Outcomes following pelvic ring fractures in the paediatric population: A systematic review

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ABSTRACT

Background: Pelvic fractures represent a small proportion of all paediatric fractures, but are likely to be associated with a high-energy mechanism, multiple injuries, and significant morbidity and mortality. Operative fixation of unstable pelvic fractures is accepted. However, there remains a paucity of data on functional outcomes and complications following pelvic fractures in the skeletally immature.

Methods: A PRISMA-compliant systematic review was performed, searching Medline, Embase, and Cochrane central review. The primary outcome was functional outcome after pelvic fractures in the paediatric population following operative or non-operative treatment. Secondary outcomes included mechanism of injury, associated injuries, mortality rate, and method of surgical fixation if required. Where possible, weighted totals of the data set were performed.

Results: In total, 23 studies were included in this review. Only eight studies reported functional outcomes, with limb length discrepancy and limp being the most common complication. Only 8.8% of all pelvic fractures underwent surgical fixation. Motor vehicle collision was the most common cause of injury, and extremity fracture was the most common associated injury.

Conclusion: Paediatric pelvic fractures are caused by high-energy mechanisms and have significant morbidity and mortality. There remains a paucity of information on functional outcomes after these injuries.

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1. Introduction

Paediatric pelvic fractures are relatively uncommon injuries, with an approximate incidence of 0.2% of all paediatric fractures.^{1,2} Despite their infrequency, paediatric pelvic fractures are often the result of highenergy trauma and constitute up to 5% of all admissions to Level 1 paediatric trauma centres.^{1,2} These injuries are often associated with multi-system injury and a corresponding high Injury Severity Score (ISS).^{2–4}

The skeletally immature pelvis has many differences from an adult pelvis. It is composed of a higher percentage of cartilage, leading to a lower modulus of elasticity, and is therefore more likely

to deform under force rather than fracture.^{5,6} Thus, pelvic radiographs may only demonstrate asymmetry without obvious fracture.⁷ This increased elasticity may also result in a fracture at only one location of the pelvic ring, which goes against the concept of the “double break,” which is commonly described in adult pelvic ring injuries.⁷

Non-operative treatment of pelvic fractures in the paediatric population has historically been the standard of care.⁸ This was based on the concept of the skeletally immature pelvis being able to remodel. However, there has been an increasing trend toward operative fixation, with some studies suggesting that there is increased long-term morbidity with malunion.⁹ Limb length discrepancy (LLD), chronic pain, and low back pain have all been reported in paediatric patients following pelvic fractures.⁹

Appropriate pelvic fracture treatment, both operative and non-operative, is well studied and reported in the adult literature. Understanding of the osseous anatomy has led to improved fracture

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reduction and use of minimally invasive percutaneous screw placement techniques.¹⁰ It is well documented that poor anatomical reduction of pelvic fractures in adults leads to poor long-term functional outcomes.¹¹

There have been several small cohort studies reporting on paediatric pelvic fractures in the literature. The purpose of this systematic review was to assess the functional outcomes of paediatric pelvic ring injuries in the paediatric population. Secondary outcomes were treatment modalities, mechanism of injury, and associated injuries.

2. Materials and methods

This systematic review was performed using a predetermined study protocol in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Fig. 1). Table 1 demonstrates the search strategy.

2.1. Search strategy and study selection

In collaboration with a medical librarian, a comprehensive search was performed using EMBASE, MEDLINE and the Cochrane Central Register of Controlled Trials (CENTRAL) in the English language from inception to May 5, 2020. The following search strategy was used:

((child*.mp OR exp child OR exp Adolescent OR youth.mp OR skeletal* immature*.mp The electronic search was supplemented with contacting study authors for unavailable articles, and forward and backward reference searching of the bibliographies from publications included in the review.

Table 1

Key words and search strategy.

Search Strategy
1. Child*.mp
2. Exp child/3. Exp adolescent/4. Youth.mo
5. Skeletal* immature*.mp
6. (paediatrics or pediatrics).mp
7. Exp pediatrics/8. OR 1–7
9. Exp fractures, bone/and pelvic bones/10. (pelvic* adj2 fracture*).mp
11. (pelvic* adj2 injur*).mp
12. (acetabul* adj2 fractur*).mp
13. (acetabul* adj2 injur*).mp
14. OR 9–13
15.8 AND 14
16. Limit 15 to English language

2.2. Study selection

All of the studies from the search were compiled using Covidence (Alfred Hospital, Melbourne, Australia) and duplicates were deleted. Two authors (SS, DY) independently screened titles and abstracts for eligibility based on inclusion and exclusion criteria followed by full text review. Discrepancies were resolved by a consensus decision. Randomized controlled trials, observational cohort studies, case-control studies, and case series with eight or more patients (including meeting abstracts) were included for review if they included patients 17 years of age or younger with skeletally immature pelvic ring injuries. Exclusion criteria included: adult patients with pelvic ring injuries, tri-radiate closed or skeletally mature pelvic fractures, clinical studies which reported exclusively on avulsion fractures, case reports, review articles, letters to the editor, commentary, and studies/abstracts not available in the English language.

Fig. 1. PRISMA flow diagram.

2.3. Data extraction

Two authors (SS and DY) independently extracted data including author, publication date, study design, number of patients, patient demographics, and outcomes of interest using a standardized data extraction form. The primary outcome was to assess functional outcomes following pelvic fracture. Secondary outcomes included associated injury, transfusion rate, rate of operative fixation, method of operative fixation, mechanism of injury, and mortality rate.

2.4. Statistical analysis

The aggregate clinical outcomes were determined by calculating weighted mean totals for each of the variables reported. The

weighted mean totals were calculated by summing the mean variable for each included study multiplied by the number of patients for the corresponding study, then dividing the sum by the total number of patients of all studies reporting the variable. The total number of patients was adjusted by subtracting the number of patients from studies which did not report on a specific outcome.

3. Results

3.1. Study characteristics

The initial search produced 4775 citations: 1501 from MEDLINE, 1500 from EMBASE and 809 from CENTRAL (Fig. 1). In total, 1308 duplicate studies were removed, leaving 3467 studies. 3414 articles were deemed irrelevant following title and abstract screening. Of

Table 2

Summary of baseline demographics for pediatric patients with pelvic fractures.

Study	Year	Study Design	n	Male, n	Mean age, yrs	Mean follow-up, mos	Fracture Classification									
							Torode/Zeig				Tile			AO/OTA		
							I	II	III	IV	A	B	C	A	B	C
Abdelgawad et al	2016	Case series	11	6	14	15.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Bajaj et al	2018	Retrospective cohort	179	116	4	NR	38*	38*	84	57	NR	NR	NR	NR	NR	NR
Banerjee et al	2008	Retrospective cohort	44	28	8.3	26	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Blaiser et al	2000	Retrospective cohort	43	25	11	56	NR	NR	5	38	NR	37	6	NR	NR	NR
Chia et al	2004	Retrospective cohort	120	79	9	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Chotai et al (4 unclass)	2018	Retrospective cohort	53	32	M- 8.8											
F-10.7	NR	0	2	28	4	NR	NR	NR	NR	NR						
de la Calva et al	2018	Retrospective cohort	81	50	9.9	NR	3	8	36	10	51	24	1	NR	NR	NR
Demetriades et al	2003	Retrospective cohort	95	52	9	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Guimaraes et al	2014	Retrospective cohort	14	6	9.4	NR	NR	NR	NR	NR	NR	NR	NR	NR	2	12
Hermans et al	2017	Retrospective cohort	51	29	11	7	NR	NR	NR	NR	14	29	8	NR	NR	NR
Karunakar et al	2005	Retrospective cohort	20	9	12.3	SI- 31										
SM- 22	NR	NR	NR	NR	NR	NR	NR	3	8	8						
Kruppa et al	2018	Retrospective cohort	90	39	11.5	NR	NR	NR	NR	NR	NR	NR	NR	24	64	2
Leonard et al	2011	Retrospective cohort	39	29	8.6	27	1	6	39	13	NR	NR	NR	NR	NR	NR
Marmor et al	2015	Retrospective cohort	9377	4237	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mulder et al	2019	Retrospective cohort	163	99	13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Oransky et al	2010	Case series	8	5	7.4	132	NR	NR	NR	NR	NR	NR	NR	2	3	6
Pascarella et al	2013	Case series	8	4	12.1	17	NR	NR	2	6	NR	2	6	NR	NR	NR
Scolaro et al	2018	Retrospective cohort	67	32	15.5	8.3	NR	NR	NR	NR	NR	NR	NR	NR	29	38
Shaath et al	2017	Retrospective cohort	178	111		NR	1	7	90	80	NR	NR	NR	NR	NR	NR
Signorino et al	2005	Retrospective cohort	20	16	9.9	NR	0	5	13	1	NR	NR	NR	NR	NR	NR
Smith et al	2005	Retrospective cohort	20	NR	9.5	78	NR	NR	NR	NR	NR	4	16	NR	NR	NR
Subasi et al	2005	Retrospective cohort	58	55	7	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Tosounidis et al	2015	Retrospective cohort	49	25	10.9	NR	NR	NR	NR	NR	NR	NR	NR	19	27	3
Zwingmann et al	2018	Prospective cohort	1433	835	9.3	NR	NR	NR	NR	NR	449	407	198	NR	NR	NR
Weighted Totals (%)	N/A	N/A	12,221	5919 (48.4)	9.5	29.0	5 (1.3)	28 (7.5)	297 (49.4)	209 (34.8)	514 (32.8)	503 (30.7)	235 (14.4)	48 (62.3)	133 (53.6)	69 (27.8)

N, number of patients; yrs, years; mos, months; NR, not recorded; M, male; F, female; SI, skeletally immature; SM, skeletally mature.

*Torode/Zeig Type I and Type II fractures combined.

the remaining 53 articles, 30 studies were excluded following full-text review based on our inclusion criteria, resulting in 24 unique articles.^{12–34} Our systematic review included these 24 articles for a total of 12,221 pediatric patients with pelvic ring injuries with a mean follow-up of 29.0 months. There was one prospective cohort study, twenty retrospective cohort studies, and three case series included in the review.

3.2. Patient demographics

In total, outcomes of 12,221 patients were reported (Table 2). The weighted mean age of patients was 8.1 years with a weighted mean follow-up of 29.0 months. Males comprised 48.4% (n = 5919) of patients. The overall mortality rate was 8.6% (n = 1019) (Table 3), where 38.2% (n = 4105) and 7.4% (n = 7.4) of pelvic fractures were the result of motor vehicle collisions and pedestrian vs. motor vehicle collision respectively. The most common associated injuries were extremity fractures (55.2%, n = 561), head injuries (41.6%, n = 415), and abdominal injuries (34.2%, n = 341). In total, 34.1% (n = 248) of patients required a blood transfusion and 4.3% (n = 19) of patients required pelvic angioembolization (Table 4).

3.3. Operative management outcomes

Of 15 studies which reported on operative and non-operative management of pediatric pelvic fractures, 8.8% (n = 891) were managed with surgical fixation (Table 5). The most common

method of surgical fixation was open reduction internal fixation (ORIF) with or without iliosacral screw fixation (83.6%, n = 745), followed by percutaneous screw fixation alone (7.2%, n = 64). Reported operative complications were low and included infection (5.0%, n = 7), implant complication and/or removal (2.9%, n = 4), and nerve injury (0.7%, n = 1).

3.4. Functional outcomes

Of 11 studies which reported on functional outcomes following paediatric pelvic fracture (Table 6), the most common long term complication was pelvic ring asymmetry (9.2%, n = 14), followed by limp (6.0%, n = 18), and limb length discrepancy (5.0%, n = 18). The Functional Independence Measure (FIM) was reported in two studies, with both demonstrating high independence with functional abilities following pelvic fracture.

4. Discussion

Though pelvic ring injuries are rare, they are potentially life-threatening injuries in the paediatric population, and can result in significant long-term morbidity. To our knowledge, this is the first and largest systematic review on this subject. In this review, we identified 24 studies, with only 11 reporting on post-fracture or post-operative function outcomes. MVC was the most common cause of pelvic fracture, and pelvic fracture was associated with a mortality rate of 8.6%. Extremity fracture was the most commonly

Table 3
Summary of injury characteristics and mortality rate associated with paediatric patients with pelvic fractures.

Study	N	Mechanism of Injury					Mortality, n	Mean ISS (range)		Associated Injuries, n						
		MVC (n)	Ped vs MVC (n)	Bike vs MVC (n)	NAT (n)	Other (n)		Survivor	Non-Survivor	Chest	Abdomen	Head	Extremity fracture	Urogenital	Other	
Bajaj et al	179	41	83	17	2	38	11	15	46	NR	NR	NR	NR	NR	NR	
Banerjee et al	44	6	29	1	0	8	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Blaiser et al	43	20	12	3	0	6	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Chia et al	120	15	74	7	0	23	5	19.5 (4–89)	65.6	27	20	53	50	0	0	
Chotai et al	53	45	0	0	1	7	3	23.6 (4–57)	56.6 (38–75)	15	12	29	42	3	15	
de la Calva et al	81	0	60	0	0	21	7	NR	NR	6	20	40	45	9	0	
Demetriades et al	95	22	67	0	0	6	10	13.8	0	13	0	0	0	0	0	
Guimaraes et al	14	10	0	0	0	4	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Hermans et al	51	40	0	0	0	11	3	24.5 (7–50)	12	19	22	39	0	0	0	
Karunakar et al	20	12	1	2	0	3	NR	NR	NR	0	4	2	4	1	0	
Kruppa et al	90	44	27	0	0	19	2	NR	NR	41	34	44	27	18	7	
Leonard et al	39	5	27	3	0	8	1	17.1 (4–75)	14	6	18	22	10	0	0	
Marmor et al	9377	3553	272	0	0	5552	814	NR	NR	NR	NR	NR	NR	NR	NR	
Mulder et al	163	67	51	0	0	45	NR	23(16)*	87	123	40	98	0	45	NR	
Oransky et al	8	0	8	0	0	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Pascarella et al	8	2	1	1	0	4	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Scolaro et al	67	41	9	0	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
Shaath et al	178	88	62	9	7	5	7	20(13)*	63	63	113	178	0	145	NR	
Signorino et al	20	3	12	0	0	5	NR	14.9(10.5)*	NR	NR	NR	12	2	8	NR	
Subasi et al	58	47	0	0	0	0	NR	22 ^{14–41}	3	8	21	27	42	6	NR	
Tosounidis et al	49	44	0	0	0	5	5	29.5	45.2	0	19	33	17	3	4	
Zwingmann et al	1433	NR	NR	NR	NR	NR	130	NR	NR	NR	NR	NR	NR	NR	NR	
Weighted Totals, n (%)	10,757	4105 (38.2)	79 (7.4)	43 (0.4)	10 (0.09)	5770 (53.6)	1019 (8.6)	N/A	N/A	268 (26.9)	341 (34.2)	415 (41.6)	561 (55.2)	88 (8.7)	230 (22.6)	

n, number of patients; ISS, Injury Severity Score; MVC, motor vehicle collision; ped, pedestrian; NAT, non-accidental trauma; NR, not recorded; N/A, not available.

*Reported as mean and standard deviation.

Table 4

Summary of paediatric patients with pelvic fractures requiring blood product transfusion and embolization.

Study	N	Patients requiring transfusion, n	Mean units pRBC, (range)	Patients requiring embolization, n
Bajaj et al	11	83	2	NR
Chia et al	120	35	4 (0.5–17)	2
de la Calva et al	81	26	NR	NR
Demetriades et al	95	31	433 mL*	NR
Hermans et al	51	10	NR	NR
Kruppa et al	90	8	NR	8
Leonard et al	39	7	3.5 ^{1–4}	NR
Mulder et al	163	22	NR	3
Pascarella et al	8	5	4 ^{1–10}	NR
Smith et al	20	15	6.3 ^{4–14}	6
Tosoundis et al	49	6	2.5 ^{1–9}	0
Weighted Totals, n (%)	727	248 (34.1)	3.7	19 (4.3)

n, number of patients; pRBC, packed red blood cells; NR, not recorded.

*reported as mean volume of pRBC

Table 5

Summary of operative management in paediatric patients with pelvic fractures.

Study	N	Pelvic fracture management, n		Method of surgical fixation			Operative complications			
		Operative	Non-operative	Ex-fix (±SI screw)	Closed reduction	ORIF (±SI screw)	Percutaneous screw only	Nerve injury	Infection	Hardware Removal
Abdelgawad et al	11	8	3	0	0	0	8	1	0	3
Bajaj et al	179	13	166	4	2	7	0	NR	NR	NR
Blaiser et al	43	13	30	1	3	9		NR	NR	NR
Chia et al	120	7	113	2	0	5	0	NR	NR	NR
Chotai et al	53	3	50	0	1	0	2	NR	NR	NR
de la Calva et al	81	4	77	3	0	1	0	NR	NR	NR
Guimares et al	14	14	0	13				0	3	0
Hermans et al	51	11	40	4	0	7	0	NR	NR	NR
Karunakar et al	20	20	0	0	0	20	0	0	0	0
Leonard et al	39	2	37	0	1	1	0	NR	NR	NR
Marmor et al	9377	696	8681	0	26	670	0	NR	NR	NR
Pascarella et al	8	8	0	0	0	8	0	0	0	0
Scolaro et al	67	67	0	0	0	13	54	0	0	1
Smith et al	20	14	6	11	2	0	0	0	4	0
Tosoundis et al	49	11	33	8	0	3	0	NR	NR	NR
Weighted totals, n (%)	10,132	891 (8.8)	9236 (91.2)	46 (5.2)	35 (3.9)	744 (83.5)	64 (7.2)	1 (0.7)	7 (5.0)	4 (2.9)

n, number of patients; Ex-fix, external fixation; SI, sacroiliac; ORIF, open reduction internal fixation; NR, not recorded.

Table 6

Summary of functional outcomes in paediatric patients with pelvic fractures.

Study	N	Limb length discrepancy	Pelvic asymmetry	Back pain	Chronic pain with activity	Limp	Acetabular dysplasia	Functional independence measure
Blaiser et al	43	8	NR	0	9	13	0	NR
Chia et al	120	3	NR	0	0	0	NR	NR
Hermans et al	51	1	NR	NR	3	NR	NR	NR
Karunakar et al	20	2	NR	0	0	0	NR	NR
Leonard et al	39	3	NR	1	0	1	1	NR
Oransky et al	8	0	5	NR	NR	NR	0	NR
Pascarella et al	8	NR	NR	1	NR	NR	1	125.3 (120–126)
Scolaro et al	67	NR	0	8	NR	NR	0	NR
Signorino et al	20	NR	NR	NR	NR	NR	NR	120
Smith et al	20	0	9	0	0	0	0	NR
Subasi et al	58	1	0	6	0	4	1	NR
Weighted totals, n (%)	454	18 (5.0)	14 (9.2)	16 (4.3)	12 (3.4)	18 (6.0)	3 (1.2)	N/A

n, number; NR, not recorded, N/A, not available

associated injury, followed by head injury. Almost a third (34%) of patients required packed red blood cell transfusion. Pelvic asymmetry, LLD, and limp were the most common complications reported following pelvic ring injuries, with no distinction being made with operative or non-operative management.

Our study demonstrates that only 8.8% (n = 891) of all pelvic

fractures were treated operatively. The study by Marmor et al., contributed 696 surgical patients but did not report on the fracture classification of the pelvic fractures being fixed.²³ Excluding patients from this study, in our analysis, only 196 out of 214 patients with Torode/Zeig type 4 pelvic fractures were treated operatively. Torode/Zeig type 4 fractures are by definition unstable injuries,

with disruption of the anterior and posterior pelvic ring. It is accepted in the adult literature that these injury patterns warrant surgical fixation[35, 36], however in our systematic review, there were patients who suffered a type IV injury, but were managed non-operatively. Some potential explanations might be that these are patients who died prior to treatment and were not reported, or because our review includes studies from the past 20 years, therefore some reports are from prior to pelvic fixation becoming more common, or lastly, that patients were managed at a hospital without expertise in the management of paediatric pelvic fractures.

Functional outcomes after pelvic injuries are better documented in the adult population.^{37–41} Most studies utilized the 36-item Short Form survey (SF-36), and reported worse quality of life in individuals who suffered a pelvic fracture when compared to age-matched controls without pelvic fracture.^{41,42} In our study, functional outcome reporting was limited to specific symptoms. There were limited reporting using pelvic specific outcome scores or health related quality of life scores. Reporting on outcomes following pelvic fractures may be confounded as many of these injuries can involve other concomitant injuries, and limiting reporting to specific symptoms fails to capture the entire functional status of these patients post-injury. This represents a significant gap in our understanding of how paediatric patients with pelvic fractures do post-injury, especially long term. Going forward, the Pediatric Quality of Life Inventory, is a validated health related quality of life questionnaire that can be used in the paediatric population to characterize functional outcome after pelvic fracture.⁴³ Long-term functional data can lead to better informed discussions with families following this injury.

Strengths of this review include the inclusion of recent studies and the large combined data set for a relatively uncommon injury. By pooling data, we were able to summarize current management of these injuries as well as available post-injury outcomes. This study has limitations. Due to the rare nature of this injury, many studies collected data over significant time periods, some spanning a decade. Given that our understanding of fracture patterns and corresponding treatment algorithms may have changed during this time, the final results of the pooled data may be biased towards non-operative management. Another challenge for this review was the inconsistency in functional outcome measures reported as well as limited reporting of functional outcome scores, with many studies only reporting specific symptoms. Finally, a limitation of this review was the inability to associate fracture type to treatment received, as this was not always clear in the studies reviewed.

5. Conclusion

In conclusion, the results from this review demonstrate pelvic injuries in children are commonly the result of high-energy trauma and are associated with multi-system injuries and a high mortality rate. Based on this review, less than 10% of these injuries are managed operatively. With increased knowledge of the osteology of the skeletally immature pelvis, advances in minimally invasive surgical techniques, and increasing comfort with the management of pediatric pelvic fractures, there may be increased operative management to decrease long-term complications. There remains a lack of reporting on both overall quality of life outcomes and pelvic-specific outcome scores. Future work is required to fully delineate indications for operative fixation and elucidate long-term outcomes.

Declaration of competing interest

None.

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