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SPECIALTY UPDATE

What's New in Orthopaedic Trauma

William M. Ricci, MD, Christopher McAndrew, MD, David Merriman, MD, and Michael J. Gardner, MD

The management of patients who have musculoskeletal trauma continues to evolve. Even procedures that are well entrenched as “gold standards” such as femoral nailing are being refined and improved. The literature in the past year has provided practical as well as theoretical solutions to common problems, methods for improved diagnosis of subtle injuries, and insight for the relative advantages of one treatment over another. The present update provides a synopsis of more than sixty of the most clinically relevant high-quality studies. The key methods (◆), results (>), and take-home points (★) for these studies are presented.

Hip Fractures

Fractures in the elderly present a unique set of hurdles with regard to perioperative management and surgical treatment. Recent studies have reaffirmed the advantages of arthroplasty for the treatment of displaced femoral neck fractures, have shed new light on the safety of restricted transfusion protocols and complications of iron supplementation, have indicated that provider volume has a limited effect on mortality following hip fracture, and have shown the relative equivalence of plate and nail fixation for the treatment of intertrochanteric fractures.

Femoral Neck Fractures

- ◆ In a large series of >4300 patients with an age of more than seventy years from the Norwegian Hip Fracture Register, internal fixation was compared with hemiarthroplasty for the treatment of a displaced femoral neck fracture¹.
- > The reoperation rate at one year was 3% in the arthroplasty group, compared with 23% in the internal

fixation group. Functional outcomes and satisfaction were higher in the arthroplasty group. There was no difference between the groups in terms of the one-year mortality rate.

- ★ This study reaffirms that elderly patients with displaced femoral neck fractures are best treated with arthroplasty rather than with open reduction and internal fixation (ORIF).

Anemia and Transfusion in Hip Fracture Patients

- ◆ The Functional Outcomes in Cardiovascular Patients Undergoing Surgical Hip Fracture Repair (FOCUS) trial randomized >2000 patients with hip fracture to two post-fracture transfusion protocols². The groups received a transfusion when either the hemoglobin was <10 g/dL or when anemia symptoms occurred. In the more restrictive group, transfusion was permitted but not required if the hemoglobin was <8 g/dL.
- > In-hospital mortality, cardiac events, infections, and length of stay did not differ between the groups. The sixty-day mortality was also similar between the groups.
- ★ A restrictive transfusion threshold appears to be safe and may help to decrease transfusion reactions, infection rates, and cost.
- ◆ A randomized trial of 300 patients with hip fractures and anemia compared patients treated with and without iron supplementation³.
- > No significant difference was found in terms of hemoglobin increase, length of hospital stay, or mortality. Seventeen percent of the patients in the iron supplement group reported adverse effects of the medication.
- ★ The use of iron supplementation for the treatment of anemia associated with hip fractures was ineffective and had detrimental side effects.

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Provider Volume and Mortality

- ◆ A Medicare database review of 192,365 elderly patients with intertrochanteric proximal femoral fractures analyzed the effect of hospital and provider volume on mortality⁴.
- Lower-than-median-volume hospitals had an increased risk of inpatient mortality. The sixty-day mortality following procedures performed by surgeons who treated two to three cases per year was higher than that following procedures performed both by higher-volume surgeons (those performing at least four procedures per year) and lower-volume surgeons (those performing zero or one procedure per year). Case volume had a smaller positive effect on geriatric intertrochanteric fracture outcomes than on elective hip arthroplasty outcomes.
- ★ Establishing hip-fracture centers and transfer protocols is not expected to have a large effect on mortality rates.

Nail Versus Plate for Intertrochanteric Fractures

- ◆ A randomized trial of 210 intertrochanteric femoral fractures was performed to compare long cephalomedullary nailing with sliding hip screw treatment⁵.
- No differences were found between the groups in terms of the reoperation rate, the complication rate, or EuroQol 5D outcomes. The mortality rate was higher in the nailing group, but the rates were similar when adjusted for mini-mental status scores.
- ★ The use of sliding hip screws and intramedullary implants resulted in similar outcomes for the treatment of intertrochanteric femoral fractures.

Pelvis and Acetabulum

Many aspects of the diagnosis and treatment of pelvic and acetabular fractures have remained unclear. A frequent anatomic variation of the sacrum, sacral dysmorphism, and its implications on posterior pelvic fixation has received increased attention. The incidence of sacral dysmorphism was found to be higher than previously reported, and the ability to place S1 and S2 iliosacral screws in these patients was defined. Dynamic examinations of the pelvis, performed to augment standard static radiographs and computed tomography (CT) scans, more accurately determined stability of pelvic ring injuries and acetabular fractures. These dynamic examinations potentially offer new standards for determining surgical indications. The results of strategies for the treatment of geriatric acetabular fractures with use of ORIF or arthroplasty, or both, provide guidance for treatment recommendations.

Sacral Dysmorphism

- ◆ A series of CT scans from a consecutive series of trauma patients was analyzed to determine the prevalence of sacral dysmorphism and to determine the

safe zone, screw size, and implications for iliosacral screw placement⁶.

- The prevalence of sacral dysmorphism was 44%. In these patients, the upper-segment safe zone was smaller than normal but could accommodate an oblique iliosacral screw that was long enough to reach beyond midline; however, it could not accommodate a trans-sacral screw. The second-segment safe zone was larger and could accommodate a trans-sacral screw.
- ★ High vigilance should be maintained for sacral dysmorphism in patients with unstable posterior pelvic injuries. Iliosacral screw positions and vectors should be carefully planned preoperatively. Another clinical study confirmed the feasibility and efficacy of iliosacral screw placement in these patients⁷.

Evaluation of Pelvic Stability

- ◆ A cadaveric study correlated the degree of symphysis pubis diastasis with the degree of pelvic ligament injury⁸.
- A threshold of 2.5 cm of symphysis pubis diastasis did not accurately predict associated pelvic ligament injury.
- ★ An arbitrary threshold of the magnitude of symphysis pubis diastasis should not be used universally to infer associated pelvic ligament injury or pelvic stability.
- ◆ Twenty-two patients with anterior-posterior compression pelvic injuries underwent dynamic stress examinations under anesthesia⁹.
- Twenty-seven percent of the patients demonstrated dynamic pelvic instability, not predicted from static radiographs, that altered the treatment.
- ★ Diagnosing pelvic instability on static radiographs or CT scans may be inaccurate. This concept was corroborated in another study that included a variety of pelvic fracture patterns¹⁰.

Pelvic Imaging

- ◆ CT scans of sixty-eight patients were analyzed to determine optimal inlet and outlet pelvic radiographs to profile the relevant surgical pelvic anatomy¹¹.
- An inlet view with a caudal tilt of 25° and an outlet view with a cranial tilt of 60° were optimal.
- ★ Screening inlet and outlet radiographs of the pelvis at a caudal tilt of 25° and a cranial tilt 60° are recommended rather than the customary 45° angle tilt.

Posterior Wall Fractures

- ◆ Twenty-one patients with stable posterior wall acetabular fractures (determined with dynamic stress fluoroscopy with the patient under anesthesia) were treated nonoperatively, and the functional outcome was determined¹².
- With use of this protocol and diagnostic method, nonoperative treatment led to hip joint congruity, an

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excellent radiographic outcome, and good-to-excellent early clinical outcomes.

- ★ This study adds to the support for the use of dynamic stress examinations to determine the indications for the operative treatment of posterior acetabular wall fractures.

Geriatric Acetabular Fractures

- ◆ Eighty-four elderly patients with displaced acetabular fractures underwent acute ORIF, and functional outcomes were assessed at a minimum of two years¹³.
- Fifty-eight patients (69%) achieved near-normal age-matched function and had durable hips. Less-accurate fracture reduction predicted the need for subsequent total hip arthroplasty.
- ★ Efficient surgical treatment of geriatric acetabular fractures is safe and effective, with an acceptably low rate of major complications. Several additional studies have emphasized the utility of a Stoppa window for reduction and buttress plate fixation of the quadrilateral surface, which is commonly displaced in association with geriatric acetabular fractures^{14,15}. Additionally, the “combined hip procedure” (acute ORIF and arthroplasty) was demonstrated to be a feasible option for elderly fracture patients with severe osteoporosis or extensive fracture comminution¹⁶.

Femur and Tibia

Several studies examined the anatomic implications of suprapatellar, semi-extended intramedullary tibial nailing. A potential for injury to the articular cartilage and menisci was identified. The risk of knee infection after retrograde intramedullary nailing of open femoral fractures was noted to be exceptionally low.

Semi-Extended Intramedullary Nailing of the Tibia

- ◆ Pre-nailing and post-nailing arthroscopy were used to examine whether articular cartilage damage occurred during eighteen suprapatellar nailing procedures¹⁷.
- Of the eighteen patients, four (22%) had damage visualized during post-nail arthroscopy that was thought to be due to the nailing procedure. All damage was localized to the intercondylar groove.
- ★ Cartilage injury was thought to represent the “learning curve” associated with the technique as all of the patients with cartilage damage were managed early in the series. Another cadaveric study demonstrated that the intrameniscal ligament was injured in 81% of specimens and that the medial meniscus was damaged in 12.5% after retropatellar nailing¹⁸. A modification of the semi-extended retropatellar technique that does not violate the knee joint was also recently described¹⁹.

Knee Infection After Retrograde Femoral Nailing

- ◆ A retrospective, multicenter review of ninety-three open femoral fractures that were treated with retrograde intramedullary nailing analyzed the rate of knee infection²⁰.
- One case of knee infection was found.
- ★ The very low rate of knee infection indicates that open fracture should not be a contraindication to retrograde femoral nail fixation. The low rate of knee infection was corroborated in another study of civilian gunshot wound fractures in which no cases of knee infection were found after retrograde nailing²¹.

Foot and Ankle

The surgical indications and specific techniques for the treatment of fractures of the distal part of the tibia, the ankle, and the calcaneus are not universally agreed upon. One randomized study and several prospective cohort studies have been performed to clarify some of the factors that affect the treatment of these challenging periarticular lower extremity injuries. Data from three studies of pilon fractures, each involving different surgical timing or techniques, confirmed consistently poor outcomes following these severe injuries.

Operative Versus Nonoperative Treatment of Ankle Fractures

- ◆ Eighty-one patients with undisplaced isolated fibular fractures and unknown injury to the deep deltoid ligament were randomized to operative treatment (n = 41) or nonoperative treatment (n = 40)²².
- Functional outcomes were no different between the groups at one year. In the nonoperative treatment group, eight patients (20%) had medial clear-space widening and eight (20%) had delayed union or nonunion. One patient in the operative group had an increase in tibiofibular clear space.
- ★ Patients in whom this ankle injury pattern was treated nonoperatively had a higher risk of displacement at the ankle mortise. Outcomes at one year were equivalent, but longer-term follow-up may reveal differences between the groups.

Pilon Fracture Outcomes

- ◆ Sixty-eight open pilon fractures were treated with staged ORIF. Fifty-nine patients were followed for an average of thirty-four months, and functional outcomes were assessed²³.
- Eighty-eight percent of the fractures healed following the initial ORIF procedure. Three percent were associated with the development of a deep infection. Functional outcomes were below age-matched norms.
- ★ ORIF for the treatment of pilon fractures, with an emphasis on staged procedures, meticulous soft-tissue management, and widespread use of temporizing external fixation, can lead to low complication rates. Nevertheless, patient outcomes are often relatively poor.

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- ◆ Ninety-five patients with OTA (Orthopaedic Trauma Association) Type-C pilon fractures were managed with acute ORIF (with 88% of these patients being managed within forty-eight hours after the injury)²⁴.
 - Anatomic reduction was achieved in 90% of the patients. Six percent of the patients had development of a wound complication or deep infection that required surgical intervention.
 - ★ Immediate ORIF of pilon fractures by experienced trauma surgeons can lead to low complication rates and may facilitate articular surface reductions. Soft-tissue status should be carefully assessed, and ORIF timing should be individualized.
- ◆ Forty-three patients with pilon fractures were managed definitively with spanning articulated external fixation and were followed prospectively²⁵.
 - By the time of the six-month follow-up, the mental component score of the Short Form-36 (SF-36) had recovered to age-matched norms. The physical component score improved between one and two years, but pain and function were dramatically worse than normal at two years after the injury.
 - ★ Pilon fractures that were treated with definitive external fixation continued to improve up to two years after the injury but remained a source of substantial disability over the long term. Patients should be counseled on the basis of these data.

Calcaneal Fractures and Advanced Age

- ◆ One hundred and ninety-one patients with fractures of the calcaneus underwent ORIF, and 158 were available for follow-up²⁶. Outcomes for patients older than fifty years of age were retrospectively compared with those for patients younger than fifty years of age.
 - The functional outcomes for older patients were significantly better than those for younger patients on multiple scales.
 - ★ Advanced chronological age does not appear to be a contraindication to ORIF for the treatment of a displaced calcaneal fracture. Physiological age and activity level should be considered, and treatment should be individualized.

Shoulder

The optimal treatment of proximal humeral fractures continues to be somewhat elusive, as illustrated in a study evaluating intramedullary nails for the treatment of fractures that extend into the humeral shaft. The relative importance of the posterior humeral circumflex artery for humeral head perfusion represents new clinically relevant information. Elbow motion was found to be affected to a greater extent than shoulder motion after the plating of humeral fractures, and

problems associated with intramedullary nailing of comminuted clavicular fractures were described.

Fixation of Associated Proximal and Shaft Fractures of the Humerus

- ◆ The use of intramedullary nailing for the treatment of proximal humeral fractures associated with humeral shaft extension was evaluated in a retrospective study of twenty-one cases²⁷.
 - There were a modest number of complications, including three nonunions, one case of humeral head osteonecrosis, and one unacceptable loss of fracture reduction. Shoulder function was marginal, with no patient regaining full range of motion and eight patients having mild residual pain.
 - ★ An unsupported conclusion was that intramedullary nailing offers a reliable option for the treatment of this injury pattern. There were no direct comparisons with other methods of treatment; therefore, it remains unclear if this method of treatment is optimal.

Vascularity of the Humeral Head

- ◆ A cadaveric injection study was performed to identify the relative importance of the anterior and posterior humeral circumflex arteries to humeral head perfusion²⁸.
 - Sixty-four percent of the vascularity of the humeral head was from the posterior humeral circumflex artery, and 36% was from the anterior humeral circumflex artery.
 - ★ These data help to explain the low rate of osteonecrosis seen in association with displaced proximal humeral fractures, which are associated with up to an 80% rate of anterior humeral circumflex artery disruption.

Range of Motion of the Shoulder and Elbow After Minimally Invasive Plating of the Humerus

- ◆ Shoulder and elbow range of motion after minimally invasive plating for the treatment of humeral shaft fractures with use of proximal deltobicipital and distal brachialis-splitting incisions was reviewed in a study of fourteen cases²⁹.
 - Shoulder motion recovery required nineteen days, whereas elbow motion recovery required sixty days.
 - ★ The threefold increase in time for elbow motion recovery represents new information and indicates that postoperative rehabilitation should include the elbow.

Nailing of Midclavicular Fractures

- ◆ The results of titanium elastic nailing for the treatment of displaced midclavicular fractures were prospectively evaluated in a study of twenty-three patients³⁰.
 - Seven patients required open reduction. The mean shortening was 0.32 cm; however, two patients with

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comminuted fractures had shortening of 1.5 cm. One patient required revision because of nail misplacement.

- ★ Surgeons treating clavicle fractures with intramedullary nails should expect shortening in patients with comminuted fractures and should be prepared to perform an open reduction.

Elbow

The need for and efficacy of ulnar nerve transposition during ORIF for the treatment of distal humeral fractures continues to be debated. Two studies provided support for not routinely performing transposition of the ulnar nerve during ORIF of distal humeral fractures. Also, Level-I evidence provides insight into the utility of and complications associated with the use of radiation therapy for prophylaxis against heterotopic ossification after elbow trauma.

Ulnar Nerve and Distal Humeral Fractures

- ◆ A multicenter, retrospective review of patients with distal humeral fractures that were treated with ORIF was conducted to determine the prevalence of ulnar nerve dysfunction and to determine if ulnar nerve transposition was protective³¹.
- Ulnar nerve symptoms were four times more prevalent in patients who underwent transposition as compared with those who did not (33% compared with 9%).
- ★ These data indicate that transposition may not be beneficial for preventing the development of ulnar neuritis after ORIF for the treatment of distal humeral fractures. An additional study that supported these findings demonstrated that the prevalence of ulnar nerve dysfunction after ORIF of distal humeral fractures was 16% and that ulnar nerve transposition was not protective³².

Radiation Therapy for Prophylaxis Against Heterotopic Ossification

- ◆ A prospective, randomized, multicenter trial examined the safety of using single-fraction postoperative radiation therapy (700 cGy) to prevent heterotopic ossification after elbow trauma³³.
- The study was stopped early by the safety monitor because of a 38% rate of fracture nonunion in the group receiving radiation, as compared with a 4% rate in the group without radiation treatment. The rate of heterotopic ossification was not significantly different between the radiation group and the control group ($p = 0.2$).
- ★ Because the study was stopped early, it was underpowered to determine the efficacy of radiation in the prevention of heterotopic ossification, but radiation treatment appears to significantly increase the rate of nonunion.

Forearm, Distal Part of the Radius, and Hand

Mechanical studies have indicated the number, location, and length of distal screws used during volar locked plating of the distal part of the radius that optimize stability and that potentially reduce the chance of extensor tendon irritation. Evidence that challenges the success of nonoperative treatment of ulnar shaft fractures has been provided. A Level-I study compared CT scanning with magnetic resonance imaging (MRI) for the diagnosis of the occult scaphoid fracture.

Results of Treatment of Isolated Ulnar Shaft Fractures

- ◆ Seventy patients with isolated ulnar shaft fractures (thirty-seven of whom were managed with ORIF and thirty-three of whom were managed nonoperatively) were retrospectively reviewed to examine outcomes³⁴.
- There were more nonunions and malunions in the nonoperative treatment group (twelve and fifteen, respectively) as compared with the ORIF group (two and two, respectively). Advanced age, female sex, and displacement of >2 mm were independent predictors of nonunion.
- ★ The outcome of nonoperative treatment of seemingly benign isolated ulnar shaft fractures appears to be worse than previously thought, and consideration should be given to operative treatment to decrease the rate of nonunion and malunion.

Technical Aspects of Volar Locked Plating of Distal Part of Radius

- ◆ To determine the necessity for bicortical screw placement with the use of volar locking plates, three different screw lengths (bicortical, up to but not through the dorsal cortex, and 75% of the distance to the dorsal cortex) were strength-tested in a cadaveric extra-articular distal radial fracture model with metaphyseal comminution³⁵.
- No significant differences were found among the three groups in terms of load to failure, and all three types of screws were found to resist previously documented activity-related loads.
- ★ The use of screws that penetrate the dorsal cortex and place the extensor tendons at risk for injury and/or irritation does not appear to add additional strength compared with the use of shorter, safer screws. Another group of investigators examined the number and configuration of screws used in the distal segment during volar locked plating of the distal part of the radius for the treatment of extra-articular fractures and recommended that at least four screws be used and that at least two of these screws be in the distal row of holes³⁶.

Comparison of CT and MRI for Diagnosis of Suspected Scaphoid Fractures

- ◆ A Level-I study examining the diagnostic characteristics of CT and MRI included thirty-four patients who presented with tenderness over the scaphoid and

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normal radiographic findings after a fall on an outstretched hand³⁷.

- The sensitivity, specificity, and accuracy were 67%, 89%, and 85% for MRI, compared with 67%, 96%, and 91% for CT. These differences were not significant.
- ★ It is unclear which method, MRI or CT, represents the “gold standard” for the diagnosis of occult scaphoid fractures. The authors reported that the presence of bone edema on MRI and unicortical disruptions on CT are of uncertain importance.

Spine

Trauma of the spine, particularly with associated neurologic injury, continues to have a defining effect on the outcomes for injured patients. Multidetector CT scans rather than traditional flexion-extension radiographs appear to have greater utility to accurately delineate cervical spine injury in unresponsive patients. MRI has been found to be more accurate for predicting recovery after thoracolumbar spine injury than traditional classification schemes, and the use of high-dose corticosteroids following spinal cord injury is now questioned.

Cervical Spine Flexion-Extension Radiographs

- ◆ A prospective study of 402 unresponsive patients in the intensive-care unit (ICU) was performed to evaluate a protocol in which multidetector CT (MDCT) scanning followed by passive flexion-extension radiographs was used to detect possible cervical spine injury³⁸.
- One patient with negative findings on multidetector CT scanning was diagnosed with instability on the basis of flexion-extension radiographs.
- ★ The authors recommended against the use of passive flexion-extension radiographs in unresponsive patients and recommend reliance on multidetector CT scanning alone. The elimination of flexion-extension radiographs in cervical spine clearance protocols was corroborated in a recent study of cooperative patients that suggested the inadequacy of such radiographs in the diagnosis of clinically relevant injury³⁹. Flexion-extension radiographs appear to have limited use in clearance of the cervical spine.

Recovery After Thoracolumbar Spine Injury

- ◆ Recovery related to vertebral and neural axis injury level was evaluated more than two years after a thoracolumbar spine injury in a study of fifty-one patients⁴⁰.
- Assuming conus medullaris termination at L1 and using the vertebral injury level as the basis for classification led to misclassification of the neural axis injury in 33% of the patients. MRI classification of neural axis injury predicted significant differences in motor improvement between patients with spinal cord, conus medullaris, and cauda equina injuries.

- ★ MRI classification of neural axis injuries associated with thoracolumbar fractures is more appropriate for prognostication than the use of vertebral injury level is. MRI classification should be used in studies involving this patient population.

Complications After Thoracolumbar Stabilization

- ◆ The records of 230 patients from a multicenter database were reviewed to define factors that predict complications after thoracolumbar spinal surgical stabilization⁴¹.
- The use of high-dose corticosteroids, the American Spinal Injury Association (ASIA) score, and the Charleston Comorbidity Index (CCI) score were associated with major complications. Surgical approach, time to surgery, tobacco use, sex, age, body-mass index (BMI), the Glasgow Coma Scale score, and the Injury Severity Score (ISS) were not associated with complications.
- ★ The only surgeon/physician-controlled variable associated with complications was the use of high-dose corticosteroids, and their risks and benefits should be scrutinized prior to use in patients with thoracolumbar spine fractures.

Polytrauma

Multiple recent studies have explored the complex physiology and psychological factors surrounding the care of trauma patients. Benefits were shown in association with the use of plating for the treatment of rib fractures and with the early treatment of spine, pelvic, and acetabular injuries. The limitations of physical examination for the diagnosis of compartment syndrome and the potential benefits of noninvasive tests were demonstrated.

Domestic Violence

- ◆ Two hundred and eighty-two injured women in fracture clinics who were screened for domestic violence participated in a survey-based cross-sectional study⁴².
- Thirty-two percent of the women reported emotional, physical, or sexual abuse within the last twelve months. Eight and one-half percent reported physical abuse within the last twelve months, and nearly one-third of those patients reported that the current injury was a result of such abuse.
- ★ Domestic abuse is prevalent in women presenting to fracture clinics, and identification of this cause may prevent further injury.

Rib Plating for Flail Chest Injuries

- ◆ In a case-control study, the outcomes for twenty-one patients who were managed with rib ORIF for the treatment of flail chest segments were compared with a cohort of patients, matched by age,

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mechanism, and ISS score, who were treated nonoperatively⁴³.

- Shorter lengths of stay in the ICU and hospital, fewer tracheostomies, reduced home oxygen requirements, less narcotic use, and less need for reintubation were associated with ORIF of rib fractures.
- ★ ORIF of rib fractures for the stabilization of flail chest segments should be considered as an effective intervention to improve short-term outcomes.

Acute Treatment of Spine, Pelvic, and Acetabular Injuries

- ★ Operative treatment of thoracic spine injuries within seventy-two hours decreased the length of stay in the ICU as well as the total length of stay in the hospital for severely injured patients (ISS >38) as compared with those who were managed later⁴⁴.
- ★ Operative treatment of fractures of the pelvis and acetabulum within twenty-four hours was associated with fewer overall complications, decreased length of stay in the ICU, and decreased total length of stay in the hospital⁴⁵ and was shown to decrease the length of stay in the hospital and transfusion rate⁴⁶ when compared with those for cohorts of patients who were operatively managed after twenty-four hours.
- ★ Acute operative treatment of spine and pelvic injuries improves short-term outcomes in multiply injured patients, and resource allocation for this treatment approach should be sought.

Compartment Syndrome

- ◆ Two reports regarding compartment syndrome highlighted the need for objective measures as well as new technologies that may provide a noninvasive means of diagnosis.
- A cadaveric study of the ability of surgeons to diagnose compartment syndrome by means of palpation showed a sensitivity of only 54% and a specificity of 76% for appropriate fasciotomy recommendation⁴⁷.
- Near-infrared spectroscopy showed measurable differences between legs with compartment syndrome and uninjured, contralateral legs and may provide a noninvasive method for the diagnosis of compartment syndrome⁴⁸.
- ★ The clinical diagnosis of compartment syndrome in obtunded patients by means of palpation is not reliable, and the use of invasive diagnostic tools is currently recommended until further study of new noninvasive diagnostic tools establishes their efficacy.

Pediatrics

The use of shorter casts than are typically recommended for common pediatric lower extremity fractures was evaluated. Single-leg hip spica casts were effective for the treatment of pediatric femoral shaft fractures, and short leg casts were effective for the treatment of tibial fractures. Treatment princi-

ples for pediatric femoral shaft fractures were the subject of an American Academy of Orthopaedic Surgeons Clinical Practice guideline⁴⁹.

Pediatric Femoral Fractures

- ◆ Single-leg hip spica casts were compared with one and one-half hip spica casts in a prospective, randomized trial involving fifty-two children who had sustained femoral fractures between the ages of two and six years⁵⁰.
- No differences in healing or complication rates were identified between the two groups. Single-leg hip spica casts were associated with better fit in car seats and chairs, and with less time away from work by the caregiver.
- ★ The authors supported the use of single-leg hip spica casts because those casts were easier to care for and were not associated with an increased rate of complications.

Cast Immobilization of Isolated Pediatric Tibial Shaft Fractures

- ◆ Pediatric patients who presented with an isolated tibial shaft fracture (with the fibula intact) were managed with a below-the-knee cast or an above-the-knee cast on the basis of surgeon discretion⁵¹.
- There were no significant differences between the two groups in terms of alignment before or after casting, the rate of malunion, or the rate of refracture.
- ★ Immediate below-the-knee casting for the treatment of pediatric tibial fractures when the fibula is intact appears to be an effective treatment in comparison with above-the-knee casting.

Open Fractures, Nonunions, Infections, and Bone Graft Materials

A new scientifically derived classification scheme for open fractures was published in the *Journal of Orthopaedic Trauma*⁵². Further testing is required to establish its validity and any benefits over existing systems. New data from the Lower Extremity Assessment Project (LEAP) study indicate that time from the injury to debridement for the treatment of open fractures is not the most important factor with regard to infection risk. Retaining implants while treating infection following fracture fixation appears to be reasonably safe. A smoking-cessation program, repeated surgical debridement after open fracture, and the use of an antibiotic-impregnated bioabsorbable bone substitute were each shown to have utility in either treating or avoiding complications.

Time to Debridement and Infection Risk After Open Fracture

- ◆ A prospective analysis of 315 patients from the LEAP study was used to determine risk factors for subsequent infection⁵³.

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- Twenty-seven percent of the patients had development of infection, and there were no differences in the infection rate according to the time from injury to operative debridement, the time from admission to operative debridement, or the time from debridement to soft-tissue coverage. The time between injury and admission to a trauma center was an independent predictor of the likelihood of infection.
- ★ It appears that the experience that trauma centers have in treating trauma patients is more important for reducing infection than a short time from injury to debridement is.

Maintenance of Implants After Postoperative Infection Following Internal Fracture Fixation

- ◆ A retrospective study of 123 postoperative wound infections that occurred within six weeks after internal fixation of acute fractures was used to determine the rate of failure associated with the maintenance of implants⁵⁴. Failure was defined as nonunion or removal of implants prior to radiographic fracture union, necessitating revision or the inability to clear the infection.
- Seventy-one percent of the fractures united after operative debridement, retention of implants, culture-specific antibiotic treatment, and suppression. The predictors of failure were an open fracture and the presence of an intramedullary nail. *Pseudomonas aeruginosa* infection, smoking, and lower extremity fracture trended toward an association with failure.
- ★ The authors indicated that fracture union without chronic infection is possible in the majority of patients who are managed with debridement, antibiotics, and implant retention.

Smoking-Cessation Intervention and Results of Acute Fracture Surgery

- ◆ One hundred and five smokers with acute fractures requiring surgical treatment were randomized to either standard care or a six-week smoking-cessation intervention program⁵⁵.
- The rate of complications was significantly higher ($p = 0.048$) in the control group (38%) than in the intervention group (20%). There was a trend toward a significantly higher rate of wound infection in the control group (20%) than in the intervention group (8%).
- ★ These results support the utility of smoking-cessation programs to help to reduce postoperative complications after acute fracture treatment.

Timing of Wound Closure in Open Fractures

- ◆ Three hundred and forty-six patients with open fractures were managed with a prospective protocol of

repeated irrigation and debridement procedures until negative cultures were obtained⁵⁶.

- The overall rate of deep infection was 4.3% (4% for Gustilo Type-II fractures, 1.8% for Type-IIIA fractures, 10.6% for Type-IIIB fractures, and 20% for Type-IIIC fractures). Fractures requiring multiple debridement procedures and those in diabetic or obese patients were associated with higher infection rates.
- ★ A low rate of deep infection following open tibial fracture was associated with a protocol of repeat debridement procedures until negative cultures were obtained.

Antibiotic-Impregnated Bioabsorbable Bone Substitutes in Treatment of Bone Infections

- ◆ A prospective randomized trial involving patients with either chronic osteomyelitis or an infection at the site of a nonunion was performed to compare the results of treatment with an antibiotic-impregnated bioabsorbable bone substitute ($n = 15$) with the results of treatment with antibiotic-impregnated polymethylmethacrylate (PMMA) ($n = 15$)⁵⁷.
- Both groups had similar infection eradication rates (86%), but there were more reoperations in the PMMA group. There was no difference between the groups in terms of the rate of healing of infected nonunions.
- ★ Antibiotic-impregnated bioabsorbable bone substitutes are effective for the treatment of bone infections and reduce the number of reoperations.

Basic Science

Biomechanical and biological factors each play key roles in fracture-healing. As fracture-fixation techniques and implants continue to evolve, biomechanical studies remain an important initial step in evaluating the mechanical properties of constructs. Several new studies have focused on some of the variables involved in the use of locking plates. The development and evaluation of the use of biological enhancement of fracture-healing continues to evolve at a rapid pace, and the application of recombinant human bone morphogenetic protein-2 (rhBMP-2) to metaphyseal defects was studied.

Locked Plating

- ◆ To test a new concept of far cortical locking that decreases the axial stiffness of locked plating constructs, a fracture-healing study in sheep was performed to compare far cortical locking with standard locked plating⁵⁸.
- Compared with standard locked plating, far cortical locking led to 36% greater callus volume and 44% greater bone mineral content. Additionally, bone formation under the plate was greater in the far cortical

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locking group. These fractures also healed to be stronger in torsion.

- ★ Although the exact indications for far cortical locking remain unknown, preliminary data using this novel approach are promising.
- ◆ A biomechanical study of an osteoporotic synthetic bone model involved the use of multiple configurations of locking and nonlocking screws to determine the effect of the number and position of each screw type⁵⁹.
- Stiffness was most affected by the number of screws, not the type of screw. However, three locking screws on each side of the fracture led to the greatest effect of locking screws.
- ★ Although this study shed some light on the mechanical behavior of locking screws in osteoporotic bone, surgeons should not necessarily attempt to create the stiffest construct possible. These data are in contrast with those from a similar study of osteoporotic humeri from cadavers, which demonstrated no benefit in association with the addition of a third locking screw⁶⁰.

Biologics

- ◆ The use of rhBMP-2 for the treatment of metaphyseal defects has been poorly characterized. Using proximal and distal femoral core defects in a large animal model, one study evaluated the bone formation response with and without rhBMP-2⁶¹.
- rhBMP-2 ultimately led to abundant bone formation in the metaphyseal defects; however, this occurred at two weeks after implantation. Prior to that time, a short period of bone resorption occurred.
- ★ This study adds to the understanding of the effects of rhBMP-2 on bone formation. Knowledge of the early resorption phase should be considered with its clinical use in metaphyseal defects.

Periprosthetic Fractures

Fractures about hip resurfacing prostheses and fractures between total hip and total knee implants are being increasingly identified and characterized.

Periprosthetic Fractures After Hip Resurfacing

- ◆ The prevalence of femoral neck fracture after hip resurfacing ranges from 1.0% to 3.0%. An analysis of 107 femoral head and neck specimens retrieved after periprosthetic fracture was used to determine the location of the fracture and to classify the fractures into three groups: acute biomechanical, acute postnecrotic, or chronic biomechanical⁶².
- Fifty-nine percent of the fractures occurred within the bone inside the femoral component. Fifty-one percent of the fractures were acute postnecrotic, 40% were chronic biomechanical, and 8% were acute biomechanical.
- ★ Osteonecrosis was frequently associated with fracture. The authors suggested that both weakening of the bone due to osteonecrosis and altered biomechanics contribute to femoral neck fracture after hip resurfacing.

Interprosthetic Fractures Between Hip Stems and Knee Components

- ◆ Twenty-five patients with interprosthetic femoral fractures between total hip and total knee components were retrospectively reviewed⁶³.
- Supracondylar femoral fractures were twice as common as diaphyseal femoral fractures. All fractures healed after the index procedure. There were more complications in patients with supracondylar fractures.
- ★ Fracture between a femoral stem and a total knee prosthesis is more likely to occur near the knee, and complications are more likely to occur after fixation of these supracondylar fractures.

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