Current Concepts Review

Fractures of the Distal End of the Radius

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More than 176 years have passed since Colles described a fracture of the distal end of the radius[24]. It is remarkable that this common fracture remains one of the most challenging of the fractures that are treated non-operatively. Moreover, there is no consensus regarding the description of the condition, the appropriate treatment, or even the anticipated outcome. Many physicians believe that no special treatment is needed, as the resulting deformity rarely results in a loss of function[41]. However, this concept is being challenged, so much so that reports addressing the operative treatment of complex intra-articular fractures of the distal end of the radius now are common[7,15,50,64,65,77].

Incidence

Fractures of the distal end of the radius have been estimated to account for one-sixth of all fractures that are seen and treated in emergency rooms[41,44,50,71]. In an epidemiological survey of all fractures of the forearm that were treated over a five-year period in Malmö, Sweden (urban population during the time of study, slightly more than 200,000), Alffram and Bauer recorded nearly 2,000 fractures of the distal end of the radius. This number represented 74.5 per cent of all fractures of the forearm[2]. The greatest frequency of these fractures occurred in patients whose ages were in two ranges: between six and ten years and between sixty and sixty-nine years. The fractures most commonly resulted from low-energy trauma. Women substantially outnumbered men in the group of patients who were sixty years or older. The authors noted that fractures of the radial styloid process occurred in 2.4 per cent of all fractures of the forearm.

Two studies[74,98] have focused on the prevalence of marginal, shearing-type fracture-dislocations in relationship to all fractures of the distal end of the radius; the prevalence was 1.2 and 2.3 per cent.

Several investigators have attempted to correlate fracture of the distal end of the radius with an increased risk of subsequent fracture of the hip. Owen et al. observed a twofold increase of fracture of the hip in women who had sustained a fracture of the distal end of the radius at seventy years or older, but they did not find a similar association in men or in younger female patients[71].

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Classification

Eponyms such as Colles, Smith, or Barton fracture have been used to describe fractures of the distal end of the radius and continue to be used in the current literature[75]. Unfortunately, the confusion resulting from this inaccurate method of classification has resulted, at times, in the publication of conflicting recommendations with regard to treatment and expected outcome.

In order to be useful, a system of classification must consider the type and severity of the fractures and serve as a basis for selection of treatment and evaluation of its outcome[67]. Over the past quarter-century, a number of classifications have been developed in an attempt at more accurate representation of the variety and extent of fracture patterns of the distal end of the radius. Some have proved more helpful than others in predicting outcome.

Gartland and Werley, in 1951, and Lidström, in 1959, developed systems of classification that were based on the presence, but not the extent, of displacement at the site of the fracture and of involvement of the radiocarpal joint[39,55]. In 1965, Older et al. published an extremely useful system of classification of metaphyseal Colles-type fractures that was based on extent of displacement, dorsal angulation, shortening of the distal fragment of the radius, and presence and extent of comminution of the dorsal metaphyseal cortex[69]. They divided fractures into four groups, ranging from relatively non-displaced fractures (Type I) to considerably displaced fractures with extensive dorsal comminution, extension into the radiocarpal joint, and shortening of the distal fragment of two to eight millimeters proximal to the distal radio-ulnar joint (Type IV). Several more recent prospective studies that have been done with this system of classification concluded that the presence of dorsal comminution and the extent of the initial deformity are the best indicators of the possible later loss of reduction[47,89].

In 1967, Frykman established a system of classification that identified involvement of the radiocarpal and the radio-ulnar joint, as well as the presence or absence of a fracture of the ulnar styloid process[38]. Although this has been accepted by many authors, the system does not include the extent or direction of the initial displacement, dorsal comminution, or shortening of the distal fragment. As such, it has less prognostic value in evaluating the outcome of treatment.

In an attempt to define the unstable fracture of the distal end of the radius further, Cooney et al. suggested that widely displaced fractures with extensive dorsal comminution, dorsal angulation of 20 degrees or more, or extensive intra-articular involvement would have a good chance of redisplacement after reduction[27]. Weber extended this suggestion to include any fracture in which the dorsal comminution extends volar to the mid-axial plane of the radius on the lateral radiograph[102].

Recent systems of classification have focused, in part, on the mechanism of injury and reflect an expanded understanding of the various patterns of fracture[61,64]. Fernandez subdivided fractures of the distal end of the radius according to the mechanism of injury[36]: (1) bending — metaphysis fails due to tensile stress (Colles and Smith fractures), (2) compression — fracture of the surface of the joint with impaction of subchondral and metaphyseal bone (so-called die-punch fracture), (3) shearing — fracture of the surface of the joint (Barton fracture and fracture of the radial styloid process), (4) avulsion — fracture of ligamentous attachments (fracture of the ulnar and radial styloid processes), and (5) combinations of types one through four and high-velocity injuries.

The identification and classification of intra-articular involvement in the distal end of the radius have also been expanded. McMurtry and Jupiter defined intra-articular fractures on the basis of the number of their parts[61]: (1) two parts — the opposite portion of the radiocarpal joint remains intact (dorsal/palmar, Barton, chauffeur, and die-punch fractures); (2) three parts — the lunate and scaphoid facets separate from each other and the proximal portion of the radius; (3) four parts — the same as three parts, except the lunate facet is further fractured into dorsal and volar fragments; and (4) five parts or more — including a wide variety of comminuted fragments. In 1984, Melone further defined the four-part fracture into four subgroups based on the extent of the separation and displacement of the articular fragments[64].

The most detailed classification, to date, is the AO system, which is organized in order of increasing severity of the osseous and articular lesions[67]. The classification divides these fractures into extra-articular (Type A), partial articular (Type B), and complete articular (Type C). Each type is subdivided into three subgroups. Type C, for example, can be divided into C1 (simple articular and metaphyseal fractures), C2 (simple articular with complex metaphyseal fracture), and C3 (complex articular and metaphyseal fractures). These, in turn, can be further subdivided to reflect the morphological complexity, difficulty of treatment, and prognosis. In addition, fractures of the distal end of the ulna can be identified.

Radiographic Anatomy

Three radiographic measurements are accepted in the anatomical evaluation of the distal end of the radius[22,32,39,55,79,81,85,88,99]. All three are recorded in relationship to the longitudinal axis of the radius. On the lateral radiograph, the palmar slope of the distal end of the radius averages 11 to 12 degrees[37]. Radial inclination is measured on the anteroposterior radiograph and is represented by the angle formed by a line drawn from the tip of the radial styloid process to the ulnar corner of the articular surface of the distal end of the radius and a line drawn perpendicular to the longitudinal axis of the radius. The average radial inclination is 22 to 23 degrees[32,37,85,97]. Radial length, also measured on the anteroposterior radiograph, is represented by the distance between the two perpendiculars to the long axis of the radius, one at the tip of the radial styloid process and the other at the distal articular surface of the ulnar head[39,69,81]. The normal length of the radius averages eleven to twelve millimeters.

A fourth radiographic measurement that has prognostic value in assessing fractures is radial width, or shift[99]. The distance between the longitudinal axis through the center of the radius and the most lateral tip of the radial styloid process is measured on the anteroposterior radiograph and is compared with that of the contralateral side.

Functional Anatomy

The metaphyseal flare of the distal end of the radius has a large biconcave surface for articulation with the proximal part of the carpal row. In addition, the distal end of the radius articulates with the convex articular surface of the distal end of the ulna at the sigmoid notch. This latter articulation plays an integral role in the functional anatomy of the hand and wrist, as the radius and hand rotate about the fixed ulna. Instability of this articulation may be taken into account in the assessment and management of some unstable fractures of the distal end of the radius[72,73].

The loads that are borne on the distal ends of the radius and ulna during normal functional activities have not been defined accurately. Brand et al. calculated that the potential forces generated by the muscles of the forearm are about 500 kilograms[16]. Experimental data by Palmer have suggested that approximately 80 per cent of axial loads are supported by the distal end of the radius and 20 per cent, by the triangular fibrocartilage and the distal end of the ulna[72]. Linscheid noted that 46 per cent of the axial load across the carpus normally is distributed to the contact area of the lunate fossa of the distal end of the radius; 43 per cent, to the scaphoid fossa; and 11 per cent, to the triangular fibrocartilage[56].

Reversal of the normal palmar tilt of the distal end of the radius has deleterious effects. In mechanical studies using pressure-sensitive film, Short et al. noted a considerable transfer of load onto the ulna with progressive dorsal angulation of the distal end of the radius[87]. With a 45-degree dorsal angulation deformity, 65 per cent of the axial load across the carpus is directed onto the ulna. The remaining loads on the radius were observed to be eccentric and concentrated on the dorsal aspect of the scaphoid fossa. Clinically, this may result in pain at the radiocarpal articulation, as well as in limited grip strength, if the angulation is not reduced.

In some patients, especially those who are younger than twenty-five years, a pattern of mid-carpal instability has been described in association with loss of normal palmar tilt. Pain, decreased grip strength, and a mid-carpal instability pattern that is seen on lateral radiographs are the hallmarks of this dynamic intercarpal instability, which can be corrected by restoration of the palmar tilt of the distal end of the radius through a corrective osteotomy[35,51,97].

Loss of volar tilt, when associated with shortening of the fracture fragment of the distal end of the radius, may result in dysfunction of the distal radio-ulnar joint, manifested by limited rotation of the forearm and impingement of the ulna on the radius[55].

Evaluation of Outcome

The variability in the outcomes that have been reported in a number of clinical studies can be explained, in large part, by the wide variation in fracture patterns, the numerous methods of radiographic and clinical evaluation, and the length of time from injury to the final follow-up.

Radiographic Evaluation

Studies of radiographic outcome have varied: some included measurement of only residual dorsal angulation[76], some noted dorsal angulation and either radial inclination[85] or shortening[55], and some used all three of these standard measurements[38,39,69]. In a prospective study, van der Linden and Ericson evaluated the applicability of these three measurements, as well as that of radial shift[99]. They observed that only radial shift and dorsal angulation were independent of each other and concluded that residual displacement could be measured accurately with these two criteria alone.

The radiographic outcome of intra-articular fractures has been subjected to more recent evaluation. Knirk and Jupiter developed criteria to identify residual articular incongruity within the radiocarpal articulation[52]. Four grades were established, ranging from excellent (zero to one millimeter of residual step-off) to poor (more than three millimeters).

Functional Evaluation

Most authors have relied on the functional evaluation system of Gartland and Werley[39] who, in turn, had modified the demerit point-system of McBride, which was based on disability evaluation charts[59]. These systems evaluate a number of subjective, objective, and radiographic parameters, but they lack objectivity. For example, demerit points are given for an observer's assessment of residual deformity or radiographic changes, even when there are no subjective symptoms or functional loss. Also, the objective evaluation is not quantitative and does not compare the injured extremity with the contralateral side. Sarmiento et al. modified these systems, adding evaluation of grip strength and loss of pronation[83]. Lucas and Sachtjen further modified the evaluation, adding more specific criteria for function of the hand, including compression of the median nerve, reflex sympathetic dystrophies, and stiffness of the digits[57].

Several investigators have expressed concern that the demerit system of Gartland and Werley[39] does not accurately present functional outcome. Porter and Stockley developed a functional index that objectively measured grip strength, angular and rotational movement of the hand and wrist, and functional movements performed against resistive torque[78]. These authors compared the measurements with those of the contralateral wrist. Functional evaluation was extended further by McQueen and Caspers, who incorporated a number of tests used for interpreting dexterity of the hand, grip strength and endurance, and functional tasks of daily living, and included pain and aesthetic parameters in their evaluation[62]. Bradway et al.[15] utilized the evaluation scale of Green and O'Brien[43], which proved more stringent with respect to evaluating motion and strength. However, the scale did not take radiographic outcome into account. In their series of patients who were operated on, 56 per cent had a good or excellent result with this evaluation, compared with 81 per cent who had these results according to the system of Gartland and Werley.

The literature suggests that an accurate interpretation of the radiographic and functional outcome after fracture of the distal end of the radius must take into account a host of parameters related to functional anatomy and the needs of many patients.

Anatomy and Function

Extra-Articular Anatomy

Although conflicting data exist, even studies that reported a successful outcome, irrespective of the skeletal anatomy, noted that evaluation can be difficult and that the objective results may not be as satisfactory as the subjective assessment of the patients[3,76,88]. Despite the inclusion of a variety of types of fractures and the use of different methods for evaluation, a number of retrospective studies have suggested a direct relationship between residual deformity and disability[9,22,27,29,33,39,42,45,48,55,59,62,79,81,85,90,94,95,99,101]. Several recent prospective studies attempted to focus on the relationship between anatomy and function. Howard et al. compared external fixation and immobilization in a plaster cast and found that the functional results were related more to the quality of the anatomical restoration than to the method of immobilization[45]. These findings were confirmed by van der Linden and Ericson[99], Jenkins et al.[48], and Porter and Stockley[79].

In each of these studies, function, as reflected by grip strength and endurance, was impaired if the fracture healed with more than 20 degrees of dorsal angulation, less than 10 degrees of radial inclination, and more than two millimeters of radial shift. Radial shortening was associated with disruption of the distal radio-ulnar joint in some instances.

Intra-Articular Anatomy

Involvement of the radiocarpal or radio-ulnar articulation, or both, is common with fractures of the distal end of the radius. Fortunately, articular involvement in low-energy fractures in older, post-menopausal women has little effect on the generally favorable outcome in these patients[38,55,79]. For patients who have a higher energy, shearing, two-part radiocarpal fracture-dislocation, restoration of the articular anatomy is necessary to ensure function of the hand and wrist and prevent post-traumatic arthritis[28,34,74,98].

Impacted intra-articular fractures have received more attention in recent years, as the failure to reduce these fractures to within two millimeters of articular congruity, especially in young adults, will likely lead to symptomatic post-traumatic arthritis[8,15,21,50,52,64,65,77,82,96]. Termed die-punch injuries by Scheck[85], these fractures are a result of compressive force delivered through the carpus into the end of the radius. In younger patients, these fractures are often the result of high-energy trauma and can be associated with a spectrum of injuries, including carpal instability[12,52,64], disruption of the distal radio-ulnar joint, and local soft-tissue injury.

A greater understanding of the pathomechanics of these fractures has led to the recognition that conventional manipulation or reduction by traction may not adequately reduce many of these impacted or rotated articular fractures and may not restore intercarpal-ligament dissociations.

The therapeutic approach to fractures of the distal end of the radius is still influenced today by the observations of Colles, who noted, 176 years ago, that "one consolation only remains, that the limb will at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain: the deformity, however, will remain undiminished through life"[24]. Some patients function well with obvious deformity[18,88]. Because most of these fractures occur either in young patients, who have the potential for remodeling, or in older patients, who generally have lower functional demands, it is not surprising that the majority of these patients do relatively, although not uniformly, well[18,20,22,27,29,32,33,38,39,42,47,48,53,55,57,69,76,79,81,83,88,93,94,99]. Problems do exist, particularly in patients who place a high demand on the wrist. Bacorn and Kurtzke evaluated a large number of patients who had a work-related fracture of the distal end of the radius and found that the average loss of function of the involved limb was 24 per cent; only 3 per cent had no dimunition of grip[9].

Treatment

In addition to the fracture pattern that is seen on anteroposterior, lateral, and oblique radiographs, local factors, including the quality of the bone, associated comminution, extent of displacement of the fracture, and energy of the injury must be taken into account when a plan of treatment is formulated, as all of these contribute to the inherent instability of the fracture and, thus, may influence the choice of immobilization[25,27,45,61,69,90,94]. In addition, factors associated with the individual patient, such as life-style, psychological outlook, associated medical conditions, and compliance, must be considered. The functional loading that is anticipated should influence the choice of the method of stabilization far more than does the chronological age of the patient[61].

Stable Fractures

Closed reduction and immobilization in a plaster cast remains the accepted method of treatment for 75 to 80 per cent of fractures of the distal end of the radius and for extra-articular fractures that are minimally displaced or impacted and, thus, are judged inherently stable[25,39,55]. The manipulative method of reduction that was suggested by Jones involved increasing the deformity, applying traction, and placing the hand and wrist in the reduced position[49]. Positioning the hand and wrist in too much flexion in the so-called Cotton-Loder position led to complications such as compression of the median nerve and stiffness of the digits. This method has largely been supplanted by the techniques of Böhler, who advocated longitudinal traction followed by extension and realignment[13].

Despite the widespread acceptance of immobilization in a plaster cast, questions remain regarding the optimum position, the duration of immobilization, and the need to extend the cast proximal to the elbow. Several prospective studies[74,76,90,99] have addressed these issues, with comparisons of different positions of the hand and wrist[99], functional bracing with the forearm in supination and short splints[90], and above-the-elbow and below-the-elbow casts[76]. Neither the position of the forearm in immobilization nor extension of the cast proximal to the elbow appears to influence the anatomical outcome to any noteworthy degree. However, immobilization of the fracture with the forearm in supination, as advocated by Sarmiento et al., offers the advantage of holding the distal radio-ulnar joint in a reduced position[83,84] and minimizing the tendency of the brachioradialis to cause the distal fragment to displace in a radial direction[99].

Redisplacement of fractures during immobilization in a cast or splint can occur, and remanipulation is common practice, yet little has been written about the ultimate fate of a fracture that has been remanipulated. Two retrospective studies found lasting improvement in 33 per cent[23] and 54 per cent[63] of fractures after remanipulation. There was a greater likelihood of retention of the reduction in younger patients and in fractures that were remanipulated seven to fifteen days after the initial reduction[23,55]. In unstable fractures with displacement or extensive dorsal comminution, especially in elderly patients, reduction was lost even after the remanipulation.

Unstable Fractures

A number of options for treatment may offset the loss of reduction in an unstable fracture of the distal end of the radius in a patient in whom the maintenance of anatomy is considered important for functional demands. These options include percutaneous pinning of the distal fragment[20,29,32,93], immobilization of the limb with pins incorporated in the plaster[17,19,22,42,85,103], metal external skeletal-fixation devices[4,21,27,45,46,48,80,88,100], limited open reduction with or without bone-grafting[8,53], and extensive open reduction and internal fixation[7,15,51,64,65,77,96].

Percutaneous Pinning

Extra-articular fractures with extensive comminution or fractures that have no more than two articular fragments, in which anatomical reduction is obtainable, are amenable to percutaneous pinning of the fracture fragments and application of a plaster cast. This technique was advocated as early as 1952 by DePalma[29]; recently, Clancey reported on thirty consecutive patients who had a displaced unstable fracture and were treated by percutaneous pinning[20]. Anatomical reduction was maintained in twenty-eight, with few complications in the series. This technique is not as effective for high-energy, complex fractures or fractures associated with soft-tissue problems that preclude the use of a circular cast. However, the technique can be effectively combined with metal external fixation in these situations.

Pins and Plaster

Placement of pins in the metacarpals and bones of the forearm was initially advocated by Böhler in 1923, but it reached widespread popularity after the report by Green in 1975, who documented good or excellent results in 86 per cent of his patients[42]. However, Green noted a high incidence of both minor and major complications, with one-third of the patients having problems related to the pins. Recent studies have corroborated the finding of a substantial incidence of complications with this technique. Chapman et al. also noted that one-third of complications were related to the pins and that 16 per cent of the patients needed reoperation for the complication[19]. In a series of fractures caused by high-energy trauma, Weber and Szabo reported that the rate of complications was 53 per cent[103]. Carrozzella and Stern also reported a high number of complications, which resulted in the premature termination of the treatment in more than 30 per cent of their patients[17]. Although pins and plaster offer a method of maintaining reduction of many unstable fractures at limited expense, the complications of incorporating pins into circumferential plaster have led to a re-evaluation of this technique.

External Skeletal Fixation

External skeletal fixation has become increasingly popular in the management of complex fractures of the distal end of the radius. This popularity can be attributed, in part, to the recognized problems that are associated with the use of pins and plaster, as well as to improvements in design of the frame and in methods of insertion of pins[48,68,88]. A number of studies have reported favorable results with external fixation, although most of the studies were retrospective and, thus, are difficult to interpret due to the heterogeneous groups of patients who had a variety of skeletal and soft-tissue injuries[4,27,46,68,103]. Even so, the incidence of complications in these series was high, ranging from 20 to 60 per cent. The complications included infection of the pin track, radial sensory neuritis, reflex sympathetic dystrophy, stiffness of the wrist, and fracture through the pin-sites. However, in two recent prospective, randomized studies in which external fixation was compared with immobilization in a plaster cast for unstable fractures, external fixation was significantly more effective in maintaining the reduction of the fracture, with resultant improved function of the hand[45,48]. The over-all rate of complications in these two series was appreciably lower than in the past.

Although improved techniques of insertion of pins, including pre-drilling, open placement, and more strategic placement of pins, have reduced the frequency of problems related to the pins[68,86], the potential for permanent loss of motion of the wrist remains a concern. In a landmark study in 1979, Cooney et al. reported only a slight loss of motion in patients who were followed for two years or more[27]; however, other authors have recommended decreasing the amount of traction that is applied by the external fixation frame across the radiocarpal ligaments after three weeks, limiting the duration of treatment by adding percutaneous pins or autogenous bone graft to permit earlier removal of the external frame without loss of reduction[8,53,86], or using hinged fixators to allow motion of the wrist while traction is maintained[21]. Interest in the concept of so-called dynamic external fixation has been tempered by the complexity of the operative protocol and by difficulty in controlling the position of impacted die-punch fragments and the reduction of an unstable distal radio-ulnar joint. The range of motion of the wrist that was reported by Clyburn[21] in 1987, who used a mobile external-fixation device, showed little, if any, improvement compared with the series of Cooney et al.[27]; it must be pointed out, however, that many of the patients in Clyburn's series were younger and had high-energy fractures.

Although radial length and inclination are usually re-established and maintained with traction (ligamentotaxis), the palmar tilt of the radius is rarely restored to normal. An anatomical study by Bartosh and Saldana suggested that this may be due to the fact that the stout palmar radiocarpal ligaments reach maximum length before the z-shape dorsal ligaments, preventing the latter from pulling the dorsal aspect of the distal end of the radius into its normal palmar inclination[10]. In turn, this may limit the effectiveness of some hinged external fixators that offer the potential for multiplanar reduction of fractures.

Limited Open Reduction

In intra-articular fractures that have more than two millimeters of displacement, the radiocarpal joint may be incongruent, despite adequate attempts at closed reduction. The incongruity usually involves the lunate facet of the distal end of the radius, as the radial styloid process and scaphoid facet are more amenable to reduction through ligamentotaxis or by manipulation and reduction with a large, pointed bone clamp. Anteroposterior and lateral tomography is helpful in accurately defining the nature and extent of the articular injury.

Axelrod et al. reported on their technique of combining external skeletal fixation with open reduction of the displaced lunate facet through a small, longitudinal dorsal incision and elevation of the impacted fragment without direct visualization of the surface of the joint[8]. They detailed the operative steps on the basis of two different patterns of fracture (impaction or shear) that were previously identified by Saito and Shibata[82], and they recommended supporting the reduction with transverse or oblique Kirschner wires and an autogenous iliac-crest graft. In this way, settling of the elevated articular fragments is avoided, and the external fixation frame can be removed by six weeks after application. Leung et al. reported on 100 complex fractures of the distal end of the radius in which the reduction was supported with an autogenous iliac-crest graft, permitting removal of the external fixation frame at three weeks and use of a functional brace for an additional three weeks[53]. They noted few complications, and there was maintenance of the reduction with good or excellent function in nearly all patients.

Open Reduction and Internal Fixation

Despite the complex skeletal and articular anatomy of the distal end of the radius and the limited operative access, there are two groups of fractures for which open reduction and internal fixation may be advisable. The first group includes the two-part shear fracture (Barton and reverse Barton), which actually is a radiocarpal fracture-dislocation. Although anatomical reduction is possible by closed means in some cases, these fractures are extremely unstable and are difficult to control in plaster. In several studies, these fractures have been specifically assessed: an anterior fracture-dislocation has been far more common than a dorsal one, and the fracture often occurs in younger adults, whose stronger bone is amenable to supporting the reduction with a small buttress plate[28,34,74,98].

The second group includes complex articular fractures in which the articular fragments are displaced, rotated, or impacted and not amenable to reduction through a limited operative exposure. These fractures are more likely to be caused by high-energy trauma in younger adults and are associated with concomitant skeletal or soft-tissue injury[7,15,50,52,63,77]. Several studies have suggested that restoration of the articular anatomy is the most critical factor in obtaining a good functional result and preventing late post-traumatic arthritis[7,15,52,63,64,77].

The operative management of these fractures is difficult and is associated with a high rate of early and late morbidity[7]. Preoperative planning, including anteroposterior and lateral tomography, is exceptionally helpful. Before the incision is made, distraction and the temporary application of an external fixator will make it easier to manipulate the small articular fragments and minimize soft-tissue dissection. The anterior approach is useful for fractures with anterior displacement or rotation of the articular fragments. When the radius is approached ulnarly to the flexor tendons, trauma to the median nerve and its palmar cutaneous branch is minimized. When exposing the articular fragments anteriorly, the surgeon must be aware of the critical anterior radiocarpal ligaments. Disruption of these ligaments can result in subsequent intercarpal instability. The articular reconstruction should be supported by an autogenous cancellous-bone graft, as well as a small buttress plate in most cases. When the fracture involves multiple small articular fragments, the use of a plate may not be possible; definitive fixation is then accomplished with Kirschner wires and external skeletal fixation[50].

The severity of these injuries is reflected by the fact that most patients will have some residual limitation of mobility of the wrist as well as of grip strength[7,15,50,65,77]. Although enthusiasm for the operative approach for complex articular fractures of the distal end of the radius is growing, serious complications, including loss of fixation, neuritis of the median nerve, reflex sympathetic dystrophy, infection of the wound, and late post-traumatic arthritis, can occur even when the surgeon is experienced[7,50,77].

Complications

Despite Colles' optimistic outlook, the management of fractures of the distal end of the radius is fraught with complications. In a large retrospective series of 565 fractures, Cooney et al. reported a rate of complications of more than 31 per cent; the complications included dysfunction of the median nerve, malposition, arthritis of the radiocarpal or radio-ulnar joint, stiffness of the digits, rupture of a tendon, causalgia, and even Volkmann ischemic contracture[26]. Some of these complications were the sequelae of treatment rather than of the original fracture. Colles admonished his colleagues against the use of constricting bandages[24]. Even so, the end of the nineteenth century saw widespread use of standardized splints and overzealous immobilization, which all too often resulted in permanent disability. Recognition of this problem led many authors, at the turn of the twentieth century, to recommend a limited duration of immobilization (one to three weeks), followed by an active program of therapy[56].

Dysfunction of the median nerve has been the most frequent complication in most series[5,38,58,60,76,91,95]. In several studies, the transient neuropathy associated with the injury has not appeared to be related to the type of fracture, the extent of the initial displacement, or the accuracy of the primary reduction. In contrast, persistent compression of the median nerve appeared to be more prevalent with malunited fractures[5,38,54,95].

McCarroll established a series of sound guidelines for the management of compression of the median nerve associated with a fracture of the distal end of the radius[60]. If a complete neural lesion does not improve after reduction of the fracture, operative exploration is justified. Lewis stressed that decompression of the median nerve should include not only the transverse retinacular ligament but, more importantly, the antebrachial fascia over the anterior aspect of the distal portion of the forearm[54]. If a patient has a partial lesion of the nerve, the fracture should be reduced and the patient should be observed for at least seven days. McCarroll recommended that exploration should be considered if no change is noted and there is some motor weakness. If the neural lesion develops after reduction of the fracture or worsens despite the reduction, the cast or splints should be released and the wrist should be placed in a neutral position. Pressures in the carpal tunnel can be measured; Gelberman et al. observed that when the wrist was in 45 degrees of flexion, the pressures in the carpal tunnel were more than the critical threshold at which viability of the nerve fibers is jeopardized[40]. If sensory abnormality or motor weakness persists despite the change in the position of the wrist, exploration is indicated. When a neural lesion, even an incomplete one, is present in a patient who has a fracture that needs operative intervention, McCarroll, as well as Axelrod and McMurtry, recommended release of the nerve at the same time[7,60].

When increasing pain, swelling, loss of mobility of the joint, or paresthesias are present, an impeding causalgia should be considered. Atkins et al. observed some or all of these symptoms to be more common in association with fracture of the distal end of the radius than previously was thought[6]. Lynch and Lipscomb[58], as well as Stein[92], noted the strong possibility that compression of the median nerve is a common precursor of major causalgia (reflex sympathetic dystrophy) in patients who had this type of fracture. In fact, Stein observed considerable improvement after decompression of the median nerve in four patients who had causalgia secondary to a fracture of the distal end of the radius.

Most authors have agreed that early recognition of neural compression is important for the prevention of long-term disability[6,9,38,55,58,60,92].

A number of studies have highlighted the importance of the distal radio-ulnar joint in the functional outcome after fracture of the distal end of the radius[26,38,41,66]. This joint can be involved both by diastasis due to direct injury and by residual deformity of the distal end of the radius. Pain, instability, and loss of rotation of the forearm can be disabling[38]. Although excision of the distal part of the ulna has been used widely, the outcome is unpredictable[1], since the procedure may result in weakness[14,35] as well as instability of the distal end of the ulna[11,14].

Although there have been numerous reports of post-traumatic arthritis after intra-articular fracture of the distal end of the radius[7,8,15,21,52,64,65,77,96], the frequency of osteoarthrosis after a Colles-type fracture has been investigated in only a few studies[26,38,39,55,70,88]. Smaill noted that ten of forty-one patients, followed for five to six years after the fracture, had radiographic changes of osteoarthrosis, but only three had symptoms[88]. Overgaard and Solgaard found that, over a seven-year follow-up, seventeen (30 per cent) of their fifty-six patients had radiographic evidence of osteophytes and eight patients (14 per cent) had advanced radiographic changes[70]. The occurrence of osteoarthrosis in their series was not related to residual dorsal angulation or radial shortening, but rather to the initial displacement and to advanced age at the time of injury. Frykman found a high rate (19 per cent) of arthrosis of the distal radio-ulnar joint, which was frequently symptomatic[38].

Complications involving tendons include peritendinous adhesions involving both the extensor and flexor tendons, as well as rupture of a tendon. The extensor pollicis longus is the tendon that is most frequently ruptured[18,31]. Rupture of this tendon after minimally displaced fractures suggests an ischemic etiology rather than attritional rupture over an osseous spike. In most cases, tendon transfer using the adjacent extensor indicis proprius provides a predictable outcome.

The recognition of the role of anatomical restoration in functional recovery has led to greater interest in osteotomy of malunited fractures of the distal end of the radius[35,50,87,97]. The technique that was described by Fernandez may be used for this complex reconstructive procedure[35].

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