COA Paper Session 11: Trauma Lower Extremity 2
Moderators Stéphane Leduc, AB, and Richard E. Buckley, AB

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Minimally Invasive Treatment of Unstable Pelvic Ring Injuries with an Internal Anterior Fixator (INFIX) and Posterior Iliosacral Screws

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Purpose: The purpose of this paper is to present a novel technique of anterior fixation of unstable pelvic fractures which is minimally invasive, biomechanically suitable, easy to apply, and uses readily available spinal implants. **Method:** Eighteen consecutive patients with unstable pelvic fractures (AO type A-12 patients and type B-6 patients) underwent stabilization using the novel technique of fixation and were included in the study. Two trauma trained orthopedic surgeons performed all the procedures. All patients were evaluated clinically and with imaging studies that included antero-posterior, inlet and outlet radiographs and a CT scan. At surgery the posterior instability was addressed first with ilio-sacral screw fixation following reduction of the fracture in a standard fashion. A 2-3cm longitudinal incision was then made over the anterior inferior iliac spine bilaterally to obtain a starting point in the supra acetabular region. Pedicle screws of size 7mm or 8mm x 80mm (Synthes Spine Paoli, USA) were then placed in the supra-acetabular position under fluoroscopic guidance. A pre-contoured 6mm titanium rod with a bow was then tunneled subcutaneously to connect the screws. Care was taken to place the rod just below the lower abdominal crease to prevent pressure on the bowel or vascular structures. The implants were compressed using standard compressors and C-rings. Patients were followed until the pelvis fracture healed as documented on X-rays and clinical exam. **Results:** Patients were followed for a minimum 6 months (range 6-12 mo). All patients healed by 3 months (similar to our prior experience using other methods). Complications included: 2 deaths in poly trauma patients unrelated to the pelvic procedure; 2 patients with transient lateral femoral cutaneous nerve palsy (one on each side), and one early implant failure due to a surgical technical error that was re-operated the next day. **Conclusion:** Disruptions of the pelvic ring are complex injuries and should be managed on a case specific basis. By employing the established principles of supra-acetabular fixation, this technique allows for minimally invasive, definitive internal anterior fixation. The potential complications of pin tract infection and a cumbersome external appliance associated with external fixation are avoided with this technique and better patient acceptance is achieved.

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Early Experience with Reduction of Displaced Pelvic Ring Disruptions Using a Pelvic Reduction Frame

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Purpose: To describe operative experience and reductions of pelvic ring fractures treated with a novel pelvic reduction frame. **Method:** All patients with displaced pelvic ring disruptions treated with the pelvic reduction frame were included. The series includes 35 patients, with 34 acute fractures and one malunion. Pre-operative and immediate post-operative radiographs were reviewed, and maximal displacement measured using two reproducible methods. Procedure and injury data were also recorded. **Results:** In our series of 35 patients, we had 19 vertical shear fractures and 16 compression injuries. Mean age was 33.5 + 2.4, and mean delay to surgery was 4.7 + 0.6 days. Mean operative time in isolated procedures was 103.4 + 6.5 minutes. All but one patient had iliosacral screws placed, 18 had anterior column screws, six had symphysis plates and 12 had anterior external fixators. Maximum horizontal or vertical displacement was improved from 30.8 + 2.7 mm to 7.1 + 0.7 mm. Diameter asymmetry as measured on the AP view was improved form 26.4 + 2.7 mm to 5.2 + 0.7 mm. Very good, good or fair reduction was obtained in all acute cases. There was no statistically significant impact of obesity, fracture type or delay to surgery on quality of reduction ($p>0.05$). **Conclusion:** This novel pelvic reduction frame is a powerful tool in the effective reduction and fixation of displaced acute pelvic ring disruptions.

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What Constitutes a Young and Burgess Lateral Compression-I (OTA 61-B2) Pelvic Ring Disruption? A Description of CT Based Fracture Anatomy and Associated Injuries

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Purpose: To provide a CT-based description of the anatomic specifics of LC-1 pelvic ring disruptionsand to describe injury severity to other body systems, and their correlation with fracture anatomy. **Method:** We identified a consecutive series of 100 patients with Young and Burgess LC-1 pelvic ring disruptions. The CT scan was reviewed for each patient. Sixteen categories were reviewed for each patient. Sacral fractures were graded based on severity. The age, ISS, and six categories of AIS were recorded for each patient. A statistical analysis was performed to test the associations between fracture characteristics and injury severity. **Results:** All patients but three had one or more rami fractures, and all but two had a sacral fracture. Of the 98 anterior sacral injuries, there were nine (9.2%) buckles, 39 (39.8%) simple fractures, and 50 (51.0%) comminuted fractures. Of these 98 anterior sacral injuries, 47 (48.0%) were complete, passing through the sacrum and exiting the posterior cortex. Increasing severity of anterior sacrum fracture was associated with the presence of a complete sacral fracture (p value <0.0001). Of the 98 sacral fractures, 50 (50.0%) were Denis type I, 41 (41.8%) Denis type II, and 7 (7.1%) Denis type III. Higher Denis types had higher likelihood of complete fractures of the sacrum (p value <0.0001). There was a significant association between the presence of a comminuted rami fracture and a complete sacrum injury ($p = 0.003$), and a trend to higher rates in Nakatani two superior rami fractures ($p = 0.169$). There was a trend

to higher mean ISS scores (p = 0.2287), and significantly higher abdominal AIS scores (p = 0.0014), in those with a complete sacral fracture. Those with comminuted and complete sacral fractures were more likely to be symptomatic and require posterior ring stabilization (p-value 0.003 and 0.043 respectively). **Conclusion:** LC-1 fractures of the pelvic ring represent a spectrum of injuries, with a large proportion having complete disruption of the sacrum. This complete injury of the sacrum is predicted by Denis type, severity of anterior ring disruption, Abdominal AIS, and potentially location of rami fracture and ISS. CT scanning best defines these injuries.

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Effect of Delay to Surgery on Functional Outcomes for Displaced Acetabular Fractures

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Purpose: To determine the effect of delay to surgery on functional outcome in patients with operatively-treated acetabular fractures. **Method:** Two hundred and thirty-two patients with acetabular fractures were identified from a pelvic trauma database. Functional outcome data was assessed using the validated Musculoskeletal Functional Assessment (MFA) and the Short Form 36 (SF-36) surveys in 162 patients. After 1997, functional outcome scores were collected prospectively at 6 months, 1 year and 2 years (or greater) post-operatively. Functional outcome scores, quality of reduction, and risk of complications were modeled as a function of days of delay to surgery via multivariate regression analysis adjusting for age, gender, fracture type, and associated injuries. **Results:** At 6 months post-operatively, functional outcome scores were significantly worse with increasing delay to surgery. A delay of between 7 and 13 days or 14 or more days decreased the SF-36 physical component (PCS) z-scores by 0.75 (95% CI: -1.41 to -0.09) and 1.5 standard deviations (95% CI: -2.43 to -0.56) respectively. Delay of 14 or more days was associated with a worsening of the lower extremity (Move) subsection of the MFA by 18.6 points (95% CI: 3.3 to 33.8). Delay to surgery was associated with a significantly higher risk of poor reduction among those with available radiographic follow-up (n=67). Delay 14 days or more was associated with a 5 times (95% CI?.04 to 23.99) greater risk of a post operative step or gap over 2 mm. Delay to surgery was associated with an increase in thrombotic complications. In those patients who were diagnosed with a pulmonary embolism(PE) the mean delay was 11.3 days versus 7.3 days for the rest of the cohort (p=0.01). For patients with a deep vein thrombosis (DVT) average delay was 14.1 days versus 7.1 days (p=0.01). **Conclusion:** Delay to surgery is associated with worsening functional outcome scores after as little as 7 days of delay. After 14 days, functional outcomes deteriorate further and radiographic outcomes are negatively influenced. Increased delay also increases risk of thrombotic events. These conclusions underscore the importance of timely treatment for displaced acetabular fractures.

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The Value of Postoperative Computer Tomographic Imaging in Acetabular Fractures

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Purpose: To compare the accuracy of post-operative plain radiographs versus computed tomography (CT) scans for the assessment of acetabular fracture reduction. **Method:** A retrospective assessment of sixty-four fractures in sixty-two patients was performed independently by three orthopedic trauma surgeons. Pre-operative CT scans and three plain radiographs (one anteroposterior pelvis and two Judet views) were used to classify the fracture pattern and measure pre-operative articular step and gap. Post-operative reduction quality was assessed using three plain radiographs and an axial CT assessing for step, gap, intra-articular hardware or fragments and necessity to re-operate. **Results:** Fracture patterns were as follows; posterior wall (n=10), posterior column (n=1), anterior wall (n=4), anterior column (n=1), transverse (n=12), posterior column posterior wall (n=4), transverse posterior wall (n=8), T-type (n=6), anterior column posterior hemi-transverse (n=5) and associated both column (n=11). Pre-operatively, the average step and gap on plain radiographs was 8.7 mm (±SD) and 15.3 mm (±SD). Post-operatively, the average step and gap was 0.6 mm (SD) and 0.9 mm (SD) based on 46 patients. The assessment was not possible in 18 patients due to overlying hardware. Using plain radiographs, one patient was found to have an inadequate reduction (>2mm step and/or >3mm gap). Post-operative measurement of step and gap by CT scan were 1.2 mm (SD) and 2.3 mm (SD) respectively. Using CT scans, eight patients were found to have either an inadequate reduction, intra-articular hardware or retained fragments. Computed tomography demonstrated 2 times more step and gap compared to plain radiographs. **Conclusion:** Post-operative CT was found to be more sensitive than plain radiographs to assess the quality of acetabular fracture reduction. Plain radiographs detected only 1 out of 8 cases where further operative intervention may have been beneficial. Given the consequences of missing an unacceptable reduction, intra-articular hardware, or retained intra-articular fragments, it is recommended that all fractures should be assessed post-operatively with CT unless the patient is not a candidate for further surgery for reasons independent of reduction quality. The benefits of post-operative CT imaging in acetabular fractures likely outweigh the cost and radiation exposure associated with its use.

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The Effect of Femoral Neck Cut, Cable Tension and Muscle Forces on the Stability of Greater Trochanter Reattachment

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Purpose: Greater trochanter reattachment is frequently accomplished using cable grip type systems. There is a relatively high failure rate for these

systems, the mechanisms of which are unclear. One possible source of instability could be femoral neck cut location. Another concern is the effect of variability in cable tension. The objective is to create a femur implant model which allows for variation in cable tension, common muscle forces and the placement of the femoral neck cut in order to analyse trochanter fragment fixation. **Method:** A finite element model (FEM) of a femur with simulated greater trochanter osteotomy (30º) was combined with the femoral component of a hip prosthesis and a greater trochanter reattachment system with 4 cables (Cable-Ready®, Zimmer). A total of 18 simulations were modeled in a full factorial design using three independent variables; cable tightening (178N, 356 N and 534 N), muscle forces (rest, walking and stair climbing) and femoral neck cut (10 mm and 15 mm above the lesser trochanter). Displacement of the fragment, in terms of both gap and shear components, as well, stress in the bone were investigated. **Results:** The location of the femoral neck cut reduced contact surface area by 20% and had the largest influence on displacement (0.24 mm). Pivoting of the fragment was observed with a maximum gap (0.38 mm) and maximum total displacement (0.41 mm) at the bottom of the fragment. This was observed during stair climbing, while the cables were tightened to 177.9 N and with the femoral neck cut at 10 mm. Increased tightening of the cables provided no significant reduction in fragment displacement. However, higher cable tension significantly increased the stress in the bone (8 MPa and 26 MPa for cable tension of 178 N and 534 N respectively). **Conclusion:** Placement of the femoral neck cut closer to the lesser trochanter significantly increased fragment displacement. Preservation of the contact surface area is recommended. Excessive cable tightening did not reduce fragment movement and only exacerbated bone stress. Caution must be used to not over tighten the cables. This model can be used to test and compare the performance of new implant designs.

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Prognostic Baseline Factors for Predicting Re-operations in Patients with Tibial Shaft Fractures

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Purpose: Accurate prediction of re-operation following tibial nailing may facilitate optimal patient care. We recently completed the SPRINT trial, a large, multi-centre trial of reamed versus non-reamed intramedullary nails in 1226 patients with tibial shaft fractures. Using the SPRINT data, we conducted an investigation of baseline and surgical patient characteristics to determine if they are associated with increased risk of re-operation within one year. **Method:** Using multivariable logistic regression analysis, we investigated 15 characteristics for association with increased risk of re-operations. Because the primary SPRINT analysis found that reamed nailing reduced events in patients with closed but not open fractures, we considered both open and closed as well as treatment status in our model. **Results:** We found an increased risk of re-operation in patients with a high energy mechanism of injury (odds ratio, OR=1.57, 95% CI 1.05 to 2.35), stainless

steel versus titanium nail (OR=1.52, 95% CI 1.10 to 2.13), fracture gap (OR=2.40, 95% CI 1.47 to 3.94) and post-operative weightbearing (OR=1.63, 95% 1.003 to 2.64). Open fractures increased the risk of re-operation in patients who received a reamed nail (OR=3.26, 95% CI 2.01 to 5.28) but not in patients who received a non-reamed nail (OR=1.50, 95% CI 0.92 to 2.47). Patients with open fractures who had either wound management without any additional procedures, or delayed primary closure, had a decreased risk of re-operation when compared to patients who required subsequent reconstruction (respectively, OR=0.18, 95% CI 0.09 to 0.35; OR=0.29 95% CI 0.14 to 0.62). **Conclusion:** To ensure optimal patient care surgeons should consider the characteristics identified in our analysis to reduce risk of re-operation.

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Revision of Provisional Stabilization in Pilon Fractures Referred from Outside Institutions

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Purpose: Pilon fractures demonstrate complex osseous and soft tissue injury. Protocols involving immediate tibial reduction and external fixation, with or without fibular fixation, then delayed definitive fixation result in decreased complications. Our purpose was to evaluate the treatment course of pilon fractures provisionally stabilised at outside institutions and subsequently transferred, focusing on the incidence and reasons for revision procedures, and subsequent complication rates. **Method:** An institutional trauma database was retrospectively reviewed, demonstrating 668 pilon fractures treated at our institution between 2000-2007. Of these, 39 patients with 42 fractures had a temporising surgical procedure prior to referral. Demographics, injury characteristics, reason for revision, and subsequent complications were determined. Clinical follow-up averaged 60 weeks (range, 1 to 281). **Results:** Mean age was 41 years (range, 18-78). Twenty-two fractures (52%) were open; 38 (90%) demonstrated a fractured fibula. Referral occurred an average of 5.8 days (range, 1-20) after initial stabilization. Pre-transfer fixation was revised in 40 fractures (95%). Reasons for revision included tibial malreduction (33 fractures, 83%), fibular malreduction (4 fractures, 10%), pins in the proposed incision (5 fractures, 13%), or loose pins (3 fractures, 8%). Of the 34 fractures with distal pins, 24 (71%) required revision for pin malposition, loosening, drainage, talar placement, or extraosseous placement. Late complications occurred in 14 fractures (33%), including deep infection in 10 (24%), and non-union in 3 (7%). Twenty-three patients (55%) required additional procedures following definitive fixation, including 9 soft tissue coverage procedures and 3 amputations. **Conclusion:** The majority of patients with pilon fractures treated with provisional stabilisation followed by referral to our institution required revision prior to definitive fixation. This resulted in many avoidable additional procedures, and a higher complication rate than recent contemporary controls. The authors recommend that, when possible, the

initial and definitive management of these injuries be performed at the accepting institution.

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ORIF of High-energy Pilon Fractures: Violating the 7-cm Skin Bridge Rule

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Purpose: The purpose of this study was to review our results in patients with pilon fractures treated with ORIF in which surgical planning involved multiple skin incisions, ensuring that the distance incisions overlapped was less than the distance between them. We hypothesized that soft-tissue complications would be minimal despite incisions placed <7-cm apart. **Method:** A retrospective chart review identified 37 pilon fractures in 32 patients treated by three orthopedic traumatologists at The Ottawa Hospital between August 2000 and February 2007. Follow-up included measurements of incision placement and functional outcome measures. **Results:** There were nine OTA type B and 28 OTA type C fractures; 28 were closed and nine were open. The mean age was 46.5 ±14.5 years, and average follow-up was 3.2 ±1.7 years. Of the patients reviewed, the average number of incisions was 3.7 ±1.1. The average overlap between incisions was 4.6-cm ±1.9 and the average skin bridge between incisions was 5.9-cm ±1.9, with 80% of the skin bridges <7-cm. Average ROM was 4.3° ±7.1 dorsiflexion and 39.1° ±11.6 plantarflexion. The mean AMA lower extremity impairment score was 18.9% ±12.4, and mean SIP ambulation score was 9.6 ±8.8. Complications included two superficial infections, one deep infection, and three non-unions. There were no cases of wound dehiscence or necrosis, or cases requiring revision soft-tissue coverage. These outcomes were comparable to recent reports with similar injuries. **Conclusion:** With careful planning and good soft-tissue management, incisions can be placed to maximize articular exposure based on fracture lines. It does not appear that the dogma of keeping incisions >7-cm apart must be followed in most cases. Prudent surgical timing and meticulous soft-tissue handling can allow for multiple incisions to be placed as necessary for fracture reduction and optimal fixation while maintaining a low rate of complications.

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A Clinically Relevant Classification of Posterior Malleolus Fractures to Guide Imaging and Treatment

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Purpose: Lower extremity articular fracture treatment requires acccurate diagnosis and anatomic reduction and fixation. As articular injuries, posterior malleolus (PM) fractures are still poorly defined: for example the incidence of associated PM marginal impaction and of free articular fragments is unknown. The purposes of this study were: 1) to define the articular injuries of PM fractures into clincially relevant groups, as complex articular injuries could require specific surgical steps; 2) to identify clinical and radiographic

parameters which would alert the surgeon to the presence of complex injuries. **Method:** Our prospectively-collected orthopaedic trauma database (OTDB) query identified 796 ankle fractures treated operatively between 2003-2007. Of these 147 cases involved the posterior malleolus. Four were misclassified leaving 143 cases. We obtained demographic and injury data from the OTDB, and validated the OTDB coded mechanisms of injury by an individual chart review. We reviewed all radiographs to describe the PM injuries (fracture patterns and dimensions) and to identify the associated injuries. **Results:** Of the 143 cases: Mean age was 50 years (sd=19), 68.5% were female, 51% were right sided injuries, and the median ISS=4 (in fact, 97.5% had ISS=4, most therefore being isolated trauma). The mean post malleolus AP size=11mm (sd=5). We identified recurrent patterns and classified the PM fracture as SIMPLE or COMPLEX (to include marginal impaction or free comminuted fragment, which should be anatomically reduced), 42% of cases (60/143) were COMPLEX (18 were impaction, 42 were free fragment). To help clinicians identify which cases could be COMPLEX we correlated (Chi-sq) the presence of a COMPLEX PM fracture to common clinical and radiographic variables. COMPLEX PM were statistically significantly associated with (p values) 1) an axial loading injury mechanism (.000), 2) a radiographically captured dislocation (.006), 3) posteromedial comminution [as defined Tornetta] (.005) 4) the size of the fragment (.000). For example, axial loading would result in a complex fracture in >85% of cases. In contrast, there was a statistically significant association between a Weber C fracture and older age and the presence of a SIMPLE PM fracture. These factors being potentially "protective" from joint comminution. **Conclusion:** We have defined and quantified the PM articular lesions which require anatomic reduction and fixation, beyond what has been published. We have defined clinical and radiographic criteria which, because higly associated with COMPLEX lesions, could 1) prompt surgeons to order further imaging (CT) to better delineate the lesion, and 2) draw his/her attention to potentially malaligned fragments at the time surgery.