Fractures and Dislocations About the Elbow in Children

James H. Beaty, MD

Fractures of the Lateral Humeral Condyle

Fractures of the lateral condyle account for 10% to 15% of elbow fractures in children.[1-6] Most occur in children around six years of age. Classification is based on the amount of displacement (Fig. 1): stage I is nondisplaced (1 to 2 mm of displacement); stage II is moderately displaced (2 to 4 mm of displacement; and stage III is completely displaced.[5] Treatment also depends on displacement. Stage I fractures generally can be treated with cast immobilization until union is seen on roentgenographs; however, serial roentgenographic evaluation should be carried out to detect any late displacement. Stage II and III fractures are best treated by open reduction and internal fixation.

Although type I fractures appear innocuous (Fig. 2), late displacement (Fig. 3) or late nonunion has been reported in as many as 10% of such injuries.[2,7-12] Varus stress views may be used to determine fracture stability and the presence or absence of a cartilaginous hinge. Arthrography also has been used in treating type I fractures to detect intra-articular displacement that requires surgical fixation.[1,12,13]

Open reduction is performed through a straight lateral approach, and the fragment is replaced and fixed with two smooth Kirschner wires (K-wires) (Fig. 4). The posterior soft tissues are left attached to the lateral condyle to protect its blood supply. The pins are removed at three to six weeks, as soon as satisfactory healing has occurred.

The most common complications after lateral condylar fractures are nonunion and progressive cubitus valgus deformity. These usually occur because the initial injury was unrecognized and untreated. In carefully selected patients, late open reduction and internal fixation may be performed.[9,14] The criteria for late treatment, as outlined by Flynn and associates,[9] are a large metaphyseal fragment, displacement less than 1 cm from the joint, and an open physis. Extra-articular late open reduction and internal fixation, which often requires bone grafting and screw fixation, can result in loss of range of motion (Fig. 5).

The natural history of nonunion of the lateral humeral condyle is progressive cubitus valgus with a high risk of tardy ulnar nerve palsy.[15] Children and adults with established nonunions are best treated by "benign neglect," with early transposition of the ulnar nerve when symptoms appear (Fig. 6).

Fractures of the Medial Epicondyle

About 40% of all medial epicondylar fractures in children occur with elbow dislocations.[16,17] Most occur in children between the ages of nine and 12 years.

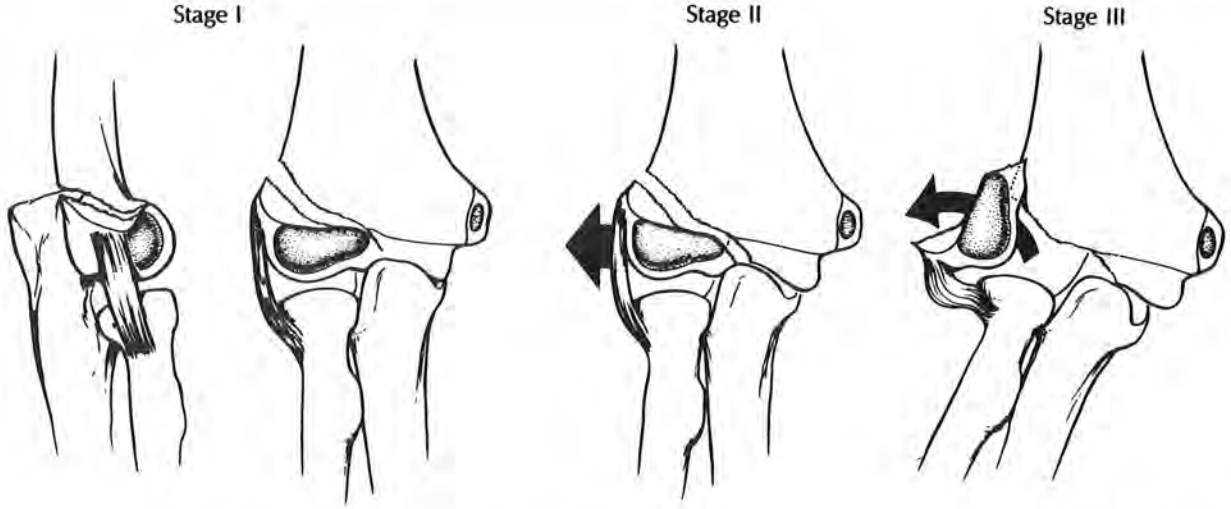

Fig. 1 Classification of fractures of lateral condyle: stage I nondisplaced, stage II moderately displaced, and stage III completely displaced. (Reproduced with permission from Wilkins KE: Fractures and dislocations of the elbow region, in Rockwood CA Jr, Wilkins KE, King RE (eds): *Fractures in Children*, ed 2. Philadelphia, JB Lippincott, 1991, vol 3, p 628.)

Fig. 2 Stage I fracture of lateral condyle. Note small metaphyseal fragment with 2 mm of displacement.

The medial epicondyle is a traction apophysis. In the early stages of ossification, it is part of the distal humeral epiphysis, but with growth it becomes separated by metaphyseal bone. Ossification of the apophysis begins at from 4 to 6 years of age, and fusion occurs at approximately 15 years. Irregularities of ossification may be misinterpreted as a fracture.[18]

Three mechanisms of medial epicondylar fractures have been proposed: a direct blow, pure muscle avulsion, and in association with an elbow dislocation. Direct trauma as a source of these injuries seems rare. Muscle avulsion injuries occur during a fall on an outstretched arm with the elbow in extension and the wrist and fingers hyperextended. The forearm flexor muscles place a tension force on the epicondyle and cause the avulsion.[19]

Fractures of the medial epicondyle are classified by the amount of displacement: type I is nondisplaced; type II is moderately displaced (less than 1 cm); and in type III there is intra-articular entrapment. Types I and II fractures can be treated with cast immobilization for three to four weeks. Occasionally, a type II injury with gross medial instability will require open reduction and internal fixation.[20] Open reduction and internal fixation are indicated for type III fractures if the medial epicondyle cannot be extracted from the joint by manipulation (valgus positioning, supination of the forearm, and dorsiflexion of the wrist) in a sedated patient. Open reduction and internal fixation are required if the fracture fragment is trapped within the joint (Fig. 7).[21] At one time, ulnar nerve dysfunction was an indication for open reduction, and some authors recommended transposition of the nerve at the time of reduction. Bernstein and associates,[16] however, found that all patients with initial ulnar neuritis did well without surgery, and most authors now do not recommend nerve transposition. Delayed ulnar nerve symptoms are rare. Woods and Tullos[22] recommend that if gravity valgus stress testing shows significant instability, surgery is indicated, especially in athletes.

T-Condylar Fractures

T-condylar fractures are uncommon in young children and occur more frequently in older adolescents and teenagers.[23–25] These fractures represent type IV physeal injuries of each of the distal columns of the humerus. Occasionally the fracture is minimally displaced, but most are displaced with instability of all fragments. T-condylar fractures may be confused clinically with extension-type supracondylar fractures. In older children, a T-condylar fracture should be differentiated from a comminuted supracondylar fracture. Treatment depends on the extent of soft-tissue and bone injury. If swelling or comminution is severe, olecranon traction for two to three weeks may be required for reduction. If the fracture fragments are large and displaced, open reduction and internal fixation are indicated. Extensive dissection should be avoided to prevent osteonecrosis of the articular cartilage. K-wires, screws, or screw-reconstruction plate combinations may be used for fixation depending on the age of the child and the severity of the comminution (Fig. 8). The triceps splitting or "tongue" approach may be used, and olecranon osteotomy may be required to correct severe intra-articular comminution.

Monteggia Fracture-Dislocations

The Monteggia fracture-dislocation is a pronation injury consisting of fracture of the ulna with dislocation of the radial head (Fig. 9). Most of these injuries are caused by falls, and associated wrist injuries are common.[26–30] These injuries were classified by Bado[31] according to the direction of displacement of the radial head: in type I the displacement is anterior; in type II it is posterior; in type III it is lateral; and in type IV it is anterior with fracture of the ulna and radius. Anterior and lateral displacement of the radial head are the most common. The radial head dislocation may not be apparent on roentgenograms, because the elbow often is not included in the initial evaluation of forearm injuries. Roentgenograms of ulnar or radial fractures should include the elbow and wrist joints and should show the radial head in line with the middle of the

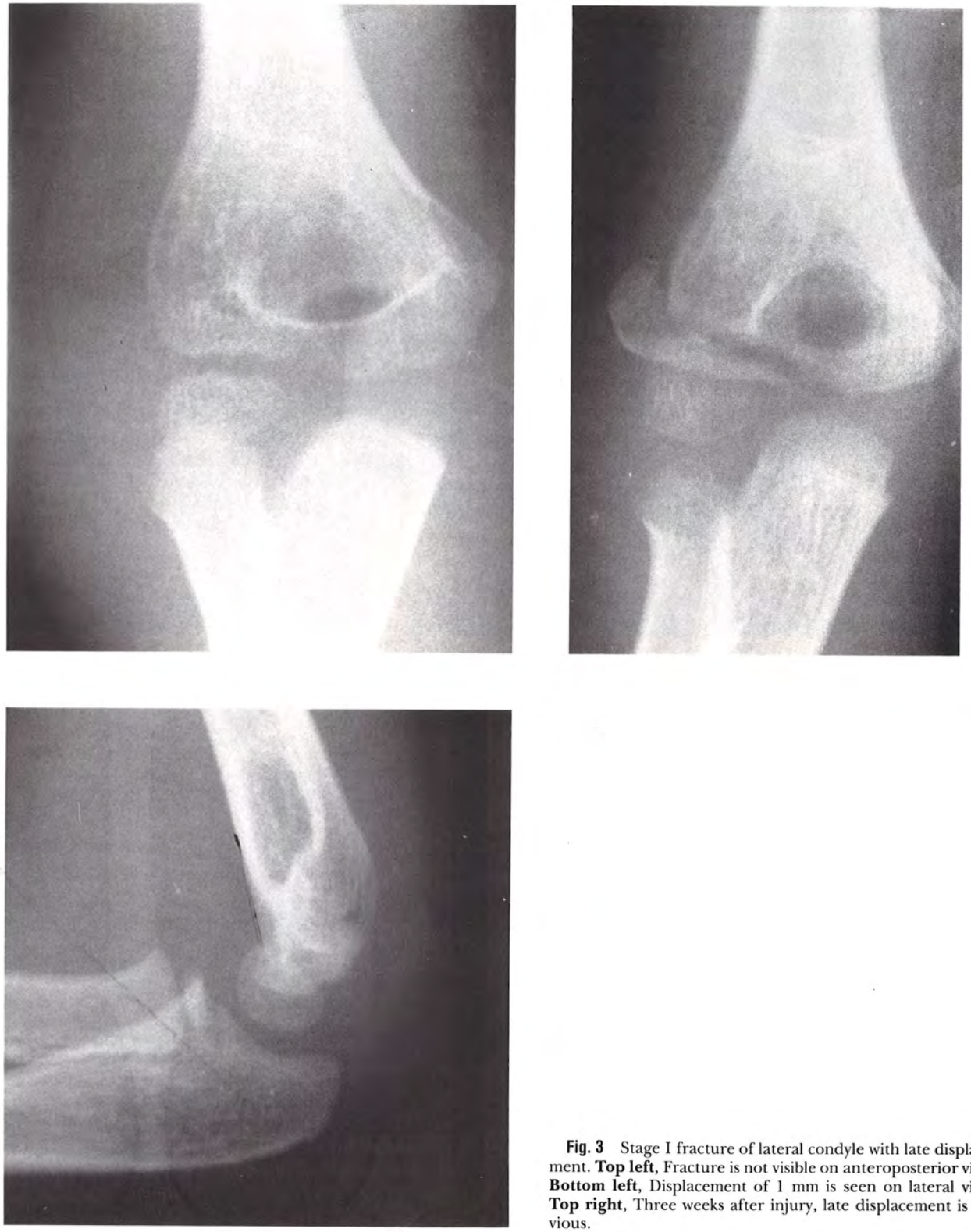

Fig. 3 Stage I fracture of lateral condyle with late displacement. **Top left**, Fracture is not visible on anteroposterior view. **Bottom left**, Displacement of 1 mm is seen on lateral view. **Top right**, Three weeks after injury, late displacement is obvious.

capitellum on all views, especially the lateral. This can be confirmed by drawing a straight line through the radial head and neck; in any position, this line should pass through the central portion of the capitellum.

For most Monteggia fracture-dislocations in children, closed manipulation can be used to reduce the ulnar fracture and the radial head dislocation.[32,33] A cast is applied with the arm in a stable position

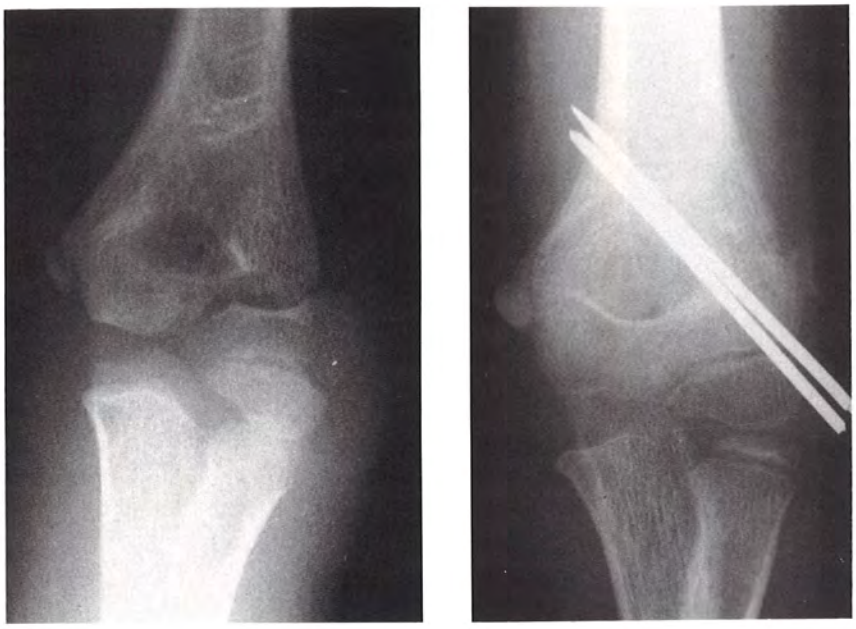

Fig. 4 **Left**, Completely displaced fracture of lateral condyle in 8-year-old. **Right**, After open reduction and internal fixation with two smooth 5/64-inch K-wires.

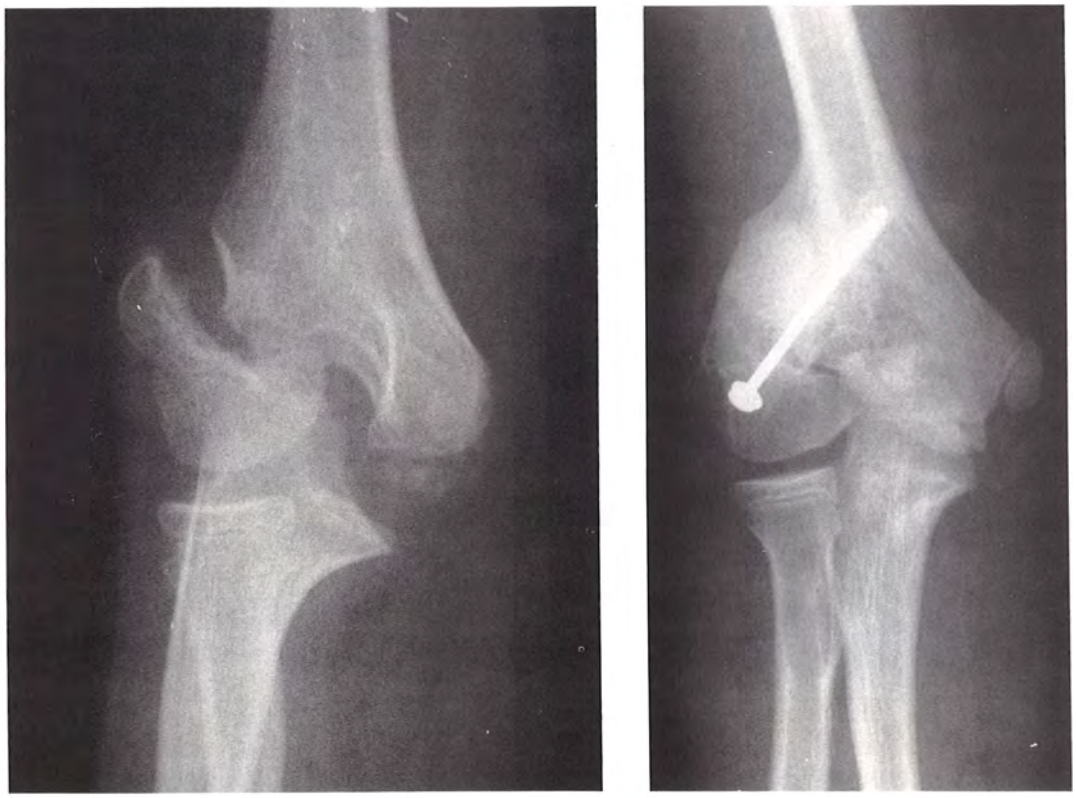

Fig. 5 **Left**, Nonunion two years after lateral condyle fracture with large metaphyseal fragment. **Right**, After open reduction, internal fixation, and iliac crest bone graft, metaphyseal fragment has united, and patient has good clinical range of motion.

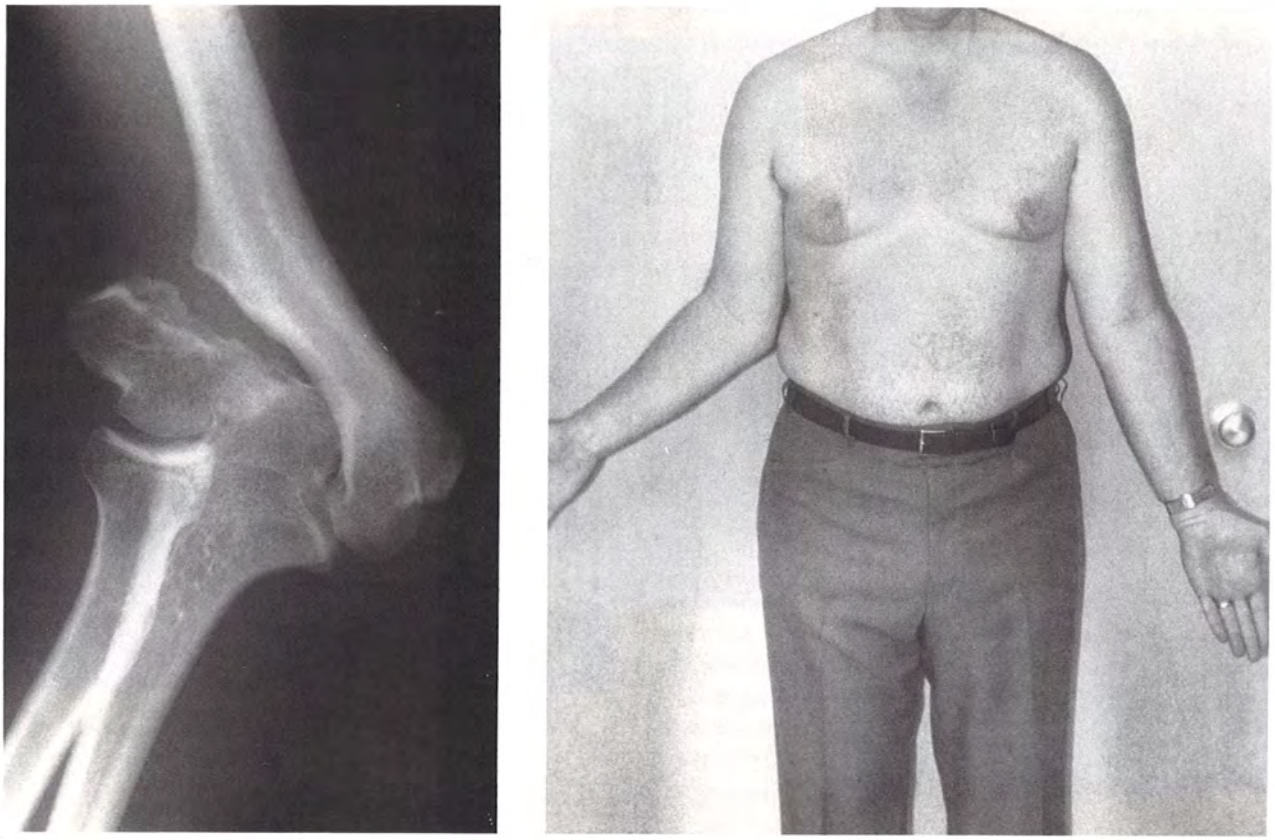

Fig. 6 **Left**, Established nonunion in 30-year-old man after untreated fracture of lateral humeral condyle. **Right**, Clinical appearance with cubitus valgus and mild elbow flexion contracture.

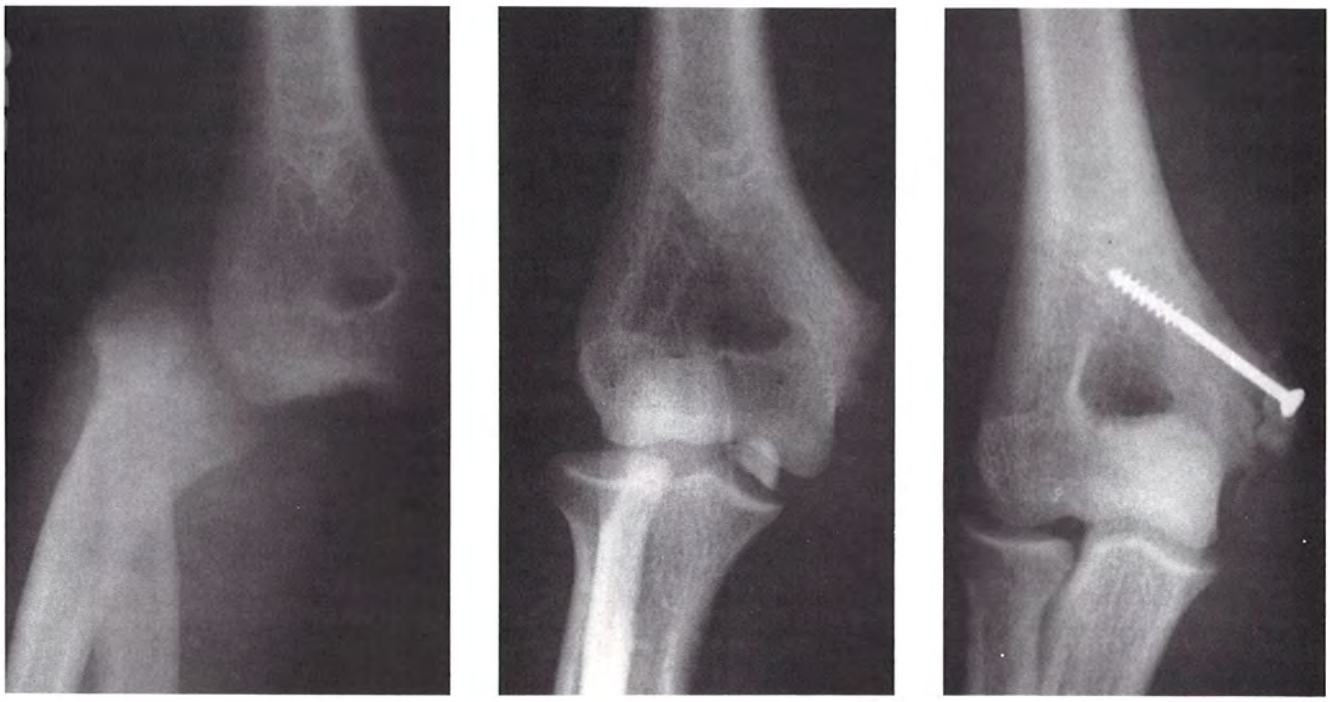

Fig. 7 **Left** and **center**, 15-year-old boy with posterolateral elbow dislocation and fracture of medial epicondyle, which was trapped in joint following reduction. **Right**, After open reduction and internal fixation with small fragment screw.

Fig. 8 **Top left** and **top right**, T-condylar fracture in 14-year-old girl. **Bottom left** and **bottom right**, After olecranon osteotomy, open reduction, and internal fixation with acetabular reconstruction plates and screws.

Fig. 9 Monteggia fracture-dislocation.

(flexion or extension) and remains in place for six to eight weeks. After closed reduction the position of the radial head relative to the capitellum should be confirmed by roentgenograms. Open reduction and internal fixation may be required if soft tissue interposition makes closed reduction of the radial head impossible. In younger children and adolescents, open reduction may be required for acute, irreducible injuries. If reduction of the ulnar fracture fails, soft tissue interposition (such as the annular ligament, capsule, or anconeus muscle) must be surgically corrected to obtain reduction of the radial head. The older the child, the more likely that ulnar fixation will be required. Intramedullary fixation or compression plating of the ulna, as in adults, may be performed depending on the age of the child and the level of the ulnar fracture (Fig. 10).

The treatment of undetected, untreated Monteggia lesions is controversial.[34–36] Historically, radial head resection after skeletal maturity has been recommended for symptomatic untreated Monteggia fracture-dislocations. Recent reports indicate that the radial head may be satisfactorily reduced as late as 24 months after dislocation. Late treatment may require reconstruction of the annular ligament, as well as a reduction of the radial head (Bell-Tawse proce-

Fig. 10 **Top left**, A 13-year-old boy with anterior Monteggia fracture-dislocation, open Type I ulnar fracture. **Right** and **bottom left**, Postoperative irrigation and debridement ulnar fracture, compression plate fixation, reduction of radial head.

Fig. 11 **Top left**, A 5-year-old boy with acute anterior Monteggia lesion. **Top right**, Three months later, ulna healed, radial head dislocation undetected. **Bottom right**, Postoperative lengthening. Angulation osteotomy of ulna, annular ligament reconstruction, reduction of radial head.

dure).[37] Angulation-lengthening osteotomy of the ulna may be necessary to allow stable radial head reduction (Fig. 11).

Posterior interosseous nerve palsy is not infrequent with this injury, but most patients recover spontaneously.[34] Migration and breakage of transcapitellar pins also have been reported. Compartment syndrome, myositis, and synostosis of the proximal radius and ulna are infrequent complications.[38]

Fractures of the Olecranon

Fractures of the olecranon are infrequent in children, constituting only 5% of all elbow fractures.[39-41] These fractures generally result from a fall in which the child lands directly on the elbow. Olecranon fractures are of two types: physeal separation and metaphyseal fracture. They are classified by the mechanism of injury: flexion, extension, valgus, varus, or shear. If the fracture is displaced less than 5 mm, it should be immobilized in the most stable position, usually 45 degrees of elbow flexion, for three to six weeks. Open reduction and internal fixation using AO technique are indicated for unstable fractures. Olecranon fractures frequently occur in association with fractures of the radial head and neck, and these should be sought on initial roentgenograms. A "simple" olecranon fracture may be part of a Monteggia lesion, so radial head position should be evaluated carefully.

Fractures of the Radial Head and Neck

Fractures of the radial head and neck also are rare in children, and most occur in children between 4 and 14 years of age. The radial neck is fractured

Fig. 12 **Top left**, Type A (Salter-Harris type II) fracture of radial neck. **Top right**, Type B (Salter-Harris type IV) fracture of radial head. **Bottom left**, Type C (completely displaced) fracture of radial neck with anterior displacement of proximal fragment. **Bottom right**, After open reduction and internal fixation with two small, oblique K-wires.

more frequently than the radial head, and most radial neck fractures occur through the metaphysis. The most common mechanism of injury is a fall.[42-47] These fractures are generally classified as a valgus fracture (type I) or a fracture with an elbow dislocation (type II). Wilkins[48] divided valgus injuries into three categories: type A, Salter-Harris types I and II fractures (Fig. 12, *top left*); type B, Salter-Harris type IV fractures (Fig. 12, *top right*); and, type C, fractures of only the proximal metaphysis. Displacement is characterized as degrees of angulation, percentage of translocation, or total displacement (Fig. 12, *bottom left* and *bottom right*).

Treatment should be by closed methods if possible. Satisfactory results can be obtained with angulation of 25 to 50 degrees and displacement or translation of less than 50%. If manipulation is required for reduction, traction should be used with a varus force and direct pressure applied to the radial head. Percutaneous manipulation with image intensification has been reported,[49] but long-term results are not yet available. Open reduction through a lateral approach is indicated when angulation is more than 60 degrees or displacement is more than 50%.[50-52] Fixation should be with small oblique K-wires, which are removed early, at three weeks if possible. Complica-

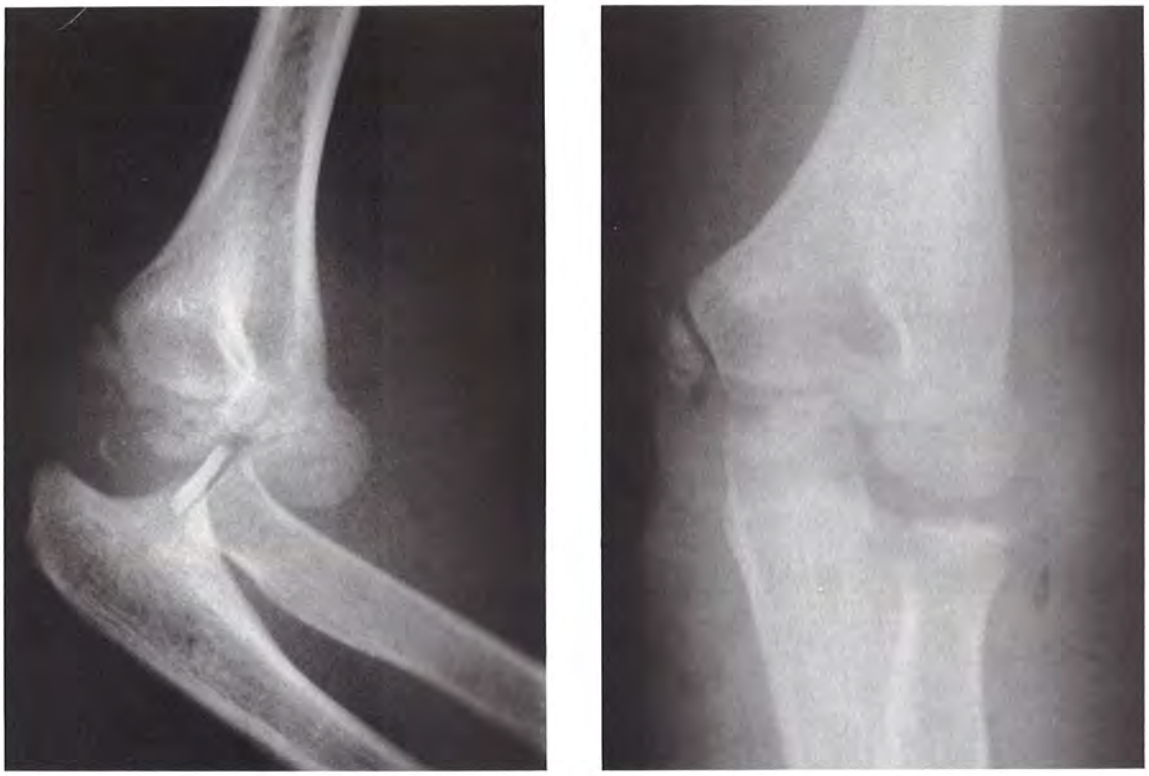

Fig. 13 Posterior elbow dislocation (**left**) that after reduction showed no associated fracture (**right**).

Fig. 14 Displaced fracture of lateral humeral condyle after posterior dislocation of elbow in 5-year-old boy.

tions include osteonecrosis, which appears to remodel somewhat with growth, and synostosis, which may occur after severe injury and surgical treatment.

Elbow Dislocations

Elbow dislocations, which account for approximately 6% of all elbow injuries, occur most frequently in males (70%). Generally elbow dislocations are classified as having the proximal radioulnar joint intact or divergent. Dislocations with intact joints (Fig. 13) may be posterior, anterior, medial, or lateral; most are posterior.[53] Dislocations with divergence of the joint may be anteroposterior or transverse; these are rare.[54]

Most posterior elbow dislocations can be treated with closed reduction by the use of traction and the application of pressure on the olecranon.[55] The elbow is immobilized for 10 to 14 days. Open reduction rarely is indicated for an irreducible dislocation, an open injury, or a dislocation associated with intra-articular fractures of the same elbow. There is a high incidence of associated fractures with elbow dislocations (as frequent as 50% in children), especially fractures of the radial head and neck (Fig. 14), the lateral condyle, and the medial epicondyle. Vascular injury is rare,[56] but should be suspected in open

dislocations.[57] Nerve injuries occur in approximately 10% of patients, but most recover spontaneously. Rarely, the median nerve or brachial artery is entrapped after reduction and requires surgical correction.[56-63] Recurrent elbow dislocations have been reported occasionally, and these require special treatment.[64,65]

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