construct was stronger than two crossed pins in intact humeri, and statistically similar to 2 crossed pins in the model simulating a deficient medial column.[6] The superior torsional stiffness of 3 crossed pins compared to 3 divergent lateral pins has also been replicated by a more recent biomechanical study.[7]

Ulnar Nerve Injury

The primary disadvantage of medial pinning is that it risks iatrogenic injury to the ulnar nerve, which courses just posterior to the medial epicondyle in the cubital tunnel. Ulnar nerve injury can result from direct penetration of the nerve, but can also result from irritation or compression of the nerve by a medial pin post-operatively. The finding that many children have anterior ulnar nerve subluxation complicates pin placement, as one must be mindful not to damage a mobile nerve. Furthermore, even when the medial pin is appropriately placed anterior to the cubital tunnel, a mobile ulnar nerve may still be prone to irritation as the nerve translates anteriorly and stretches around the medial pin. The reported incidence of ulnar nerve injury with medial pinning has been reported to range from 0-12%.[6] Most ulnar nerve injuries resolve

Table 1. Relative Resistance to Deforming Forces

	A	B	C	D
Extension	+++	++++	++++	++++
Rotation	++	+	+++	+

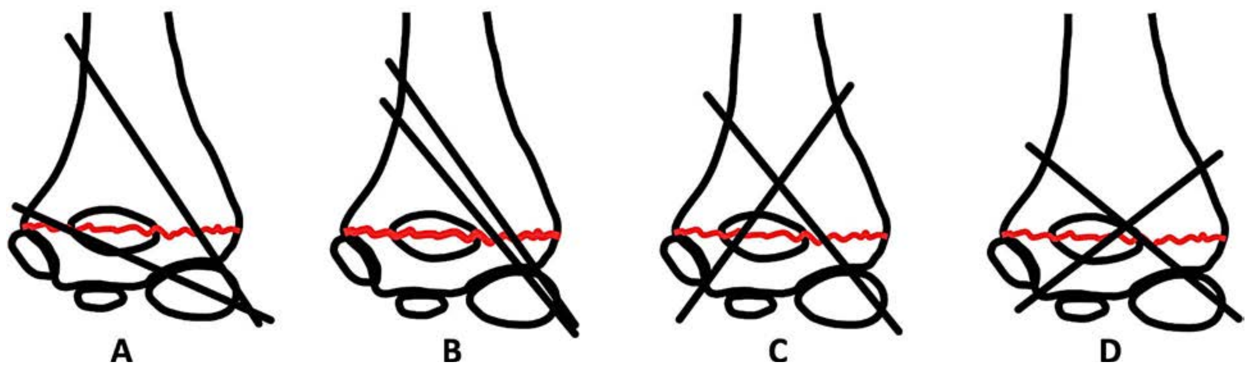

Figure 1. Two pin constructs; **(A)** Ideal 2 lateral pin construct with good separation; **(B)** Less ideal 2 lateral pin construct with poor pin separation but good bony purchase for both pins; **(C)** Ideal 2 crossed pin construct with good bony purchase for both pins and good spread at the fracture site; **(D)** Less ideal 2 crossed pins with no spread.

Table 2. Relative Resistance to Deforming Forces

	A	B	C	D
Extension	+++++	+++	++++++	+++++
Rotation	++++	++++	+++++	+++

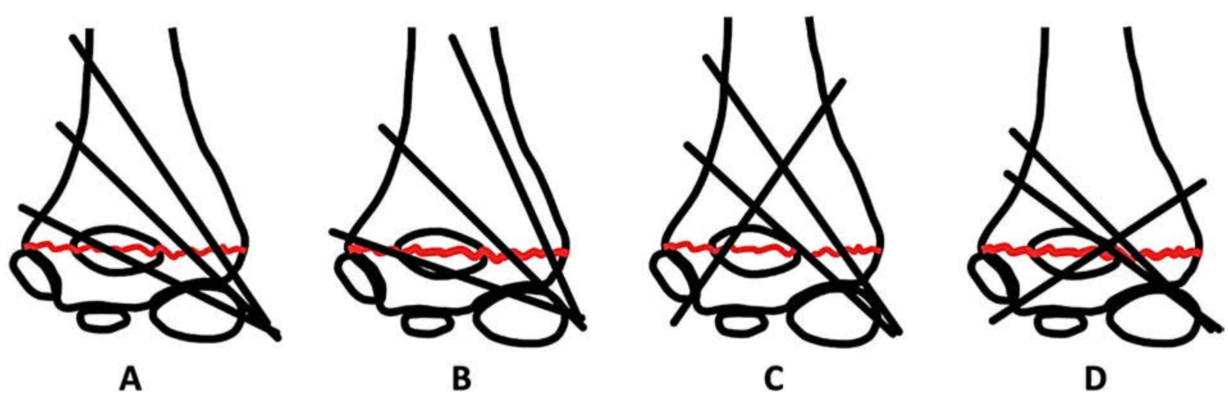

Figure 2. Three pin constructs; **(A)** Ideal 3 divergent lateral pin construct has two lateral pins with good bony purchase and one transverse pin providing good pin spread. **(B)** Less ideal 3 lateral pin construct with one central pin with good bony purchase in both fragments but with two additional medial and lateral pins with good pin spread but less ideal bony purchase. **(C)** Ideal 3 cross-pin construct has two lateral pins and one medial pin all with good bony purchase and good spread at the fracture site. **(D)** Less ideal 3 cross-pin construct with two lateral pins and one medial pin, with good purchase for all pins but with less ideal pin spread at the fracture site.

spontaneously within 6 months, but permanent injuries have been reported and can cause significant disability.[8]

Clinical Outcomes

The ideal pin configuration for supracondylar humerus fractures must balance the need for stable fracture fixation with avoidance of iatrogenic ulnar nerve injury. While early studies suggested that the risk of ulnar nerve injury was minimal, case series in the 1990's brought greater attention to the risk of iatrogenic ulnar nerve injury. Royce et al advocated for the use of lateral-only pinning for fractures that are stable after closed reduction, and recommended medial pins only for comminuted fractures or those that are unstable after closed reduction.[9] In 2001, Gordon et al studied 138 Type II and III fractures and compared three pin configurations: 2 lateral pins, 2 crossed pins, and 3 crossed pins. There was no significant loss of reduction in any group, but they found that the 2 lateral pin construct had slightly more rotational instability. They recommended placing 2 divergent lateral pins, and placing a medial pin only if there is concern for instability on intraoperative stress radiographs.[10]

More recent studies have suggested, however, that lateral pinning provides sufficient fixation of supracondylar humerus fractures if proper technique is used. In 2004, Skaggs et al treated 124 consecutive children with type II and III supracondylar fractures with lateral pinning only.[11] Two divergent lateral pins were placed in all cases, and a third lateral pin was placed when there was concern for instability. There was no loss of reduction, cubitus varus, or loss of elbow motion, and there were no ulnar nerve injuries. They also reported on a separate series of 8 cases of fixation failure after lateral pinning, and highlighted key technical points when placing pins: (1) maximize pin separation at the fracture site, (2) engage the medial and lateral columns proximal to the fracture, (3) engage sufficient bone in the proximal and distal fragments, and (4) have a low threshold for use of a third lateral pin to augment stability.[11] These findings were reinforced by Sankar et al, who evaluated a series of 279 cases found that 8 (2.9%) lost fixation.[12] Seven of eight failures had initially been managed only with 2 divergent lateral pins, and in each case the failure appeared to be due to technical error. They identified the following pin-fixation errors: failure to engage both fragments with at least 2 pins, failure to achieve pin separation >2mm at the fracture site, and failure to achieve bicortical fixation with at least 2 pins (Figure 3). There were no fixation failures when 3 divergent lateral pins were used, and there were no reports of ulnar nerve injury with lateral-only pinning. The data suggest that while a construct consisting of a medial pin and 2 divergent lateral pins is biomechanically stronger than 3 lateral pins, the difference does not impact clinical outcomes. Given these data, Sankar et al recommend against medial pinning due to the risk of ulnar nerve injury with no clear clinical benefit.[12]

Discussion

The decision to use medial pinning remains a subject of controversy, and ultimately depends on surgeon preference and the details of a particular case. Different fracture patterns have different kinds of instability, and thus benefit from different pin configurations. Broadly speaking, the vast majority of extension type 2 SCH fractures are unstable only in extension with little rotational instability, while type 3 fractures are unstable in extension and rotation. Thus, while type 3 fractures may benefit from greater pin spread at the fracture to help control rotation, fractures with no rotational instability only need fixation to resist extension. For laterally based pin constructs, this has led to the suggestion that type 2 fractures can be effectively treated with 2 lateral pins whereas type 3 fractures should get a third pin to help with pin spread at the fracture site and thus rotational control. The biomechanical data would suggest that this pin should ideally be a media pin. However, the clinical data suggests that a third lateral pin placed to engage the fracture site across the medial column works just as well and almost eliminates the risk of ulnar nerve irritation or injury.

There may also be specific fracture patterns that benefit from a medial pin. As Larson et al demonstrated, fractures with medial comminution have significantly less rotational stability because they cannot rely on the intact medial column to resist internal rotation and cubitus varus. Biomechanical studies demonstrate that the most stable way to fix these fractures is with 3 crossed pins (1 medial pin and 2 lateral pins), as lateral pins are less able to stabilize the medial column and prevent rotation (Figure 4A).[6,7] The orientation of a fracture must also be considered. In fractures that run from proximal-medial to distal-lateral, laterally placed pins will run more parallel to the fracture site and achieve weaker fixation (Figure 4B). A medial pin will cross the fracture site orthogonally, greatly augmenting construct strength.

Clinical data suggest that for the vast majority of SCH fractures, lateral fixation can achieve adequate stability and optimal outcomes without risking iatrogenic ulnar nerve injury.[11, 12] However, while there are certain fracture patterns may greatly benefit from or even require a medially based pin for optimal fracture stabilization, some instability patterns are not apparent until the fracture reduction is attempted. In both of these scenarios, the sequence of pin placement is nearly always to place most if not all of the lateral fixation first. We proceed to medial fixation only if there is concern for residual instability based on intra-operative imaging or the fracture pattern. This avoids medial pinning in patients who do not need it. It also provides provisional fixation, allowing for extension of the elbow and placement of the medial pin through a small open approach that enables direct visualization and protection of the ulnar nerve. It is critical that proper technique be used with placing lateral pins, with at least 2 pins engaging both fracture fragments, achieving adequate separation at the fracture site, and achieving bicortical fixation in both fragments.

Conclusion

We recommend that fixation for all supracondylar humerus fractures begin with the placement of the lateral fixation. In

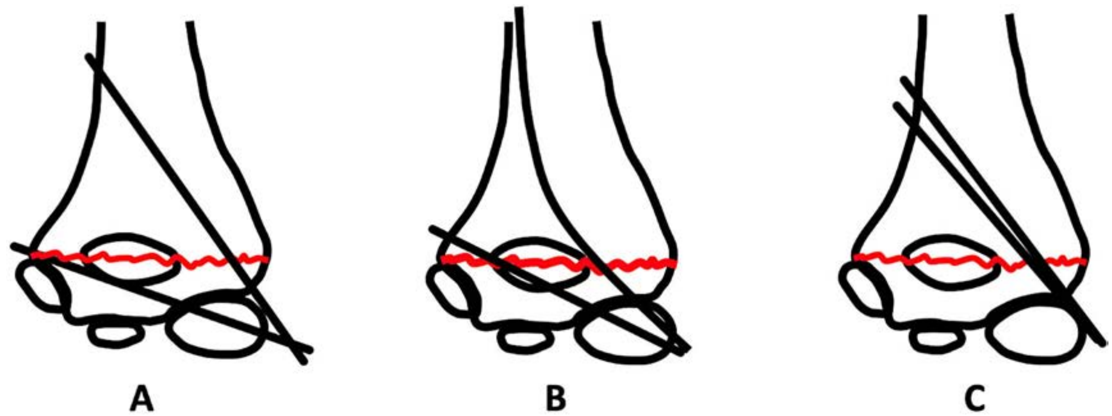

Figure 3. Common technical errors that contribute to fixation failure after lateral-only pinning: **(A)** failure to engage both fragments with at least 2 pins; **(B)** failure to achieve bicortical fixation with at least 2 pins; **(C)** failure to achieve pin separation >2mm at the fracture site12.

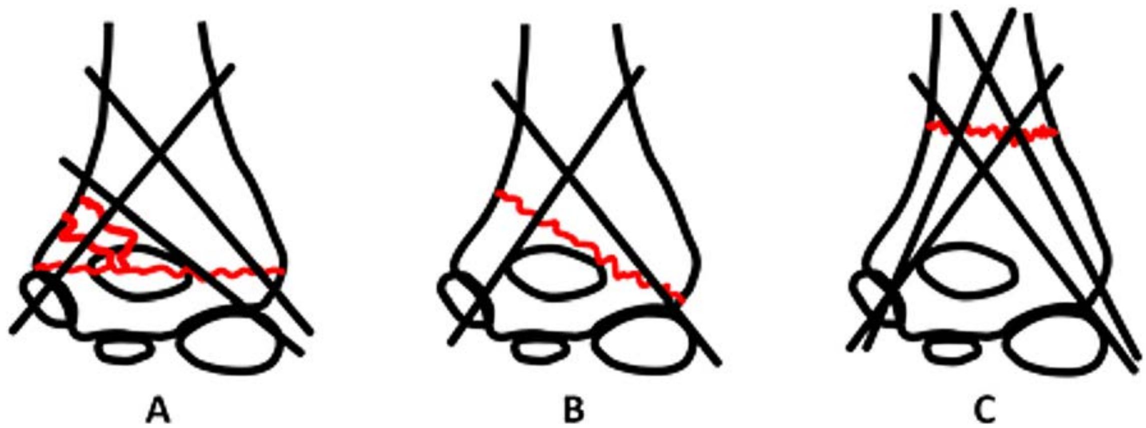

Figure 4. Supracondylar humerus fracture patterns that benefit from a medial pin; **(A)** Medial comminution; **(B)** Oblique fracture line from proximal medial to distal lateral; **(C)** Proximal fractures.

many cases, this will be sufficient. Medial fixation may then be added if there is concern for instability based on the fracture pattern or intra-operative imaging.

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