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Specialty Update

What’s New in Orthopaedic Trauma

By Peter A. Cole, MD, Theodore Miclau III, MD, Thuan V. Ly, MD, Julie A. Switzer, MD, Mengnai Li, MD, Robert A. Morgan, MD, and Mohit Bhandari, MD, MSc, FRCSC

Introduction

Changes this year to the Specialty Update on Trauma reflect a clinical trend emerging in the field of orthopaedic traumatology toward greater specialization in certain areas. Examples of crystallizing expertise around certain clinical domains include geriatric and pediatric fracture management. Of course, such has already occurred with regard to anatomic trauma expertise in areas such as the upper extremity, the foot and ankle, the pelvis, and the spine. Accordingly, new sections have been added this year on fragility fractures and fracture treatment in the elderly.

This update will begin with an introduction covering the methodology for this year’s review, followed by a section on general non-fracture-specific topics and the review of seven key basic science articles. Then, reviews are presented of fracture highlight articles (published from June 2007 to May 2008), categorized anatomically.

We conducted both database and hand searches of all clinical studies with an orthopaedic trauma focus that had been published from June 2007 through May 2008. Specifically, we searched the Cochrane Database, six orthopaedic journals, one general trauma journal, and four high-impact medical journals (see Appendix). Of the 6573 papers that were reviewed, 307 were identified as potentially eligible studies. The complete abstracts of these 307 studies were reviewed in duplicate for final inclusion by one of us (P.A.C.). After abstract selection, 136 articles were divided among all authors according to their specialty focus for critical review. Thirty-eight manuscripts were discarded, leaving ninety-eight studies for final inclusion in this update. Consensus on the final studies was achieved. In this review, we summarize the salient findings of twenty-four level-I studies, twenty-seven level-II studies, ten level-III studies, and thirty-six level-IV studies across subspecialties of orthopaedic trauma. Of these, fifty-nine represented studies of therapy, thirty-one involved prognosis, six evaluated diagnostic tests, and one involved economic and decision analyses (see Appendix). One of the final studies, which developed an evidence-based algorithm, was nonclassifiable.

Based on positive feedback from last year’s update, we have brought back the basic science section author (T.M. III) to help us to interpret key bench research projects that we believe to have a high level of clinical relevance. Twenty recognized experts were asked to identify the one or two most important trauma-related research articles in their field.

General Topics

Developing a universal language for the description of fractures continues to be a high priority for orthopaedic leadership. Eleven years after the Orthopaedic Trauma Association (OTA) published its classification system, its classification committee highlighted reliability and reproducibility as fundamental principles, moving forward with changes in nomenclature based on new science on the validation of classification processes. Another new goal is unifying the alphanumeric code between the AO and OTA systems. Dislocations will be integrated on an anatomic basis and coded separately. Recently, the classification codes were revised for clavicular, scapular, foot, hand, and patellar fractures. The OTA classification committee plans that these new changes will be validated in the next couple of years.

Additionally, for the first time, Slongo et al. made the effort to introduce the first comprehensive classification of pediatric long-bone fractures. Given known differences between pediatric and adult fractures, efforts are being made to incorporate the most prevalent classification systems, such as the Salter-Harris, Tillaux, Monteggia, and Galeazzi systems, as well as to account for the location and morphology of fractures as has been done in the AO-OTA system.

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Clinical indications regarding hardware removal certainly enter the “art of medicine” realm due to the lack of objective evidence to guide such decisions. The following three studies addressed this issue, the last of which dealt with the context of infection. Minkowitz et al. evaluated patient outcomes and pain relief after removal of hardware after fracture-healing. All sixty patients in that study were satisfied and stated that they would elect to have the procedure again. Objective measures of that satisfaction included a decrease in pain and improvement in the Short Musculoskeletal Function Assessment (SMFA) and Short Form-36 (SF-36) outcome scores over baseline ($p = 0.0001$).

The indications for the removal of intramedullary nails after tibial fractures are also debated. This fact was underscored by a recent study in which the results for one series of seventy-one patients who had removal of tibial nails were not encouraging. Thirty-nine patients had decreased pain but were not completely asymptomatic, fourteen patients had no change in pain, and eighteen patients actually had increased pain.

The removal of implants because of infection can complicate treatment if the fracture is not healed. Rightmire et al. evaluated the effectiveness of treating infections with retention of hardware, irrigation, debridement, and antibiotic suppression. Treatment was considered to be successful (that is, the fracture united with retained hardware) in forty-seven (68%) of sixty-nine cases, and it was considered to be unsuccessful (that is, hardware removal was required before the fracture united) in twenty-two cases (32%). Although the authors appropriately suggested that their data support the concept that hardware may be removed in the presence of osteomyelitis and appropriately suggested that their data support the concept that hardware may be removed in the presence of osteomyelitis and the resultant nonunion can be treated once the infection has resolved, another perspective could be that ultimate healing in over two-thirds of the cases of these difficult clinical problems supports current recommendations to leave stable hardware in place until healing takes place or a frankly infected pseudarthrosis prevails.

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Basic Science
Developmental Biology
Potent bone-forming agents called bone morphogenetic proteins (BMPs) are expressed throughout fracture repair and are implicated in a wide variety of processes, with specific expression patterns that often overlap. Musculoskeletal healing occurs through a series of molecular and cellular events that are mediated by growth factors. Our understanding of the role of growth factors in musculoskeletal repair recently has been augmented by gene-inactivation studies; however, understanding is limited with regard to molecules such as BMP2 and BMP4 as the loss of these molecules results in embryonic lethality before skeletal development. Recently, Tsuji et al. studied the degree to which BMP2 is required during fracture-healing by creating transgenic mice lacking limb-specific expression of Bmp2 ($Bmp2^{c/c}; P r x 1::C r e$) and evaluated limb development and skeletal repair. They found that both BMP2 and BMP4 may overlap during limb skeletogenesis, whereas they do not overlap during fracture repair. Furthermore, other BMPs do not appear to compensate for the absence of BMP2 during fracture-healing, whereas they appear to be able to do so with the loss of BMP4.

Like BMPs, matrix metalloproteinases (MMPs) have been shown to have a role in both limb skeletogenesis and fracture repair, and may have overlapping functions. Loss of MMP9, for example, results in delayed but eventual bone-healing. MMP13 has been shown to promote hypertrophic cartilage resorption and remodeling of newly developed trabecular bone in the growth plate during skeletogenesis, and...
Behonick and coauthors further evaluated the role of MMPs in fracture repair\(^{17}\). By creating closed stabilized and non-stabilized tibial fractures in mice lacking \textit{Mmp13} \((\text{Mmp13}^{-/-})\), the investigators evaluated healing histologically, hystomorphometrically, radiographically, and with use of molecular analyses. They found that, like its role during development, MMP13 was required for proper resorption of hypertrophic cartilage and normal bone remodeling, possibly by acting directly during the initial stages of extracellular matrix degradation prior to the invasion of osteoclasts and new blood vessels.

**Stem Cells**

Muscle contributes cells to healing skeletal tissues. Zheng et al. studied the anatomic, molecular, and developmental relationships of myogenic and endothelial cells in human skeletal muscle\(^{16}\). They showed that adult human skeletal muscle contains myogenic cells (CD56\(^{+}\), CD34\(^{-}\), CD144\(^{+}\)), endothelial cells (CD56\(^{-}\), CD34\(^{+}\), CD144\(^{-}\)), and cells that co-express endothelial and myogenic cell markers (CD56\(^{-}\), CD34\(^{+}\), CD144\(^{-}\)). Following the injection of these three different cell populations into a chemically-injured gastrocnemius muscle in an immunodeficient mouse, the authors found that the group of cells that co-expressed endothelial and myogenic markers had the most potent response, with both this group and the endothelial cell marker group performing better than the conventional myogenic cell group. Additionally, the population of myoendothelial cells also could differentiate into myogenic, chondrogenic, and osteogenic cells under appropriate conditions in vitro. The authors concluded that adult human muscle-derived stem cells have multi-lineage potential and high muscle regenerative capacity and that they may be located in blood-vessel walls.

**Angiogenesis**

New blood vessel formation plays a key role during skeletal development and repair. The initial signals for angiogenesis are not fully understood, but tissue hypoxia has been implicated in the initiation of this process. The hypoxia-inducible factor (HIF) pathway is central for detecting changes in local oxygen tensions in different organisms by activating genes encoding for adaptive angiogenic responses, such as vascular endothelial growth factor (VEGF). Wang et al. used a genetic approach to investigate the cellular and molecular effects of gain or loss of HIF function in osteoblasts during development\(^{16}\). They created mice overexpressing HIF\(x\) \((OC-Cre; Vhl^{0/0})\) by selectively deleting the von Hippel-Lindau gene \((Vhl)\), which binds directly to hydroxylated HIF\(x\) subunits and regulates their destruction by the proteosomes, and they also created mice lacking HIF-1\(\alpha\) \((OC-Cre; Hif-1^{a/b})\). The investigators found that mice overexpressing HIF\(x\) in osteoblasts showed elevated Vegf expression, and had development of dense, highly vascularized long bones. In contrast, mice lacking HIF-1\(\alpha\) in osteoblasts had development of narrow, less vascularized bone.

Mice lacking both \textit{Vhl} and \textit{Hif1} had a bone phenotype intermediate between those of the individual mutants, suggesting that the HIFs may have overlapping functions in bone. The authors concluded that the activation of the HIF\(\alpha\) pathway in osteoblasts during bone development coordinates the timing, direction, and degree of new blood vessel formation in bone.

In a follow-up study, Wan et al. used a murine distraction osteogenesis model to evaluate the role of HIF in bone regeneration\(^{17}\). They demonstrated that, in wild-type mice, hypoxia developed during distraction osteogenesis that was associated with the appearance of HIF-1\(\alpha\) and VEGF. Using the model of HIF\(\alpha\) overexpression in osteoblasts described previously, they found an increase in both angiogenesis and bone formation during regeneration. Conversely, mice underexpressing HIF-1\(\alpha\) in osteoblasts had impaired angiogenesis and bone healing. The increased vascularity and bone formation in the Hif\(a\) overexpressing mice were VEGF-dependent and were eliminated by the simultaneous administration of VEGF-receptor antibodies. These results suggest that the HIF-1 pathway mediates angiogenesis and osteogenesis during distraction osteogenesis and may represent a possible molecular target to enhance bone formation\(^{17}\).

**Fracture-Healing**

The role of the WNT signaling pathway in fracture repair has attracted recent attention. This interest initially stemmed in part from observations that gain and loss-of-function mutations of one of its co-receptors, lipoprotein-related peptide 5 (LRP5), result in a gain or loss of bone mass, respectively, and the disease osteoporosis pseudoglioma syndrome\(^{14}\). Additionally, WNT pathway members and target genes, such as the WNT target gene \textit{WNT-induced secreted protein 1} \((\text{WISP1})\), are expressed during fracture-healing\(^{19,20}\). There are eighteen identified murine WNTs, which are divided into canonical and noncanonical classes on the basis of their functional ability to form a secondary embryonic body axis\(^{21}\). While the non-canonical WNT signaling pathway is not well understood, the canonical pathway has been studied widely in relation to endochondral bone formation, including its role in regulating mesenchymal progenitor lineage selection, osteogenesis, and chondrogenesis\(^{19}\). Recent studies have further evaluated the possibility of enhancing fracture repair through the pharmacological activation of the canonical WNT pathway.

Cheon et al. studied the \(\beta\)-catenin signaling pathway in a murine tibial fracture model\(^{22}\). \(\beta\)-catenin has been identified as a key regulator of bone during development. In the absence of WNT family protein binding to a WNT receptor on the cell surface, \(\beta\)-catenin is normally degraded. However, in the presence of this ligand-receptor binding, \(\beta\)-catenin translocates to the nucleus, where it interacts with the T cell factor (TCF) protein and activates the transcription of a wide range of genes. The authors found that there was a significant up-regulation of \(\beta\)-catenin during fracture repair, and, using TCF reporter mice in which TCF controls the expression of a...
marker gene (*LacZ*), they noted that TCF-dependent transcription was activated during both bone and cartilage formation. β-catenin signaling and fracture-healing were inhibited by treating mice with an antagonist of the WNT/β-catenin pathway as well as by creating a loss of osteoblast-specific β-catenin function in transgenic mice. In contrast, transgenic mice with osteoblast-specific expression of an active form of β-catenin demonstrated enhanced healing. After establishing that β-catenin signaling played a role in fracture repair, the investigators administered lithium, which prevents the degradation of β-catenin and has been shown to activate β-catenin signaling in the healing of cutaneous wounds. Lithium administration enhanced fracture repair only if given after treatment had been started and interfered with healing if given prior to the fracture. The authors concluded that β-catenin functions differently during the course of repair, functioning early in the differentiation of progenitor cells into osteoblasts or chondrocytes and later in the positive regulation of osteoblasts, and that lithium has future potential as a pharmacological intervention to enhance bone-healing.

Parathyroid hormone (PTH) and parathyroid hormone related peptide (PTHrP) signal through a common receptor PTHR1, and it has been hypothesized that systemic PTH regulates endochondral bone formation by altering the local PTHrP/Indian hedgehog (IHH) regulatory loop. In the growth plate, this pathway has been shown to coordinate chondrocyte and osteoblast proliferation and differentiation, which appears consistent with the same function in fracture repair. Additionally, regulatory interactions in the growth plate have shown that Ihh signaling is coordinated with canonical WNT signaling during endochondral bone formation. Kakar et al. evaluated the mechanisms by which systemic PTH (PTH [1-34]) affects fracture repair. With use of a closed murine femoral fracture model, bones were harvested at periods throughout healing following injections with 30 μg/kg PTH or saline solution for fourteen days after fracture. The authors found a threefold greater increase in chondrogenesis relative to osteogenesis over the course of repair, with earlier appearance of chondrocyte hypertrophy in the PTH-treated calluses. Furthermore, PTH treatment significantly induced an increased level of canonical WNT-signaling in PTH-treated bones, suggesting that the effects of PTH administration occur at least in part through WNT signaling.

**Inflammation**

Nonsteroidal anti-inflammatory drugs have been shown to inhibit experimental fracture repair, further supporting the concept that inflammation may play an important role in bone-healing. However, there is limited information concerning the reversibility of these effects on repair and the extent to which drug dose affects prostaglandin E2 (PGE-2) levels in skeletal tissues during healing.

Gerstenfeld et al. investigated whether the previously observed impairment of fracture-healing by the selective and nonselective inhibition of cyclooxygenase-2 (COX-2) is reversible and related to the recovery of PGE-2 levels in the fracture callus. Following the creation of a closed, intramedullary pin-stabilized femoral fracture in rats, the median effective dosages (ED50) of ketorolac (a nonselective, nonsteroidal anti-inflammatory drug), valdecoxib (a COX-2-selective nonsteroidal anti-inflammatory drug), or vehicle (control) were administered orally to the animals for either seven or twenty-one days. A second set of experiments measured callus PGE-2 levels following daily administration of the drugs and after their withdrawal. The authors reported that the fractures that were treated for seven days showed only a trend toward a greater nonunion rate in the valdecoxib and ketorolac groups as compared with controls and that there were no differences between the groups at thirty-five days. Among the fractures that were treated for twenty-one days, there were significantly more nonunions in the valdecoxib group relative to the ketorolac and control groups at twenty-one days, but there were no differences between the groups at thirty-five days. Histological evaluation of the calluses showed delayed remodeling of calcified cartilage and decreased bone formation in the valdecoxib group. Ketorolac treatment led to two to threefold lower callus PGE-2 levels than valdecoxib, and withdrawal of either drug after six days led to a twofold increase in these levels at fourteen days. Collectively, these results suggest that COX-2-specific nonsteroidal anti-inflammatory drugs inhibit fracture repair more than the nonspecific nonsteroidal anti-inflammatory drugs and that the overall effect is related to treatment duration. Additionally, callus PGE-2 levels and strength are eventually regained to levels similar to controls following treatment discontinuation. The authors concluded that while these data confirm the inhibitory effect of COX-2 on fracture-healing, discontinuation of the drug may restore healing.

**Geriatric Orthopaedics**

**Risk Analysis**

Bone-related and fall-related risk factors in women and men over the age of fifty years who had sustained a recent clinical fracture were determined in a cohort of 568 individuals. Bone-related factors included previous fracture after the age of fifty years, a history of maternal fracture, lower mean body weight, immobility, and the use of glucocorticoids. Fall-related risk factors included an assessment of the ability to carry out activities of daily living, a history of documented falls, vision impairment, use of psychoactive drugs, urinary incontinence, osteoarthritis, and Parkinson disease. The prevalence of bone-related risk factors (53% [95% confidence interval, 49% to 57%]; n = 299) and the prevalence of fall-related risk factors (75% [95% confidence interval, 71% to 78%]; n = 425) at the time of the incident fracture were higher than the prevalence of osteoporosis (36% [95% confidence interval, 31% to 39%]; n = 201). These data suggest that a fracture risk assessment...
should involve bone and fall-related risk factors, not just osteoporosis screening.

This perspective was echoed in the study by Robbins et al. In that report on one arm of the Women’s Health Initiative longitudinal study, which included 1132 hip fractures that were followed for a mean of 7.6 years, eleven clinical factors were determined to be associated with a higher risk of hip fracture: increased age, lower self-reported health, decreased weight, lower height, white race, less physical activity, history of fracture after the age of fifty-four years, hip fracture in a parent, current smoking, current corticosteroid use, and diabetes mellitus.

The question of inclusion of patients in studies was addressed, although in a different population, by Mackey and the Study of Osteoporotic Fractures (SOF) and Osteoporotic Fractures in Men Study (MrOS) Research Groups. Those researchers evaluated a cohort of individuals in the SOF and MrOS trials who had sustained a fracture as the result of high-energy trauma (n = 358) and compared them with individuals who had sustained a fracture as the result of low-energy trauma (n = 3357). The authors concluded that nonspine fractures that occur as the result of high-energy trauma mechanisms are also associated with low bone mineral density and increase the risk of subsequent fracture in older adults. They also observed that for each negative standard deviation in total hip bone mineral density, there was a similar increase in the risk of high and low-energy fractures in both women and men.

The same SOF Research Group analyzed its data on the long-term risk of vertebral fracture. In that article, the researchers described follow-up of 2680 women (from the original 9704 enrolled) who attended a clinic visit an average of 14.9 years after baseline. Of these 2680 women, 487 (18.2%) had sustained a vertebral fracture. However, of the 394 women in this cohort who entered the study with a vertebral fracture, 163 (41.4%) had an incident vertebral fracture during the follow-up period; in comparison, of the 2286 women in the cohort who entered the study without a prior vertebral fracture, 324 (14.2%) had an incident vertebral fracture during the follow-up period. There was positive association between decreased bone mineral density and incident vertebral fractures.

With a degree of skepticism, Gerdhem and Akesson underlined questions on the validity of epidemiological studies in the geriatric population when questions of fracture risk and osteoporosis are raised. In a discrete population of individuals in Malmö, Sweden, for whom lifetime radiologic data were available, they determined that individuals who had sustained a previous fracture were more likely to participate in the study than those who had not sustained a fracture. Additionally and surprisingly, the investigators found that individual recall of fractures was only fair (78.4%). They concluded that caution should be applied when analyzing fracture data from only one source (an individual's memory).

Another observational study from a research group in Sweden showed, not surprisingly, that the mean fracture-related costs after hip, distal radial, and vertebral fractures were high. In that analysis, in which the investigators strove to calculate only the fracture-related costs, vertebral compression fractures that required hospitalization were determined to be especially costly.

**Treatment Interventions**

Many researchers have addressed the question of the utility of bisphosphonates for the prevention of fragility fractures. In a randomized, double-blind, placebo-controlled trial, zolendronic acid, administered once intravenously within ninety days after a hip fracture, was found to decrease the rate of fragility fractures and the rate of mortality compared with placebo administration (with a 35% risk reduction in the fracture rate). Another group, headed by Wells, produced Cochrane reviews of the efficacy of three other bisphosphonates in the prevention of osteoporotic fractures in women.

Significant prevention of vertebral fractures and nonvertebral fractures (including hip fractures) in women with low bone density was seen in meta-analyses of risedronate and alendronate use. Alendronate also prevented wrist fractures in women with low bone density and vertebral fractures in women with normal bone density. Etidronate prevented only vertebral fractures in women with low bone density. However, a possible risk is emerging in association with bisphosphonate treatment. In an interesting review of patients who had sustained a low-energy femoral shaft fracture and were managed at a level-1 trauma center, it was determined that a simple, transverse fracture with associated beaking was associated with alendronate use. That observational study showed that, of the seventy patients with a low-energy femoral shaft fracture (average age, seventy-five years), twenty-five (36%) were being managed with alendronate. Of those twenty-five patients, nineteen demonstrated the above-described fracture pattern, and, of the remaining forty-five patients, only one demonstrated this fracture pattern.

A meta-analysis by Tang et al. examined whether calcium or vitamin D could prevent fragility fractures and bone loss in individuals over the age of fifty years. Twenty-nine randomized trials involving 63,897 patients were identified. The seventeen trials in which a fracture was reported as an outcome demonstrated a 12% reduction in the risk of fracture (risk ratio, 0.88 [95% confidence interval, 0.83 to 0.95]; p = 0.0004).

Hip protectors were also re-evaluated as a means of preventing hip fractures in nursing home residents. In a multicenter, randomized, controlled clinical trial, 1042 nursing home residents wore a hip protector on one side, thus providing a method to aid in determining protective effect through statistical methods. After twenty months of follow-up, the trial was discontinued because of a lack of demonstrated efficacy. Three hundred and thirty-four patients (32%) who
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wore the hip protector >80% of the time as well as those who did not adhere to the prescribed usage did not demonstrate a difference in the hip fracture rate between the protected and unprotected hips (5.3% [95% confidence interval, 2.6% to 8.8%] compared with 3.5% [95% confidence interval, 1.3% to 5.7%]).

In an analysis involving 5683 military veterans with an age of sixty-five years or more who had been managed for a hip fracture between 1998 and 2003, Radcliff et al. confirmed that a surgical delay of more than four days following admission was associated with a higher adjusted thirty-day mortality risk (odds ratio, 1.29; 95% confidence interval, 1.02 to 1.61) and suggested that, in this population, the use of general anesthesia was also associated with a greater risk of death (odds ratio 1.27; 95% confidence interval, 1.01 to 1.55).”

Programmatic Intervention

Although the American Orthopaedic Association’s (AOAs) “Own the Bone” initiative holds promise for improving the practice of orthopaedic surgeons who care for patients who have sustained a fragility fracture, the write-up of the pilot project for this web-based quality-improvement registry did not show an improvement in the prescription of osteoporosis medications or the ordering of bone mineral density testing. Rather, that study on 635 patients with fragility fractures at fourteen sites demonstrated that the utilization of this form of quality-improvement tool significantly improved inpatient counseling with regard to calcium and vitamin-D supplementation, exercise, and fall prevention and significantly improved communication between orthopaedists and primary-care physicians.

In an investigation that was performed to answer the question, “Is all of the attention on osteoporosis evaluation and treatment following fragility fracture worth it?” Sander et al. determined that an osteoporosis coordinator program, which they had previously shown to improve capture of fragility fracture patients for osteoporosis evaluation, was also cost-effective. In a cost-effectiveness probabilistic sensitivity analysis, it was determined that a hospital could save money if the coordinator were to see as few as 350 patients per year. In an analysis of a population of patients who had sustained a distal radial fracture, Rozental et al. confirmed that, if the treating orthopaedic surgeon ordered a bone mineral density test in addition to sending a letter to the patient’s primary care physician, the rate of osteoporosis treatment in this population increased from 26% to 74% (p < 0.001) as compared with the rate when the orthopaedic surgeon only sent a letter to the primary care physician.

In a thoughtful approach to radiographic triage for geriatric patients who fall, Lakshmanan et al. retrospectively reviewed the magnetic resonance imaging scans for 106 patients with a mean age of 81.4 years (range, sixty-seven to 101 years) who fell and were unable to bear weight and in whom initial pelvic radiographs demonstrated no hip fracture. No patient with a hip fracture had a pelvic fracture, and vice versa. Therefore, the authors recommended that, if an individual demonstrates a pelvic fracture on a plain radiograph, there is little reason to search further for an occult hip fracture.

Axial Skeleton

Spine

The controversial subject of odontoid fractures in the elderly was explored in the first two articles to be described in this section. Dens fractures account for as many as 15% of all cervical spine fractures, with an increasing prevalence in elderly patients. Platzer et al. retrospectively reviewed the records of 110 patients who had been managed operatively with anterior screw fixation for the treatment of an Anderson and D’Alonzo Type-II odontoid fracture. The patients were divided into two groups on the basis of age (less than or more than sixty-five years). The two-screw technique as described by Bohler was associated with a high technical complication rate in both groups (10% and 12%). These complications resulted in a reoperation rate that was higher for the younger group than for the older group. The elderly patients had a higher pseudarthrosis rate (12% compared with 4%; p < 0.05) and had a 9% rate of perioperative mortality, but the data suggested that the elderly patients tolerated a pseudarthrosis somewhat better than the younger patients did.

The second article, also by Platzer et al., specifically evaluated anterior screw fixation compared with atlantoaxial arthrodesis in the elderly. The authors retrospectively reviewed fifty-six patients (mean age, 71.4 years) and identified thirty-seven fractures that had been stabilized with anterior screw fixation with a two-screw technique as described by Bohler and nineteen fractures that had been treated with a dorsal C1-C2 arthrodesis as described by Brooks and Jenkins. The fractures consisted of forty-eight Anderson and D’Alonzo Type-II fractures and eight Type-III fractures. All Type-III fractures were treated with a dorsal arthrodesis, whereas only eleven of the Type-II fractures were so treated. Radiographic outcomes were assessed. Of note, none of the posterior technical complications (including two cases of loss of reduction and one case of an improperly placed wire and graft construct) resulted in reoperation, whereas three of the five anterior screw placements resulted in reoperation. Even with over a 10% pseudarthrosis rate (four of thirty-seven), the anterior fusion group had better pain and function characteristics than did the posterior fusion group. Without a nonoperative control, definitive conclusions on the relative value of these techniques were not possible, and the 16% morbidity rate and 6% mortality rate reported in the study confirmed that the treatment of this injury pattern remains controversial.

Two articles from the Spine Trauma Study Group evaluated the outcomes and classifications of subaxial cervical spine injuries. The first article addressed the isolated unilateral facet injury and included fractures, subluxations, and dislocations that were treated operatively and nonoperatively.
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While unilateral facet injuries are not common and typically represent approximately 6% of all cervical spine injuries, they continue to generate controversy regarding many aspects of the workup and treatment. This multicenter, retrospective review was drawn from the experience of thirteen surgeons who contributed data on a total of ninety patients who had been managed within three weeks after the injury and had been followed for 3.5 months to fourteen years. Sixty percent of the injuries were at the C6-C7 level, and 17% were at C5-C6. Ninety-four percent of the nonoperatively treated injuries were nondisplaced or minimally displaced superior facet fractures, yet the mean SF-36 Physical Component Score for patients who were followed for more than eighteen months was significantly higher for the operative treatment group (p = 0.017) and significantly more pain was reported for the nonoperative treatment group (p = 0.014). The study suggested that operative treatment may result in improved outcomes of even stable facet injuries but that additional research is needed to verify these surprising findings.

The second study from the Spine Trauma Study Group introduced an evidence-based algorithm utilizing the previously introduced subaxial cervical spine injury classification system. This study was a comprehensive review of the literature, conducted initially by two spine surgeons. The article inclusion criteria were a patient age of more than sixteen years; the presence of a subaxial cervical traumatic injury from C3 to T1, inclusive, that was treated surgically with an anterior, posterior, or combined anterior-posterior approaches; measurement of outcome with use of validated outcome measures and/or radiographic measures; and a description of the surgical approach used. The literature was then synthesized into algorithmic form and circulated to the members of the study group for their opinion on the validity of the proposed algorithm. Controversy still remains on the optimal treatment of subaxial injuries, but this study presents a tool for validation in future studies.

Two articles addressed thoracolumbar and lumbar fractures in adults. The first of these, by Daniels et al., evaluated the variability among different institutions with regard to the rates of arthrodesis for patients with thoracolumbar spine fractures with and without associated neurologic injury. This was a retrospective cohort study using data from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample and involved 24,098 patients matching requisite ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) codes from 1998 to 2002. The overall rates of arthrodesis were 9.1% for patients without neurologic injury and 61.4% for patients with a neurologic injury. An increased rate of arthrodesis correlated with hospital patient volume and teaching status, whereas hospital patient volume and teaching status correlated with increased injury severity.

When the analysis was limited to only the hospitals with the greatest volume of fractures, there was a 1.8-fold variation in the rates of spinal arthrodesis procedures for patients with associated neurologic injury and a 5.8-fold variation for patients without associated neurologic injury. The authors noted that the variability in surgery for traumatic injuries is less than the variability in surgery such as arthrodesis for degenerative conditions, for which a greater than 20-fold variation may be present.

Adding to the variability in treating these fractures, Korovessis et al. presented a prospective consecutive series of patients who were managed with an innovative method of restoring anterior column support. Currently, anterior column support is required when insufficient vertebral body structure is left to allow for short-segment fixation or when an anterior canal decompression is performed. Previous studies have evaluated the use of polymethylmethacrylate during kyphoplasty for the treatment of burst fractures, but this material is not suitable for a young patient population. The authors presented twenty-three consecutive patients with an average age of forty-eight years who underwent posterior instrumented spinal fusion for a burst fracture with immediate intraoperative bilateral transpedicular kyphoplasty with use of a calcium phosphate cement. Two groups of patients undergoing short-segment or long-segment fusion were compared, although the authors’ indication for a short-segment fusion was restricted to a fracture in the L2-to-L4 region whereas all of the long-segment fusions were in the T9-to-L1 region. The operative technique involved the use of intercalary segment fixation (with pedicle screws in the fractured segment) in both the long and short-segment fusion groups, and there was no control group of patients managed without cement, so the effect of the cement on outcomes could not be determined. Canal encroachment was reduced from 32% to 20% through an indirect ligamentotaxis effect solely due to balloon kyphoplasty, and kyphosis was reduced from 16° preoperatively to 1° postoperatively. There was no difference between the long and short-segment fusion groups with regard to any of the radiographic parameters assessed. However, the rate of cement leakage was 17.4% (four of twenty-three), and, although no adverse sequelae were reported in association with the leakage, the potential for complications must be recognized. This is clearly an interesting and viable technique but is one that requires further investigation before widespread use.

In the study by Grafe et al., forty consecutive patients with painful osteoporotic vertebral compression fractures were treated with kyphoplasty with use of either polymethylmethacrylate or calcium-phosphate cement. After a minimum duration of follow-up of three years, visual analog scale pain scores improved significantly, from 74.5 to 52.7 in the polymethylmethacrylate group and from 73.1 to 55.2 in the calcium-phosphate group. Significant improvement was also demonstrated in mobility scores. In the polymethylmethacrylate group, vertebral height averaged 8.4 mm initially and 6.4 mm at
the time of the latest follow-up, whereas in the calcium-phosphate group, it averaged 6.6 mm initially and 4.4 mm at the time of the latest follow-up. Calcium-phosphate cement may be useful when combined with an operative instrumentation strategy to obtain and maintain anterior column height restoration in younger patients with deforming compression fractures.

“Seat-belt syndrome” is a well-recognized entity, but one with sparse literature related to the pediatric population. Mulpiri et al. presented an observational analysis of Chance fractures in twenty-five skeletally immature patients who had been managed from 1984 to 2001 and introduced a deformity index in an attempt to help quantify the injury\(^2\). This index is determined through a series of calculations that ends up with a ratio of lost ventral height to gained posterior height. Operative treatment consisting of posterior instrumentation was performed in sixteen patients, and nonoperative treatment including casting or bracing was carried out in nine. The average age was 11.2 years for the operative treatment group and 10.5 years for the nonoperative treatment group. The male-to-female ratio was 4:12 for the operative treatment group and 4:5 for the nonoperative treatment group. As might be expected, the operative treatment group had more severe injuries than did the nonoperative treatment group. Failure of nonoperative management occurred in three of nine patients, all at the L3 level. The deformity index was significantly greater for patients with abdominal injuries (p < 0.01) and patients who had operative treatment (p < 0.01). While the deformity index needs validation, the authors presented outcomes for a relatively large series of patients with an uncommon injury.

A more common injury is the vertebral end plate fracture known as a Schmorl node. Moller et al., in an observational cohort study, presented data for pediatric thoracic and lumbar compression or burst (Denis Type-A and B) fractures after a minimum duration of follow-up of thirty-three years\(^2\). Nine boys and eleven girls with a mean age of twelve years had been retrospectively identified in a previous investigation that registered radiographs from 1950 to 1971 for individuals younger than sixteen years. The radiographs that had been made at the time of the initial injury were then compared with magnetic resonance images to determine the effect of a fracture on the adjacent discs. The authors found no increase in the prevalence of degenerated changes in discs adjacent to the previously fractured vertebrae. There were, however, more Schmorl nodes at adjacent disc levels, leading the authors to conclude that stable pediatric vertebral fractures without neurologic deficit do not increase the risk of subsequent disc degeneration. Additionally, the authors suggested that Schmorl nodes in healthy children and young adults are a marker for trauma and are not a result of a degenerative process.

A Cochrane review by Bagnall et al. investigated the effect of spinal fixation surgery for the treatment of acute traumatic spinal cord injury\(^2\). Although iatrogenic kyphosis has been well documented in the literature in association with the resultant advances in spinal care achieved through combining thorough decompression with instrumented reconstruction, Bagnall et al. attempted to document the role of instrumentation in the treatment of spinal cord injury. Because no study has evaluated the effect of decompression of spinal cord injury with use of noninstrumented decompression as a control group, no studies were included to evaluate methodologic quality or results. This led the authors to conclude that current evidence does not enable conclusions to be drawn about the pros and cons of spinal fixation surgery in patients with spinal cord injury.

**Pelvis**

Totterman et al. examined pelvic trauma associated with displaced sacral fractures in a prospective single-cohort study of thirty-one patients who were managed operatively between 1996 and 2001\(^3\). The method of fixation was individualized and consisted of open posterior plate fixation in thirteen patients, percutaneous iliosacral screw fixation in six, and triangular osteosynthesis in twelve. Posterior fixation was supplemented with anterior plating in fourteen patients, with a switch in protocol for anterior ring fractures to plating during the study period. A laminectomy was performed in fourteen cases, with the indications being defined as signs and symptoms of major neurotrauma in patients who were able to cooperate with an examination and occlusion of the central canal as seen on a computed tomography scan. Neurologic dysfunction at the time of follow-up was common, with 87% of patients having sensory dysfunction, 45% having motor nerve dysfunction, 52% having voiding dysfunction, 36% having bowel dysfunction, and 39% having altered sexual function. Additionally, SF-36 data demonstrated dysfunction across all major dimensions of health (physical, mental, and social). Although previous studies have demonstrated posttraumatic pain rates ranging from 17% to 66%, the authors reported a 90% rate. This difference may be explained by the high prevalence of malunion in this study, with a mean fracture displacement of 11 mm postoperatively and a 93.5% prevalence of zone-II and III sacral fractures. This study supports the need for improved treatment strategies for these severe injuries.

In a study by Mullis and Sagi, twenty-three patients were retrospectively identified to form a cohort of isolated sacroiliac joint dislocations that had been treated with iliosacral screw stabilization through either open or closed reduction\(^4\). The patients were followed clinically and radiographically for a minimum of one year. The only predictor of favorable outcome was the achievement and maintenance of an anatomic reduction at the time of surgery, corroborating previously published work correlating anatomic sacroiliac reduction with improved outcome. This underpowered study did not demonstrate a correlation between subsequent joint ankylosis and favorable outcomes.

Fixation of the anterior pelvic ring can augment posterior ring fixation, but exact indications remain controversial.
Starr et al. reported on eighty-two patients who had been managed with percutaneous fixation of superior ramus fractures and introduced a new classification system to describe these fractures. Zone-I fractures are medial to the obturator foramen, zone-II fractures are lateral to the obturator foramen, and zone-III fractures are between zones I and II. The rate of fixation failure was 15% (twelve of eighty-two). Increased age, female sex, zone-I and II fractures, and retrograde techniques were common risk factors for loss of reduction. No neurologic, vascular, or visceral injuries were reported in this series.

Along a similar minimally invasive theme, Frey et al. assessed the safety and efficacy of percutaneous sacroplasty for the treatment of painful sacral insufficiency fractures. Thirty-seven patients with a zone-I fracture were managed with the injection of polymethylmethacrylate under fluoroscopic views. Only one patient had development of radicular pain during the procedure, and the procedure was aborted. With use of a visual analog scale, the authors reported that 14% of the patients had complete relief of pain within thirty minutes after the procedure, 27% were pain-free at two weeks, and 35% remained pain-free at four weeks. Although the authors concluded that the procedure was safe and effective, a randomized controlled trial is required to test efficacy of this treatment relative to the natural history of sacral sufficiency fractures.

**Acetabulum**

Moed and McMichael used the Musculoskeletal Function Assessment (MFA) and the Merle d’Aubigné score to evaluate forty-six patients who had a posterior wall fracture of the acetabulum. Despite the overall good-to-excellent hip function illustrated by the Merle d’Aubigné score (mean score, 17), there was a high negative correlation ($r = -0.62; p < 0.001$) with the total MFA score (mean, 23.17). This study implies that the Merle d’Aubigné score may be useful for evaluating specific hip function but may be limited as a general index of patient function. Moreover, the higher MFA score seen in these injured patients as compared with normative means (uninjured patients) shows that other factors, perhaps psychosocial, determine overall functional outcome.

Issack et al. performed a retrospective study on ten patients who had a sciatic nerve injury following an acetabular fracture. The patients underwent sciatic nerve exploration and release in conjunction with either open reduction and fixation of an acetabular fracture, total hip replacement, or hardware removal of the acetabulum. While sensory symptoms were likely to improve after surgical release of the sciatic nerve from scar tissue, heterotopic bone, or impinging hardware, motor symptoms were less likely to improve.

Lenarz and Moed reported on six atypical anterior wall fractures of the acetabulum that were treated by a single surgeon. The fracture pattern involved the anterior acetabular rim but did not involve the pelvic brim as previously described by Letournel and Judet. This atypical anterior wall variant is analogous to a posterior wall fracture. Good-to-excellent clinical outcomes were achieved with use of a modified Smith-Petersen approach to fix these fractures.

Although the epidemiology is clear regarding the association of pelvic fractures with intra-abdominal and intracranial injuries, it is less clear regarding similar associations with acetabular fractures. Porter et al. performed a retrospective review of 323 patients with displaced acetabular fractures to evaluate this association. Anterior wall, anterior column, anterior column plus posterior hemitransverse, both-column, transverse, transverse plus posterior wall, and T-type acetabular fractures were classified as lateral load injuries, whereas posterior wall, posterior column, and posterior column plus posterior wall acetabular fractures were attributed to axial load mechanisms. The authors found that the lateral load injuries resulted in a higher association with retroperitoneal hematomas as well as spleen, liver, vascular, kidney, and bladder injuries in comparison with axial load acetabular fractures ($0.001 > p < 0.008$ for all comparisons).

**Appendicular Skeleton**

**Upper Extremity**

**Clavicle and Scapula**

Two studies from Germany investigated the use of intramedullary nail fixation of clavicular fractures with use of elastic titanium implants; both promoted the less invasive nature of this technique. The first study, from Munich, included eighty-seven patients and nonunion in an additional two patients. Migration of the nail also occurred in four patients, leading to implant removal. Surgeons missed the lateral medullary canal in two patients, necessitating repeat nailing, and plate fixation was necessary in two other patients who experienced fracture displacement after early nail removal. In the second study, from Bonn, thirty-two midclavicular fractures in adults were treated in the same fashion. After a median duration of follow-up of twenty-seven months, no complications, however, twelve fractures healed with shortening of $>5$ mm. As in the first study, nail migration was a problem, occurring in 25% of the cases, and nail breakage was observed twice. The nails were removed in twenty-nine patients at a median of six months postoperatively, and no patient sustained a refracture. The functional outcomes were comparable with those in the Munich series, and the authors of both studies pointed to this treatment option as a less invasive solution as compared with plate fixation. On the basis of these reported complications, however, it seems that more work needs to be done for the results to be comparable with those of plate fixation.

Maquieira et al. documented the natural history of fourteen consecutive displaced (>2 mm) anteroinferior
What’s New in Orthopaedic Trauma

Glenoid Rim Fractures

Glenoid rim fractures (mean width, 8 mm; range, 4 to 14 mm) that were treated nonoperatively. The authors noted that post-reduction radiographs showed a centered glenohumeral joint, a criterion not met by twelve other patients with a similar injury who were not included in the report. After a mean duration of follow-up of 5.6 years, the mean Constant score and subjective shoulder value were 98% and 97%, respectively, and there were no redislocations or subluxations. All patients had a negative apprehension test. The average intra-articular step-off after healing was 3.0 mm. No patient had symptoms of arthritis, although radiographs were scored as demonstrating mild or moderate degenerative joint disease and one shoulder demonstrated subluxation.

Shoulder and Proximal Part of the Humerus

A Swedish prospective, multicenter trial was started in 1978 to evaluate the results of nonoperative treatment of primary anterior shoulder dislocation. Two hundred and fifty-seven shoulders in 255 patients were enrolled, and 229 shoulders were available for follow-up twenty-five years later. Ninety-nine shoulders (43%) did not redislocate, and seventeen (7%) redislocated once. Sixty-two shoulders (27%) underwent a stabilization operation. Of the remaining fifty shoulders that had demonstrated recurrent instability, thirty-three became stable over time whereas seventeen remained unstable. Neither an associated greater tuberosity fracture nor lack of immobilization was found to predispose to recurrent dislocation. The authors therefore suggested that their data supported a period of observation in an especially high-risk group, namely, patients between the ages of twelve and twenty-five years who have sustained an anterior shoulder dislocation.

Robinson et al. performed a randomized controlled trial to determine whether arthroscopic stabilization is better than arthroscopic lavage alone for the treatment of primary anterior shoulder dislocation. Eighty-eight patients under the age of thirty-five years were enrolled in the trial. The study demonstrated significant improvement in terms of function, patient satisfaction, and treatment cost in the group of patients who had undergone stabilization. However, similar to the findings of the Swedish study noted above, only sixteen of the forty-two patients who had been managed with lavage alone demonstrated recurrent instability, and, interestingly, among those who did not have a redislocation, outcomes were not significantly different if stability was achieved through surgical stabilization or through natural healing of the injury.

Failure of fixation also was highlighted in a report on the experience of a single surgeon with fifty-three patients who had the same fracture. Although there was a 98% union rate by six months and only two cases of osteonecrosis, nineteen patients (36%) had radiographic signs of a complication, including screw cutout with intra-articular penetration (twelve patients; 23%), >10° of varus collapse (thirteen patients; 25%), and frank screw cutout (nine cases). These complications were more common in patients over the age of sixty years. Not surprisingly, these failures of fixation were associated with poorer outcomes on the SMFA and Quick Disabilities of the Arm, Shoulder and Hand questionnaires.

The next two studies to be discussed were smaller prospective trials involving the same type of implant and emphasizing similar themes of high union rates and low rates of frank hardware failure and osteonecrosis, but with fewer surgical failures. Moonot et al. evaluated thirty-two patients with three and four-part fracture variants and found no differences in function (Constant scores) between patients older or younger than sixty years of age; however, the one case of malunion, nonunion, and screw breakage occurred in the older age-group. The mean duration of follow-up in that group, however, was only eleven months, with the shortest duration being three months.

Egol et al. emphasized an analysis of complications in a retrospective review of fifty-one fractures or fracture nonunions that had been treated with a locked plate and followed for a minimum of six months. The average age of the patients was sixty-one years, and the rate of osteonecrosis was only 4%. The authors reported a 92% rate of union by three months, and sixteen complications were reported in twelve patients. The complications included penetration of the articular surface by screws (eight shoulders), plate failure (one shoulder), and infection (one shoulder).

Agudelo et al. performed a retrospective review to document the surgical results for 153 adult patients in whom a displaced fracture of the proximal part of the humerus had been treated with a locked plate at one of five trauma centers. The vast majority of these fractures (90.2%) were addressed through a deltopectoral approach, and no intraoperative complications were reported. These authors found that a varus malreduction was associated with a higher failure rate and emphasized the importance of executing fixation in proper alignment. The mean postoperative head-shaft angle was 130°, and the overall rate of loss of fixation was 13.7%. There was a significant association between varus reduction (<120°) and loss of fixation (30.4% when the head-shaft angle was <120°, compared with 11% when the head-shaft angle was >119°).

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Laflamme et al. and Gardner et al. described a percutaneous approach for plate fixation of the same fracture type. Although the duration of follow-up was shorter, both groups of authors noted good clinical outcomes and low failure rates and emphasized the safety of a small-incision anterolateral approach off the edge of the acromion, which splits the deltoid and requires sliding of the plate under the axillary nerve. No axillary nerve palsies were detected in these two studies.
The next two studies to be discussed investigated minimally invasive osteosynthesis with use of different fixation techniques. Both studies demonstrated generally good results, although again they included no control or comparison study group. The first study evaluated the use of an antegrade nail that provides angular and sliding stability in the proximal part of the humerus75. Ninety-seven patients were followed for as long as twenty-four months. There was a low rate of osteonecrosis (1.9%) and a low rate of nonunion, despite the fact that more than two-thirds of the fractures were three-part fractures. The rate of hardware failure (screws backing out) was 9.8%, and the rate was significantly greater among the fractures. The rate of hardware failure (screws backing out) was 9.8%, and the rate was significantly greater among the 22% of the patients over the age of eighty years. The second study was a retrospective review of a consecutive series of 165 of 188 patients who were followed for a mean of 5.4 years after open reduction and internal fixation with transosseous sutures76. The authors concluded that less surgical soft-tissue dissection, fixation sufficient to allow early passive joint motion, and the avoidance of bulky and expensive implants favor this approach. Two-thirds of the fractures were three or four-part fractures, possibly explaining the 7% rate of osteonecrosis. Overall, only 1.2% of the fractures went on to nonunion, although 5% were malunited. The final outcome evaluation revealed a mean Constant score of 91 points, which was close to the function of the unaffected shoulder and provided the basis for the authors’ conclusions.

In a study involving an unusual cohort of patients at the severest end of the proximal humeral injury spectrum, Robinson et al. retrospectively reviewed a large, consecutive series of twenty-eight shoulders with a posterior dislocation of the humeral head and an associated Neer two, three, or four-part proximal humeral fracture77. The authors noted that the study involved a younger population of patients (mean age, fifty-three years) who had sustained a high-energy injury (or seizure in the cases of eleven patients). All shoulders had a displaced primary fracture of the anatomic neck of the humerus, and all underwent open relocation, reduction, and fixation. No shoulder was treated with a locking plate, and six were treated with allograft to fill a reverse Hill-Sachs defect of the anterior aspect of the humeral head. The results were surprisingly good despite the gravity of the injury, with a median Constant score of 83.5 points and a median DASH score of 17.5 points, leading the authors to conclude that attempts at salvage of the humeral head are likely worthwhile.

The approaches to the treatment of proximal humeral fractures as shown in this section are varied and often reflect the surgeon’s perception of how stable the fracture is. Certainly, this perception also dictates the postoperative plan for rehabilitation as well. In the randomized controlled trial by Lefevre-Colau et al., early mobilization within three days after the fracture was compared with a conventional immobilization period of three weeks78. The study included seventy-four patients (mean age, 63.2 years) with a truly impacted proximal humeral fracture, with the majority of fractures having fewer than two displaced parts according to the Neer classification system. At both six and twelve-week intervals, mobility and pain scores showed significantly better results in the early mobilization group, and there were no complications of fracture displacement in association with the early mobilization protocol.

Moving to the reconstructive challenge in patients with osteoporosis, Krause et al. described their experience with the use of cable wires and bone-grafting when reattaching tuberosities in the setting of shoulder hemiarthroplasty for the treatment of three and four-part proximal humeral fractures, most of which were in elderly patients79. Although the results were confounded to some degree by a number of coexisting variables, the data tended to support the use of 1-mm cable wire and bone graft passed hemicircumferentially around the prosthesis through holes in the prosthesis. As loss of tuberosity fixation or tuberosity absorption continues to thwart positive outcomes in this population of patients, this study suggests a technique that could improve tuberosity healing, and, possibly, outcome.

**Humeral Shaft and Elbow**

The debate between intramedullary nail fixation and open reduction and internal fixation of humeral shaft fractures generally tilts toward open reduction and internal fixation, largely on the basis of the argument that shoulder symptoms are a common manifestation of antegrade nailing. O’Donnell et al. performed magnetic resonance imaging for the evaluation of thirty-three shoulders after the treatment of a humeral shaft fracture and found that an abnormality existed in twenty-one shoulders (63.6%) on the injured side only79. The abnormalities included bursitis of the subacromial space (ten shoulders), evidence of a partial tear of the rotator cuff (five), complete rupture of the supraspinatus tendon (one), inflammatory changes in the acromioclavicular joint (four), and fracture of the coracoid process (one), leading the authors to conclude that not all shoulder pain following antegrade nailing likely results from the procedure.

An emerging treatment for humeral shaft fractures is minimally invasive plate fixation. The authors of a small, prospective study from Shanghai, China, reported on thirteen patients with an average age of 38.1 years79. Anterolateral proximal and distal incisions were made for percutaneous submuscular sliding of the plate after closed reduction of the fracture, and all fractures were fixed with nonlocking narrow 4.5-mm plates with use of a bridging construct. Although this was only a preliminary report on this technique, all fractures united at a mean of 16.2 weeks, with <8° of angulation, and there were no nonunions, radial nerve palsies, or implant failures. Perhaps the greatest value of the report is the description of the surgical technique.

Doornberg et al. assessed thirty patients with comminuted intra-articular distal humeral fractures at an average of nineteen years (range, twelve to thirty years) after surgery79. All
fractures were fixed primarily with plates and screws, and two-thirds of the patients had an olecranon osteotomy; in most cases, the osteotomy site was fixed with use of a tension-band technique. It is encouraging that there were nineteen excellent, seven good, one fair, and three poor results. With the exclusion of one elbow that had a poor result and was salvaged with an arthrodesis, the mean arc of motion was 106° of flexion and 165° of pronation-supination. Functional outcome scores were exceptional, but 40% of the patients required a repeat procedure; the majority of the repeat procedures were performed for removal of hardware and/or contracture release.

Ruchelsman et al. reported on sixteen adults with a variety of capitellar fractures who were managed with an extensile lateral approach and articular fixation with buried cannulated variable-pitch headless compression screws. The lateral collateral ligament was intact in fifteen of the sixteen elbows. Supplemental mini-fragment screws were used for four of eight Type-IV fractures and one of two Type-III fractures. All fractures healed, with an overall elbow arc of flexion of 123°. Clinical outcomes were very good as measured on the basis of a mean Mayo Elbow Performance Index score of 92 ± 10 points, with nine excellent results, six good results, and one fair result. Patients with a Type-IV fracture had a greater magnitude of flexion contracture ($p = 0.04$), reduced terminal flexion ($p = 0.02$), and a reduced net ulnohumeral arc ($p = 0.01$). An ipsilateral radial head fracture did not affect ulnohumeral motion or functional outcome. Anderson et al. reported on thirty-two patients with olecranon fractures who were managed with a plating system with features that were thought to distinguish it from other existing precontoured systems. The authors reported only two nonunions and four elective hardware removals at a mean of 2.2 years and indicated that even comminuted olecranon fracture-dislocations can be treated effectively with this device.

Lindenhovius et al. evaluated ten patients with anterior olecranon fracture-dislocations and ten patients with posterior olecranon fracture-dislocations eighteen years after the injury. The average age at the time of the injury was thirty years. All patients except one had open reduction and internal fixation with plates and screws or a tension band construct. The mean arc of elbow flexion was 105° at one year and 122° at the time of the latest evaluation. Five patients (25%) had ulnar nerve dysfunction at the time of the latest evaluation. The Mayo Elbow Performance Index was excellent for thirteen patients, good for four, fair for two, and poor for one, and the mean DASH score was 9 points, indicating that the initial good results seen at approximately one year after surgery held up over almost two decades.

Unfortunately, elbow contracture is an all-too-familiar complication of elbow fracture-dislocations. Gundlach and Eygendaal assessed the results for twenty-one patients who were managed with an elbow contracture release through a lateral approach. The average age was forty years. The mean range of motion improved from $69°$ preoperatively to $104°$ by three months postoperatively, and this improvement was maintained through two years of follow-up. There were no neurovascular complications, and one patient required repeat release.

**Forearm and Distal Part of the Radius**

In recent years, we have learned of examples of fractures which were previously thought to be associated with an excellent outcome, not to be so straightforward. The sophistication of outcome instruments and rigor in follow-up has increased, and thus more subtle deficiencies in outcome can be detected. Droll et al. reported on thirty patients with a mean age of 43.9 years who were managed with open reduction and plate fixation of a both-bone forearm fracture and were followed for a mean of 5.4 years. Surprisingly, compared with the uninjured arms, the injured arms had reduced strength of forearm pronation (70% of that of the uninjured arm), forearm supination (68%), wrist flexion (84%), wrist extension (63%), and grip strength (75%). In addition, the injured arms had a significantly reduced active range of forearm supination (90% of that of the uninjured arm), forearm pronation (91%), and wrist flexion (82%). The mean DASH score (18.6 points) was significantly worse than the normative value in the United States. Limitations in strength were correlated with a worse DASH score, and pain and a work-related injury were independent determinants of the DASH score. Fracture types and specific fracture reductions were not assessed for stratification of results on the basis of these variables.

We reviewed two key studies about the distal part of the radius this year, both of which were randomized controlled trials that yielded fresh new information. In the first study, 144 intra-articular distal radial fractures in patients younger than sixty years were randomized to receive either spanning wrist external fixation and percutaneous pin fixation or open reduction and internal fixation with nonlocking plates. Internal fixation was performed through a volar approach in 57% of cases and through a dorsal and volar approach in 26% of cases. Bone graft was used in a high percentage of the fractures in both groups. At the time of the twenty-four-month follow-up, all fractures had united and the results for the plate fixation group were significantly better than those for the external fixation group according to the Gartland and Werley point system and the radiographic arthritis grading system. All clinical assessments were done independently by a therapist, although range of motion was not reported.

However, a protocol for range of motion in the other study may shed light on these two methods of fixation. Lozano-Calderón et al. performed a clinical trial of sixty randomized patients to compare mobilization of the wrist joint within two weeks (early motion) or at six weeks (late motion) after fixed volar plate fixation of a distal radial fracture. Surprisingly, an early approach to mobilization did not positively affect wrist motion at either three or six months, and there were no significant differences in terms of grip strength,
radiographic parameters, or functional outcome scores, suggesting that, at least for the wrist, surgeons should not feel compelled to adopt an early and aggressive postoperative strategy for motion.

Forward et al., in a prospective observational study, assessed the prevalence and one-year outcome of intercarpal ligament injury after high-energy distal radial fractures. Fifty-one patients with a median age of forty-one years underwent fracture treatment and wrist arthroscopy at the time of the injury, and any ligament injuries were left untreated. Patients were reviewed at one year and underwent physical and radiographic evaluation and were grouped according to a modification of the Geissler system: Group I consisted of ten patients with a grade-3 scapholunate ligament injury, and Group II consisted of forty-one patients with a grade-0, 1, or 2 injury. Although there were no significant differences between the two groups with respect to objective outcomes according to range of motion, grip strength, and tip pinch strength, grade-3 scapholunate ligament tears were associated with more scapholunate joint pain and positive radiographic markers for instability at one year, leading the authors to conclude that residual symptoms after even excellent distal radial fracture reduction and osseous healing may be explained by these extraosseous injuries.

Lower Extremity

Proximal Part of the Femur

Gjertsen et al. reviewed 8577 femoral neck fractures (including acute fractures and fractures with failed fixation) that were treated with a total hip arthroplasty with use of cemented acetabular and femoral components. The authors found a higher risk of failure for the fracture fixation revision group as compared with an osteoarthritis group that was examined in the same study. The two main modes of failure in the patients who underwent arthroplasty because of failed fixation were dislocation and periprosthetic fractures primarily in the first six months. Interestingly, the risk of acetabular component loosening was found to be significantly lower than that for the patients with osteoarthritis.

Accurate prediction of osteonecrosis of the femoral head after femoral neck fracture is difficult. Watanabe et al. used a polarographic oxygen electrode intraoperatively to measure intramedullary oxygen tension before the fixation of femoral neck fractures. Magnetic resonance imaging scans showed that seven of eighteen femoral neck fractures were associated with the development of osteonecrosis; the osteonecrosis occurred in patients who had a difference in the intramedullary oxygen tension between the center and the peripheral part of the femoral head.

Peyser et al. reported the results of a prospective randomized study in which percutaneous compression plate fixation was compared with compression hip screw fixation for the treatment of simple two or three-part (AO/OTA 31A1-A2) fractures. One hundred and four patients were randomized, and 103 were included in the final analysis. The results in terms of blood loss, the pain score, the ability to bear weight at six weeks, and radiographic evidence of collapse were all significantly improved in the percutaneous compression plate group, suggesting that this implant solution shows promise.

A research group from the University of Minnesota analyzed Medicare claims and enrollment data between 2000 and 2002 for 212,821 patients who had been managed for an intertrochanteric hip fracture and determined that there was geographic variation in the choice of implant used to fix these fractures. Specifically, different states had different rates of intramedullary nail usage. Anglen et al. echoed the theme of selective implant use for this fracture in a review of the American Board of Orthopaedic Surgery Database. Those authors reported that the use of intramedullary nail fixation for intertrochanteric fractures increased dramatically during that same time period.

Peskun et al. used the SF-36, the SMFA, and the Lower Extremity Functional Scale to assess the functional outcome of ipsilateral intertrochanteric and femoral shaft fractures. Internal fixation of these concomitant fractures was performed with a reconstruction nail (n = 13) or a sliding hip screw and a retrograde nail combination (n = 13). The authors of this retrospective review concluded that for most outcome measures, there was no significant difference between the two methods of fixation for this injury combination.

The difference in outcomes following hip fracture between women and men was revisited by the Scottish Hip Fracture Audit. On the basis of the 25,649 patient records that were analyzed, men (constituting 22% of the hip fracture population in this database between 1998 and 2005) had higher thirty-day and 120-day mortality rates than women did. As previous studies have generally shown, men also were less likely to return to their homes and to walk independently following hip fracture.

Diaphysis and Distal Part of the Femur

The greater trochanteric entry portal for femoral shaft fractures is gaining popularity with the advance of a new nail design with an increased proximal lateral bend. Ricci et al. performed a prospective cohort study evaluating trochanteric and piriformis entry portals for the treatment of these shaft fractures. Thirty-eight fractures were treated with an intramedullary nail that has a 4° proximal lateral bend to accommodate trochanteric entry, and fifty-three fractures were treated with a nail designed for a piriformis fossa starting point. The authors found similar results between the two groups with regard to union rates, complication rates, and functional results. While the average operative time was somewhat greater in association with the piriformis entry portal, a significant difference was discovered with regard to the fluoroscopy time, which was 61% greater for the piriformis entry group. In addition, this difference was more substantial when the patient had a body mass index of >30, with fluoroscopy time being 73% higher.
Ricci et al., in a retrospective study, compared retrograde intramedullary nailing with antegrade intramedullary nailing for the treatment of femoral shaft fractures. The retrograde nailing group included 134 fractures, and the antegrade nailing group included 147 fractures; the average duration of follow-up was twenty-three months for each group. The authors found no significant difference between the two techniques with regard to the union rate. As anticipated, the rate of knee pain was greater for the retrograde nailing group than for the antegrade nailing group (36% compared with 9%). In contrast, the rate of ipsilateral hip pain was greater for the antegrade nailing group than for the retrograde nailing group (10% compared with 4%).

Herrera et al. performed a systematic review of 415 acute distal femoral fractures that occurred proximal to a total knee replacement to investigate different options for the treatment of this injury. Compared with nonoperative treatment, significant relative risk reductions for nonunion and revision surgery were found in the retrograde nailing and locking plate groups. Interestingly, compared with traditional plate fixation, retrograde nailing was associated with a relative risk reduction of 87% for the development of a nonunion and of 70% for the need for revision surgery.

Proximal Part of the Tibia
A recent review underscored the importance of recognizing the posteromedial coronal fragment often seen in association with high-energy bicondylar tibial plateau fractures. Among fifty-seven patients who had medial articular fracture involvement, 74% had a posteromedial fragment. The morphology of this fragment was better delineated in this study; however, the key importance is to ensure that surgeons recognize the fragment and address it in their surgical planning.

Diaphysis and Distal Part of the Tibia
Karac and Tornetta reported on a series of sixty-two patients with a segmental tibial fracture that was treated with unreamed nailing. The series included thirty-six open fractures (with the exclusion of type-IIIC fractures) and twenty-six closed fractures. Ninety-one percent of the fractures healed with one operation, and five patients required additional surgery to obtain union. Open fractures and fractures associated with compartment syndrome took the longest time to heal (mean, 294 days). The authors emphasized the technique of obtaining cortical contact at both fracture sites and deferring secondary surgical interventions for at least six months if the patient is progressing clinically.

Vallier et al. performed a retrospective study in which medial plate fixation was compared with intramedullary nailing for the treatment of extra-articular distal tibial fractures; seventy-six fractures were treated with an intramedullary nail, and thirty-seven were treated with a medial plate. Although not significant, delayed union or nonunion was more common after intramedullary nailing (12%) as compared with plate fixation (2.7%). However, with concurrent fixation of the fibula, nonunion was more common in the intramedullary fixation group (14% compared with 2.6%). Malunions occurred significantly more often in the intramedullary nail fixation group (29% compared with 5.4%). The authors acknowledged that all of these malunions were initially fixed in a malaligned position, so late failure of fixation was not the cause of these deformities.

Respect for the soft tissues is a clinical imperative when treating high-energy distal-third tibial or tibial plafond fractures. Collinge et al. performed a retrospective review of twenty-six patients with high-energy metaphyseal distal tibial fractures. Minimally invasive plate osteosynthesis with a medial plate was used to treat these fractures that had little or no articular involvement. The authors reported a high rate of reoperation (35%) and a prolonged time to union (22%). They noted that risk factors for healing problems included open fractures, highly comminuted fractures, and bone loss. They recommended early intervention (bone-grafting) when no callus is seen along the lateral or posterolateral cortex within eight to ten weeks after the injury.

Stuermer and Stuermer performed a prospective study to determine the rate, mechanism, and radiographic signs of concomitant ipsilateral tibial shaft and ankle injuries. Twenty-one percent of the tibial fractures were found to be associated with an ankle joint injury. Indirect trauma with a rotational force, spiral fracture of the distal third of the tibia, the Maisonneuve fracture, a tibia fracture with an intact fibula, and alcohol consumption were all risk factors for this injury combination.

Papadokostakis et al. performed a systematic review of the literature, which yielded fifteen articles describing 465 tibial plafond fractures that were treated definitively with external fixation devices. Ankle-spanning external fixators were compared with the ankle-sparing technique (involving the use of hybrid frames) with regard to complications and healing times. There was no significant difference between the two methods with regard to the rate of infection, nonunion, or the time to union. However, a higher malunion rate was found in the ankle-spanning group, indicating that hybrid frames with wires near the fracture may provide better stabilization than spanning frames that rely on ligamentotaxis.

To further delineate the “personality” of high-energy tibial plafond fractures, LeBus and Collinge used computed tomography angiography to evaluate twenty-five patients with regard to the presence of arterial injuries. The authors identified fourteen arterial lesions (seven complete occlusions, two partial occlusions, four vessels tented over fracture fragments, and one vessel entrapped in the fracture site). The anterior tibial artery was involved in nine of the thirteen legs with vascular disturbances. The authors concluded that computed tomography could be used to guide the surgical approach to these injuries.

Grose et al. reported on a series of forty-four tibial plafond fractures that were treated through a lateral
Thirty-five fractures were classified as AO/OTA type C, with the majority being type-C3 fractures. A surgical approach just anterior to the fibula between the interosseous membrane and the anterior compartment was used to access the anterior and lateral aspects of the distal parts of the tibia and fibula. A low rate of wound complication resulted, and forty-one fracture-reductions (93%) were graded as anatomic and fibula. A low rate of wound complication resulted, and the anterior and lateral aspects of the distal parts of the tibia membrane and the anterior compartment was used to access the anterior skin bridge. The mean width of the skin bridge was 5.9 cm, with 83% of the bridges being <7 cm. The soft-tissue complication rate was low (four of forty-six) and was comparable with the rate in previous reports in the literature. The authors stressed that other factors besides the width of a skin bridge, such as surgical timing, careful handling of the soft tissue, smoking cessation, and nutritional supplements, are more important for minimizing wound complications.

The next four reports discussed the supination-external rotation (SER) fracture of the ankle. Medial ankle tenderness, ecchymosis, and swelling have been shown to be unreliable indicators of a medial-sided ankle injury with these fractures. Schock et al. compared the use of a gravity stress radiograph with the manual stress radiograph for the evaluation of supination-external rotation ankle fractures for deltoid ligament complex disruption. The gravity stress test was performed with the patient lying in the lateral decubitus position on the injured side. An ankle mortise radiograph was made with the injured lower limb lying dependent off the table edge. The authors concluded that the gravity stress test was as reliable as the manual stress test but resulted in less pain to the patient.

Koval et al. took this concept one step further in evaluating supination-internal rotation ankle injuries with imaging studies. Twenty-one patients with a Weber type-B lateral malleolar fracture associated with a positive ankle stress test (>5 mm clear space) underwent magnetic resonance imaging to evaluate the deep deltoid ligament. Nineteen of the twenty-one patients had partial deep deltoid ligament disruption, and two had a complete deep deltoid tear. The nineteen patients with partial deep deltoid disruption were managed nonoperatively and were allowed to bear weight as tolerated, whereas the two patients with complete deltoid disruption were managed surgically. The authors suggested that, while further study is needed, more effective diagnostic strategies may save patients from unnecessary surgery for an isolated lateral malleolar fracture.

Stark et al. reported a higher rate of syndesmosis instability (39%) in association with an unstable Weber type-B supination-external rotation lateral malleolar fracture than has previously been reported. Intraoperative external rotation stress examinations were performed after fixation of 238 Weber type-B fractures with deltoid ligament disruptions (the SER-4 fracture pattern). Ninety-two syndesmosis disruptions were identified and treated with screw fixation.

Tejwani et al. evaluated the difference in epidemiology and outcomes between the two types of SER-4 injury variants (bimalleolar fractures and lateral malleolar fractures with deltoid disruption). Bimalleolar fractures are seen more commonly in older individuals, female patients, and patients with more comorbidities. Furthermore, the bimalleolar fractures had a significantly worse functional outcome as compared with the ligamentous equivalents. Strauss et al. retrospectively reviewed 279 patients with unstable ankle fractures to compare obese patients to nonobese patients. Obese patients tended to have more comorbidities and higher fracture severity (OTA types B and C) than the nonobese patients did. However, the authors did not find a significant difference between the two groups with respect to complications or functional outcomes.

White et al. performed a prospective randomized study evaluating an intra-articular block sedation as compared with conscious sedation for closed reduction of ankle fracture-dislocations. Twenty-one patients were randomized to each group, and the groups were compared with respect to age, fracture pattern, repeat reduction, and average pain scores before and after reduction. The authors confirmed their hypothesis that an intra-articular block of the ankle would provide sufficient analgesia to allow successful closed reduction of the ankle fracture dislocation as compared with conscious sedation.

**Foot**

Tezval et al. reported on thirty-one patients with displaced talar fractures who were followed for at least thirty-six months. The authors found that a full or partial positive Hawkins sign by the ninth week after surgery was associated with a low osteonecrosis rate. In this study, the sensitivity of a Hawkins sign was 100% but the specificity was only 57.7%, indicating that the absence of the Hawkins sign does not predict whether osteonecrosis will develop.

Von Knoch et al. reported on a large series of twenty-three lateral process fractures in snowboarders from Switzerland who were followed for a mean of 3.5 years. Overall, the mean American Orthopaedic Foot and Ankle Society hindfoot score was 94. The seven patients who had nonoperative treatment of a minimally displaced fracture scored higher (98 points) than did the sixteen patients who had operative treatment of a displaced or unstable fracture (93 points). In 88% of the operative cases, substantial concomitant hindfoot injuries were found at the time of surgery. All but eight patients (35%) regained their preinjury level of sporting activity, although the degree of displacement and associated injuries correlated with a worse outcome.

Poeze et al., in a systematic review, sought to discover whether the rates of serious infection and subtalar arthrodesis...
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after open reduction and internal fixation of closed, displaced, intra-articular fractures correlated with institutional calcaneal fracture load. Of 236 studies reviewed, twenty-one (comprising 1656 patients) met the inclusion for analysis. The median infection rate in the studies combined was 5.1% and increased exponentially with a decreasing fracture load ($r^2 = -0.5; p = 0.03$). The median rate of subtalar arthrodesis was 2.5%, and a significant inverse correlation was present between fracture volume and the subtalar arthrodesis rate ($r^2 = -0.7$).

Conclusion

In an attempt to be sufficiently comprehensive, this annual survey of the fracture landscape is necessarily cursory. However, we trust that it will provide a ready and well-organized source for orthopaedic surgeons to quickly reference, leading the way to dive deeper when desired. Please do not hesitate to provide your feedback so that we can best direct future Subspecialty Updates in a direction most useful to our readers.

Appendix

Tables presenting the journals searched for this update and listing the studies according to Level of Evidence are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on “Supplementary Material”) and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD).

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