Displaced Fractures of the Radial Head: Internal Fixation or Excision?

Robert N. Hotchkiss, MD

Abstract

Displaced fractures of the radial head in the young active patient should no longer be routinely treated with excision of the radial head. Better techniques of imaging, surgical exposure, and implant placement have improved the likelihood of preserving the head. Associated injuries may make preservation of the radial head important for both acute and long-term stability. In patients with suspected injury to the interosseous ligament of the forearm, saving the radial head may prevent pathologic proximal migration. Rigid internal fixation, permitting early mobilization, can be applied to the radial head and neck in a "safe zone" that does not impede motion. Radial-head excision should be performed in patients with grossly comminuted fractures and in those with low demand on their upper extremities.

J Am Acad Orthop Surg 1997;5:1-10

In years past, most of the debate on the treatment of displaced radial-head fractures has centered on the need for excision and on whether silicone replacement was needed after excision.[1-7] Internal fixation of radial-head fractures had been mentioned, but was not reported with regularity until the mid-1980s.[1,8-16] With the availability of more versatile implants for internal fixation and an increasing understanding of the role of the radial head, internal fixation of displaced radial-head fractures is now more widely practiced with reported success. Nonetheless, this operation is technically demanding, and complications can occur. The purpose of this review is to consider the mechanical role of the radial head, to enumerate the indications for internal fixation after fracture, and to discuss the technical details of internal fixation and the avoidance of complications.

The Mechanical Role of the Radial Head

In orthopaedic anatomic studies, it may be erroneous to conclude that form follows function (e.g., assuming that if a ligament is thick, it must be important, or if a bone is large and strong, it must be crucial to skeletal stability). As Stephen Jay Gould has pointed out, this concept relies on a strict Darwinist interpretation that may not always be valid. For example, the coracoacromial ligament may or may not play a role in the stabilization of the shoulder. There is now considerable evidence that the ligament is the source of pathologic impingement and often should be excised. We also know from microsurgical experience that the gracilis and even the large latissimus dorsi can be moved (or removed) without noticeable loss of function. Clearly, size, location, and presence alone are not enough to justify preservation of any structure, including the radial head. It is helpful to review what is currently known about the stabilizing function of the radial head.

Stability of the Elbow

The radial head potentially stabilizes the elbow and forearm in two ways. First, radiocapitellar contact may resist valgus forces,[17-21] preventing recurrent dislocation or excessive valgus displacement. Second, the forearm and wrist are stabilized in grip activity as load is transferred from the wrist to the radiocapitellar joint.[22-25] The magnitude of the load borne by the radial head in both of these situations has not been fully established in laboratory or clinical investigations. Nonetheless, if preservation of the radial head with the use of internal fixation is considered, it is

Dr. Hotchkiss is Chief of Hand Surgery, The Hospital for Special Surgery, New York, and Assistant Professor of Orthopaedic Surgery, Cornell University Medical College, New York.

Reprint requests: Dr. Hotchkiss, The Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021.

important to justify this practice on the basis of the published literature and experience.

Valgus Stability

Laboratory Studies

The valgus stability of the elbow has been studied in the laboratory by several investigators. In 1980, Schwab et al[17] postulated, on the basis of anatomic study, the mechanical contribution of the radial head in resisting valgus deformity. A number of other studies followed in which investigators used a somewhat different technique of testing, confirming, and perhaps exaggerating the stabilizing effect of the radial head.[18-20,26] In the most sophisticated of these studies, that by Morrey et al,[20] the weight of the arm was used as the deforming force. The results demonstrated that the radial head is a secondary stabilizer resisting valgus load. Retention of the radial head seemed to shift the point of rotation in the varus-valgus plane, decreasing the lever arm and the relative load on the medial ligaments (Fig. 1). However, in cadaveric specimens, without the coaptive force of muscle tension, the elbow became grossly unstable if the medial and lateral ligaments were sectioned, whether the radial head was present or absent.

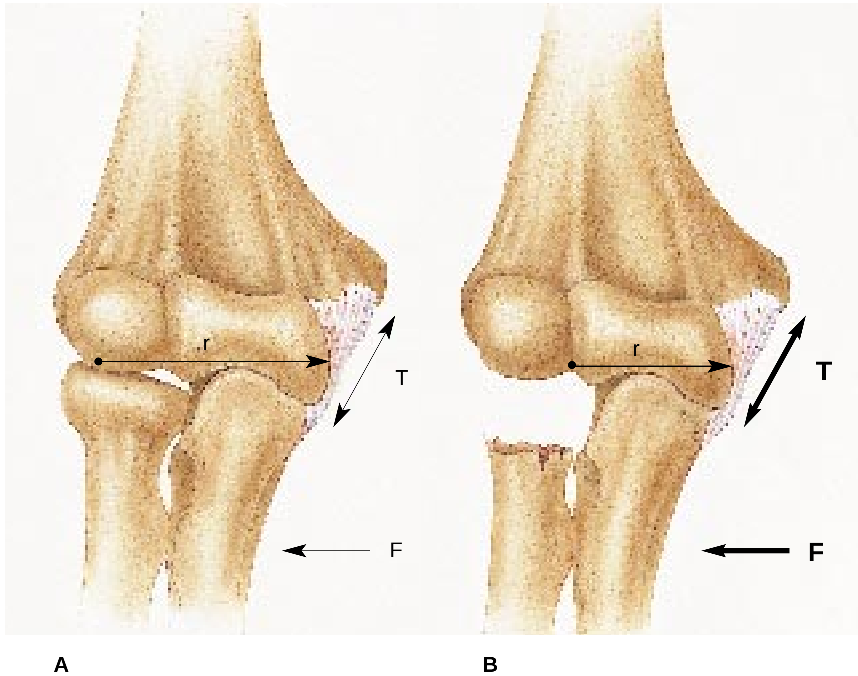


Fig. 1 Mechanical role of the radial head in valgus stability. F represents valgus force; T, tension that develops in the medial collateral ligament; r, distance from the fulcrum to the point of action of the ligament (lever arm). **A,** With an intact radial head, the entire complex is stable. **B,** After excision of the radial head, the same force or torque results in increased tension on the ligament.

Clinical Studies of Acute Instability

Acute fractures of the radial head with dislocation may be associated with gross instability and recurrent acute dislocation. However, this complex injury is quite different from most uncomplicated radial-head fractures. With dislocation, concomitant injury to the anteromedial and posterolateral ulnohumeral ligaments and a fracture of the coronoid may be present, reflecting the severity of traumatic forces. In this setting, the deforming or destabilizing forces that lead to recurrent acute dislocation are more complex than simply a pure valgus load. Therefore, the management of this complex injury, referred to as the “terrible triad” of the elbow, requires attention to the ligaments and muscle-tendon unit as well as joint position and skeletal reconstruction.

The stability of the lateral side of the elbow is enhanced by a combination of tension in the posterolateral ligament complex and compression in the radiocapitellar joint.[27] Radiocapitellar contact with an intact radial head, in combination with a functioning posterolateral ligament complex, will resist posterolateral “rollout” of the joint. In patients with fracture-dislocation, the forearm must be positioned in pronation to protect the repair and maximize the contact at the joint. During healing, the contact at the radial head combined with tension in the ligamentous complex widens the base of support of the elbow. In fact, restoring stability on the lateral side may be more critical for acute stability than repair of the medial side. Unfortunately, the radial-head fracture itself may be too comminuted to permit repair and reconstruction. In this situation, replacement with a silicone or metallic prosthesis may be needed, although these devices are not without problems.

Clinical Studies of Chronic Instability

There is little evidence in clinical studies that loss of radial-head contact in the otherwise normal elbow leads to excessive valgus laxity or instability over the long term. The valgus laxity noted on physical examination by some investigators[2-5] was more prominent after radial-head excision but does not seem to have been clinically disabling. A search of the literature disclosed no reports of pathologic valgus laxity or late recurrent elbow dislocation secondary to radial-head excision alone. If the patient is a throwing athlete, there may be a greater need to retain the radial head, as the valgus load of the pitching arm may be quite high; however, this remains only theoretical.

Longitudinal Stability

Laboratory Studies

Load sharing at the elbow between the radius and the ulna with grip activities and lifting is still poorly understood in the intact upper extremity. Although Halls and Travill[23] tried to measure the amount of load sharing at the proximal ulna and radius with loading at the wrist, the experimental methods used were not optimal to answer this question. Although they reported that 60% of the load was borne by the ulna and 40% by the radial head at the elbow, they noted no change in this ratio after incision of the entire soft-tissue connection between the radius and the ulna, including the interosseous ligament of the forearm.

The importance of the interosseous ligament of the forearm has been documented in other studies,[22,28] suggesting that even with an intact upper extremity, a change in load sharing would occur with a change in forearm rotation as the interosseous ligament of the forearm alters shape and alignment. In addition, contact pressures at the radiocapitellar joint have been shown to change with different positions of flexion and extension.[24]

It is known from laboratory studies that the radial head does bear some load at the radiocapitellar joint. Once the radial head has been removed, this can no longer occur. If the main soft-tissue structures linking the radius and ulna (i.e., the interosseous ligament and the triangular fibrocartilage complex) are disrupted, the radius will displace proximally relative to the ulna. In contrast, if the radial head is intact, whether in the minimally displaced fracture or after internal fixation, proximal translation (migration) of the radius is precluded in spite of injuries to the soft tissues linking the radius and ulna.[29]

Clinical Evidence

Proximal displacement of the radius after radial-head fracture or resection has been described by many investigators over the past 50 years. Because of the variable nature of these reports, it is difficult to gauge the risk of asymptomatic and symptomatic migration; estimates range from 20% to 90% of patients after radial-head resection. The principal deformity after proximal translation is at the wrist; the distal ulna sits dorsal and distal to the carpus, blocking supination and extension of the wrist.[30]

Ascertaining the natural history and timing of proximal translation has not been possible, as most reports addressing "proximal migration" did not specify the status of the wrist and forearm ligaments at the time of injury. In addition, it is unclear whether the proximal translation of the radius occurred over the first few weeks or took months or years. Whatever the timing, the principal injury is the loss of mechanical support from radiocapitellar contact and the associated compromise of the interosseous ligament of the forearm. (In the past, the term "interosseous membrane" was used, although in fact the central portion has the structure and function of a ligament.) If the ligament is not torn, proximal movement of the radius is unlikely, although this is not certain.

In patients who present with acute proximal translation (often referred to as the Essex-Lopresti lesion[31]), there is little doubt that the interosseous ligament is torn. All attempts at radial-head preservation should be made if this injury is suspected. Reliable repair of the interosseous ligament has not been reported. Cross-pinning the radius and ulna, in the hope that the ligament will heal in the reduced position, has not been shown to be clinically reliable.[29]

The inability of the interosseous ligament of the forearm to heal has also been documented in a study by Knight et al.[32] In their study of the efficacy of use of a radial-head metallic prosthesis, one patient required removal of the device months after implantation because of loosening. Despite the fact that the radius had been held out to length for months, proximal migration of the radius was evident and symptomatic within weeks of removal of the prosthesis, reaching a full centimeter of radioulnar inequality. Interestingly, at the time of initial treatment, this patient was not noted to have any proximal displacement of the radius, and the prosthesis had been placed to prevent that possibility. The radius translated a full centimeter, suggesting that the interosseous ligament does not heal with mechanical integrity, despite protection for several months.

For longitudinal stability after injury to the interosseous ligament, the radial head is of paramount importance. The intact or repaired radial head can continue to share load at the elbow, precluding proximal migration. As Essex-Lopresti first pointed out,[31] the optimal solution to acute forearm dissociation would probably be internal fixation of the radial head. His use of the subjunctive was necessitated by the lack of surgical possibilities at that time, but was nonetheless conceptually correct.

Another alternative to radial-head preservation is prosthetic replacement. Speed[33] first proposed prosthetic replacement of the radial head in 1941 in an attempt to restore radiocapitellar contact and prevent proximal translation of the radius. He implanted ferrule caps over the neck of the radius but found that they displaced and caused inflammation. Other authors have since reported the use of acrylic, metallic, and silicone radial-head prostheses.[32,34-37]

Interestingly, Mackay et al[34] reported that despite use of a silicone prosthesis, 4 of 16 patients demonstrated more than 4 mm of proximal translation of the radius. Sowa et al[29] also reported that several patients had continued proximal translation of the radius despite use of a silicone prosthesis. As experience with the prosthesis grew, more reports of material failure and dislocation were published.[34,38-40]

For established proximal translation of the radius, shortening of the ulna to correct the wrist deformity has not been consistently helpful, whether achieved by an ulna-shortening osteotomy, the Sauve-Kapandji procedure, or Darrach resection. Temporary equality of length at the wrist is usually achieved, followed by continued proximal translation.[29] In many cases, as Brockman[41] first suggested in l931, the creation of a radioulnar synostosis may be the best solution when there is an established wrist deformity secondary to proximal translation. Creation of a radioulnar synostosis has been the most reliable salvage procedure, principally used to maintain wrist function and flexion and extension of the elbow. However, as Peterson et al[42] have recently shown, patients do not necessarily do well. We have also discovered that patients whose wrists are fixed in neutral forearm rotation (often recommended in the past as the optimal position) find use of a standard keyboard difficult. This is an important consideration as our society becomes more keyboard-dependent.

A return to use of a metallic prosthesis in an attempt to improve load bearing has also been attempted. There is not enough evidence at this time to recommend the routine use of the metallic radial-head implant. Knight et al[32] reported the use of a metallic prosthesis with encouraging results in 21 patients.

Overview

In summary, on the basis of both laboratory and clinical information, the radial head is both necessary and sufficient to prevent longitudinal proximal migration in the patient at risk. In the case of ulnohumeral dislocation, repair and reconstruction of the lateral side, including internal fixation of the radial head, may be sufficient to prevent acute redislocation in the grossly unstable elbow. Chronic valgus instability after radial-head resection does not seem to be a clinical problem that causes catastrophic dislocation.

The radial head is probably increasingly important as the injury becomes more severe and the structures that can substitute for load sharing are injured. The radial head may also be more essential in a vigorous patient who performs lifting and grip activities. This combination of patient activity and injury necessitates consideration of internal fixation of the radial head.

Classification of Radial-Head Fractures

It is not possible to discuss management of fracture of the radial head without discussing the familiar Mason classification.[7] As with most classifications conceived by using a retrospective examination of radiographs and charts, some modification has been needed for contemporary use. The modification that may be useful is based on more than the radiographic appearance and includes features of the clinical examination and an assessment of associated injuries.

As summarized in Table 1, radial-head fractures can be categorized as follows: type I, those that are minimally displaced and require no operative treatment; type II, those that require operative intervention because of displacement and can be either fixed internally or excised; and type III, those that are so comminuted and displaced that internal fixation is technically impossible. With type III fractures, excision is usually needed to permit forearm rotation.

In this classification, it is those fractures that fit into type II that should be considered for internal fixation. Those that fit into type I are not displaced enough to warrant internal fixation, and those that are type III are so severely comminuted that open reduction with secure fixation is technically impossible. This clinical feature of type II fractures, that they are displaced but repairable, is a departure from the original classification, which was based solely on the radiographic appearance. For example, a three-part fracture of the head and neck might have been classified

Table 1
Modified Mason Classification*

Type I: Nondisplaced or minimally displaced fracture of the head or neck
- Forearm rotation (pronation / supination) is limited only by acute pain and swelling (no mechanical block)
- Intra-articular displacement of the fracture is usually <2 mm or a marginal lip fracture

Type II: Displaced (usually >2 mm) fracture of the head or neck (angulated)
- Motion may be mechanically blocked or incongruous
- Without severe comminution (technically possible to repair by open reduction with internal fixation)
- Fracture involves more than a marginal lip of the radial head

Type III: Severely comminuted fracture of the radial head and neck
- Judged not reconstructable on basis of radiographic or intraoperative appearance
- Usually requires excision for movement

* All of these fractures may have associated injuries (e.g., interosseous ligament injury, posterior elbow dislocation with or without coronoid fracture).

type III in the original scheme; however, if the fragments are large and discrete and internal fixation is possible, the fracture would now be considered a type II.

Decision-Making Factors

Age and Demands

As with other fractures being considered for operative intervention, it is helpful to try to classify the patients on the basis of whether they make high or low demands on their elbows (e.g., the 26-year-old athlete versus the 72-year-old retired banker). There are, of course, patients who do not fit easily into either of these two categories; however, if the surgeon is considering preservation of the radial head with the use of internal fixation, the patient should fit into the high-demand group. Likewise, a low-demand patient is less likely to suffer from the ill effects of proximal migration of the radius after radial-head resection. Radial-head excision, if needed, is usually better tolerated by low-demand patients.

The principal caveat regarding age and demand pertains to the patient with associated ulnohumeral dislocation, for whom radial-head preservation could mean the difference between external fixation of the joint and pinning the joint for stability. Generally speaking, the older patient with the displaced radial-head fracture has not suffered a high-energy injury leading to global and acute instability.

Associated Injuries

Acute Instability With Posterior Dislocation

Patients with associated elbow dislocations and coronoid-process fractures may have type II radial-head fractures (Fig. 2). In this situation, internal fixation of the radial head with lateral ligament repair is not only helpful, but may provide enough of a difference that temporary fixation across the joint, whether external or internal, is unnecessary. Early motion, as tolerated, can be initiated with less fear of redislocation.

Injury to the Interosseous Ligament of the Forearm

In patients who exhibit forearm tenderness and radiologic evidence of proximal translation of the radius, internal fixation of the radial head is the optimal treatment. In cases of gross displacement, the radial-head fracture should be repaired but not expected to bear load until skeletal healing has been achieved. It may be helpful to use temporary cross-pins or an external fixator that holds the radius out to length during healing.

When injury to the interosseous ligament of the forearm is not obvious but is suspected on the basis of the clinical examination findings, the use of internal fixation is somewhat more controversial. In these cases, the radial head should be repaired if possible. There is no clinical comparison study of patients with suspected injury to the interosseous ligament who were treated with excision or internal fixation. However, if the patient is at risk for proximal migration of the radius and the surgeon is capable of restoring radial-head function, the optimal outcome is more assured, especially in the younger patient. As reported by Sowa et al,[29] once symptomatic proximal migration has occurred, there are few reliable alternatives (e.g., prosthetic replacement).

In summary, younger active patients with displaced but repairable fractures of the radial head should be considered for internal fixation, especially if there is any suspicion of injury to the interosseous ligament of the forearm.

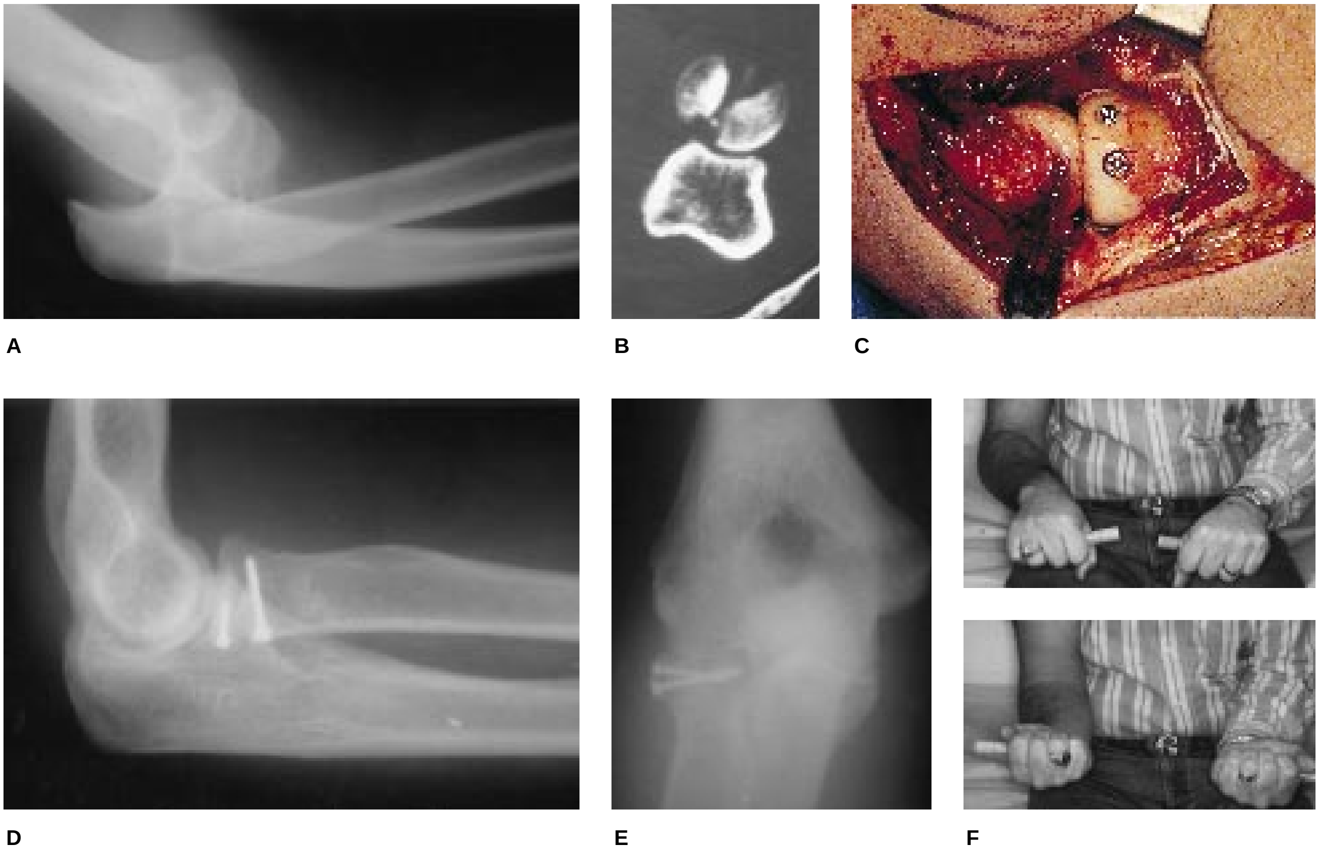


Fig. 2 **A,** Dislocation of the elbow with a type II radial-head fracture. **B,** Computed tomographic scan shows the displaced fracture with fragments amenable to internal fixation. **C,** Open reduction and internal fixation of radial head with two lag screws (one 2.0-mm and one 2.7-mm screw) in the "safe zone." **D** and **E,** Lateral and anteroposterior views obtained 5 months postoperatively. **F,** Pronation and supination approximately 1 year postoperatively. (Parts C and F, copyright Robert N. Hotchkiss, MD)

Internal Fixation of the Radial Head

Exposing and repairing the radial head is not simple and can result in loss, rather than preservation, of radial-head function if not properly planned and executed. In addition to appropriate imaging and preoperative assessment, plans for excision should always be made as a fallback position should internal fixation not be possible. In some cases, there is commensurate injury to the capitellum that cannot be repaired. In other cases, the comminution is so great that adequate fixation is not possible, and excision should be performed, the patient being forewarned.

Preoperative Imaging

In addition to good-quality plain radiographs, computed tomographic (CT) scans also have a role in preoperative evaluation of the radial head. Axial, sagittal, and coronal sections can be quite helpful in estimating the size of fragments and the degree of displacement. If open reduction and internal fixation is under consideration, CT can be used to better visualize the fracture. If the CT study shows less displacement than expected from the plain-radiographic appearance, an unnecessary procedure may be obviated. Reconstructed images are less clear than nonreformatted images. The latter can be obtained by reorienting the limb in the scanner with assistance from the radiology staff.

Surgical Approach

The optimal surgical approach is lateral (Fig. 3), but anterior to the posterolateral collateral ligament complex. The skin incision is centered over the lateral epicondyle and extends distally over the radial head and neck, anterior to the anconeus. This approach differs from the Kocher approach often used for radial-head excision. The goals of the approach are adequate exposure and maintenance and protection of the posterolateral ligament complex. If a plate is needed, the exposure must be extensive enough to allow access to the joint and at least 4 cm of the radial neck.

The anterior surface of the lateral epicondyle is exposed. The capsule is elevated sharply down to bone. A Hohmann retractor can be used to elevate the capsule, and the dissection is then carried distally, elevating the anterior capsule at the level of the capitellum. Care must be taken not to disturb the collateral ligament, which originates from the more posterior portion of the lateral condyle. The articular surface should be bisected as one looks from the vantage point of the lateral aspect of the capitellum. All of the ligamentous origin may be detached anterior to that line. Little or none of the ligament should be elevated posterior to that line, unless needed.

As the capsule is elevated as a single layer to the level of the joint, the annular ligament is elevated as well. If the fracture includes only the head, the incision of the capsule need continue only another 1 to 2 cm to obtain adequate access to the head alone. This is usually not enough, and more distal exposure is required.

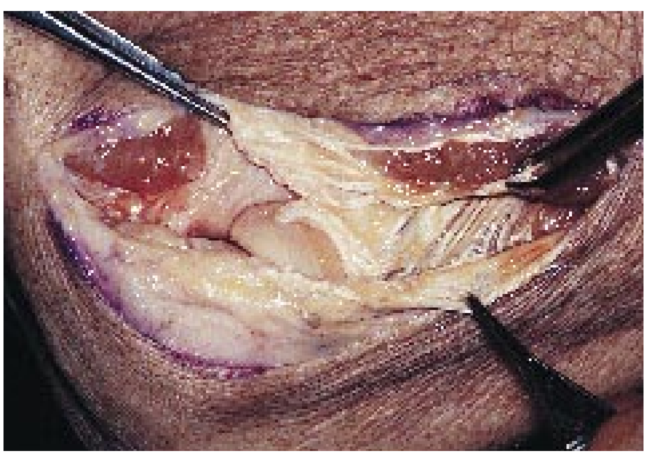
To gain exposure of the neck, the common extensor compartment is entered at the posterior border. The muscle fibers are carefully teased anteriorly. By incising the dorsal aspect of the floor of the extensor compartment, the posterior margin of the supinator is exposed. The muscle fibers are identifiable by their characteristic oblique orientation, nearly 45 degrees from the longitudinally oriented fibers of the extensor compartment. When the fibers of the supinator are identified, they can be divided at their most posterior origin with the forearm in full pronation. This approach protects the posterior interosseous nerve, as well as the posterolateral ligament complex. If there is any doubt as to the location of the posterior interosseous nerve, it can be exposed through the same incision. The nerve is medial to the posterior border by about 2 cm at the level of the radial neck. The nerve courses obliquely, coming closer to the edge of the supinator as the exposure continues distally. If a larger plate that requires distal exposure is being used, the nerve should be identified to ensure its protection. In addition, it may not be advisable to use any retractors (e.g., Bennett and Hohmann retractors) around the radial shaft or neck at this level, because they place too much pressure on the nerve. Deep right-angle retractors are safer. If the surgeon is unfamiliar with this approach, practicing on a cadaveric specimen is worth the time.

Equipment and Hardware

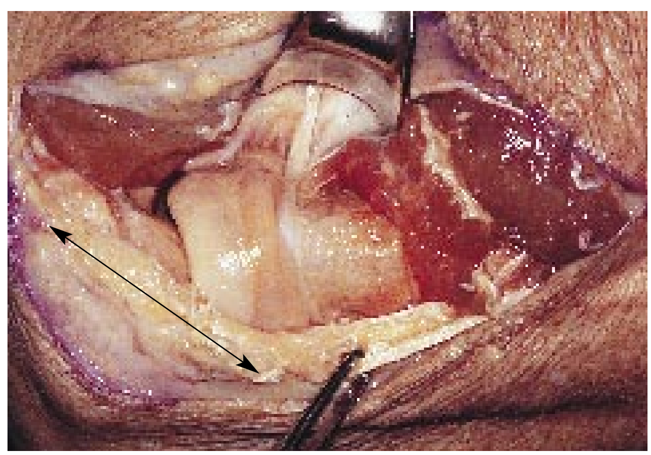
A complete and comprehensive supply of implants for internal fixation should be available before going to surgery. This should include Kirschner wires (for temporary fixation); a mini-fragment internal-fixation set with reconstruction plates, including the minicondylar plate (Synthes); a small-fragment set; and a Herbert mini-screw set (Zimmer).

Operative Technique

The three major technical challenges are reassembling the frac-



A



B

Fig. 3 **A,** Lateral approach to the radial head demonstrates the posterior edge of the supinator. **B,** The supinator has been reflected anteriorly, exposing the radial neck. The line indicates the location of the posterolateral ligament complex. This should be protected if possible. (Copyright Robert N. Hotchkiss, MD) tured head, securing the fractured head to the neck, and ensuring that the implants do not interfere with pronation and supination.

Once the fracture has been thoroughly exposed, the pieces should be positioned so as to reconstruct the head. Small Kirschner wires can be used to temporarily hold the fracture, but there is little room to place the plates and screws. Wires should not be used for permanent fixation. Pins do not provide enough stability for early motion and can fragment (Fig. 4). Rigid internal fixation should be employed.

On the basis of information obtained from anatomic dissections, there is a "safe zone" for hardware placement measuring approximately 100 degrees, centered on the equator in the neutral position (Fig. 5). If this zone is used, both headed screws and plates can be placed without fear of impinging on the proximal radioulnar joint. If the fracture is limited to the head, without extension to the neck, the Herbert mini-screw can be placed below the chondral surface. Use of absorbable pins for this purpose has also been repored, but I have no experience with these implants. Mini-fragment screws can be used (sizes 1.5 to 2.7 mm). Each fracture requires a careful strategy, with use of an implant of appropriate size for the fragment. Traditional lag-screw fixation with overdrilling of the proximal fragment may not be needed if the fragments are tapped while being held in compression. Overdrilling may be risky if the fragment is somewhat small and therefore at risk for fragmentation.

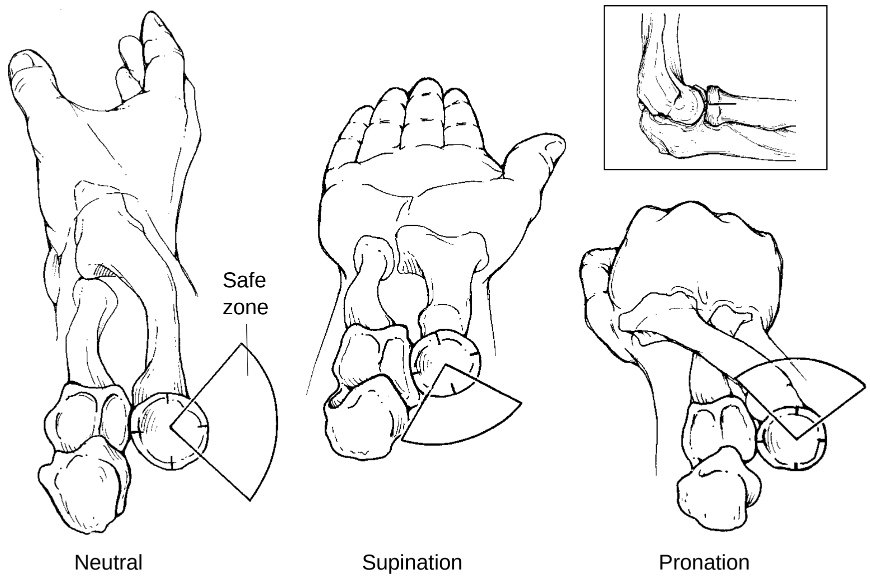


Fig. 5 The safe zone for hardware placement can be found by bisecting the midline of the radial neck in neutral forearm rotation (inset).

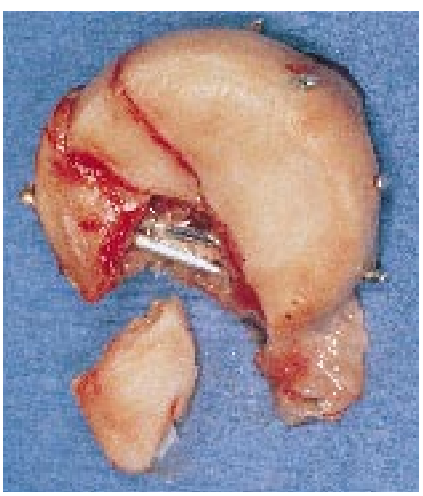


Fig. 4 An attempt at internal fixation of a radial-head fracture resulted in fragmentation and loss of motion. The radial head was resected to improve function. (Copyright Robert N. Hotchkiss, MD)

The head often requires plate fixation to the rest of the neck. In this instance, the incision must be extended distally. If there is any question as to location or safety, the posterior interosseous nerve should be identified. The 2.0 or 2.7 L-shaped plates can be carefully contoured to fit over the neck (Fig. 6), providing excellent fixation. Bone graft should be used to fill in any defects, especially in the area of the neck. The reduction should be checked with pronation and supination in several positions of flexion and extension. Despite detachment of all soft tissue from the head fragments, these fractures seem to heal without collapse due to avascular necrosis.

The lateral capsular complex should be carefully repaired. Occasionally, suture anchors fixed at the lateral epicondyle are helpful in attaining a sound repair of the posterolateral ligament complex. The annular ligament, a component of this structure, is usually secured into position by this repair. Therefore, the annular ligament does not usually require repair as a separate structure. Active motion should be initiated as soon as the patient is comfortable (usually within the first few days).

Complications

Early complications from internal fixation are due to improperly placed hardware, inadequate fixa-

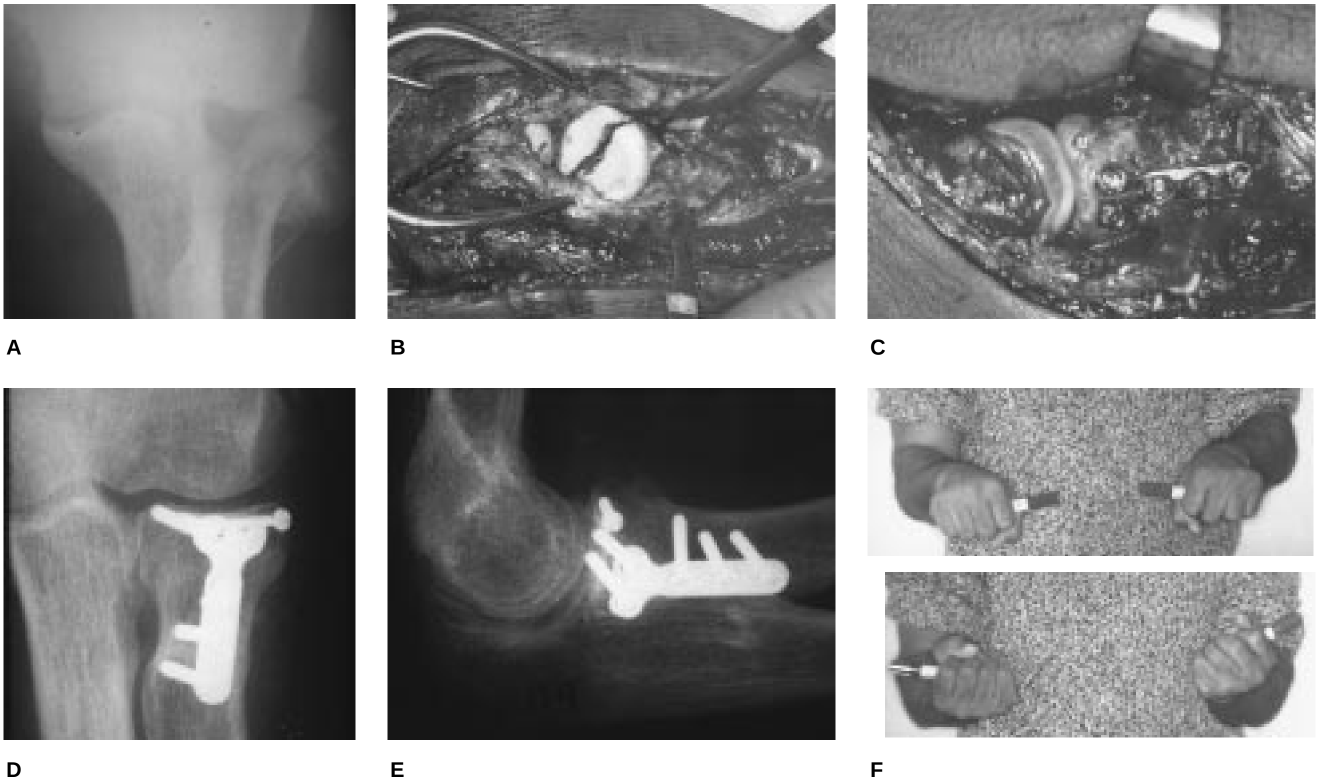


Fig. 6 **A,** Displaced fracture of the radial head and neck treated with open reduction and a contoured plate. **B,** Displaced fracture seen through the lateral approach. **C,** Contoured plate in place. **D** and **E,** Anteroposterior and lateral radiographs obtained after fixation. **F,** Motion after 1 year.

tion, or injury to the posterior interosseous nerve. These complications can be minimized with experience and planning.

Late complications include nonunion, hardware prominence, and elbow stiffness. Although nonunion can occur, it is rare. After healing, the plate may be prominent along the lateral side, being especially notable in thinner patients during forearm rotation. The plate can be removed safely after 4 to 6 months.

Stiffness in the elbow should be minimized by early active motion, emphasizing the extremes of position in extension and flexion. If the lateral ligament was repaired for instability, supination should be limited during the first 4 to 6 weeks after surgery. If not, progressive exercises to enhance pronation and supination are often helpful. It is reasonable to expect some loss of extension, especially in the older patient. Loss of 20 to 25 degrees of extension should not preclude effective function.

Summary

Internal fixation of displaced fractures of the radial head should be considered for active patients. When there is acute instability or concern about proximal migration of the radius and injury to the interosseous ligament of the forearm, preservation of the radial head offers the best solution. The procedure requires careful preoperative planning and a clear understanding of the lateral ligamentous anatomy and the location of the posterior interosseous nerve. Implants should be appropriate for the size of the fragments and must be placed in a manner that does not restrict forearm pronation and supination. Proper placement of internal fixation is imperative for an acceptable result.

References

1. Carstam N: Operative treatment of fractures of the head and neck of the radius. *Acta Orthop Scand* 1950;19:502-526.
2. Coleman DA, Blair WF, Shurr D: Resection of the radial head for fracture of the radial head: Long-term follow-up of seventeen cases. *J Bone Joint Surg Am* 1987;69:385-392.
3. Gerard Y, Schernburg F, Nerot C: Anatomical, pathological and therapeutic investigation of fractures of the radial head in adults [abstract]. *J Bone Joint Surg Br* 1984;66:141.
4. Johnston GW: A follow-up of one hundred cases of fracture of the head of the radius with a review of the literature. *Ulster Med J* 1962;31:51-56.
5. Morrey BF, Chao EY, Hui FC: Biomechanical study of the elbow following excision of the radial head. *J Bone Joint Surg Am* 1979;61:63-68.
6. Adler JB, Shaftan GW: Radial head fractures: Is excision necessary? *J Trauma* 1964;4:115-136.
7. Mason ML: Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg* 1954;42:123-132.
8. Bunker TD, Newman JH: The Herbert differential pitch bone screw in displaced radial head fractures. *Injury* 1985;16:621-624.
9. McArthur RA: Herbert screw fixation of fracture of the head of the radius. *Clin Orthop* 1987;224:79-87.
10. Odenheimer K, Harvey JP Jr: Internal fixation of fracture of the head of the radius: Two case reports. *J Bone Joint Surg Am* 1979;61:785-787.
11. Geel CW, Palmer AK: Radial head fractures and their effect on the distal radioulnar joint: A rationale for treatment. *Clin Orthop* 1992;275:79-84.
12. Khalfayan EE, Culp RW, Alexander AH: Mason type II radial head fractures: Operative versus nonoperative treatment. *J Orthop Trauma* 1992;6:283-289.
13. Perry CR, Tessier JE: Open reduction and internal fixation of radial head fractures associated with olecranon fracture or dislocation. *J Orthop Trauma* 1987;1:36-42.
14. Geel CW, Palmer AK, Ruedi T, et al: Internal fixation of proximal radial head fractures. *J Orthop Trauma* 1990; 4:270-274.
15. Pelto K, Hirvensalo E, Bostman O, et al: Treatment of radial head fractures with absorbable polyglycolide pins: A study on the security of the fixation in 38 cases. *J Orthop Trauma* 1994; 8:94-98.
16. Shmueli G, Herold HZ: Compression screwing of displaced fractures of the head of the radius. *J Bone Joint Surg Br* 1981;63:535-538.
17. Schwab GH, Bennett JB, Woods GW, et al: Biomechanics of elbow instability: The role of the medial collateral ligament. *Clin Orthop* 1980;146:42-52.
18. Hotchkiss RN, Weiland AJ: Valgus stability of the elbow. *J Orthop Res* 1987;5:372-377.
19. Morrey BF, An KN: Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med* 1983;11:315-319.
20. Morrey BF, Tanaka S, An KN: Valgus stability of the elbow: A definition of primary and secondary constraints. *Clin Orthop* 1991;265:187-195.
21. Pribyl CR, Kester MA, Cook SD, et al: The effect of the radial head and prosthetic radial head replacement on resisting valgus stress at the elbow. *Orthopedics* 1986;9:723-726.
22. Hotchkiss RN, An KN, Sowa DT, et al: An anatomic and mechanical study of the interosseous membrane of the forearm: Pathomechanics of proximal migration of the radius. *J Hand Surg [Am]* 1989;14(2 pt 1):256-261.
23. Halls AA, Travill A: Transmission of pressures across the elbow joint. *Anat Rec* 1964;150:243-247.
24. Morrey BF, An KN, Stormont TJ: Force transmission through the radial head. *J Bone Joint Surg Am* 1988;70: 250-256.
25. Walker PS (ed): *Human Joints and Their Artificial Replacements.* Springfield, Ill: Charles C Thomas, 1977, p 190.
26. Sojbjerg JO, Ovesen J, Nielsen S: Experimental elbow instability after transection of the medial collateral ligament. *Clin Orthop* 1987;218:186-190.
27. O'Driscoll SW, Bell DF, Morrey BF: Posterolateral rotatory instability of the elbow. *J Bone Joint Surg Am* 1991; 73:440-446.
28. Rabinowitz RS, Light TR, Havey RM, et al: The role of the interosseous membrane and triangular fibrocartilage complex in forearm stability. *J Hand Surg [Am]* 1994;19:385-393.
29. Sowa DT, Hotchkiss RN, Weiland AJ: Symptomatic proximal translation of the radius following radial head resection. *Clin Orthop* 1995;317:106-113.
30. Hotchkiss RN: Injuries to the interosseous ligament of the forearm. *Hand Clin* 1994;10:391-398.
31. Essex-Lopresti P: Fractures of the radial head with distal radio-ulnar dislocation: Report of 2 cases. *J Bone Joint Surg Br* 1951;33:244-247.
32. Knight DJ, Rymaszewski LA, Amis AA, et al: Primary replacement of the fractured radial head with a metal prosthesis. *J Bone Joint Surg Br* 1993; 75:572-576.
33. Speed K: Ferrule caps for the head of the radius. *Surg Gynecol Obstet* 1941; 73:845-850.
34. Mackay I, Fitzgerald B, Miller JH: Silastic replacement of the head of the radius in trauma. *J Bone Joint Surg Br* 1979;61:494-497.
35. Cherry JC: Use of acrylic prosthesis in the treatment of fracture of the head of the radius. *J Bone Joint Surg Br* 1953;35: 70-71.
36. Gordon M, Bullough PG: Synovial and osseous inflammation in failed silicone-rubber prostheses. *J Bone Joint Surg Am* 1982;64:574-580.
37. Carr CR, Howard JW: Metallic cap replacement of radial head following fracture. *West J Surg Obstet Gynecol* 1951;59:539-546.
38. Bohl WR, Brightman E: Fracture of a silastic radial-head prosthesis: diagnosis and localization of fragments by xerography—A case report. *J Bone Joint Surg Am* 1981;63:1482-1483.
39. Mayhall WS, Tiley FT, Paluska DJ: Fracture of silastic radial-head prosthesis: Case report. *J Bone Joint Surg Am* 1981;63:459-460.
40. Morrey BF, Askew L, Chao EY: Silastic prosthetic replacement for the radial head. *J Bone Joint Surg Am* 1981;63:454-458.
41. Brockman EP: Two cases of disability at the wrist-joint following excision of the head of the radius. *Proc R Soc Med* 1931;24:904-905.
42. Peterson CA II, Maki S, Wood, MB. Clinical results of the one-bone forearm. *J Hand Surg [Am]* 1995;20:609.