Extremity Fractures in the Patient With a Traumatic Brain Injury

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Abstract

Extremity fractures are common in patients with traumatic brain injuries (TBIs). These injuries are often inadequately treated and occasionally are completely missed due to the unique problems inherent to the TBI patient. However, appropriate evaluation of the TBI patient allows prompt diagnosis and optimal treatment of extremity fractures. The increased survival rate of these patients has resulted in a greater emphasis on minimizing dysfunction and disability, especially that due to concomitant orthopaedic trauma. Advances in anesthetic technique permit earlier operative fixation of extremity fractures. Most injuries, particularly those in the lower extremity, require operative stabilization to allow early mobilization and rehabilitation. Upper extremity fractures are often associated with peripheral nerve injuries. Heterotopic ossification is common, especially about the elbow and hip. Contrary to prevalent belief, fracture healing is not necessarily accelerated in the TBI patient; hypertrophic callus, myositis ossificans, and heterotopic ossification occur frequently and are often misperceived as accelerated healing.

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The probability that a patient with a traumatic brain injury (TBI) will survive the injury has increased dramatically in recent years. Advances in emergency care and the establishment of trauma centers and specialized intensive care units have improved the overall rate of survival of these patients. Extremity injuries are present in 40% to 60% of head-injured patients.[1-3] Approximately 80,000 head-injured patients survive every year in the United States, with a considerable portion having some disability as a sequela of an orthopaedic injury.[4] Minimizing disability is especially important because most survivors are young males, with many years of potential productivity. Optimizing the orthopaedic care of these patients is critical to improving overall outcome and function.

The head-injured patient presents a number of diagnostic and therapeutic challenges. Complete evaluation of extremity injuries is often delayed or compromised due to life-threatening central nervous system and abdominal injuries. In addition, the comatose or disoriented patient is not able to point out areas of pain or tenderness that would call attention to these other injuries. Often, even when an injury is recognized, optimal care is not given because of neurologic instability or lack of understanding of the actual prognosis of a severe head injury.

Four basic treatment principles have been formulated on the basis of the experience at a large brain-injury rehabilitation center: (1) Establish the diagnosis, being suspicious for occult and missed injuries. (2) Assume a reasonable neurologic recovery for survivors. (3) Provide orthopaedic care that will allow rapid and aggressive mobilization of the patient. (4) Assume poor patient compliance.

Diagnosis

One of the most important problems in TBI patients is delayed recognition of injuries. As many as 10% of orthopaedic injuries in this population will be missed,[5] including injuries to the spine, hip, and peripheral nerves. In a review of 254 adult patients with TBIs, there were 72 fractures or dislocations and 29 neuropathies.[5] Of the 254 patients, 29 were found to have a total of 39 previously undetected injuries. The most common neuropathies involved the peroneal, ulnar, and median nerves and were associated with fractures. In anoth-

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er series of 50 adult patients with TBIs,[6] the incidence of previously undiagnosed peripheral nerve injuries was 34%. The most frequent were ulnar nerve (10%) and brachial plexus (10%) injuries.

Delay in recognition is even more common in children. Whole-body bone scanning has been recommended for this group. In one study,[7] this modality revealed 19 previously unrecognized fractures in a group of 48 children and young adults. In another series of 60 children,[8] 49 new injuries were detected with bone scanning.

To prevent this high rate of undetected injury, certain guidelines should be followed in the subacute phase (10 to 14 days after injury): (1) Screening radiographs of the cervical and thoracolumbar spine and pelvis should be obtained in all TBI cases. The knees should also be included if the patient was involved in a pedestrian-auto accident. (2) A whole-body bone scan should be considered for skeletally immature patients. (3) Electromyography and nerve-conduction-velocity studies should be considered for any patient with clinical signs of neuropathy. Peripheral nerve injury should be suspected in the vicinity of every fracture. It should be noted, however, that both studies may be difficult to perform early in this population due to agitation.

Prognosis

With advances in the medical management of the TBI patient, the overall survival and outcome have improved dramatically. The Glasgow Coma Scale (Table 1) has been used to assess the severity of a head injury. A score on a scale of 3 to 15 points is obtained by evaluating three aspects of a patient's examination: eye opening, motor response, and verbal response. With this scale, the severity of a head injury and the prognosis for recovery can be assessed.

In a recent review of the data on 1,264 brain-injured patients (Glasgow Coma Scale score less than 9) evaluated 10 years after injury, 55% had good recovery, 19% had clinically significant disability, and 7% were in a vegetative state.[9] Most deaths occurred in the acute phase. In another series,[10] of 40 severely head-injured patients (those with fixed and dilated pupils), 25% still had a good recovery (defined as mild to moderate functional disability). The mortality was 43%. Factors associated with increased risk for mortality were advanced age, a diagnosis of subdural hematoma, and surgery performed more than 6 hours after fixation of the pupils. In yet another series,[11] the results in 181 head trauma survivors were very encouraging. At 2 years, 93% were able to ambulate independently, 90% were able to perform activities of daily living (ADLs), and 68% had returned to full-time employment.

These numbers have improved since the late 1970s, when a 2-year review conducted at Rancho Los Amigos Medical Center found that about two thirds of TBI patients were able to ambulate and perform ADLs independently.[12] Most of the improvement occurs in the first 6 months, according to Choi et al,[13] who reviewed the data on 786 patients. In their study, functional improvement tended to plateau after 6 months. Follow-up of 88 operatively managed fractures in head-injured patients revealed that in only 11 patients was the orthopaedic treatment irrelevant due to the severity of head injury. Almost 70% of patients in that series had a full return to function.[3]

As a group, the elderly have been found to consistently have a poor recovery after head injury. Mortality is high, ranging from 61% to 75% for those over age 65.[14] Glasgow Coma Scale scores of less than 5, unilateral or bilateral pupillary dilatation, and age over 75 were all associated with 100% mortality in one series of 66 elderly patients.[14] Coma lasting more than 3 days and intracranial pressure (ICP) greater than 20 mm Hg were two factors that were each associated with a mortality greater than 90% in another series of 195 elderly patients.[15] Goldstein et al[16] found that elderly patients who survive function poorly, with major cognitive deficits, compared with control subjects. However, the risk of dementia is not necessarily increased, according to Breteler et al.[17] They found no increased risk of dementia within 8 years after injury in a group of head trauma patients, aged 50 to 74 years, compared with an age-matched reference group.

On the basis of available data, it can be concluded that young head

Table 1
Glasgow Coma Scale[4*]

Eye opening	
Spontaneous	4
In response to speech	3
In response to pain	2
None	1
Motor response	
Obeys commands	6
Purposeful movements in response to pain	5
Withdrawal in response to pain	4
Flexion in response to pain	3
Extension in response to pain	2
None	1
Verbal response	
Oriented	5
Confused	4
Inappropriate	3
Incomprehensible	2
None	1

* One score (the highest value) is recorded for each category. Thus, the possible combined scores range from 3 to 15.

trauma patients, if they survive the acute trauma, can be expected to have a good functional recovery. They will ambulate and perform ADLs independently and may even return to the workplace. Therefore, these patients should be afforded prompt and appropriate orthopaedic treatment, rather than assuming they will have low functional demands and therefore require less aggressive care.

Anesthesia and Timing of Operative Fracture Treatment

It has long been assumed that general anesthesia is dangerous for the brain-injured patient and that operative fixation of fractures should therefore be delayed, as long as 2 weeks if necessary.[1] It is certainly true that surgery and general anesthesia can cause significant problems for the head-injured patient. Hypertension, tachycardia, hypercarbia, coughing, airway manipulation, and certain anesthetic agents can all increase ICP.[18] However, recent advances in anesthetic pharmacology and technique have decreased the risk of surgery for the head-injured patient, and thus have changed the philosophy regarding the timing of fracture fixation. For example, certain general anesthetic gases (e.g., isoflurane, halothane) may increase ICP but also increase cerebral blood flow. These anesthetics, when combined with continuous ICP monitoring and certain anesthetic techniques, such as hyperventilation and the use of adjunctive anesthetic agents, make early fracture fixation possible and desirable.

Cerebral edema increases in the first 24 hours after injury, reaching maximum levels at 3 to 5 days before subsiding at 7 to 10 days. Prolonged operative procedures should still be avoided in the acute setting, as there is some evidence that a secondary brain injury can occur in TBI patients under anesthesia for prolonged periods. Therefore, it is advisable either to perform surgery before significant edema occurs or to do so once it has decreased, especially if the procedure will require extended anesthesia time.

In several series,[19-21] early fracture fixation in head-injured patients did not result in increased risk of neurologic complications. Faster patient mobilization and decreased risk of pulmonary complications were noted in patients who underwent early fracture stabilization, often in the same operative session as the neurosurgical intervention. In all three series, adverse pulmonary and neurologic outcomes were related more to the severity of the original head injury than to any other factor. Kotwica et al[22] evaluated early (within 12 hours of injury) and late (after 4 days) osteosynthesis of lower extremity fractures and found higher mortality and more severe pulmonary complications in the patients whose orthopaedic treatment was delayed.

The most important factor in the outcome of a TBI patient is the severity of the head injury. However, as soon as neurosurgical clearance is obtained, orthopaedic treatment should be initiated. An analysis of 734 TBI patients showed that extracranial complications, such as pneumonia, sepsis, and coagulation disturbances, were critical in determining overall outcome.[23] Early fracture stabilization and patient mobilization may help minimize some of these extracranial complications.

Nonoperative Orthopaedic Care

Closed treatment of isolated extremity fractures with circular casts is an acceptable treatment option, with appropriate monitoring. Circumferential casts should be used with caution, however, as head trauma patients are not able to express pain arising from a tight cast. Neurovascular compression and compartment syndrome are dangers that should be anticipated and prevented by bivalving the cast, especially in the acute injury phase. Splints, when used, should be sturdy and applied with care, as they are easy for disoriented patients to remove and may allow motion when hypertonicity is severe. Loose casts also allow excess motion, and should be replaced as swelling subsides. Excess motion may result in not only loss of reduction but also pressure sores.

A recent review of treatment of cast fractures in 20 head-injury patients found only one malunion, and functional recovery was not delayed due to the orthopaedic care.[3] When used to immobilize a fracture both above and below the adjacent joints, casts are especially valuable in preventing contractures and decreasing hypertonicity. Serial casting has also been shown to aid in the mobilization of established contractures.[24]

The position of the adjacent joints is also important when cast immobilization is used. Flexion should be avoided, as it may facilitate a myostatic contracture. In the upper extremity, the elbow should be immobilized at 45 degrees, the wrist at 0 degrees, the metacarpophalangeal joints at 45 to 60 degrees, and the interphalangeal joints at 0 degrees. The thumb should be extended and abducted. In the lower extremity, the hip, knee, and ankle should be immobilized in a neutral position.

Traction methods are not recommended for prolonged fracture management of the TBI patient. Nursing care is difficult for the often agitated and unstable TBI patient, and use of a traction apparatus further complicates care. Mobilization and rehabilitation of the patient are also delayed by long-term traction management.

Upper-Extremity Fractures

Upper-extremity fractures are not as common as lower-extremity fractures. In a recent series of 188 long-bone fractures,[3] 81 involved the upper extremity. In another series of 142 fractures, 62 involved the upper extremity.

Peripheral nerve injuries occur more frequently in the upper extremity than in the lower extremity, in spite of the fact that lower-extremity fractures are more common. Of the 27 cases of peripheral nerve injury in the study by Groswasser et al,[2] 18 were in the upper extremity, and 9 were in the lower extremity. Therefore, the index of suspicion must be high, as these are among the most frequently missed injuries.

Shoulder Girdle

The shoulder girdle is the most common site of upper-extremity bone injury in the head-injured patient. Chest radiographs will often demonstrate an injury to the acromioclavicular joint, clavicle, or sternoclavicular joint. Most shoulder girdle fractures can be treated with a simple sling or shoulder immobilizer. However, physical therapy and range-of-motion exercises should be instituted as soon as possible, as internal rotation contractures can occur. Heterotopic ossification is common in the injured shoulder at the coracoclavicular ligament or in the periarticular region (Fig. 1). Prompt physical therapy can help to maintain range of motion.

Brachial plexus injuries are commonly associated with shoulder girdle fractures, constituting 10% of peripheral nerve injuries in one series.[2] A fall resulting in impact on both the shoulder and the head is often responsible for concomitant injuries, with brachial plexus palsy resulting from traction. An underlying brachial plexus palsy should be suspected in any head-injured patient with a flail upper extremity.

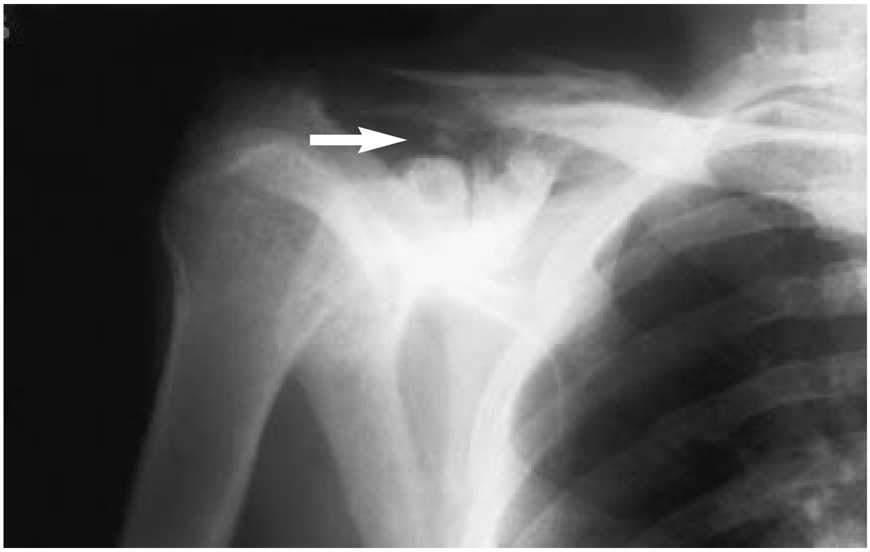

Fig. 1 Shoulder radiograph demonstrates heterotopic ossification (arrow) in the coracoclavicular ligaments after mild acromioclavicular separation in a TBI patient.

Humerus

Fractures of the humerus are also relatively common, constituting about 10% of all fractures in one series of head-injured patients.[2] Radial nerve injury should be suspected, but the diagnosis is more difficult to establish, as the TBI patient often is not able to cooperate with a proper examination. Treatment with closed methods is problematic, as agitated patients frequently remove coaptation splints or fracture braces, and a hanging arm cast may not be appropriate for a bed-ridden patient. Therefore, fixation of a humeral fracture with an intramedullary rod or open reduction and internal fixation (ORIF) with a plate and radial nerve exploration are indicated more often than in the non-TBI patient. With secure internal fixation, immediate range-of-motion therapy may be instituted to prevent contractures of both the elbow and the shoulder. In addition, if ORIF is chosen, the status of the radial nerve can be determined during the dissection.

Elbow

Fractures, dislocations, and fracture-dislocations about the elbow present a number of treatment difficulties, including heterotopic ossification, ulnar nerve palsy, and contracture resulting from spasticity. Open reduction and internal fixation is the preferred treatment for most fractures, allowing early range of motion. In one series,[25] the incidence of heterotopic ossification was 89% in patients with elbow fractures and 100% in those with dislocations, compared with 3% in the general population.[26] Traumatic heterotopic ossification may occur in any area around the elbow and may be associated with spasticity (Fig. 2). Injury to the

Fig. 2 Lateral elbow radiograph shows heterotopic ossification posteriorly after a posterior fracture-dislocation.

ulnar nerve, whether early or late, is frequently unrecognized until finger clawing appears. Ulnar neuropathy can be the result of either the initial injury or, more commonly, heterotopic ossification on the medial side of the elbow. A 2.5% incidence of late ulnar neuropathy has been reported, usually occurring on the neurologically impaired side and generally associated with spasticity.[27]

Management of elbow injuries involves four principles: (1) Secure internal fixation and early mobilization help to prevent flexion contractures. (2) Prophylaxis against heterotopic ossification should be instituted in the immediately postoperative period, in the form of etidronate, indomethacin, or radiation. (3) Manipulation under anesthesia should be considered to help mobilize difficult contractures.[28] (4) Ulnar neuropathy should be treated with surgical release of the nerve with transposition. In one study,[27] anterior transposition of the ulnar nerve resulted in complete recovery in 23 of 27 (85%) patients. Prolonged compression probably accounted for incomplete recovery in the other 4 patients.

Forearm

Fractures of the forearm constituted 33% of long-bone fractures in one series[3] and 7% (47/661) of total fractures in another.[29] These fractures present considerable management difficulties, regardless of whether closed or operative treatment is used. Residual restriction of pronation and supination can occur with either treatment method. This stiffness is not restricted to the forearm, as there is a 20% incidence of heterotopic ossification in the elbow in patients with forearm fractures.[29] Closed reduction is sometimes difficult to obtain and is almost always difficult to maintain. Isolated ulnar fractures with minimal displacement may be treated nonoperatively, especially in the cooperative patient. Operative treatment is recommended for all other injuries, to minimize immobilization and achieve optimal early range of motion. Stable ORIF with standard AO hardware and technique is indicated; however, this type of surgical dissection results in high rates of both interosseous membrane ossification (50%) and synostosis (33%) (Fig. 3).[29] In contrast, the synostosis rate after forearm plate fixation is only 3% to 6% in the general population.[30] Surgical excision of a synostosis led to a satisfactory outcome in only 50% of the patients in one small series.[31]

To minimize the risk of synostosis and forearm stiffness, intramedullary nailing of forearm fractures can be considered. The union rates with intramedullary nailing of forearm fractures are comparable to those obtained with standard plating, and intramedullary fixation has the advantage of minimal surgical dissection and trauma.[32] Closed nailing is generally possible; a small incision can be made to assist in reduction.

Wrist and Hand

Distal radius fractures, especially those that are minimally displaced, frequently are unrecognized and diagnosed late. A high index of suspicion should be maintained, as distal radius malunions are common. Treatment of these malunions may result in a poor functional outcome compared with the results of acute reduction and treatment.

Early treatment should consist of closed reduction and application of a sugar-tong splint or bivalve cast, as carpal tunnel syndrome may occur, which is difficult to recognize in the head-injured patient. Definitive treatment with external fixation or percutaneous pinning

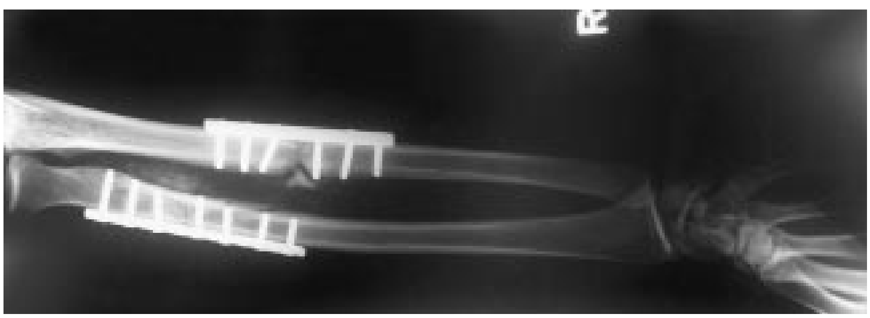

Fig. 3 Forearm radiograph shows early synostosis after ORIF in a both-bone forearm fracture associated with TBI.

should be considered, especially in fractures prone to loss of reduction, such as those with dorsal comminution. External fixation or pinning can allow more rapid joint mobilization, which is also important in this group of injuries. Heterotopic ossification, although extremely rare, has been described in the wrist and fingers as well.[33]

Lower-Extremity Fractures

Fractures of the lower extremity occur as a consequence of high-energy mechanisms. The incidence of lower-extremity fractures in head trauma patients varies from 50% to 75%.[3] Polytrauma involving the head, chest, abdomen, and extremities makes the care of these patients difficult. As a result, care of the extremity injuries is often triaged last. Systemic complications are more common with lower-extremity fractures than with upper-extremity fractures. Appropriate treatment of these injuries and prompt patient mobilization are the keys to preventing these complications.

Pelvis

Pelvic trauma occurs predominantly in victims of auto-auto and auto-pedestrian injuries, with an incidence of pelvic fracture greater than 50%.[9] The dynamics of the automobile crash may further reveal what injuries to suspect. In an analysis of organ injury patterns and mechanism of trauma, Siegel et al[34] found that lateral compression fractures of the pelvis had a high association with head trauma. Injuries that resulted in anteroposterior compression were more often associated with abdominal trauma. Application of this knowledge has led to the development of side-impact air bags to reduce the rate of lateral compression injury. The specific history, combined with significant blood loss, should raise suspicion of a pelvic fracture. The initial diagnosis can usually be made on the basis of a routine anteroposterior film of the pelvis.

External fixation of pelvic ring disruptions has been advocated to stabilize fractures and allow patient mobilization. Riemer et al[35] found that the mortality of TBI patients with pelvic ring injuries fell from 41% to 7% as the use of external fixation went from 3% to 31% in a 2-year period. They recommended that orthopaedic stabilization of pelvic injuries, rather than reconstruction, should be viewed as part of the initial treatment of the TBI patient.

Once the patient's condition has stabilized, it is preferable to treat pelvic injuries definitively with internal fixation, rather than with long-term external fixation. Many patients have multiple extremity injuries, and prolonged pelvic external fixation results in awkward rehabilitation and pin-tract problems. Plate fixation of anterior or posterior ring disruptions can avoid these problems when performed in the subacute phase.

Acetabulum

Treatment of an acetabular fracture is difficult and often ends with a poor result if appropriate precautions are not taken. Nonoperative treatment, including traction, has been recommended in the past, with institution of early range-of-motion exercises. However, TBI patients are poorly compliant, and significant displacement of the fracture can occur. Pin-tract infection is common due to limb spasticity and uncontrolled motion. Operative stabilization in this population has been advocated, but this is fraught with difficulty, with a complication rate approaching 70%.[36]

Heterotopic ossification, already a potential risk in the nonfractured hip of a TBI patient, has an incidence greater than 60% in the operatively managed acetabular fracture (Fig. 4).[36] Surgery is compli-

Fig. 4 Anteroposterior view of the pelvis shows significant heterotopic ossification (arrow) associated with acetabular fracture.

cated by the poor compliance of TBI patients (which resulted in displacement of 2 of 23 surgically treated fractures in one study[36]), spasticity, and concomitant polytrauma that delays hip rehabilitation. To reduce the incidence of heterotopic ossification, routine aggressive prophylaxis has been advocated, as well as the use of an anterior ilioinguinal approach whenever possible.

Hip Fractures

Fractures of the femoral neck and intertrochanteric regions are uncommon. In one series of 591 head trauma victims with fractures, only 29 had hip fractures, three of which were initially unrecognized.[4] Most TBI patients are young and have been involved in high-energy accidents that resulted in injuries of the pelvis and the femoral and tibial shafts, rather than the hip. When these fractures are encountered, standard ORIF techniques and heterotopic ossification prophylaxis should be used.

Femur

The incidence of femoral fractures is 9% to 22% in the head-injury population. Standard intramedullary nailing is recommended, although myositis ossificans is frequently seen at the site of nail insertion or at any surgical incision.[37] Open reduction should therefore be performed only when necessary. The high (16%) incidence of wound infection documented in one series[38] was attributed to the problem of bowel and bladder incontinence in the brain-injured patient and the resultant contamination. Heterotopic ossification has been reported to occur in as many as 82% of patients who undergo femoral nailing, especially medially (Fig. 5); moreover, the severity of the head injury was correlated with a higher grade of heterotopic ossification, as graded on the Brooker scale.[39] The medial location of the lesion is associated with adductor spasticity, which also tends to displace the proximal fragment medially, causing valgus deviation rather than the more commonly encountered varus.

Despite these problems, excellent results can be achieved. Fracture healing in the femur was found to approach 100% in two series,[38,40] with an average time to union of approximately 4 months. In one series of 42 fractures, including 12 open fractures, there were only three complications: two malunions requiring subsequent osteotomy and one deep infection in a type IIIA open fracture.[40]

Fig. 5 Abundant callus in a midshaft femoral fracture after nailing.

Knee

The indications for surgical fixation of fractures of the distal femur and proximal tibia are the same in the TBI population as in the general population. A hinged brace is recommended for additional stability after operative fixation, as many TBI patients are poorly compliant. Heterotopic bone is much less common at the knee than at the shoulder, elbow, or hip.[1]

Ligamentous injuries initially should be treated nonoperatively. Early ligament reconstruction is not recommended because concomitant trauma often impairs appropriate rehabilitation. In addition, many patients have hemiplegia or spasticity, which will cause ligament reconstruction failure. Reconstructive surgery can be performed after full recovery has taken place, according to the demands of the patient at that time. Consideration should be given to using the hamstrings as a graft source for anterior cruciate ligament reconstruction, as TBI patients often have hamstring spasticity.[41] In severe ligamentous injuries or knee dislocations, continuous passive motion in a hinged knee brace will help preserve knee motion while the patient is bedridden. This controlled motion may help prevent arthrofibrosis, which could make future knee function unsatisfactory.

Tibia

Tibial fractures accounted for 65 of 188 long-bone fractures in one series[3] and 47 of 115 lower extremity fractures in another.[2] Isolated tibial fractures can be treated with standard techniques. Plaster or fiberglass casts are preferred to fracture braces, as the noncompliant or agitated patient can remove the latter. Special consideration should be given to padding the fibular head in cast application, as peroneal palsy can occur and is not easily diagnosed in a TBI patient. Casts should be bivalve when there is still swelling and should be monitored regularly. Loosening of the cast will occur as the swelling subsides, which can result in excess motion that can not only lead to nonunion but also cause pressure sores.

Reamed or nonreamed closed intramedullary nailing is the treatment of choice for patients with polytrauma and for those with isolated fractures when a cast will not be well tolerated. External fixation of severe open fractures is sometimes necessary, but early removal and alternative treatment should be instituted as soon as feasible. Brain-injured patients are poorly compliant with pin care, and cumbersome frames may make range of motion of the knee and ankle difficult, as well as be a danger to the opposite limb. Unreamed locked tibial nails have been shown to be effective for most open fractures, even type IIIB.[42]

Ankle and Foot

Treatment of foot and ankle fractures in the head-injured patient should follow the same guidelines as for the general population. A short leg cast should be considered even after secure internal fixation, as TBI patients will be poorly compliant. A cast also tends to decrease spasticity in a neurologically involved limb. Care should be taken to place the ankle in neutral, as an equinus contracture is a problem, especially in the hemiplegic patient.

Fracture Healing

It has generally been believed that fractures heal faster and with "exuberant callus" in TBI patients. Anecdotal accounts and case reports in the literature documenting such findings in long-bone fractures have fostered this belief. However, the results in large series of both tibial and femoral fractures have contradicted this notion. Moreover, the exuberant callus described in many instances is myositis ossificans from surgical trauma or heterotopic ossification adjacent to joints and, as such, is not clinically significant in terms of healing.[43,44] In one review of 47 tibial fractures in head trauma patients, the average time to union was almost 6 months, and the incidence of nonunion was 4% (Fig. 6).[45] These values are similar to those for the general population. There is some evidence of accelerated healing in femoral fractures. In one series of 68 femoral fractures, treated either operatively or nonoperatively, healing occurred at about 4 months.[38] In another series of fractures treated with intramedullary rods,[40] healing occurred slightly faster. To date, only operatively treated femoral fractures have been shown to heal rapidly with copious callus.

It has been suggested that spasticity may be a stimulus for accelerated healing. This has been supported only by anecdotal evidence and the experience in small series. The effect of spasticity has been examined more definitively in the hemiplegic population with bilateral fractures. The time to union for

A B

Fig. 6 **A,** Closed distal tibia fracture with no healing at 6 months. **B,** Autogenous iliac-crest bone graft was required to achieve fracture union.

a tibial fracture on the hemiplegic side was found to be the same as in the neurologically intact extremity. The time to union in femoral fractures was actually 1 month longer on the hemiplegic side. Exuberant callus was not seen in either the tibia or the femur on either side. A review of 51 fractures in 68 head-injury patients also found no correlation between hypertonicity and the extent of callus formation.[45]

Accelerated fracture healing in the TBI patient is also not supported in the basic science literature. In a rat model, heterotopic induction of osteogenesis showed no difference with respect to the type of neural injury. A humoral mechanism has been proposed for osteoinduction in the head-injured patient; however, evaluation of serum mitogenic activity in TBI patients showed no difference compared with control subjects.[46,47] Basic fibroblast growth factor immunoreactivity has been shown to be increased in the sera of head-injured patients, but this increased immunoreactivity has not been shown to have growth-promoting effects in vitro.[48]

On the basis of the available literature, extremity fractures in the head-injured adult should be expected to have the same healing rates as in the general population. Inadequate orthopaedic management should not be excused by the dogma that head-injury patients have some magical healing property, and fractures in them always unite. In fact, due to compliance problems, these patients often have greater problems with healing. Two thirds (4/6) of the malunions and delayed unions in one series of 188 fractures were due to poor patient compliance.[3] In a series of 23 acetabular fractures in head-injury patients,[36] failure of internal fixation was the result of poor compliance.

Summary

Survival of patients after TBI has increased dramatically over the past 20 years. Extremity trauma is frequent in this population, with a high incidence of occult and missed injuries. Mobilization of these patients and optimal long-term function are dependent on prompt recognition of orthopaedic injuries and appropriate treatment, as many patients will have a good neurologic recovery. Orthopaedic care of the TBI patient is complicated by neurologic instability, associated trauma, and poor compliance. Satisfactory results can be achieved with knowledge of the challenges specific to the TBI patient, such as heterotopic ossification and joint and myostatic contractures. Treatment methods that minimize the need for patient compliance, encourage early osteosynthesis, and maintain range of motion form the basis for good orthopaedic care.

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