Operative Versus Conservative Management of Displaced Tibial Shaft Fractures in Adolescents

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Purpose: Despite the commonplace nature of displaced tibial shaft fractures in adolescents, there is wide variability in management strategies. The purpose of this study was to assess treatment outcomes and determine predictors of failure in patients treated for displaced tibial shaft fractures.

Methods: We retrospectively reviewed all patients aged 12-18 years who presented to one of two Level I trauma centers with a displaced tibial shaft fracture that required reduction. Exclusion criteria included open fractures and lack of follow-up to either radiographic union or to 6 months from the index procedure. Fractures were treated based on surgeon preference with one of two approaches: (1) closed reduction and casting (CRC) under conscious sedation or general anesthesia, or (2) immediate operative fixation with a rigid intramedullary nail or flexible nails. Radiographic healing was defined as bridging of 3 of 4 cortices on radiographs and adequacy of final fracture alignment was defined as less than 5° of angular deformity and less than 1.0 cm of shortening. Outcomes were analyzed both on intent-to-treat principles and by definitive treatment method.

Results: 74 patients were included, of which 17 were initially managed with operative fixation and 57 with CRC. While all fractures in both cohorts achieved bony healing, 23 of the 57 patients who underwent initial CRC failed closed treatment and ultimately required operative intervention (40.3%). Multivariate analysis of patient and fracture characteristics revealed initial fracture displacement of >20% of the tibial width (odds ratio [OR] = 7.8, P <0.05) and the presence of a fibula fracture (OR = 5.06, P = 0.05) as independent predictors of closed treatment failure. Patients managed operatively had longer hospital stays (5.4 vs 1.9 days, P <0.001), fewer clinic visits (4.8 vs 5.9, P <0.01), a higher incidence of anterior knee pain at healing (20% vs 0%, P <0.01) and trended towards better final alignment (92.5% adequate vs 72.4%, P = 0.10). There were no differences between cohorts with respect to time to radiographic healing, final range of motion, and return to activity.

Conclusion: Treatment outcomes between initial operative fixation and attempted closed reduction of displaced tibia fractures in adolescents are similar, but treatment failure is higher in CRC. Predictors of CRC failure include initial fracture displacement >20% and presence of a fibula fracture. Patients must be counseled about the high failure rates with CRC and the need for active follow-up during treatment, whereas those undergoing surgical management should understand the risk of anterior knee pain and prolonged hospitalization.

See pages 47 - 108 for financial disclosure information.

Fracture Classification Predicts Functional Outcomes in Supracondylar Humerus Fractures: A Prospective Study

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Purpose: This study was conducted to prospectively evaluate the relationship between fracture classification and functional outcome in children with supracondylar humerus fractures (SCHFX) using validated outcome measures.

Methods: An IRB-approved prospective enrollment of consecutive patients with operative SCHFX was performed over a 3-year period. Fracture pattern and Gartland classification were recorded by the treating surgeon at the time of surgery. Functional outcome was assessed at final follow-up using the Pediatric Outcomes Data Collection Instrument (PODCI) and the QuickDASH Outcome Measure, an abbreviated version of the Disabilities of the Arm, Shoulder and Hand questionnaire. Multiple regression analysis was used to determine the relationship between fracture classification / pattern and functional outcome while controlling for other injury parameters including patient age, neurologic deficit, vascular abnormality, and presence of an open fracture.

Results: 752 patients were enrolled during the study period of whom 199 (average age 6.7 years) completed functional outcome measures at final follow-up. Of these, 10 patients (5%) sustained flexion injures and 189 (95%) sustained extension injuries of which 62 (33%) were Type II fractures and 127 (67%) were Type III fractures. 65 (34%) of the extension injuries were posteromedially displaced, 58 (31%) were posterolaterally displaced, 54 (29%) were posteriorly displaced without coronal plane deformity, and 12 (6%) were multidirectionally unstable. The average PODCI global functioning scale score and QuickDASH scores for the entire cohort were 93.5 and 10.5 respectively indicating excellent function. No differences in outcome scores were noted between patients with Type II fractures, Type III fractures, and those with multidirectional instability. For extension injuries, no difference in outcome was identified based upon fracture pattern. Flexion injuries demonstrated significantly lower PODCI transfer and basic mobility (93.9 vs 98.7, $P < 0.001$) and PODCI pain and comfort scores (77.8 vs 94.8, $P < 0.3$) than Type III extension injuries. As a whole, extension injuries demonstrated significantly higher PODCI pain and comfort scores (94.8 vs 77.8, $P < 0.02$) than flexion injuries.

Conclusion: This is the first study to prospectively determine an association between fracture classification and functional outcome using validated outcome measures following the operative treatment of children with SCHFX. While children generally have excellent functional outcomes following the operative treatment of SCHFX, flexion injuries may be predictive of poorer outcomes with regards to pain and mobility when compared to extension injuries at final follow-up.

Factors that Predict Instability in Pediatric Diaphyseal Both Bone Forearm Fractures

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Background/Purpose: Diaphyseal forearm fractures are among the most common fractures in children. Significantly displaced or angulated fractures are treated with initial closed reduction and immobilization, with follow-up to determine if displacement occurs. The purpose of this study was to determine what factors upon initial presentation would predict failure of initial closed reduction and casting.

Methods: Radiographic and hospital records of skeletally immature patients who underwent closed reduction and casting of diaphyseal forearm fractures in the emergency department were evaluated. Demographic, time course, and radiographic data were evaluated at presentation and at varying time intervals until union was achieved. Univariate logistic regression analysis of these factors was performed to identify predictors of failure of initial closed reduction and immobilization as defined as requiring a repeat procedure.

Results: 188 patients meeting the inclusion criteria were identified and analyzed. 174 patients had adequate follow-up to union. The average patient age was 7.7 years old and 68% of patients were male. A total of 19 patients underwent a repeat procedure. Patients who underwent a repeat procedure had an average initial reduction time of 36.9 ± 22.2 minutes, whereas those patients who did not require additional procedures had an initial reduction time of 23.4 ± 11.8 minutes ($P < 0.0103$). Odds of requiring repeat reduction were the greatest in those patients who presented with fractures translated greater than or equal to 50% in any plane (odds ratio [OR] = 10.1; 95% confidence interval [CI] 3.1-33.1), age greater than 9 years (OR = 4.1; 95% CI 1.5-11.3), complete fracture of the radius (OR = 9.1; 95% CI 2.0-40.5), follow-up angulation of the radius >15° on lateral radiographs (OR = 5.0; 95% CI 1.3-18.6), follow-up angulation of the ulna >10° on AP radiographs (OR = 8.7; 95% CI 2.7-28.4), and follow-up translation of either bone >50% (OR = 13.5; 95% CI 4.5-40.2). There was no significant correlation with respect to initial angulation parameters and cast index.

Conclusion: Patients requiring lengthy initial reductions are at an increased risk of having a repeat procedure than those with short initial reduction times. Age, initial translation, complete fractures of the radius, and residual translation on follow-up are highly predictive of patients having repeat procedures. These patients require carefully monitored follow-up and families should be counseled appropriately as to their risk of repeat intervention.

See pages 47 - 108 for financial disclosure information.

Best Trauma Paper of the 2015 POSNA Annual Meeting
Implementation of a Standardized Clinical Assessment and Management Plan (SCAMP) for Pediatric Distal Radius Fractures: Effect on Quality and Care

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Background/Purpose: Standardized Clinical Assessment and Management Plans (SCAMPS) have been proposed as a means of improving quality, safety, and cost-effective care. The purpose of this investigation was to evaluate the effect of a distal radius fracture (DRF) SCAMP on clinical care and resource utilization.

Methods: 199 patients treated from October 2010 to March 2012 prior to the initiation of the DRF SCAMP (pre-SCAMP) were compared to 384 patients treated from August 2012 to April 2013 after DRF SCAMP implementation (post-SCAMP). All patients were 4 to 18 years of age with acute DRFs. Exclusion criteria included open fractures, pathologic fractures, refractures, and vascular insufficiency. Mean patient age was 10.5 years. Approximately 45% of patients sustained torus fractures, 40% bicortical metaphyseal fractures, and 15% physeal fractures. There were no significant differences between the pre- and post-SCAMP cohorts with respect to age, gender, or fracture type. Radiographic alignment was assessed at each encounter. Acceptable radiographic alignment was deemed <10° angulation and 50% translation or <20° angulation and 50% to 100% translation for older and young patients, respectively. Remanipulation, surgical intervention, and complications were recorded.

Results: Torus fractures: All patients with torus fractures achieved satisfactory clinical healing with nonoperative care. However, following SCAMP implementation, there was significant improvements in avoidance of casting (99% pre-SCAMP vs 28% post-SCAMP), appropriate use of splinting (1% pre- to 72% post-SCAMP), and avoidance of unneeded follow-up clinical visits after 3 weeks of immobilization. Bicortical metaphyseal and physeal fractures: While there were no significant changes in remanipulation or surgery rates, there were significant decreases in rate of initial fracture reduction after SCAMP implementation (68% pre- vs 53% post-SCAMP). There were also increased rates of acceptable alignment after the first encounter (86% pre- vs 99% post-SCAMP) and at the 6-week post-injury mark (83% pre- vs 98% post-SCAMP). Overall: Throughout the post-SCAMP period, there was a trend for decreased number clinical visits and radiographs for all patients. Over time, adherence to the SCAMP approached 82% to 100%. No cases of compartment syndrome, malunion, or postsurgical infection were recorded.

Conclusion: Implementation of a DRF SCAMP resulted in equivalent clinical outcomes, improved adherence to best practice guidelines, decreased number of clinical visits and radiographs (and thus cost of care), and high provider acceptance. SCAMPs are an effective tool to improve clinical care and resource utilization. Further investigation is underway to characterize accompanying reductions in cost in the DRF model.

Factors Associated with Development of Nonunion or Delayed Healing Following Open Fracture: A Prospective Cohort Study of 736 Subjects

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Purpose: We sought to evaluate the factors associated with nonunion following open long bone fractures (humerus, radius/ulna, femur, tibia/fibula) including the relationship between time to initial surgical management. Secondarily, we examined factors associated with development of delayed healing.

Methods: Between 2001 and 2009, 736 subjects with 791 open fractures were enrolled in a prospective cohort study undertaken at 3 Level Itrauma centers and followed for 1 year. Demographics and injury information (Gustilo grade, fracture site, injury mechanism, timing of antibiotic administration, and initial surgery) were recorded. Subjects were evaluated postoperatively using standardized data forms until the fracture healed. Phone interviews were undertaken at 1 year. Nonunion was defined as unplanned surgical intervention after definitive wound closure or incomplete radiographic healing at 1 year post fracture. Delayed union was defined as lack of progression of radiographic healing at 2 consecutive postoperative visits or incomplete radiographic healing and ongoing clinical symptoms between 6 months and 1 year post fracture. Univariate logistic regression was undertaken for age, gender, time from injury to surgery, and antibiotic administration calculated in hours, Gustilo grade and fracture location (upper extremity, femur, tibia/fibula), presence of deep infection, smoking status, comorbid conditions, having associated injuries, multiple fractures, and receiving a transfusion. Two multivariate logistic regression models using nonunion and delayed union (yes/no) as dependent variables were developed.

Results: The mean age was 41.5 ± 17.1 years and 530 (72%) were male. Fractures occurred in motor vehicle accidents (n = 359 [49%]), falls (n = 230 [31%]), crush injuries (n =131 [18%]) and assaults (n = 16 [2%]). Tibia/fibula fractures were most common (n = 413 [52%]), followed by upper extremity (n = 285 [36%]) and femur (n = 93 [12%]) fractures. Follow-up (1 year interviews and/or clinical follow-up of >90 days) was completed by 695 (94%) subjects (746 fractures). Overall, 124 (17%) subjects had nonunions while 63 (10%) subjects experienced delayed healing. The median time to initial surgery was 9.0 hours(h) (interquartile range [IQR] 6.8, 12.0) for healed fractures and 8.3 h (IQR 6.3, 11.3) for nonunions (P = 0.36). The median time to surgery was 9.0 h (IQR 7.0, 12.5) for fractures without healing problems, and 8.0 h (IQR 5.5, 12.3) for those with delayed healing, respectively (P = 0.34). Multivariate logistic regression also showed no significant association between time to initial operative management and developing nonunion (odds ratio [OR] 0.97; 95% confidence interval [95% CI] 0.92, 1.01) or experiencing delayed healing (OR 0.96; 95%CI 0.90, 1.02). Deep infection (OR 12.75; 95% CI 6.1, 26.8), Gustilo grade 3A relative to grade 1 fractures (OR 2.5; 95% CI 1.3, 4.8) and smoking (OR 1.7; 95% CI 1.1, 2.8) retained a significant association with developing a non-union in the multivariate model. Deep infection (OR 4.3; 95% CI 1.2, 15.5) and Gustilo Grade 3B/C relative to grade 1 (OR 3.7; 95% CI 1.4, 9.4) fractures were significantly associated with delayed healing.

Conclusion: Development of nonunions or delayed healing is strongly associated with the presence of a deep infection and higher Gustilo grade fractures.

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A Predictive Model of Tibial Shaft Fracture Nonunion at the Time of Definitive Fixation

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Background/Purpose: A clinical tool that would allow surgeons to predict the likelihood of nonunion at the time of intramedullary nail (IMN) fixation of tibial shaft fractures could change the management of those at high risk of nonunion. Previous authors have explored possible factors influencing reoperation in tibial shaft fractures; however, no authors have developed a tibial shaft nonunion prediction model for the time of initial fixation for fractures treated with reamed IMNs (time zero). We posited that commonly collected data on patients, evaluation of the fracture and soft-tissue injury and postoperative films at the time of definitive IMN fixation, would allow us to extract statistically significant variables predictive of nonunion. Employing these variables we aimed to create a nonunion prediction model that would enable surgeons to predict nonunions in tibial shaft fractures at the time of IMN fixation.

Methods: Our final study group consisted of 382 adult patients treated with IMN for tibial shaft fractures (n = 56 progressed to nonunion, n = 326 healed without further intervention). All patients were followed to fracture healing or surgical intervention for nonunion and we excluded patients with adequate follow-up but indeterminate healing status. Importantly, no patients were included who had planned nonunion surgery, typically based on large fracture gap. We reviewed perioperative and follow-up radiographs, charts, and laboratory data. We defined nonunions as fractures expected to heal without further intervention that eventually, in the surgeon's judgment, required an additional operative intervention to ensure union. We collected patient data on 35 factors thought to contribute to delayed bone healing. Bivariate and multivariate regression techniques, as well as stepwise modeling approaches, were used to examine the relationship between variables available during the index hospitalization and subsequent nonunion. Over 26 variables were examined in the analysis but found to be insignificant. Nine factors were found to be significant.

Results: A multiple variable logistic regression model was developed that included 7 significant factors ($P < 0.05$ and odds ratio >2.0 in bivariate or multiple variable models): use of flap, open fractures, compartment syndrome, male gender, American Soceity of Anesthesiologists (ASA) classification, percent cortical contact, and chronic disease status (HIV/HepC/diabetes). Additionally, we found spiral fractures and low-energy mechanism predictive of union. Based on these factors we developed a model titled the Nonunion Risk Determination (NURD) score. The NURD score assigns 1 point per level for ASA and % cortical contact, 1 point for male gender, 2 points for open fracture, 3 points for chronic conditions, 4 points for compartment syndrome, and 5 points for requiring a flap. One point

each was subtracted from the score for spiral fractures or low-energy injury. Patients with a NURD score of 0 to 5 had a 1.72% chance of nonunion (4/232). Patients with a NURD score of 6 to 8 had a 22% chance of nonunion (22/101), Patients with a NURD score of 9 to 11 had a 42% chance of nonunion (13/31), and patients with a NURD score >12 had a 61% chance of nonunion (11/18).

Conclusion: We determined that a number of factors predict nonunions and can reliably be formed into a union prediction model to allow clinicians to determine very early in the treatment course which patients have a higher risk of nonunion. The ability to predict nonunion early in the patient's course may help guide patients and clinicians as to when patience (as union is likely) is the best approach and when interventions aimed at enhancing healing of the fracture through earlier surgical interventions may be reasonable options.

See pages 47 - 108 for financial disclosure information.

Prospective Prediction of Tibial and Femoral Shaft Fracture Nonunion at 4 Months

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Purpose: A retrospective single-center study recently determined that the presence or absence of bridging callus at 4 months postoperatively accurately discriminated between tibial shaft fractures bound for union and nonunion. However, there remains no consensus regarding early prognostication of long bone nonunion. The purpose of this study was to prospectively assess the accuracy and reliability of the previously described assessment of any bridging callus at 4 months in a prospective cohort expanded to include both tibial and femoral shaft fractures.

Methods: A prospective prognostic study is being performed at a Level I trauma center. To date we have identified 78 consecutive tibial (OTA 42-A,B,C) and femoral (OTA 32-A,B,C) shaft fractures treated with intramedullary nailing. Ten patients had yet to achieve a final healing outcome, while others were excluded due to death before final outcome (2), early planned bone grafting for critical bone loss (1), and failure to return to clinic (5). Thus, the final analytic cohort included 60 fractures (26 tibias and 34 femurs). Postoperative digital radiographs were obtained between 3 and 4 months postoperatively and assessed independently by three orthopaedic traumatologists for the presence of bridging callus. The patients were followed to radiographic and clinical union. The accuracy of varying callus criteria (any bridging, bicortical bridging, and tricortical bridging) was assessed with the chi-square test for ability to predict union and nonunion. Interobserver reliability (kappa statistic) was calculated for each criterion.

Results: The nonunion rate was 6.7% (4 of 60). The presence of any bridging callus by 4 months postoperatively accurately predicted union when present and nonunion when absent (56/56 and 4/4 respectively, $P < 0.001$). This included the prediction of nonunion in both the tibia (3/26) and femur (1/34) without error. Bicortical bridging was accurate for 59 of 60 (98.3%), predicting union when present and nonunion when absent (55/55 and 4/5, respectively, $P < 0.001$), incorrectly predicting one healing fracture as a nonunion. Tricortical bridging was accurate for 50 of 60 fractures (83.1%), predicting union when present and nonunion when absent (46/50 and 4/14, $P = 0.01$), incorrectly predicting ten healing fractures as nonunions. Interobserver reliability was calculated for any bridging callus (kappa = 0.96), at least bicortical bridging (kappa = 0.89), at least tricortical bridging (kappa = 0.58), and the exact number of cortices bridged (kappa = 0.51).

Conclusion: Prospective assessment for any bridging callus by 4 months postoperatively predicted union and nonunion with high accuracy and reliability. This clinical criterion is simple, reliable, and requires only standard radiographic views. This relatively early radiographic finding discriminates between fractures achieving late union with observation alone and those destined to nonunion. Requiring additional cortices to be bridged risks overestimation of the nonunion rate and is associated with relatively poor reliability.

Ketorolac Administered in the Recovery Room for Acute Pain Management Does Not Affect Healing Rates of Femoral and Tibial Fractures

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Background/Purpose: Ketorolac is a nonsteroidal anti-inflammatory drug that is used effectively as a postoperative analgesic. Orthopaedic surgeons have been reluctant to use this medication in the setting of fracture repair because its mechanism of action disrupts the first phase of bone healing, and therefore may increase the risk of nonunion. The purpose of this study is to compare the healing rates of acute femoral and tibial shaft fractures in patients who were administered ketorolac in the postanesthesia care unit (PACU) to the healing rates in patients who did not receive ketorolac.

Methods: This was a retrospective review of skeletally mature patients who underwent intramedullary rodding of a femoral shaft (OTA 32) or a tibial shaft (OTA 42) fracture at a single institution from 2003 to 2013. Patients were divided into two groups: those who received ketorolac in the PACU or on the floor within the first 24 hours after the surgical procedure (Group 1), and those who did not (Group 2). Minimum 1-year clinical and radiographic follow-up was required. The primary end points were reoperation for repair of a nonunion and time to union. Data collection included age, gender, extent of soft-tissue injury, diabetes, smoking status, and dosage of ketorolac. Statistical analysis utilized Fisher's exact test for categorical variables and Mann-Whitney U test for continuous variables with significance set at P value less than or equal to 0.05.

Results: Group 1 consisted of 80 patients (52 tibia, 33 femur) and Group 2 consisted of 233 patients (139 tibia, 94 femur). Patient demographics were similar between the two groups. Average time to union of the femur was 147 days for group 1 and 159 days for group 2 (P = 0.57). Average time to union of the tibia was 175 days for Group 1 and 175 days for Group 2 (P = 0.57). There were three femoral nonunions (9%) in Group 1 and eleven femoral nonunions (11.7%) in Group 2 (P = 1.00). There were three tibial nonunions (5.8%) in Group 1 and seventeen tibial nonunions (12.2%) in Group 2 (P = 0.29). All patients with a nonunion in the study group were current smokers. The average dose of ketorolac given to the patients who developed a nonunion and those who went on to heal was 47 mg and 98 mg, respectively.

Conclusion: Ketorolac administered in the first 24 hours after acute fracture repair for acute pain management does not appear to have a negative impact on time to healing or incidence of nonunion for femoral or tibial shaft fractures.

See pages 47 - 108 for financial disclosure information.

Posttraumatic Tibial Defects Treated by the Ilizarov Method: Comparison of Classic Versus Integrated Technique

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Background/Purpose: Limb salvage in the presence of posttraumatic tibial bone loss can be accomplished using the Ilizarov method. Internal fixation at the beginning of the consolidation phase stabilizes the regenerate and allows for early removal of the external fixator. We compared patients with posttraumatic tibial bone loss treated with either a circular external fixator exclusively, termed the "classic technique" (Fig. 1) or a combination of a circular external fixator and plating or insertion of an intramedullary nail during the consolidation phase, termed "integrated technique" (Fig. 2). We asked: (1) Does integrated fixation decrease the time in the external fixator? (2) Is there a difference in the rate of complications between the two groups? and (3) Are the results obtained at final follow-up comparable?

Methods: 58 consecutive patients (58 tibiae) with posttraumatic tibial bone loss were retrospectively identified. Patients were divided into two groups, "classic technique" (30 patients) and "integrated technique" (28 patients). The mean follow-up was 33 months (range, 6-90). IRB approval was obtained prior to initiation of the study. Baseline demographics, surgical variables, and outcomes were compared. Adverse events were reported as problems, obstacles, or complications as described by Paley. Functional and radiographic outcomes were reported using the Association for the Study and Application of Methods of Ilizarov (ASAMI) scoring system.

Results: Baseline demographics were similar in both groups. Mean tibial bone loss was 5.3 cm (range, 1.6-13) and 50% of patients were actively infected. Patients treated with integrated fixation had significantly less time ($P < 0.001$) in the external fixator, 7 months (range, 1.3-15) compared with 11 months (range, 4.5-15). There were 49 adverse events in 31 patients (17 problems, 31 obstacles, 1 minor complication). There was no difference in the severity ($P = 0.8703$) or number ($P = 0.359$) of complications between both groups. Overall, patients required a mean of 4.05 surgical procedures (range, 2-5) for limb salvage. There was no difference ($P = 0.2194$) in the incidence of unplanned surgical procedures (obstacles) between groups. All patients had no recurrence of infection and all had bony union at final follow-up. Good-to-excellent ASAMI function, and bone scores were obtained in 100%, and 98% of patients, respectively.

Conclusion: Limb salvage with distraction osteogenesis in the presence of posttraumatic tibial bone loss is a challenging surgical entity. The integrated fixation method allows for earlier removal of the external fixator while the frequency of adverse events and ability to restore limb lengths are similar in both groups. A mean of 4.05 surgical procedures were required for tibial reconstruction. Adverse events did occur in 53% of patients; however, good/excellent results can be expected in all patients with proper management.

Figure 1. A, Antero-posterior, and **B**, lateral x-rays of a 34 year-old male with a 6 cm distal tibial metaphyseal defect. The patient was treated with the "classic method" of distraction osteogenesis, **C**,**D**. Final result, **E**, **F**, with restoration of limb-lengths and normal coronal and sagittal alignment. Time in frame: 302 days.

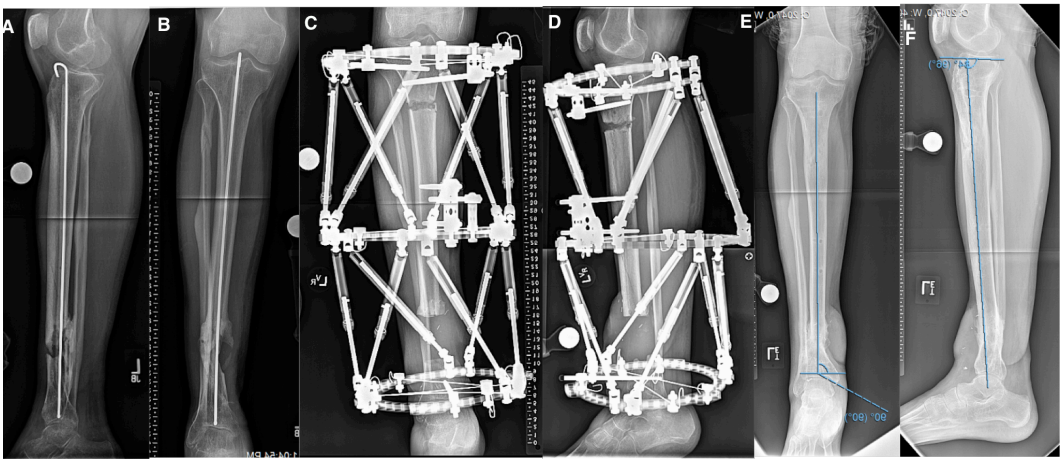
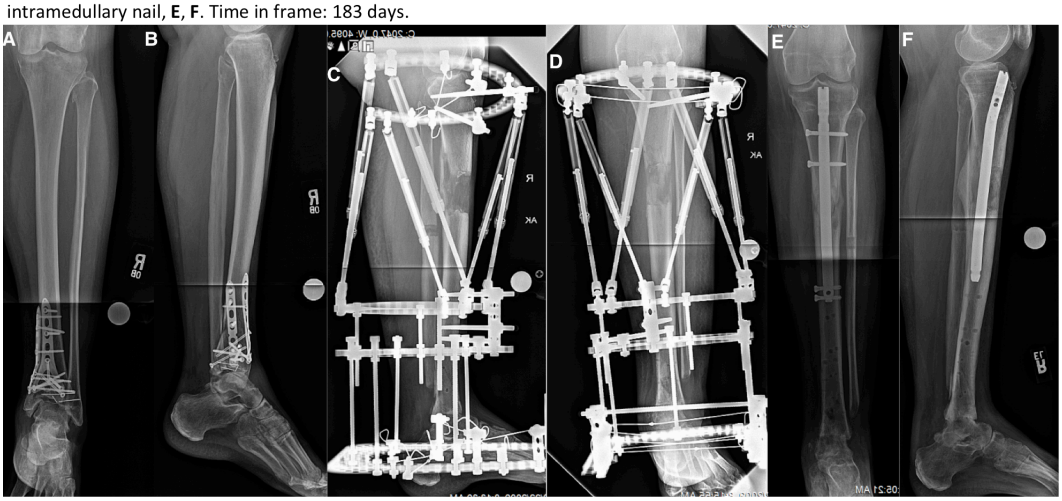


Figure 2. A, Antero-posterior, and **B**, lateral x-rays of a 50 year-old female with an infected Pilon fracture and 4 cm of nonviable bone at the ankle joint. Patient was treated with "integrated fixation", lengthening, **C**, **D**, and then insertion of an intramedullary nail, **E**, **F**. Time in frame: 183 days.



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Is This Autograft Worth It? The Blood Loss and Transfusion Rates Associated with RIA Bone Graft Harvest

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Purpose/Background: The previous decade has witnessed the emergence of the reamer-irrigator-aspirator (RIA) as a widely used method of bone graft harvest. The literature is sparse regarding complications associated with RIA. One small series focused on donor-site morbidity compared to conventional methods such as anterior or posterior iliac crest. To date no papers have examined the rate of blood loss or transfusion in a group larger than eight patients. We hypothesized that the hematocrit drop and transfusion rates after RIA harvest would be much greater than historical controls for iliac crest bone graft harvest since the RIA technique attaches suction directly to the intramedullary canal.

Methods: We conducted a retrospective chart review of all patients who underwent RIA bone graft harvest from January 2008 to December 2014. A search of our electronic record system yielded 65 patients who underwent RIA autograft harvest. Demographic information, date of surgery, indication for surgery, type of surgery, preoperative hematocrit (HCT), postoperative HCT, transfusion rate, reported intraoperative blood loss, reported volume of graft harvested, and other major complications were recorded.

Results: A total of 61 (94%) patients were included in the study as there were insufficient preoperative data to include 4 patients. Mean patient age was 51 years (range, 18-80), with 32 males and 29 females. The most common indications for an RIA was tibial nonunion (51%) followed by femoral nonunion (39%), ankle fusion (8%), and bilateral calcaneal nonunions (2%, one case). The femur was used for graft harvesting in 49 cases with the tibia being used in the remaining 12 cases. The amount of harvested bone graft was reported in 40 cases and averaged 53 mL (rang,e 30-100 mL). The mean HCT drop postoperatively was found to be 13.7 (range, 4.1-27.4) with operative reports documenting a mean estimated blood loss (EBL) of 674 mL (range, 100-2000). EBL was noted to be much higher than historical data that suggest EBL with Iliac crest bone grafting ranges from 336 mL to 371 mL. A total of 27 patients (44%) required a blood transfusion for a mean postoperative HCT of 22.0. The majority of those transfused received two units of packed red blood cells (range 1-4 units). There were no documented cases of iatrogenic fracture or fat emboli syndrome.

Conclusion: This series demonstrated that 44% of patients undergoing RIA bone graft harvest required transfusion, with a mean hematocrit drop of 13.7 across all subjects. This is certainly significantly higher than the risk of transfusion associated with iliac crest harvest. The EBL intraoperatively, which is widely acknowledged as a very unreliable estimate, was also greater than double that of historical controls for iliac crest. Given the likelihood of blood transfusion, risks associated with this must be factored into the decision to utilize RIA for the harvest of autogenous bone graft.

Treatment of Hypovitaminosis D in an Orthopaedic Trauma Population

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Purpose: The purposes of this study were to (1) determine the incidence of hypovitaminosis D in an urban trauma population and (2) evaluate a vitamin D supplementation intervention strategy. We hypothesized that if given a free sample, patients would exhibit high adherence and their vitamin D levels would become sufficient.

Methods: 62 consecutive skeletally mature patients were treated surgically over 4 months for acute fractures of the pelvis or extremities by one traumatologist. Baseline calcium and vitamin D intake was recorded, and vitamin D levels were measured, serving as our initial study group to determine the prevalence of hypovitaminosis D. Subsequently, 144 patients were treated by the same surgeon for acute fractures, serving as the intervention group. All patients were prescribed 600 mg calcium and 800 U vitamin D3 capsules to take twice daily. For those patients discharged to home, they were provided with a free bottle (6-month supply) of calcium/D supplement with instructions. Vitamin D levels were obtained at time of injury and after approximately 6 to 8 weeks of supplementation. Patients were surveyed in the outpatient clinic to determine adherence to the supplement, dietary intake of vitamin D, and exposure to the sun.

Results: 62 consecutive patients, including 34 men and 26 women, with mean age 55 years (range, 19-95) were all deficient for vitamin D, except two (3.2%) who were taking supplements prior to injury. Mean baseline level was 17.4 ng/mL (sufficient is >30ng/mL). The intervention group (n = 144) consisted of 91 men and 53 women, with mean age 45 years (range, 14-98), and mean body mass index 28.1 (range, 16.1-47.4). Ethnicity was 69% Caucasian, 26% African American, and 2.1% Hispanic. Most common mechanisms of injury were motor vehicle collision 47%, low-energy fall 25%, and fall from height 15%. Mean baseline vitamin D level in the intervention group was 19.9 ± 11.4 ng/mL. Ten (6.9%) were taking vitamin D prior to injury, and 80% of them had a sufficient level. All others (mean baseline level 16.9 ± 6.9 ng/mL) were prescribed calcium and vitamin D and were offered free supplements when discharged to home. 77 patients completed surveys, and mean vitamin D level (n = 74) was 36.3 ng/mL after a mean of 10.4 weeks of supplementation ($P < 0.0001$). 79% reported adherence or partial adherence to supplement recommendations. All adherent patients had achieved normal vitamin D levels at follow-up. 16 patients were nonadherent, with 10 who forgot to take the supplement, and 6 choosing not to take the supplement.

Conclusion: Hypovitaminosis D was present in 100% of our orthopaedic trauma patients who were not already taking vitamin D supplements. The intervention was effective in decreasing the prevalence of hypovitaminosis D within several weeks, with all supplemented patients achieving normal levels. 79% of patients adhered to recommendations. Further study to determine the long term cost-effectiveness of this strategy appears warranted.

See pages 47 - 108 for financial disclosure information.

Incidence of Complications After Therapeutic Anticoagulation in the Postoperative Spine Trauma Patient

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Background: There have been numerous studies on prophylactic anticoagulation after spinal surgery but none have investigated the risks of therapeutic doses of anticoagulation indicated for the treatment of a thromboembolic event such as PE (pulmonary embolism), DVT (deep venous thrombosis), or MI (myocardial infarction). The incidence of complications secondary to initiation of therapeutic anticoagulation, including spinal epidural hematoma, has yet to be established.

Methods: A retrospective cohort study was conducted using prospectively collected data at a Level I trauma center. Patient selection criteria included those who: (1) underwent spinal surgery and (2) sustained a symptomatic PE, DVT, or MI thus requiring the initiation of therapeutic anticoagulation. Patients were excluded if: (1) the thromboembolic event was sustained before spinal surgery or (2) anticoagulation was subtherapeutic. Of 1712 patients who underwent spine surgery at our institution from 2001 to 2014, 63 patients met these criteria. A control group of 63 operative spine trauma patients who did not undergo therapeutic anticoagulation were obtained and compared. Logistic regression models were used to evaluate the association between covariates of interest and odds of reoperation.

Results: Initial anticoagulation was obtained by heparin infusion, LMWH (low molecular weight heparin), and warfarin in 32 (50.7%), 29 (46.0%), and 2 (3.2%) patients, respectively. After postoperative initiation of therapeutic anticoagulation, 11 (17.5%) patients sustained complications requiring unplanned reoperation with 10 of 11 patients returning within the first 26 days compared with 4 (6.3%) patients in the control. Two (3%) patients underwent re-exploration due to the development of epidural hematomas after therapeutic anticoagulation compared to 0 patients in the control group. Patients required reoperation for indications including wound infection, hemorrhage, and pseudarthrosis. In addition, the initial use of a heparin infusion compared to LMWH demonstrated a 13.3-times higher odds for reoperation due to a spinal surgery complication and a 17.9-times higher odds for reoperation for any reason in our multivariate model.

Conclusion: This represents the first attempt to quantify complications secondary to therapeutic doses of anticoagulation after spine surgery. We found a nearly three times higher rate of complications requiring reoperation in the therapeutic anticoagulation group compared to the control group (17.5% vs 6.3%). Surgical decompression for epidural hematoma was required in 3% of anticoagulated patients versus 0% in our control group. Furthermore, our data suggest that initial anticoagulation using a heparin infusion compared to LMWH may increase the rate of reoperation.

Can Thrombelastography Predict Venous Thromboembolic Events in Patients with Spine Trauma?

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Purpose: Despite increased bleeding risk during the acute trauma resuscitation, trauma-induced coagulopathy is associated with greater likelihood of hypercoagulability, and eventual venous thromboembolic events (VTEs). Rapid thrombelastography (r-TEG) is a whole blood assay that identifies both hypo- and hypercoagulable states. It has been shown that an elevated maximal amplitude (mA) value on admission can identify general trauma patients with increased risk of VTE. We hypothesized that (1) the risk of VTE is higher in patients with spine trauma than those without and (2) an elevated admission mA value could be used to identify patients with spine fractures at risk for VTE during initial hospital admission.

Methods: This is a retrospective review of a prospectively collected database of 9090 trauma patients admitted to an urban Level I trauma center between September 2009 and February 2011. We then evaluated only those patients who met highest-level trauma activation criteria, were 18 to 85 years of age, and were direct scene transports. Patients with burn wounds greater than 20% total body surface area or who died within 30 minutes of arrival were excluded. Two groups were created, one presented with a spine fracture (SPINE) and those without a spine fracture (non-SPINE). VTEs were defined as those pulmonary emboli (PEs) confirmed by CT angiography and those symptomatic deep vein thromboses (DVTs) confirmed by venous duplex. Univariate analyses were conducted followed by purposeful regression analysis.

Results: 3005 patients met the inclusion criteria (722 SPINE, 2233 non-SPINE). SPINE patients were older (36 vs 33 years), were more likely to be white (61% vs 52%), and blunt trauma (93% vs 74%); all $P < 0.05$. SPINE patients were more badly injured according to individual systems AIS (Abbreviated Injury Scale) scores, all $P < 0.001$. They also had lower systolic blood pressure (117 vs 130), higher pulse (100 vs 95), and lower Glasgow Coma Scale (GCS) (9 vs 13) on arrival; all $P < 0.05$. Despite more hypocoagulable r-TEG values on arrival (alpha angle 72 vs 73 and mA 63 vs 64, both $P < 0.05$), SPINE patients had higher rates of VTE (8.5% vs 3.4%, $P < 0.001$) and PE (5.2% vs 2.4%, $P < 0.001$). Stepwise regression generated three values to predict development of VTE (SPINE, ISS, and mA >65). After controlling for gender effect, admission mA = 72 (odds ratio 4.81) was an independent predictor of VTEs during hospitalization.

Conclusion: Admission r-TEG mA values can identify patients with spinal injuries who present with an increased risk of in-hospital DVT and PE. Patients presenting with admission r-TEG mA value of 72 are at a 4.81-fold increased risk for in-hospital VTE. Admission r-TEG values can help to identify patients at greatest risk for VTE and best target those who might benefit from an early, aggressive prophylaxis strategy.

See pages 47 - 108 for financial disclosure information.

Narcotic Requirement Is Not Predictive of Adult Traumatic Compartment Syndrome

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Background/Purpose: The diagnosis of compartment syndrome is often difficult to make, especially in the nonverbal or obtunded patient. In the pediatric trauma population, increased narcotic requirement has been thought to be a predictor of compartment syndrome. However, the presence of these signs and symptoms may be unreliable. The purpose of this study was to assess the presence of classic physical examination findings, pain medication requirements prior to fasciotomy, and changes in vital signs to identify predictors of compartment syndrome. We sought to asses if narcotic requirement is a predictor of adult compartment syndrome in the trauma patient and hypothesized that it is not.

Methods: A case-control study of patients, admitted to a Level I trauma center between 2007 and 2012, who were diagnosed with compartment syndrome and underwent fasciotomies (n = 47) compared to a randomly selected control group of trauma patients (n = 47) matched for age, extremity, and mechanism of injury, was conducted. Objective data including heart rate, systolic blood pressure (SBP), pain score (based on visual analog scale), narcotic requirement prior to surgery, and time from injury to fasciotomy (cases) or open reduction and internal fixation (controls) were obtained from the medical record. In addition, the of presence of the "6 Ps" (pain, paresthesia, pallor, paralysis, pulselessness, and poikilothermia) was recorded. Differences in these parameters were compared between cases and control patients.

Results: 17.4% of cases had 2 of the "6 Ps" compared with 2.1% of control patients ($P < 0.05$). Patients with compartment syndrome presented with pain on passive stretch in 43% of cases compared to none of the controls ($P < 0.05$) as well as significantly more frequent decrease in sensation and "firm/tight" compartments. There was a significant difference in the mean heart rate in the last 4 hours and mean heart during the interval period between the cases versus controls by approximately 10 beats per minute (99.95 vs 87.9, 98.6 vs 89.4, respectively; $P < 0.05$). The mean SBP in the last 4 hours prior to surgery was also different in cases versus controls by approximately 10 mm Hg (142 vs 130, $P < 0.05$). The mean narcotic requirement in the cases versus controls in the last 4 hours prior to surgery was not significantly different. We also did not find an increased rate of narcotic administration in the cases or controls.

Conclusion: In our patient population, a score of at least 2 out of the "6 Ps" was predictive of compartment syndrome compared to a score of less than 2. Heart rate, SBP in last 4 hours, presence of "tight compartments," and decreased sensation were also significantly associated with fasciotomy. Narcotic requirements and patient reported pain scores were not significant predictors of compartment syndrome. In an adult trauma population the classic "6 Ps" in addition to pulse rate and SBP may be more useful indicators of developing compartment syndrome and should be closely monitored in the at-risk patient.

Microdialysis Detects Ischemic Change Early in the Evolution of Acute Compartment Syndrome

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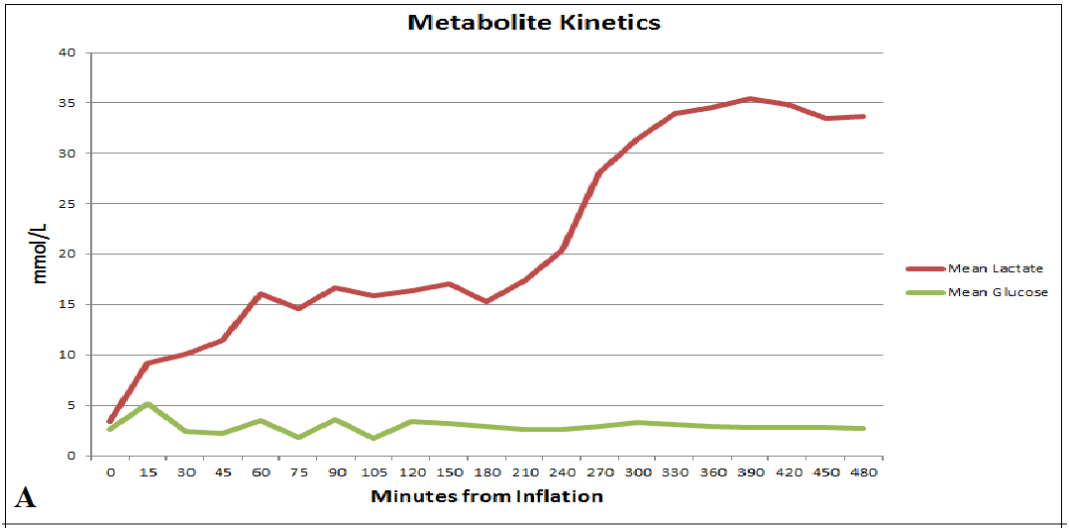
Purpose: Acute compartment syndrome (ACS) develops when intracompartmental pressure (ICP) elevates to a level impairing local muscle perfusion. In the setting of ischemia and hypoxia, myocytes transition from aerobic to anaerobic cellular respiration. Currently, microdialysis technology is used in the neurosurgical setting to detect evidence of brain hypoxia. The purpose of this study is to determine whether microdialysis is capable of detecting local extracellular metabolic changes in skeletal muscle indicative of ischemia secondary to ACS.

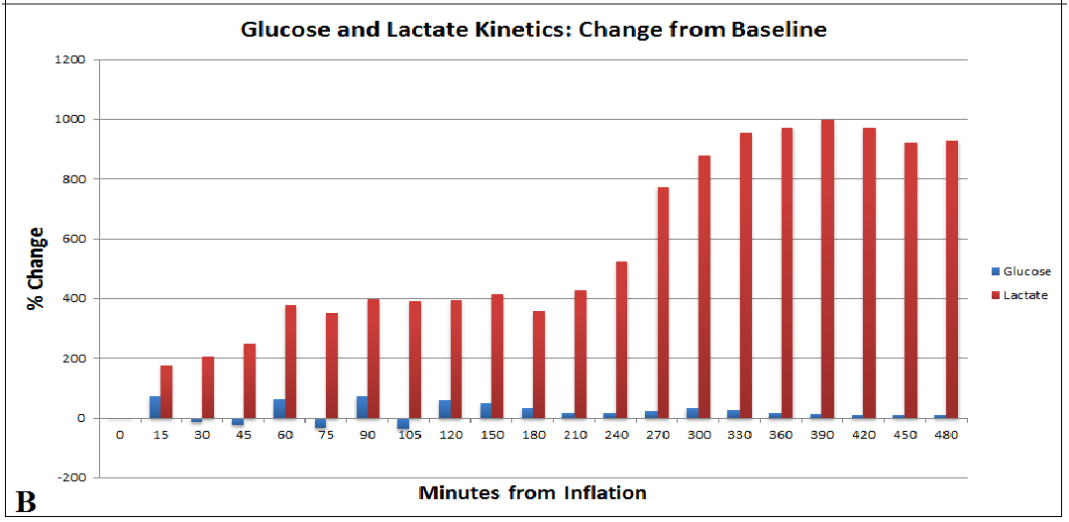
Methods: Following International Animal Care and Use Committee (IACUC) approval, an ACS was created in the anterior compartment of New Zealand White rabbits' legs using a previously validated balloon inflation model. After submuscular placement of the balloon, an intramuscular microdialysis (mDialysis) catheter was placed. The balloon was inflated and compartment pressures were measured using an Intra-Compartmental Pressure Monitor (Stryker). Dialysate was collected at 30-minute intervals over an 8-hour period. Glucose and lactate levels were recorded at each point and a lactate-glucose ratio was determined. Pearson's correlation coefficient (r) was used to determine correlation between glucose and lactate levels.

Results: An average ICP of 52 mm Hg was maintained via balloon inflation (mean delta P = 8 mm Hg). Mean intracompartmental glucose levels increased from 2.6 mmol/L at baseline to 5.2 mmol/L at 15 minutes. After this initial surge, glucose levels remained fairly constant over the remaining time (Figure 1A). Lactate underwent steady increase, indicating progressive ischemia. At 60 minutes, lactate levels had increased 377% from baseline and this was maintained through 180 minutes. Between 210 and 330 minutes, there was another marked increase in lactate (427% to 955%). Lactate remained markedly elevated (>900% from baseline) through the remainder of the trial (Figure 1B). The lactate-glucose ratio steadily increased from 1.4 at baseline to 10.1 at 75 minutes. This ratio peaked and remained elevated over the subsequent 7 hours and 15 minutes. There was a high correlation (r = 0.91) between percent change in glucose and lactate levels (from immediately previous values) in the first 60 minutes and this correlation gradually diminished by 2 hours (r = 0.65) and remained steady over the remainder of the trial (r = 0.65 at 8 hours).

Conclusion: Myocytes undergo predictable transition to anaerobic metabolism in the setting of ACS-induced ischemia, resulting in the steady production of lactic acid. This study is the first to demonstrate that microdialysis is capable of detecting local ischemia in acute compartment syndrome. In addition, microdialysis was able to elucidate local extracellular glucose and lactate kinetics that have been previously unreported in the setting of ACS. We believe this technology may provide a more sensitive and specific method of diagnosing ACS, can be used easily in the clinical setting, and may yield information leading to novel therapeutic strategies for prolonging muscle viability in the setting of ACS.

See pages 47 - 108 for financial disclosure information.





The FDA has stated that it is the responsibility of the physician to determine the FDA clearance status of each drug or medical device he or she wishes to use in clinical practice.