



Paediatric acetabular fractures Data from the German Pelvic Trauma Registry Initiative

Johanna VON HEYDEN, Oliver HAUSCHILD, Peter C. STROHM, Fabian STUBY, Norbert P. SÜDKAMP, Hagen SCHMAL

From the Department of Orthopaedic Surgery, University of Freiburg Medical Center, Freiburg, Germany

The aim of this study was to present an analysis of acetabular fractures during childhood as compared to those in adults.

Within a multicenter register study, data of 3 time periods (1991-93, 1998-2000, 2004-2008) were pooled and analyzed for incidence, epidemiology, classification, outcome and treatment of acetabular fractures in children (< 15 years).

One hundred fifty three children (2.1%) among 7360 patients with pelvic fractures were included in the study. Only 15 children sustained an acetabular fracture (9.8%). Simple fracture types according to Letournels' classification were more frequent in paediatric patients ($p < 0.01$), receiving less often operative treatment. Multiple injuries were present in 36% of children, the average Injury Severity Score (ISS) of all children was 17 points. Clinical results were good with an average Merle d'Aubigné score of 16.4 points and a Karnofsky performance of 90%.

Fractures of the acetabulum in childhood remain a rare injury with distinct fracture characteristics, usually caused by high impact accidents.

Keywords: children ; pelvic fracture ; acetabulum ; registry study.

INTRODUCTION

Paediatric acetabular fractures are extremely rare (6). The majority of these injuries occurs in

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adolescents and only very few are seen in children younger than ten years (11). Different incidences of acetabular fractures in paediatric pelvic fractures can be found in the literature with ranges from 1% to 20% (3,6,10,12). In relation to all children's fractures, pelvic fractures account for only 2.4% to 7.5% (26). The incidence of pelvic and acetabular fractures overall is similar and adds up to approximately 3% to 8% (10).

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- Johanna v. Heyden, MD, assistant physician.
Department of Orthopaedic Surgery, University of Freiburg Medical Center Freiburg, Germany.
 - Oliver Hauschild, MD, PhD, senior physician.
Department of Orthopaedic Surgery, University of Freiburg Medical Center Freiburg, Germany.
 - Peter C. Strohm, MD, PhD, senior physician.
Department of Orthopaedic Surgery, University of Freiburg Medical Center Freiburg, Germany.
 - Fabian Stuby, MD, senior physician.
Department of Trauma and Orthopaedic Surgery, Berufsgenossenschaftliche Unfallklinik Tübingen, Germany.
 - Norbert P. Südkamp, MD, PhD, head of department.
Department of Orthopaedic Surgery, University of Freiburg Medical Center Freiburg, Germany.
 - Hagen Schmal, MD, PhD, senior physician.
Department of Orthopaedic Surgery, University of Freiburg Medical Center Freiburg, Germany.
- Correspondence : Hagen Schmal, MD, University of Freiburg Medical Center, Department of Orthopaedic Surgery, Hugstetter Str. 55, D-79106 Freiburg i.Br., Germany.
E-mail : hagen.schmal@freenet.de
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Pelvic and acetabular fractures in children are usually caused by high-energy trauma such as traffic accidents or falls from great heights (5,8,23,26). This explains the high risk for multiple associated injuries like head, thoracic and abdominal trauma. A life-threatening visceral injury can be combined with minimal skeletal injury of the pelvis (11). High forces are necessary to fracture the strong and elastic paediatric pelvis. Joint elasticity, thicker cartilage and strong ligaments allow a significantly higher energy absorption before a fracture occurs as compared to adults (12,15). Another anatomical difference in children is the triradiate cartilage, which is formed by a composite of the growth plate and epiphysis of the pelvic, iliac and ischial bones (33). The possibility of physeal damage to the triradiate cartilage in paediatric acetabular fractures leads to premature closure and consecutive growth disturbances of the socket (10,12,33). Fortunately, injuries of the triradiate cartilage seem to occur less frequently than non-physeal fractures of the acetabulum (10). However, Bucholz *et al* classified paediatric acetabular fractures with regard to the physeal injury based on the Salter and Harris classification and discerned two main trauma patterns (3,6). On the one hand, shearing force leads to type 1 or 2 injuries at the interface of the 2 superior limbs associated with a good prognosis for normal acetabular growth. On the other hand, crushing force causes type 5 injuries with premature closure of the triradiate cartilage (3,6,33). The classification of Letournel and Judet, which is mainly used to describe acetabular fractures in adults, disregards these aspects (7). For this reason, some paediatric acetabular fractures cannot be classified according to Judet and Letournel.

Historically, pelvic and acetabular fractures in children were treated conservatively with bed rest, pelvic slings, skeletal traction, or hip spica casting (15,28,31). Arguments for this treatment strategy were the anatomical differences in children with a thick periosteum and increased ligamentous strength resulting in increased fracture stability and the greater capability for union and remodelling in the skeletally immature child (15,20). Furthermore, conservative treatment was favoured because of the risk of laceration of the triradiate cartilage during surgery followed by secondary acetabular dyspla-

sia (15,20). More recent studies showed, however, that the potential for union and remodelling was overestimated and non-operative management of displaced acetabular fractures can lead to a remaining unreduced position, pelvic asymmetry and leg length discrepancy (4,8,12,15,28). Therefore, some authors recommend operative management with open reduction and internal fixation of paediatric acetabular fractures in case of gross displacement and/or involvement of the weight-bearing areas of the acetabulum (10,15,23,24,31).

This study aimed to give an overview of the epidemiology and treatment strategy of fractures of the acetabulum during childhood as compared to those in adults. Very few reports exist concerning clinical evaluation following acetabular fracture in children; therefore, further clinical results will be presented.

METHODS

Characterisation of patients

In a multicenter register study, data of all patients (n = 7360) with pelvic or acetabular fracture who have been treated since 1991 were included. The multicenter register was introduced by the Pelvic Injury working group of the Pelvic Trauma Working Group of the German Trauma Association and the German section of AO International in 1991 including 27 Level I trauma centres. Data from 3 time periods (1991-93, 1998-2000, 2004-2008) were pooled and analyzed for incidence, epidemiology, fracture type distribution and treatment of acetabular fractures in children and in adults (n = 153) (22,27). All patients with an age < 15 years at the time of injury were defined as children (open physis) with the remainder of patients referred to as adults.

Data management

From the original data set, an EXCEL data sheet was exported comprising all paediatric patients with acetabular fractures (n = 15). The following items were taken for analysis: age, gender, date of injury, Injury Severity Score (ISS), Hannover Polytrauma Score (PTS), fracture type (according to Judet and Letournel's classification (14)), further discriminating simple from combined fracture types, need for emergency operative treatment measures, type of treatment (conservative vs. operative), choice of implant if applicable, fracture displacement,

surgical approach if applicable, complications and mortality.

All acetabular fractures were classified by experienced trauma surgeons in the 27 participating Level I Trauma centres and prospectively registered in the multicenter database. Classification was based on plain radiographs and computed tomography (CT) scans when available. Since 1998 CT scans have been routinely used.

Follow up

Six of the 15 children were available for follow-up examination 2-11 years after injury. Follow-up examination included assessment of the score of Merle d'Aubigné (subscales pain (6 points), range of motion (6 points) and gait (6 points) (18)). Additionally, the Karnofsky performance (19) status scale was assessed to measure the ability to perform daily activities after treatment (quality of life). Four patients additionally completed SF-12 (1) and EuroQol-5D (EQ-5D) questionnaires, standardised instruments to measure the general outcome or quality of life. The EQ-5D comprises five items: health, mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each item consists of three levels: no problems, some/moderate problems, and extreme problems (2,7). Radiological evaluation was based on plain radiographs and included assessment of the Kellgren and Lawrence osteoarthritis score (16) and measurements of pelvic symmetry.

Statistics

From the original data sets including 7360 patients, subgroups were formed according to the indicated age groups. Epidemiological data are presented as mean \pm standard deviation. Categorical data are presented as absolute frequency and percent distribution. Data (incidences) were arranged in cross tables and statistical significance of differences was calculated using a 2-tailed Fisher's exact test. A p-value of < 0.05 was considered statistically significant. Data management was done using Microsoft Excel (Microsoft Corp, Redmond, WA); SPSS 14 (SPSS inc. Headquarters, Chicago, Illinois, USA).

RESULTS

Out of 7360 patients with pelvic and acetabular fractures 153 children under 15 years of age (2.1%) were included in the study. Among these, acetabu-

lar fractures were present in 15 cases only, accounting for 9.8% of all pelvic fractures in children or 0.2% of all registered pelvic fractures. One thousand six hundred and four adults sustained a fracture of the acetabulum, accounting for 22.3% (1604/7207) of all pelvic fractures in adults or 21.9% of all registered pelvic fractures. Both frequencies of pelvic ($p < 0.0001$) and acetabular ($p = 0.0001$) fractures were significantly different in children as compared to adults (Table I).

The average age of all children with acetabular fractures was 10.67 ± 2.99 years (range: 5-14). Only one patient was younger than 5 years, 5 were between 6 and 10 years and 9 were between 11 and 14 years. Sixty percent of these patients were male.

The average injury severity score (ISS) and the Hannover Polytrauma Score (PTS) were 16.43 ± 11.93 and 15.79 ± 14.99 ($n = 15$), respectively. Forty percent had multiple injuries; one child died in the emergency room from a severe head injury; all other patients survived.

A combination of an acetabular and a pelvic ring fracture was present in three cases (one C type and two B type fractures, respectively) with the remaining patients (12/15) sustaining isolated acetabular fractures.

According to the classification of Judet and Letournel, fractures of the posterior column (4), the posterior wall (3) and transverse fractures (3) predominated (Fig. 1). Only one combined fracture was found. An epiphyseolysis was present in two cases which could therefore not be classified. The distribution of plain and combined fractures of the acetabulum in children was significantly different as compared to that of adults ($p = 0.0081$, Table II).

As generally seen in pelvic fractures, treatment strategy has changed with a tendency towards more frequent operative management. During the time period between 1991 and 1993 no child received operative treatment; between 2004 and 2008 the percentage of surgically treated children reached 80% (Fig. 2). An operation was indicated following an average displacement of 5 mm. Six out of 15 children presenting with acetabular fractures were treated operatively as compared to 931 out of 1336 adults ($p = 0.2234$, Table III).

Table I. — Frequency of paediatric pelvic and acetabular fractures in the multicenter register of the Pelvic Trauma Working Group (percentages of paediatric and adult pelvic fractures among the total, and percentage of acetabular fractures among the paediatric and the adult pelvic fractures)

	Number	Percentage	P*
Total pelvic fractures (period 1-3)	7360		
Paediatric pelvic fractures	153	2.1	
Pelvic fractures in adults	7207	97.9	< 0.0000001
Paediatric acetabular fractures	15/153	9.8	
Acetabular fractures in adults	1604/7207	22.3	0.0001073

*two-sided Fisher's exact test.

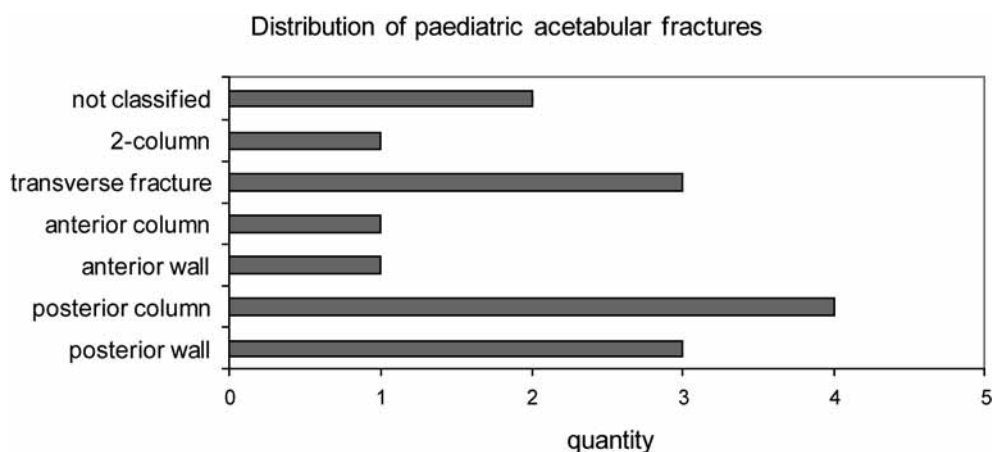


Fig. 1. — Distribution of paediatric acetabular fractures (≤ 15 years of age).

Depending on fracture localization and classification, a Kocher-Langenbeck approach and osteosynthesis with a plate was used 4 times, and percutaneous lag screws were used in 2 patients. There were no complications related to the surgical procedures. A peroneal palsy occurred in a conservatively treated child with hip dislocation and femoral shaft fracture.

Six paediatric patients, who had sustained an acetabular fracture, were clinically evaluated. Follow-up examinations were carried out two to 11 years following injury. The average Merle d'Aubigné score was 16.4, representing a good clinical result regarding pain, gait and range of motion. The Karnofsky performance averaged 90%, representing a good quality of life. Four patients were analysed with EuroQol-5D (EQ-5D) and SF-12. EQ-5D reached a medial health index of

0.77. The mean mental and physical SF-12 scores were 55 and 50 points, respectively.

Furthermore, radiological evaluation based on plain radiographs showed a Kellgren-Lawrence score of 0 or 1 points (average 0.75, $n = 5$); in all of these cases pelvic symmetry was not disturbed.

DISCUSSION

Throughout the literature paediatric acetabular fractures are quite uncommon: the incidence in a series of pelvic fractures in children ranges from 1% to 20% (3,6,10,12,18,33). Our data confirm that acetabular fractures in children are rare (9.8% of all pelvic fractures in patients ≤ 15 years) and occur significantly less often as compared to the 22.3% of acetabular fractures observed in adults. Ismail *et al* reported similar results with a 12.7% incidence of

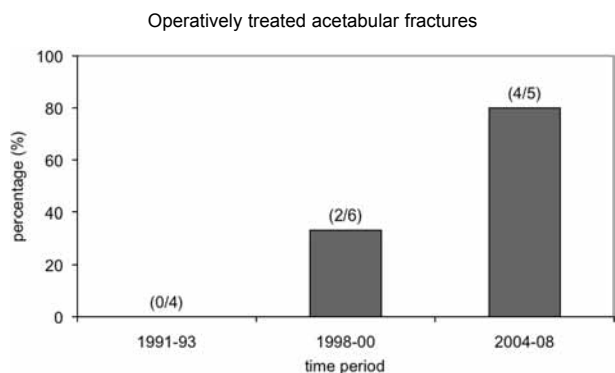


Fig. 2. — Proportions of paediatric acetabular fractures (≤ 15 years of age) treated operatively during the three time periods analyzed

acetabular fractures in children and a 17.7% incidence of acetabular fractures in adults (13). Silber *et al* found a significantly lower incidence of acetabular fractures in the immature group: 6% (6/97) compared to 44% (14/32) in the mature group in a series of 129 children with pelvic fractures (30). Because fracture patterns and treatment vary between adults and children it is important to comprehend when a child's pelvis makes the transition to an adult pelvis (30). Fusion of the triradiate cartilage normally appears between the fifteenth to eighteenth year (3). Because of this, we excluded from the study all adolescents who were older than fourteen years at the time of trauma. The younger the patient is at the time of injury, the greater is the chance to develop acetabular dysplasia over the years (29). One identified reason is the high cellularity of the growth plate cartilage, which reaches the highest degree during infancy and early adolescence (18,29). Some authors even supposed that the patient's age at the time of injury is the most important factor affecting the growth and changes of the acetabulum (18,29). On the contrary, Buchholz *et al* described no severe deformity after injury of the acetabulum incurred after the age of 11 years (3). Separation of the physis, crush of the physis or disruption of the blood supply (germinal zone vessels or epiphyseal vessels) can arise when the physis is injured (18) and may lead to a shallow acetabulum with a lateralized hip joint. This has been shown clinically and in animal models (3,18,33). However, very few patients with paediatric

Table II. — Distribution of simple and complex acetabular fractures depending on age (children ≤ 15 years). The difference reaches statistical significance (two-sided Fisher's exact test)

	Simple fracture		Total
	Simple	Complex	
Children	12	1	13
Adults	1228	1048	2276
	1240	1049	2289

Table III. — Incidence of operative treatment of acetabular fractures in children (≤ 15 years) and in adults. The difference does not reach statistical significance (two-sided Fisher's exact test)

	Operation		Total
	Yes	No	
Children	6	9	15
Adults	1336	931	2267
	1342	940	2282

acetabular fractures sustain a specific injury of the triradiate cartilage (3,10,18,25,29), resulting in premature closure. This seems to occur only in less than 5% of cases (range 0-11%) (18,29,33). A possible bias of the presented study is that no prospective differentiation has been made between subgroups of patients with mature and immature pelvis based on the presence of open growth plates at the triradiate cartilage (15,30). Our analysis was based on the assumption that all patients with an age ≤ 15 years had an immature pelvis. Unfortunately, a radiological follow-up was only available in 5 cases, which was caused by the limited availability of patients for a follow-up examination and the restrictions made by the evaluating ethical board. Since no case of pelvic asymmetry was identified in this series, and further taking the results of other studies into account, the conclusion can be made that a growth disturbance is indeed a rare event in the course of a fracture of an immature pelvis. On the other hand paediatric acetabular fractures mainly occur in adolescents and are rarely seen in children younger than 10 years (11). This data is supported by the current study, showing similar results with an average age of about 11 years, and five children (33.3%) with an age under 10 years at the time of injury.

Two children, a girl of seven years and a boy of 14 years, sustained an epiphyseolysis. These fractures could not be classified, since the classification of Letournel and Judet does not describe this injury. Considering this, some authors use the classification of Buchholz, which is based on the Salter and Harris classification of epiphyseal injuries to the long bones (3,6,26). Heeg *et al* (11) classified 29 paediatric acetabular fractures according to Letournel and Judet and Watts (34), who discriminates 4 types of acetabular fractures: stable, non displaced fractures, unstable, displaced fractures and two types of fracture with central dislocation. Heeg *et al* stated that non-displaced, linear acetabular fractures are common in children and may be difficult to classify anatomically with the classification of Letournel and Judet. Displaced acetabular fractures in adolescents usually resemble acetabular fractures in adults and are best classified using the classification of Letournel and Judet (11). Similar to our results they found that simple fracture types such as posterior wall fractures or transverse fractures were frequent. Fractures of the posterior column were the most common in our series. Furthermore, we found only one combined fracture of the acetabulum, a two column fracture in a 14-year-old girl. Comparing the distribution of simple and combined fractures of the acetabulum in adults and children, a statistically significant difference could be demonstrated. In a study of Judet and Letournel both columns (27%), posterior wall (24%) and transverse posterior wall fractures (21%) were the most prevalent fractures in adults (10,14). However, this distribution is age dependent, e.g. the anterior column is more affected in the elderly (21,32). Increased laxity seen in joints of children's pelvis may allow a fracture to occur only in one area of the acetabulum, in contrast to both column fractures in adults, which are the most common fractures seen in the series of Letournel and Judet.

As generally seen in pelvic fractures, the treatment strategy in adults with acetabular fractures has changed towards a more frequent operative management. Several studies have been published on approaches, technique, and long-term follow-up. In contrast, very few reports exist on how to treat paediatric acetabular fractures and the number of

cases is always small. The current series shows that surgical treatment of acetabular fractures has become increasingly common over the years – not only in adults, but also in children. Yet, this is only an observation reflecting the current status of treatment reality without evaluation of effectivity. During the time period between 1991 and 1993 no child received operative treatment. Between 2004 and 2008 the percentage of surgically treated children had already reached 80%. Good or excellent clinical results presumably correlate with the congruence of the reduction as extensively shown in adults (12). Thus, several authors underline the necessity for reduction of displacements and articular step-offs greater than 2 mm irrespective of age (3,10,18,26,33). In the current study an operation was indicated following an average displacement of 5 mm, but only the maximal range of displacement was recorded without differentiation between step-off, gap or an extraarticular localisation.

Out of 15 children with an acetabular fracture, 6 were operatively treated as compared to 931 out of 1336 adults. Altogether, the proportion of surgically treated fractures in adults is higher than in children, but the difference was not statistically significant with the number of patients available.

Four operatively and 2 conservatively treated children reached a satisfactory clinical outcome. Very few reports about clinical evaluation with instruments measuring quality of life such as SF-12 and EQ-5D after pelvic surgery exist, but a study of the German Pelvic Trauma Working Group of the German Trauma Association showed that the quality of life is well represented by these standardized questionnaires comparing their results to other reports and scores (32). Merle d'Aubigné clinical hip score is generally accepted for assessing the outcome after acetabular fractures in adults (6). In the literature no report for the evaluation of clinical outcome in children sustaining an acetabular fracture with these scores could be found. Usually, children's outcomes after severe skeletal trauma are mostly good to excellent as a result of the remarkable potential for union and remodelling in the skeletally immature patient on the one hand and structural properties adding to fracture stability such as a thick periosteum and higher ligament

strength, on the other hand. Our clinical evaluation of children after acetabular fractures demonstrates a moderate, but persistent functional impairment in most of the cases. The underlying reason is not only the acetabular fracture. Associated injuries, often combined with paediatric pelvic trauma, can also add to unfavourable clinical results.

The primary limitation of this study results from the small number of patients and the limited number of patients available for follow-up examination. However, paediatric acetabular fractures are rare. In this multicenter study including 27 Level I trauma centres only 15 children sustaining an acetabular fracture could be found over a time period of 9 years. Furthermore, time periods to follow-up examinations varied between 2 and 11 years. This was caused by the multicenter approach and the long time frame making it difficult to relocate the patients. In return, a follow-up time of eleven years has historical value. Some authors declare that children with acetabular fractures should be followed at least until skeletal maturity (3,33). Patients with a posttraumatic dysplastic hip may have no long term symptoms as described previously (3,25). However, it is not possible to eliminate the risk that patients with acetabular dysplasia may become symptomatic after the second or third decade of life (33).

In summary, paediatric acetabular fractures remain a rare injury usually caused by high impact accidents leading to a high injury severity. Specific characteristics of this injury such as frequency, patho-anatomy, fracture type and outcome vary as compared to adults. The treatment strategy has changed with growing experience in surgery of acetabular fractures in adults to an increasing incidence of operative care also for paediatric acetabular fractures over the last years. Long-term follow-up examinations are still necessary to evaluate outcome including long-term symptoms after skeletal maturity.

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