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Radiology

INTRAARTICULAR INJURIES IN PEDIATRIC KNEE IN RELATION TO PHYSEAL CLOSURE –AN MRI STUDY

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ABSTRACT INTRODUCTION: It is found that ACL injury in younger age is a significant public health burden with gradually rising incidence over the last decade. Present study is about the incidence of ACL injuries and associated meniscal and osteochondral injuries in children aged less than 18years with comparison of the pattern of various injuries before and after closure of physes. MATERIAL AND METHODS: Children were divided into two groups depending on the status of closure of the physis. Intra articular injuries involving cruciate ligaments, menisci and articular cartilage were analyzed for prevalence in relation to the skeletal maturity. RESULTS: Complete rupture including avulsion was significantly more common in mature skeleton and partial tears were more common in immature skeleton with a p value of 0.039 (less than 0.05). CONCLUSION: Commonest injuries involved ACL followed by medial meniscal tears, osteochodral lesions and lateral meniscal injuries.

KEYWORDS : Pediatric Knee; Knee MRI; ACL injuries; Menicsal injuries

INTRODUCTION:

ACL injury is very common in adults. It is found that ACL injury in younger age is a significant public health burden with gradually rising incidence over the last decade according to a report published in 2017. 10-14 years age group is the worst affected (as cited in Shaw et al, 2017). Present study is about the incidence of ACL injuries and associated meniscal and osteochondral injuries in children aged less than 18years with comparison of the pattern of various injuries before and after closure of physes. Incidence and distribution are correlated with those in previous studies in children and adults.

MATERIAL AND METHODS: 55 children of 18 years or lesser age had MRI examination of knee joint in our hospital in the last three years. Youngest child was 7 years old.

This is a retrospective observational study including 39 knee studies of 36 children with recent knee trauma during the last three years. All of them had history of knee injury within one week of MRI study. Youngest child in this group was 9 years old. 8 out of 36 children were girls. Three children had MRI of both knee joints.

Other children had vascular malformations (6), infective or inflammatory diseases (9), bone infarcts (1), ACL reconstruction (2) and Osgood Schlatter disease (1).

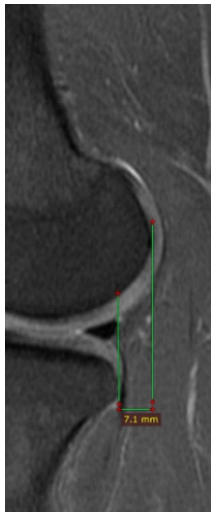
Fig 1. Example for immature skeleton. 9year old boy with unfused distal femoral and proximal tibial physes. PD FS FSE sagittal image with uniformly hyperintense physeal regions (vertical arrows) of both the long bones. Posterior metaphyseal line: linear hyperintensity along the posterior metaphysis (horizontal arrow) is a normal finding in children which should not be mistaken for fracture Children were divided into two groups depending on the status of closure of the physis. Hyperintense signal of the physis of distal femur or proximal tibia was intact (Fig 1) through the entire length in those with immature skeleton (group I). Those with mature skeleton (group II) had partial or complete obliteration of physeal hyperintense signal. Group I included 22 knees of 19 boys and 3 girls with chronological age ranging from 9 to 17 years. 12 boys and 5 girls with ages ranging from 14 to 18 years were included in group II with mature skeleton.

Fig 2. PD FS FSE images through the lateral condyle (A) and in the midline

(B) reveal complete discontinuity of ACL with two separate fragments in (B) –one
of the primary signs of ACL tear. Bone contusions in the lateral femoral and posterolateral tibial condyles in (A) –one of the secondary signs of ACL rupture.

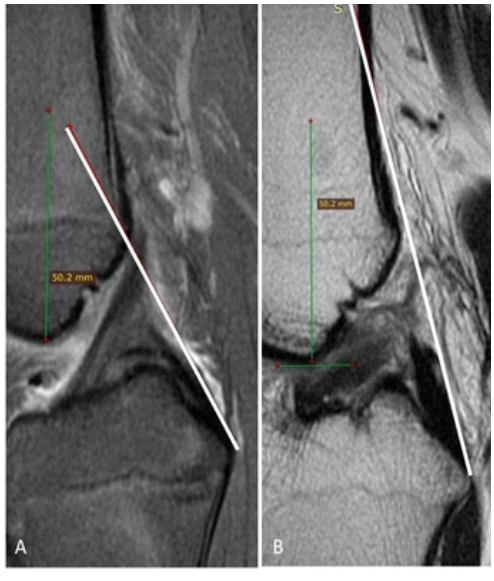
Intra articular injuries involving cruciate ligaments, menisci and articular cartilage were analyzed for prevalence in relation to the skeletal maturity.

Fig 3. Secondary signs of ACL tear: Anterior tibial translocation. PD FS FSE image in the midsagittal plane of lateral femoral condyle selected with the help of coronal sequence. Draw vertical lines tangential to the posterior cortex of the femoral and tibial condyles parallel to the picture frame. Measure the distance between these two lines. More than 7mm anterior displacement of tibia in relation to femur is diagnostic of ACL tear. Between 5 to 7mm is indicative with 99% specificity. Tibial line crossing i.e. evidence of uncovering the posterior horn of lateral meniscus is another sign of anterior tibial translocation. Two of the three best predictors of ACL tear. Other is the posterior cruciate line not crossing the femoral medullary canal within 5cms of the distal portion



All studies were performed on a 8 channel 1.5 Tesla superconducting Essenza MRI unit [Siemens, Germany]. No specific patient preparation was needed. IV contrast or sedation was not required in any of these children. PD FS FSE (TR 2800, TE 27, slice thickness 3.5mm with a gap of 1.3mm) and T1 FSE (827/ 13/ 3.5mm/1.3mm) sagittal, STIR coronal (2990/ 38/4mm/ 1mm) and PD FS FSE axial (4280/ 42/ 4.5mm/ 2.0mm) sequences were performed in all cases though studies included more detailed examination. 8 channel knee coil was used. Knee was imaged in the relaxed state of 5o of external rotation in extended position. FOV was 18- 20cms.

Fig 4. Secondary signs of ACL tear. PD FSE FS sagittal (A) and and T1SE (B) images best depicting the vertical portion of PCL are selected. Posterior cruciate line is drawn tangential to the vertical portion of PCL. PC line extended proximally crosses the femoral medullary canal within the distal 5cms when not associated with ACL tear as seen in (A). Posterior cruciate line in (B) with ACL tear does not cross the medulla within the distal 5cms.



MR Evaluation

Following criteria were used in identifying the ligament, meniscal and osteochondral injuries.

Primary signs of ACL tear: 1. Abnormal signal intensity: ACL appears as a taut continuous linear band of low signal intensity from the medial aspect of lateal femoral condyle to the anterior tibial spine on all sequences and imaging planes. Any focal or diffuse increased singal intensity is considered as tear (as cited in Lee et al, 1999 & Ng et al, 2011).
2. Abnormal aligment: Normally ACL is parallel to the Blumensaat line along the roof of the intercondylar notch.

3. Discontinuity is focal gap in the anterior cruciate ligament or visualisation of more than one piece of ligament (Fig 2). Empty notch sign or fluid between the ligament and the lateral femoral condyle are helpful signs (as cited in Lee et al, 1999 & Ng et al, 2011).

Secondary signs of ACL tear: Secondary sign of ACL injury have high specificity and moderate to low sensitivity and increase confidence of diagnosis.
1) Typical bone contusions : Subcortical areas of nonlinear, reticular or geographic areas of hyperintensities on T2 or T2 fat suppressed images with corresponding hypointensities on T1 in the lateral femoral condyle, posterolateral tibial condyle or both (Fig 2). 2) Anterior drawer sign: Anterior tibial translocation of 5mm or more (Fig 3)
3) Uncovering of the posterior horn of lateral meniscus.

4) Posterior cruciate line (Fig 4) is positive for anterior cruciate ligament tear if the line does not intersect the medullary cavity within 5cms of its distal end (as cited in Schweitzer et al, 1992). Menisci were evaluated by modified Crues' criteria. Normal – Uniform low signal intensity or intrameniscal signal that does not contact the articular surface. Definite tear – a) Linear increased signal abnormality that disruputs an articular surface on more than one slice; b) Morphological

abnormality – Step off, truncation, fragmentation, small size or absence. Meniscal contusion – Amorphous increased signal intensity after acute trauma that touches the articular surface without a definite linear component. Intrasubstance increased signal in the meniscus in children that does not contact the articular surface is of no significant and reflects increased vascularity (as cited in Zobel et al, 1994, Davis, 2010, Prince et al, 2005 & Crues, P et al, 1987) (Fig 5).

Grading of osteochondral lesions: Grade I - only cartilage lesion with edema of subchondral bone; Grade II - partial discontinuity with T2 hypointense interface between the fragment and the parent bone; Grade III - detached but undisplaced fragment with T2 hyperintense rim; Grade IV -displaced but within the crater; Garde V - empty crater loose bodies (as cited in Subasi et al, 2015) (Fig 6).

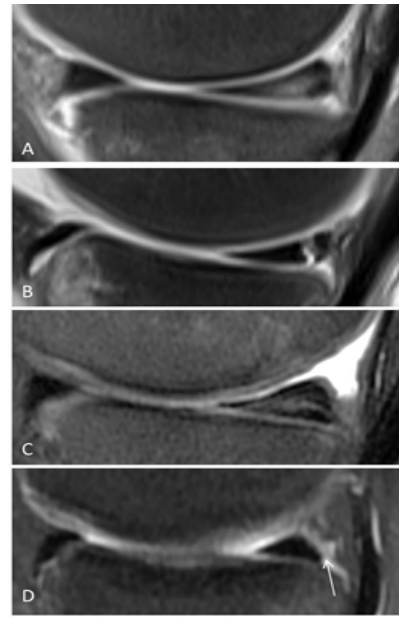


Fig 5. PD FS FSE sagittal images of different patients showing (A) Meniscal contusion -Amorphous increased signal intensity after acute trauma that touches the articular surface without a definite linear component (B) Vertical tear – vertically linear increased signal crossing both the articular surfaces

(C) Horizontal tear –horizontally linear increased signal crossing the tibial articular surface (D) Meniscal ramp lesion or meniscocapsular separation (arrow in D) –fluid signal separating the posterior horn of medial meniscus and the adjacent capsule.

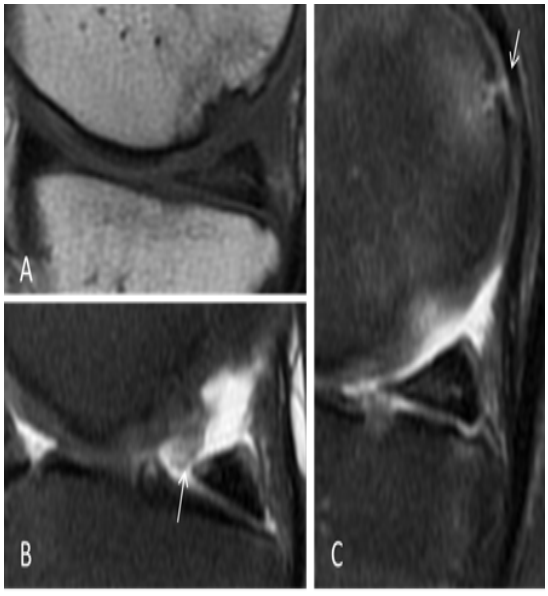


Fig 6. Osteochondral lesions in a 18 year old male. Sagittal T1WI (A) and PD FS FSE (B and C) reveal osteochondral lesions. Unstable osteochondral lesion in the posterior inferolateral

aspect of medial femoral condyle with fluid at the base. Dislodged fragment visualised (arrow in B). Small full thickness cartilage lesion (arrow in C) with focal increased signal in the articular cartilage in the posterosuperior aspect of medial femoral condyle associated with marrow edema

No.of Knees		Immature skeleton		Mature Skeleton		TOTAL
		Our Study	Prince (2005)	Our Study	Prince (2005)	Our Study
		22	31	17	51	39
Age Range(yrs)		9-17	7-17	14-18	12-19	9-18
ACL	Complet	2 (9%)	15 (48%)	7 (41%)	43	9 (23%)
	Partial	17 (77%)	8 (26%)	10 (59%)	6 (12%)	27 (69%)
	Avulsion	1 (5%)	9 (26%)	0	2 (4%)	1 (3%)
	Total	20 (91%)	31 (100%)	17 (100%)	51 (100%)	37 (95%)
Medial Meniscus	Tear	11 (50%)	5 (16%)	12 (71%)	15 (29%)	23 (59%)
Lateral Meniscus	Tear	6 (27%)	3 (10%)	6 (35%)	9 (18%)	12 (31%)
Osteochondral lesions	8 (36%)		12 (71%)		20 (51%)	

Table 1. Comparison statistics of intrarticular injuries according to maturity of skeleton between our study and that of Prince et al, (2005)

Table 1 shows comparison of the results of our study with that of Prince et al, (2005) Data submitted for statistical analysis with Chi square test for the calculation of p value using the Open EPI software version 3.01

RESULTS:

Overall ACL injury was the commonest abnormality seen in 37 out of 39 followed by medial meniscal tears in 23 and osteochondral lesions in 20. Lateral meniscal tears were seen in 12.

ACL injury was seen in all the knees in group II with mature skeleton and in 91% of those with incompletely fused physis. Complete rupture including avulsion was significantly more common in mature skeleton (41% compared to 14% in immature skeleton) with a p value of 0.039 (less than 0.05). Partial tears were more common in immature skeleton than in mature skeleton (77% compared to 59% respectively). This was statistically significant with a p value of 0.039 (less than 0.05).

Medial meniscal injuries occurred in 47.8% of those with immature skeleton and in 52.2% after physeal fusion. This difference was not statistically significant with a p value of 0.263 (more than 0.05). Similarly there was no statistically significant difference in the incidence of lateral meniscal inujruy between the groups with a p value of 0.3676 (more than 0.05).

Osteochondral lesions were seen in significantly higher number in those with mature skeleton (60% versus 40% in immature skeleton) with a p value of 0.033 (less than 0.05). Femoral osteochondral lesions are more common in both groups followed by those in patella and tibia.

There was one discoid meniscus in each group. Tears were seen in both discoid menisci.

DISCUSSION:

MRI is 80% specific for ACL injuries in adult population with no false negatives (as cited in Behairy et al, 2009). It has 90% sensitivity and specificity of 88% in children (as cited in Lee et al, 1999). MRI is 40 – 75% sensitive and 51 – 89% specific for the diagnosis of partial ACL tears. With 3Tesla imaging sensitivity increased to 77% and specificity reached to 97% for partial tears (as cited in Ng et al, 2011).

Number of girls in our study was very small. Therefore assessment of the gender based incidence of the ACL injuries was not possible. AS per the literature, however there is increased incidence of ACL tears in adult females as in girls with mature skeleton, whereas more numbers of boys had ACL tears before physeal fusion (as cited in Davis, 2010, Huston et al, 2000, Fayad et al, 2003 & Prince et al, 2005).

More mid substance tears than avulsions were seen in children with immature skeleton as in other recent studies. It was long held that children with open physes manifest mainly with avulsions of tibial spine (as cited in Mohtadi et al, 2006 & Davis, 2010).

In our study typical contusions were found in 35% ACL tears in immature skeleton and in 29.4% of those with mature skeleton. Over all 32% of ACL injuries showed typical contusions. The sensitivity is on par or slightly less than that reported in the article by McCauley (1994). However these typical contusions were found to be less reliable in pediatric age group (as ciited in Davis, 2010 & Prince et al, 2005). Lateral tibial and femoral condyle contusions in children indicate ACL tear in only 33-72% (as cited in Snearly et al, 1996, Coursey et al, 2006, Davis, 2010 & Gill et al, 2014).

Partial tears were the commonest type of ACL injury in our study population at 69% and partial tears outnumbered complete tears in both immature and mature skeletons. This is in contrast to the distribution in a previous study by Prince (2005), where complete tear was the commonest type of ACL injury and it outnumbered partial tears and avulsions in both immature and mature skeletons (as cited in Prince et al, 2005). ACL tears were seen in all cases like in our study where only 2 out of 39 were normal. Meniscal tears were less common than ACL tears as in our study.

In pooled data from adult studies medial meniscal injuries were significantly more common than lateral meniscal or ACL injuries with p values less than 0.001 for both and lateral meniscal injuries were more than ACL injuries with p value of less than 0.01(as cited

in Crues, P et al, 1987, Kelly et al, 1991, Lee et al, 1988 & Mandelbaum et al, 1986). In a previous study by Zobel (1994) also, medial meniscal injuries were the commonest followed by lateral meniscal and ACL injuries (as cited in Zobel et al, 1994).

Medial meniscal tears were more common than lateral meniscal tears in all these studies including those done in adults. However in a more recent study by Samora (2011), in children with ACL tears, lateral meniscal injuries were more common than medial meniscal tears in those with open physes (as cited in Samora, 2011).

CONCLUSION: Complete tears of ACL and osteochondral lesions were significantly more common in mature skeleton and partial tears were more common in immature skeleton.

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