

Surgical treatment for unstable pelvic fractures in skeletally immature patients

João Antonio Matheus Guimarães^{a,*}, Pedro Henrique B Mendes^a, Frederico C M Vallim^a,
Leonardo R Rocha^a, Tito H N Rocha^a, Isabel Cristina C do Val^b, Maria Eugenia L Duarte^a

^a National Institute of Traumatology and Orthopaedics, Rio de Janeiro, Brazil

^b Department of Health Science Post-Graduate Studies at the Federal Fluminense University, Rio de Janeiro, Brazil

KEYWORDS

Unstable pelvic fracture
Children
Reduction
Stabilisation
Pelvic asymmetry
Pelvic ring
Skeletally immature patients

ABSTRACT

Objective: To present the results and conclusions of our study on surgical treatment for unstable pelvic fractures in children subjected to surgical reduction and stabilisation.

Methods: We analysed the cases of fourteen skeletally immature patients with unstable pelvic fractures who underwent surgery for this condition between March 2004 and January 2011. The surgical technique used was based on the principle of surgical reduction and stabilisation of anterior and posterior lesions of the pelvic ring. This was a retrospective study, based on clinical assessment and X-ray analyses.

Results: The mean age of patients at the time of the condition was 9.4 years (range 2–13 years). Eight patients were female and six were male. The cause of the trauma was being hit by a car in ten cases, falls in three cases and an accident involving a motorcycle in one case. Five patients presented with other associated injuries, including fracture of the clavicle, femur shaft, proximal humerus, tibial shaft or olecranon, and bladder damage. All the patients assessed showed excellent clinical progress. Pelvic asymmetry prior to surgery varied from 1.1 to 2.9 cm (mean 1.5 cm) and dropped to a range of 0.2 to 0.9 cm (mean 0.4 cm) after reduction. In none of the cases was there a change between the pelvic asymmetry measured immediately after surgery and at the end of the follow-up period.

Conclusion: Pelvic fracture in skeletally immature patients is rare and surgery is not normally indicated. Various authors have questioned this conservative type of treatment due to complications encountered. Bone remodelling does not seem to be sufficient to ensure an improvement in pelvic asymmetry, which justifies opting for surgery to reduce and correct deformities in the pelvic ring.

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Introduction

Pelvic fractures in skeletally immature patients are relatively rare, accounting for less than 0.2% of all paediatric fractures and 1–5% of admissions to tertiary children's health clinics [1,2]. These fractures are usually caused by high-impact accidents and are often combined with injuries to other organs (the genitourinary system, abdominal viscera, central nervous system, neurovascular and musculoskeletal structures) [3].

Although they have a relatively low rate of occurrence, pelvic injuries in children are associated with high levels of morbidity and mortality. A post-mortem study that examined 66 deaths caused by trauma in children showed pelvic fracture and severe bleeding to be the cause of death in 42% of the cases. As with adults, retroperitoneal bleeding is the worst complication in cases of unstable pelvic fractures [4–6].

Children with pelvic fractures have a greater survival rate for the associated injuries compared with adults and thus represent a higher socioeconomic cost and higher morbidity over the long term. A prospective study conducted on 95 children with pelvic fractures evaluated the patients' locomotive capacity and level of dependency. The results showed that 80% of the patients with unstable fractures, and 52% of those with stable fractures, were dependent on help for getting around [6–8].

Conservative treatment involving rest, traction and a cast has been recommended for pelvic fractures in children, because of the potential of this approach for curing the injury via the bone remodelling that occurs in this age group. However, many cases progress negatively due to potential complications, which are characterised by pelvic asymmetry, non-structural scoliosis, lower back pain, discrepancy in length of the lower limbs and claudication when walking. The conservative type of treatment does not produce satisfactory functional outcomes for some injuries that involve major displacement, particularly the presence of dislocation of the sacroiliac joint due to a vertical instability, or even in cases of acute accentuated horizontal instability. The presence of open triradial cartilage in the child promotes remodelling, but there is no consensus in the literature

* Corresponding author at: Instituto Nacional de Traumatologia e Ortopedia (INTO), Avenida Brasil 500, São Cristóvão, 20940-070, Rio de Janeiro, RJ, Brazil. Tel.: 55-21-2134-5102; fax: 55-21-2135-5089.

E-mail addresses: jomatheus@uol.com.br (J.A. Matheus Guimarães).

on the best way to treat these serious injuries and there is still much controversy over which children are likely to benefit from this invasive type of treatment [1,3,4]. In an emergency situation where there is haemodynamic instability, immediate treatment must be conducted using an external fixation, even if only temporarily, to prioritise controlling the bleeding and saving the patient's life [9]. In cases with dislocation of the sacroiliac joint, using only an anterior external fixation will not be sufficient to reduce and stabilise the posterior ring [10].

The purpose of this article was to present the results of definitive surgical treatment for unstable pelvic fractures in children subjected to surgical reduction and stabilisation on an elective basis after primary care has been given in the emergency ward.

Methods

After receiving approval from the Research Ethics Review Board, we evaluated fourteen skeletally immature patients with unstable pelvic fractures who were treated surgically at the National Institute of Traumatology and Orthopaedics (Rio de Janeiro, Brazil) between March 2004 and January 2011. The selected patients underwent outpatient clinical assessment and pre- and post-operative X-rays were analysed. All the patients had been given primary care at the emergency ward of another institution and were referred to our department for final treatment because of the complexity of their injuries. The inclusion criterion for the study subjects was an unstable pelvic fracture in patients with radiological signs of an immature skeleton, which was defined by the presence in X-rays of triradial iliac cartilage. Any patients with a stable fracture or with a pattern of non-displaced fracture of the iliac or the sacrum were excluded from the study.

The surgical technique used in this study was based on the principle of surgical reduction and stabilisation of anterior and posterior fractures of the pelvic ring. The anterior component, a fracture of the rami or symphysis pubis dislocation, was reduced indirectly using a tubular external fixation frame comprising only two Schanz pins in the supra-acetabular region of each iliac, inserted with the help of radioscopy based on inlet and outlet views of the iliac. The diameter of the Schanz pins used was suited to the diameter of the patient's bone: in three cases, 5.0 mm were used and in all the other cases, 3.5 mm pins were used due to the dimensions of the pelvis in question, along with the corresponding connectors and bars, to assemble the external fixation.

An anterior access to the pubic symphysis for direct reduction of the dislocation was performed in only one case because of the time elapsed since the injury, and a 3.5 mm plate was used to set the bone. For the posterior pelvic fracture, the indirect reduction method, via anterior manipulation with the supra-acetabular Schanz pins, combined with longitudinal traction of the lower limb, enabled the use of a cannulated screw inserted through the small incision into the injured sacroiliac. In 11 cases, this screw was 4.0 mm in diameter because the safety corridor for insertion was smaller due to the dimensions of the immature bone. In three cases, the grooved screw was 7.0 mm in diameter because these three were older children whose pelvis was large enough to support this dimension. In only one case, where the posterior injury was a "crescent" fracture in the wing of the iliac, the anterior fixation with a supra-acetabular external fixator frame was used alone and bone consolidation took place successfully without loss due to reduction. In three cases where there were fractures in both sacroiliac joints as a result of lateral compression, the bilateral fixation was used with cannulated screws. The anterior external fixation was removed at between six and eight weeks, following radiological evidence



Fig. 1. Keshishyan et al. [5] method of measuring pelvic obliquity, where the pelvic asymmetry is the difference in length between the diagonals ($X - Y$ cm). The degree of deformity corresponds to the difference in the diagonals ($X - Y$ cm) divided by the sum of the diagonals ($X + Y$ cm).

of consolidation of the fractures. In all thirteen cases where cannulated screws were used for posterior stabilisation of the sacroiliac joint, it was not necessary to remove this implant after the injury had healed.

This was a retrospective study based on an evaluation of medical records, clinical assessments and X-rays, with a mean follow-up period of 808.83 days after the original injury. The study endpoint was based on a radiographic quantification of residual pelvic asymmetry after surgery, using the method of Keshishyan et al. [5] (Figure 1), comparing pre- and post-operative findings. In this method, pelvic asymmetry is determined by the difference, in centimetres, between the lengths of two diagonal lines drawn from the rim of the sacroiliac joint to the contralateral triradial cartilage. Normal anatomical variation in this measurement is considered to be 4 mm of asymmetry, which may occur due to rotation of the pelvis at the time of the X-ray; over 5 mm, this deformity must be considered to be pathological [5]. Pelvic asymmetry was also correlated with the deformity index, which is the difference in length of the two diagonal lines divided by their sum, to provide a minimal error due to this rotation of the pelvis in antero-posterior X-rays.

Patients were clinically assessed by means of an interview and a physical examination. Assessments included the arc of movement and the abductor force of the hip joint, deviations in the spinal column, neurological sequelae, gait characteristics and the presence of pain upon palpating the pelvis. These data were correlated with X-ray findings.

Results

Patient clinical data are shown in Table 1. There were eight females and six males in the study. The mean age at the time of injury was 9.4 years (range 2 to 13 years). Patients underwent surgery with a mean elapsed period of 11 days from the time of fracture (range 4 to 29 days). The cause of the initial trauma was being hit by a car in ten cases, falling from heights in three cases, and an accident involving a motorcycle in one case. The bone and joint injuries to the pelvis were divided into anterior and posterior, with symphysis pubis dysfunction present in seven patients, fracture of two rami in four patients and fracture of four rami in three patients. In eight cases, the posterior injuries corresponded to dislocation of the sacroiliac joint; in one case,

Table 1
Patient clinical data

Case	Age (years)	Sex	AO-OTA classification	Mechanism of trauma	Posterior injury	Anterior injury	Cause of the accident	Related injuries
1	2	F	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Hit by a car	None
2	13	F	61 B1	Antero-posterior compression	Anterior sacroiliac injury	Fracture: 4 rami	Motorcycle accident	None
3	8	F	61 B2	Lateral compression	Dislocated sacroiliac	Fracture: 2 rami	Hit by a car	None
4	4	F	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Hit by a car	Fracture of the femur
5	7	M	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Hit by a car	Fracture of the collarbone
6	6	F	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Hit by a car	None
7	13	M	61 C2	Lateral compression	Dislocated sacroiliac + anterior compression (bilateral)	Fracture: 2 rami	Hit by a car	Bladder injury
8	10	M	61 C1	Vertical shearing	Posterior iliac fracture	Fracture: 2 rami	Hit by a car	None
9	12	F	61 C3	Lateral compression	Dislocated sacroiliac (bilateral)	Fracture: 4 rami	Hit by a car	Fractures of the humerus + tibia
10	13	F	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Fall	Fracture of the olecranon
11	12	M	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Fall	None
12	11	F	61 C3	Lateral compression	Dislocated sacroiliac (bilateral)	Fracture: 4 rami	Hit by a car	None
13	11	M	61 C1	Vertical shearing	Dislocated sacroiliac	Symphysis dislocation	Fall	None
14	10	M	61 C3	Lateral compression	Dislocated sacroiliac (bilateral)	Fracture: 2 rami	Hit by a car	None

there was a unilateral fracture of the posterior ilium; in one case, there was unilateral anterior opening of the sacroiliac joint; in one case, there was dislocation of the sacroiliac on one side and compression on the other caused by lateral compression; and in three cases, there was bilateral dislocation of the sacroiliac joints. The trauma mechanism was considered to be lateral compression in five cases, antero-posterior compression in two cases, and vertical shearing in seven cases. The AO-OTA classification [8] was used to assess the cases, and produced the following distribution: 61 B1 (one case); 61 B2 (one case); 61 C1 (eight cases); 61 C2 (one case) and 61 C3 (three cases). All of the patients were given primary care at another healthcare institution and were transferred to our hospital after initial clinical stabilisation. Five patients presented other associated injuries, and one case with a clavicle fracture was treated without surgery using external immobilisation. One patient presented with a shaft fracture of the femur and was treated using flexible intramedullary nails. One patient presented a fracture of the proximal humerus and an ipsilateral tibial fracture; the upper limb was treated conservatively and the tibia was fixed with flexible intramedullary nails. One fracture of the olecranon in a patient who suffered a fall was fixed using a tension band. One patient had a concomitant injury to the bladder, diagnosed using exploratory laparotomy during primary care; this injury progressed during hospitalisation to a urinary infection, which was treated with antibiotics.

The main complication of this method was the presence of superficial infection on the trajectory of the Schanz pins of the anterior external fixation in three patients. This infection completely disappeared after the pins were removed. The external fixation remained on the patients for a mean period of 40.5 days (range 28–48 days). The period of hospitalisation varied from 2 to 14 days, with a mean of 3.8 days. All of the patients showed excellent clinical progress, as assessed during the check-up visits. There were no cases of pain upon palpation of the pelvis, abnormal gait, discrepancy in leg length or scoliosis during the physical examination. There was no evidence of any vascular or nerve injury caused by use of the cannulated screw in the sacroiliac joint.

In the radiographic evaluation, pelvic asymmetry prior to surgery ranged from 1.1 to 2.9 cm (mean 1.5 cm) and dropped

Table 2
Assessment of pelvic asymmetry and degree of deformity

	Pre-operative	Post-operative	p
Pelvic asymmetry	1.53 (0.46)	0.41 (0.21)	<0.0001
Degree of deformity	0.12 (0.04)	0.04 (0.02)	<0.0001

to a range of 0.2 to 0.9 cm (mean 0.4 cm) after the reduction ($p < 0.0001$), see Tables 2 and 3. The follow-up period ranged from 210 to 1,896 days.

Figures 2 to 11 show X-rays and CT scans for two of the patients in the study.

Discussion

Unstable pelvic fractures in children are relatively rare and are caused by high-impact traumas. Pelvic injuries in children, as with those in adults, are accompanied by various organ injuries that are associated with high morbidity and mortality. Nevertheless, little is known about how these injuries progress in the long term [11–16].

The profile of the children studied is similar to that reported in the literature, except for the distribution by sex. Although these injuries generally occur more often in male children than female, eight (61.5%) of the thirteen cases studied were female. The most common cause of fracture in the current study was being hit by a car on the street, which agrees with that reported by Signorino et al. [4]. The nature of the most common cause of fracture indicates the high-impact type of trauma required to cause this kind of damage to a child's pelvis, particularly as the bone is more pliable than in adults and has a greater capacity to absorb the force generated in the initial impact. This capacity in children is also reflected in their lower mortality following high-impact trauma with damage to the pelvis. In statistical terms, this type of injury is fatal in 5% of the cases involving children and in 17% involving adults [12,13].

Several studies [13–17] have analysed the long-term progression of unstable and stable pelvic injuries treated conservatively. Schwarz et al. [17] report a 47% rate of poor results due to pelvic asymmetry; they stress the importance of achieving anatomical reduction and conclude that unstable pelvic fractures

Table 3
Results of the treatment administered

Case	Time between the accident and surgery (days)	Surgery performed	Pre-op pelvic asymmetry (cm)	Post-op pelvic asymmetry (cm)	Pre-op degree of deformity (Keshishyan)	Post-op degree of deformity (Keshishyan)
1	16	Symphysis plate + SI screw	1.7	0.2	0.2	0.02
2	5	External fixator + SI screw	1.2	0.5	0.1	0.04
3	11	External fixator + SI screw	1.8	0.3	0.17	0.04
4	6	External fixator + SI screw	1.2	0.5	0.15	0.04
5	14	External fixator + SI screw	1.2	0.2	0.09	0.03
6	14	External fixator + SI screw	1.5	0.6	0.09	0.05
7	29	External fixator + SI screw	2.9	0.9	0.15	0.09
8	12	External fixator	1.1	0.4	0.12	0.03
9	8	External fixator + bilateral SI screws	1.5	0.5	0.07	0.03
10	4	External fixator + SI screw	1.2	0.2	0.09	0.03
11	10	External fixator + SI screw	1.7	0.2	0.07	0.01
12	7	External Fixator + Bilateral SI screws	1.3	0.6	0.10	0.05
13	7	External Fixator + 2 SI Screws	1.8	0.2	0.16	0.01
14	7	External Fixator + Bilateral SI screws	1.3	0.4	0.15	0.04



Fig. 2. Case 9, female, 12 years old, hit by a car, mechanism of trauma was lateral compression; anterior injury was a fracture of four rami and posterior was a bilateral sacroiliac dislocation.



Fig. 3. Case 9, CT scan revealing dislocations in both sacroiliac joints.



Fig. 4. Case 9, postoperative X-ray, AP view showing supra-acetabular external fixation and cannulated screws in both sacroiliac joints.



Fig. 5. Case 9, postoperative X-ray, AP view showing the final result.



Fig. 6. Case 13, male, 11 years old, fall from a height, mechanism of trauma was vertical shear, anterior injury was a symphysis disruption and a posterior sacroiliac dislocation.



Fig. 7. Case 13, CT with 3 D reconstruction.



Fig. 8. Case 13, CT in axial view showing a sacroiliac dislocation.

treated conservatively progress with unacceptable functional outcomes. Other authors [3,14,18–22] report cases of unstable

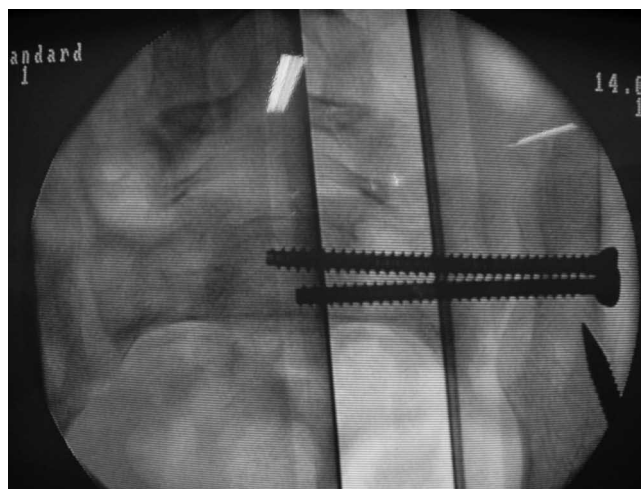


Fig. 9. Case 13, intraoperative C-arm view after posterior fixation.



Fig. 10. Case 13, postoperative X-ray, AP view showing supra-acetabular external fixation and two cannulated screws in the left sacroiliac joint.



Fig. 11. Case 13, postoperative X-ray, AP view showing the final result.

pelvic fractures treated without surgery that progress with unsatisfactory results, including residual lower back pain, a discrepancy in lower limbs, Trendelenburg's sign, and lumbar

scoliosis due to residual pelvic asymmetry. None of the cases treated surgically in our study population progressed with residual pain, altered gait or any abnormalities in their physical examination. A limitation in our study is the relatively small patient population, but as this is a rare type of fracture that affects approximately one child out of 100,000 per year, we believe that this sample is relevant; furthermore, there are no major series published on surgical treatment of this type of injury [23]. The results encourage us to continue recommending surgical treatment for those cases where there is pelvic asymmetry greater than 0.5 cm and, mainly, whenever there is a related dislocation of the sacroiliac joint that is not likely to progress satisfactorily using non-surgical treatment methods. Posterior fixation was combined with a sacroiliac cannulated screw because this method is not very invasive, provides adequate mechanical stability to the posterior portion of the pelvis and has proven to be a safe and reproducible method for use in children. Isolated application of an anterior external fixation does not enable the control of the posterior portions of the pelvis [24]. Smith et al. [3] showed that patients treated using reduction with combined anterior and posterior fixation had less residual pelvic asymmetry than patients treated with an anterior external fixation alone.

The diameter of the Schanz pins in the anterior external fixation must be suited to the bone dimensions of the child in question. The 4.0 mm cannulated screw proved to be adequate for stabilising a small pelvis where the safety margin of the sacroiliac was too small to use a 7.0 mm diameter. Likewise, Schanz pins of 3.5 mm in diameter enable anterior external fixation in cases where the dimensions of the ilium do not permit the use of a larger pin in the supra-acetabular region.

Pelvic fractures in skeletally immature patients occur relatively rarely, and surgery is not normally recommended as treatment. Various authors question the conservative type of treatment, which has been recommended for a number of years for these fractures, due to complications encountered, mainly a discrepancy in the length of the lower limbs and residual pain in the sacroiliac joint [25]. The bone remodelling that normally occurs in children with growth does not seem to be sufficient to ensure an improvement in their pelvic asymmetry when it is greater than 1.1 cm, as described in Smith et al. [3] This finding justifies the option of surgical treatment for reduction and correction of pelvic deformities, early on, at the time of the injury.

Conflict of Interest Statement

There have been no conflicts of interest in the preparation of this manuscript.

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