TITLE PAGE

Paediatric medial epicondyle fractures of the distal humerus.

Mr Robert Allen Stevenson
Orthopaedic Department Alder Hey Children's Hospital, Eaton Road, Liverpool, L12 2AP, UK.
Email: rastevenson@doctors.org.uk
Phone: 07540243363
MB ChB, FRCSEd (Tr & Orth)
Senior Academic Clinical Fellow
PhD student, University of Liverpool, UK.
ST8 Trauma and Orthopaedics, Mersey.

Mr Daniel Christopher Perry
Orthopaedic Department Alder Hey Children's Hospital, Eaton Road, Liverpool, L12 2AP, UK.
Email: danperry@liverpool.ac.uk
Phone: 07815122361
MB ChB(Hons), PhD, FHEA, FRCS (Tr & Orth).
National Institute for Health Research Clinician Scientist
Consultant in Children's Orthopaedic Surgery
Senior Clinical Lecturer, University of Liverpool, UK

Conflicts of interest:

Mr Robert Allen Stevenson: no conflicts of interest.
Mr Daniel Christopher Perry: no conflicts of interest.

ABSTRACT

Medial humeral epicondyle fractures represent approximately 12% of elbow injuries in children. It is a controversial topic in paediatric fracture management, as there is a trend towards extending the indications for surgical management that is not supported by high quality evidence. In fact, the current literature can be contradictory and consists of mainly retrospective studies including small numbers of patients. The only absolute indication for surgery is when the medial epicondyle fragment becomes incarcerated within the elbow joint. In this article, we will present the important anatomical, physiological and interventional factors to allow independent interpretation of the literature. The current literature will be reviewed and a pragmatic approach to treatment presented.

Due to the porosity of the current evidence on medial epicondyle fractures high quality research is urgently required in the form of an adequately power definitive randomised control trial.

Introduction

Paediatric medial humeral epicondyle (MHE) fracture management is one of the most controversial topics in paediatric fracture care. Historically, simple displaced MHE fractures have been treated conservatively with excellent to good results. However, in recent years there has been a trend to treat these fractures surgically. The indications have been insidiously extended, with some authors relating outcomes such as grip strength and elbow instability to the amount of fragment displacement (1,2,3). Other studies have shown no difference between surgical and conservatively treated cases at long term follow-up (mean 35 years) in regard to instability and surgeon reported outcomes (4,5). Unfortunately, this change in practice has therefore not been supported by any high-quality evidence. A consensus study amongst members of the British Society of Children's Orthopaedic Surgery (BSCOS) recently highlighted this injury as the most important area of paediatric fracture care in need of high-quality research.

There is broad consensus for surgical fixation in MHE fractures with associated injuries, such as open fractures and incarceration of the medial epicondyle. Some controversy remains on the relative indication for surgery in elbow dislocation. In the UK, a recent review of practice (6) showed that 98% of MHE fractures with associated elbow dislocations were treated surgically.

In this article, we summarise the important anatomical, physiological and interventional factors that will allow the reader to independent interpret the current literature but also offer a pragmatic approach to the treatment of MHE fractures. We also outline a recently funded nationwide UK-based clinical trial addressing this question, and the rationale for the chosen methodology.

Anatomy

To understand the rationale of treatment for medial epicondylar fractures, it is important to have a good working knowledge of the complex anatomy, development and physiology of the paediatric elbow. Thus, allowing our understanding of the underlying concepts of treatment, to draw one's own conclusion from the current literature. We shall outline the importance of each structure and their relevance to the common treatment strategies.

Ossification centres and physis of the distal humerus

The shape of the distal humeral physis changes significantly with age. Before the age of 5 the physis is almost transverse. From 5 to10 years of age the growth plate becomes irregular and angulated. The medial epicondyle then begins to separate from the trochlea with the development of a metaphyseal flare on the medial physis. After the age of 10 years the physis is undulating and all ossification centres are present. As the physis and ossification centres develop the areas of biomechanical weakness change and thus the fracture patterns can be associated with age.

Transphyseal fractures are most common in the very young owing to the little resistance offered to shearing forces by the smooth, transverse orientation of the physis (Fig 1A). At the age of 5-7 years lateral condyle fractures are more common as the capitellar ossification centre acts as a fulcrum on application of a varus / supination force.

As the ossifications centres continue to develop, the capitellum and the trochlea become more biomechanically stable. Around the age of 10 years old the medial epicondyle is at its most susceptible to fracture as it is a apophysis and the last physis to fuse in the elbow. These fractures are also associated with a significant rate of elbow dislocation. The age-related development and fracture patterns are described in Figure 1.

Figure 1: Elbow fracture patterns by mean age.

Elbow stability

Elbow stability post displaced medial epicondyle fracture management is a major concern in the paediatric population. This is particularly true in regions where baseball, American football, basketball and wrestling are popular. However, long-term studies do not reflect these concerns and elbow instability is uncommon even after conservative treatment of medial epicondyle fractures. (4)

Elbow Ligaments

Lateral ligamentous complex.

The lateral ligamentous complex arises from the lateral epicondyle at a point level with the isometric centre of the capitellum. The radial collateral ligament is considered to be isometric through the elbows range of movement, however the lateral ulnar collateral ligament is not and becomes tight in flexion and loose in extension due its path over the bony protrusion of the lateral epicondyle in flexion (7).

Medial ligamentous complexes

The most important restraint to valgus force are the anterior bands of the medial collateral ligament, with the most important secondary stabiliser being the flexor origin.

Anterior bundle of the medial collateral: originates from the posterior aspect of the medial epicondyle and attaches into the sublime tubercle of the ulna. This may be dysfunctional following a medial epicondyle fracture resulting in positive moving valgus stress test (supinated, 90 degrees flexed and pull thumb to apply a valgus stress through the full ROM. Positive if unstable between 70-120 degrees)

Posterior bundle of the medial collateral: originates from the posterior aspect of the medial epicondyle and attaches to the olecranon. Weak fan like structure that forms the floor of the cubital tunnel.

Oblique bundle of the medial collateral (Cooper's ligament): runs from the inferior border of the anterior and posterior medial collateral ligament. Has almost no role in the stabilisation of the elbow.

Figure 2: Ligaments of the elbow.
Figure 3: Primary ligamentous restrain.
As the elbow moves through its range of movement there is a transition of the primary constraint to coronal stress. The ligament closest to the lateral anatomical line of the humerus during a valgus or varus forces offers the primary resistance i.e. in extension; a valgus force is resisted by the anterior bundle of the medial collateral ligament first and a varus force is resisted by the radial collateral ligament first.

Muscle Origins

Figure 4: Summary of muscle origins.

BLOOD SUPPLY

Medial epicondyle

On the medial side of the elbow there is a periarticular anastomosis which consists of the 2 descending branches of the superior and inferior ulnar arteries and 2 recurrent branches of the ulnar artery. The medial epicondyle has a single vessel supply in 27.5% of patients but in most cases, it has anterior and posterior vessels and therefore has a low rate of AVN compared to some other fractures, such as lateral condyle fractures.

Figure 5: Blood supply of the medial epicondyle and the lateral condyle of the distal humerus.

Medial epicondyle fractures

Mechanism

The most commonly described mechanism is an avulsion of the medial epicondyle by falling onto an extended elbow with a valgus force and supination of the forearm. Other mechanisms included direct impact in which results in comminution of the fragment and avulsion and direct trauma together which has been theorised as the mechanism of dislocation (9).

Medial Epicondyle Fracture Classifications

There is no consensus in the literature on the most appropriate classification system to be used in categorising medial epicondylar fractures. The AO foundation have recently modified their original classification of medial epicondyle fractures.

Original AO classification was 13-A.1.2 (.1 undisplaced, .2 displaced, .3 fragmented) and 13-A.1.3 for incarcerated fractures. The modified paediatric AO classification is 13-M/7m. Which is broken down like this: 1(humerus) 3(distal) –M (metaphyseal)/7(epicondyle) m (medial)

Several authors have offered classification systems for medial epicondylar fractures. These classifications have developed with time to include more variations of fracture displacement and associated injuries. Smith et al 1950 was the first classify the fracture and this classification was based on the displacement of the fragment. There have been subsequent modifications including that by Papavasiliou et al (10) which classified the fracture into 4 types: Type 1 - Small degree of avulsion of the epicondylar fragment, Type 2 - Avulsed epicondylar fragment on the same level of the joint but not trapped, Type 3 - Avulsed fragment trapped in the joint, Type 4 - Avulsion of the fragment associated with an elbow dislocation and the fragment in the joint.

The most recent classification by Wilkin et al is a descriptive classification and includes displacement, dislocation, incarceration and comminution of acute fractures. It also includes tension stress injuries under the heading chronic fracture. Figure 6.

Whilst these classifications exist, they offer little benefit to surgeons or patients in terms of guiding treatment strategies, or the ability to prognosticate.

Figure 6: Wilkin's classification of medial epicondyle fractures.

Investigations

Radiographs

AP and lateral, internal oblique views have been advocated in medial epicondyle fractures however the predictive accuracy of displacement is at best 60% (11). Axial humeral views have been shown to offer the best compromise between accurate measurement of the displacement and amount of radiation exposure (12). This cadaveric study compared standard axial humeral views with AP and internal oblique. It showed that the correlation between actual and axial humeral radiographic displacement was r=0.998 versus AP radiographic measurement which was r=0.655.

CT

Edmonds et al compared the ability of radiographs to assess displacement with CT as the comparator. They concluded that the most common direction of displacement was anterior and that AP radiographs can miss up to 1cm of displacement when compared to CT. This suggests the possibility that displacement may be underestimated and that inadvertent conservative treatment of displaced fractures may frequently occur. Although shown to be the most sensitive and specific modality to assess displacement of the fracture, it is not indicated in simple fractures due to the radiation exposure.

MRI

MR imaging is suggested in complex elbow dislocations to identify possible chondral shear fractures and lateral collateral ligamentous injury. Which allows appropriate pre-operative planning. MR is also useful if after attempted reduction there is still subluxation of the elbow on radiographs and there is no evidence of fracture fragment incarceration. In these cases, MR can identify loose bodies as the cause of subluxation.

In unossified medial epicondyle fractures MR is the only modality that will identify the injury. These injuries should be considered in patients were there is medial sided bony tenderness with a consistent mechanism and no evidence of ossification of the medial epicondyle on plain radiographs.

Management

Conservative

Management of displaced medial epicondyle fractures has recently been highlighted as one of the top areas of paediatric orthopaedic research. There remains no consensus as to the optimal treatment modalities, which is a reflection of the poor quality of the available literature. One of the major concerns regarding conservative management is that there will be loss of function and instability related to the degree of displacement of the fracture. Computer simulations have predicted a mean of 2% wrist flexor power loss for every 1mm of displacement, however, there is no clinical evidence to support this in vivo.

Standard conservative management consists of 3-4weeks in an above elbow cast in 90 degrees of elbow flexion. Some advocate less than 2 weeks in plaster followed by conversion to a hinged elbow brace, but at present there is no evidence to support this. Results of plaster immobilisation appear functionally comparable to surgically treated fractures. The frequency of fibrous non-union has been reported as high as 89% (4, 5,9) however the majority of these fibrous non-unions cause no symptoms or functional deficit at long term follow up (up to 35 years) (5).

The position of minimally displaced fragments has been observed to improve with time. Lim et al reported a reduction of displacement with conservative management with a maximal period of immobilisation of 35 days. They showed a mild improvement of approximately 20% in minimally displaced fractures. These findings cannot be extrapolated to more displaced fractures but may offer some explanation for the excellent outcomes of conservative treatment.

Stability of the anterior bundle of the medial collateral ligament has remained a concern after conservative treatment of displaced medial epicondylar fractures. Farsetti et al (4) performed retrospective long term follow up (mean 34 years) of 42 patients in three treatment groups. 19 patients treated conservatively had no evidence of instability, 1 patient had pain on stressing a stable medial collateral ligament, 1 patient suffered from ulnar paraesthesia on valgus stress and 1 patient had developed asymptomatic OA. In the second group of 17 patients treated with ORIF, they had no signs or symptoms of instability, one patient had pain on valgus stressing and there was one patient with ulnar nerve paraesthesia in another. In the third group, from those whom the bony fragment was excised, there was a high prevalence of pain and instability and the authors advised against excision. The study had selection bias, patients were identified retrospectively and no validated outcome assessment tool was used for data collection.

Young athletes are a subgroup that have been identified as having a lower threshold for surgical fixation (13), however, more recent literature indicates that conservatively treated patients do not have a higher incidence of elbow instability. One study evaluated eight young professional arm wrestlers treated with collar and cuff immobilisation and it was found that all returned to pre-injury activity with no patient perceived change in performance after several months.

Incarcerated fragments are an absolute indication for surgery. Long-term incarceration of the medial epicondyle fragment can lead to chronic elbow instability that is almost untreatable. Cases have been reported where the incarcerated fragment has been extruded from the joint

and the fragment treated without operative fixation, with good outcomes an a recommendation that in the absence of instability the fragment may be treated expectantly.

Surgery

Current Indications for surgery:

Open fracture, fracture fragment incarceration.

Current relative indications for surgery:

Concurrent elbow dislocation, displacement greater than a radiographic threshold (typically 5 mm), fracture amongst upper-limb dependent athletes (9)

The variation of treatment within Great Britain has been demonstrated by a recent study by the Elbow Study collaborative. (6). Of 520 medial epicondylar fractures identified in 27 NHS trusts in Great Britain, 66% were displaced and 63% of these were treated surgically with a single screw. Wide variation was identified between trusts in the approach to treating displaced fractures, which has highlighted the need for a randomised control trial.

Screw Fixation.

Standard treatment for fixation of medial epicondyle fractures is by a single cannulated screw with K-wiring and tension band wiring reserved for younger patients. Excision of the medial epicondyle and soft tissue reattachment has been shown to give poor outcomes and should be avoided (4). Outcomes of screw fixation have been shown to offer excellent return of movement and bony union, however it has a high rate of symptomatic hardware and elbow pain (14).

Partially threaded screws negate the need for bicortical fixation, which has been shown to increase the risk of iatrogenic radial nerve injury. A recent radiological study (15) has shown that up to the age of 6 years old that the radial nerve crosses the distal lateral humerus at a distance of (age x1cm) proximal to the physis. Care should also be taken to avoid penetration of the olecranon fossa, as metalwork prominence can lead to a reduction of extension. Figure 7(a).

Washer

The use of a washer with the screw is debateable. It is thought that it may reduce the risk of fragmentation of the fracture fragment, however one small study showed no increased risk of fragmentation with either a screw and washer or screw alone. There was a statistically significant increase in the need for removal of metalwork when a washer was used, this was secondary to metalwork irritation.

Suture / Bone anchors.

Excision of the medial epicondyle has been shown to result in poor long-term outcomes with reduced grip strength and elbow instability (4). It is therefore advised that excision of the avulsion fragment is avoided if at all possible.

K-wires

Kirschner wire fixation has been shown to have similar outcomes as screw fixation and have not shown any difference in range of motion despite the increased immobilisation time. There is the added benefit that removal of metal can be done as an outpatient procedure and negates the need for further surgery. Figure 7(b)

Removal of metalwork

As the medial epicondyle is a apophysis it contributes no longitudinal growth to the distal humerus and therefore leaving the screw in situ does not lead to coronal growth disturbance. Screws should be removed if there is any ulnar nerve irritation or pain related prominence. K-wires should be unburied and removed at 3 weeks to reduce the risk of superficial and deep infection.

Having reviewed the literature, we have developed an algorithm for the management of Medial Epicondyle fractures. Figure 8.

Outcome measures

There are a wide variety of outcomes used to report success or failure in medial epicondyle fractures. The heterogeneity in outcome reporting is part of the problem propagating treatment uncertainties. Agreement as to the core set of outcomes is urgently needed, to standardise the reporting of studies, and enable systematic comparisons between studies. Core outcome sets (COS) are increasingly common across medicine and surgery, and they seek to identify, by consensus, the most important outcomes from participant groups involved in the treatment of a condition which should universally be recorded.

There is widespread agreement that functional outcomes should be measured, using patient reported outcome measures (PROMs). The three most commonly used paediatric upper limb PROMs in orthopaedics are the Patient-Reported Outcomes Measurement Information System (PROMIS) upper extremity questionnaire, the Paediatric Outcomes Data Collection Instrument (PODCI) and the ABILHAND. Of these the PROMIS upper extremity questionnaire appears to have the greatest face-validity in this patient population. However, at present, there the minimally clinically important difference (MCID) is not known for PROMS related to this patient population, and there is ongoing work seeking to resolve this. Other adult PROMs have also sometimes been used in this injury (i.e. DASH), but are not validated in the paediatric trauma population.

Complications in medial epicondyle fractures

Union
Nonunion rates in conservative treatment have been reported as high as 50.8% with the majority of these cases asymptomatic. There is a lower rate of pain at final follow up for the non-surgically treated cases versus surgically (14). Union rate post-surgical fixation is dependent on type of fracture, with rates of non-union ranging from 0-7.5% but this is significantly higher in incarcerated fractures (57%). (9)

Range of movement.
Range of movement has been shown to be reduced in both treatments modalities. With an average reduction of extension reported as 15 degrees in non-operative group and 37 degrees in the surgical. Earlier mobilisation in the surgical group has been advocated from day 2 post op to reduce this.

Deformity
Cubitus valgus rates post medial epicondyle fracture range widely in the literature from 0-35.5% (9). The majority of literature report an incidence of < 10%. As the medial epicondyle is an apophysis it has been hypothesised that growth disturbance is as a result of undetected physeal fracture at the time of injury (4).

Instability
The prevention of instability has been suggested as an indication for surgery in young athletes. However, long term follow up have shown even in this high demand group that there is no difference in the incidence of elbow instability between surgical and conservatively managed cases (4,5)

Ulnar nerve injury
Ulnar nerve injury is rare but is associated with elbow dislocation and the highest rate is seen when the medial epicondyle is incarcerated. There is debate on the appropriate treatment of ulnar nerve injuries sustained preoperatively. Transposition has been both advocated to increase the rate of recovery and discouraged due to the risk of ulnar nerve neuritis. Ulnar nerve palsy after reduction of dislocation is a relative indication for surgical exploration and fixation.

Missed incarcerated fragment
An incarcerated medial epicondyle fragment is not a surgical emergency and delays in surgery of up to 40 hours have shown no detrimental effect on outcome even in association with ulnar nerve palsy. Reduction of the elbow joint does however, remain an emergency and priority should be placed on this.

KEY POINTS

- Historically medial epicondyles treated conservatively with excellent / good outcomes.
- Associated with (up to 50%) elbow dislocation rate and (up to 20%) incarceration of fragment rate.
- No evidence in long term studies that any difference in outcome (including grip strength and instability) between conservative and surgically treated case.
- Some articles report higher levels of pain and reduced ROM in surgically treated patients.
- Asymptomatic non-union rate up to 50% in conservatively managed cases.
- Incarceration of fragment and open fractures absolute indications for surgery.
- Amount of displacement not been shown to have an effect on outcome.
- Displacement poorly measured on standard AP views.
- Axial distal humerus view has best correlation with CT measured displacement.
- Recent review of practice in the UK showed wide variation in management - Stevenson
- Upcoming UK national SCIENCE trial.

References

1. Edmonds EW, Santago AC 2nd, Saul KR. Functional Loss With Displacement of Medial Epicondyle Humerus Fractures: A Computer Simulation Study. J Pediatr Orthop. 2015 Oct-Nov;35(7):666-71.
2. Schwab GH, Bennett JB, Woods GW, Tullos HS. Biomechanics of elbow instability: the role of the medial collateral ligament. *Clin Orthop.* 1980;146:42-52.
3. Papavasiliou VA: Fracture-separation of the medial epicondylar epiphysis of the elbow joint. *Clin Orthop Relat Res* 1982;171:172-174.
4. Farsetti P, Potenza V, Caterini R, Ippolito E. Long-term results of treatment of fractures of the medial humeral epicondyle in children. J Bone Joint Surg Am. 2001 Sep;83-A(9):1299-305.
5. Josefsson P.O., Danielsson L.G. Epicondylar elbow fracture in children: 35 year follow-up of 56 unreduced cases. J Shoulder Elbow Surg. 1986;57:313–315.
6. Stevenson RA, Dorman SJ, Mohammed M, Perry DC, The Elbow Study collaborative. Paediatric medial humeral epicondyle fracture management: a national review of practice in Great Britain, EPOS Oslo, Norway, 2018.
7. Moritomo H, Murase T, Arimitsu S, Oka K, Yoshikawa H, Sugamoto K. The in vivo isometric point of the lateral ligament of the elbow. J Bone Joint Surg Am. 2007 Sep;89(9):2011-7.
8. Tribst, M. F., Zoppi, A., Camargo, J. C. S., Sassi, D., & de Carvalho, A. E. (2012). Anatomical and functional study of the medial collateral ligament complex of the elbow. *Acta Ortopedica Brasileira*, *20*(6), 334–338.
9. Gottschalk HP, Eisner E, Hosalkar HS. Medial epicondyle fractures in the pediatric population. J Am Acad Orthop Surg. 2012 Apr;20(4):223-32.
10. Papavasiliou VA: Fracture-separation of the medial epicondylar epiphysis of the elbow joint. *Clin Orthop Relat Res* 1982;171:172-174.
11. Gottschalk HP, Bastrom TP, Edmonds EW. Reliability of internal oblique elbow radiographs for measuring displacement of medial epicondyle humerus fractures: a cadaveric study. J Pediatr Orthop. 2013 Jan;33(1):26-3.
12. Souder CD, Farnsworth CL, McNeil NP, Bomar JD, Edmonds EW. The Distal Humerus Axial View: Assessment of Displacement in Medial Epicondyle Fractures. J Pediatr Orthop. 2015 Jul-Aug;35(5):449-54.
13. Schwab GH, Bennett JB, Woods GW, Tullos HS. Biomechanics of elbow instability: the role of the medial collateral ligament. *Clin Orthop.* 1980;146:42-52.
14. Kamath AF, Cody SR, Hosalkar HS: Open reduction of medial epicondyle fractures: Operative tips for technical ease. *J Child Orthop* 2009;3(4):331-336.
15. Nielson, Andras and Skaggs. Quantifying the location of the radial nerve in children for intraoperative use. EPOS Oslo, Norway, 2018.