Is There a Higher Risk of Infection with Delayed Treatment of Pediatric Seymour Fractures?

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Purpose: The purpose of this study is to describe treatment methods and complication rates of all Seymour fractures (open Salter-Harris I/II fractures of the distal phalanx of the hand with associated nailbed laceration; OTA 78) treated at or referred to a pediatric Level I trauma center over a 10-year time period. We hypothesized that delayed or inappropriately treated Seymour fractures would be associated with higher infectious complication rates.

Methods: All patients treated in the orthopaedic pediatric hand clinic at our institution with an ICD-9 diagnosis of 816.02 or 816.12 (closed or open fracture of distal phalanx or phalanges of hand, respectively) between August 2002 and December 2012 were identified. All charts and radiographs were retrospectively reviewed. 47 patients treated for 48 Seymour fractures were identified. Patients were divided into groups based on timing and quality of treatment. "Appropriate" treatment was defined as irrigation and debridement, fracture reduction, nailbed repair, and antibiotics. "Partial" treatment was defined as any type of incomplete treatment. "Acute" treatment was defined as management within 48 hours of the injury, and "delayed" as presenting for treatment past 48 hours from time of injury. Statistical comparisons were performed using Fisher's exact test.

Results: Average patient age was 8.7 years (range, 1-15 years), with 35 males and 12 females. Most common mechanism of injury was sports (32%, 15/47), followed by closed in door/window (30%, 14/47). 57% (27/47) were treated in an acute, appropriate manner; 15% (7/47) received acute, partial treatment; and 28% (13/47) received delayed treatment. One patient initially treated at an outside hospital had inadequate documentation to determine appropriateness of treatment but had no complications. There were 9 complications: 3 superficial infections, 5 osteomyelitis, and 1 malunion. With respect to infectious complications, only 1 (superficial infection) occurred in the acutely, appropriately treated group (infection rate 3.7%, 1/27); 1 (osteomyelitis) occurred in the acutely, partially treated group (14%, 1/7); and 6 (2 superficial, 4 osteomyelitis) occurred in the delayed treatment group (46%, 6/13). Differences in infection rates among the treatment groups were statistically significant ($P < 0.003$ including all infections; $P < 0.007$ including osteomyelitis only).

Conclusion: Timing and quality of treatment of Seymour fractures significantly influences infectious complication rates, as patients with delayed treatment had a 12-fold risk of infection compared to those treated early and appropriately. This study, the largest reported cohort of Seymour fractures, highlights the importance of timely, appropriate treatment of this outwardly benign fracture to reduce the risk of infection.

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All Lateral Versus Medial and Lateral Flexible Intramedullary Nails for the Treatment of Pediatric Femoral Shaft Fractures

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Purpose: Multiple techniques for flexible intramedullary fixation of pediatric femur fractures have been described. To our knowledge, no study comparing medial and lateral entry versus all lateral entry retrograde nailing has been reported. The purpose of this study is to compare surgical outcomes, radiographic outcomes, and rates of complications between these techniques.

Methods: An IRB-approved, retrospective review of patients treated by retrograde, dual flexible intramedullary fixation of femur fractures was performed at a Level I pediatric trauma center from 2005-2012. Demographics, blood loss, and operative time were collected from the medical and surgical record. We assessed radiographs for fracture pattern and canal fill as well as shortening, and angulation at the time of osseous union. Rates of symptomatic hardware and hardware removal were noted. Data was compared between patients treated with all lateral entry nailing and those treated with medial and lateral entry nailing using the Student *t*-test and correlation statistics.

Results: 282 children with femoral shaft fractures were treated with retrograde flexible intramedullary fixation using Ender's stainless steel nails (Richards). 109 were treated with two lateral entry nails and 173 were treated with one medial and one lateral entry nail according to surgeon preference. There were no statistical differences in gender, weight, body mass index, blood loss, or fracture pattern between the two groups. The average total anesthesia time was 31 minutes shorter in the all lateral group (P <0.0001). There was no difference between the techniques in shortening or coronal angulation at union, regardless of fracture pattern. In comminuted fractures, the all lateral group demonstrated less sagittal angulation (0.6° vs 3.3°, P = 0.0162). In the all lateral group, there was a strong correlation between fill of the canal and reduced shortening at union. No statistical differences were found in the presence or degree of varus alignment, procurvatum, or recurvatum between the two constructs. However, all femurs that healed with greater than 10° of valgus were instrumented with the all lateral technique (P = 0.015). There were no differences between the groups in the rate of symptomatic hardware removal or surgical complications.

Conclusion: Final fracture alignment, surgical complications, and rates of symptomatic hardware are clinically comparable between pediatric femur fractures treated with all lateral entry flexible nailing and those treated with medial and lateral flexible nailing. The all lateral technique is potentially a faster procedure, although when using this construct, specific attention should be paid to percentage of canal fill of the nail and ensuring that the fracture is not reduced in a valgus position.

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Pediatric Pelvic Ring Injuries: How Benign Are They?

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Purpose: Pediatric pelvic ring fractures are rare, with scant outcomes in the literature. The etiology is usually high-energy trauma with associated major injuries that require multidisciplinary trauma team intervention. Historically, conservative treatment was mainly performed, but has changed to more operative treatment of unstable fractures. Leg-length discrepancy (LLD) and pain are reported. The purpose of this study was to determine clinical and radiographic outcome following pediatric pelvic ring injuries.

Methods: Between 2002 and 2011, 33 pediatric pelvic ring fractures were retrospectively analyzed. Fractures were classified according to AO/OTA classification as 2 A2, 3 B1, 16 B2, 10 B3, and 2 C2 fractures. Mechanism of injury, associated injuries, transfusion requirement, Glasgow Coma Scale (GCS), Injury Severity Score (ISS), and length of hospital stay were recorded. Treatment of the pelvis injury, infection, and nonunion rates were determined. Deformity, low back/sacroiliac (SI) joint pain, LLD, and hip range of motion were evaluated on final follow-up.

Results: Age averaged 12.6 years (range, 4-16). 91% (30) injuries were caused by traffic accidents. GCS averaged 13.6 (range, 3-15) and ISS averaged 26 (range, 4-66). Length of hospital stay averaged 6 days (range, 1-39). 10 (30%) children required blood transfusion. 30 (91%) children had associated injuries, of whom 11 (33%) required surgery. Two (6%) required interventional embolization for intrapelvic bleeding. Clinically unstable fractures were treated operatively in 16 children and conservatively in clinically stable fractures in 17 children. Follow-up averaged 25.6 months (range, 6-84). One superficial wound infection and in one case repeat debridement for Morel Lavallée lesion was documented. No nonunion was recorded. 20 (74%) children had a sacral or ischial height difference of 5-10 mm on follow-up (outlet). 18 (67%) children had a sacral or iliac height difference of 5-10 mm (inlet). 67% complex, unstable fractures had a permanent ischial height difference >5 mm versus 42% less complex, stable fractures. Unstable, operatively treated fractures had a higher permanent pelvic asymmetry (12.3 mm vs. 6.6 mm) ($P = 0.15$) and ring width difference (6.9 mm vs. 3.9 mm) as compared to stable, nonoperatively treated fractures. All children returned to full, unrestricted activity. 13 children (39%) had low back or SI joint pain on their final follow up, which was significantly higher in the operatively treated group ($P = 0.008$), and in children with 5-10 mm sacral height difference (inlet) compared to children with 0-4 mm ($P = 0.034$). 3 (9%) children had an LLD of 5-15 mm. One child had persistent neurological symptoms. One (3%) demonstrated rotational limitation on final follow-up.

Conclusion: The majority of pediatric pelvic ring fractures are caused by traffic accidents, with associated major injuries. Radiographic deformity persisted without remodeling. De-

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formity occurs more commonly with complex unstable ring injuries, which may plastically deform the ring, are mostly operatively treated, and have continued associated low back or SI joint pain, but no limitations.

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Iliosacral Screw Pathways in the Pediatric Population: Are There Safe Bony Corridors?

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Purpose: Bony corridors for safe iliosacral screw placement in the first (S1) and second (S2) sacral segments are commonly used to place screws with diameters of 6.5 mm and greater in the adult pelvic ring. Data regarding the size of these corridors in pediatric patients are limited to case reports. We hypothesize that bony corridors for 6.5 mm diameter screws in the S1 and S2 segments will be less common in patients aged 2 to 10 years when compared to patients aged 10 to 16.

Methods: After obtaining IRB approval, our digital imaging archive was retrospectively searched for all patients between ages 2 and 16 years who underwent a CT scan including the pelvis from January 1, 2013 to February 12, 2013. The only exclusion criterion was incomplete imaging of the pelvic ring. A total of 175 patients were identified, with 91 males and 84 females. Average age was 10.7 years (SD = 3.9). CT images were transferred to TeraRecon (Foster City, CA) thin client 3D platform. Corrected axial images were created that were perpendicular to the plane of the sacrum centered at S1 and S2 corridors. Two representative images were transferred back to Centricity picture archiving and communication system (PACS) (GE Healthcare, Waukesha, WI): one of the S1 corridor and one of the S2 corridor. Three distances were defined in each hemipelvis. S1 reduction was defined as the shortest distance from anterior sacral cortex to the anterior border of the S1 nerve root tunnel that was perpendicular to the pathway of a sacroiliac or "reduction-type" screw. The S1 sacral corridor was defined as the shortest distance from the anterior border of the S1 foramen between a line connecting the anterior borders of the left and right S1 foramina and a line connecting the most posterior limits of the left and right anterior ilium or sacrum. The S2 corridor was defined as the shortest distance from the anterior border of the S2 foramen between a line connecting the anterior borders of the left and right S2 foramina and a line connecting the posterior borders of the S1 foramina. All measurements were independently made using PACS on a diagnostic quality monitor by three orthopaedic surgeons: a resident, a trauma fellow, and a trauma attending. Two means were compared using a paired Student *t*-test and proportions were compared using Fisher's exact test. Interobserver reliability was measured using the inter-rater reliability coefficient.

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Results:

Average Bony Corridor (in mm)				
	Ages 2-10 (n = 70)		Ages 10-16 (n = 105)	
Measurement	R	L	R	L
S1 Reduction	14.2	14.1	17.9	17.7
S1 Sacral	5.8	5.8	8.1	8.0
S2	8.6	8.6	9.8	9.7

The interrater reliability coefficient between the three surgeons was greater than 0.93 for all six measurements. Measurements for bilateral S1 reduction, bilateral S1 sacral, and bilateral S2 were significantly less for ages 2-10 than ages 10-16 (all $P < 0.003$). All 175 patients had bilateral S1 reduction measurements >6.5 mm. S1 sacral measurements >6.5 mm were significantly higher in the older group and present in 48% of patients ages 2-10 and 68% of patients ages 10-16 ($P = 0.04$). S2 measurements >6.5 mm were present in 92% of patients ages 2-10 and 94% of patients ages 10-16 with no significant difference ($P = 0.77$).

Conclusion: Contrary to our hypothesis, 100% of pediatric patients aged 2-16 had a screw pathway to accommodate a 6.5 mm diameter screw in the S1 corridor in a "reduction-type" vector, and more than 93% of all patients had pathways for a 6.5 mm diameter screw in the S2 corridor. S1 corridors in a "sacral" vector are much less predictable and are more likely to accommodate a 6.5-mm screw with older age.

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Risk of Hip Arthroplasty After Open Reduction Internal Fixation of a Fracture of the Acetabulum: A Matched Cohort Study

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Purpose: Displaced or unstable fractures of the acetabulum are commonly treated with open reduction and internal fixation (ORIF) to restore hip joint congruity and minimize arthritic progression. The reported risk of subsequent hip replacement is between 8.5% and 14% in small case series. Using a longitudinal population-based cohort, our study aimed to: (1) define the rate and temporal relationship between acetabulum ORIF and eventual hip arthroplasty in a large population, and (2) identify risk-modifying patient, provider, and injury/surgical factors.

Methods: Administrative data sets (including the Ontario Health Insurance Plan physician billing database and the Canadian Institute of Health Information hospital admission database) were utilized to identify all patients over age 16 (for presumed skeletal maturity) in Ontario, Canada, who underwent acetabulum ORIF between July 1996 and March 2010. Excluded were non-Ontario residents, bilateral injuries, and prior hip surgery. The primary outcome was hip arthroplasty, defined by physician and procedural coding from cohort entry until March 2012. The Kaplan-Meier (K-M) time-to-event approach was utilized, censoring patients who died, emigrated from Ontario, or had hip fusion. Four patients from the general population were matched to each surgical patient for age, sex, income quintile, urban/rural address, and year of injury. Matched patients were excluded for prior hip surgery only. Rates of hip arthroplasty at 2, 5, and 10 years after the index date were compared. Among surgical cases, a Cox proportional hazards multivariate model was fit and included potentially predictive patient (demographic), surgical/injury (one- versus two-column fixation), and provider (surgeon volume, time from admission to surgery) factors for the risk of arthroplasty. Hazards ratios (HRs) with 95% confidence intervals were calculated.

Results: We identified 1725 patients (median age, 43 years [interquartile range (IQR) 30-54]; 72.5% male) who met criteria and were matched to 6900 controls. Among cases there was a 13.9% (N = 240) rate of hip arthroplasty after a median of 6.25 (IQR 3.5-10.1) years, compared to 0.6% (N = 38) among matched controls (relative risk = 23). The K-M survivorship was 99.9% (controls) and 91.4% (cases) at 2 years, 99.6% (controls) and 87.6% (cases) at 5 years, and 99.2% (controls) and 83.3% (cases) at 10 years. Only baseline comorbidity scores differed between cases and controls, which was adjusted in the final Cox model. Risk factors for hip arthroplasty among case patients included older age (HR 1.035 [1.027, 1.044]; $P < 0.0001$) and female sex (HR 1.65 [1.257, 2.165]; $P = 0.0003$). The median surgeon volume of acetabulum ORIF was 10 per year (IQR 4-19) overall, but was 7 per year (IQR 4-16) in patients who had an eventual arthroplasty, and 11 per year (IQR 4-19) in those who did not; a finding that was significant in multivariate Cox modeling, which revealed a 2.6% decreased risk of arthroplasty for each acetabulum ORIF above 10 per year (HR 0.974 [0.960, 0.989]; $P = 0.0007$) performed by the index surgeon.

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Conclusion: Patients who underwent acetabulum fracture ORIF had a 23-times higher prevalence of hip arthroplasty after 6.25 years compared to age- and sex-matched controls. The risk of eventual arthroplasty was greater in females and older patients. Hip arthroplasty was less likely after acetabulum ORIF performed by higher volume surgeons.

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Clinical Outcome and Survival of Total Hip Arthroplasty After Acetabular Fracture: A Case-Control Study

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Background/Purpose: Acetabular fractures are complex intra-articular injuries that occur in a bimodal distribution, typically in younger patients involved in high-energy blunt trauma and in older patients with low-energy falls in the setting of osteoporosis. Although modern fracture management techniques allow for near-anatomic reduction of these fractures, the incidence of posttraumatic arthritis is 20%-30% and total hip arthroplasty (THA) may be required. Many factors play a role in the outcomes of THA after acetabular fracture including age, management of the initial fracture, fracture pattern, and the amount of displacement. The aim of this study was to investigate the long-term clinical and radiographic results in patients who have undergone THA after an acetabular fracture as compared to patients who underwent THA for primary hip osteoarthritis.

Methods: This retrospective case-control study compared findings of patients who underwent THA after acetabular fracture versus a matched cohort of patients who had received a primary THA for nontraumatic osteoarthritis. 80 patients were identified from those who presented with an acetabular fracture between January 1, 1987 and March 31, 2011 at a Level I trauma center and who subsequently underwent THA. The second cohort of patients was matched for date of operation, age, gender, and type of implant to control for their confounding effects on outcomes. The primary outcome measurements were revision and complication rates. All patients who were treated for acetabular fracture (both operatively and nonoperatively) and subsequently underwent THA for posttraumatic arthritis were screened for inclusion in the study.

Results: The cohort of acetabular fracture patients included 55 male and 25 female patients with a mean age of 52 years (range, 25-85)and mean follow-up of 8.1 years (range, 2-23 years). The majority of acetabular fractures were treated by open reduction and internal fixation (ORIF) (74%), while 23% were treated nonoperatively and 3% had an acute THA. The mean time between the initial treatment of the acetabular fracture and the THA was 6.2 years (SD, 5.5 years) for patients after ORIF and 5.8 years (SD, 12.9 years) for patients after nonoperative treatment ($P = 0.941$). The number of revisions for patients with THA after acetabular fracture was 24/80 (30%) as compared to the matched cohort with 12/80 (15%) ($P = 0.038$). There was a significant difference in the time from the initial THA to the revision between patients with previous acetabular fracture (7.7 years; SD, 5.1 years) and the matched cohort (12.8 years; SD, 5.9 years; $P = 0.015$). Patients with previous acetabular fracture had a 6.25% rate of infection and a 10% dislocation rate compared to no infections and a 2.5% dislocation rate in the matched group. The functional outcome was assessed using a standardized hip score and was found to be significantly higher in the matched cohort than the acetabular fracture group at 1 year postoperative and at the most recent follow-up ($P < 0.01$).

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Conclusion: Patients with a prior acetabular fracture had a THA revision rate that was significantly higher than the matched cohort and also required a revision THA 5 years earlier than those without a prior acetabular fracture. This case-control study substantiates a higher complication rate and impaired function in patients who have undergone THA after an acetabular fracture.

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A Predictive Model for Complications After Flap Coverage of Open Tibia Fractures

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Purpose: Previous studies have reported high complication rates for treatment of open tibia fractures that require acute flap coverage for limb salvage; however, little data exist to predict the likelihood of complications for these mangled limbs. Our hypothesis is that risk factors can be identified that increase the likelihood of complication after flap coverage of type IIIB open tibia fractures.

Methods: A retrospective review of all acute fractures of the tibia requiring flap coverage at a single Level I trauma center yielded 134 patients (139 flaps) from 2005 to 2013. Patients were excluded if they required a delayed flap for failed primary closure of a traumatic wound, had a limb-threatening vascular injury, or inadequate follow-up. The primary outcome measure was any complication requiring unplanned surgical treatment of the study injury, including infection and flap complication such as thrombosis or necrosis. Patient, injury, and treatment characteristics were abstracted from the medical record. Bivariate and multiple variable regression techniques were used to identify independent predictors of flap complications while adjusting multiple confounders.

Results: Overall 55 patients (41%) experienced complications after flap coverage. Of these complications, 34% were flap-related (thrombosis, necrosis, hematoma, or dehiscence) and 66% were infectious. The limb salvage rate for the study population was 87%. A number of variables were tested and found not to be risk factors for flap complications including age, sex, body mass index, American Society of Anesthesiologists score, Injury Severity Score, use of negative-pressure wound therapy or an antibiotic bead pouch, external fixation, and type of definitive fracture fixation. Only three statistically significant predictors of flap complications were identified: patients with fractures classified as AO/OTA type B or C (odds ratio [OR]: 4.2, 95% confidence interval [CI]: 1.1, 16.3), delay of flap coverage >7 days (OR: 1.5, 95% CI: 0.6, 2.8), and patients treated with anterolateral thigh (ALT) free flaps (OR: 4.6, 95% CI: 1.7, 12.3). In this sample, patients with none of these risk factors had an 18% chance of complication after flap coverage (2/11). Those with one risk factor had a 32% chance of complication (24/74). Patients with two risk factors had a 44% chance of complication (21/48), and those with all three risk factors had a 90% chance of complication (9/10).

Conclusion: Analysis of this large cohort of type IIIB open tibia fractures identified strong predictors of complication including fracture severity, timing of surgery, and the type of tissue used for flap coverage. To our knowledge, we are the first to report an increased risk of complication with use of the ALT flap. The etiology of complications associated with the

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ALT flap is unclear at this time and may be related to surgeon selection, limited ability of this flap to contour to large defects, the tenuous vascular pedicle, or an undetected variable in patients receiving coverage with this type of tissue.

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