

# Pelvic Ring Injuries in Children. Part II: Treatment and Results. A Review of the Literature

## Zlomeniny pánevního kruhu u dětí. Část II: Léčba a výsledky. Přehled literatury

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### 9. EMERGENCY TREATMENT

Emergency treatment in the pediatric trauma patient with a pelvic fracture is orientated to the concepts established in adults (59). The main parameters in decision making are the hemodynamic situation and the grade of instability of the pelvis (36).

It has to be considered that the child has a longer hemodynamic compensation before a severe shock state results in a potential near fatal situation.

Hauschild et al. found that in children emergency measures were taken in 17.9% compared to a rate of 11.1% in adults patients (19).

Due to the anatomical differences of the child's pelvis and the higher risk of injury to the pelvic viscera, it has to be considered that the presence of pelvic and extremity fractures predicts concomitant abdominal and head injuries (5, 6, 50, 61) and therefore the overall risk of bleeding complications (5, 23, 30, 58, 61).

Bleeding is commonly secondary to associated solid-organ injuries (6, 15, 23, 41, 43, 50, 58).

#### Pelvic bleeding control

To evaluate the hemodynamic situation a helpful parameter is the initial base deficit, which is a strong prognostic indicator of shock, high injury severity, shock related complications and mortality (24).

The presently accepted measures in controlling pelvic hemorrhage are angiography/embolization and pelvic packing. Angiography and embolization to stabilize hemodynamics in pediatric patients with pelvic fractures can be successful, but reported time intervals between admission and the beginn of embolization ranges between 12 and 15 hours (38).

The incidence of angiographic interventions is reported to be approximately 5% (8).

Direct bleeding control is possible by vascular ligation, vascular clips (clamps) and rarely a vascular reconstruction of major vessels and is the principle aim of every haemostasis in the pelvic region (12). The more common venous bleedings from large ruptured venous

plexus have the disadvantage of a time-consuming bleeding control with sometimes additional blood loss. Therefore, in exsanguinating diffuse pelvic bleeding pelvic tamponade is proposed under a condition of emergent posterior pelvic ring stabilization (35). Therefore, angiography/embolization is recommended in patients with moderate hemodynamic instability (12), whereas pelvic packing is recommended in patients "in extremis" (12).

#### Pelvic emergency fixation

Historically it was stated that operative pelvic stabilization to control bleeding is rarely necessary (33, 43).

Today, several emergency measures are described to stabilize a mechanical unstable pelvis.

Antishock trousers are no longer routinely used in adults due to their high rate of complications (12). Prophylactic application of pelvic slings, pelvic bed sheets or pelvic belts this device at the scene or in the emergency department has to be considered in pediatric patients with unstable pelvic fractures (51).

Pelvic external fixation is the commonly used stabilization technique in pediatric pelvic fractures (3, 9, 16, 17, 40, 42, 44, 45, 53, 58).

Advantages are the experience in applying an external fixator and the application is faster and less morbid than other surgical treatments for unstable pelvic fractures, and therefore provides an excellent alternative to pelvic open reduction in the acute treatment of pediatric patients with multi-system injuries.

McIntyre et al. found a 60% rate of controlled bleeding after external fixation was applied (30). Even in children, the pelvic C-clamp can be used to stabilize the posterior pelvic ring (22).

In conclusion, emergency stabilization of unstable pelvic ring injuries in children should at least be stabilized by pelvic sheeting or external fixation.

Definitive reduction and internal fixation in the acute management is only recommended when the patient is in a stable condition. Symphyseal plating, anterior plating of the SI-joint and application of transiliosacral screws are feasible (46).

## 10. DEFINITIVE TREATMENT

There was a long-term dominance of treating pediatric pelvic fractures in children with bed rest, traction, pelvic slings, or hip spica casts (2, 6, 15, 33, 34, 39, 41, 45, 58). The overall aim of treatment should be anatomic reduction and maintenance of a symmetrical pelvis (6, 48). This can be achieved in the majority of children by conservative-functional treatment (Figs 1 and 2).

Recent, operative stabilization of pelvic ring injuries in children plays an increasing role in present management concepts. Several authors report on their experience with closed or open reduction especially in unstable pelvic ring injuries (Table 1). Most authors prefer external fixation (9, 16, 42, 44, 58).

Today, external fixation is rarely recommended and is stated to be indicated only when pelvic ring displacement is greater than 2 cm to avoid limb-length discrepancies (21).

In contrast, Keshishyan et al. had better results after external fixation compared to conservative treatment (28).

As previous authors have suggested that nonoperative management of displaced pelvic fractures may result in pelvic asymmetry, leading to poor clinical results, several authors focussed on operative stabilisation of the pelvic ring (3, 27, 45, 55, 58).

Accepted indications for operative fixation were:

- concomitant treatment when open wound treatment is necessary
- additional hemorrhage control during resuscitation (4)
- optimization of patient mobility
- prevention of deformity in severely displaced fractures (6, 28, 34, 42, 48)
- in special situation to improve patient care (e.g. polytrauma).

Therefore, only displaced fractures require surgical reduction and stabilization (4, 20, 48, 50, 58) and at the present time, only case descriptions are reported in the literature.

- Zimmermann et al. stabilized three children with PDS-banding of the pubic symphysis in two and of the SI-joint in one case (63).

- Gänsslen et al. reported on symphyseal plating and anterior plating of a disrupted SI-joint of a C1.2 injury in a three-year-old child with a good clinical and radiological follow-up result after 17 months (13).



Fig. 1. 12-year-old boy injured in a car crash as a restrained passenger. Initial pelvis a.p. x-ray shows a fracture dislocation of the right SI-joint and a left anterior ring fracture (a). Conservative treatment with pain dependent mobilization after 3 weeks was initiated. 21-year follow-up shows complete bony healing with complete restoration of the bony pelvis in the a.p. view (b), the inlet (c) and outlet view (d).



Fig. 2. 10-year-old boy injured in a car crash as a restrained passenger. Initial pelvis a.p. x-ray shows left anterior ring fracture (a). Conservative treatment with pain dependent mobilization was initiated and after 3 weeks good callus formation was already present with clinically no symptoms (b). 2-year follow-up shows a complete bony healing with some minor malunion (c).

Table 1. Numbers of type of treatment

(EF = external fixation, ORIF = open reduction internal fixation, CRIF = closed reduction internal fixation)

Author	Year	Conservative	EF	ORIF	CRIF	ORIF+EF	% osteos.	No.	Overall
Banerjee	2009	43	1	0	0	0	2.2%	1	44
Spiguel	2006	11	2	0	0	0	15.4%	2	13
Karunakar	2005	134	0	12	2	0	9.5%	14	148
Chia	2004	118	2	5	0	0	5.6%	7	125
Grisoni	2002	52	0	0	0	1	1.8%	1	57
Silber	2001	165	0	1	0	0	0.6%	1	166
Uppermann	2000						9.5%	9	95
Rieger	1997	38	6	6	1	0	29.6%	16	54
Keshishyan	1995	31	12	0	0	0	27.9%	12	43
Rangger	1994	18	1	1	1	0	14.3%	3	21
Barabas	1991						5.5%	3	55
Stachel	1987						2.8%	3	108
Musemeche	1987	51	2	4	0	0	10.5%	6	57

- Stiletto et al. performed open reduction and anterior plate osteosynthesis of an disrupted SI-joint without anterior ring stabilization in two patients  $\leq 3$  years of age (55).
- The latter three patients had long-term follow-up with an uneventful situation 2 years after the injury.
- Blasier et al. analysed 43 of 57 patients with unstable Tile type B and C injuries. 13 patients were treated operatively. In nine patients a combined anterior plating and posterior iliosacral screw fixation was performed, one patient had an external fixator alone, and in three patients manipulative reduction and application of a spica cast was performed (4).
- Baskin et al. treated SI-joint (fracture) dislocations by closed reduction and CT-guided percutaneous iliosacral screw fixation in three children with an age of 8, 13 and 14 years (3). In all three cases an anterior external fixator was additionally applied prior to posterior ring fixation. All cases showed near-anatomic reduction. Removal of the external fixator was performed after 5–6 weeks postoperative. At follow-up at least 12 months postinjury only slight impairments at the posterior pelvis were observed.

Despite these case presentations especially performed in C-type injuries of the pelvis no clear concept is presented in the recent literature.

There is still a wide range of operative intervention in pediatric pelvic fractures ranging from 0.6% up to 30% with comparable rates of external fixation and internal fixation (1, 2, 7, 17, 27, 28, 33, 40, 45, 50, 53, 54, 60).

Our own concept was developed with the knowledge of several long-term sequelae after treating pediatric patients with complex pelvic trauma (31).

We propose a treatment concept of these injuries, under consideration of associated organ injuries, and the hemodynamic stability of the patient, which depends on the patient's age, the type of fracture and the stability of the pelvic ring (36). A comparable concept was recently reported by Silber and colleagues (49).

## 11. TREATMENT OPTIONS IN PELVIC RING INSTABILITY

In pediatric patients with an unstable pelvic ring with stable hemodynamics, reconstruction and anatomic stabilization of the pelvis is the primary goal. The indication of pelvic ring stabilization depends on the stability of the pelvis.

In stable type A fractures surgical stabilization is normally not required as functional treatment will not lead to further displacement. Treatment consists of short time bed-rest and early ambulation, depending on the patient's pain. Open reduction and internal stabilization is only performed in severely displaced or open fractures (e.g. iliac crest fractures, pubic rami fractures with the risk of concomitant bladder lesions and rarely in avulsion fractures in young athletes).

In rotational unstable B-type fractures operative stabilization of the anterior pelvic ring provides sufficient stabilization for early ambulation with partial weight bearing. B-type fractures with a symphyseal disruption normally need an open reduction and plate stabilization of the pubic symphysis, as external fixation alone leads to a high rate of secondary displacement in adults, whereas the more "stable" lateral compression injuries, especially minimally displaced lateral compression sacral fractures, in the majority of cases can be treated by conservative means. External fixation of these injuries is rarely necessary.

C-type injuries with a complete instability of one or both hemipelvises should be treated by combined posterior and anterior stabilization as posterior displacement of  $> 5$  mm leads to a high rate of malunion.

The type of implant depends on the fracture/injury region and more important on the patient's age.

In adolescent patients (age 14–18 years) the well known osteosynthesis concepts can be applied to children (59).

Within the group of immature patients with an open triradiate cartilage we distinguish between patients with an age  $\leq 10$  years and a group between 10–14 years.

In patients > 10 years of age normally implants comparable to adults can be used. Possibly, anatomy-adapted implants should be used.

In the younger age group (age ≤ 10 years) the special anatomic situation has to be considered when choosing the type of osteosynthesis:

- **symphyseal disruption:** screw/cerclage osteosynthesis, possibly with additional transosseous suturing in toddlers, in older children plate osteosynthesis with a two-hole 1/3 tubular plate or a two-four-hole small fragment plate (Figs 3–6)
- **displaced upper pubic rami fractures:** in risk of bladder laceration: open reduction and stabilization in toddlers with a K-wire, in older children with a 3.5mm transpubic cortical screw
- **unstable transpubic fractures as part of a type B- or C-injury:** supraacetabular external fixator
- **iliac wing fracture:** in toddlers: K-wire stabilization, in older children screw- and/or plate osteosynthesis
- **transiliac fracture dislocation (“crescent fracture”):** posterior screw fixation of the iliac fracture by closed or open reduction (Fig. 1)
- **sacroiliac dislocation:** anterior plate osteosynthesis with “mini-implants” (e.g. small H-plate), in older patients 3-hole small fragment plate(s) (Fig. 5)
- **sacral fractures:** minimal invasive stabilization technique with percutaneous iliosacral K-wire fixation or with a 3.5mm screw.

Mobilisation with partial weight bearing is started 3–4 weeks postoperatively or dependent on associated injuries. A pain adapted mobilisation is favoured. We recommend an implant removal of internal implants after 3–6 month. An external fixator can be replaced 2–3 weeks postoperatively.

## 12. HOSPITAL COURSE

Data from the american national inpatient pediatric database showed an average stay in the hospital of 5.2 days with pelvic fractures being the

second most expensive hospitalization cause with an average cost of 15011.61 \$ per patient (11).

The typical duration of stay in the hospital is reported to range between 6 and 22 days with a median of

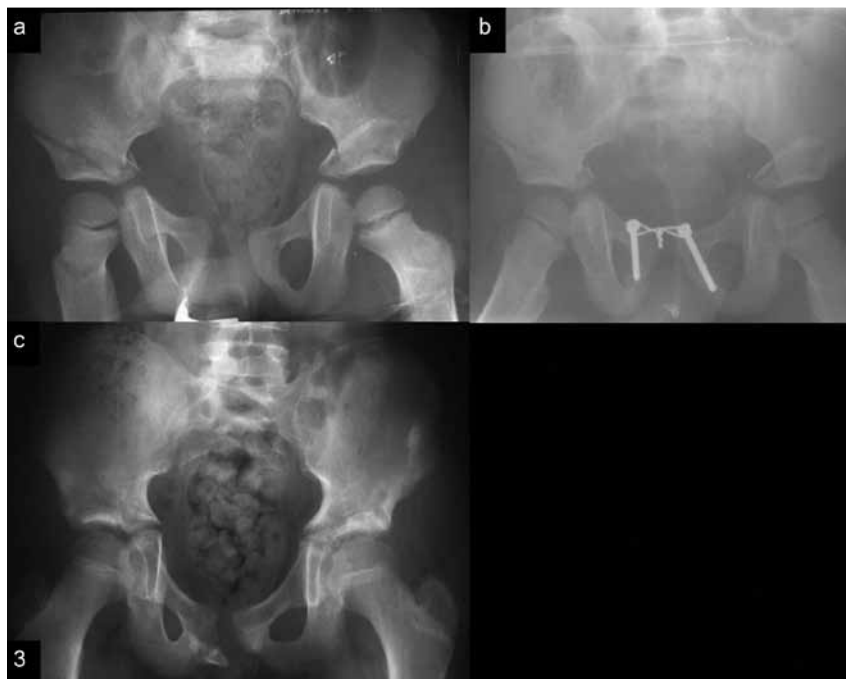


Fig. 3. 4-year-old boy hit by a car as during walking. Pelvis a.p. x-ray shows symphyseal disruption and left widening of the SI-joint in combination with bilateral acetabular triradiate injuries (a). Symphyseal stabilization was performed with screw/cerclage-wiring (b). Follow-up x-ray 8.5 years after the injury shows anatomical healing of the pelvic ring with presently no signs of growth disturbances of both hip joints (c).

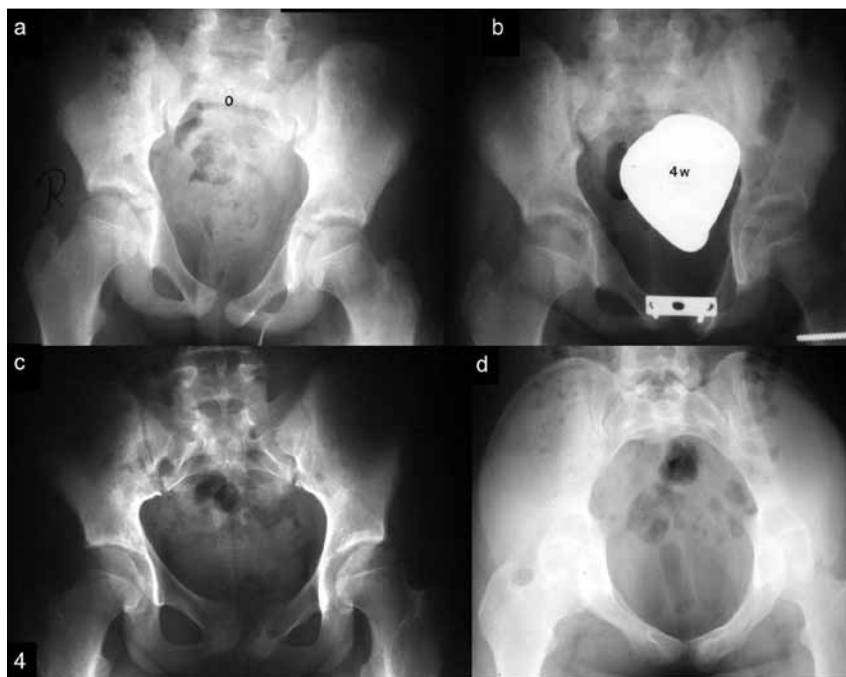


Fig. 4. 10-year-old girl hit by a car as during walking. Pelvis a.p. x-ray shows symphyseal disruption with no clear signs of SI-joint involvement (a). Initial treatment consisted of symphyseal stabilization with a 3.5mm DC-plate (b). Follow-up 4 years after the injury shows adequate bony healing with good reconstruction of the inner pelvic ring (c) and a normal ring structure (d).

Table 2. Mortality in pediatric pelvic fractures

Author	Year	No. of patients	Patients died	%
Banerjee	2009	44	7	15.9%
Hauschild	2008	x	x	8.2%
Spiguel	2006	13	0	0%
Vitale	2005	1190	86	7.2%
Chia	2004	125	5	4%
Grisoni	2002	57	3	5.3%
Guillamondegui	2002	130	3	2.3%
Junkins	2001	16	2	12.5%
Silber	2001	166	6	3.6%
Uppermann	2000	95	4	4.2%
Rieger	1997	54	8	14.8%
Lane O'Kelly	1995	68	0	0%
McIntyre	1993	57	2	3.5%
Vazquez	1993	79	3	3.8%
Barabas	1991	55	4	7.3%
Bond	1991	54	6	11.1%
Gottorf	1991			6.8%
Garvin	1990	36	1	2.8%
Musemeche	1987	57	8	14.0%
Stachel	1987	108	3	2.8%
Torode	1985	141	11	7.8%
Reichard	1980	120	2	1.7%
Bryan	1979	52	4	7.7%
Stuhler	1977	68	6	8.8%
Reed	1976	83	2	2.4%
Poigenfürst	1972	23	2	8.7%
Quinby	1966	20	5	25.0%

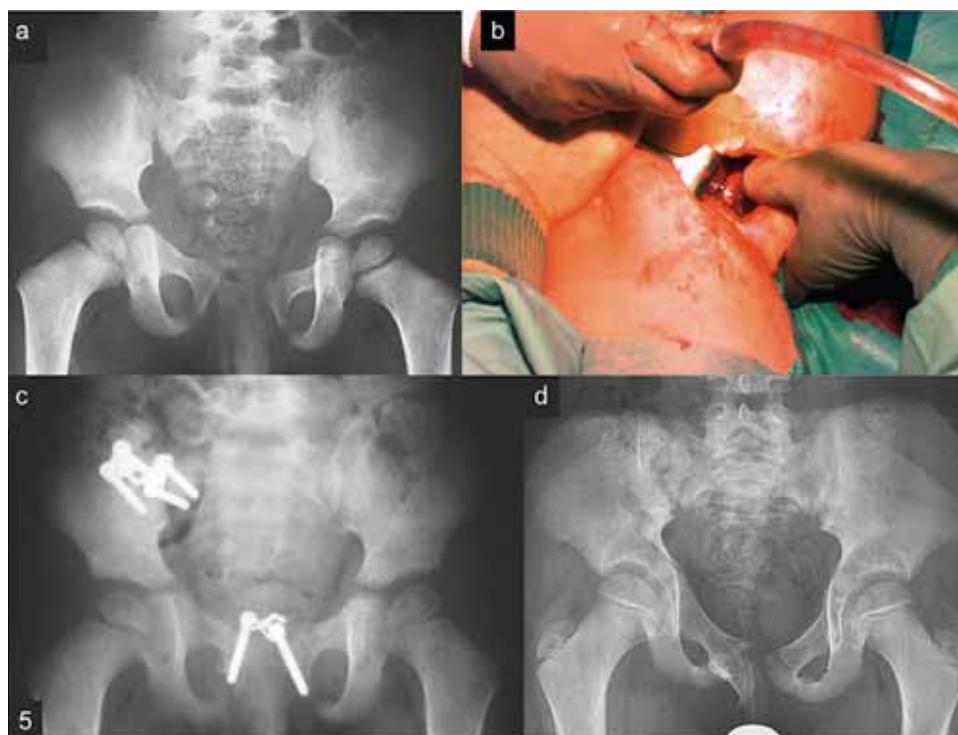


Fig. 5. 3-year-old boy after roll-over injury with right SI-joint dislocation and symphyseal disruption (a). A small H-plate was via an antero-lateral approach (b) used to stabilize the SI-joint and symphyseal stabilization was performed by 3.5mm schrew and cerclage osteosynthesis (c). Implant removal was performed after 10 weeks. 6-year follow-up shows some right hemipelvic deformity and heterotopic ossification at the pubic symphysis (d).

8–9 days (1, 7, 25, 53, 62) and the majority of patients can be discharged home (approximately 70%) (1, 53).

Within this time an average of 5 days is for ICU therapy (1, 7, 50).

### 13. MORTALITY

Mortality is reported to between 0% and 25% with an average of 6.4% (Table 2) (1, 2, 5–7, 15–19, 26, 29, 30, 33, 37, 39, 41, 43, 45, 50, 53, 54, 56, 58, 60–62).

There was no significant change on mortality in pediatric pelvic trauma during the last 30 years (5.6–6.4%).

Some authors state that death from pelvic fractures is rare in children (5, 33, 41). Analysis of the available data show an

incidence of 1% (Table 3) (6, 19, 45, 50).

Analysis of the cause of death showed a significant association with additional severe head injury and the overall injury severity (62). Further factors which significantly influence mortality were the presence of complex pelvic trauma (19% mortality) (31), the type of pelvic fracture (30, 58) and the presence of an open crush injury, a subgroup of complex pelvic trauma (20% mortality) (32), whereas in the analysis of Subasi et al. no change in overall mortality could be found in unstable type B- and C-injuries (57).

#### 14. LONG-TERM RESULTS

Several long-term problems are stated in the literature.

Fracture related sequelae were persistent nerve deficits (7, 9), a recto-vaginal fistula (33), dyspareunia or altered vaginal sensation, vaginal obstructive complications (10) and pelvic infection (33).

Especially after complex pelvic trauma a high rate of local complications were observed. Mosheiff et al. had 11 wound and septic complications in 15 patients with open crush injuries of the pelvis in 15 patients (73%), two cases of recurrent bowel obstructions and one case of vascular graft failure (32). Meyer-Junghänel et al. reported on a 38% complication rate (31). Two patients had wound complications and three had severe bleeding complications.

The majority of reported complications are due to bony healing. These are leg length discrepancies (7, 9), delayed pubic union (9), fracture non-union (7, 9, 14, 45, 58), subluxation of an SI-joint (7), premature sacroiliac fusion (9, 15, 20, 58), persistent symphyseal diastasis (14, 45, 58), symphyseal ankylosis (Fig. 7) (54), pelvic asymmetry due to malhealing (Fig. 8) (9, 54), hemipelvic undergrowth (9, 15, 20, 58), development of lumbar scoliosis (7) and low back pain (9, 15).

Nonunions of the anterior pelvic ring, including diastasis of the pubic symphysis, usually causes no long term problems and thus does not need specific therapy (9, 14, 45, 58).

Malunion can create leg length discrepancy and may lead to low back pain and spinal deformity (9, 15), but no data on displacement tolerance are available from the literature.

Sacroiliac injury can progress to premature sacroiliac fusion with development of hemipelvic undergrowth (9, 15, 20, 58).

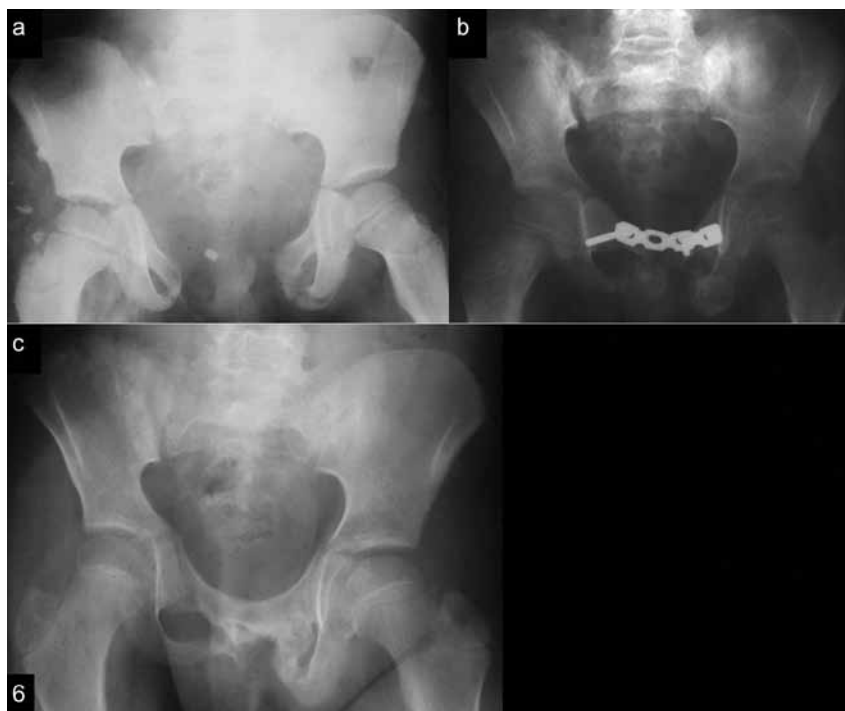


Fig. 6. 6-year-old girl after roll-over injury with open complex pelvic trauma. Initial pelvic a.p. x-ray shows significant symphyseal disruption, right SI-joint widening (a) and open right groin with a right Morell-Levallé-lesion and lacerations of the urethra, rectum and vagina. Primary stabilization of the pelvis was performed by symphyseal plating with a reconstruction plate leading to an acceptable pelvic ring reconstruction at 6 weeks (b). 3.5-year follow-up shows ankylosis of the symphysis with some internal rotation deformity of the right hemipelvis (c).

#### Several reports focus on long-term results

126 children had a follow-up after a mean of 4 years (1–28 years) in the analysis by Richter et al. (44).

11 patients had pain, 16 had impairments during sporting activity and in 14 patients the pelvis showed clinical asymmetry. Bony deformities were present in 29 cases (23%).

Rieger et al. analysed 35/44 patients after an average of 135 months (18–235) (45). They found an increase in long-term problems from type A to type C injuries.

11 of 12 patients after type A-injury were without any symptoms, only one patient reported low back pain, probably due to leg length discrepancy after femoral and lower leg fracture. The incidence of long-term problems is therefore 8.3%.

Of eight type B-injuries, in one case a non-union at the anterior ring together with degenerative changes of the SI-joint was observed but with only slight clinical impairments. Another patient showed a symphysiodesis and a third patient developed an urethral stenosis resulting in an overall incidence of 37.5% long-term sequelae.

Of 11 patients after type C-injuries, seven reported on low back pain and two had functional restriction due to pelvic injury related gait abnormalities and due to nerve injuries. The overall incidence of long-term sequelae was 63.6%.

Schwarz et al. in a multicentre study had long-term results in 17 of 32 patients (follow-up rate: 53%), which were less than 12 years at the time of injury (48) and





Fig. 7. 14-year-old girl fell from a horse, which crushed on her pelvis. She sustained bilateral inferior pubic rami fractures (a) and a left SI-joint disruption seen on CT evaluation (b). The SI-joint was stabilized by anterior plate osteosynthesis. After 1,5 years a near anatomic reconstruction was seen on a.p. (c) and inlet views (d).

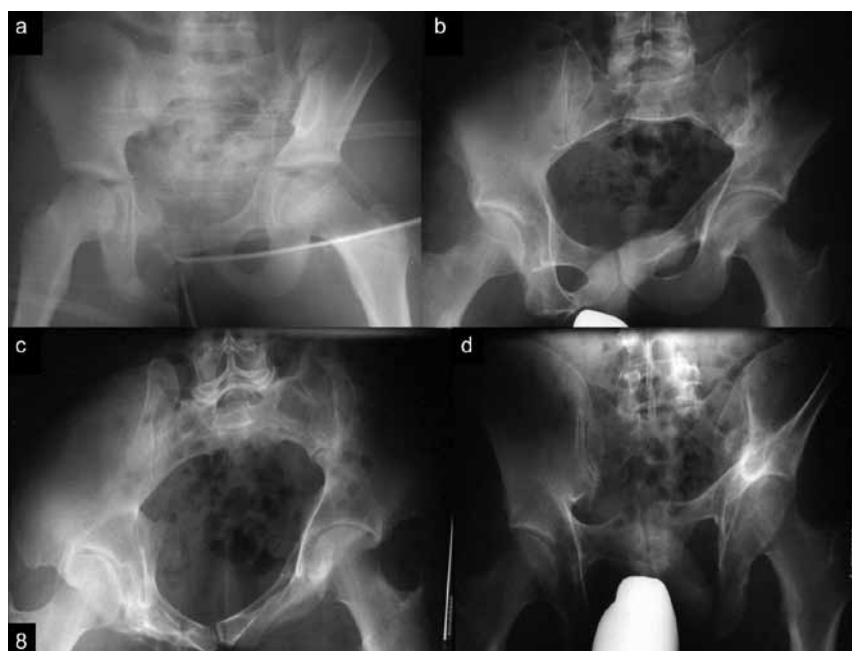


Fig. 8. 9-year-old boy driving bicycle was hit by a car with approximately 50 km/h. Pelvis a.p. x-ray shows a left crescent fracture and a contralateral anterior ring fracture (a). Conservative treatment was initiated. A follow-up study 14 years after trauma shows hemipelvic malhealing with rotational deformity of the hemipelvis and hemipelvic hypoplasia (b), posterior malhealing (c) while no relevant superior malhealing was observed (d).

found a correlation between healing in malposition and poor results.

Follow-up was at least two years after the injury ranging from 2 to 25 years. Low back pain which was

present in 6 patients (35.3%). This correlated strongly with pelvic asymmetry. Eight patients had a lumbar scoliosis and eight had significant radiographic asymmetry (each: 47.1%). Five patients had a leg length discrepancy of > 2 cm (29.4%). Overall, five patients complained about chronic back pain (29.4%).

In a former analysis the same Schwarz et al. reported on long-term results of 17 children from a multi-center study (47). Nine patients had a type B- and eight an type C-injury. No non-unions have been observed. One patient had a hemipelvic asymmetry due to acetabular dysplasia. Two patients had asymptomatic widening of the pubic symphysis and 10 patients had scoliosis. Again, there was a correlation between the clinical and radiological result.

Meyer-Junghänel et al. analysed 16 of 21 (76.2%) patients after complex pelvic trauma (31). Nine patients were completely painfree at an average follow-up of 9 years. Three had moderate to severe pain. Persistent nerve deficits could not be observed. Four patients had urinary incontinence (25%).

The radiological result showed only nine anatomical healings (incidence of radiological abnormalities: 43.7%). Two patients had a malhealing with 10–12mm displacement. Three patients showed degenerative changes at the SI-joint and three patients had an ankylosed SI-joint. Two patient developed ankylosis of the pubic symphysis. Re-evaluation of the primary and follow-up x-ray found overlooked injuries in 8 patients. In the majority of patients sacral fractures were not diagnosed primarily.

Blasier et al. found no significant difference in subjective scoring between type B- and C-injuries for pain at rest, pain with activity, limp and leg length discrepancy. Overall, there were 92% good or excellent results in the patients who were treated operatively and 80% good or excellent results in the patients who were treated nonoperatively (4).

Subasi et al. followed 55 patients with unstable type B- and C-injuries (95% of their series) after a mean of 7.4 years. Gait abnormalities were seen in 4 patients (7.3%), leg length discrepancies and low back

Table 3. Pelvic fracture related mortality in children

Author	Year	No.	Patients died	Pelvic source	% pelvic source/death	% pelvic source/all
Bryan	1979	52	4	2	50%	3.8%
Hauschild	2008	134	11	1	9.1%	0.7%
Rieger	1997	54	8	1	12.5%	1.8%
Silber	2001	166	6	0	0%	0%

pain each in 6 patients (10.9%), degenerative SI-joint changes and symphyseal sclerosis each in two patients (3.6%) and an ankylotic SI-joint in one patients.

Additionally, there were 11 urethral strictures (20%), 6 patients suffered from urinary incontinence and 6 from erectile dysfunctions (10.9%). 56% of the patients had long-term psychiatric disorders (57).

Overall, after type C-injuries more long-term sequelae were observed (Fig. 3).

Smith et al. analysed 20 patients 3–12 years of age with unstable fractures at an average follow-up of 6.5 years. In patients with primary pelvic asymmetry no remodelling was observed until to the last examination (52).

Overall, 17 of 20 patients showed pelvic asymmetry. There was a 48% vs. 18% reduction of asymmetry after operative vs. conservative treatment. External fixation alone showed more asymmetry than results after anterior + posterior stabilization. After type C-injuries, asymmetry was 3.5 cm initially and 3.3 cm at follow-up after external fixation and 3.9 cm and 0.6 cm after posterior internal fixation.

## CONCLUSION

Pelvic ring injuries in children  $\leq 14$  years are rare. The main injury mechanism is a high energy trauma resulting in a significant rate of additional head injury. Anatomical differences compared to adults result in larger forces necessary to produce pelvic injuries. The rate of complex pelvic trauma is higher. The mortality rate is comparable to adults 6.4%. Emergency treatment is orientated to adult standards, whereas definitive treatment is performed by conservative means in the majority of patients. During the last years increasing evidence shows that unstable injuries should be treated by external or internal fixation techniques with child adapted implants. The main treatment modality is the external fixator.

Present data on long-term results after pediatric pelvic trauma indicate several long-term sequelae in unstable pelvic injuries depending on the instability of the child's pelvis at the time of injury. There is a good correlation between the clinical and radiological result. Type A-injuries normally heal without any problems.

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