Number, treatment, and mortality of paediatric pelvic ring fractures in two level 1 trauma centres in the Netherlands

a multicentre retrospective cohort study

From Amsterdam University Medical Centres, Amsterdam, the Netherlands

Correspondence should be sent to A. H. M. Mennen a.h.mennen@amsterdamumc.nl

Cite this article:
Bone Jt Open 2025;6(3):
254–263.

DOI: 10.1302/2633-1462.63.BJO-2024-0242

A. H. M. Mennen,[1] E. M. M. Van Lieshout,[2] F. W. Bloemers,[1,3] A. E. Geerlings,[1] M. E. Van Haeringen,[1] J. R. De Jong,[4] M. H. J. Verhofstad,[2] M. G. Van Vledder,[2] D. Van Embden[1]

[1]Department of Surgery, Amsterdam University Medical Center, Amsterdam University, Amsterdam, the Netherlands
[2]Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, the Netherlands
[3]Department of Surgery, Amsterdam UMC location Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
[4]Department of Paediatric Surgery, Amsterdam University Medical Center, Amsterdam University, Amsterdam, the Netherlands

Aims

Paediatric pelvic ring fractures are rare but severe injuries, presenting significant treatment challenges. This study aimed to analyze patient characteristics and explore trends in incidence, treatment methods, and mortality associated with these injuries.

Methods

This multicentre, retrospective cohort study analyzed paediatric patients (aged ≤ 18 years) with pelvic ring fractures treated between 2001 and 2021 at two level 1 trauma centres. Data on patient demographics, injury characteristics, treatment approaches, and outcomes were collected, and visual trend analysis was conducted to identify patterns.

Results

A total of 157 patients with pelvic ring fractures were included. The median age was 15 years (IQR 12 to 17), with 52% (n = 81) being female. Traffic accidents were the leading cause of injury, accounting for 68% of cases (n = 106). Concomitant injuries were observed in 83% of patients (n = 131). The one-year mortality rate was 11.5%, with 76% of deaths occurring within 48 hours of admission, primarily due to traumatic brain injury (53%). Most patients (60%) were treated nonoperatively, while 48% of surgically treated patients underwent internal fixation without prior external fixation. Visual trend analysis revealed an increase in the absolute number of paediatric pelvic ring fractures over time, though no significant shift towards surgical treatment was observed. Among surgically treated patients, there was a trend towards open reduction and internal fixation rather than external fixation as definitive treatment. Nonoperative treatment was more common in children (69%) than in adolescents (55%). For surgical cases, external fixation was preferred in children (44%), while ORIF was more common in adolescents (53%).

Conclusion

The incidence of paediatric pelvic ring fractures has increased over time, with a high mortality rate largely attributable to severe neurotrauma. There has been a shift towards surgical treatment without prior external fixation, with differences noted in the treatment approaches between children and adolescents, particularly in surgical fixation methods.

Bone & Joint Open

Take home message

- There is a positive trend in the absolute number of paediatric patients with a pelvic ring fracture in the Netherlands.
- Paediatric pelvic ring fractures are serious injuries with high mortality rates due to severe neurotrauma.
- This study shows that the rate of nonoperatively treated patients did not significantly change over the years, but the preferred mode of fixation did shift to open reduction and internal fixation, while external fixation as a definitive treatment method has been used less frequently.

Introduction

Paediatric pelvic fractures can be divided into two major groups: fractures that do not involve the pelvic ring (e.g. avulsion fractures or isolated iliac wing fractures) and so-called pelvic ring fractures where stability of the mechanical ring might be compromised. Fractures that do not involve the pelvic ring are the most common fracture patterns (60% to 80%), but they are relatively benign, stable fractures with overall good outcomes.[1] Pelvic ring fractures, however, are more challenging to treat in children. The estimated incidence of this injury varies between 0.04% and 4% of all paediatric trauma patients.[2] These fractures are often caused by high-energy trauma and therefore accompanied by other severe injuries.[3] Due to the rare nature of the injury, there is a lack of consensus on fracture stability and optimal treatment.

Evaluating the outcomes of paediatric patients with pelvic ring fractures is troubled by the fact that most studies do not differentiate between avulsion and pelvic ring injuries, thus influencing outcomes. Moreover, assessment of patient outcomes is also influenced by the use of the Torode and Zieg classification.[4] This classification system was based on survival rates of children with pelvic fractures and does not take mechanical aspects into account.[5–9] Which pelvic ring fracture patterns should be considered unstable is still open for debate, primarily due to the unique biomechanical characteristics of the immature paediatric pelvis, such as open triradiate cartilage, and lack of appropriate classification systems. While it is generally accepted that paediatric pelvic fractures without involvement of the ring can be treated nonoperatively, the optimal treatment for ring fractures remains unclear. Historically, most pelvic ring fractures in children have been treated conservatively, but experts are increasingly promoting surgical stabilization of unstable fractures.[3,7,10]

The primary aim of this study is to report on the number, treatment methods, and mortality of paediatric pelvic ring fractures in two level 1 trauma centres in the Netherlands (University Medical Centre (EMC) and Amsterdam University Medical Centres (AUMC)) to gain insight into the epidemiology of this specific type of injury within the paediatric population, and to assess the current practices and trends in managing these injuries. The secondary aims of the study include assessing trends in patient numbers, treatment methods, and mortality rates across different time periods, examining the overall proportion of paediatric patients with pelvic ring fractures who underwent surgical fixation, investigating the proportion of surgical fixation in children (aged 0 to 12 years) and adolescents (aged 13 to 18 years), comparing outcomes between children with a presumed immature pelvis (aged 0 to 12 years) and presumed mature pelvis (aged 13 to 18 years), and examining the impact of skeletal maturation on fracture patterns and treatment.

Methods

Patient characteristics

Table I shows the patient and injury characteristics of the included patients. The median age was 15 years (IQR 12 to 17), and a slight majority of the patients was female (52%; n = 81). The mechanism of injury in most patients was a traffic accident (n = 106; 68%). Approximately one-quarter of the patients were presented in shock (n = 44; 28%) and 34% were intubated (n = 54). The median Glasgow Coma Score (GCS)[11] was 15 (IQR 5 to 15). Most children with a pelvic ring fracture had concomitant injuries (n = 131; 83%), and most common were fractures in the lower limb (n = 59; 45%) and thoracic soft-tissue injuries (n = 57; 44%).

Study design and study setting

All paediatric patients (aged ≤ 18 years) with a pelvic ring fracture who presented between 1 January 2001 and 31 December 2021 to one of the two major urban level 1 trauma centres in the Netherlands (AUMC and EMC) were identified from the Dutch trauma registry and electronic patient records. Inclusion criteria were the availability of a CT scan of the initial trauma admission and complete medical records regarding the type of final treatment the patient. Patients with avulsion, isolated iliac wing, or coccygeal fractures, or those who were transferred to another hospital before definitive treatment, were excluded. Patients with a pelvic ring fracture who died before a CT scan or definitive treatment were performed are included in the study cohort in order to avoid underestimating the mortality rate, but are excluded from further analysis.

Data collection

The primary focus of the study was to report on the number, treatment methods, and mortality of paediatric pelvic ring fractures in two level 1 trauma centres in the Netherlands. Secondary objectives included assessing trends in patient numbers, treatment methods, and mortality rates across different time periods, examining the overall proportion of paediatric patients with pelvic ring fractures who underwent surgical fixation, investigating the proportion of surgical fixation in young children (aged 0 to 12 years) and adolescents (aged 13 to 18 years), comparing outcomes between children with a presumed immature pelvis (aged 0 to 12 years) and a presumed mature pelvis (aged 13 to 18 years), and examining the impact of skeletal maturation on fracture patterns and treatment. Other parameters that were examined were the mechanism of injury, number and location of concomitant injuries, GCS at admission, intubation at admission, hospital admission and length of stay, intensive care unit (ICU) admission and length of stay, complications, and time to follow-up. Classification of the fracture patterns was done by three observers (AHMM, AEG, DVE), using CT scans from the initial assessment. For the children who died before undergoing a full assessment, plain radiographs were used to classify the fracture patterns.

Definitions

Given the impact of skeletal maturation on fracture patterns and treatment in children with pelvic ring fractures, a

comparison was made between the outcomes of children with an immature pelvis and mature pelvis. The timing of triradiate cartilage closure varies, and there are limited data regarding the mean age of physeal closure. To address this issue, children in this study were classified into two groups: 'children' aged 0 to 12 years, presumed to have an immature pelvis, and 'adolescents' aged 13 to 18 years, presumed to have a mature pelvis. These categories were based on findings from previous studies by Shaath et al[12] and Silber and Flynn.[13]

If a patient died due to fatal thoracic or abdominal injuries, the cause of death was defined as 'exsanguination from thorax' or 'exsanguination from abdomen'. If the patient died of exsanguination and the most severe injury was the pelvic fracture, the cause of death was defined as 'pelvic fracture related'.

If a patient got injured while driving or as a passenger of any type of motor vehicle, the mechanism of injury was classified as 'motor vehicle accident (MVA)'. If a patient was on a bicycle or walking and was hit by a motor vehicle, the mechanism of injury was classified as 'bike versus motor vehicle (MV)' and 'pedestrian versus MV', respectively. The mechanism of injury of patients who were injured while riding a horse, skiing, or were hit by a train was classified as 'other'.

The Paediatric Age-Adjusted Shock Index (SIPA)[14] was used to determine if a patient was in shock on arrival.

Fracture patterns were classified according to the Young and Burgess (Y and B),[15] Tile,[16] and Torode and Zieg (T and Z) classifications.[4] Patients with multiple bilateral fractures in both pubic rami (i.e. a straddle fracture), without injury to the posterior side of the pelvis, were considered unstable pelvic ring injuries and included as a Tile type A, as this type represents fracture patterns with anterior injuries only. It should be noted that this type normally refers to fracture patterns without a breakage of the pelvic ring. This fracture pattern was classified as 'unclassifiable' using the Y and B classification, as this classification does not include fracture patterns with isolated anterior fractures.

Concomitant injuries were systemically categorized, covering a variety of injury types. These included traumatic brain injury (bleeding and/or contusion), thoracic soft-tissue injuries ((haemato)pneumothorax, lung contusion, or laceration), abdominal injuries (abdominal organ contusion or laceration, large intra-abdominal haematoma), urogenital injuries (genital injuries, perineal injuries, bladder and/or ureter injuries), spinal cord injuries (complete and incomplete), major wounds (deglovement and lacerations in need of treatment), and other injuries (traumatic hip luxation, traumatic arteria femoralis superficialis (AFS) injury). Concomitant fractures were grouped based on their anatomical location.

Some of the intrahospital complications were grouped in categories, consisting of the following problems: allergic reaction (medicine, contrast, or blood products); respiratory problems (pneumonia, pneumothorax, atelectasis, lung abscess, and acute respiratory distress syndrome (ARDS)); fracture-related infections, local infections not related to fracture; and systemic infections (sepsis, bacterial, and fungal infections).

Statistical analysis

Data were analyzed using SPSS v.28.0 (IBM, USA). Descriptive analyses were performed for the entire group. Normality of continuous data was tested with the Kolmogorov-Smirnov test and categorized variables with the chi-squared test. For parametric data, the mean and SD were reported, and for non-parametric data the median and IQR were reported. Missing values were not imputed. To assess the trends over time, the absolute number of cases presented in both study centres each year, the absolute number of in-hospital deaths, and the absolute number of surgically treated patients were summed up. Since the sample size was too small to perform logistic regression analysis,[17] a visual trend analysis was performed using Excel (Microsoft, USA). The mortality rate was calculated as the ratio between the absolute number of in-hospital deaths and the total number of cases presented in both centres, expressed as a percentage. Statistical significance was set at $p < 0.05$.

Results

In total, 157 patients were included: 80 from hospital 1 and 77 from hospital 2. Figure 1 shows the absolute number of paediatric patients who presented to the emergency department (ED) in either of the hospitals. Visual trend analysis shows a positive trend in the absolute number of patients over the years.

Almost all patients were classified as T and Z[4] type IV (n = 148; 94%). Using the Y and B classification,[15] lateral compression (LC) was the most common fracture pattern (n = 52; 33%). According to the Tile classification,[16] most patients appear to have a B3 fracture pattern (n = 65; 41%). A total of 14 patients had an open pelvic fracture (9%). Almost all open fractures were the result of a traffic accident (n = 13; 93%). All patients with an open fracture had concomitant injuries, most often urogenital injuries (n = 9; 64%). All 13 surviving patients were treated operatively: 54% (n = 7) with external fixation as final treatment, 21% (n = 3) with initial external fixation and secondary open reduction and internal fixation (ORIF), and 21% (n = 3) with initial ORIF. The mortality rate of patients with open pelvic fractures was 7% (n = 1).

Final treatment was administered to 140 patients (89%) who survived until that stage. Most of the patients were treated nonoperatively (n = 84; 60%). Figure 2 shows the annual distribution of treatment methods for paediatric patients with pelvic ring fractures. Each bar represents the proportion of patients treated surgically and nonoperatively per year. The visual trend analysis shows no notable trend for surgical treatment. Of all the surgically treated patients, almost half underwent surgical fixation without prior external fixation (n = 27; 48%). An overview of the treatment per fracture pattern according to the Y and B classification can be seen in Table II. The fracture patterns anteroposterior compression (APC) and vertical shear (VS) were predominantly surgically treated. Figure 3 shows the distribution of the type of surgical treatment over the years. Visual trend analysis shows a negative trend for the use of external fixation and a positive trend for the use of ORIF. A subtle positive trend can be seen for the group, which reflects the use of external fixation as initial fixation method and ORIF as definitive fixation method.

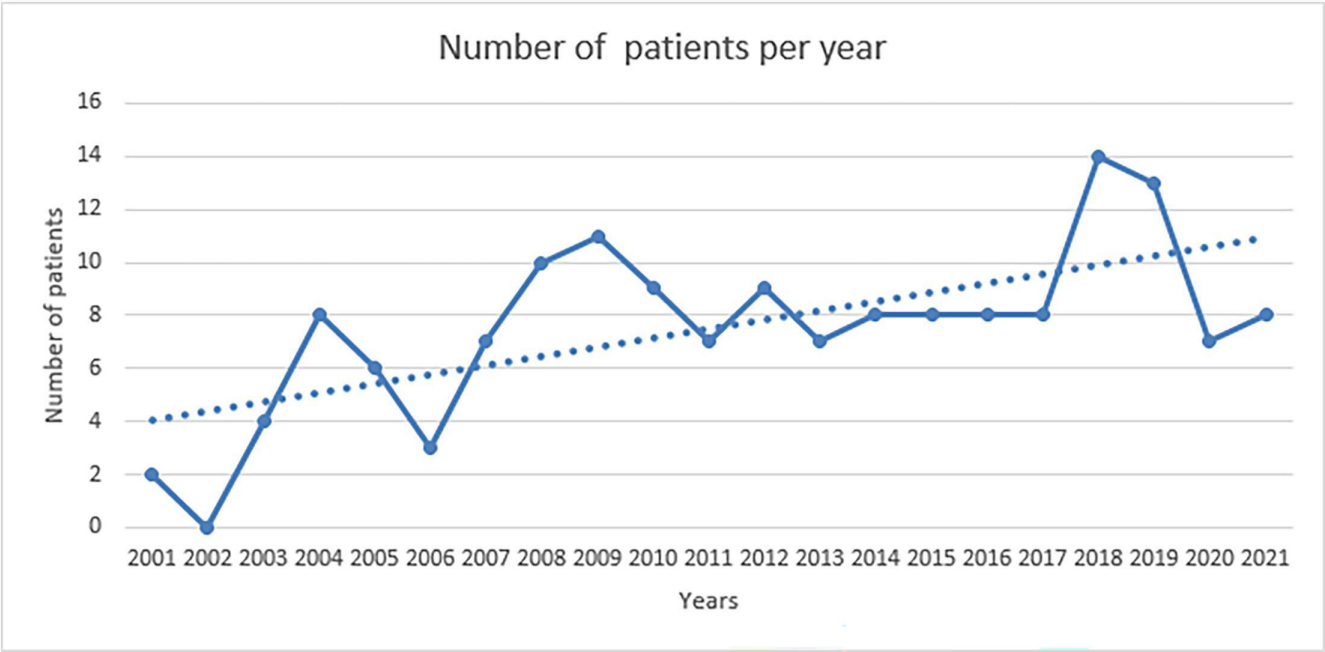

Fig. 1
Annual distribution of the absolute number of paediatric patients diagnosed with a pelvic ring fracture who presented to the emergency department (ED) per year. The x-axis represents the years, while the y-axis shows the total number of cases each year. The solid blue line indicates the yearly fluctuations in incidence of these fractures among paediatric patients. A dotted trend line is included, representing the overall average incidence rate throughout the study period. This information is crucial for understanding the frequency and trends in the occurrence of pelvic ring fractures in the paediatric population over time.

Figure 4 shows the frequency of the different complications during hospital admission. One in five patients (21%; n = 30) had one or multiple complications during admission. Most common were respiratory problems (n = 11; 37%), and fracture-related infections (n = 4; 13%). One patient had an in-hospital cardiac arrest but survived.

The median hospital stay was 12 days (IQR 6 to 24). Most of the patients (n = 90; 57%) were admitted to the ICU for a median of three days (IQR 1 to 13).

Figure 5 shows the annual percentage of patient mortality over the study period. Visual trend analysis shows a stable trend over the years. Overall, 17 patients died during hospital admission and one patient died during follow-up. This resulted in a one-year mortality rate of 11.5% and an in-hospital mortality rate of 10.8%. Most patients who died during admission were male (56%, n = 10) and the median age was 14 years old (IQR 11 to 17). Most of these patients (71%) presented in shock, and all 17 patients were intubated. Since not all patients underwent a diagnostic work-up due to haemodynamic instability, the Injury Severity Score (ISS)[18] of only ten patients could be determined. The median ISS of these patients was 46 (IQR 35 to 75). The main mechanisms of injury were traffic accidents (n = 15; 88%): six MVAs, five bike versus MV, and four pedestrian versus MV. In addition, there was one fall from height and one train-related accident. One patient did not have adequate imaging available to determine fracture classifications. All 16 other patients were T and Z type IV. Using the Y and B classification, there was one (6%) APC1, two (13%) APC2, one (6%) APC3, three (19%) LC1, four (25%) LC2, and five (31%) LC3. Using the Tile classification, there were two (13%) B1, eight (50%) B2, and six (37%) B3. One patient who died had an open pelvic fracture (n = 1; 6%). The timing of the in-hospital deaths was distributed as follows: six (35%) died on the day of arrival at the hospital, seven (41%) within 48 hours, two (12%) within seven days, one (6%) within 14 days, and one patient (6%) 34 days after admission. In three patients (18%) the pelvic ring fracture was the cause of death. Severe traumatic brain injury was the cause of death in nine patients (53%), thoracic or abdominal injuries in four patients (23%), and one patient (6%) died due to exsanguination from lower limb injuries. Since 2013, no patient has died because of exsanguination caused by their pelvic fracture, solely as a result of the concomitant injuries. During the follow-up period, one patient died 52 days after the trauma. The cause of death was identified as aspiration pneumonia, resulting from dysphagia due to the traumatic brain injury sustained during the initial trauma.

Influence of skeletal maturation on patient outcome, fracture pattern, and treatment

Table I shows the patient and injury characteristics of the children and adolescent patient groups. Children were more likely to get injured when participating in traffic on a bike or as a pedestrian, while adolescents were most often injured while in or on a motor vehicle. Children had higher rates of shock (35% vs 24%) and intubation (42% vs 30%). Children were overall more severely injured with a higher median ISS (17 vs 13) and higher rate of concomitant injuries (93%). The Y and B type LC3 fracture pattern was most common in both children and adolescents (n = 18; 31% and n = 33; 34%, respectively). The second most common pattern in children was APC2 (n = 15; 25%) while in adolescents it was LC1 (n = 32; 33%). Children were treated nonoperatively more often than adolescents (69% vs 55%). When children were

Table I. Details of patient characteristics, injury characteristics, fracture patterns, and treatment characteristics in the overall cohort, the children cohort, and the adolescent cohort. Values as presented as n (%), unless otherwise stated.

Variable	Overall (n = 157)	Children (n = 60)	Adolescent (n = 97)
Median age, yrs (IQR)	15 (12 to 17)	11 (8 to 13)	17 (16 to 18)
Sex			
Female	81 (52)	30 (50)	51 (53)
Male	76 (48)	30 (50)	46 (47)
Mechanism of injury			
Traffic accident	106 (68)	47 (78)	59 (61)
Motor vehicle accident	43 (41)	5 (8)	38 (64)
Bike vs motor vehicle	34 (32)	21 (35)	13 (22)
Pedestrian vs motor vehicle	29 (27)	21 (35)	8 (14)
Fall from height	32 (20)	9 (15)	23 (24)
Crush	13 (8)	3 (5)	10 (10)
Other	6 (4)	1 (2)	5 (5)
Shock	44 (28)	21 (35)	23 (24)
Intubated	54 (34)	25 (42)	29 (30)
Median ISS (IQR)	14 (9 to 22)	17 (9 to 26)	13 (9 to 21)
Median GCS (IQR)	15 (5 to 15)	14 (3 to 15)	15 (7 to 15)
Concomitant injuries	131 (83)	56 (93)	75 (77)
Skull fracture	24 (18)	7 (13)	17 (23)
Spine fracture	38 (29)	6 (11)	32 (43)
Thoracic fracture	45 (34)	13 (23)	32 (43)
Upper limb fracture	29 (22)	3 (5)	26 (35)
Lower limb fracture	59 (45)	20 (36)	39 (22)
Traumatic brain injury	38 (29)	11 (20)	27 (36)
Thoracic soft-tissue injury	57 (44)	14 (25)	43 (57)
Abdominal injury	42 (32)	11 (20)	31 (41)
Urogenital injury	11 (8)	6 (10)	5 (7)
Spinal cord injury	2 (2)	1 (2)	1 (1)
Major wounds	16 (12)	7 (13)	9 (12)
Other	9 (7)	4 (7)	5 (7)
Torode and Zieg classification			
III	8 (5)	2 (3)	6 (6)
IV	148 (94)	57 (95)	91 (94)
Unclassified	1 (1)	1 (2)	0 (0)
Young and Burgess classification			
APC1	7 (5)	4 (7)	3 (3)
APC2	21 (13)	15 (25)	6 (6)
APC3	2 (1)	1 (2)	1 (1)
LC1	38 (24)	6 (10)	32 (33)
LC2	20 (13)	10 (17)	10 (11)
LC3	52 (33)	18 (31)	33 (34)
Vertical shear	9 (6)	3 (5)	6 (6)
Unclassified	7 (5)	2 (3)	6 (6)
Tile classification			
A2	7 (5)	1 (2)	6 (7)
B1	21 (13)	11 (18)	10 (10)
B2	54 (34)	16 (26)	38 (39)
B3	65 (41)	28 (47)	37 (38)
C1	7 (5)	2 (3)	5 (5)
C2	2 (1)	1 (2)	1 (1)
C3	0 (0)	0 (0)	0 (0)
Unclassified	1 (1)	1 (2)	0 (0)
Mortality	18 (12)	8 (13)	10 (10)
Open fracture	14 (8)	7 (12)	7 (7)
Nonoperative	84 (60)†	36 (69)†	48 (55)†
Operative	56 (40)†	16 (31)†	40 (45)†
Initial ORIF	27 (48)	6 (37)	21 (53)
Initial EXFIX, ORIF final	15 (27)	3 (19)	12 (30)
EXFIX final	14 (25)	7 (44)	7 (17)
Hospital admission	157 (100)	60 (100)	97 (100)
Median length of hospital stay, days (IQR)	12 (6 to 24)	11.5 (5 to 30)	12 (6 to 22)
ICU admission	90 (57)	39 (72)	51 (53)
Median ICU stay, days (IQR)	3 (1 to 13)	4.5 (1 to 16)	2 (1 to 12)

*Percentage within group.
†Percentage in patients who survived until definitive treatment.
APC, anteroposterior compression; EXFIX, external fixation; EXFIX > ORIF, initial treatment by external fixation and definitive treatment by open reduction and internal fixation; GCS, Glasgow Coma Score; ICU, intensive care unit; ISS, Injury Severity Score; LC, lateral compression; ORIF, open reduction and internal fixation.

treated surgically, the treatment modality most often used was external fixation as definitive treatment (n = 7; 44%). In adolescents, the most used treatment method was immediate ORIF (n = 21; 53%). Children were admitted to the ICU more often than adolescents (72% vs 53%).

Discussion

The results of this study show that pelvic ring fractures in children are rare but the absolute number of paediatric patients with a pelvic ring is rising. In the Dutch national trauma registry, 4,311 paediatric patients admitted to the hospital were registered in the capture areas of both hospitals in 2011.[19] This resulted in an incidence of 17.4 children with a pelvic ring fracture per 10,000 admitted paediatric trauma patients per year. The one-year mortality is 11.5%, and is mostly caused by traumatic brain injury. Most patients have been treated nonoperatively (60%), and the rate of nonoperatively treated patients did not significantly change over the years. More recently, ORIF has become the preferred method of fixation, while external fixation as a definitive treatment method has been used less frequently.

In the Netherlands, most school-age children travel to school by bike (49%) or by foot (37%).[20] As a result, Dutch children are exposed to traffic participation and are at risk for traffic-related accidents early on in life. Since traffic accidents

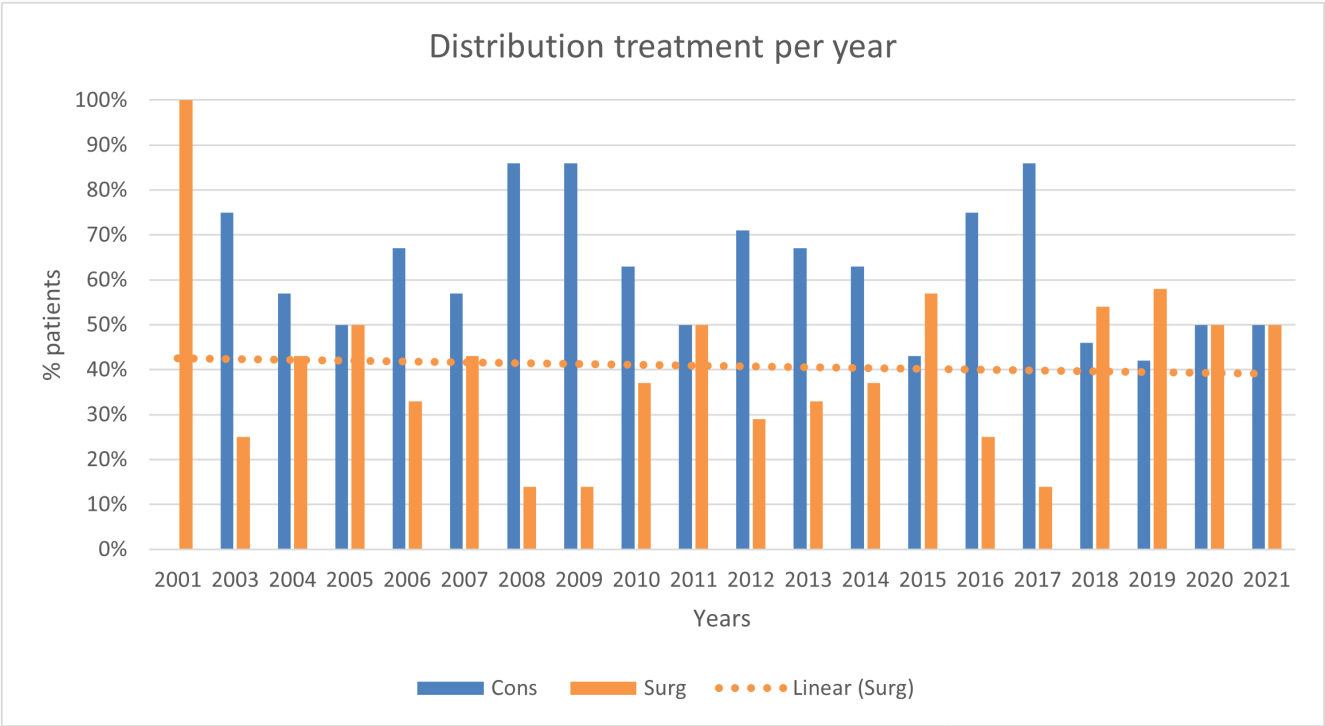

Fig. 2
Annual distribution of treatment methods for paediatric patients with pelvic ring fractures. This figure illustrates the distribution of nonoperative versus surgical treatment types among patients from 2001 to 2021. The x-axis represents the years, while the y-axis indicates the percentage of patients who received each type of treatment. The bars are colour-coded to represent the two types of treatments: Cons (conservative, shown in blue) and Surg (surgical fixation, shown in orange). The dotted trend line indicates the changes in surgical treatment preference over time.

greatly contribute to the burden of pelvic ring fractures in children, the incidence of this injury in Dutch children might be relatively high compared to other Western countries.[8] Our study shows that, on average, 7.5 children with a pelvic ring fracture per year are presented to the ED of these two large urban teaching level 1 trauma hospitals, which results in 3.75 children per year per hospital. The incidence of children with a pelvic ring fracture is 17.4 per 10,000 paediatric trauma patients per year in both trauma regions. The participating hospitals are situated in the most population dense regions of the Netherlands, with 5.57 million inhabitants living in these two trauma regions. This adds up to 31.8% of the entire population of the Netherlands. Since most studies report on all pelvic fracture types collectively it is difficult to compare these numbers to the incidence in other countries. Tosounidis et al[21] described a rate of 30 children with pelvic ring fractures over the course of ten years in a level 1 trauma centre in England, which results in an incidence of three children per year per hospital. Zwingmann et al[22] report on the incidence of paediatric pelvic fractures in the German pelvic trauma registry, consisting of data from 23 level 1 trauma centres over a 14-year time frame. They describe 703 pelvic ring fractures, which results in an incidence of 2.2 children per year per hospital. Furthermore, the incidence of pelvic ring fractures in children reported in our study during 2020 and 2021 will be influenced by the lockdown during the COVID-19 pandemic. Literature reports a decrease in the number of motor vehicle collisions during this period.[23] Due to the lockdown, children did not travel to and from school, and there were fewer vehicles on the road, which might have had a protective effect on the chances of obtaining a pelvic ring fracture caused by a MVA.

Due to the rarity of the injury, it is difficult for surgeons to gain experience in the management of these complex fractures and their severe concomitant injuries. This unfamiliarity with the injury might negatively influence the outcome of children with a pelvic ring fracture.[24] Centralization of care might be a possible solution to this problem. However, centralization should not be solely based on a minimal number of procedures per year, but rather on the availability of a specialized multidisciplinary paediatric management team and expertise in pelvic and acetabular surgery.[25] This is especially important in the context of paediatric pelvic ring fractures since they are almost always presented with high rates of concomitant fractures and injuries, which makes a multidisciplinary treatment approach essential.

In our study, the overall one-year mortality rate was 11.5% and the in-hospital mortality 10.8%. The mortality cohort consisted of 17 Tile B patients and one patient who could not be classified due to a lack of imaging, resulting in a mortality rate of 13.7% for Tile B patients. A recent systematic review consisting of all types of pelvic fractures describes an overall mortality rate of 8.6%.[26] It should be noted that this review includes studies which also describe patients who have pelvic fractures that do not involve the pelvic ring (e.g. Tile A), which has an impact on the mortality rate. Zwingmann et al[22] reported a 5.1% mortality in Tile B patients and 15% in Tile C patients. Tosounidis et al[21] reported a mortality of 14.8% in Tile B patients and 0% in Tile C patients.

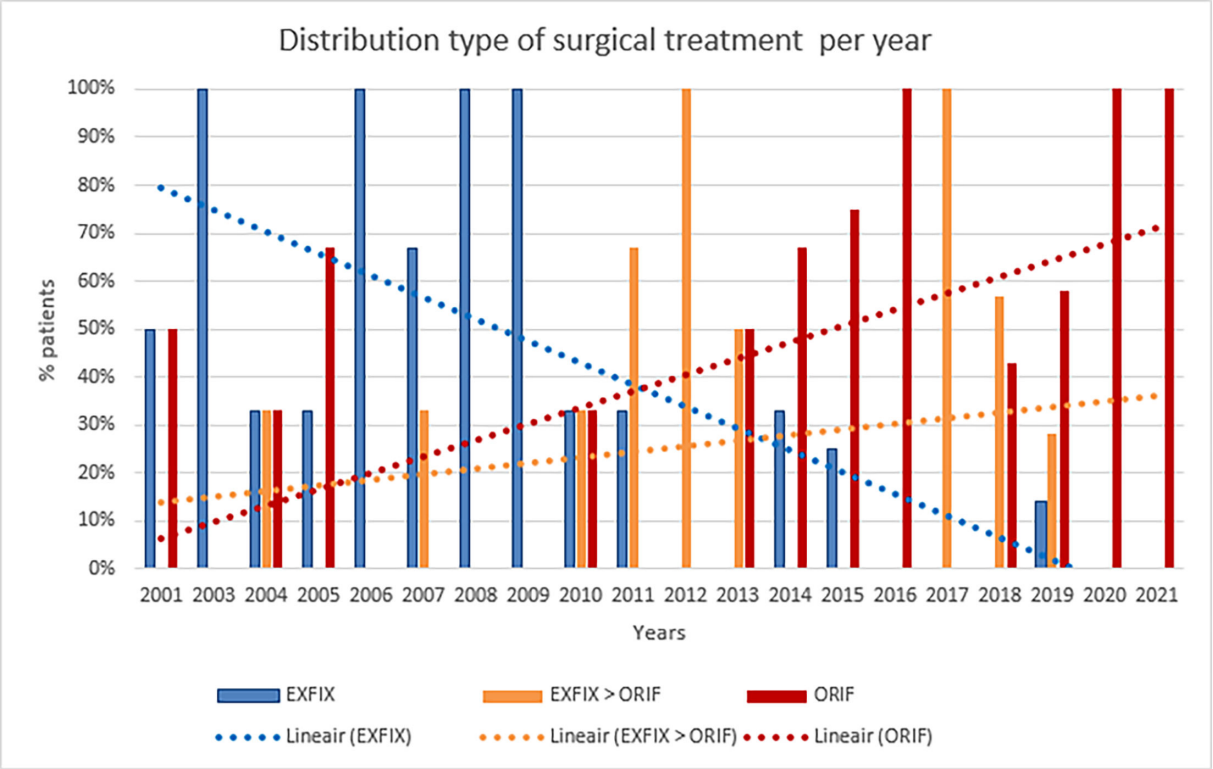

Fig. 3

Distribution of the type of surgical treatment over the years. This figure illustrates the distribution of different surgical treatment types among patients from 2001 to 2021. The x-axis represents the years, while the y-axis indicates the percentage of patients who received each type of surgical treatment. The bars are colour-coded to represent three types of treatments: EXFIX (external fixation, shown in blue), EXFIX > ORIF (initial fixation with external fixation and definitive fixation with open reduction and internal fixation, shown in orange), and ORIF (open reduction and internal fixation, shown in red). Dotted trend lines for each treatment type (colour-matched) indicate the changes in treatment preference over time. The figure highlights a decrease in the use of EXFIX, while the preference for ORIF steadily increased over the study period.

Table II. Treatment per fracture pattern according to the Young and Burgess classification of the overall cohort of patients.

Treatment	APC1, n (%)	APC2, n (%)	APC3, n (%)	LC1, n (%)	LC2, n (%)	LC3, n (%)	VS, n (%)	UC, n (%)
Conservative	4 (67)	14 (74)	N/A	23 (68)	10 (63)	26 (54)	1 (11)	6 (86)
Operative	2 (33)	5 (26)	1 (100)	11 (32)	6 (37)	22 (46)	8 (89)	1 (14)
ORIF	1 (50)	2 (40)	N/A	6 (55)	2 (33)	11 (50)	4 (50)	1 (100)
EXFIX > ORIF	1 (50)	1 (20)	N/A	2 (18)	1 (17)	6 (2)	4 (50)	N/A
EXFIX	N/A	2 (40)	1 (100)	3 (27)	3 (50)	5 (23)	N/A	N/A

APC, anteroposterior compression; EXFIX, treatment by external fixation; EXFIX > ORIF, initial treatment by external fixation and definitive treatment by open reduction and internal fixation; LC, lateral compression; N/A, not applicable; ORIF, open reduction and internal fixation; UC, unclassifiable; VS, vertical shear.

This study reflects on the influence of age and presumed skeletal maturation on fracture patterns and treatment. A higher rate of surgical fixation was seen in adolescent patients, which is in line with Kruppa et al.[27] A recent review by Sridharan et al[26] shows that conservative treatment of unstable paediatric pelvic fractures leads to poor clinical outcomes in the short term. In our cohort, 40% of all pelvic ring fractures were surgically treated; 37.9% of all Tile B patients and 88.9% of all Tile C patients. Sridharan et al[26] report that 8.8% of all pelvic fractures underwent surgical treatment, which is significantly lower. However, it again should be noted that these results are heavily influenced by the inclusion of studies that include Tile A patients. Zwingmann et al[22] reported pelvic surgery in 46.2% of the Tile B patients and 66.2% of the Tile C patients. Tosounidis et al[21] reported surgical fixation in 36.7% of the pelvic ring fractures.

Although external fixation can be helpful in the management of haemodynamically unstable patients, it only provides mechanical stability to the anterior pelvic ring. The role of an external fixator alone in the definitive treatment of pelvic ring fractures might therefore be limited. Evidence on the optimal treatment is sparse, but experts advise to treat paediatric patients with Tile B and C fracture patterns with open reduction and internal fixation, either only anterior

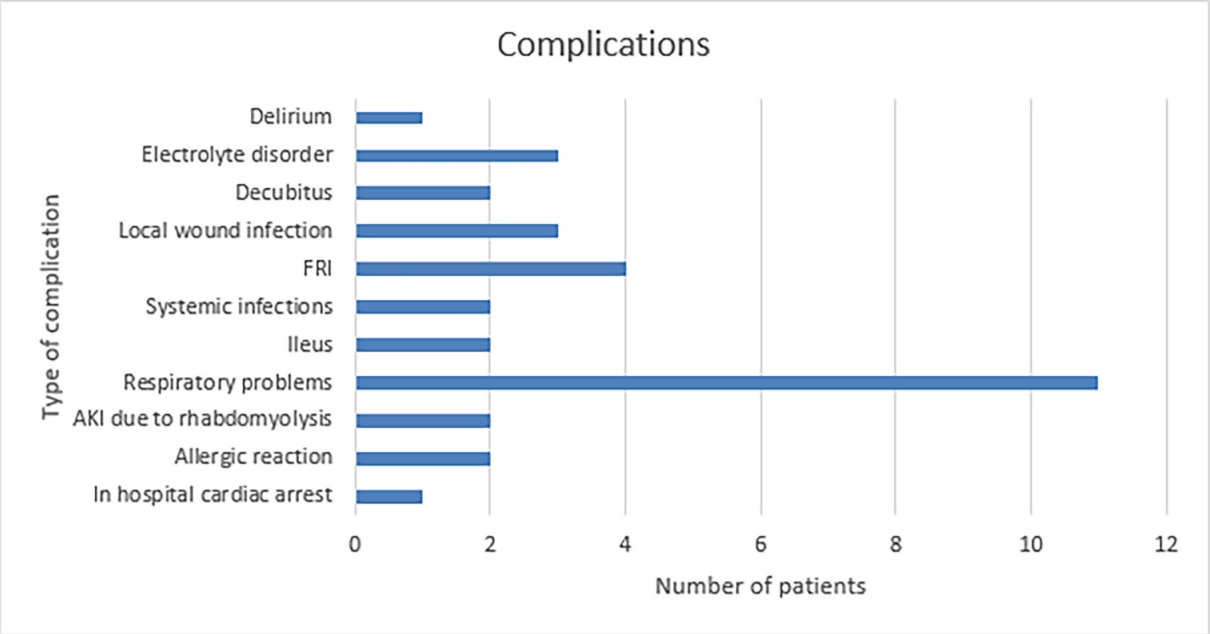

Fig. 4
Frequency of complications observed during hospital admission, with the number of patients indicated on the x-axis. The y-axis lists the types of complications, including delirium, electrolyte disorders, decubitus, local wound infections, fracture-related infection (FRI), systemic infections, ileus, respiratory problems, acute kidney insufficiency (AKI) due to rhabdomyolysis, allergic reactions, and in-hospital cardiac arrest. The x-axis represents the number of patients experiencing each complication. The chart highlights the distribution of different complications among the patient population during the study period.

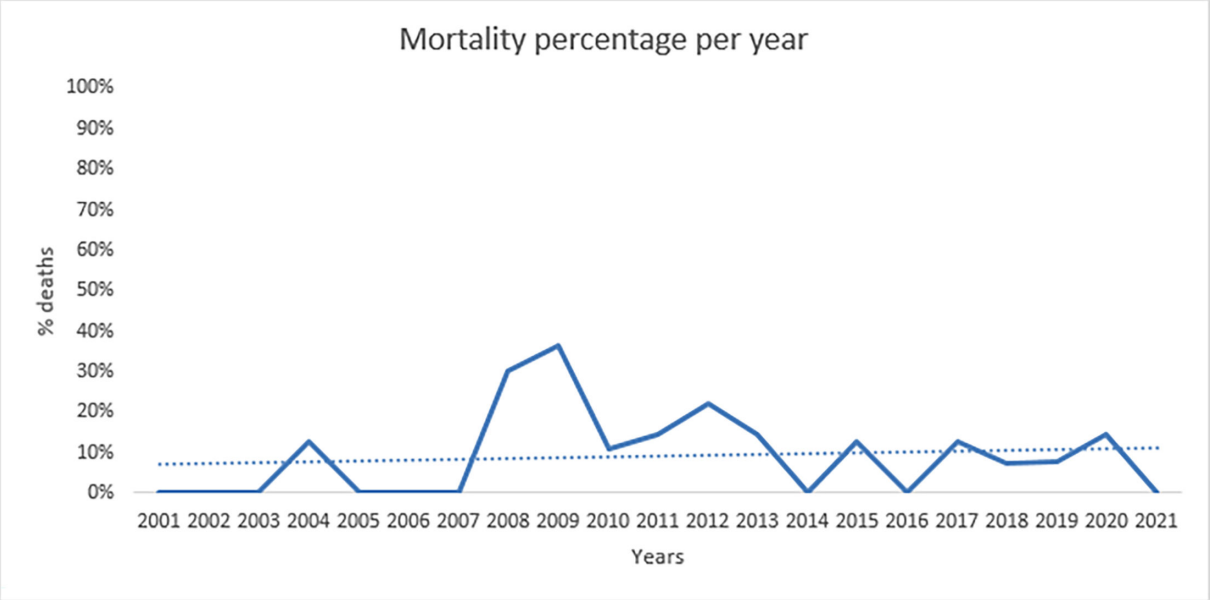

Fig. 5
Annual percentage of patient mortality over the 20-year study period, from 2001 to 2021. The x-axis represents the years, while the y-axis shows the percentage of deaths per year. The solid blue line indicates the yearly fluctuations in mortality percentages, with notable peaks observed in certain years. A dotted trend line is included, representing the overall average mortality rate throughout the study period. This visual representation helps identify any significant deviations or trends in patient mortality across the observed years.

or both anterior and posterior.[10] The greatest advantage of this method is immediate anatomical reduction and sufficient posterior stabilization, which cannot be achieved with external fixation alone. There are some concerns about the possible interference of osteosynthesis in combination with open growth plates. No data on screw placement across or near growth plates resulting in growth disturbances around the pelvis is available in the literature. However, experts advise for elective hardware removal in skeletally immature patients during follow-up to limit growth disturbances.[28–31] Other types of surgical treatment with minimal risk of growth

plate involvement are internal external fixation (INFIX) or suturing of the symphysis.[29,32]

Since this injury is so rare, it is not realistic to conduct randomized controlled trials to determine the optimal treatment strategy. Future research should therefore be prospective observational and/or expert consensus based, and focus on the classification of fracture stability of the paediatric pelvis and optimal treatment.

To our knowledge, this is the largest cohort of paediatric pelvic ring fractures reported in literature. It provides insight into the complexity of the management of these children, and underlines the necessity for consensus regarding fracture stability and optimal treatment. The study evaluates a comprehensive range of patient demographics, injury characteristics, and treatment methods. Furthermore, the trend analysis allows for insights into temporal patterns and shifts in clinical practices, which offers more nuanced interpretation of the findings. The multicentre approach with data collection of two major urban level 1 trauma centres enhances the generalizability of the findings.

A notable limitation of this study is related to the age inclusion criteria. While there is currently no universally agreed upon age limit for paediatric pelvic fracture research, existing studies suggest considering skeletal maturity as a defining factor, distinguishing between patients with open triradiate cartilage and closed (skeletally immature vs mature).[7] In our approach, we opted to include all patients aged up to 18 years. It is crucial to acknowledge that other research underscores distinctions in the classification and treatment of immature pelvic fractures. However, since it is unclear which parameters are most reliable to determine skeletal maturation in the paediatric pelvis (e.g. Risser sign, triradiate cartilage closure, greater trochanteric apophysis closure, proximal femoral epiphysis closure, or ischial apophysis closure), and due to practical constraints, we did not individually assess the skeletal maturity of each patient, but categorized them based on age and thus presumed skeletal maturity. This methodological choice introduces the possibility of selection bias in our study results. Future research endeavours may benefit from a more nuanced examination of skeletal maturity in each patient to enhance the precision of findings.

In conclusion, pelvic ring fractures in the paediatric population represent a rare yet severe injury, and tend to increase in absolute numbers over time. Concomitant injuries should be carefully assessed during initial trauma screening due to the complexity and severity of these injuries. Our findings revealed a one-year mortality rate of 10.8%, primarily attributed to severe concomitant traumatic brain injuries. Notably, the landscape of treatment methods has evolved. While the rate of surgical interventions has not changed, the preferred method of stabilization has shifted towards immediate ORIF instead of the previous reliance on external fixation as the definitive method. Importantly, our study identified variations in treatment preferences among different age groups and between hospitals, underscoring a lack of consensus in the optimal management of paediatric pelvic ring fractures. This emphasizes the need for more evidence on the assessment of fracture stability and treatment methods tailored to the specific characteristics of pelvic ring fractures in children.

References

1. **Gänsslen A**, **Hildebrand F**, **Heidari N**, **Weinberg AM**. Pelvic ring injuries in children. Part I: epidemiology and primary evaluation. A review of the literature. *Acta Chir Orthop Traumatol Cech*. 2012;79(6):493–498.
2. **Nguyen ATM**, **Drynan DP**, **Holland AJA**. Paediatric pelvic fractures: an updated literature review. *ANZ J Surg*. 2022;92(12):3182–3194.
3. **Aprato A**, **Giudice C**, **Bedino P**, **Audisio A**, **Massè A**. Current concepts in pediatric pelvic ring fractures: a narrative review. *Trauma Care*. 2022;2(2):359–372.
4. **Torode I**, **Zieg D**. Pelvic fractures in children. *J Pediatr Orthop*. 1985;5(1):76–84.
5. **Alhammoud A**, **Moghamis I**, **Abdelrahman H**, **et al**. Clinical characteristics, injury pattern and management of pediatric pelvic fracture: an observational retrospective study from a level I trauma center. *BMC Musculoskelet Disord*. 2021;22(1):626.
6. **Banerjee S**, **Barry MJ**, **Paterson JMH**. Paediatric pelvic fractures: 10 years experience in a trauma centre. *Injury*. 2009;40(4):410–413.
7. **Lu V**, **Gowrishankar S**, **Arshad Z**, **et al**. The clinical characteristics and management of paediatric pelvic fractures: a changing landscape based on skeletal maturity. *Eur J Trauma Emerg Surg*. 2023;49(1):559–570.
8. **Hermans E**, **Cornelisse ST**, **Biert J**, **Tan E**, **Edwards MJR**. Paediatric pelvic fractures: how do they differ from adults? *J Child Orthop*. 2017;11(1):49–56.
9. **Spiguel L**, **Glynn L**, **Liu D**, **Statter M**. Pediatric pelvic fractures: a marker for injury severity. *Am Surg*. 2006;72(6):481–484.
10. **Gänsslen A**, **Heidari N**, **Weinberg AM**. Fractures of the pelvis in children: a review of the literature. *Eur J Orthop Surg Traumatol*. 2013;23(8):847–861.
11. **Teasdale G**, **Jennett B**. Assessment of coma and impaired consciousness: a practical scale. *Lancet*. 1974;2(7872):81–84.
12. **Shaath MK**, **Koury KL**, **Gibson PD**, **et al**. Analysis of pelvic fracture pattern and overall orthopaedic injury burden in children sustaining pelvic fractures based on skeletal maturity. *J Child Orthop*. 2017;11(3):195–200.
13. **Silber JS**, **Flynn JM**. Changing patterns of pediatric pelvic fractures with skeletal maturation: implications for classification and management. *J Pediatr Orthop*. 2002;22(1):22–26.
14. **Acker SN**, **Ross JT**, **Partrick DA**, **Tong S**, **Bensard DD**. Pediatric specific shock index accurately identifies severely injured children. *J Pediatr Surg*. 2015;50(2):331–334.
15. **Burgess AR**, **Eastridge BJ**, **Young JW**, **et al**. Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma*. 1990;30(7):848–856.
16. **Tile M**. Acute pelvic fractures: I. Causation and classification. *J Am Acad Orthop Surg*. 1996;4(3):143–151.
17. **Bujang MA**, **Sa'at N**, **Sidik T**, **Joo LC**. Sample size guidelines for logistic regression from observational studies with large population: emphasis on the accuracy between statistics and parameters based on real life clinical data. *Malays J Med Sci*. 2018;25(4):122–130.
18. **Baker SP**, **O'Neill B**, **Haddon W**, **Long WB**. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187–196.
19. **No authors listed**. Rapport Landelijke Traumaregistratie 2017-2021. LNAZ. https://www.lnaz.nl/trauma/landelijke-traumaregistratie (date last accessed 7 February 2025).
20. **Pucher J**. *City Cycling. Children and Cycling*. Cambridge, MA: MIT Press, 2012: 125–137.
21. **Tosounidis TH**, **Sheikh H**, **Giannoudis PV**. Pelvic fractures in paediatric polytrauma patients: classification, concomitant injuries and early mortality. *Open Orthop J*. 2015;9:303–312.
22. **Zwingmann J**, **Lefering R**, **Maier D**, **et al**. Pelvic fractures in severely injured children: results from the TraumaRegister DGU. *Medicine*. 2018;97(35):e11955.
23. **Vandoros S**. COVID-19, lockdowns and motor vehicle collisions: empirical evidence from greece. *Inj Prev*. 2022;28(1):81–85.
24. **Reichert M**, **Sartelli M**, **Askevold IH**, **et al**. Pediatric trauma and emergency surgery: an international cross-sectional survey among WSES members. *World J Emerg Surg*. 2023;18(1):6.
25. **Vonlanthen R**, **Lodge P**, **Barkun JS**, **et al**. Toward a consensus on centralization in surgery. *Ann Surg*. 2018;268(5):712–724.

26. **Sridharan SS**, **You D**, **Ponich B**, **Parsons D**, **Schneider P**. Outcomes following pelvic ring fractures in the paediatric population: a systematic review. *J Clin Orthop Trauma*. 2020;11(6):963–969.
27. **Kruppa CG**, **Khoriaty JD**, **Sietsema DL**, **Dudda M**, **Schildhauer TA**, **Jones CB**. Does skeletal maturity affect pediatric pelvic injury patterns, associated injuries and treatment intervention? *Injury*. 2018;49(8):1562–1567.
28. **Galos D**, **Doering TA**. High-energy fractures of the pelvis and acetabulum in pediatric patients. *J Am Acad Orthop Surg*. 2020;28(9):353–362.
29. **Amorosa LF**, **Kloen P**, **Helfet DL**. High-energy pediatric pelvic and acetabular fractures. *Orthop Clin North Am*. 2014;45(4):483–500.
30. **Scolaro JA**, **Firoozabadi R**, **Routt MLC**. Treatment of pediatric and adolescent pelvic ring injuries with percutaneous screw placement. *J Pediatr Orthop*. 2018;38(3):133–137.
31. **Oransky M**, **Arduini M**, **Tortora M**, **Zoppi AR**. Surgical treatment of unstable pelvic fracture in children: long term results. *Injury*. 2010;41(11):1140–1144.
32. **Rad D**, **van Embden D**, **Bijlsma P**, **Bates P**. Complex open pelvic fracture in an 8-year-old girl treated with INFIX-a case study. *J Am Acad Orthop Surg Glob Res Rev*. 2019;3(4):e089.

Author information

A. H. M. Mennen, MD, PhD, PhD Candidate
A. E. Geerlings, MD, Medical Student
M. E. Van Haeringen, BSc, Medical Student
D. Van Embden, MD, PhD, Trauma Surgeon
Department of Surgery, Amsterdam University Medical Center, Amsterdam University, Amsterdam, the Netherlands.

E. M. M. Van Lieshout, PhD, MSc, Research Coordinator Traumatology
M. H. J. Verhofstad, MD, PhD, Full professor (Surgery)
M. G. Van Vledder, MD, PhD, Trauma Surgeon
Trauma Research Unit Department of Surgery, Erasmus MC, University Medical Center Rotterdam, Rotterdam, the Netherlands.

F. W. Bloemers, MD, PhD, Full Professor (Surgery), Department of Surgery, Amsterdam University Medical Center, Amsterdam University, Amsterdam, the Netherlands; Department of Surgery, Amsterdam UMC location Vrije Universiteit Amsterdam, Amsterdam, the Netherlands.

J. R. De Jong, MD, PhD, Paediatric Surgeon, Department of Paediatric Surgery, Amsterdam University Medical Center, Amsterdam University, Amsterdam, the Netherlands.

Author contributions

A. H. M. Mennen: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.
E. M. M. Van Lieshout: Methodology, Project administration, Supervision, Writing – review & editing.
F. W. Bloemers: Writing – review & editing.
A. E. Geerlings: Investigation, Methodology.
M. E. Van Haeringen: Investigation.
J. R. De Jong: Writing – review & editing.
M. H. J. Verhofstad: Writing – review & editing.
M. G. Van Vledder: Investigation, Supervision, Writing – review & editing.
D. Van Embden: Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing.

Funding statement

The author(s) disclose receipt of the following financial or material support for the research, authorship, and/or publication of this article: The Amsterdam University Medical Centres Graduate School Scholarship by A. H. M. Mennen.

ICMJE COI statement

A. H. M. Mennen discloses an Amsterdam University Medical Center Graduate School scholarship.

Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

Ethical review statement

This study was reviewed by the Medical Ethics Review Committees (METC) of both Amsterdam UMC and Erasmus MC, the Netherlands. Both committees determined that the study does not fall within the scope of the Medical Research Involving Human Subjects Act (WMO) and is therefore classified as non-WMO research. Appropriate data transfer agreements have been established between the participating centers. Data exchange and processing comply with applicable privacy regulations and institutional guidelines to ensure confidentiality and data security.

Open access funding

The open access fee for this manuscript was self-funded.