Physeal injuries of the proximal humerus: long-term results in seventy two patients

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Abstract

Purpose The aim of this study was to evaluate our treatment methods of proximal humeral physeal injuries retrospectively and elucidate the relationship between the trauma mechanism, the radiographic injury pattern, the consequent therapy and the functional outcome, and to further deduct and verify prognostic criteria.

Methods At our Department of Trauma Surgery, 303 children and adolescent patients with fractures of the proximal humeral epiphysis were treated from 1992 to 2009. 72 cases were diagnosed as physeal fractures according to the Salter–Harris classification and were included in our study.

Results 15 physeal fractures of the proximal humerus were reconstructed anatomically by open or closed reduction and produced 93.3% excellent results. 57 physeal fractures were treated in a conservative way and produced 94.7% excellent results.

Conclusion We state that epiphyseal injuries should to be treated depending on the age of the patient. This is the only way to decrease the rate of posttraumatic epiphysiodesis with consequent problems, including limb-length discrepancy and/or angular deformities.

Keywords Physeal injury · Growth plate · Physeal growth arrest · Limb length · Discrepancy · Epiphysiodesis · Proximal humerus · Open or closed · Reduction · Prognostic criteria

Introduction

Epiphyseal injuries of the proximal humerus are the most common injuries of the shoulder and upper arm among adolescents. Fractures of the proximal humerus represent approximately 0.45% of all paediatric fractures [1], and according to Neer and Horwitz [2] fractures of the proximal humeral epiphysis represent 3% of all physeal injuries. A physeal growth arrest with consecutive bone bridge can occasionally occur after an injury of the proximal humeral physis. Angular deformity or length discrepancy can be the consequence. Permanent damage to the growth plate can be produced due to the trauma or by inadequate treatment [3]. The proximal humeral epiphysis is responsible for 80% of the humeral growth in length [4]. As a consequence, its remodelling potential is considerable, and is related to the age of the patient: the older the child the lower the potential [5]. Regarding the paediatric age groups, injuries to the proximal humerus occur most frequently during the first decade and relatively frequently between 11 and 16 years of age. This fact probably is due to the greater exposure to high energy trauma, like in sports [6] and motor vehicle accidents. Child abuse should be taken into consideration as a possible trauma mechanism in children under 18 months and should be addressed in the differential diagnosis [7]. The circumstances leading to an injury of the proximal humerus can be traced back to one of two mechanisms. The mechanism occurring most frequently is a fall on the

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Table 1 Frequency of physeal injuries on 72 patients according to the Salter–Harris (SH) classification I–V

Classification	Patients	Average age	Percent
SH 1: Epiphyseolysis	23	8.86	31.9
SH 2: Epiphyseolysis and metaphyseal fracture	42	10.14	58.3
SH 3: Epiphyseolysis and epiphyseal fracture	4	13.00	5.6
SH 4: Epi-metaphyseal fracture	3	12.66	4.2
SH 5: Crush injury	was not seen		
Total	72		100.0

extended, abducted and externally rotated arm, representing a defending position [6].

This causes a metaphyseal lesion in toddlers and an epiphyseal lesion in children and adolescents [7]. The second mechanism constitutes a direct trauma caused by a fall on the shoulder, resulting in direct injury of the physis, the epiphysis, or the metaphysis. Participation in top- performance sports can be seen as a significant predisposing factor for trauma to the shoulder [8–10]. The diagnosis of non-displaced fractures sometimes can be very complicated and therefore frequently missed in diagnosis because of the initially three and later two core ossification centres.

The epiphyseal ossification core becomes radiologically evident in the first year of life. Between the second and third years of life the second ossification core forming the greater tubercle and the third ossification core maturing to the lesser tubercle can be spotted radiologically. The tubercle core fuses with the core of the humeral head between the age of 14 and 16. Around the age of 20 the entire humeral epiphysis shows fusion with the diaphysis. This explains the typical fracture types. Isolated epiphyseal separation is rare and occurs typically in newborns and toddlers [11, 12]. Because of the high potential of spontaneous correction due to the proximal humeral epiphysis the prognosis of proximal humerus fractures is good. The ability of spontaneous correction, especially of side-to-side displacement and shaft breaks in the frontal and sagittal plane, is enormous.

Till the age of 12 years a correction of 50–60 degrees of shaft breaks in the frontal- and sagittal planes is possible. Beyond the age of 12 years the correction ability shrinks to half of the primary malposition, which can be tolerated to a maximum of 40 degrees of correction [13]. The most frequent and major complications in children and adolescents are limb-length discrepancy [11] and varus deformity [14] which often lead to a decrease of range of motion—mainly abduction. In many cases this restriction remains for the rest of the patient's lifetime [15]. Several hypotheses were described about the etiology of growth plate damage after trauma, e.g. Aitken [16] or Salter and Harris [12] and guidelines have been set forth by many others, e.g. Blount [14] and von Laer [13]. But still the treatment of displaced fractures is controversial in the international literature.

Purpose

The purpose of this work was to review our experience in the treatment of these fractures and to clarify which extent of displacement should lead to surgery and how the patient's age influences the indication for surgery.

Methods

At the Department of Trauma Surgery at our University 303 children and adolescent patients with fractures of the

Fig. 1 X-ray injury

Table 2 Outcome of all physal injuries

Outcome	Score	Patients	Percent
Good	≥ 25	68	94.4
Average	≥ 15	3	4.2
Poor	≤ 10	1	1.4
Total		72	100

proximal humeral epiphysis were treated between January 1992 and October 2009. We used every patient's clinical chart, and every X-ray and/or CT-scan was reviewed. Demographic data, the type of injury, the trauma mechanism, diagnostic and therapeutic procedures and the follow-up treatment were reviewed. 154 of the patients were male and 149 female. The mean age was 10.1 years. 72 cases (23.4%) were diagnosed as physal fractures according to the Salter–Harris classification [12]. In 231 cases the injury was classified as a subcapital fracture (76.2%). We excluded this group and focused on the epiphyseal injuries of the proximal humerus presented in Table 1.

57 children underwent conservative treatment; in 15 cases surgical treatment was performed. Regarding conservative treatment, Gilchrist's bandage, Desault bandage and Mitella bandage were performed.

Open or closed reduction, with or without internal fixation, was performed in patients with a pre-operative axial deviation of more than 30° (Fig. 1). A bandage immobilization followed in every case to obviate compliance problems and secure good results, although a stable osteosynthesis would not require additional external fixation.

The decision for weight bearing or non-weight bearing mobilization in the bandage is based on the following facts: fracture location (extra/intraarticular), fragment size, stable/unstable fracture, stability of osteosynthesis, patient age and compliance.

The mean overall follow-up time was 4.4 weeks (range 1 week–2.2 years). This major disparity of follow-up time was due to the variable healing time and was dependent on

the patient's age and the type of lesion. The mean follow-up time of operatively treated fractures was three months.

The assessment of the clinical outcome was based on three principals: function (ROM), subjective satisfaction and pain or discomfort. Full range of motion was rated with ten, which is the highest score (good). ROM reduced by a maximum of 20% compared with the uninjured extremity was rated five (average) and ROM reduced by more than 20% was rated zero (poor). Subjective satisfaction was rated ten (good) when the individual had no restriction in their usual sports. Average level of satisfaction was rated five (average) when the individual had no restrictions in their daily routine but more or less restrictions in their sport activities. Poor level of satisfaction was rated zero (poor) when the patient had more or less restrictions in their daily routine. No pain or discomfort was rated ten (good), on effort five (average) and constant pain was rated zero (poor). A total score regarding the three principals mentioned above of ≥ 25 was rated as a good result, ≥ 15 was an average result and ≤ 10 was rated as a poor result as presented in Table 2.

Correlations followed using SPSS 18.0 (Statistical Program for the Social Sciences) comparing the results of each classification, type of treatment and clinical and radiographic outcome in cross tables.

Results

57 patients (79.2%) could be treated conservatively; 15 patients (20.8%) underwent a surgical procedure. K-wires were used in all cases for primary reduction and operative stabilisation (Fig. 2). Three patients (4.2%) underwent open reduction and 12 (16.7%) closed reduction. Anatomical reduction was achieved in all of the 15 cases. The implants were removed after an average time of five weeks (range 3–16 weeks, retrospectively) (Fig. 3). No neurological nor vascular complications were recorded and there were no cases of superficial or deep wound infection.

Fig. 2 X-ray postoperative

Fig. 3 X-ray follow-up in anatomical correct position with no epiphysiodesis

A total of 94.4% of the patients had a full and immediate recovery without any complications, no angular deformities or persisting pain. Only 5.6% of the patients had average or poor results as presented in Table 2.

One patient presented an angular deformity of more than 20° in the primary X-ray. After a conservative treatment with a Desault bandage for four weeks the patient still suffered from an axial deviation of more than 20° at the final follow-up. Although we recommended an operative treatment the patient's parents refused the surgical intervention. No patient presented a clinically significant limb-length discrepancy.

The average age pattern (male and female), according to the Salter–Harris classification, was 8.9 years for type I injuries, 10.1 years for type II injuries, 13 years for type III injuries and 12.7 years for type IV injuries. In all 15 patients that underwent a surgical procedure the primary dislocation of the fracture showed an axial deviation of more than 30° .

Forty-two patients showed a Salter–Harris type II injury and seven patients a Salter–Harris III/IV injury (4 Salter–Harris III and three Salter–Harris IV). The most common radiographic injury patterns were type II injuries in 42 patients (58.3%), followed by type I injuries in 23 patients (31.9%), type III fractures in four patients (5.6%) and type IV fractures in three patients (4.2%) presented in Table 1. The operative intervention in all 15 patients produced 93.3% good and 6.7% average results.

Patients with Salter–Harris type II injuries had a mean immobilization time of 2.8 weeks, type III injuries 3.3 weeks and type IV injuries three weeks. Patients presenting a Salter–Harris type I injury had good results in every case (100%) and a short period of immobilization and recovery with a mean time of 1.5 weeks.

Discussion

The physeal injury of the proximal humerus is rare and many surgeons have little experience with this type of

injury. The correct treatment of fractures of the proximal humerus in children and adolescents depends on the fracture location, degree of displacement and the child's age. The type one Salter–Harris fracture is a fracture through the physis, a pure epiphyseal separation while the Salter–Harris type II fracture goes through the lateral part of the physis and then extends into the metaphysis, detaching a posterior-medial triangular fragment [12].

Type III injuries are fractures through the physis and epiphysis passing the hypertrophic layer of the physis and extending to split the epiphysis. A type IV fracture involves all three elements of the bone: the fracture passes through the metaphysis, physis and epiphysis [12].

The Salter–Harris type V physeal injury is difficult, if not impossible to diagnose acutely. The only radiographic indication may be a decrease in the normal width of the radiolucent physis. These fractures are usually diagnosed in retrospect, sometime after the injury. The development of a bony bar within a few months following the initial injury is associated with a complete arrest of growth of only a portion of the entire physis [17].

This eventually produces a joint surface deformity, an angular deformity and/or length discrepancy of the defected extremity. Injuries with no obvious fracture line extending to the physis, but the persistence of significant pain at the level of the physeal plate over a week, should be absolute indications to perform a MRI [18]. We don't

Table 3 Aneururation compared to surgical treatment

Angulation	Average age	Patients	Percent
Axedeivation $<10^\circ$	10.08	9	12.5
Axedeivation $>10^\circ$	8.12	8	11.1
Axedeivation $>20^\circ$	9.66	3	4.2
Axedeivation $>30^\circ$	11.80	15	20.8
No deviation	9.70	37	51.4
Total		72	100.0

agree that physeal fractures of this type in older children, in whom growth is nearly complete, or in younger children, in which those fractures are associated with little risk for disturbance in growth, will do well with a conservative treatment.

According to von Laer [13] we believe that the patient's age has a major influence on the treatment of such injuries. As aforementioned the remodelling potential of the proximal humerus is considerable and related to age. The younger the patient the higher the remodelling potential. Our results show that physeal injuries of the proximal humerus requiring surgery occur at an average age of 11.8 years.

In all cases the angulations constituted more than 30°, as presented in Table 3. This indicates that under the age of ten years angulations up to 20° may be tolerated. According to Dameron and Reibel [11] and Rockwood et al. [19] angulations up to 70° from one to five years of age and 40° from five to 12 years are tolerated.

The most commonly injured area of the growth plate is the proliferative layer of cells. This area of damage to the physis after fracture displacement is the cause of complications. Although the growth plate is interrupted at the level of degenerative layer of cells, the lesions remain with low risk of disturbance in types I and II. Type III and IV lesions of the growth plate, caused by compressive trauma or a fracture passing through the physis, may damage the proliferative layer of cells severely with a high risk of growth disturbance [20].

Salter and Harris [12] also showed that fractures passing through the physis are replaced by bone tissue, followed by a bone bridge and the problems associated with this. Growth disturbance also can be caused by the use of inadequate surgical fixation.

Our study shows that anatomical reduction with K-wires, if necessary by open means, leads to good results and reduces the risks of a secondary damage of the growth plate, which may cause growth arrest. We could also show that in 94.7% a classic conservative treatment with a Gilchrist bandage, Mitella or Desault bandage for an average of 2.5 weeks, accompanied by X-ray controls after application of the bandage, and after removal of the bandage, in stable, non displaced fractures shows a good outcome.

Conclusion

We believe that the knowledge of common fractures of the proximal humerus in children and adolescents with their evaluation and treatment will help the surgeon to manage these rare injuries.

The young patient must be carefully assessed, fracture displacement must be clarified by X-ray or, if necessary, by

CT/MRI scan. We state that epiphyseal injuries ought to be treated depending on the age of the patient. Our operative results as well as our conservative treatment underline this statement.

The necessity to achieve an absolute anatomic fracture reduction in all planes by closed or open procedures is applicable to patients by the age of 12 and older. This is the only way to decrease the rate of posttraumatic epiphysiodesis with consequent problems, including limb- length discrepancy and/or angular deformities. Under this age we agree with most authors that the remodelling potential of the proximal humerus allows a conservative treatment.

Yet it should be considered that the numeric age is not always comparable to the biologic age, as those patients who may have the constitution of a 12- to 14-year-old, but are aged eight to ten years. In this case the treatment should be adapted to the patients development which again shows that a careful assessment is the key to a successful treatment.

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