Review

Current Concepts in Pediatric Pelvic Ring Fractures: A Narrative Review

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Abstract: Trauma is still the leading cause of death in children. Post mortem studies have shown a high incidence and a high rate of deaths related to pelvic fractures and associated injuries. The pelvic ring in children has characteristics that differentiate it from the adult. The bone tissue is more elastic and is covered with a thick periosteum. Elasticity mainly translates into plastic deformity when it is impacted. Overall, lesions tend to be more stable as the relatively thick periosteum limits bone breakdown. As a result of this elasticity, the intrapelvic organs are more vulnerable and injuries can occur in the absence of fractures. High energy is required to produce a fracture and this energy can be transferred to the pelvic organs. Minimally displaced fractures may be the result of high energy trauma with a significant risk of further intrapelvic and intra-abdominal injury. This leads to a relatively high incidence of pelvic and abdominal organ injuries associated with stable fractures. A complete lesion of the pelvic ring anteriorly or posteriorly or a complex pelvic lesion is a high risk factor for morbidity and mortality. Treatment in the pediatric patient with a pelvic fracture has historically been guided by concepts that have become established in adults. The main parameters in the decision making process are hemodynamic stability and the degree of mechanical instability of the pelvis. The purpose of this review is to report current knowledge on pelvic ring fractures with a particular focus on their management and treatment.

Keywords: pediatric pelvic ring fractures; trauma center; pelvic injury; children

1. Introduction

Trauma is still the leading cause of death in children worldwide and is a significant cause of hospitalization and disability in children and adolescents [1–3]. Pelvic fractures are generally related to high-energy trauma, and the presence of associated injuries should always be considered [2]. In polytrauma, pelvic ring fracture is not the leading cause of death; however, a post mortem study showed significantly higher pelvic fracture-related deaths than commonly reported [4].

2. Epidemiology

Pelvic ring fractures in pediatric age are rare and less frequent than in adults. Historically the incidence is 1 case per 100,000 children per year and compared to the total number of fractures, they represent 0.5% to 4% of the fractures [5–7]. A recent retrospective epidemiological study in a level I trauma center in the Czech Republic showed an incidence of 4.2 cases per 100,000 [8], which is higher than the most recent European and American data [9,10]. Di Censo et al., in an epidemiological analysis of a population-based database, reported an incidence of pediatric pelvic fracture of 9.8/100,000 children per year. The highest incidence is between 8 and 10 years of age [11]. The epidemiological data of the studies are difficult to compare since there is a lack of homogeneity in the age to be associated with “pediatric patients”. Considering that the characteristics of growing bone are different...
from those of bone that has completed skeletal maturation, it seems appropriate to define as pediatric those patients who have not reached skeletal growth rather than considering only the age factor. The average age of triradiate cartilage closure is 14 years, which is why pediatric age in these cases means the age range between 0 and 14 years [7].

3. Mechanism of Injury

Pelvic ring fractures in childhood are mainly related to high-energy trauma. The most frequent correlation is with road accidents, particularly with situations in which the child is inside a motor vehicle or is run over while cycling or walking. Less frequent traumatic mechanisms are falls from heights and sports injuries. Abuse is a rare cause of pelvic ring fracture [11]. Sports injuries are the leading cause of avulsions of the secondary ossification nuclei of the pelvis during the growth period [12]. An observational study including 60 patients reported that the cause of the injury in almost 80% of the cases was either a traffic accident or a fall from height [13]. These data are in line with a recent retrospective study performed in a first-level trauma centre; in this study, the pelvic ring fracture was related to motor vehicle accidents in 52.9% of the cases and fell from height in 12.6% [14].

4. Anatomical Considerations

The pelvis during the growth phase has characteristics that differentiate it from the adult pelvis. The bone tissue is more elastic and covered by a thick periosteum. The ligaments are relatively more robust, and the growth plates and joints allow for a significant capacity to absorb kinetic energy. Histologically, it has a higher proportion of cartilage [15]. This elasticity results mainly in plastic deformity when subjected to impact [16]. Overall, lesions tend to be more stable since the relatively thick periosteum limits bone break-down. As a result of this elasticity, intrapelvic organs are more vulnerable, and injuries may occur in the absence of fractures or dislocations [17]. High energy is required to produce a fracture, and this energy can be transferred to the pelvic and abdominal organs [16,17]. Stable fractures may result from high-energy injury mechanisms and may correlate with the presence of injuries to internal pelvic and abdominal organs. This leads to a relatively high parenchymal damage associated with isolated ileum or ischiopubic branch fractures or iliac wing fractures. For these reasons, the presence of a complex pelvic ring fractures (Tile C) is a high-risk factor for morbidity and mortality [18–28]. In 2015 Kanawey et al. described the pathoanatomic peculiarities of the pelvic ring in pediatric age; in young children with a growing pelvis, pubic symphysis and sacroiliac joint lesions are more frequent than in adolescents, who have more bone lesions. In addition, unstable pelvic ring fractures in young children are often correlated with iliac apophysis avulsion and sacroiliac joint injuries [29]. In contrast to adults, damage to the transverse process of the fifth lumbar vertebra (L5 TP) is much less frequent [29], as is the simultaneous presence of acetabular and pelvic ring fracture (correlation in 4–20% of cases) [10,30]. A recent systematic review and meta-analysis found that there is no correlation between an L5 TP fracture and the simultaneous presence of an unstable pelvic ring fracture [31].

5. Associated Injury

This In an epidemiological study in the United States of America (USA), children with pelvic injuries had 5.2 concomitant injuries [26]. The German pelvic trauma registry data reported an ISS of 16.7 points [32]. The Injury Severity Score (ISS) was almost twice as high at 31.4 points in the British registry [33]. Recent retrospective studies report the presence of associated lesions in up to 70% of cases [14,30,33]. Pelvic hemorrhage is the leading cause of death in approximately 2% of pediatric pelvic fractures [21,34]. About 10–40% of patients with this type of injury require transfusion [21,33,35] and about 10–31% of patients with pelvic hemorrhage go into hemorrhagic shock by the time of admission. Compared to adults, pelvic ring fractures in children have lower bleeding rates and retroperitoneal hematoma, while transfusion requirements are similar [30]. This is probably linked to the faster vasoconstriction response of children’s blood vessels which, unlike adults, are not
characterized by atherosclerotic phenomena [19]. The source of potentially fatal bleeding is usually secondary to trauma-associated intra-abdominal and intrathoracic organ injury [19,20,22,23,25,35,36]. The rate of concomitant retroperitoneal hematoma ranged from 9-46% [11,19], and hematoma within the small pelvis was 9-39%. Vascular lesions of the pelvis are present in around 8% of cases [11,37], and the incidence increases in unstable pelvic fracture to around 40% [11]. Bleeding is more frequent in posterior than in anterior pelvic ring fractures [11,37]. Patients with exposed pelvic fractures have a mortality rate of up to 20%. Perineal injuries have been re-reported to occur in 3.5-7.8% [38]. The reported incidence of exposed fractures is approximately 9-13% [5,39]. Head trauma is the injury most associated with pelvic ring injuries, with an incidence of about 40%. One-quarter of patients presented with a concomitant thoracic injury and one fifth with additional abdominal injuries. Spinal injuries are less common, with an incidence of about 7% [5,19,20,22,23,34]. Approximately 19% of patients had an additional fracture of the femur and approximately 13% of the tibia [19,20,22,25,33]. Fractures of the humerus are present in about 5.5% and forearm fractures in about 5% [20,22]. Complex pelvic trauma is associated with significantly higher incidence rates, with 9.5% of upper limb injuries and 57% of lower limb injuries [38]. The additional injuries to the lumbosacral plexus vary between approximately 2-6% [11]. The incidence of urogenital lesions is about 10% [14,30,33,35,40], and increases to around 40% following complex injuries. Approximately 10% of these lesions involve the bladder, and usually, a quarter of patients also have a urethral lesion. Renal, vaginal and rectal lesions are reported with an incidence of 8%, 14.9%, and 10.7%, respectively. Macrohematuria was observed in 7-57% and microhematuria in 21-36% [5,11,19,20,23,33]. Table 1 shows data on associated injuries from retrospective studies published in the last ten years [14,30,33,35,40].

### Table 1. Associated injuries.

<table>
<thead>
<tr>
<th>Study and Year</th>
<th>Age N</th>
<th>Head %</th>
<th>Chest %</th>
<th>Abdomen %</th>
<th>Pelvic Hematoma %</th>
<th>Limb Fractures %</th>
<th>Urogenital %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheng Ding 2022</td>
<td>2–15 60</td>
<td>30</td>
<td>NR</td>
<td>NR</td>
<td>13.3</td>
<td>23.3</td>
<td>23</td>
</tr>
<tr>
<td>Alhammoud 2021</td>
<td>0–18 109</td>
<td>24</td>
<td>46</td>
<td>34.5</td>
<td>5.9</td>
<td>17.6</td>
<td>NR</td>
</tr>
<tr>
<td>Mulder 2019</td>
<td>0–17 163</td>
<td>25</td>
<td>48</td>
<td>75</td>
<td>5</td>
<td>60</td>
<td>11</td>
</tr>
<tr>
<td>De La Cava 2018</td>
<td>1–14 81</td>
<td>49.4</td>
<td>NR</td>
<td>24.7</td>
<td>NR</td>
<td>55</td>
<td>11.1</td>
</tr>
<tr>
<td>Herrans 2017</td>
<td>3–16 51</td>
<td>43</td>
<td>24</td>
<td>37</td>
<td>4</td>
<td>76</td>
<td>12</td>
</tr>
<tr>
<td>Shaat 2016</td>
<td>2–14 60</td>
<td>60</td>
<td>40</td>
<td>26.7</td>
<td>33</td>
<td>100</td>
<td>NR</td>
</tr>
<tr>
<td>Tosounidis 2015</td>
<td>0–17 49</td>
<td>67.3</td>
<td>61 *</td>
<td>38.7 **</td>
<td>NR</td>
<td>34</td>
<td>6.1</td>
</tr>
</tbody>
</table>

* Associated with dorsal spine injuries. ** Associated with lumbar spine injuries. NR, not reported. N, number of patients included. % Per-centage of patients related to the associated lesion.

### 6. Diagnosis

Pediatric pelvic trauma, as previously mentioned, is often associated with other injuries in the context of polytrauma, typically with a high-energy mechanism. For this reason, it always requires a multidisciplinary (trauma team) and systematic evaluation through a standardized diagnostic process following ATLS (Advanced Trauma Life Support) principles. It is possible to divide patients into hemodynamically stable and unstable, which require different times and management modalities.
6.1. Clinical Examinations

Initial evaluation includes a comprehensive neurologic and peripheral vascular examination, followed by a careful inspection of possible soft-tissue injuries in the pelvis, including the perineum, rectum, and genitalia (e.g., urethral meatus and vagina bleeding, scrotal ecchymosis). Digital rectal exam (DRE) and vaginal exam, due to their low accuracy, should only be performed in cases of severe trauma with a high suspicion of unstable pelvic fracture to evaluate sphincter tone and presence of intracavitary bleeding or protruding bone fragments [41,42].

The clinical orthopedic evaluation of the pelvis initially includes inspection for any deformities with the patient supine, including pelvic asymmetry, leg length discrepancy, or abnormal rotations. Subsequently, pubic symphysis diastases and iliac crest dislocations are evaluated by direct palpation, while pelvic stability is assessed by applying anterior and lateral compression (sensitivity: 69%; specificity: 95%) [21]. In order not to increase the risk of bleeding, repeated maneuvers should be avoided [43]. Limitations of hip range of motion and pain during internal or external rotation testing (FADIR/FABER test) allow detection of hip or sacroiliac joint injuries. The patient is then log-rolled to inspect the spine, sacrum, and SI joints; deformity or pain should be revealed by direct palpation [44].

6.2. Imaging

Imaging assessment of pelvic injuries is related to trauma severity and energy. Polytrauma patients require a FAST examination to rule out active bleeding and trauma series radiographs (chest and AP pelvis X-ray). Radiographs of other body segments and second-level examinations are directed by the patient’s clinical suspicion and hemodynamic stability [19].

6.2.1. Plain Radiographs

The first-line imaging study for polytrauma patients is AP pelvis radiography (APPR), which is the gold standard for diagnosing pelvic fractures. Radiological signs of pelvic fractures are triradiate cartilage displacement, teardrop asymmetry, iliopectineal or Kohler’s line interruption, and intraarticular effusion. The acetabulum, SI joints, and sacrum are difficult to evaluate on APPR. In the case of clinically stable patients, other projections may be performed to assess better the kind of fracture and the amount of displacement, such as inlet/outlet views or iliac/oburator oblique views (Judet views) [9,11].

The main advantages of APPRs are their rapid execution, easy interpretation, and low exposure dose of radiation (an essential aspect in pediatric patients). However, since the presence of radio-lucent cartilage in the immature pelvis, subtle fractures could be challenging to identify on radiography in pediatric patients, especially for thus which involve the posterior pelvic ring. For this reason, a negative APPR associated with a high clinical suspicion of pelvic fracture should always require a second-line imaging study (e.g., CT scan), as well as in the presence of one fracture. Further investigations could be helpful to identify associated injuries. Note that some fractures might be reduced in the case of a negative x-ray in the patient with a pelvic binder. Therefore, it could be useful to repeat the exam after removing the device in safe condition [4,9].

In conclusion, APPRs are a routine exam in polytrauma patients. However, their sensitivity in detecting pelvic fractures among pediatric patients (about 50–80%) is comparable to the clinical exam alone (about 70%) and significantly lower than CT scan [45,46]. For this reason, some authors suggest that APPRs should be avoided in conscious patients with negative pelvic examination and no peripheral neurovascular lesions [47,48]; however, since the low risk of a single X-ray, APPR is still generally recommended in trauma with a high risk of pelvic injury.

6.2.2. Computed Tomography (CT)

CT scan is the most accurate exam to detect pelvic fractures, but its use in pediatric patients is limited to reducing radiation exposure. CT scan is aimed primarily at unstable
patients with vascular or abdominal injuries. In contrast, it is not recommended as a screening examination in case of radiographic suspicious only without clinical signs of pelvic fracture [9,49].

Finally, CT is undoubtedly worthwhile to better characterize and classify the fracture type and give a more precise assessment of quiet areas on APPRs such as acetabulum, SI joint, or sacrum; however, it rarely changes the concept of treatment [22].

6.2.3. Magnetic Resonance Imaging (MRI)

MRI allows assessment of cartilaginous structures of the immature pelvis, which cannot be evaluated by radiography or CT scan, and injuries involving capsular and ligaments structures. Nevertheless, its application is contraindicated in acute trauma settings or in the case of an unstable patient. In contrast, it is undoubtedly a valuable tool in the second phase of planning the surgical treatment [50].

7. Classification

The classification of pelvic fractures, diagnosed using different tools reported above, is essential for a better comprehension of biomechanical principles and treatment management implications, as well as identifying the severity of life-threatening pelvic injuries in an emergency. Several classification systems have been developed over decades, such as Key/Conwall [51], modified Torode/Zieg [43,52] (Figures 1–3), Young-Burgess Classification, and the AO/Tile/OTA [53], which are described afterward. In the emergency setting, it has also been proposed a simplified and rapid valuable classification in the prediction of mortality [54,55]:

- Simple pelvic trauma (90%): pelvic fracture associated with instability of osteoligamentous structures and mild soft tissue injuries;
- Complex pelvic trauma: pelvic fracture related to severe soft tissue injuries;
- Unstable pelvic fracture associated with hemodynamic instability

Figure 1. A case of 14 years old affected from MTZ Type I avulsion fracture.
The modified Torode and Zieg classification (MTZ, 2012—see Table 2) is the widely used system in pediatric pelvic fracture, identifying four groups (I–III: stable fracture; IV unstable fracture).

Table 2. The modified Torode and Zieg classification (2012).

<table>
<thead>
<tr>
<th>MTZ type</th>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>3%</td>
<td>Avulsion fractures</td>
</tr>
<tr>
<td>Type II</td>
<td>15%</td>
<td>Iliac wing fractures caused by lateral forces (II-A: apophyseal; II-B: bony)</td>
</tr>
<tr>
<td>Type III</td>
<td>55%</td>
<td>Simple pelvic ring fractures, stable:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• III-A: involves anterior elements (e.g., pubic rami fractures or stable symphyseal disruptions); associated with genitourinary injuries.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• III-B: involvement of anterior and posterior elements, associated with a high incidence of associated injury and worse prognosis.</td>
</tr>
<tr>
<td>Type IV</td>
<td>28%</td>
<td>Multifocal fractures with pelvic ring disruptions, unstable (e.g., unstable pelvic segment, straddle fractures, associated acetabular fractures, anterior and posterior ring fractures).</td>
</tr>
</tbody>
</table>

The other different systems of classification are reported in tables (Tables 3–5).
### Table 3. Key and Conwall Classification.

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>38–56%</td>
<td>Isolated fracture not involving the pelvic ring (e.g., avulsion, iliac wing, pubis/ischium ramis, sacrum, or coccyx fracture)fractures</td>
</tr>
<tr>
<td>Type II</td>
<td>28–43%</td>
<td>Single break in the pelvic ring (e.g., fracture of two ipsilateral pubic rami, symphysis pubis disruption, SI joint disruption)</td>
</tr>
<tr>
<td>Type III</td>
<td>11–12%</td>
<td>Double break in the pelvic ring (e.g., anterior-posterior or straddle fracture)</td>
</tr>
<tr>
<td>Type IV</td>
<td>5–9%</td>
<td>Acetabular fracture</td>
</tr>
</tbody>
</table>

### Table 4. Young-Burgess classification.

<table>
<thead>
<tr>
<th>Type</th>
<th>Subtype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APC</td>
<td>APC-I</td>
<td>Anterior-posterior compression (APC), result of frontal impact forces</td>
</tr>
<tr>
<td>APC</td>
<td>APC-II</td>
<td>Mild symphyseal (&lt;2.5 cm), intact SI joint; external rotation displacement of hemipelvis, stable pattern.</td>
</tr>
<tr>
<td>APC</td>
<td>APC-III</td>
<td>Severe symphyseal diastasis (&gt;2.5 cm) with anterior SI joint disruption; external rotation displacement of hemipelvis, rotationally unstable and vertically stable.</td>
</tr>
<tr>
<td>LC</td>
<td>LC-I</td>
<td>Lateral compression (LC), result of side-on collision (e.g., run over pedestrian)</td>
</tr>
<tr>
<td>LC</td>
<td>LC-II</td>
<td>Ipsilateral sacral compression or ipsilateral horizontal pubic rami fractures; internal rotation displacement of hemipelvis, stable pattern.</td>
</tr>
<tr>
<td>LC</td>
<td>LC-III</td>
<td>Ipsilateral iliac wing fracture or posterior SI joint disruption; internal rotation displacement of hemipelvis, rotationally unstable and vertically stable.</td>
</tr>
<tr>
<td>VS</td>
<td></td>
<td>Vertical shear (VS), result of inferior-superior forces (e.g., fall from height), characterized by vertical pubic rami fractures and SI joint disruption; cranial displacement of hemipelvis, rotationally and vertically unstable.</td>
</tr>
</tbody>
</table>

### Table 5. AO/OTA classification.

<table>
<thead>
<tr>
<th>Type</th>
<th>Group</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>A1</td>
<td>Avulsion fractures</td>
</tr>
<tr>
<td>Type A</td>
<td>A2</td>
<td>Complete fracture without displacement of the pelvic ring, with</td>
</tr>
<tr>
<td>Type A</td>
<td>A3</td>
<td>Transverse fracture of sacrum and coccyx</td>
</tr>
</tbody>
</table>
8. Treatment

Management of pelvic fractures in an emergency trauma setting follows the same principles established in adults according to ATLS, essentially based on hemodynamic and pelvic fracture stability. As reported before, is essential a systematic and multidisciplinary approach preferable in a specialized children’s hospital [56,57]. Trauma specialists, such as anesthesiologists or critical care physicians, coordinate the first assessment and care of a traumatized pediatric patient, while pediatric orthopedic surgeon is essential for the initial evaluation of circulation. Pelvic hemorrhage is less frequent and morbid in the children population [36,58], but it is described as a higher risk of pelvic viscera injuries [59]. The general principles for the management of pelvic fractures are resuscitation, temporary stabilization, and definitive fixation, although no consensus or guidelines have been published [28].

8.1. Emergency Treatment

In hemodynamically unstable patients, the first challenge is to control pelvic hemorrhage adequately. Angiography/embolization is the currently accepted measure to manage pelvic bleeding in a patient with moderate hemodynamic instability [60], while in severe pelvic bleeding the pelvic packing with concomitant posterior ring stabilization is recommended [37,61].

Pelvic emergency external fixation is preferred in unstable fractures with multisystem injuries to control blood loss, using simple anterior constructs or pelvic C-clamp, according to “damage control” principle. Even if the pelvic C-clamp provides a direct stabilization of the posterior pelvic ring, both techniques allow an adequate pelvic tamponade [11]. Rarely, early ORIF of pelvis fractures may be indicated in the presence of urgent surgical
non-orthopedic injuries. The external fixator pins should be placed in the supra-acetabular zone and do not violate the iliac crest or physis of the triradiate cartilage, while pins into the iliac crest should be avoided in skeletally immature patients for the risk of apophyseal damage and impairment of abdominal muscle development. 4-mm Steinmann pins are used to treat <8 years, while 5-mm pins are used in older patients. Usually, one on each side is adequate [62].

8.2. Definitive Treatment

Several studies report that most pelvic fractures require no surgical management (78–94%) [32,33]. Age, associated injuries, and fracture pattern guide the decision. When surgery fixation is needed, the procedure is usually performed ten days after the trauma under more favorable conditions and with a low risk of bleeding [9]. Current post-surgical and rehabilitation approaches are centered on rapid mobilization to improve rehabilitation and minimize complications.

The primary predictive indicator of outcome is pelvic asymmetry (length difference between diagonal lines between the inferior edge of the SI joint and the contralateral triradiate cartilage on an APPR), specifically if greater than 0.5–1 cm [11], which cannot remodel and leads to complications, such as pain or growth alteration [27,63]. Surgical approaches and fixation techniques are determined by the location of the fracture, displacement, and soft-tissue damage. The principal options are closed reduction and external/percutaneous fixation, open reduction and internal fixation, or a combination of these.

8.2.1. Stable Fractures

Type Tile A fractures are sufficiently treated conservative with a short bedrest period and early walking after 30–45 days [10], with no risk of secondary displacement. Surgical treatment with close/open reduction and fixation (K-wire or screw—Figure 4) is reserved for severely displaced fractures for potential high risk of nonunion [11,64].

![Figure 4](image-url)

*Figure 4. A case of 14 years old male patient affected by ASIS avulsion treated with percutaneous reduction and fixation with screw.*

8.2.2. Partial Unstable Fractures

In type Tile B fractures with >2 cm of displacement, symphyseal dislocation and rotationally instability due to APC, ORIF with symphyseal plating provides adequate stabilization of the anterior pelvic ring than external fixation [65]. Otherwise, LC mechanism fractures are generally treated conservatively.

8.2.3. Unstable Pelvic Fractures

The unstable fractures of the pelvis, Tile C and MTZ type IV, apart from MTZ IV with double anterior disruption (usually treated conservatively), should undergo surgical treatment. Since these types of fractures are more frequent in patients older than 12 years of age with closed triradiate cartilage, the treatment is comparable to that of adults. In a hemodynamically stable patient, surgical treatment could be postponed.
In these types of unstable fractures, there is no consensus about the preferable treatment option, and in younger patients with minimal displacement (<0.5–1 cm), conservative treatment may be considered. The anterior ring disruption could be treated with an external fixator (Figure 5), while ORIF with pubic plate must be reserved for non-reducible fractures [62]. The posterior arch injuries are generally adequately treated with close reduction and percutaneous internal fixation using a single screw (<45 mm is preferable to avoid damage of S1 root). Some authors suggest implant removal after two to three weeks for external fixators and three to six months post-operatively for internal implants [11], although there is no consensus. Figure 6 shows a treatment flowchart based on the current evidence described above.

Figure 5. 13 years old patient affected by MTZ type C treated with external fixation and posterior plate fixation.

Figure 6. Treatment flowchart in pediatric pelvic ring fractures.
9. Outcomes

Historically, the reported mortality ranges from 2.5% to 25% of cases [22,36]. A recent systematic review of the literature on pelvic ring fracture outcomes shows an overall mortality rate of 8.6% (12,220 patients included in the study) [66]. Factors that significantly influence mortality are severe head trauma, complex abdominopelvic trauma (19% mortality), the type of pelvic fracture, and the presence of a crush injury with loss of substance [9,67]. About 15% higher mortality rates have been found in type C injuries, almost twice as high as in type A and B injuries [7]. Pelvic fracture and associated hemorrhage cause death in less than 1% of pediatric cases, while the rate in adults is about 4% [22,24]. Some authors have tried to relate mortality and morbidity to injury scores; however, the clinical usefulness of quantitative injury scales is questionable [2,6,9]. The main complications related to pelvic ring fractures are pelvic ring malunion resulting in leg length discrepancy, arthritis of the hip and spine, SI joint pain or fusion, and distortion of the birth canal obstructing vaginal delivery. Premature closure of the triradiate cartilage for related acetabular fractures leads to acetabular dysplasia and early hip arthritis. Heterotopic ossification can cause pain at the site, hip impingement, and limited hip range of motion. Genitourinary complications include urethral and bladder injury, incontinence, chronic pelvic floor pain, and sexual dysfunction [68]. Sridharan et al., in their systematic review of outcomes, have reported several critical issues in the understanding of outcomes concerning fracture type and treatment. As the authors themselves declare, due to the rarity of pelvic ring fractures, many studies collected data over significant periods, some of which spanned a decade; the understanding of fracture patterns and corresponding treatment algorithms may have changed over the periods considered, and the final results of the data collected may be biased. Many studies report only specific symptoms and not overall functional scores, and often the association between the type of fracture and the treatment received is unclear. This study shows that only 8.8% were treated operatively [66]. Schwarz et al. reported lower limb length discrepancies of 1 to 5 cm in 10 of 17 patients after non-surgical treatment of unstable pelvic fractures; 5 had low back pain at long-term follow-up [63]. In the operatively treated patients, Sridharan et al. reported the following functional outcomes in terms of symptoms: 5% lower limb discrepancy, 3.4% chronic pain with activity, limp 6%, back pain 4.6%. The weighted average follow-up was 29 months. The main short-term complications related to the surgical option were infection and hardware-related complications (5% and 2.9% of cases, respectively). Pelvic asymmetry is a crucial outcome indicator [27]. Unstable pelvic fractures treated conservatively have shown most patients to have a poor clinical outcome in the short term [28]. A retrospective study including 230 pelvic ring fractures showed promising results in patients with asymmetry of less than 1 cm and poor outcomes in those with asymmetry of more than 1 cm, considering both objective and subjective parameters [27]. In this study, surgical treatment reported an 18% rate of pelvic asymmetry compared with 48% for conservative treatment [27]. Pelvic ring asymmetry does not correlate with the possibility of remodeling and is the only parameter capable of predicting outcomes; for these reasons, the most important goal of treatment to improve outcomes is to avoid asymmetries more significant than 1 cm [28]. The same recommendation emerges from a recent literature review by Wharton et al. [69].

10. Conclusions

In addition to the already mentioned and well-known anatomical, physiological, and management differences compared to adults, the literature review clearly shows the most significant difference between the two parts, namely the total discrepancy of studies and evidence. This difference can only be partly justified by the greater rarity of pelvic ring fractures in children compared to adults. The main controversies and limited evidence concern the definitive treatment in terms of absolute indications (conservative treatment versus surgical treatment) and the type of surgical treatment to be adopted. The main parameters in the decision-making process are hemodynamic stability and the degree of mechanical instability of the pelvis. Complications are not uncommon and are more
frequent in patients in whom proper pelvic ring reduction is not achieved. We support the concept of avoiding fracture consolidations with asymmetries >1 cm and the need for surgical treatment by surgeons experienced in pelvic trauma. Unstable fractures require a correct reduction associated with a stable osteosynthesis (internal or external according to the type of fracture) to prevent bad outcomes and the most frequent complications (lower limb length discrepancy, spine pain, and SI arthritis).

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