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Does skeletal maturity affect pediatric pelvic injury patterns, associated injuries and treatment intervention?☆,☆☆

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ABSTRACT

Introduction: Pediatric pelvic injuries are rare. Due to anatomic differences of the immature pelvis, different injury patterns may occur as compared to adults. The purpose was to analyze the effect of skeletal maturity on pediatric pelvic injury pattern, associated injuries, and treatment intervention.
Patients and Methods: Ninety children with a pelvic injury receiving treatment at a private orthopaedic practice in association with a Level One Teaching Trauma Center, between March 2002 and June 2011, were retrospectively analyzed. Skeletal maturity was determined as closed triradiate cartilage. Forty-one (46%) were skeletally immature and 49 (54%) were skeletally mature. Mean age was 11.5 years (2–16). Fractures were 23 A2, 1 A3, 4 B1, 44 B2, 16 B3, and 2 C2 according to OTA/AO classification. OTA B and C fractures were 26 LC1 (lateral-compression), 20 LC2, 10 LC3, 4 APC1 (anterior-posterior-compression), 5 APC2, and 1 VS (vertical-shear) injury according to Young and Burgess. Treatment of the pelvic injury was operative in 28 (31%) and non-operative in 62 (69%) of children. Mechanism of injury, Injury Severity Score (ISS), deaths, and associated injuries were recorded.
Results: More complex and unstable injuries occurred in skeletally mature vs. immature children ($p = 0.014$). Skeletally mature children had a significantly higher rate of operative intervention ($p = 0.009$). The ISS in skeletally mature children was higher 25 (1–66) than in skeletally immature children 17 (4–43) ($p = 0.013$). 84% (41) skeletally mature and 78% (32) skeletally immature children sustained associated injuries. Twenty-two% (11) of all skeletally mature children sustained urinary tract injuries, but only 7% (3) of all skeletally immature children ($p = 0.049$).
Discussion: Skeletally mature children are more likely to sustain more complex injury patterns with a higher rate of operative treatment, to have a higher rate of associated injuries, and to have a higher ISS than immature patients.
Level of Evidence: Retrospective comparative study, Level III.

Introduction

Due to high flexibility and elasticity of the sacroiliac joints and symphysis pubis, more cartilage structure to absorb energy, and the osseous plasticity, more energy is required in children to injure the pelvis than in adults [1]. Different fracture patterns may occur [2] and may require different intervention as compared to the adult population. For pelvic ring injuries in mature children, treatment and classification such as in adults is suggested [2]. Even though Silber and Flynn, as well as Shaath et al. more recently described the immature pelvic fracture as less likely to require surgical

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intervention [3,4], more research is still required to differentiate whether these finding are due to the remodeling potential of the immature skeleton or due to the occurrence of different types of injuries. Further it is important to develop knowledge if associated injuries differ in immature vs. mature children or if they are comparable despite the presence of a higher rate of stable pelvic ring injuries in immature children. The purpose of this study was to analyze the effect of skeletal maturity on pediatric pelvic injury pattern, associated injuries, and initial fracture treatment.

Patients and methods

This study was an Institutional Review Board approved retrospective exploratory review at a single large private orthopaedic practice associated with a Level One teaching trauma center. Between March 2002 and June 2011, 133 consecutive children with pelvis fractures were identified by Current Procedural Terminology (CPT) Code 27194, 27193, 27215–18, 27226-28, 27222, and 27,220. Inclusion criterion consisted of patient age $\leq$ 16.0 years. Patients with isolated acetabular (13), coccygeal (1), and avulsion fractures (29) were excluded. The resulting study sample consisted of 90 patients.

Injury patterns as well as skeletal maturity were analyzed on plain radiographs including anterio-posterior (AP), inlet and outlet view of the pelvis, as well as CT pelvis views and reconstructions, when available, using plain films or digitally using the picture archiving and communication system (PACS) (Kodak Carestream PACS 2006, EASTMAN Kodak Company, Rochester, NY). Additional historic and clinical data were used for establishment of the injury type. Demographics were recorded (Table 1). The triradiate cartilage is the fusion point of the three primary ossification centers of the pelvis, the os ischium, os pubis and os ischii, fusion at this area shows maturity of the pelvis. Therefore skeletal maturity of the pelvis was determined as closed triradiate cartilage on plain AP radiographs and if unclear, with additional CT-films. Regarding other pelvic physes such as the femoral epiphysis as well as the Risser sign, we found the triradiate cartilage easiest to assess which was similar to a previous study by Silber et al. (3) (see SDC 2, 3, 4, 5).

Table 1
Demographics and Mechanism of Injury.

	n (%)	Average (range)
Age		11.5 years (1.9-16.0)
Gender		
- Male	39 (43.3%)	
- Female	51 (56.7%)	
Skeletal Maturity		
- Immature	41 (45.6%)	7.9 years (1.9-13.7)
- Male	23 (25.6%)	8.2 years (3.0-13.7)
- Female	18 (20.0%)	7.4 years (1.9-12.6)
- Mature	49 (54.4%)	14.4 years (11.4-16.0)
- Male	16 (17.8%)	14.9 years (13.5-16.0)
- Female	33 (36.7%)	14.2 years (11.4-16.0)
Mechanism of Injury		
- MVC	44 (48.9%)	
- Peds	27 (30.0%)	
- Falls	11 (12.2%)	
- Others	8 (8.9%)	
Open Fracture	4 (4.4%)	3 IIIA, 1 Morel Lavalle

MVC = motor vehicle crash; Peds = Pedestrian versus car.

The fractures were classified according to OTA/AO (Orthopaedic Trauma Association/Arbeitsgemeinschaft für Osteosynthesefragen) [5]. OTA/AO B and C fractures were additionally classified according to Young and Burgess [6].

The senior surgeons examined all patients once. The clinical exam was performed with manual lateral compression over the iliac crests. Any form of manual instability was correlated with CT injury pattern and displacement [7]. If the manual exam was inconclusive, an exam under anesthesia was performed to confirm or refute instability in operation stand-by. Injury Severity Score (ISS), Glasgow Coma Score (GCS) at initial evaluation, length of hospital stay and blood transfusion requirement as units packed red blood cells (RBC) were recorded. Comorbidities were reactive airways disease (11), cardiovascular (3), depression (2), scoliosis (1) and others (2).

Descriptive statistics were completed. Nominal variables, such as mature, immature, operative, non-operative, were evaluated using the chi-square test, unless the sample size was too small, in which case the two-tailed Fisher's Exact test was used. For variables such as GCS and ISS, *t*-test analysis was performed. Multiple regression analysis was additionally performed to determine the predictor of urinary tract injury, classification and maturity status. Significance was determined at $p < 0.05$. Data were analyzed using SPSS version 19.0 (IBM, Armonk, NY). The short term outcomes of 33 patients from this study population have been previously reported [8].

Results

The majority of injuries in immature (32, 78%) and mature (39, 80%) children were caused by traffic injuries such as motor vehicle crash (30, 61% mature vs. 14, 34% immature) or pedestrian versus motor vehicle (9, 19% mature vs. 18, 44% immature) (See Table 2). Immature children were more likely to sustain a pelvic ring injury from a pedestrian versus motor vehicle injury than mature children ($p = 0.008$). Seven (14%) mature and four (10%) immature sustained their injury due to a fall, and a total of eight (9%, 3 mature, 5 immature) had other mechanism of injuries. Initial treatment for the pelvic ring injury was operative in 28/90 (31%) and non-operative in 62/90 (69%). Mature children had a significantly higher ISS (25.3 (1–66) vs. 17.3 (4–43); $p = 0.013$), a lower GCS 12.9 (3–15) vs. 13.4 (3–15), a longer hospital stay (7 (0–39) days vs. 4 (0–30) days) and a significantly higher number of RBC transfusions (15 (30.6%) vs. 3 (7.3%); $p = 0.006$) compared to immature children (See Table 3).

Children with skeletal maturity had more complex injury pattern and had significantly more LC3+APC2+VS injuries than immature patients ($p = 0.014$) (Figs. 1 and 2). 75% (12/16) B3 fractures and 100% (2/2) C2 injuries, as well as 80% (8/10) LC3 injuries, 80% (4/5) APC 2 injuries and 100% (1/1) vertical shear injuries occurred in mature children (Figs. 3 and 4).

Immature patients with anterior and posterior ring injury were clinically stable in 23/30 (77%) and 7/30 (23%) were unstable in 7/30 (23%) on initial exam ($p = 0.01$). Mature patients with anterior and posterior ring injury were clinically stable in 17/36 (47%) and clinically unstable in 19/36 (53%) on exam. Mature patients were more likely to sustain an unstable B3 or C2 pelvic fracture type in a MVC than immature children (B3: 30.0% vs. 7.1%; C2: 6.7% vs. 0.0%), and more likely to sustain a B3 type fracture in a pedestrian versus car crash than mature children, respectively (33.3% vs. 5.6%) (Table 2).

Associated injuries occurred in 73/90 (81%) children. 41/49 (84%) children were mature and 32/41 (78%) children were immature (Tables 2 and 4). Two children died because of associated injuries; one because of a traumatic brain injury (TBI) and the other one because of a hypoxic ischemic encephalopathy secondary to an

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