Original article
https://doi.org/10.18019/1028-4427-2025-31-2-153-164

Treatment of children with pelvic polytrauma with minimally invasive and combined osteosynthesis techniques

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Abstract

Introduction Pelvic fractures in children are rare but extremely severe injuries associated with a significant threat to life. The search for new rational tactics of their surgical treatment based on a combination of various minimally invasive osteosynthesis techniques and instruments for its implementation remains relevant.

The **aim** of the work was to evaluate the results of staged treatment and a combination of minimally invasive osteosynthesis techniques at different periods of traumatic disease in children with combined and multiple pelvic injuries.

Materials and methods An analysis of 48 cases of treating pelvic ring fractures in children who sustained combined and multiple injuries within the period of 2000 to 2023 was carried out. The study group included 23 children treated at the pediatric polytrauma center of the Amur Regional Children's Clinical Hospital, in whom the author's methods and instruments were used for anti-shock and final osteosynthesis of the pelvic ring. The comparison group included 25 patients treated at the Republican Scientific Center for Emergency Medical Care (Tashkent). The comparison group was divided into three subgroups based on the treatment method: conservative treatment, osteosynthesis with pins, osteosynthesis with an external fixation device (EFD). Pelvic fractures were classified according to AO/ASIF; the severity of polytrauma was assessed according to the ISS scale. Anatomical and functional treatment results were evaluated using the methods of I.L. Shlykov and S.A. Majeed.

Results In patients of the main study group, residual displacement was observed by 57.6 % less frequently than in the subgroup with conservative treatment, by 32.6 % than in the subgroup with wire osteosynthesis and by 15.9 % than in the subgroup with osteosynthesis with an external fixation device (EFD). The functional treatment result of patients in the main study group was significantly better than in the subgroups of conservative treatment and wire osteosynthesis of the comparison group, with no significant difference when compared with the subgroup of EFD osteosynthesis.

Discussion Staged combined treatment using developed techniques and metal structures for osteosynthesis allows better reduction and stabilization of pelvic ring fractures and achieves good functional results. Not all problems of pelvic surgery can be solved with EFD; a number of injuries require the use of internal osteosynthesis for more accurate reduction. Disintegrating pelvic injuries accompanied by complete bilateral instability should be operated using temporary transpedicular fixation, since there is no alternative to this method.

Conclusion The combination of external fixation with internal osteosynthesis provides accurate reduction and reliable stabilization of pelvic ring fragments. Staged specialized care including internal bleeding arrest and fixation with an anti-shock device at the first stage and final stabilization of pelvic ring fragments at the second stage is the most rational tactical approach to polytrauma in children. External fixation can be used not only as a reliable and simple anti-shock fixation, but also as a method of final osteosynthesis.

Keywords: pelvic ring fractures, paediatric trauma, multiple and combined trauma, damage control orthopaedics, external fixation device

For citation: Borozda IV, Nikolaev RV, Karimov MYu, Salakhiddinov FB, Mashsripov FA. Treatment of children with pelvic polytrauma with minimally invasive and combined osteosynthesis techniques. *Genij Ortopedii*. 2025;31(2):153-164. doi: 10.18019/1028-4427-2025-31-2-153-164.

INTRODUCTION

Pelvic fractures in children are rare but extremely severe injuries associated with a significant threat to life and the need for surgical interventions [1]. The anatomically immature skeleton of a growing child features increased flexibility with a greater range of motion of the sacroiliac joints and pubic symphysis. Factors contributing to the overall elasticity of the child's pelvis include an abundance of cartilaginous tissue, which provides excellent shock absorption, and an increased remodeling potential [2, 3, 4]. Therefore, a pelvic fracture in children is an indicator of a severe devastating injury, which leads to damage to other body systems and, accordingly, an increase in mortality.

As shown by current studies, pelvic trauma in children occurs in 1.6–2 % of cases, with the most common cause of pelvic trauma being road traffic accidents [5]. Having analyzed 163 hospitalization cases, Michelle et al [6] found that the most common concomitant trauma in children with pelvic ring fractures is fractures of other segments of the musculoskeletal system (60 %), damage to parenchymatous organs of the abdominal cavity (55 %) and organs of the chest (48 %), with the majority of children (61 %) sustaining injuries to several organs. Unstable pelvic fractures are associated with damage to the chest (70 % versus 40 %), heart (15 % versus 2 %) and spleen (40 % versus 18 %), $p < 0.05$. Concomitant injuries often cause such late sequelae as chronic pain, scoliosis, sexual dysfunction, leg length discrepancy, and even growth retardation, which are observed in up to 30 % of pelvic fracture cases in children [7]. In a retrospective study of 29 acetabular fractures in children aged 2 to 16 years with an average follow-up of 14 years, Heeg et al. showed that patients with central hip dislocations had a relatively poor outcome, with only one out of four patients who underwent surgical treatment achieving congruence [7]. The researchers note that the most common complications recorded after pelvic fractures are pelvic asymmetry (9.2 %), lameness (6.0 %), and leg length discrepancy (5.0 %) [8]. Although pelvic fractures occur in a relatively small number of children with injuries, the mortality rate after them reaches 25 %, which is mainly due to concomitant injuries to other organs and systems. Moreover, mortality among boys is 13 % higher than among girls (18 % versus 5 %) [1, 9–14].

Most contemporary authors agree that classifications and treatment strategies used for adults are not applicable to children due to differences in the physiology and mechanisms of pelvic injury [1, 15–17]. Publications on this topic have small sample sizes, limited analysis, or are simply outdated, which is noted by a number of researchers. Most articles are based only on the analysis of the nature and location of fractures and do not contain data on concomitant injuries, their treatment, and outcomes [2, 3, 16–21]. All this leads to the lack of clear recommendations for the management and treatment of pediatric patients with pelvic injuries [5, 11]. The search for a new rational tactic of surgical treatment based on a combination of various minimally invasive osteosynthesis techniques and instruments for its implementation remains relevant.

Purpose To evaluate the results of staged treatment and a combination of minimally invasive osteosynthesis techniques at different periods of traumatic disease in children with combined and multiple pelvic injuries.

MATERIALS AND METHODS

We analyzed the treatment results of 48 children who sustained combined and multiple pelvic ring injuries in the period from 2000 to 2023.

Inclusion criteria were patients under 17 years of age, pelvic ring fractures with impaired stability, relatively stable and unstable according to the AO/ASIF classification [22] in combination with damage to other bones of the skeleton and internal organs (multiple and combined injuries).

Based on the conducted retrospective analysis, two clinical groups were formed: the main group of the study (n = 23) and the comparison group (n = 25).

The main group of the clinical study included children aged 3 to 17 years who were treated at the pediatric polytrauma center (Level I TC) in the Amur Regional Children's Clinical Hospital (ARCH, Blagoveshchensk). The author's methods and tools were used in the treatment of patients.

The comparison group was formed from patients aged 5 to 17 years who received treatment at the Republican Scientific Center for Emergency Medical Care (RSCEMC, Tashkent, Republic of Uzbekistan), and was divided into three subgroups depending on the treatment method: conservative treatment (n = 8), osteosynthesis with pins (n = 9), osteosynthesis with external fixation devices (n = 8).

The study began in 2000, when transosseous osteosynthesis with external fixation devices (EFD) started to be used for the first time in the above-mentioned medical institutions. These institutions are regional (republican) centers for the provision of specialized care for children, which ensured the random nature of the study groups, since all patients who sustained severe pelvic injuries in the region were transferred to these institutions.

The main group and the comparison group were homogeneous in gender and age, and the groups did not have significant differences. The average age of the groups was 13.5 years in the main group, and 14.4 years in the comparison group ($p > 0.05$) (Table 1).

In the overwhelming majority of cases, the cause of the injuries was road traffic accidents (Table 2).

Table 1

Distribution of patients according to gender and age

Groups		Gender		Age					
		Boys	Girls	0–3	4–7	8–11	12–15	16–17	Mean value
Основная группа (n = 23)	абс.	14	9	1	2	2	7	11	13,5
	%	60,9	39,1	4,3	8,7	8,7	30,4	47,8	
Группа сравнения (n = 25)	абс.	14	11	–	1	1	8	15	14,4
	%	56	44		4	4	32	60	

Table 2

Distribution of patients based on trauma mechanism

Mechanism	Main study group (n = 23)		Comparison group (n = 25)	
	No	%	No	%
Road traffic accident	19	82,6	22	88
Fall from height	3	13,1	2	8
Compression	1	4,3	1	4

All patients in the main study group were diagnosed with closed pelvic ring fractures of AO/ASIF types B and C and acetabular fractures accompanied by traumatic shock. The children sustained pelvic injuries as a result of high-energy injuries, mainly road traffic and catatrauma; all these injuries were combined and multiple (Table 3). The severity of the injuries according to the ISS scale ranged from 15 to 50 points.

All patients in the comparison group were also diagnosed with closed pelvic ring fractures of AO/ASIF types B and C and acetabular fractures accompanied by traumatic shock (Table 3).

Table 3

Distribution of patients based on associated pathology

Complications and associated injuries	Pelvic injury type											
	Relatively stable				Unstable				Acetabular fracture			
	Main study group (*n* = 23)		Comparison group (*n* = 25)		Main study group (*n* = 23)		Comparison group (*n* = 25)		Main study group (*n* = 23)		Comparison group (*n* = 25)	
	No	%	No	%	No	%	No	%	No	%	No	%
Traumatic shock	15	65.2	19	76	8	34.8	6	24	12	52.2	12	48
Fractures of other segnebts	1	4.3	3	12	2	8.7	2	8	–		2	8
Celebro-cranial injury	1	4.3	6	24	3	13.1	4	16	4	17.4	2	8
Trauma of abdominal organs	2	8.7	7	28	7	30.4	7	28	3	13.1	1	4

Five patients of the main study group (mostly residents of the region central city) were referred to the ARCCH within the first three hours after the injury, 18 patients were transported to the clinic within a period of one day to two weeks from level II trauma centers. The treatment tactics was based on the principles of staged medical care in full compliance with damage control orthopaedics. All patients in the level II trauma center were treated according to the ATLS protocol by the on-duty team or the mobile team of the level I trauma center and injuries were fixed with anti-shock devices with an anterior frame. Then, after complete stabilization of the general condition, on the sixth to eighth day, final reduction and stabilization of the pelvic ring fragments were performed using one of the selected methods, according to the developed algorithm (rationalization proposal No. 1837 dated 20.03.2012).

The following author's techniques and instruments were used for anti-shock and final osteosynthesis of the pelvic ring: devices for repduction and fixation of pelvic fractures [23, 24]; a method of combined osteosynthesis for unstable pelvic injury with rupture of the sacroiliac joint [25], a method of transosseous osteosynthesis for unstable pelvic injury associated with a vertical fracture of the sacrum [26], a method of transosseous osteosynthesis for unstable pelvic injury [27], and a transosseous module for reduction and fixation of the posterior sections of the pelvis [28]. Osteosynthesis of the sacroiliac joint with a screw and fixation with a half-pin apparatus with an anterior module was used in four patients. Three patients underwent final reduction and fixation with a device with a posterior external module in addition to the anti-shock apparatus with an anterior frame. Osteosynthesis of the acetabulum fracture with screws, as a final osteosynthesis after conversion of the anti-shock apparatus with an anterior external frame, was performed in two patients.

During the first three hours after the injury, 12 patients of the comparison group were delivered to the RRCEM, and 13 were transported there from district medical institutions within a period of one day to two weeks. All patients sustained high-energy trauma (road traffic accidents and catatrauma). The ISS severity of the injuries ranged from 15 to 50 points, similar to the main group patients. Eight injured children (32 %) received intensive anti-shock treatment, arrest of intracavitary bleeding and stabilization of pelvic ring fragments with skeletal traction until fracture consolidation (conservative treatment). Damage control tactics and the ATLS protocol were used in 17 patients (68 %). Pelvic osteosynthesis with an external fixation device with an anterior frame was performed in eight patients (32 %), internal pelvic osteosynthesis with Kirschner wires (36 %) in nine patients.

Anatomical and functional treatment results were assessed using the methods of IL Shlykov [29] and SA Majeed [30]. The residual deformation (anatomical result) was assessed using the method of IL Shlykov, and the functional treatment result (except for sexual dysfunction, since not all patients were adults at the time of assessment) was assessed using the method of SA Majeed. Thus, combining these scales allowed us to obtain an integrated indicator (overall result), which we reported in our earlier studies [31]. The studies were approved by the Ethics Committee. The patients' parents gave informed consent for the treatment.

Statistical analysis was performed using the Statistica v 12.0 software packages. The reliability of differences in mean values was assessed using the nonparametric Student's t-test (for independent samples). To assess the sample indicators, the arithmetic mean (*M*) and the error of the mean (*m*) were calculated. Differences were considered significant at $p < 0.05$.

RESULTS

Treatment results were followed from one to 14 years after the injury (Table 4). To assess the anatomical treatment result, an analysis of the presence and magnitude of residual displacement was used [29]. In patients of the main study group, residual displacement was detected in four (17 %) cases. Its mean value was (5.0 ± 0.3) mm.

Table 4

Treatment results

Результат лечения	Main study group		Comparison group (n = 25)					
			Conservative treatment		Osteosynthesis with pins		EFD osteosynthesis	
	No	%	No	%	No	%	No	%
Number of patients	23	100	8	32	9	36	8	32
Anatomical result								
Number of residual displacement	4	17,4	6	75	6	66,6	4	50
Magnitude of residual displacement, M ± m, mm	5.0 ± 0.3		9.5 ± 1.1		6.0 ± 0.33		6.0 ± 0.38	
	$p_{1,2} < 0.001$				**$p_{1,3} < 0.05$**		**$p_{1,4} < 0.05$**	
Functional outcome according to Majeed (1989)								
Excellent (85–96 points)	12	52.2	2	25.0	1	11.1	4	50.0
Good (70–84 points)	6	26.1	–	–	3	33.3	2	25.0
Fair (55–69 points)	5	21.7	2	25.0	1	11.1	2	25.0
Poor (< 55 points)	–	–	4	50.0	4	44.5	–	–
Mean, M ± m, points	77.0 ± 2.5		69.0 ± 1.09		70.0 ± 1.33		79.0 ± 2.82	
	$p_{1,2} < 0.01$				**$p_{1,3} < 0.05$**		**$p_{1,4} > 0.05$**	
Total result								
Good	19	82.6	2	25.0	4	44.5	6	75.0
Fair	4	17.4	2	25.0	3	33.3	2	25.0
Poor	–	–	4	50.0	2	22.2	–	–

Note: $p_{1,x}$ — significance of the criterion of reliability of the difference between the indicators in the main study group and the comparison groups

Thus, the functional treatment outcome of (77.0 ± 2.5) points in patients of the main study group was significantly better than in the subgroups of conservative treatment, (69.0 ± 1.09) points ($p_{1,2} < 0.01$), and osteosynthesis with pins in the comparison group (70.0 ± 1.33) points ($p_{1,3} < 0.05$), with no significant difference in comparison with the subgroup of osteosynthesis with EFD (79.0 ± 2.82)

points ($p_{1,4} > 0.05$). Consequently, the use of osteosynthesis with EFD in the treatment of children with combined pelvic injuries provides better functional results compared to conservative treatment and osteosynthesis with pins.

However, residual deformity at the end of treatment was detected in 16 (64 %) patients of the comparison group. The values of this indicator were as follows: 6 (75 %) patients in the conservative treatment subgroup — (9.5 ± 1.1) mm ($p_{1,2} < 0.001$); 6 (66.6 %) patients in the subgroup of osteosynthesis with pins H_{mean} = (6.0 ± 0.33) mm ($p_{1,3} < 0.05$); in the subgroup of osteosynthesis with an external fixation device (EFD) in 4 patients (50 %) — with H_{mean} = (6.0 ± 0.38) mm ($p_{1,4} < 0.05$).

Thus, in patients of the study main group compared with the subgroup of conservative treatment, residual displacement was observed less frequently by 57.6 %, with the subgroup of osteosynthesis with pins by 32.6 %, with the subgroup of osteosynthesis with external fixation devices by 15.9 %. The average value of residual displacement in patients of the main study group was significantly lower than in patients of the comparison group in all compared subgroups. Consequently, the use of the developed methods and metal structures for osteosynthesis in the patients of the main group provides more accurate reduction and reliable fixation of pelvic fractures than with the use of conservative treatment and traditional methods of osteosynthesis.

The evaluation of the overall treatment outcome in patients of the main study group found that the number of good results was 57.6 % higher than in the patients treated conservatively, 38.1 % higher than in patients with osteosynthesis using pins, and 7.6 % better than in the subgroup of traditional EFD osteosynthesis. The number of satisfactory results was lower than in the subgroups of the comparison group, and there were no poor results in patients of the main study group and in the comparison subgroup of EFD osteosynthesis.

The long-term treatment outcome was assessed as fair in two patients of the main study group who sustained severe high-energy pelvic trauma due to fall from a five-story building (a 15-year-old boy) and being hit by a tractor (a 9-year-old girl) despite the complete restoration of the musculoskeletal system, since in the first case there remained a neurological deficit due to rupture of the sacral plexus roots, and in the second case, there were long-term consequences of damage to the urinary tract.

Case report 1 *(main group patient)*

Patient Z., 14 years old, sustained a road traffic injury while driving a motobike, he collided with a car. First aid was provided by an ambulance team. He was transported to the central district hospital at his place of residence (level II trauma center), where his examination revealed damage to the pelvic ring, closed craniocerebral injury, forearm fracture, blunt abdominal trauma, and traumatic I–II degree shock. Anti-shock therapy was administered.

Clinical diagnosis: severe combined road traffic injury; closed fracture of the pelvic bones (fracture of the upper branch of the left pubic and ischium without displacement of fragments, rupture of the pubic symphysis with displacement, rupture of the sacroiliac joint on the right with diastasis in the upper part up to 2 cm and bone fragments (AO type C 1.2); closed fracture of the L5 transverse process on the right with displacement of fragments; closed fracture of the middle third of the right radius with displacement; blunt abdominal trauma; closed craniocerebral injury; concussion; multiple abrasions and bruises of the upper and lower extremities, on the head and body; traumatic shock stage II. ISS = 21.

CT of the pelvis revealed a rupture of the pubic and right sacroiliac joints with vertical displacement of the right half of the pelvis, a fracture of the pubic and ischial bones on the left without displacement, and a fracture of L5 right transverse process with displacement of fragments (Fig. 1 a).

In an emergency, two hours after admission, osteosynthesis was performed with an anti-shock half-pin based EFD with an anterior frame. After stabilization of the general condition, two days later, the child was delivered by air ambulance to the level I pediatric polytrauma center of the Regional Children's Clinical Hospital, where he was treated for three days in the intensive care and anesthesiology department, then transferred to the department.

A repeated operation was 10 days after the injury, osteosynthesis was performed with an additional posterior module using our own technique for the purpose of final reduction of the pelvic fragments (Fig. 1 b). A course of restorative treatment was carried out from the second day after the operation (Fig. 2 a).

The EFD was dismantled after eight weeks. Partial weight-bearing on the right leg was allowed one month after the operation, full weight-bearing after two months. The patient's treatment period was three months. The long-term result was assessed one year after the injury (Fig. 2 b). The overall treatment result is good. There is no residual displacement; the functional result is 90 points on the Majeed scale.

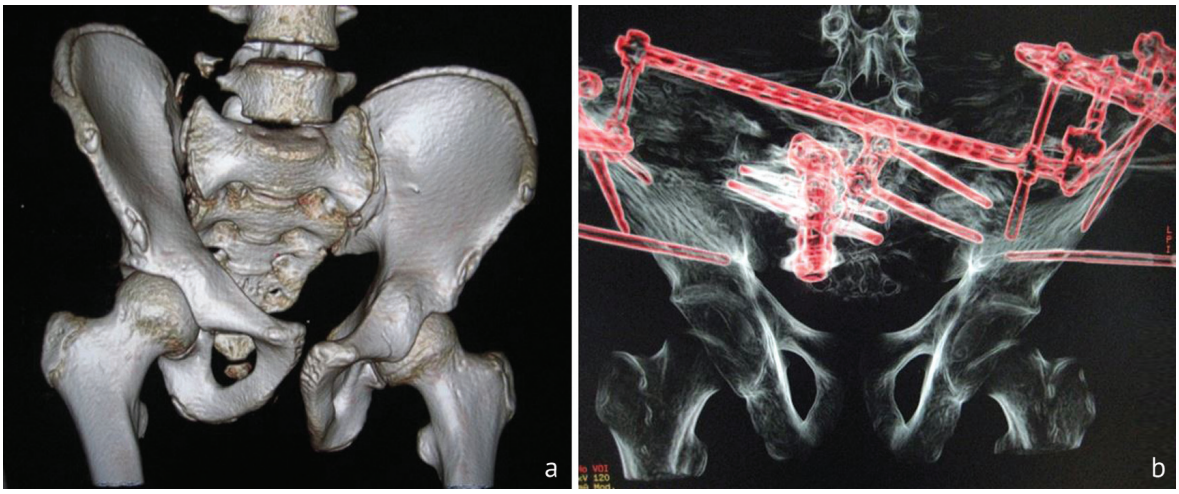

Fig. 1 CT scan of the pelvis with 3D reconstruction: *a* rupture of the pubic and right sacroiliac joint, fracture of the pubic bone and ischium on the left, fracture of L5 right transverse process of with displacement of fragments; *b* condition after final osteosynthesis with a half-pin based external fixator with two modules

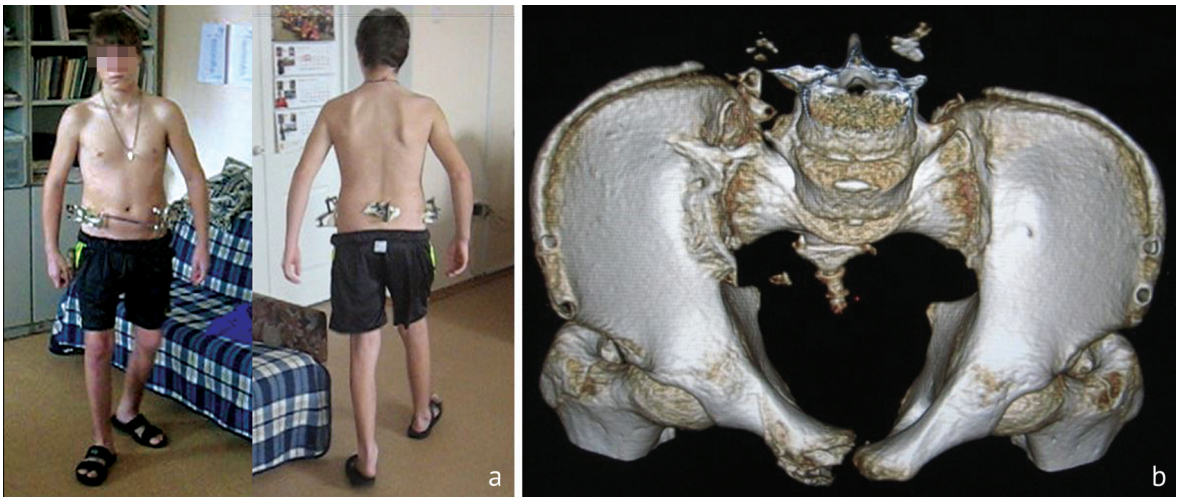

Fig. 2 The result of treatment of the patient of the main group: *a* photo during treatment, exercise therapy; *b* CT of the pelvis with 3D reconstruction one year after the injury

Case report 2 *(main group patient)*

Patient S., 5 years old, was struck with a falling heavy metal object (a vise) on her pelvic area. She was taken by an ambulance team to the Central District Hospital (Level II Trauma Center) 30 minutes after the injury.

Diagnosis upon admission: severe combined injury; open unstable multi-fragmentary fracture of the pubic and ischial bones, with a rupture of the pubic and sacroiliac joints (AO type B 1) (Fig. 3 a); urethra and vaginal injury, rupture of the bladder; traumatic shock stage III. ISS = 33.

In the course of anti-shock therapy, urgent suturing of the bladder wound, primary surgical treatment of the vaginal wound, and epicystostomy were performed. Fixation with skeletal traction was performed. Two days after stabilization of the condition, the patient was transferred to a level I trauma center (Amur Regional Children's Clinical Hospital). The operation was performed as planned, on the third day after the injury, pelvic osteosynthesis with an external fixation device and urethral reconstruction were performed (Fig. 3 b). Stabilization with the external fixation device continued for four weeks (Fig. 4).

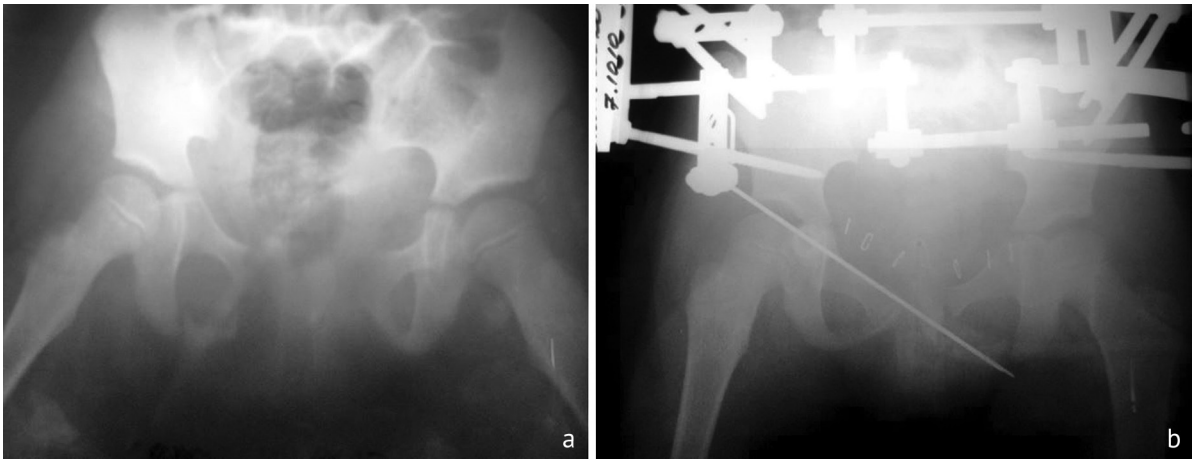

Fig. 3 Radiographs of the pelvis: *a* upon admission (direct view, fracture of the pubic and ischial bones with rupture of the pubic and sacroiliac joints); *b* condition after the intervention (urethral reconstruction, pelvic osteosynthesis with a wire-and-half-pin EFD)

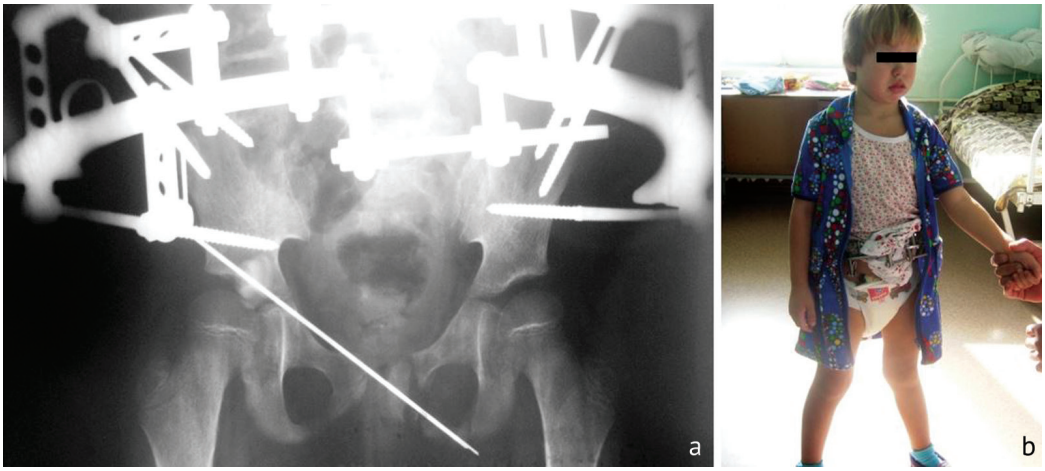

Fig. 4 The patient 4 weeks after the operation before dismantling the external fixation device: *a* X-ray of the pelvis; *b* photo during treatment

The device was dismantled four weeks later and a course of rehabilitation treatment started. The function of voluntary urination was restored three months after the operation. The treatment period was four months. The long-term result was assessed after three years (Fig. 5 a) and 10 years after the injury (Fig. 5 b). The overall treatment result was rated good. There was no residual displacement; the functional outcome was 90 points on the Majeed scale.

Fig. 5 Long-term follow-up result: *a* photo of the patient 3 years after the injury; *b* CT scan of the pelvis with 3D reconstruction 10 years after the injury

Case report 3 *(comparison group patient)*

Patient G., 16 years old, was injured by a stack of wooden boards that fell on the pelvic area. Forty minutes later, an ambulance team delivered him to the Margilan City Medical Association. After examination, the following clinical diagnosis was made: combined injury; multiple fractures of the pelvic bones; closed fracture of the pubic and ischial bones on both sides with displacement of bone fragments with transition to the bottom of the acetabulum; rupture of the symphysis; fracture of the lateral mass of the sacrum on the right with transition to the bodies S1,2 (AO Type C 1.3); complete rupture of the membranous part of the urethra; traumatic shock I–II stage. ISS = 25 points.

The radiograph of the pelvic bones showed a fracture of the pubic and ischial bones on both sides with displacement of bone fragments with transition to the bottom of the acetabulum on both sides, rupture of the symphysis, a fracture of the lateral mass of the sacrum on the right with transition to the bodies S1,2 (Fig. 6 a). On cystography (with a bladder filled with contrast), the bladder is completely filled, has a rounded shape, the contrast leak is noted in the projection of the membranous part of the urethra (Fig. 6 b).

According to emergency indications, laparotomy, abdominal cavity revision, epicystostomy, tamponade and drainage of the small pelvis were performed. The pelvic fragments were fixed with skeletal traction and a "hammock". After stabilization of the general condition, the patient was transported to the RSCfor EMC the next day.

On the 13th day after the injury, under endotracheal anesthesia, anterior stabilization of the pelvic bones was performed with a halfpin-based EFD, and the symphysis rupture was eliminated. A control X-ray of the pelvic bones revealed that the position of the bone fragments was satisfactory, the symphysis rupture was eliminated (Fig. 7 a).

Diagnostic urethroscopy was also performed intraoperatively: a 19 CH urethrocystoscope tube was freely passed through the urethra. The revision showed that the mucosa of the hanging section and bulbous part of the urethra was normal. At the level of the membranous section of the urethra, swelling of the mucosa and a sharp narrowing of the urethral lumen were observed, followed by complete obliteration, due to which it was not possible to pass the cystoscope tube. It was decided to stop the diagnostic intervention and the cystoscope tube was removed. There were no complications. The course of restorative treatment was started on the second day after the operation (Fig. 7 b).

The EFD was dismantled after eight weeks. Partial weight-bearing on the right leg was allowed one month after the operation and after two months full weight-bearing was initiated. The patient's treatment period was three months. The long-term result was assessed one year after the injury (Fig. 8). The overall treatment result was good, there was no residual displacement and the functional result was 90 points on the Majeed scale.

Fig. 6 X-ray of the pelvis: *a* fracture of the pubic and ischial bones on both sides with displacement of bone fragments with transition to the bottom of the acetabulum on both sides, rupture of the symphysis, fracture of the lateral mass of the sacrum on the right with transition to the bodies of S1 and S2; *b* leakage of thecontrast in the projection of the membranous part of the urethra

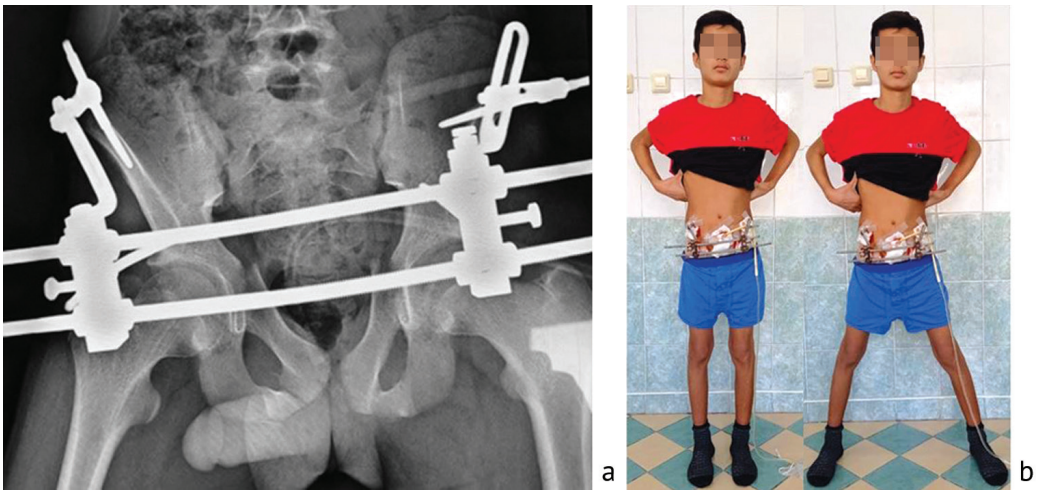

Fig. 7 The period of rehabilitation treatment: a X-ray of the pelvis with EFD fixation; b photo during treatment, exercise therapy

Fig. 8 X-ray of the pelvis one year after the injury

DISCUSSION

The use of staged combined treatment with the developed methods and metal structures for osteosynthesis allows improving the reduction and stabilization of pelvic ring fractures and achieves good functional treatment results. Therefore, staged transosseous osteosynthesis

in the treatment of children with pelvic fractures and polytrauma can be positioned as a method of choice in the fight against shock in the first period of traumatic disease, and can also be successfully used for final reduction and stable fixation of pelvic fragments.

Transosseous osteosynthesis has a number of advantages that are especially important in the treatment of multiple injuries. First of all, it is low invasiveness of transosseous elements, the ability to control fragments "in time" and combine the method with internal treatment technologies.

Back in 2004, the authors from the Ural Research Institute of Traumatology and Orthopedics demonstrated a series of technological solutions for treating patients with chronic pelvic injuries, allowing for full or partial correction of the deformation and stabilization of the pelvic ring [29]. If the most severe spatial deformations of the pelvic ring can be successfully corrected with halfpin-based external fixation devices, then the use of the same devices for the final reduction and retention of bone fragments allows for guaranteed good anatomical and functional treatment results.

However, not all problems in pelvic surgery can be solved with the help of external fixation devices; a number of injuries require internal osteosynthesis for more precise reduction, primarily acetabular fractures and sacral fractures with compression of the lumbar plexus roots. Heeg et al [7] and Michelle et al [6] indicate that these fractures are the cause of such long-term consequences as chronic pain, scoliosis, sexual dysfunction, leg length discrepancy and even growth retardation, which are observed in 30 % of pelvic fractures in children. However, transosseous osteosynthesis can also be used in this case as anti-shock fixation, after which it is possible to convert to open reduction with internal fixation.

The technical solutions we propose allow us to eliminate deformity and reliably fix the fragments until complete consolidation in case of unilateral vertical instability of the pelvic ring, as in the presented case 1. However, patients with disintegrating pelvic injuries accompanied by complete bilateral instability should be operated on using temporary transpedicular fixation, since there is no alternative to this method. In case of sacral fractures with compression of nerve roots, their early decompression is necessary in a specialized hospital with the mandatory participation of a neurosurgeon.

In case of damage to the urinary and genital tracts, it is necessary to strive to carefully restore the anatomy of the pelvic ring. A team approach is also necessary with the participation of a urologist and, if necessary, a gynecologist, which will allow to avoid severe post-traumatic complications not only from the musculoskeletal system, but also from the internal organs of the pelvis in the future, as in clinical case 2.

CONCLUSION

Optimization of the tactics of staged treatment of children with combined and multiple pelvic injuries using rational diagnostics and minimally invasive osteosynthesis with original designs provided a greater number of good and satisfactory results in the main study group compared to the treatment with traditional surgical methods in the comparison group. The severity of injury in children with pelvic fractures equal to 15 points of the ISS scale requires to use the damage control tactics. External fixation can be used not only as a reliable and simple anti-shock fixation, but also as a method of final osteosynthesis. The combination of external fixation with internal osteosynthesis can achieve accurate reduction and reliable stabilization of pelvic ring fragments. Staged provision of specialized care to stop internal bleeding and fixation with an anti-shock device at the first stage and final stabilization of pelvic ring fragments at the second stage is the most rational tactical approach to polytrauma with pelvic injuries in children.

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The article was submitted 18.06.2024; approved after reviewing 26.11.2024; accepted for publication 05.02.2025.

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