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A PROSPECTIVE STUDY OF MANAGEMENT OF PHYSEAL INJURIES OF LONG BONES IN CHILDREN BY VARIOUS MODALITIES

Dr Saurabh Xalxo	Junior Resident ,Department of orthopaedics, GMCH Aurangabad.
Dr Shubham Shivnath Dhakane	Junior Resident ,Department of orthopaedics, GMCH Aurangabad
Dr Sagar Ratnakar Zite	Junior Residenr , Department of orthopaedics, GMCH Aurangabad.
Dr Satish Raghunath Gawali*	Prof. Academic, Department of orthopaedics, GMCH Aurangabad. *Corresponding Author

ABSTRACT **Background –** The physeal injury in children is very common can lead to premature physel arrest if do not intervene. It can be managed conservatively or surgically depending upon the type of fracture. There are various modalities of management of physeal injury in childrens like cast immobilization, k-wire fixation and screw fixation. The goal of treatment of physeal fractures is to achieve and maintain an acceptable reduction without compromising the germinal layer of the growth plate. **Methods-** The present study consists of 30 cases of pyseal injury treated in Government Medical College and hospital between September 2019 to September 2021. The study was conducted with due emphasis on clinical observation and analysis of the management of physeal injury with different modalities. Patients were assessed using Zimmermann et al outcome scoring system. Patients were followed up on 1st, 3rd and 6 months. Result- A good radiological union was observed in most of the Salter-Harris Type 1 and Salter-Harris Type 2 cases managed with closed reduction, however, Salter-Harris Type 3 and Salter-Harris Type 4 fracture were best managed by closed or open reduction either with k wire or with the screw. More than 90 % of Close Reduction & Cast Immobilization have excellent to good results, 100% of Close Reduction & K-Wire have excellent to good results and all cases of Close Reduction or SOS Open Reduction & Screw fixation have equally divided in excellent to fair. **Conclusion-** Types I and II have good prognosis with cast immobilization. Types III and IV have an unpredictable prognosis and often require either closed or open reduction surgery. The prognosis of a type V lesion is poor.

KEYWORDS : close reduction, partial physeal arrest, Salter-harris classification, Zimmermann et al outcome score

INTRODUCTION

The growth plate, or physis, is the translucent, cartilaginous disc separating the epiphysis from metaphysis and is responsible for the longitudinal growth of long bones. The key difference between a child's long bone and that of an adult is the presence of physis. Physeal injuries are very common in children making up 15-30% of all bone injuries.

A child's long bone consists of two epiphyses, two physes (or growth plates), two metaphyses, and a diaphysis. The periosteum is the envelope around the bone; it has distinct mechanical and biological functions. It is very thick in the young child and contributes to the growth in the width of the bone. The physis is responsible for longitudinal growth. With the completion of growth at skeletal maturity, the physis disappears and the periosteum becomes a thin fibrous layer. A basic understanding of the anatomy and physiology of the physis is mandatory to manage injuries to the growth plate effectively.[1]

The presence of growth plate at the end of long bones makes fracture management in children unique in terms of the potential risk of growth disturbances such as developing angular deformities and growth arrest.

Physeal growth may be disturbed by avascular necrosis, direct crushing (salter-harris type 5), formation of a bony bar, non-union, and hyperemia.

The majority of physeal injuries heal quickly and recover fully. In minority growth disturbance or arrest may occur and can result in deformity and impaired function.

Growth plate injuries of long bones require a high index of suspicion and close monitoring during skeletal growth. Early recognition and proper management of these injuries can minimize long-term morbidities. The treatment plan should be individualized after a comprehensive analysis of injury patterns in each patient. SH1 and SH2 injuries with greater than 3mm of displacement are also at increased risk of growth arrest. Salter-Harris 3 or 4 fractures should be reduced regardless of acute or late presentation due to the involvement of the joint. SH3 and SH4 fractures should have less than 2mm step off at the articular surface.

After performing reduction, the fracture should be stabilized initially with cast immobilization (4 to 6 weeks). Unstable fractures may require closed reduction and percutaneous pinning or fractures where interposed periosteum is blocking reduction may require open reduction and internal fixation. If an open reduction is necessary, the fracture should be approached from the tension side to reach the interposed tissue easily. In patients who develop physeal bars and growth arrest, there are multiple options for treatment based on the amount of growth remaining. Skeletal age must be determined to help guide treatment. Boys typically grow until 16, while girls grow until 14 years old.2

METHODES

The present study consists of 30 cases of pyseal injury treated in Government Medical College and hospital between September 2019 to September 2021. The study was conducted with due emphasis on clinical observation and analysis of the management of physeal injury with different modalities.

The sample size for the present study was calculated by conducting pilot study; pilot study was conducted on physeal injury patient. The sample size is 30. Inclusion Criteria were as follows: Age group below 18 years, Radiologically diagnosed fractures of physeal injuries of long bones, Consent to participate in the study, Open fractures up to Gustilo Anderson type II. Exclusion Criteria were as follows: Fractures of long bones in children with compartment syndrome needing fasciotomy, Fractures of long bones in children with neurovascular injury, Refusal to provide informed consent, Open fractures Gustilo Anderson type III A, B, C.

The statistical software SPSS version 26 was used for the analysis of the data. Microsoft Word and Excel have been used to generate graphs, tables etc.

In all high trauma situations, it is important to begin with the trauma basics - the ABCs (airway, breathing, circulation). Once assessed and addressed, evaluation of other injuries may occur. The skin should be assessed for any evidence of open fracture. A neurovascular exam is necessary to assess for any disruption before any type of intervention. Compartments should undergo an assessment to look for compressibility and to check for signs of developing compartment syndrome in high-energy mechanism injuries. X-ray of the part was taken and immobilized in a A/E POP posterior slab. The affected limb was kept elevated. Analgesics and antibiotics were given if necessary. The patient was then prepared for surgery and anesthesia after the pre-anesthetic check-up and adequate fitness for surgery.

CLOSED REDUCTION AND CAST IMMOBILIZATION- While pain control and sedation are often required, techniques are needed for calming and distracting a child during cast application. Speak with a soft voice, sitting and placing oneself at a level at or below that of the child to present a less intimidating stature. Initial examination techniques should be soft and distant from the site of concern, progressing slowly to the area of concern. After you receive pain medicine, your provider will set the bone in the right position by pushing or pulling the bone. This is called traction. After the fracture is reduced have an c arm image to make sure the bone is in the right position. A cast made of plaster of paris will be put on limb to keep the bone in the right position. Advice patient to do not weight bear on the affected limb.

CLOSED REDUCTION & PERCUTANEOUS K WIRE FIXATION- The operation was performed under general anesthesia or brachial block for upper limb and spinal anesthesia for lower limb. For distal end radius type 2 physeal injury fixation, the fracture is reduced with traction and manipulation and checked under an image intensifier. A small skin incision is required for the K-wire insertion. Care should be taken to avoid the sensory branch of the radial nerve. The incision is deepened to the bone using blunt artery forceps and a protective sleeve is inserted. Via the protective sleeve, a single smooth 1.5 or 2 mm K-wire is inserted through the dorsal metaphyseal fragment engaging the anterior cortex of the radial diaphysis. The wire should be inserted with an oscillating drill and cooled with saline to prevent thermal injury. Alternatively, the wire can be inserted manually using a T-handle. Ideally, wires are inserted using image intensification control, to check the trajectory of the wire and to ensure engagement of the far diaphyseal cortex without penetration of soft tissues. Each K-wire is left protruding through the skin, bent and cut. The skin is protected with sterile padding before the application of a cast.

CLOSED REDUCTION SOS OPEN REDUCTION SCREW FIXATION- The operation was performed under general anesthesia or brachial block for upper limb and spinal anesthesia for lower limb. For distal end femur type 4 physeal injury in open reduction perform a parapatellar arthrotomy on the side of the fracture to remove debris and allow direct visualization of the articular fracture. In Minimally open reduction we directly reduce the fracture and hold the fragment with forceps. Confirm anatomical reduction with image intensification. If an anatomical reduction cannot be achieved extend the incision proximally to visualize the metaphysis. Remove debris and soft tissue from the fracture. Reduce the fracture under direct vision. Insert a K-wire in the epiphysis, parallel to the growth plate, to temporarily stabilize the fracture.

At this point, the reduction forceps can be removed. Confirm anatomical reduction with image intensification. Insert a guidewire, through a separate stab incision, in the epiphysis parallel to and away from the growth plate. If the K-wire for temporary fixation is in an ideal position, this can be used for screw insertion. Choose a partially threaded screw ensuring that the thread will not cross the fracture. Insert the screw and compress the fracture. Confirm anatomical reduction, fixation, and stability with image intensification. Remove the temporary K-wire. Close the arthrotomy and percutaneous incisions with sutures. This construct usually requires protected weight-bearing and knee immobilization with a moulded long leg cast or brace for 3–6 weeks.

RESULTS

The age group of 6-10 years children have being most commonly affected i.e. 17 cases (56.66%) and mean age of 10.06 years.

In this series, 0 (0%) patients between 0-5 years, 17 (56.66%) patients between 6-10 years, 12 (40%) patients between 11-15 years, and patients between 16-18 years were 1(3.33%).

Table - I: Showing the age incidence

Age in Years	0-5	6-10	11-15	16-18
No. of Cases	0	17	12	1
Percentage	0%	56.66%	40%	3.33%

In the present series, males were 22 (73.33%) and females were 8 (26.66%) with an M: F ratio of 2.7:1

TABLE –II: Sex incidence.

Sex	No. of cases	Percentage
Male	22	73.33%
Female	8	26.66%

In this series 18 cases (60%) were due to accidental falls,10 cases(33.33%) were due to RTA and 1(3.33%) patient due to assault.

TABLE – III: Mode of injury

Mechanism of injury	No. of cases	Percentage
Accidental fall	18	60%
Road Traffic Accident	10	33.33%
Assault	2	6.66%

In the present series, 18 (60%) physeal injuries were SH Type 2 , 5(16.66%) physeal injuries were SH Type 1, 5(16.66%) physeal injuries were SH Type 3 , 2(6.66%) physeal injuries were SH Type 4 . No cases of SH Type 5 physeal injury were observed.

TABLE –IV :Type of fractures

Type of fractures	No. of cases	Percentage
I) Salter-Harris Type 1	5	16.66%
II) Salter-Harris type 2	18	60%
III) Salter-Harris Type 3	5	16.66%
IV) Salter-Harris Type 4	2	6.66%
V) Salter-Harris Type 5	0	0%

In this present study physeal injury occur most 11(36.66%) in the distal radius, then 7(23%) in the distal femur, 4(13.33%) in distal tibia, 2(6.66%) in the proximal tibia, 2(6.66%) in the base of the phalanx, 1(3.33%) in the head of the metacarpal, 1(3.33%) in proximal humerus and 1(3.33%) in proximal radius

TABLE –V : Physis involved

Type of fractures	No. of cases	Percentage
I) Distal Radius	11	36.66%
II) Distal Femur	7	23.33%
III) Distal tibia	4	13.33%
IV) Proximal Tibia	2	6.66%
V) Base of Phalanx	2	6.66%
VI) Head of metacarpal	1	3.33%
VII) Proximal humerus	1	3.33%
VIII) Proximal radius	1	3.33%

In this present study most cases 17(56.66%) were fixed by CR & Cast Immobilization, then 10(33.33%) cases were fixed by CR & K Wire and 4(10%) cases were fixed by CR or sos OR & Screw. All SH type 1 fracture managed with CR and Cast immobilization , about half of SH type 2 fracture managed with CR and Cast immobilization half with CR and K wire , all SH type 4 fracture are managed by CR or sos OR & screw .

TABLE VI – Type of fixation

Type of Fixation	SH Type1	SH Type 2	SH Type3	SH Type4	No of Cases	percent age
CR & Cast immobiliz ation	5(100%)	10(55.5%)	2(40%)	0(0%)	17	56.66%
CR & K Wire	0(0%)	8(44.5%)	2(40%)	0(0%)	10	33.33%
CR or sos OR & Screw	0(0%)	0(0%)	1(20%)	2(100%)	3	10%
Total	5(100%)	18(100%)	5(100%)	2(100%)	30	100%

In this series 26(86.66%) patients had a sound union in less than 2 months, 4 (13.33%) had a union between 2-6 months, and no patient developed nonunion.

TABLE-VII: Time of union

Time of union	No. of cases	Percentage
<2 months	26	86.66%
2-6 months	4	13.33%
6months- 1year	-	-
Nonunion	-	-
Total	30	100

The mean outcome score was 3.7, 3.8 and 5.3 in CR & Cast immobilization, CR & K Wire and CR or sos OR & Screw respectively.

TABLE –VIII: Mean Zimmermann Outcome Score In Different Treatment Group

TYPE OF FIXATION	No. of Cases	MEAN OUTCOME SCORE
CR & Cast immobilization	17	3.7
CR & K Wire	10	4.2
CR or sos OR & Screw	3	5.6

More than 90 % of CR & CAST IMMOBILIZATION have excellent to good results , 100% of CR & K WIRE have excellent to good results and all cases of CR OR SOS OR &SCREW have equally divided in excellent to fair .

TABLE – IX :RESULTS

Grading	No. of Cases			TOTAL
	CR & CAST IMMOBILIZATION	CR & K WIRE	CR OR SOS OR &SCREW	
Excellent (Score 3-4)	12	7	1	20
	70.5%	70%	33.3%	66.6%
Good (Score 5-6)	4	3	1	8
	23.5%	30%	33.3%	26.6%
Fair (Score 7-8)	1	0	1	2
	5.8%	0%	33.3%	6.6%

The complications of the present study, Premature growth arrest with Angular deformity was in 1(3.33%) patients, infection seen in 1(3.33%).

TABLE X : Complications

Complication	No.of Cases			TOTAL
	CR & CAST IMMOBILIZATION	CR & K WIRE	CR OR SOS OR &SCREW	
PREMATURE GROWTH ARREST WITH ANGULAR DEFORMITY	1	0	0	1
INFECTION	0	0	1	1

FIG 1 – Intraoperative clinical photograph and fluoroscopic ap and lateral view of distal radius SH type 2 physeal injury

fig 2 – Pre and post reduction with cast and 12 weeks follow up x-ray of distal radius physeal injury

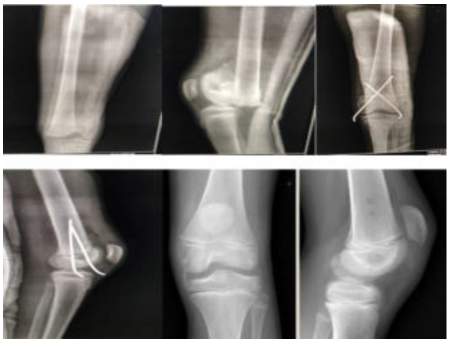

fig 3- pre and post operative with 16 weeks follow up x-ray and of closed reduction and k wire fixation in SH type 2 distal femur physeal injury

fig 4- pre and postoperative with 12 weeks follow up of distal femur SH type 4 physeal injury

DISCUSSION

Recommendations for the management of physeal injuries depend on the age, the physis involved, fracture classification, growth remaining, displacement, injury mechanism, and status of the soft tissues. For fractures with unacceptable angulation or translation, reduction should be performed. Depending on the fracture pattern, this can be done under conscious sedation or general anesthesia. The reduction should be performed early if possible. Multiple attempted reductions and reductions performed more than 5 days after the injury are discouraged, as the reduction maneuver itself may injure the growth plate. It must be remembered that many physeal injuries may have exceptional remodeling potential, for example, the commonly encountered distal Radius fracture. The healing of physeal fractures is rapid; many require only 3-4 weeks of immobilization.[15]

In our study 30 cases of physeal injury were treated with CR & Cast immobilization, CR & K Wire, and CR or sos OR & Screw. Our experience with this method of fixation has given favorable results. The findings, the results and various other data will be analyzed and compared in the following discussion.

The average age incidence; in the present study was found to be 10.6 years. This is well in accordance with the authors Harald binder and Mark Schurz(2011)[27] average age was 11.8 years and Syurabil AH (2019)[28] in his study average age was 11.4 years.

In a study conducted by H A Peterson et al (1994)[35] there were 561 (66%) males and 289 (34%) female and In a study conducted by Syurabil AH (2019)[28] 49 (86%) were male and 8(14%) female. The present study of physeal injury revealed greater incidence in males 22(73.33%). Compared with females which were 8(26.66%). Similarly, male predominance was found in the study of Syurabil AH(86% male) and H A Peterson et al series(66% male)

According to Elisabeth T. Tracy et al (2015)[20], the leading mechanism of injury is fall in 0-9 age group and road traffic accidents in 9-18 age group. In the present study, the patients with falls were 18(60%), patient with road traffic accidents were 10(33.33%), and patient with physical assault were 2(6.66%). In 0-9 age group there were 12 patients out of which 11 have injuries caused by falls and in the 9-17 age group there were 18 patients out of which 10 have injuries cause by a road traffic accidents. Well accordance with the study of Elisabeth t. Tracy.

In a study done by B. R. Garret et al. (2011)[2] 55 patients treated between 1994 and 2007, There were 46 (83.6%) Salter-Harris type II fractures, four (7.3%) type I, two (3.6%) type III and three (5.5%) type IV. In H A Peterson et al (1994) study 126 patient (13.2%) had SH Type 1 fracture, 510 patients (53.6%) had SH Type 2 fracture, 104 patient (10.9%) had SH Type 3 fracture and 62 patient (6.5%) had SH Type 4 fracture. None had SH Type 5 fracture. In the present series, 18 (60%) physeal injuries were SH Type 2, 5(16.66%) physeal injuries were SH Type 1, 5(16.66%) physeal injuries were SH Type 3, 2(6.66%) physeal injuries were SH Type 4 . No cases of SH Type 5 physeal injury were observed. well accordance with H A Peterson study(13.2%) had SH Type 1 fracture,(53.6%) had SH Type 2 fracture, (10.9%) had SH Type 3 fracture and (6.5%) had SH Type 4 fracture .

In a study of T Mizuta et al (1987)[10] in total 353 patients, distal radius involved in 100(28.3%) patients, phalanges involved in 91 (25.8%) patients, distal tibia involved in 33 (9.4%) patients, distal humerus involved in 24(6.8%), proximal radius involved in 16(4.5%) patients, metacarpals involved in 15(4.2%) patients, proximal humerus involved in 7(2%) patients, distal femur involved in 1(0.3%) and proximal tibia involved in 4(1.1%) patients. In this present study, physeal injury occur most 11(36.66%) in the distal radius, then 7(23%) in the distal femur, 4(13.33%) in the distal tibia, 2(6.66%) in the proximal tibia, 2(6.66) in the base of the phalanx, 1(3.33%) in the head of the metacarpal, 1(3.33%) in proximal humerus and 1(3.33) in proximal radius. In this study also distal radius is most involved likely T Mizuta study(28.3%) and phalanges physeal injury cases are less because of loss of follow-ups.

In a review of Syurabil AH (2019)[28] for functional outcome with Zimmermann outcome score all patients with the cast alone had 100% excellent overall results, whereas those treated with the wire had excellent overall results of 75% and good in 25%. In the present study More than 90 % of CR & CAST IMMOBILIZATION have excellent to good results, where 70% and 30% of CR & K WIRE have excellent and good results respectively and all cases of CR OR SOS OR & SCREW have equally divided in 33.3% from excellent to fair. In our study, similar patterns like the review of Syurabil AH (2019) are seen in CR & CAST IMMOBILIZATION and CR & K WIRE.

In a study of T Mizuta et al (1987) in 353 physeal injury patients there 5(1.4%) patients developed complications, all having partial growth arrest. out of which two patients who required surgical correction for angular deformity had injuries of proximal tibia physis. The complications of the present study, Premature growth arrest with Angular deformity was in 1(3.33%) patient of proximal tibial physeal injury, infection seen in 1(3.33%) patient of distal femur physeal injury.

CONCLUSION

The Salter-Harris classification of physeal injuries is based on radiographs and helps to make appropriate treatment choices. Salter-Harris type V is retrospectively diagnosed. Generally, types I and II have a good prognosis when the vascular supply to the physis is spared. Types III and IV have an unpredictable prognosis and often require surgery. The prognosis of a type V lesion is poor as there is partial or complete damage of physis. More than 10% of the growth plate must be damaged to produce complications such as growth arrest or axial deformity. Furthermore, aggressive manipulation and careless surgical approaches can damage the physis, the perichondral ring or the vascular supply of the fracture fragments. Follow-up is mandatory to minimise complications.

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