Radial head fractures are the most common type of elbow fractures. These fractures can occur in isolation or be associated with other elbow fractures and ligament injuries. Associated injuries include coronoid fractures, distal humerus articular shear fractures, Monteggia’s fractures, and disruption of the collateral ligaments, interosseous ligaments, or both [1–3].

Although a consensus has emerged that favors the nonsurgical treatment of undisplaced fractures [4], controversy surrounds the treatment of displaced radial head fractures [5]. Options for the treatment of displaced fractures include nonoperative management, fragment excision [6,7], whole head excision [8–10], open reduction and internal fixation (ORIF) [11–15], and radial head arthroplasty [16–22].

The purpose of this article is to review the mechanisms that result in radial head fracture, to describe important physical findings that assist in identifying injuries associated with radial head fractures, and to define the role of the various interventions described for the treatment of radial head fractures.

Mechanism of injury, symptoms, and signs

Elbow stability is maintained by the complex interplay among articular surfaces, ligaments, and muscles. The radial head is an important valgus stabilizer of the elbow, particularly in the setting of an incompetent medial collateral ligament, which is the primary stabilizer against valgus force [23–26]. The radial head is also an important axial stabilizer of the forearm and resists varus and posterolateral rotatory instability by tensioning the lateral collateral ligament [27,28]. In addition, up to 60% of the load transfer across the elbow occurs through the radiocapitellar articulation [29].

Radial head fractures typically result from a fall on the outstretched arm. Axial, valgus, and posterolateral rotational patterns of loading are all thought to be potentially responsible for these fractures (Fig. 1A–C). An axial force applied to the wrist is transmitted proximally and can exit through the radial head. In addition to radial head fractures, rupture of the interosseous ligament of the forearm can lead to complex injury patterns such as the Essex-Lopresti injury [30,31]. When a valgus force is applied to the elbow, the radial head can fail in compression, with resultant medial collateral ligament rupture. The final injury mechanism is associated with posterolateral rotatory instability. As the lateral collateral ligament complex fails, an episode of elbow subluxation can result in shear injuries of the radial head, coronoid, and distal humerus [3].

In addition to recognizing signs directly associated with an acute radial head fracture, the physical examiner should also identify signs associated with elbow or forearm instability. Inspection may reveal ecchymosis and swelling along the forearm and medial and lateral aspects of the elbow, which may correspond to associated ligamentous injuries. Careful palpation of the radial head, distal humerus, proximal ulna, medial and lateral collateral ligaments of the elbow, the...
interosseous ligament of the forearm, and the distal radioulnar joint should be performed in addition to careful examination of the adjacent joints such as the shoulder and wrist. Elbow range of motion (ROM) including forearm rotation should be evaluated, and the presence of crepitus or a block to motion should be noted. Aspiration of the hemarthrosis and intra-articular injection of local anesthetic is helpful in determining whether restricted motion is a consequence of pain or a true mechanical block to motion. A careful vascular and neurologic assessment of radial, median, and ulnar nerves should be performed.

**Imaging**

Anteroposterior, lateral, and oblique elbow radiographs, with the x-ray beam centered on the radiocapitellar joint, usually provide sufficient information for the diagnosis and treatment of radial head fractures. If the biceps tuberosity is included in the radiographs, then the relationship of the fracture to the radius shaft can often be
determined. This information is helpful when planning surgical exposures.

Bilateral posteroanterior radiographs of both wrists in neutral rotation should be performed when the clinical examination reveals forearm or ulnar-sided wrist pain that is suggestive of injury to the interosseous ligament. The ulnar variance should be evaluated because there is a higher incidence of an associated interosseous ligament injury in this group of patients [1].

CT with sagittal, coronal, and three-dimensional reconstructions may assist with preoperative planning and can help the surgeon predict whether a displaced radial head fracture can be treated with ORIF or whether an arthroplasty is needed.

Classification

Mason [32] classified radial head fractures as type I, fissure or marginal sector fractures without displacement; type II, marginal sector fractures with displacement; or type III, comminuted fractures involving the whole head. Mason’s original classification was subsequently modified by Johnston [33] with the addition of a fourth type, a radial head fracture associated with an elbow dislocation. Morrey [34] further modified Mason’s classification by including radial neck fractures and stratifying fractures based on significant articular segment displacement (>2 mm) and fragment size (≥30% of the articular surface).

Hotchkiss [35] applied management guidelines to the Mason classification for radial head fractures. Type I fractures are minimally displaced and can be treated nonsurgically. Type II fractures are displaced greater than 2 mm or block normal forearm rotation and can be successfully treated with ORIF. Type III fractures are comminuted, not amenable to ORIF, and treated with excision or arthroplasty. Although these guidelines help with intraoperative decision making, they do not provide preoperative criteria to determine the fracture type or guidelines for treatment. Mason’s classification remains the most widely used in clinical practice, even though it has been shown to have poor to moderate intra- and inter-observer reliability [36].

Treatment options

Important factors to consider when making treatment decisions include radial head fracture configuration, associated fractures, elbow and forearm ROM, and clinical or radiographic findings that suggest elbow or forearm instability. Bone quality, fragment size, comminution, impaction, and displacement influence decision making regarding the optimal management of each radial head fracture. Fragments that are displaced and interfere with elbow or forearm ROM need to be identified and treated. Clinical or radiographic findings that suggest collateral ligament instability or forearm axial instability need to be considered when developing a management plan.

Nonoperative treatment

Undisplaced or small (<33% of radial head) minimally displaced fractures (<2 mm) usually originate from the anterolateral aspect of the radial head and can be treated with early motion provided that there is no mechanical block to motion [4,37]. Aspiration of the hemarthrosis and intra-articular injection of a local anesthetic help the treating physician rule out a mechanical block, provide pain relief, and permit early ROM [38]. Treatment consists of a collar and cuff sling and initiation of active ROM exercises within 2 to 3 days as the injury discomfort subsides. ROM should improve within the first 6 weeks following the injury and often returns to a functional range within 6 to 12 weeks. In cases in which extension does not improve progressively within the first 6 weeks, nighttime static progressive extension splints may be used.

Most series report 85% to 95% good results for undisplaced fractures managed with early motion [6,39,40]. Fractures initially treated nonsurgically and remaining symptomatic can be treated with delayed excision of the fractured radial head with satisfactory results, providing that the interosseous membrane and medial collateral ligament are intact [41]. Akesson and colleagues [42] reported favorable results with conservative treatment of moderately displaced radial head fractures (Mason type II) at a mean follow-up of 19 years. The absolute amount of displacement that can be successfully treated nonsurgically with early ROM remains undefined.

Operative treatment

Surgical approaches

The patient can be positioned supine with the affected arm on an arm table, supine with a sandbag placed beneath the ipsilateral scapula.
to assist in positioning the arm across the chest, or in a lateral position with the affected arm held over a bolster.

A midline posterior elbow incision is made just lateral to the tip of the olecranon, and a full-thickness lateral fasciocutaneous flap is elevated on the deep fascia. This extensive incision decreases the risk of cutaneous nerve injury and provides access to the radial head, coronoid, and medial and lateral collateral ligaments for the management of more complex injuries [43,44]. Alternatively, a lateral skin incision centered over the lateral epicondyle and passing obliquely over the radial head can be used. In many circumstances, the radial head is easily visualized after opening the subcutaneous tissue due to avulsion of the lateral collateral ligament and common extensor muscles from the lateral epicondyle during the injury [45].

Splitting the extensor digitorum communis (EDC) tendon is useful for exposure of the anterior and lateral portions of the radial head. The EDC is split longitudinally at the midportion of the radial head, and the underlying radial collateral and annular ligaments are incised [35]. Dissection should remain anterior to the lateral ulnar collateral ligament to prevent iatrogenic posterolateral rotatory instability. The forearm is pronated to move the posterior interosseous nerve distally, medially, and away from the surgical approach [46,47]. The humeral origin of the radial collateral ligament and the overlying extensor muscles are elevated anteriorly off the lateral epicondyle to improve the exposure if needed.

The Kocher [48] approach is useful for exposure of the lateral and posterior portions of the radial head. The fascial interval between the extensor carpi ulnaris and anconeus muscles is identified by the diverging direction of the muscle groups and the small vascular perforators that exit at this interval. The extensor carpi ulnaris is elevated anteriorly off the lateral collateral ligament complex such that the radial collateral and annular ligaments can be incised at the midaxis of the radial head without jeopardizing elbow stability and without violating the integrity of the lateral ulnar collateral ligament. This approach provides greater protection to the posterior interosseous nerve compared to the EDC split but puts the lateral collateral ligament complex at a greater risk. Therefore, the anconeus muscle should not be elevated posteriorly.

When further exposure is required, release of the lateral collateral ligament can be considered, but careful ligament repair is required at the end of the procedure to restore varus and posterolateral rotatory stability to the elbow [27,49].

Open reduction and internal fixation

Displaced fractures that cause painful crepitus, cause restricted motion, or are associated with elbow instability patterns are managed with ORIF. Satisfactory outcomes are reported in case series when anatomic reduction and stable internal fixation is achieved [12,14,15,50]. Ikeda and colleagues [51,52] reported satisfactory and good results in patients who had comminuted Mason type III fractures of the radial head and underwent ORIF. Because the presence of greater than three fragments is associated with a greater risk of early failure of internal fixation, nonunion, and loss of forearm rotation, ORIF is not recommended in these cases [50].

As has been emphasized earlier, comminuted fractures of the radial head are often associated with a complex injury to the elbow, forearm, or both, and these additional injuries should be incorporated in to the decision making [1]. After exposing the fracture, the periosteum is usually intact over the metaphyseal fracture line, and every effort should be made to preserve the tenuous blood supply to the fragments by mobilizing them gently while using a dental pick/bone tamp/septal to the reduced anatomic position. Smooth Kirshner wires are useful as "joysticks" to reduce the fragments and for provisional fixation.

Many fixation methods and devices are described in the literature for ORIF, including standard bone screws of various sizes (2.7 mm/2.0 mm/1.5 mm), cannulated screws, variable pitch headless compression screws [53,54], small threaded Kirshner wires, fibrin adhesive seal [55], and absorbable pins and screws (Fig. 2A–D) [56–59]. The described fixation methods have similar reported outcomes, and no fixation method has demonstrated superiority over the other methods.

Fractures of greater complexity involving the entire head or neck require fixation that spans the head–neck junction. A number of fixation options exist, including small T- and L-shaped plates, mini condylar blade plates, locking plates, cross-cannulated screws, and precontoured anatomic radial head locking plates [60]. In noncomminuted head–neck fractures, a cross-cannulated screw technique is satisfactory, whereas the presence of a neck comminution or a metaphyseal defect is best treated with plate fixation (Fig. 3A–D). If necessary, bone graft for
metaphyseal defects can be obtained from the lateral epicondyle or olecranon.

Regardless of fixation technique, care should be taken to place the implants within the “safe zone” of the radial head. The safe zone can be determined clinically by a subtended arc of 90°, with the arc midpoint directly lateral when the forearm is in the neutral position (Fig. 4) [61,62]. The safe zone can be visually confirmed because the cartilage is slightly grayish and thinner than the thicker, white cartilage of the articulating portion. Care should be taken to avoid screw tip penetration through the opposite cortex and to countersink the screw heads, particularly if the screws have been inserted outside the safe zone. Prominent internal fixation may interfere with forearm rotation, irritate adjacent soft tissues, and require removal.

The role of arthroscopy remains undefined in the treatment of radial head fractures. The advantage of arthroscopy includes improved joint surface visualization without performing the usual releases associated with open surgery. A recent description of an arthroscopic technique for the percutaneous fixation of radial head fractures reported preliminary satisfactory functional outcomes [63].

**Radial head excision**

Radial head fractures that are displaced, too comminuted for stable anatomic internal fixation, and too large for fragment excision alone should...
be managed by radial head excision with or without arthroplasty. Complete fragment excision can be confirmed with the use of an image intensifier and by reassembling all the fracture fragments.

Following excision of the radial head, elbow and forearm stability must be assessed clinically and fluoroscopically by varus/valgus and axial stress. The capitellum is evaluated for chondral injuries or osteochondral fractures. Associated fractures of the coronoid are managed as indicated, and their fixation should be performed before radial head replacement. In patients who have complex elbow instability, radial head excision without arthroplasty is contraindicated.

Resection of the radial head can be done arthroscopically (in cases in which radial head arthroplasty is not required) while providing the surgeon the ability to address other intra-articular pathologies [64,65].

Biomechanical data have demonstrated an alteration in the kinematics, load transfer, and stability of the elbow following radial head excision that may lead to premature cartilage wear of the ulnohumeral joint and to secondary pain due to arthritis [66,67]. Delayed radial head resection is intended to improve forearm rotation and to alleviate some of the pain originating from the radiocapitellar arthrosis in cases of radial head malunion or nonunion [41]. Long-term follow-up

Fig. 3. Anteroposterior (A) and lateral (B) radiographs of a 26-year-old man who sustained a comminuted fracture of the radial head with metaphyseal extension. (C, D) Postoperative radiographs following ORIF of the radial head with a low profile radial head plate and fixed-angle locking screws. The patient developed a forearm rotation contracture requiring hardware removal and contracture release.
studies suggest a high incidence of radiographic arthritis with radial head excision, although the incidence of symptomatic arthritis varies widely among series [8–11,68,69].

**Radial head arthroplasty**

Radial head arthroplasty for fracture is indicated for unreconstructable displaced radial head fractures with an associated elbow dislocation or a known or possible disruption of the collateral or interosseous ligaments. Current available designs include monoblock metal implants [16,17], press-fit and ingrowth stems, cemented stems, bipolar implants [70], and ceramic designs. Various prosthetic materials have been employed for radial head arthroplasties, such as acrylic [71], silicone rubber [72], cobalt-chromium alloy [70,73], and titanium [16].

Silicone radial head arthroplasty, although initially successful in many patients, has been abandoned for several reasons [11,72,74,75]. First,
silicone has been shown to provide little axial or valgus stability to the elbow, a feature that is critical in the setting of elbow instability [24]. Second, mechanical failure such as implant wear, fragmentation, and fracture was a frequent complication seen with this implant material. Third, synovitis due to particulate wear debris has been associated with progressive and generalized joint damage [76–79]. New modular metallic implants that closely match patient anatomy [80] and have simplified implantation have been developed to address the shortcomings of silicone radial head arthroplasty (Fig. 5A–D).

The resected radial head serves as a template for sizing of the prosthesis. At the time of trialing or implantation, the diameter, height, tracking, and congruency of the prosthesis is evaluated visually and with the aid of an image intensifier. The alignment of the distal radioulnar joint, ulnar variance, and the width of the lateral and medial portions of the ulnohumeral joint are checked under fluoroscopy. Overstuffing the radiocapitellar joint, suggested by a nonparallel medial ulnohumeral joint space that is wider laterally due to a radial head implant that is too thick, should be avoided to reduce the risk of cartilage wear on the capitellum from excessive pressure [81].

The short- and medium-term results of metallic radial head implants are encouraging. Moro and
colleagues [82] reported the functional outcome of 25 patients who had unreconstructable fractures of the radial head managed with a monoblock metallic radial head arthroplasty. The average follow-up was 39 months. The results were rated as good or excellent in 17 patients, fair in 5, and poor in 3, and no patient required removal of the implant. The radial head prosthesis was shown to restore elbow stability when stability was jeopardized; however, there were mild residual deficits in strength and motion. Grewal and colleagues [18] reported similar findings in a cohort of 26 patients treated with a modular metal radial head prosthesis.

Smets and colleagues [83] reported the results of a bipolar radial head prosthesis for comminuted acute Mason type III fractures of the radial head in 13 patients. The mean follow-up was 25 months. The results were rated as excellent or good in 10 patients and fair or poor in 3 patients, and one prosthesis was removed after 8 months due to severely decreased elbow function. There were no dislocations, hardware failures, or signs of loosening, even though the polyethylene insert has the potential to create wear debris leading to osteolysis and loosening. Dotzis and colleagues [20] reported the medium-term results of the Judet floating radial head prosthesis for comminuted radial head fractures in 12 patients at a mean follow up of 5.25 years. There were 10 excellent and good results, 1 fair, and 1 poor, with one significant complication of complex regional pain syndrome. There was no evidence of secondary elbow instability, implant loosening, or osteoporosis of the capitellum.

There is a paucity of literature reporting the long-term outcomes of radial head arthroplasty with respect to loosening, capitellar wear, and arthritis. Harrington and colleagues [17] reported their experience with metallic radial head arthroplasty in 20 patients at an average follow-up of 12 years. The results were excellent or good in 16 patients and fair or poor in 4. Metallic radial head replacement has been shown to provide good clinical and radiographic outcomes in most patients at short- and medium-term follow-up, but additional long-term outcome studies are necessary.

Lateral ligament complex repair

The lateral ligament complex is an important stabilizer against varus and posterolateral rotational instability of the elbow. Following radial head repair or replacement, the lateral ligament complex and extensor muscle origins are repaired to the lateral epicondyle. If the lateral ulnar collateral ligament (posterior portion of lateral ligament complex) remains attached to the lateral epicondyle, then the anterior half of the lateral ligament complex (the annular ligament and radial collateral ligament) is repaired to the posterior half. This repair is followed by closure of the muscle-splitting interval that was used for initial exposure.

The lateral collateral ligament and the extensor origin should be securely repaired to the lateral epicondyle if they have been completely detached by the injury or by surgical exposure. Nonabsorbable running locked sutures grasp the ligament and are passed through diverging transosseous tunnels that originate from the center of rotation of the radiocapitellar joint (the center of the arc of curvature of the capitellum), which is the origin of the lateral ulnar collateral ligament. Suture anchors inserted into the center of rotation of the radiocapitellar joint can also be used for ligament repair. A disadvantage of suture anchors is that in cases of complex elbow instability requiring hinged external fixation (acutely or for delay chronic instability requiring reconstruction), insertion of the fixator center axis pin can be blocked by the previously placed suture anchor. For this reason and for cost saving, the authors prefer the transosseous repair technique. After the ligament has been repaired, the capsule is closed and the common extensor origin is repaired to the lateral supracondylar ridge.

Following ORIF or arthroplasty and lateral soft tissue repair, the elbow should be placed through an arc of flexion-extension to carefully evaluate for elbow stability in pronation, neutral, and supination [84,85]. Patients who have persistent instability may require repair of the medial collateral ligament and flexor pronator origin if the elbow subluxates at 40° or more of flexion.

Rehabilitation

For an isolated radial head replacement treated with a lateral ulnar collateral ligament sparing approach, active ROM should be initiated on the day following surgery. A collar and cuff with the elbow maintained at 90° is employed for comfort between exercises. A static progressive extension splint is fabricated for nighttime use for patients who do not have associated ligamentous disruptions and is employed for a period of
12 weeks. The splint is adjusted weekly as extension improves. In patients who have associated elbow dislocations or residual instability, extension splinting is not implemented until 6 weeks after surgery.

Patients who have associated fractures, dislocations, or ligamentous injuries should commence active flexion and extension motion within a safe arc 1 day postoperatively. Active forearm rotation is performed with the elbow in flexion to minimize stress on the medial or lateral ligamentous injuries or repairs. Extension is performed with the forearm in the appropriate rotational position, that is, pronation, if the lateral ligaments are deficient and the medial ligaments are intact [49]; supination, if the medial ligaments are deficient and the lateral ligaments are intact/repaired [86]; and neutral, if both sides have been injured/repaired. A resting splint with the elbow maintained at 90° and the forearm in the appropriate rotation is employed for 3 to 6 weeks. Passive stretching is not permitted for 6 weeks to reduce the incidence of repair attenuation and heterotopic ossification. Strengthening exercises are initiated after the ligament injuries and any associated fractures have adequately healed, usually at 8 to 12 weeks postoperatively.

For patients who have complex elbow injury undergoing any surgical intervention on the radial head, prophylactic therapy with oral indomethacin, 25 mg three times a day for 3 weeks, may be considered to potentially lower the incidence of heterotopic ossification.

Complications

Posterior interosseous nerve injury can occur as a consequence of dissection distal to the radial tuberosity or due to placement of anterior retractors around the radial neck [46]. A recent study showed that the posterior interosseous nerve is an average of 3.8 cm distal to the articular surface of the radius during pronation [47]. The forearm should be pronated while exposing the radial head, especially when the EDC splitting approach is being used. Some investigators recommend identifying the nerve when dissection onto the radial neck is required [35].

Stiffness, nonunion, malunion, avascular necrosis, and painful/prominent hardware are complications associated with radial head fractures [15,32,50,87]. Stiffness is the most frequent complication and can be due to capsular contracture, scarring of the annular ligament, heterotopic ossification, or retained cartilaginous or osseous fragments. In cases of stiffness due to capsular contracture, passive stretching should be initiated under the supervision of a physical therapist, with the concomitant use of static progressive splints. A flexion cuff may be used to regain terminal elbow flexion [87]. In refractory cases, turnbuckle splinting should be instituted 12 to 16 weeks postoperatively [88], and dynamic prosupination splinting should be used in cases of reduced forearm rotation [89]. In recalcitrant cases, open or arthroscopic capsular release may be done with satisfactory outcomes [87,90].

Instability or recurrent dislocations of the elbow due to an inadequate or failed ligament repair can be addressed with protective splinting, ligament reconstruction, or application of an articulated external fixator.

Prosthetic loosening, polyethylene wear, and capitellar wear and pain due to an overstuffed implant are complications associated with radial head arthroplasty [81,91]. Post-traumatic arthritis of the capitellum may arise due to articular cartilage damage from the initial injury or from persistent instability or may be due to increased loads transmitted to the capitellum from an overstuffed radial head arthroplasty. If the radial head implant requires removal for any reason, then the elbow must be carefully examined to ensure valgus and axial stability.

Summary

Radial head fractures are the most common elbow fracture. Nevertheless, there is a paucity of literature demonstrating the long-term results of internal fixation of displaced radial head fractures and of radial head arthroplasty. Consensus exists in the literature regarding the nonsurgical treatment of undisplaced radial head fractures. Controversy surrounds the indications for surgery and the most appropriate intervention for displaced fractures. Further research is necessary to provide a better scientific rationale for making treatment recommendations. There is a need for better guidelines as to which radial head fractures should be treated nonoperatively, which should be managed surgically with ORIF, and which should be treated with a radial head excision with or without arthroplasty.

References


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