Pelvic Ring Injuries in Children. Part I: Epidemiology and Primary Evaluation. A Review of the Literature

Zlomeniny pánevního kruhu u dětí. Část I: Epidemiologie a primární zhodnocení. Přehled literatury

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SUMMARY

Pediatric pelvic injury is of major significance despite these injuries in children are rare with a suspected yearly rate of 3% of all pelvic injuries.

The special pediatric bone anatomy of the pelvis is responsible for different fracture patterns, and overall, a bony or joint injury of the pelvis is an indicator of a severe trauma.

The vast majority of pediatric pelvic fractures is the result of a high-energy trauma, especially after strucking by a car or injured as motor vehicle passengers. Additional injuries are common, but additional head injury is only present in 1/3 of patients. An adequate structured primary diagnosis must therefore be mandatory. The a.p. X-ray of the pelvis is still the gold standard to evaluate these injuries. The majority of injuries is mechanically stable with 85-90% expected type A- and B-injuries.

Primary management of these injuries is orientated to that of adults. The standard emergency fixation procedure is the external fixator. Definitive treatment depends on the displacement of fractures and the instability of the pelvic ring. In displaced and unstable fractures, today, anatomic reconstruction of the pelvic ring by osteosynthesis is favoured. Due to the potential negative long term consequences of mal-healing child-adapted stabilization techniques should be used.

Moratlity is related to concomitant injuries, e.g. severe head injury. Risk factors of mortality are the overall injury severity, additional complex pelvic trauma and the type of pelvic fracture.

Nevertheless, growth disturbances occur in rare cases. Therefore, frequent clinical and radiological controls are proposed until the completion of growth.

Overall, good and excellent long-term results can be expected in most patients, especially after type A-injuries. But several long-term sequelae can occur in unstable pelvic injuries depending on the instability of the child's pelvis at the time of injury. Overall, there is a good correlation between the clinical and radiological result. Risk factors for a worse result can be additional significant peripelvic injuries (complex pelvic trauma).

INTRODUCTION

Trauma is still the leading cause of death in children (46). Morbidity and mortality is due to concomitant injuries in the majority of cases and not from the pelvic fracture itself. In contrast, a postmortem studies showed a high rate of pelvic fracture related deaths and a high incidence of pelvic fractures (18).

1. Anatomic characteristics

The growing pelvis differs from the one found in adults. The pelvic bones are less brittle and are covered with a thick periosteum. In addition, the ligaments are relatively stronger, growth centers and are present, which together with the sacroiliac joints and the pubic symphysis allow a significant absorption capacity.

Therefore, the pelvis is more elastic and contains more cartilage than the adult s (6).

This elasticity results primarily in plastic deformity when forces act on the pelvic bone (49) with the possibility of recoiling the deformity but normally not to the preinjury point. Thus, asymmetry can be seen without fracture comparable to the bowing forearm bones. Overall, injuries tend to be more stable as the relatively thick periostium restricts bony displacement.

Due to this elasticity, the intrapelvic viscera are not sufficiantly be protected and intrapelvic organ injuries can occur without the presence of pelvic fractures or dislocations (31). Consequently, more energy is required to produce a fracture (6, 31) and energy can be transferred to the pelvic viscera even after a fractures has been sustained. Therefore, even simple or minimal displaced fractures are mainly the result of a high energy trauma with a significant risk of additional intrapelvic and intraabdominal injuries (31). This leads to a relatively high incidence of isolated pubic rami fractures or fractures of the iliac wing (3, 5, 11, 16, 17, 23, 29, 40, 43, 44, 47, 51).

In contrast, the presence of a complete disruption of the anterior and posterior pelvis or a complex pelvic injury is therefore a high risk factor of morbidity and mortality (14, 27).

2. Epidemiology (Fig. 1)

Pelvic ring injuries in children are rare with an incidence of 2.7% in the late 90ies (14). The yearly incidence is expected to be 1.1-8.8/year (1, 27, 37, 48, 49). The incidence of pediatric pelvic fractures within the group of pediatric children is reported to be 49/100000 children (9). 10% of children have unstable immature pelvic fractures (45) and a 18.3% incidence of complex pelvic trauma within the group of pediatric pelvic injuries is reported (27).

- Incidence of pediatric pelvic fractures
- 2.7-3.7% of all pelvic fractures
- 0.3-3.5% pediatric trauma
- 49/100000 pediatric patients
- 4 patients/year

Fig. 1. Summary of incidences on pediatric pelvic ring fractures.

The incidence of pediatric pelvic fractures in the group of pediatric patients is between 0.3-3.5% (2, 11, 13, 15, 30, 36, 47, 52).

3. Age and gender

The main problem in analysing the literature is the different definition of the upper age level of "pediatric pelvic trauma" with a range between 14 and 20 years.

Overall, there is a male predominance resulting in a male/female ratio of approximately 1.4:1. The mean age depends on the age-definition of the pediatric group. In the classical immature group of patients ≤14 years of age the mean age is 8.2 years (23, 29, 37, 49), authors

reporting on patients up to 16 years of age, the mean age was 9.4 years (1, 5, 11, 18, 40, 47), whereas both groups together showed a mean age of 9 years.

4. Mechanism of injury

The majority of pediatric pelvic injuries is the result of a high energy trauma which is significantly associated with pelvic fractures (30). The summary of the present literature shows (Tab. 1), that 83.3% of all pelvic injuries were due to high energy trauma (1, 5, 11, 23, 29, 30, 39, 40, 44, 48, 49, 51, 52). A pedestrian struck by a car was the mechanism in 57.8%, a motor vehicle passenger was injured in 17.8%, a bicyclist in 4.9% and a motorcyclist in 0.6%. A fall from height was responsible to produce a pediatric pelvic fracture in 9.2%. Crush injuries (2.2%), injuries sustained during sport activities (2.1%) and farm accidents (0.5%) were uncommon.

An important prognostic mechanism of injury is the history of a roll-over or crush mechanism (ISS up to 40 points, 86.6%. associated injuries, 20% mortality rate >70% local complication rate) (28).

5. Associated injuries (Tab. 2)

Analysis of the American National Inpatient Pediatric Database revealed that children with pelvic injuries had 5.2 concomitant injuries in average (9).

Injury severity

The overall injury severity cannot be estimated by data from the literature. There is a wide range of reported Injury Severity Scores in pediatric pelvic trauma ranging from 10 points (30), 10-20 points (5, 44, 52) and up to 30.5 points (40). The average value from these studies is 15.7 points, analysing 1849 patients (5, 30, 40, 44, 52).

Pelvic bleeding

Life-threatening bleeding from pediatric pelvic fractures is rarely seen and is reported to range from only 0% to 2% (16, 17, 29, 39).

No clear data on transfusion requirements exists. It can be expected that 17.3-40% of patients need transfusions (4, 16, 39, 51). Approximately 10-31% are in shock at admission (29, 39).

The source of potentially fatal hemorrhage is commonly secondary to the associated intraabdominal and intrathoracal organ injuries (1, 4, 5, 10, 11, 15, 24, 39, 44, 47, 51).

The rate of additional retroperitoneal hematoma is reported to be between 9% and 46% (5, 39, 40) and hematoma within the true pelvis is found between 9% and 39%. Pelvic vascular lesions are present in 2-8% (27, 39, 50). This incidence increases in complex pelvic trauma up to 43% (27).

The presence of a posterior pelvic injury was associated with a higher risk of pelvic bleeding (26).

Open fractures

Patients with open pelvic fractures are severly injured with a mortality rate up to 20% is up to 12.9%, requiering an aggressive management concept (27, 28).

Tab. 1. Injury mechanism by numbers reported in the literature

Author	Year	MVA	Pedestrian	Passenger	Bicycle	Motorcycle	Fall	Sport	Farm	Crush	Other
Banerjee	2009	36	29	6	1	0	7	0	0	0	1
Nabaweesi	2008	185	114	71	0	0	18	0	0	0	16
Chia	2004	101	77	16	7	1	10	4	0	0	10
Grisoni	2002	33	22	3	4	0	9	0	0	4	5
Silber	2001	137	100	37	0	0	22	0	0	0	7
Uppermann	2000	75	45	25	5	0	3	2	0	0	15
Rieger	1997	40	17	10	10	2	1	8	3	1	0
Lane O Kelly	1995	59	49	4	4	0	7	0	2	2	0
Musemeche	1987	56	35	18	0	3	1	0	0	0	0
Stachel	1987	84	50	0	18	0	16	8	0	16	0
Torode	1985	123	103	14	6	0	11	5	2	0	0
Reichard	1980	110	80	20	8	2	6	0	0	0	4
Stuhler	1977	42	29	7	0	0	9	0	0	6	5
	no.	1081	750	231	63	8	120	27	7	29	63
	%	83.3	57.8	17.8	4.9	0.6	9.2	2.1	0.5	2.2	4.9

Perineal injuries were found in 3.5-7.8% (7, 23, 27, 29). The reported rate of open fractures is 1.9-12.9% (7, 28).

Truncal injuries

The main additional truncal injury is the head injury in about 38.8% (1, 2, 4, 5, 7, 11, 23, 29, 37, 39, 40, 44, 47, 49, 50). 14% of the patients had concomitant chest and abdominal injuries. Spinal injuries are rare with an incidence of 3.2%.

Extremity injuries

18% of the patients had an additional femur and 10.7% and additional tibia fracture. Humerus fractures are presdent in 5.5% and forearm fractures in 5% (4, 11, 23, 29, 39, 44, 50).

After complex pelvic trauma these rates are significantly higher with 9.5% injuries of the upper and 57% of the lower extremities (27).

Nerve injuries

The rate of additional lumbosacral plexus injury is low ranging from 0.8% to a maximum of 6.1% (4, 7, 23, 27, 39, 40, 49).

Genito-urinary injuries

The incidence of genito-urinary injuries is increasing to presently 11-12% (2, 5, 10, 11, 23, 26, 27, 37, 40, 47, 50, 52). These rates increases 40-50% in cases after crush injuries or complex pelvic trauma (27, 28).

10.7% of these injuries were bladder injuries and one fourth of the patients (26.4%) had an additional urethral lesion. Injuries of the kidneys were present in 8.3%, vaginal lacerations in 14.9% and rectal injuries in 10.7% (2, 5, 10, 11, 23, 26, 27, 37, 40, 47, 50, 52).

Macrohematuria is observed in 7-57% (7, 38, 39, 50, 51) and microhematuria in 21-36% (38, 39).

6. Clinical examination

In selected patients, especially in awake patients, pelvic fractures can sufficiantly detected or ruled out by clinical examination alone.

Primary inspection of the undressed patient should focus on pelvic asymmetry, differences in leg length, pelvic soft tissue injury around the complete pelvis including the perineum and search for urethral or vaginal bleeding and serach for differences of the colour of the feet, probably indicating vascular impairments.

The ATLS concept proposes the digital rectal examination as a standard in the secondary survey to identify certain occult injuries. The value of this examination technique in pediatric patients is still unclear due to high false positive and negative rates and poor sensitivity (22, 41).

Besides localization of pain, the clinical examination must aim for the degree of pelvic stability. As in adults

Tab. 2. Numbers of main associated truncal injuries

Author	Year	No.	Head	Chest	Abdominal	Liver	Spleen	Spine
Banerjee	2009	44	5	15	6	?	?	6
Spiguel	2006	13	4	4	2	?	?	0
Chia	2004	125	53	33	20	?	?	?
Grisoni	2002	57	15	4	8	?	?	?
Silber	2001	166	64	33	32	?	?	2
Rieger	1997	54	26	10	?	7	7	3
Lane O Kelly	1995	68	25	5	1	0	0	3
Sy	1995	43	8	1	2	?	?	0
Rangger	1994	21	4	5	5	0	0	1
Barabas	1991	55	43	13	30	?	?	4
Ducloyer	1988	267	150	22	41	?	?	12
Musemeche	1987	57	13	10	12	3	3	2
Reichard	1980	120	30	10	5	5	0	6
Bryan	1979	52	12	3	3	1	1	0
Stuhler	1977	68	18	1	1	0	0	0

repeated manoeuvres of stability testing should be avoided as these could increase the danger of bleeding.

Overall, clinical examination of the pelvis revealed a sensitivity of 69% and a specificity of 95%. The positive predictive value was 65% and the negative predictive value was 91% (17), but pelvic instability is rarely seen in pediatric pelvic fractures (1/33 patients, 3%) (36).

Additional diagnostics, like primary bedside hemoglobinometry, evaluation of the vascular and neurological status is recommended. Early protection against hypothermia should be performed with conective patient warming systems.

7. Radiological examination

The gold standard in pediatric pelvic injury examination still remains the anterior-posterior pelvic X-ray even when the possibility of the presence of a pelvic fracture is <1% with a negative clinical examination. This is also due to medio-legal aspects, as clinical evaluation can be negative while even minor displaced fractures can be present.

Recent data suggest that in the hemodynamically stable patient who is awake and alert without signs of peripheral nerve lesions and a negative pelvic examination, the standard a.p. X-ray cannot longer be recommended (19, 35), whereas in unstable pediatric patients an a.p. X-ray together with an abdominal-pelvic CT scan is mandatory (12).

Other pelvic views (inlet, outlet, and Judet views) and magnetic resonance imaging (MRI) allow further delineation of the more complex aspects of the injury. Therefore, they may be useful in determining the need for elective operative treatment, but have no place in the acute assessment of the pelvic fracture and their value is not definitivly stated in the literature.

Comparable to adults, conventional cystography is not further required for detecting and classification of bladder injuries. In suspected urethral lesions, a retrograde urethrogram is still the diagnostic standard.

Computed tomography (CT) has an increasing place in the initial evaluation of the pediatric trauma patient (8) and there is a potential advantage in pediatric polytrauma patients (7, 8). Presently, the rate of primarily perfomed CT diagnostic is between 60-80% (5, 11, 12, 43). Therefore, if in doubt, additional CT should be obtained (7, 8, 25).

But, despite additional fracture detection, a management change is rarely necessary (11, 12, 43).

There are some special remarks analyzing pediatric radiographs. The presence of physes and apophyses may make radiographic recognition of fractures difficult. The symphyseal width changes with different ages (33). There is a change from an average of 7.5 mm after birth to 5.5 mm in the adoslescent time. Additionally, CT-analysis of disrupted SI-joints showed typically Salter-Harris type I and II lesion of the joint and normally no pure dislocations (21).

Silber et al. found significant differences comparing pediatric patients with immature and mature pelvic injuries. In the immature pelvic fracture group significantly more pubic rami fractures and iliac wing fractures were observed, whereas in the mature fracture group significantly more acetabular fractures and fractures with pubic and SI-joint diastasis were seen (42).

8. Classification

Several classifications are used in the literature. The most commonly used classifications are the classifications of Key and Conwall (20), of Torode and Zieg (51) and the classification of the AO/Orthopaedic Trauma Association (32).

The Key & Conwall classification is a follows (20):
I: no break in the pelvic ring (avulsion, iliac wing, upper or lower pubic fracture)
II: single break in the pelvic ring
III: double break in the pelvic ring (anterior posterior, straddle fracture)
IV: isolated acetabular fracture.

The distribution of these fracture types was analysed by several authors (5, 17, 29). In the series by Chia et al. there were 55.8% type I injuries, 27.5% type II injuries and 11.7% type III injuries. Isolated acetabular fractures were seen in 5% (5). The two smaller series found an overall frequency of 37.5%, 42.8%, 10.7% and 8.9% respectively (17, 29).

The Torode classification also distinguishes between four fracture groups (51).
I: avulsion fractures
II: iliac wing fratures
III: simple pelvic ring fractures (pubic rami fractures, stable symphyseal disruptions)
IV: ring disruption fractures (unstable pelvic segment, straddle fractures, additional acetabular fractures, anterior + posterior ring fractures).

The minority of fractures belongs to group I and the majority of fracturest of group III. Four analyses were presented in the current literature (40, 43, 44, 47). The overall frequency of fracture types showed 3.1% type I, 14.8% type II, 54.5% type III and 27.6% type IV fractures.

The AO/OTA classification of pelvic injuries is well established in the adult group (32). This classification analyses the injury pattern depending on specific fracture locations and evaluates the type of pelvic stability. Three different groups of stability/instability are differentiated:
– Type A: these fractures are stable, the mechanical ring structure of the pelvic ring remains intact
– Type B: partially unstable injuries with partial posterior, rotational instability after antero-posterior or lateral compression
– Type C: unstable injuries with combined anterior and posterior, vertical instability.

The proportion of fracture groups was analysed by different authors. Blasier et al. reported on approximately 70% type A-injuries and 30% unstable injuries (type B and C) (3). Grisoni et al. stated on 83.3% type A injuries, 14.5% type B and only one type C-injury (11).

Other authors found rates of 73.5% type A, 11.8% type B and 14.7% type C injuries (23), 57.4% type A, 26.7% type B, 15.8% type C (14) and 55% type A, 35% type B and 10% type C injuries (37). Only Rieger et al. had a significant higher rate of unstable fractures (65%) (40).

Thus, an overall rate of 60-80% type A fractures, 10-35% type B injuries and 10-16% type C injuries can be expected.

In contrast, analysing patients with complex pelvic trauma Meyer-Junghänel et al. found less stable injuries (19%), but 28.6% rotationally unstable injuries and 52.4% type C injuries (27).

For emergency classification of these injuries and to facilitate the identification of life-threatening pelvic injuries, the following definitions have been shown to be useful even in the pediatric trauma group, practicable, and of relevance as far as a prediction of mortality is concerned (34):

– *simple* pelvic fractures with little soft tissue injury, and pure osteoligamentous instability. This group covers about 90% of pelvic fractures.
– *complex pelvic trauma* as a pelvic fracture combined with a serious soft tissue lesion in the pelvic region.
– fractures with *pelvic and haemodynamic instability*: mechanically unstable pelvic fractures (type B or C) combined with haemodynamic instability related to the pelvic injury with a systolic blood pressure of <70 mmHg and/or a haemoglobin concentration of <8g/dl on admission.
– *traumatic hemipelvectomy*: a total or subtotal dislocation of one or both hemipelvises with complete disruption of the vascular and neural structures of the pelvis.

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