The Effect of Pinning Across the Physis for Stabilization of Fractures in Children: An MRI Evaluation

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ABSTRACT

Certain pediatric fractures are treated by temporarily placing Kirschner wires across an open physis. It is unknown if transphyseal wires may independently pose a risk for growth disturbance. Five skeletally immature patients with unstable upper extremity fractures were treated with transphyseal pinning. MRI was used to evaluate the physis. Four of five patients had no MRI evidence of physeal disruption. One patient had physeal bridging thought to be related to the fracture, not the surgical intervention. In this study, temporary fracture stabilization with transphyseal Kirschner wires did not necessarily cause physeal growth disruption as determined by MRI evaluation.

Level of Evidence: Cohort study (evidence level rating of IV).

INTRODUCTION

In the pediatric population, traumatic fracture-separations of the physes are common injuries. As with other fractures, the goals of treatment include fracture reduction, correction of rotational deformity, maintenance of reduction, and prevention of complications. In children, special attention is given to minimizing growth disturbance caused by both the traumatic injury and treatment. Therefore, treatment techniques in children must be evaluated critically to understand their effect on the physis.

Certain fractures in children are routinely treated by reduction and stabilization with Kirschner (K) wires. For example, it is generally agreed upon that Gartland type III supracondylar fractures of the humerus should be reduced and stabilized with K-wires (1-4). Although the fracture is proximal to the physis, temporary pinning of supracondylar fractures in children requires placing smooth pins across the distal humeral physis. The potential risk of physeal dysfunction appears to be justified by the fact that the distal humeral physis only accounts for twenty percent of the longitudinal growth of the humerus.

Pinning across a physis is potentially problematic, as prior studies have suggested that complete or partial growth arrest may occur (5-10). This is particularly of concern in a physis, such as the distal radius, which contributes significantly (70-80%) to the longitudinal growth of the bone. Pin-associated factors thought to contribute to growth arrest include the use of threaded pins, pin size, location in the physis, obliquity across the physis, and duration before pin removal. However, the traumatic injury to the physis that occurs during physeal fracture-separations is likely an independent causative factor in premature physeal closure. It is thus unclear to what extent pinning across the physis poses a risk for physeal growth disruption.

Pinning across a non-injured physis, as is frequently done for supracondylar humerus fractures or distal radial metaphyseal fractures in children, offers an opportunity to study the effect of pinning on an uninjured physis. The purpose of this descriptive study is to use MRI to evaluate the effect of temporary pinning across the physis with smooth wires for the stabilization of unstable juxtaphyseal fractures in children.

MATERIALS AND METHODS

Institutional Review Board approval and informed patient consent were obtained for this study. The study design is a prospective cohort study.

Between February 1999 and February 2000, five skeletally immature patients older than age six were treated for unstable upper extremity fractures with transphyseal pinning by three different surgeons. The patients' injuries included two Gartland type III supracondylar humerus fractures, one Gartland type II supracondylar humerus fracture, one distal both bone forearm fracture, and one distal radius physeal fracture. The study population included three boys and two girls. Mean chronological age at the time of injury was 8.6 years (range, six to fifteen years). All of these patients were determined to be skeletally immature based upon open physes seen on radiographs of the injured extremity. Mechanisms of injury included fall from a climbing structure causing all three supracondylar humerus fractures, fall off of a banister causing the distal both bone forearm fracture, and a fall while snowboarding causing the distal radius physeal fracture. Inclusion in the study was dependent upon having no other prior upper extremity physeal injury. Patients younger than age six were excluded to avoid the necessity of sedation for MRI imaging.

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Statement:
Supported by a resident research grant from AO North America, and a research grant from the American Fracture Association

All five patients were evaluated initially in the emergency department and their fractures were identified by radiographs. The three children with supracondylar humerus fractures were treated by closed reduction and percutaneous pinning within twenty-four hours of presentation. The patient with the distal both bone forearm fracture failed attempted closed reduction with casting and subsequently was re-reduced with percutaneous pinning within four days of his injury. The patient with the distal radius fracture, which was identified at the time of presentation as a Salter-Harris type II fracture (11), underwent closed reduction and percutaneous pinning within four days of injury as well. With the exception of the one patient with the Salter-Harris type II distal radius fracture, percutaneous pins were placed across an uninvolved physis.

Patients underwent standard post-operative treatment with removal of K-wires in clinic three to four weeks post-operatively. This study utilized two MRI scans of the fracture site: three weeks after K-wire removal and six months after K-wire removal. The MRI images were obtained at 1.5 T using an upper extremity coil and were formatted for evaluation of the involved physis using the standard MRI protocol at our institution, which has been previously described (12-14). All studies included gradient recalled echo images optimized for visualization of physeal cartilage. A pediatric musculoskeletal radiologist evaluated the cartilaginous physis for MRI-evidence of edema, fibrous ingrowth, bony ingrowth, cartilaginous remodeling, and physeal growth.

RESULTS

The mean post-operative follow-up was seven months (range, two to nine months). There were no surgical complications. Although not formally evaluated as part of this study, clinically all patients were found to have satisfactory outcomes with excellent range of motion, rotational symmetry, good strength, and no cosmetic deformity. In addition, radiographic evaluation demonstrated all fractures to have healed well with anatomic alignment at six months.

Figure 1:
MRI of supracondylar humerus fracture 3 weeks after pin removal. Coronal fat suppressed gradient recalled echo T1-weighted image of the elbow shows the pin track, which is best seen just distal to the capitellum. Although the remnant of the track is seen in the physis, the cartilage is intact and there is no other evidence of physeal disruption.

At three weeks after K-wire removal, the three patients with supracondylar humerus fractures did not have any evidence of physeal disruption aside from evidence of a transphyseal tract that was the path of the pin. (Figure 1) The remainder of the physis appeared intact and there was no evidence of significant transphyseal bony bridging. At six months, MRI evaluation of these patients again did not show any evidence of physeal disruption and the residual pin tract was faintly visible in only one patient.

Figure 2A:
MRI of distal both bone forearm fracture 3 weeks after pin removal. Coronal fat suppressed gradient recalled echo T1-weighted image shows a transphyseal pin track. There is a tiny discontinuity of the physeal cartilage (arrow) without evidence of physeal bridging adjacent to pin track site.

Figure 2B:
MRI at 6 months after pin removal. Coronal gradient recalled T1-weighted image shows the pin tracks to still be present, but with no further evidence of bony bridging.

Figure 3:
MRI of distal radius physeal fracture 3 weeks after pin removal. Coronal gradient recalled echo T2-weighted image shows physeal bony bridging (arrow) that is separate from transphyseal pin tracts. The signal intensity of the physeal cartilage is normal in the region of the tracks.

MRI evaluation of the patient with the distal both bone forearm fracture at three weeks noted a focal interruption of the high signal intensity of the physeal cartilage, suggesting a possible small spicule of bone crossing the radial physis. (Figure 2A) The two pin sites in this patient were visible at three weeks and the area of concern for early physeal bony bridging was thought to be associated with one of the pin sites. At six months, the pin sites were still apparent, but there was no further evidence of bony bridging. (Figure 2B)

The patient with the Salter-Harris type II distal radius fracture had evidence of cartilaginous disruption across the distal radial physis at three weeks, although this focal cartilaginous abnormality was not associated with the pin sites. (Figure 3)

The pin tracts were visible at three weeks and were clearly separate from where the physeal bridge had developed. There are no imaging data for this patient at the six-month time interval.

DISCUSSION

Several animal studies have evaluated the effect of pins placed across the physis. Campbell et al. placed wires across the proximal tibial physis of dogs and found that while threaded pins that crossed the physis led to physeal arrest, smooth wires placed perpendicularly to the physis did not result in growth retardation or physeal closure (6). In the dogs that developed physeal arrest, Campbell et al. noted that physeal cartilage near the pins showed degeneration with the formation of bridging trabecular bone in a small area next to the pins. In studies of a single smooth pin crossing the proximal tibial physis in rabbits, Garces et al. found increased vascularity and chondrocyte degeneration at two weeks with bony bridging next to the wires at four weeks (7). Haas placed pins across the distal radial physis in rabbits and found that crossing wires led to the restraint of physeal growth. Haas also demonstrated that longitudinal wire placement across the physis led to less growth impairment and observed that the physeal growth restraint partially decreased when the pins were removed at three weeks (8).

Siffert, who studied pinning across the proximal tibia in rabbits, histologically examined the tract the wire left in the physis when the epiphysis grew away from the pins. He found that the wire's tract was replaced by trabecular bone and that the overall tibial and physeal growth was not affected (15). Garces assessed the effects of drilling (1 mm drill) across the distal femoral physis in rats (16). He found no differences in femoral or physeal lengths between drilled rats and controls, although he did observe the physeal cartilage next to the drill holes to have degenerated and that the drill holes were filled by bony trabeculi bridging the metaphysis and epiphysis. Another study examining the distal femur of rabbits showed that drilling of the physis (1/8 inch drill) lead to a 6.4% shortening with the development of physeal fibrous tissue or physeal bridging bony trabeculi (17).

Collectively, animal studies suggest a potential correlation between transphyseal pinning and physeal growth disturbance, although the exact relationship remains unclear. Clinically, pinning across the physis has been implicated in premature physeal closure, particularly in the distal radius (5,9,10). In these studies however, it is difficult to determine if the pins have caused the growth arrest or if the traumatic injury to the physis itself was the principle factor. Furthermore, no studies have examined the effect of temporary transphyseal pinning. In their 1991 paper, Boyden and Peterson observed that premature closure of the physes was potentially associated with pin size, location within the physis, obliquity within the physis, use of treaded pins, and duration of pinning (5). Although transphyseal pins have not clearly been shown to cause growth disruption, K-wires are currently used in ways that limit physeal disruption. In our study, K-wires used to traverse the physis were non-threaded and left in place for only three to four weeks.

Pinning across an open physis with smooth wires is a common method of treating displaced or unstable physeal or juxtaphyseal fractures in children. Pinning across an uninvolved physis is standard for supracondylar humerus fractures and is frequently performed for distal radial metaphyseal fractures. Growth disturbance at the distal humerus is less consequential than at the distal radius because of the smaller contribution to longitudinal growth of the distal humeral physis than the distal radial physis. Unstable physeal or juxtaphyseal fractures offer an opportunity to study the effects of temporary smooth wire pinning on the physis in patients whose physes are otherwise non-injured. In physeal and juxtaphyseal injuries, the cartilaginous component is a critical component of the lesion. MR imaging has been shown to accurately document cartilage and physeal abnormalities, identifying lesions not appreciated by plain radiograph (12-14). Many small physeal abnormalities detected within the first two months after trauma are not detectable on follow-up studies, particularly when the abnormalities are central and do not involve the perichondrium. Our study method was designed to provide both short-term (three weeks after pin removal) and longer-term (six months after pin removal) imaging to identify any physeal disruption associated with the wires.

In this study, we report the results of temporary smooth wire pinning across the physes of four children with unstable juxtaphyseal fractures and one child with a Salter-Harris type II distal radius fracture. Our data suggest that pinning across the physis for fracture repair does not necessarily cause physeal growth abnormalities. MRI evaluation showed all five of the patients to be healing their fracture well with no apparent physeal damage associated with the K-wire. The presence of pin tracts seen at the three-week time point is expected and does not imply damage to the physes. Results from the six-month MRI scans reveal considerable fibrous ingrowth in the pin tracks. In the patient with the distal both bone forearm fracture, imaging at three weeks was concerning for pin-associated early physeal bony bridge formation, but at six months there was no evidence of the bony bridge, growth arrest, or any physeal abnormality. The patient with the distal radius physeal fracture that had evidence of physeal bony bridging at three weeks is an example of physeal disruption associated with a traumatic injury. His MRI images clearly locate the area of bony bridging as separate from the K-wire tracts. (Figure 3)

These data suggest that pinning with a temporary smooth wire across an open physis does not necessarily cause physeal growth disruption. Growth arrest or physeal damage seen in fractures involving the physis is likely related to the original impact or injury, not necessarily from the pinning procedure, as seen in the patient with the distal radius physeal fracture. Although our data support the continued use of smooth pins to stabilize juxtaphyseal fractures, this study is limited by the small sample size. In addition, we did not study other technical aspects of pinning that may contribute to growth arrest, such as threaded pins, large pins, and pins left in for a longer duration.

CONCLUSIONS

In this study of unstable upper extremity fractures in skeletally immature children, temporary fracture stabilization with transphyseal Kirschner wires did not necessarily cause physeal growth disruption as determined by MRI evaluation at 3 weeks and 6 months after Kirschner wire removal.

DISCLOSURES

Each author certifies that he has no commercial associations that might pose a conflict of interests in connection with this study. This study was supported in part by a resident research grant from AO North America, and a research grant from the American Fracture Association.

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