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Avoiding Complications in the Treatment of Humeral Fractures

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Abstract

Three of the most common complications that may occur after the treatment of humeral fractures are nonunion, loss of fixation, and nerve injury. Nonunion may occur in up to 15% of patients who have been treated surgically. Loss of fixation often is caused by poor quality bone in the osteopenic humeral head. Nerve injury can occur as a result of trauma or from treatment.

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Most humeral fractures heal uneventfully, but a variety of complications can occur after both surgical and nonsurgical treatment. Three of the most common complications encountered are nonunion of a humeral shaft fracture, loss of fixation of a proximal humeral fracture, and radial nerve palsy.

Nonunion of a Humeral Shaft Fracture

Nonunion has been reported to occur following approximately 1% to 10% of humeral shaft fractures that have been treated nonsurgically and after approximately 10% to 15% of those that have been treated surgically.[1-3] The difference in these nonunion rates may represent both the effects of treatment and a selection effect, as more complex and high-energy fractures may be treated surgically. When a humeral nonunion occurs after surgical treatment, there are additional treatment considerations because of the presence of hardware and the risk of infection.

Some risk factors for nonunion of a humeral shaft fracture are an open fracture; a segmental, transverse, or highly comminuted fracture pattern; bone loss; wide displacement of the fracture fragments (>100% of the shaft diameter); impaired host healing (due to smoking, diabetes, medications such as nonsteroidal anti-inflammatory drugs, malnutrition, and noncompliance with physicians' instructions); preexisting shoulder or elbow stiffness; and an intervening local infection.

Prevention of nonunion of a humeral shaft fracture is not always possible, but some measures taken during treatment of the acute fracture may reduce the risk of the complication. Selection of the appropriate treatment of each patient is the first step because nonunion can result from both unnecessary surgery and failure to recognize patients who would benefit from surgical care. Most humeral shaft fractures in reasonably healthy patients heal well when treated without internal fixation. Because of the great mobility of the shoulder, moderate

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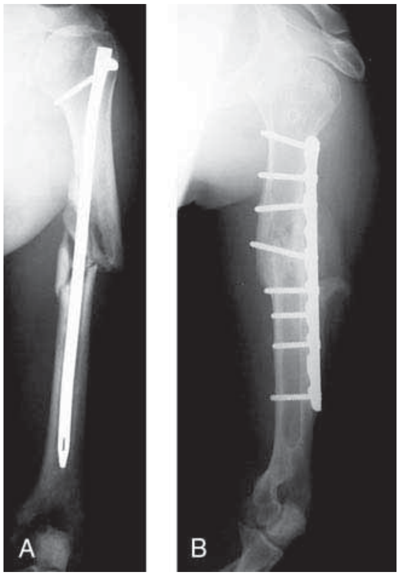

Figure 1 **A,** AP radiograph of the left humerus of a 35-year-old man made 9 months after intramedullary nail fixation of an open fracture sustained during a fall. The patient reported pain when he used the arm and a sensation of instability and weakness. The radiograph shows a small-diameter nail, locked only proximally; a malaligned fracture; and no evidence of fracture healing. **B,** The humerus healed well after the fixation was revised to a long, large plate to provide adequate stability and alignment. Excellent bone apposition was achieved, and an autogenous cancellous bone graft was placed around the nonunion site.

amounts of angulation, shortening, and rotational deviation from normal usually cause no functional problems after healing. Nonsurgical treatment should consist of a short period of immobilization in a sling and/or coaptation splint, followed by active shoulder and elbow motion in a functional brace.[3] Performing an operation without compelling reasons increases the risk of all complications, including nonunion.

When the patient has one or more of the risk factors for nonunion delineated above, when the fracture cannot be adequately reduced, or when the fracture reduction cannot be controlled with functional bracing because of patient obesity, head trauma, soft-tissue injuries, or other reasons, surgical stabilization is indicated. Bilateral humeral fractures and those occurring in patients with multiple injuries or chest trauma usually are best managed with internal fixation. Although there are proponents of both nail and plate fixation for humeral shaft fractures, the risks of nonunion and a revision have been reported to be lower with plate fixation than with nail fixation. The nonunion rate after plate fixation is approximately 4%, whereas the nonunion rate after nail fixation is approximately 10%.[4,5]

When internal fixation is selected, it is important to pay attention to certain technical details to lower the risk of nonunion. The fracture should be reduced well (but not necessarily anatomically), and it is particularly important to avoid distraction at the fracture site. This can occur during closed nailing if the nail is tight in the distal part of the canal. If bone is missing, shortening of as much as 2 to 3 cm (in our experience) is acceptable to achieve bone contact; larger gaps should be bridged with a bone graft. Because the humerus is subjected to strong rotational forces as a result of the weight of the upper extremity, the fixation construct must adequately neutralize rotational forces to achieve stability for reliable healing. In our experience, unstable fixation has been a common cause of nonunion of the humeral shaft after surgical fixation. To achieve adequate stability with an intramedullary nail, the nail must fill the diaphyseal canal and be locked with screws on both ends to resist torque. Humeral intramedullary nails usually are inserted without power reaming because of the small size of the medullary canal and the risk of tissue damage. Hand reaming is done with T-handled reamers to open the canal and allow a larger nail to be inserted, but this technique does not permit adequate shaping of the nail path to provide a tight "wedge" fit that would resist rotation. In addition, attempting to achieve a very tight fit in the distal fragment can lead to distraction at the fracture site or comminution of the distal fragment. Thus, distal interlocking is necessary to stabilize the nail and prevent rotation of the humerus around it. One interlocking screw on either end is usually sufficient.

For plate fixation to achieve stability, the plate must be of adequate thickness and length: the thickness should be >3.5 mm (a large-fragment plate) for most adults, and the length should be such that at least four screw holes overlie each major proximal and distal fragment. This does not mean that every screw hole in the plate needs a screw placed through it, as excessive screw placement can be damaging (Figures 1 and 2). The most proximal and distal screw hole in each fragment should be used to maximize resistance to rotational stresses (the so-called near-near, far-far screw pattern), a technique similar to the construction of a stable external fixator configuration for a diaphyseal fracture. More screws can be added in each fragment in situations of suboptimal screw purchase, but they may not be necessary in good bone if the two end screws are placed well and solidly secured. When a fracture of the distal part of the shaft involves the metaphysis or epiphysis, bicolumnar fixation should be achieved with good purchase in the bone of both columns distally (Figure 3).

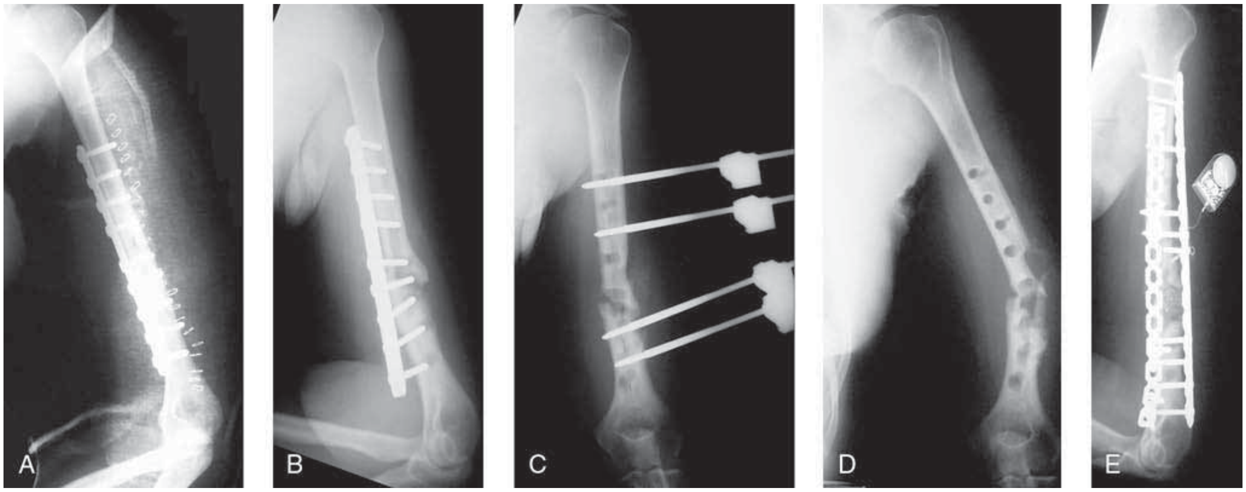

Figure 2 **A,** This isolated midshaft humeral fracture, sustained by a healthy 40-year-old woman while skiing, probably would have healed well if it had been treated with closed means. Fixation with a long large-fragment plate with an excessive number of screws was performed through a large incision. **B,** Nonunion resulted. Note the loss of screw fixation distally. **C,** External fixation was applied after hardware removal. **D,** When the pin sites became infected, the external fixator frame was removed, leading to an unstable, atrophic, and possibly infected nonunion with substantial bone loss. **E,** Union was achieved after using a long double-plate technique through a posterior approach combined with an iliac crest bone graft with bone morphogenetic protein and implantation of a bone stimulator.

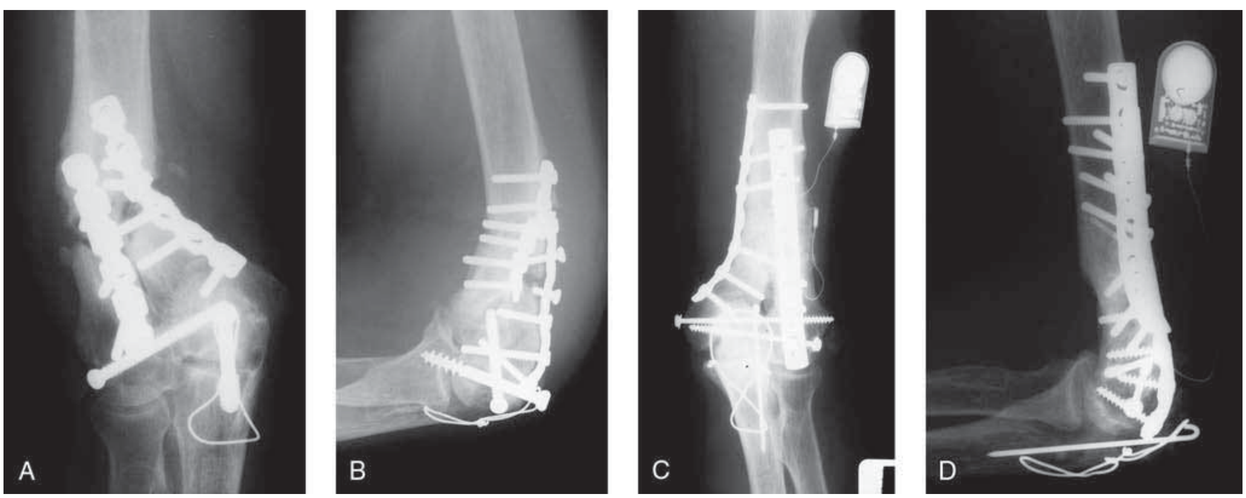

Figure 3 **A,** AP radiograph demonstrating a nonunion in a 53-year-old man who had sustained a fracture of the distal part of the humerus and had been treated with open reduction and internal fixation at another hospital 5 months previously. The patient reported pain with any motion of the arm and elbow, and the fracture site was tender to palpation and manual stress. **B,** Lateral radiograph of the elbow before the revision surgery. **C,** Revision fixation was performed with removal of hardware, bicolumnar plate fixation with longer plates to achieve better fixation on the proximal fragment, and the use of lag screws distally. A bone graft and an implantable bone stimulator were inserted. **D,** Lateral radiograph demonstrating healing after the revision.

In general, plate-and-screw fixation should be "balanced" around the center of the fracture; that is, there should be an approximately equal plate length and number of screws on both sides of the center of the fracture. The construct should appear symmetric in terms of the amount of fixation. This becomes more difficult near the ends of the bone, and metaphyseal fractures may require double-plate fixation to achieve adequate control of the smaller fragment. The use of locked-plate techniques near the epiphysis may change this rule, but the effectiveness of that approach has not yet been clearly established.

Plates should be applied without circumferential soft-tissue stripping, with gentle tissue handling, and with the least amount of bone devascularization needed to expose the radial nerve for its protection and to allow the plate to be positioned on the bone. Butterfly fragments should not be stripped of muscular attachments, and cerclage wiring can be detrimental and often is unnecessary. Excessive stripping of the soft tissue from the bone can contribute to delayed union or nonunion. Plates should be applied over the periosteum after gentle elevation of the muscle from the bone.

Good-quality radiographs in two planes that include both the shoulder and the elbow should be made in the operating room when the patient is still under anesthesia. These are made to identify any problems with fixation or distraction at the fracture site, which are more likely to be missed with fluoroscopy. These problems can then be addressed before the patient is awakened from the anesthesia.

Union is expected within 16 weeks, and a nonunion of the humerus is usually defined as a failure to heal by 24 weeks with no progress toward healing seen on the most recent radiographs. Obvious loss of stability on clinical examination or radiographs is clear evidence of a nonunion. When this is observed, there is no need to wait for an arbitrary amount of time before initiating treatment of the nonunion. Pain is usually associated with humeral nonunion, but it is not as common as it is with nonunions of weight-bearing long bones of the lower extremities. Instability may be evident clinically on physical examination. The diagnosis is usually obvious on radiographs, although if there is hardware obscuring the bone, CT with the use of hardware-subtraction algorithms may help in evaluating the fracture site.

Treatment of the nonunion requires careful analysis of causative factors. One should not forget to address medical problems, such as diabetes, malnutrition, and tobacco addiction. When nonunion is unexpected, infection should be considered as a possible cause, and a clinical examination and blood tests such as measurements of erythrocyte sedimentation rate and C-reactive protein level should be performed. Any patient with a nonunion that does not have an obvious cause should be evaluated to rule out diabetes, hypothyroidism, disorders of calcium metabolism, or another endocrine abnormality.[6]

Once a humeral nonunion is established, nonsurgical treatment is not likely to be effective. External bone stimulators have not generally been successful in treating these complications.[7,8] External fixation has been used temporarily in the staged treatment of infected nonunions, but it is rarely used as a definitive treatment because patients cannot tolerate this device for long periods.

The surgical procedure should be carefully planned. For a nonunion that has not been previously treated surgically, particularly one that shows evidence of bone reaction on radiographs (a hypertrophic type), provision of adequate stability with plate fixation may be all that is necessary. "Taking down" (débriding) the nonunion to excise the fibrous tissue between the bone ends is not necessary in this situation. However, opening the medullary canal proximally and distally is believed to aid healing, when this can be accomplished without taking down a firm fibrous union, as is possible with an atrophic nonunion. The fibrous scar tissue connecting the bone ends of a hypertrophic nonunion has the capacity to turn into bone and does not inhibit union in a stable milieu. If a true pseudarthrosis with a synovial cavity exists, the cartilage covering the ends of the bones and the lining tissue should be excised, the medullary canal should be opened in both directions, and good bone apposition should be achieved. If previous surgery has been performed, hardware removal probably will be necessary, and the correct instruments for that portion of the procedure must be available. The surgeon should have a plan for what will be done if an unsuspected infection or broken or stripped hardware is encountered.

Plate fixation of the humerus can be performed through a posterior or an anterolateral approach. The choice may be determined by the need to remove hardware; if not, the posterior approach offers a more cosmetic scar position. Proximal humeral nonunions are approached through a deltopectoral incision, and distal humeral intra-articular nonunions typically require a posterior approach, often with an osteotomy of the olecranon. In the treatment of a diaphyseal nonunion, care must be taken to identify, mobilize, and protect the radial nerve. It is useful to warn patients that they may have a transient radial nerve palsy as a result of the surgical manipulation only, and there is a small risk of permanent nerve injury. At least three samples should be taken from the nonunion site for culturing if a previous operation had been performed.

The use of bone grafts, bone morphogenetic protein, or shortening may be necessary to treat bone defects. Osteopenic or pathologic bone resulting from previous surgery may require the use of locking plates, double plates, or allograft struts, which may be used in an intramedullary position.[9,10] Unlike the situation in the lower extremity, if the previous humeral fixation implant was a nail, exchange nailing usually is not very successful.[11,12] Fixation should be achieved with a long plate (Figure 2). Healing of atrophic nonunions can be enhanced with cancellous autograft, demineralized bone matrix, or bone morphogenetic protein.[2,13,14]

Figure 1 shows radiographs of a patient in whom a nonunion had resulted mostly from inadequate stability provided by the initial fixation. The fracture was stabilized with an intramedullary nail with a relatively thin diameter, which was locked only proximally. The distal fragment, subjected to high torque forces, was able to rotate around the nail, and this excessive motion resulted in nonunion. In addition, the fracture was malaligned, most likely as a result of malreduction at the time of surgery. The lack of any hypertrophic healing response or callus suggests that a biologic component, in addition to the biomechanical deficit, caused this nonunion. Multifactorial etiologies are not uncommon and should be addressed when the nonunion is treated. The treatment in this case was removal of the nail, balanced stable fixation with a large-fragment plate, and bone grafting. Successful healing resulted.

Figure 2 shows a different cause of nonunion. In this case, a healthy patient initially had a closed isolated fracture that would most likely have healed uneventfully following closed treatment with a functional fracture brace. However, the patient was subjected to an operation with periosteal stripping and application of a large plate with filling of every screw hole; the biologic healing potential of the bone was compromised, and nonunion resulted. After plate removal, devascularization was evidenced by sclerotic bone around the screw holes. When the plate loosened and fixation failed, a large amount of bone was lost from around each screw hole. The use of external fixation with subsequent pin tract infection led to more bone loss. Successful treatment of this difficult situation required the removal of all hardware; débridement of the necrotic bone and infected soft tissue; a period of treatment with antibiotics, both systemic and local (beads); and then refixation with double plates, bone grafting, and implantation of a stimulator.

Figure 3 shows a distal humeral nonunion. The fracture was fixed with a gap at the junction of the diaphysis and metaphysis, with plates that were probably too flexible (reconstruction plates rather than compression plates) and definitely too short. Although fixation through 9 or 10 cortices was achieved in the proximal fragment, the screws all were placed in a short segment of the bone. Despite the large number of screws, the plate length was inadequate to provide good mechanical stability. The mechanical function of a plate as a nongliding splint depends more on the length of the plate than on the number of attachment points to the bone. Revision to longer bicolumnar plates was performed, and a more balanced fixation construct resulted. Lag screws were added. Bone graft and a bone stimulator were used to stimulate healing. Solid union occurred in 2 months.

Loss of Fixation of a Proximal Humeral Fracture

Fractures of the proximal part of the humerus often are complicated by a loss of fixation after surgical treatment. A loss of fixation was reported in approximately 13% of 349 cases reviewed in 1997.[15] The fixation loss is usually but not always the result of loosening of the portion of the construct in the humeral head. The humeral head comprises mostly cancellous bone and has very poor holding power for screw fixation, particularly in elderly patients. High stresses that exceed the holding power of screws in this cancellous bone may be applied to the surgical neck with arm motion. Therefore, elderly patients should not receive overly aggressive physical therapy in the postoperative period.

Traditionally used plates and screws can loosen quickly as a result of poor-quality bone, a lack of load sharing when there is fracture comminution, and the lack of a fixed angle between the plate and screws. The traditionally used large-fragment T-plate allows, at most, three screws to be placed through its proximal portion and into the humeral head fragment. Interlocking nails likewise allow only one or two screws to be used in the proximal fragment, providing an inadequate grip on this fragment. Percutaneous threaded-tipped Kirschner wires often migrate in dangerous directions and may fail quickly, particularly if too few are placed or if they are positioned poorly. Blade plates, which were initially proposed as a solution to this problem, have proved to be no panacea.[16]

Reducing the incidence of fixation failure involves several steps. The first is correct patient selection.

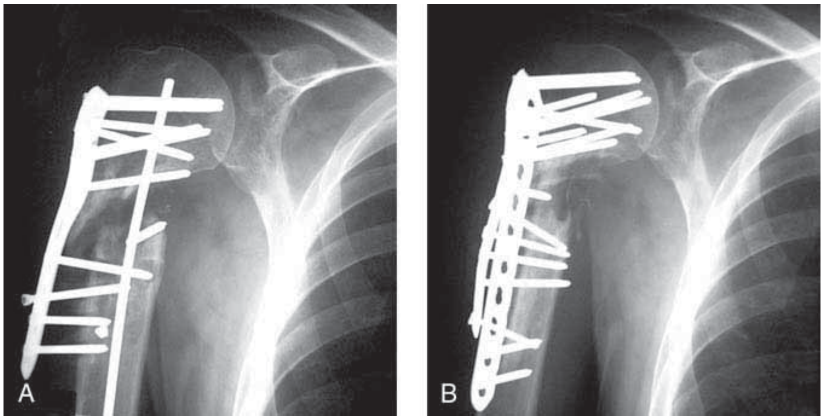

Figure 4 **A,** Shoulder radiograph demonstrating a nonunion of the proximal part of the humerus in a 35-year-old patient with diabetes who abused drugs and who had three previous operations. The locking plate lost purchase in the shaft fragment, and a retrograde Ender nail was used in an attempt to salvage the situation. The patient still had pain and clinically visible instability at the fracture site. **B,** Union was achieved with double locking plates, and an intramedullary fibular allograft was used to improve fixation in the shaft portion of the construct. Cancellous autogenous bone graft with bone morphogenetic protein was placed in the metaphyseal defect at the same time.

Nonsurgical therapy is successful for a large proportion of simple surgical neck fractures, even in elderly patients. Arthroplasty should be considered for patients with preexisting arthritis or shoulder stiffness, severe comminution, a head-splitting fracture, or an associated dislocation. Avoiding an unnecessary or incorrect operation in the initial treatment of the fracture is the first way to prevent fixation failure.

The use of suture or wire fixation has been preferred by some surgeons. This sort of fixation into tendons of the rotator cuff or through the bone at the tendon insertion can be superior to screw fixation in osteopenic bone. Multiple large nonabsorbable sutures can be placed in a tension band fashion connecting greater and lesser tuberosities to the head and shaft fragments.[17]

Locking plate fixation is a major advance in the treatment of proximal humeral fractures. It can reduce the risk of lost fixation, but it is not always successful, and there are several technical points that must be observed.[18,19] It is important to position the plate appropriately to avoid impingement with shoulder motion. Using multiple locking screws of adequate length in different planes improves fixation. The optimal number of screws is unknown, but more appears to be better. Unlike the situation in the diaphysis, where placement of additional screws that may be unnecessary can have harmful effects on bone biology, extra screws placed in the humeral head do not seem to be detrimental. This may be because these screws are placed without drilling and in bone that is very well vascularized. Intraoperative fluoroscopy, especially the axillary view, is important to ensure that no screws penetrate the head and impinge on the glenoid. Allograft cortical struts from the fibula or tibia can be used in an intramedullary location to improve fixation both proximally and distally (Figure 4).

Recognition of a loss of screw fixation usually is not difficult if radiographs are made early after surgery. Recurrence or persistence of pain and instability should prompt radiographic evaluation. When loss of fixation is identified, it usually requires revision surgery. Revision fixation with bone grafting is appropriate for young and active patients, after analysis and identification of the reasons for failure. In elderly patients, patients with severe osteopenia, and those with articular damage, hemiarthroplasty or total shoulder replacement can achieve pain relief but the functional outcome is usually poor.[18]

Nerve Injury

Nerve injury that is evident after treatment of a humeral fracture can be a result of the injury or the treatment. During the initial evaluation of any patient with a humeral fracture, it is important to perform a careful neurologic examination and to document sensation and specific motor function of the radial, median, ulnar, and axillary nerves. In closed injuries, nerves can be contused or stretched but are rarely completely disrupted, except in the setting of a scapulothoracic dissociation.[20] Open injuries can result in nerve laceration and occasionally in segmental nerve loss.[21]

Radial nerve injury associated with a fracture of the humeral shaft is the most common nerve lesion complicating any long bone fracture.[22] In a meta-analysis reviewing 35 studies in the literature that included a total of 1,045 patients with radial nerve palsy, the prevalence of this condition was estimated to be approximately 12% in patients with a humeral fracture. It was more commonly associated with middle and distal third humeral fractures than with proximal third fractures and more commonly associated with transverse or spiral patterns than with oblique or comminuted types.[22] Radial nerve injury occurs in approximately 10% of patients who have sustained multiple injuries.[23] In an electromyographic study of 143 proximal humeral fractures, 67% were found to be associated with evidence of some denervation, most commonly in the axillary or suprascapular nerve.[24] During surgical treatment, nerves can be stretched, contused, compressed, or cut. A new or recurrent postoperative nerve palsy usually is a transient condition, but it is reported to be permanent in 2% to 3% of patients.[25]

To prevent nerve injury, the treating physician must be aware of the location and anatomy of the nerves in the upper extremity. During surgical procedures, the nerves should be identified, exposed, and protected. The radial nerve lies in the spiral groove on the posterior aspect of the humeral shaft. It comes into contact with the bone as it approaches the lateral supracondylar ridge, more proximally than usually expected.[26] Gerwin and associates[27] described a modification of the typical posterior triceps-splitting approach that allows more exposure of the humeral diaphysis while protecting the radial nerve. It involves identifying the nerve as it approaches the lateral intermuscular septum and retracting the medial and lateral heads of the triceps in a medial direction. During nail fixation of a humeral shaft fracture, it is important to be sure that the nerve is not lying in the fracture site. If the fracture is oblique, in the distal third of the shaft, and cannot be reduced anatomically, and particularly if there is a preexisting nerve palsy, a small incision should be made to expose the fracture site and ensure that the nerve is not entrapped. Proximal interlocking screws placed from anterior to posterior through a humeral nail endanger the axillary nerve.[28] Percutaneous pins inserted for the fixation of proximal fractures may be near the axillary nerve as it wraps around the humerus on the undersurface of the deltoid. To reduce the risk of injury to the nerve, these pins should be placed through a small incision and, after spreading of the muscle, a drill guide should be placed directly on the bone.[29] Fixation of distal humeral fractures places the ulnar nerve at risk. During open reduction and fixation of the distal part of the humerus, the ulnar nerve should be exposed and mobilized. Anterior subcutaneous transposition is useful if there is a possibility of hardware impinging on the nerve. The nerve should be mobilized sufficiently to prevent tension or kinking. During any fixation procedure, the surgeon should minimize, as much as possible, the amount and duration of tension on both the ulnar and radial nerves during retraction. For this reason, we believe that self-retaining retractors should not be used in such cases.

Identification of nerve injury usually is not difficult. The patient often reports numbness and/or weakness, most commonly a wrist drop. The neurologic examination can be brief and still thorough enough to identify problems. Scratch or sharp sensation should be tested in the distributions of the major nerves—that is, the first dorsal web space for the radial nerve, the volar aspect of the long finger for the median nerve, the ulnar side of the small digit for the ulnar nerve, and the lateral shoulder area over the deltoid muscle for the axillary nerve. Motor function should be tested for both active motion and strength. Thumb and wrist extension should be assessed to evaluate the radial nerve; grip and the "OK" sign to evaluate the median and anterior interosseous nerves; spreading and crossing the fingers to evaluate the ulnar nerve; and active shoulder abduction to evaluate the axillary nerve. The results of the preoperative and postoperative examinations should be completely documented.

Nerve injury associated with closed fractures can be managed with observation, as it resolves in almost all patients, usually by 4 months after the injury.[30] Shao and associates[22] reviewed 30 articles describing the management of radial nerve injuries. They found that approximately 70% of patients treated with expectant management (observation) had spontaneous recovery, and, when they were combined with those who had delayed exploration after a period of observation, the overall recovery rate was 88%. Patients treated with early exploration had a recovery rate of 85%, so there seemed to be no advantage to early exploration for a primary nerve injury. The findings with regard to secondary nerve injuries were similar. Although there were not enough studies for the authors to make any clear recommendations, it appears that routine early exploration is not warranted and may cause additional, iatrogenic nerve damage. Although it has been suggested that a surgeon should explore any nerve that loses function during closed treatment, we are not aware of any studies documenting improved outcomes following this strategy, and most authors do not recommend it.[31] When nerve deficits are recognized, appropriate splinting and range of motion exercises should be instituted to prevent contractures. Some surgeons have recommended baseline electromyographic studies at 6 and 12 weeks after the identification of a nerve injury, but the effect of such studies on treatment decisions and ultimate outcomes is unclear. If a fracture-related radial nerve deficit in an adult has not resolved by 6 months, a decision should be made about exploration for repair or tendon transfer. This is controversial, but many believe that tendon transfer provides better and earlier functional recovery.[32]

Summary

Although most humeral fractures heal uneventfully, complications do occur. They cannot be prevented entirely, but the risk of common complications can be reduced. Humeral shaft nonunion can result from errors in patient selection for treatment or from technical mistakes. Both excessive and inadequate surgery can lead to nonunion. A common error is failure to provide adequate stability for the fracture, which is subjected to large angular and torsional loads. Nails, if used, should be interlocked on both sides of the fracture. Plates should be of adequate thickness and length. The risk of loss of fixation in the humeral head can be reduced (but not eliminated) with the correct use of locking plates and augmentation with bone grafts or other substances. Nerve palsy is a common complication, and the risk can be reduced with proper knowledge of anatomy, protection of the nerves, and avoidance of excessive retraction during surgery. A radial nerve palsy after a closed fracture or surgery usually resolves with observation.

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