Ulnar Epiphysiodesis: Success of the Index Procedure

Tanner Campbell, MD, L. Wade Faulk, MD, MBA,†‡ Kristen Vossler, BS,† Ezra Goodrich, BS,§ Andy Lalka, MPH,†‡ Sarah E. Sibbel, MD,†‡ and Micah K. Sinclair, MD§*

Introduction: Premature radial physeal closure is a relatively rare occurrence in children. When isolated growth arrest of the radius with continued ulnar growth occurs, the resulting ulnar positive deformity leads to altered wrist mechanics and pain. Timely epiphysiodesis of the distal ulna with and without ulnar shortening osteotomy can address these issues, but continued ulnar overgrowth is a possible complication. We seek to evaluate the success rate of the primary epiphysiodesis of the ulna and associated clinical outcomes.

Methods: A chart review was conducted at 2 children's hospitals from 2008 to 2019. Patients between the ages of 6 and 18 years old, with premature distal radius physeal closure, with or without positive ulnar variance, and > 2 months follow-up were included. We evaluated the following characteristics for each patient: demographics, initial cause of premature radial physeal closure, ulnar variance, additional procedures performed during epiphysiodesis, preoperative and postoperative pain, range of motion, instability. Summary statistics were conducted and expressed as proportions, medians and means. A paired *t* test evaluated change in ulnar variance for those who had an ulnar shortening osteotomy performed.

Results: Thirty-one wrists among 30 patients were identified, and the median age at the time of surgery was 12.2 years (interquartile range: 3.4). Ulnar shortening osteotomies were performed in 53.1% of cases and distal radius osteotomy in 15.6%. Bone graft was utilized in 25.8% of the epiphysiodesis procedures. There were 2 failures of primary epiphysiodesis indicating an index success rate of 93.7%. The average ulnar variance correction was 3.1 mm (95% confidence interval: 1.9, 4.4). The mean physeal time to closure was 134 days. Preoperative symptoms were resolved for 90.6% cases at final follow-up.

Conclusion: Ulnar epiphysiodesis successfully terminates ulnar physeal growth in 93.7% of cases. Preoperative symptoms were completely resolved with a median physeal closure of just over 4 months. Ulnar variance was corrected on average by 4.1 mm when a radial or ulnar shortening osteotomy was performed at the time of epiphysiodesis.

Level of Evidence: Level IV—case series.

Key Words: ulnar-wrist pain, ulnar abutment syndrome, epiphysiodesis, athletes, pediatrics, ulnar variance

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Premature radial physeal closure is a relatively rare occurrence in children; and is the result of a previous fracture or overuse injury to the distal radius physis. The most common fracture pattern of the distal radius is Salter Harris Type II and rates of growth arrest are between 1% and 7%.[1,2] Overuse injuries, which predominantly occur in gymnasts, have also been shown to cause growth arrest because of the repetitive compression stress across the radial physis.[3–5] When isolated growth arrest of the radius with continued ulnar growth occurs, the resulting ulnar positive deformity leads to altered wrist mechanics and often pain. In a wrist with neutral ulnar variance, weight bearing occurs with 20% of the load across the ulna and 80% across the radius. When ulnar length increases by 2.5 mm, the ulnar load doubles, with weight-bearing forces increasing to 42%.[6–8] Whether the cause of the distal radial physeal growth arrest is the result of a fracture or overuse injury, ulnar positive variance can lead to ulnar impaction syndrome. This syndrome is because of excessive load across the ulnocarpal joint and results in ulnar sided wrist pain and a spectrum of pathologic changes in the triangular fibrocartilage complex (TFCC), dome of the ulnar head, ulnar corner of the lunate, triquetrum, as well as the lunotriquetral interosseus ligament.[6,8]

Epiphysiodesis of the distal ulna is utilized to halt further ulnar growth. This can be performed in the setting of radial physeal closure in as a stand-alone procedure with ulnar neutral variance or in concert with an ulnar shortening osteotomy for joint leveling. Continued ulnar overgrowth is possible if the procedure is incomplete, and may result in additional surgical procedures.

The procedure for ulnar epiphysiodesis includes a variety of techniques including: physeal curettage, physeal curettage with bone grafting, with and without implant fixation such as stapling, screw, or plate fixation. In a study focused on the treatment for distal radius growth arrest in adolescents, failure of simple curettage was noted and the recommendation was made to include placement of corticocancellous autograft into the void following

From the *Department of Orthopedics, School of Medicine, University of Kansas; §Department of Orthopedics, Children's Mercy Hospital, Kansas City, MO; †Department of Orthopedics, School of Medicine, University of Colorado; and ‡Department of Orthopedics, Children's Hospital Colorado, Aurora CO.

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Reprints: Sarah E. Sibbel, MD, 13123 East 16th Avenue, Box 060, Aurora, CO 80045. E-mail: sarah.sibbel@childrenscolorado.org.

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curettage.[9] To our knowledge, no studies have been performed to evaluate and compare the success rates of ulnar epiphysiodesis performed with and without bone graft. The primary aim of this study is to evaluate the success rate of the primary epiphysiodesis of the ulna. Secondarily, we sought to evaluate additional characteristics including: continued growth following epiphysiodesis with and without bone grafting, time to physeal closure, improvement in preoperative symptoms and ulnar variance correction (osteotomy dependent).

METHODS

With Institutional Review Board approval, a multicenter, retrospective chart review was conducted at 2 large, regional children's hospitals from 2008 to 2019. Patients were identified using CPT codes (25450 and 25455) for ulnar epiphysiodesis in addition to ICD10 (M24.839) joint derangement of the wrist. Patients between the ages of 6 and 18 years old, with premature distal radius physeal closure, with or without positive ulnar variance, confirmed physeal closure or > 6 months follow-up were included. Exclusion criteria included: incorrect diagnosis, treatment outside the date range, pathologic fracture, inadequate follow-up, and incomplete/inadequate imaging studies. Patient data was collected and recorded in a secure database. We evaluated demographics, initial treatment utilized, type of initial injury, amount of ulnar variance, and additional procedures performed at the time of epiphysiodesis. Preoperative and postoperative symptoms were recorded as pain at rest, pain during activities, instability, loss (reduced) of range of motion. A symptom count variable was recorded for preoperative and postoperative symptoms to evaluate the clinical improvement. We measured ulnar variance preoperatively, immediately postoperatively and at final follow-up. The postoperative time point at which ulnar physeal closure occurred was calculated, as well as the number of epiphysiodesis failures.

The amount of ulnar variance was measured using standardized posteroanterior radiographs with the shoulder abducted to 90 degrees, the elbow flexed to 90 degrees, and the forearm, wrist and hand in neutral alignment. Radiographs were reviewed by the treating orthopaedic surgeon for adequacy. Ulnar variance measurements were made by a hand surgery fellow and a hand fellowship trained orthopaedic surgeon at 1 clinical site. An orthopaedic surgery resident and medical student measured the ulnar variance at the other clinical site, which was then verified by a hand fellowship trained orthopaedic surgeon. Fellowship trained hand surgeon measurements were utilized when the discrepancy was > 0.3 mm. The measurements were attained using the proven techniques of perpendiculars with high inter-rater reliability established by Steyer and Blair.[10,11] The sclerotic line indicating the volar distal radius was identified and the most ulnar point was chosen because of its consistency of appearance and consistency in usage across ulnar variance references in both adults and adolescents (Fig. 1).[3,11–13] Next, a parallel line to this along the most distal flat, articular surface of the distal ulna, excluding the ulnar styloid. The long axis of the ulna was used as a reference for our perpendicular lines. Ulnar variance was measured (in mm) as the distance between these 2 lines, with respect to the distal radius. A positive measure indicates the ulna is longer than the radius and a negative measure indicates that the ulna is shorter than the radius.[10,11,13] Before making ulnar variance measurements, all participants reviewed and agreed upon this standardized technique. We performed a Bland-Altman analysis to assess inter-rater agreement and calculate the mean difference.

FIGURE 1. The sclerotic line of the volar distal radius was identified and chosen based on its most ulnar point because of this being the most consistent in appearance and usage across ulnar variance references.[3,11–13] Next, a line is used for the distal ulna that is the most distal, flat, articular surface of the ulna (excluding the ulnar styloid). These lines are drawn parallel to each other and perpendicular to the long axis of the ulna. Ulnar variance was measured as the distance between these 2 lines (in mm), with respect to the distal radius. A positive value indicates the ulna is longer than the radius; a negative value indicates the ulna is shorter.[10,11,13] full color online

Operative procedures were individualized for each patient depending upon their clinical presentation, remaining growth potential, and pattern of growth arrest. Epiphysiodesis alone was utilized in patients with premature distal radial physeal closure, ulnar neutral alignment, and with growth remaining. Epiphysiodesis was performed by identifying the distal ulnar physis fluoroscopically and making a small incision over the ulnar border of the wrist. A 2.5 mm drill bit was then passed into the distal ulnar physis, confirming location using fluoroscopy. The physis was then drilled sequentially followed by curettage to induce closure. In some patients, bone autograft obtained from a concomitant ulnar shortening osteotomy or cancellous allograft was placed into the site of the epiphysiodesis. Epiphysiodesis was combined with ulnar shortening osteotomy in patients with significant ulnar overgrowth and growth remaining. The ulnar shortening procedure was performed utilizing a plate and/or screw fixation.

Descriptive statistics were utilized to characterize demographic and clinical characteristics. Categorical variables were described as percentages. We summarized the primary outcome, success of index epiphysiodesis, as a proportion with a 95% confidence interval (95%CI). Continuous variables which included ulnar variance were presented as means and SDs. Mean intrasubject comparisons were performed with a paired *t* test and group comparisons with a Welch *t* test. Statistical analysis was performed using Stata 14.2 (StataCorp, College Station, TX).

RESULTS

A total of 30 eligible patients with 31 wrists were included. The average age at the time of injury was 12.4 (SD: 2.0) and 13.8 (SD: 1.6) years at the time of surgery. Patients were followed for a median of 163 days (interquartile range: 101, 419). Female patients composed 48.4% of the cohort. The left wrist (58.1%) was more commonly affected than the right. The most prevalent injury types were distal radius Salter Harris II fractures (54.8%), followed by gymnast wrist/overuse (12.9%) and other (12.9%) injury types. Initial treatment was predominately operative (93.5%) for patients that were seen with the initial complaint of ulnar impaction syndrome.

Preoperatively, patients with one symptom were more common (41.9%) than those with 2 (29.0%) or 3+ (9.7%) symptoms. The most common symptom was pain with activities (77.4%), followed by loss of range of motion (28.1%), pain at rest (22.6%), and distal radioulnar joint instability (6.5%). Postoperatively, most patients (90.3%) reported no symptoms with < 9.7% reporting one or more symptoms (Fig. 2). The most common postoperative symptom, if there was 1, was pain with activities (6.5%). Additional procedures performed at the time of epiphysiodesis included: ulnar shortening osteotomy (51.6%), bone grafting to physis (25.8%), distal radius osteotomy (16.1%), TFCC debridement (12.9%), wrist arthroscopy (9.7%), and TFCC repair (3.2%). Some patients had multiple procedures performed.

Failure of epiphysiodesis was recorded in 6.5% of cases indicating a 93.5% success rate (95%CI: 78.6, 99.2). The mean time to physeal closure was 134 days (SD: 94) in those with successful primary epiphysiodesis. One who did not close at primary epiphysiodesis was followed for 9 months before revision surgery and successful physeal closure occurred. Our other failure was followed for 16 months and had growth but symptom relief at their last follow-up visit. The mean preoperative ulnar variance was 5.3 mm (SD: 3.0), immediate postoperative ulnar variance was 1.4 mm (SD: 2.7), and at final follow-up 2.1 mm (SD: 3.4). The average correction was 3.1 mm (95%CI: 1.9, 4.4) when comparing preoperative ulnar variance to last radiograph at final follow-up. In the osteotomy only group, the average ulnar variance correction was 4.1 mm (95%CI: 2.7, 5.4).

A subgroup analysis evaluated the effect of bone grafting on physeal closure. There were 2 failures in total, one in the bone graft group (N = 8) and another in the no-bone graft group (N = 16). We did not find a significant association between bone graft use and failure of epiphysiodesis ($P = 0.42$).

A Bland-Altman analysis found inter-rater agreement to have intraclass correlation values of 0.97 (95%CI: 0.95, 0.99) for preoperative radiographs and 0.98 (95%CI: 0.92, 0.98) for postoperative radiographs. The mean difference between raters was 0.4 mm for preoperative radiographs and 0.3 mm for postoperative radiographs.

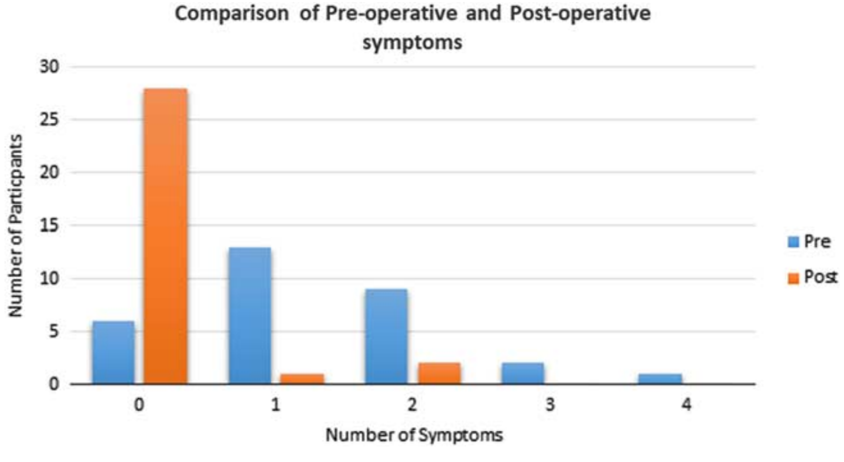

FIGURE 2. Visualization of reduction in preoperative symptoms after surgery. full color online

DISCUSSION

The results of our study are consistent with that published by Waters et al.[9] They found in their subgroup of 14 patients that received ulnar epiphysiodesis, 12 had successful ulnar physeal closure with 2 patients requiring revision because of ulnar overgrowth. In addition, in their study, 24 patients receiving joint leveling procedures (ulnar shortening osteotomy, radial osteotomy, ulnar and/or radial epiphysiodesis) improved average wrist scores from 82% to 98%. Our current patient population has experienced similar outcomes with overall ulnar epiphysiodesis success in 93.7% of cases. In our population, when ulnar epiphysiodesis is paired with appropriately indicated additional procedures, preoperative symptoms were completely resolved in 90.3% of cases. Those with residual symptoms were in the successful physeal closure group.

It has been postulated that bone grafting at the time of epiphysiodesis can improve physeal fusion.[9] Our data did not show improved physeal fusion in epiphysiodesis with bone grafting. However, this was not statistically significant possibly because of the small number of patients in this subgroup. Our estimated power was ~3.95% using our cohort parameters. We would need ~151 patients per group to identify a true difference in physeal failure rates. While these results suggest noninferiority of the bone graft group compared with the no-bone graft group, the additional expense and surgery likely outweighs the benefits of using bone grafts.

A major strength of this study is the large variety of pediatric and hand surgery trained orthopaedic surgeons with variable practices. Thus, these values predict mean appropriate values for expected outcomes for all surgeons. In addition, inter-rater reliability was excellent with small measurement differences for ulnar variance among our study team allowing us to verify changes to ulnar variance not because of measurement error. Our study population was nearly balanced by sex/sex all of whom had open physis thus, stratification by sex/sex was not necessary.

Limitations to this study include the timing of standard follow-up. Radiographs were on average obtained between 2 and 4 weeks postoperatively and often not until 3 to 4 months postoperatively. It is difficult to predict exactly the time to physeal closure, however, it can be stated that the physis is closed in 93.7% of patients by the 4-month time postoperatively. Although a limitation of this study is the small cohort of patients, the volume of this procedure is low, thus the number of patients may in fact be large for this procedure. We attempted to include range of motion data, however, numeric values were only available for 8 patients preoperatively and 4 patients postoperatively which limited the value of any potential analysis. Some studies have shown that weight-bearing forces magnify at 2.5 mm so 1 to 2 mm ulnar variance differences may affect pain and range of motion.[6–8] Future studies should evaluate the impact of ulnar variance on range of motion to determine if weight-bearing forces magnify at 2.5 mm or incrementally before 2.5 mm.

This study illustrates that patients presenting with early physeal closure with ulnar neutral variance and ulnar positive wrists with associated ulnar impaction syndrome can be treated successfully with ulnar epiphysiodesis with or without an associated joint leveling procedure with predictable and excellent outcomes both radiographically and clinically. This supports an effective treatment model for patients with early radial physeal closure with or without ulnar impaction syndrome in the setting of acute physeal trauma or chronic gymnast wrist.[1,2,8,9,14–21] Future prospective randomized controlled trials can be performed to test the use of bone graft on improved time to physeal closure and the association of bone graft utilization with maintenance of immediate postoperative ulnar variance following ulnar epiphysiodesis with and without the appropriate joint leveling.

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