



# Arcuate sign—fibular head avulsion fracture and associated injuries in the pediatric and adolescent population

Indranil Kushare<sup>1</sup> · Ramesh B. Ghanta<sup>2</sup> · Matthew Ditzler<sup>3</sup> · Siddharth P. Jadhav<sup>3</sup> 

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## Abstract

**Purpose** To describe the first “arcuate sign” case series in the pediatric population, radiologic features of the associated injuries, management, and how they compare with the adult population.

**Methods** Retrospective study included patients under 18 years of age with a classic “arcuate sign” on radiographs. Data collected included patient demographics, mechanism of injury, and management. Radiographs and advanced imaging (MRI, CT) were reviewed by two musculoskeletal radiologists in a blinded fashion and findings recorded.

**Results** Seven patients (4 males, 3 females) with mean age 15 years (range 14–17 years) were included in the study. All 7 injuries were related to sports, 5/7 (71%) being non-contact injuries. Five patients had MRI done—1 LCL injury, MPFL sprain, and MCL sprain were reported; 3 popliteofibular ligament and popliteus sprains were seen; and 3 bone contusions were present on imaging. None of the patients had meniscus or cruciate ligament tears. One patient had an additional fracture of the lateral tibial plateau at the ilio-tibial band attachment and an associated peroneal nerve injury. Five out of seven (71.4%) were treated non-operatively and were able to return back to activity at a mean of 7.2 weeks from injury. Two out of seven (28.6%) needed operative intervention for the fracture but not arthroscopic repair.

**Conclusion** Pediatric patients with a radiographic arcuate sign tend not to have ACL, PCL, or meniscal injuries, and treatment is predominantly non-operative in contrast to literature reported in adults.

**Keywords** Arcuate sign · Fibula head fracture · Knee · Magnetic resonance imaging · Posterior cruciate ligament · Posterolateral corner injury

## Introduction

The “arcuate sign” refers to an avulsion fracture of the head of fibula seen on knee radiographs and is considered to have high association with posterolateral corner injuries of the knee (Fig. 1) [1, 2]. This avulsed bony fragment is related to the insertion site of the arcuate complex [1, 3–5]. The injury has been postulated to occur via two mechanisms, either varus force with the tibia externally rotated or knee hyperextension with the tibia internally rotated. There are only a few case series of this injury reported in

adult literature which show a high association with posterior cruciate ligament tear and posterolateral corner ligament disruption, and no studies to our knowledge have been conducted in the pediatric population [6–8]. There is reason to believe that in children, who have different relative strengths of ligaments compared with their bones, the arcuate sign might not necessarily have a high association with posterolateral corner ligamentous injuries as it is in adults [9]. The purpose of our study is to describe the first case series of this injury in the pediatric and adolescent population and elaborate on the radiologic features of the associated injuries and their management. We also aim to determine how these features in pediatric patients compare with the current literature in the adult population.

✉ Siddharth P. Jadhav  
spjadhav@texaschildrens.org

<sup>1</sup> Department of Orthopedics, Texas Children’s Hospital, 6701 Fannin Street, Houston, TX 77030-2399, USA

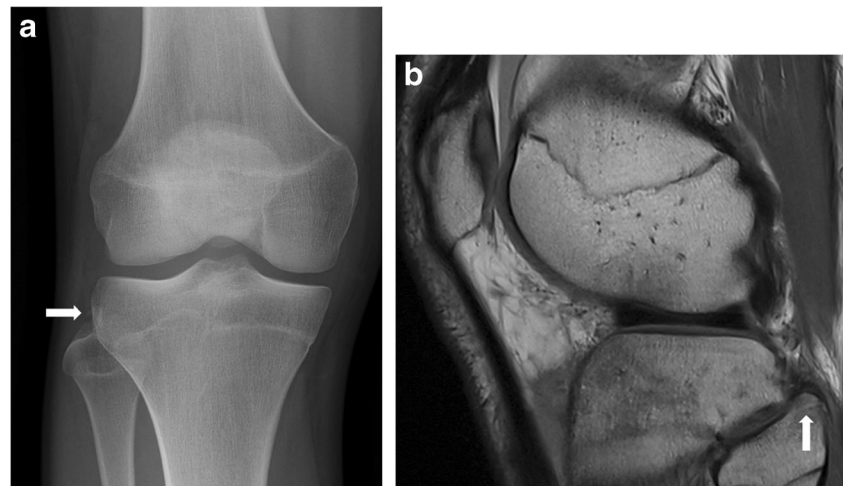
<sup>2</sup> Baylor College of Medicine, Houston, TX 77030, USA

<sup>3</sup> E.B. Singleton Department of Radiology, Texas Children’s Hospital, 6701 Fannin Street, Suite 470, Houston, TX 77030-2399, USA

## Materials and methods

This IRB-approved, retrospective study included patients under 18 years at a tertiary children’s hospital with an “arcuate

**Fig. 1** Fifteen-year-old boy with arcuate sign (arrows) demonstrated on anteroposterior knee radiograph (a) and sagittal PD-weighted image (b)



sign,” i.e., avulsion fracture of fibular head on radiologic imaging from 2005 to 2020. A search of all radiographs in our institution’s PACS (picture archiving and communication system) between January 2005 and April 2020 was performed using the keywords “arcuate sign,” “arcuate fracture,” and “fibular head fracture.” Patients with non-avulsive fibular head fractures that did not fit the definition of an arcuate fracture were excluded. Data collected from the chart review of these patients included demographics, age, gender, mechanism of injury and associated sport, time of presentation from injury, treatment, and return back to previous activity. Radiologic imaging, consisting of conventional radiographs and advanced imaging in the form of magnetic resonance imaging (MRI) and computerized tomography (CT) scans, was independently assessed by two fellowship-trained pediatric musculoskeletal radiologists with 12 years (S.P.J) and 1 year (M.G.D) post-fellowship experience. Differences were sorted by consensus review. The radiologists were blinded to patient management. All MRIs performed at our institution were obtained on either a 1.5- or 3-Tesla magnet with our routine knee protocol consisting of a sagittal proton density-weighted sequence without fat saturation, coronal and axial proton density-weighted sequences with fat saturation, and a sagittal T2-weighted sequence with fat saturation (Table 1). The presence of any meniscal, ligamentous, or popliteus injury was documented. Descriptive statistical analysis was completed and summarized as means with range values or frequencies with corresponding percentages. This was compared

with current literature on arcuate sign in adults and associated findings.

## Results

Seven patients (4 males, 3 females) with mean age 15 years (range 14–17 years) were included in the study (Table 2). The patients had an average height of 168 cm (range 154.7–178 cm), average weight of 73.6 kg (range 44.5–116.5 kg), average BMI of 22.0 (range 18.6–24.9), and average BMI percentile of 69.4% (range 36.7–91.5). The laterality of the injuries involved 4 right knees and 3 left knees; the majority of the patients (6/7) presented to the hospital within a week of the injury. All 7 injuries were related to sports; American football was implicated sport in 2/7 (29%) and 5/7 (71%) being non-contact injuries (Table 2). The mean width of the avulsed fibula fragment was 2.3 mm (range 1–6 mm, median 1.6 mm).

Of the 7 patients who were diagnosed with standard radiographs, 5 patients had MRI done for further characterization of associated injuries; the other 2 did not get advanced imaging as it was not felt necessary by the physician based on stability of the ligaments on clinical examination. One out of five patients had an LCL injury, MPFL sprain, and MCL sprain, 3/5 had mild strains of the popliteus and sprains of the popliteofibular ligament, and 3/5 had bone contusions. None of the patients had meniscal or cruciate ligament tears (Table 3). One patient additionally had a

**Table 1** MRI protocol for teenage (13–18 years old) knees

Plane	Sequence	FOV	Phase encode direction	Slice thickness/gap	TR	TE
COR	PD FS	150 × 90%	R-L	3/10%	2000–4000	20–40
AX	PD FS	150 × 90%	R-L	4/10%	2000–4000	20–40
SAG	PD	110 × 100%	F-H	3/10%	2000–4000	20–40
SAG	T2 FS	140 × 110%	F-H	3/10%	3000–6500	50–60

**Table 2** Summary of individualized associated injury and treatment strategies

Patient	Age	Mechanism of injury	Fragment size (height vs width in mm)	Associated injuries								Treatment strategy	Return to activities (weeks)
				PCL	LCL	MCL	ACL	PFL	Popliteus	Menisci	Bone contusion		
1	15	Football	8.9 × 1.9	N	N	N	N	Y	Y	N	Y	Knee brace	N/A
2	14	Horseback riding	7.8 × 2.3	N	Y	Y	N	Y	Y	N	Y	Knee brace	4.1
3	14	Trampoline	12.1 × 1.9	N	N	N	N	N	N	N	N	Knee brace	6
4	17	Skateboarding	9.3 × 1.4	N	N	N	N	Y	Y	N	N	Knee brace	2
5	14	Football	12.7 × 2.1	N	N	N	N	N	N	N	Y	ORIF	24
6	14	Basketball	5.6 × 1.4	N	N	N	N	N	N	N	N	Knee brace	0
7	14	PE class	22.7 × 6.4	N	N	N	N	N	N	N	N	Peroneal nerve graft	N/A

<sup>a</sup> Posterior cruciate ligament

<sup>b</sup> Lateral collateral ligament

<sup>c</sup> Medial collateral ligament

<sup>d</sup> Anterior cruciate ligament

<sup>e</sup> Popliteofibular ligament

displaced avulsion fracture of the lateral tibial plateau at the ilio-tibial band attachment with an associated peroneal nerve injury as defined by foot drop on clinical examination. Five out of seven patients (71.4%) were treated non-operatively with RICE (rest, ice, compression, elevation), bracing, NSAIDs (non-steroidal anti-inflammatory drugs), and physical therapy and were able to return to their baseline level of activity at a mean of 7.2 weeks from injury. Only 2/7 patients (28.6%) needed operative intervention (Table 3): one had open reduction and internal fixation (ORIF) of the proximal fibular fracture with neurolysis of the common peroneal nerve and the second patient with foot drop and underwent a peroneal nerve neurolysis and sural nerve grafting without fracture fixation.

## Discussion

Avulsion fractures of the proximal fibula can occur during isolated knee injuries or as a part of complex knee trauma. Plain radiograph evaluation may demonstrate a fleck of bone superiorly displaced from the fibula, which is also called the “arcuate sign” [1, 6, 8, 10, 11]. The “arcuate” sign is used to describe an avulsed bone fragment related to the insertion site of the arcuate complex, which consists of the fabello-fibular, popliteofibular, and arcuate ligaments [5, 7, 8, 12].

The mechanism of this injury, which leads to posterolateral instability, is most commonly a direct blow against the anteromedial tibia with the knee in extension [7]; this is most commonly described in association with motor vehicle

**Table 3** Findings and comparison with literature pertaining to arcuate sign

Year published	Study	Patients	Mean age (range)	Associated injuries				Patients needing surgery
				PCL <sup>a</sup>	LCL <sup>b</sup>	Popliteus <sup>c</sup>	PFL <sup>d</sup>	
2020	Jadhav et. al	7	15 (14–17)	0	1/5 (20%)	3/5 (60%)	3/5 (60%)	2 (28.5%)
2002	Juhng et. al	18	38 (19–64)	12 (66.7%)	-	6 (33%)	-	12 (66.7%)
2003	Huang et. al	13	26 (18–35)	13 (100%)	7 (53.8%)	1 (7.7%)	-	13 (100%)
2003	Lee et. al	12	(27–35)	-	4 (33.3%)	-	8 (66.7%)	2 (16.6%)
2008	Crimmins et. al	2	20, 28	2 (100%)	0	2 (100%)	0	0

<sup>a</sup> Posterior cruciate ligament

<sup>b</sup> Lateral collateral ligament

<sup>c</sup> Popliteus tendon

<sup>d</sup> Popliteofibular ligament

accidents, high velocity trauma, high impact sports injuries, and knee dislocations in obese individuals in the adult population [13–15]. However, sports injuries, particularly in association with American football, are commonly implicated in the pediatric population [16] as seen in our patient series.

Recognizing posterolateral knee instability is very important clinically as it is well known that unrecognized and untreated posterolateral instability may result in a failure of reconstruction of either the anterior or posterior cruciate ligaments [14, 15]. Hence, identifying the presence of an avulsion fracture of the fibular head and recognizing any associated injuries are of great clinical importance [3, 7, 17].

MRI is the imaging modality of choice and potentially demonstrates the entire spectrum of posterolateral corner injuries and associated lesions of the knee, including those that may be overlooked during clinical examination or arthroscopy [4, 18]. To determine the diagnostic performance of MRI for helping to predict posterolateral knee instability in patients with acute anterior cruciate ligament (ACL) tear, Filli et al. [19] found that a complete tear or avulsion of the LCL was the most significant predictor of posterolateral instability and the assessment of the smaller posterolateral corner structures did not improve diagnostic performance. Practically, all tears of LCL are associated with damage to posterolateral knee structures. Most injuries of the popliteus muscle and tendon are associated with damage to other knee structures [3].

In children or adolescents with open growth plates, the posterolateral corner injury pattern is considered more rare than in adults. Because knee ligaments are felt to be stronger than the adjacent physal plates, the energy of pathologic translational and rotatory stress commonly results in a fracture or avulsion injury rather than a ligamentous injury [20]. This was confirmed in our case series with only 1 patient showing a mild sprain of the LCL. One patient had medial collateral and medial patellofemoral ligament sprains. Three patients had mild sprains of the popliteofibular ligament and mild popliteus strain. None of our patients had a complete tear of a PLC structure. Also, unlike some adult case reports [6], our case series had no associated ACL tear.

Pediatric studies on isolated posterolateral corner injuries are very rare and primarily case reports [21]. In a study on collateral ligament injuries in the pediatric population, Kramer et al. [16] found that 22% of patients had LCL injuries, of which 6% had concurrent posterolateral corner injuries. Forty-two (82%) knees had injuries that occurred during sports which is similar to our patient series. Previous arcuate sign case series in adults (Table 3) suggest a much higher incidence of severe associated ligament injuries. For example, injury of the posterior cruciate ligament was seen in 100% of adult patients in 2 case series [6, 7] and 66.7% in another [22]. This is in contrast to our pediatric case series which did not show any cruciate ligament tears (Table 3). In young patients without any major ligamentous injuries, a non-operative

management is the treatment of choice which includes weight bearing as tolerated and rehabilitation [23]. Based on this, we would recommend getting an MRI only if indicated based on clinical findings.

One of our patients had another proximal tibia fracture along with a PLC injury. This has been described in adults as an often missed, unusual injury pattern that consists of a large anteromedial tibial plateau fracture associated with a posterolateral (PL) knee corner injury sparing injury to the cruciate ligaments [24].

The appropriate treatment for either injury (posterolateral corner or posterior cruciate ligament) remains controversial in the skeletally immature patient [20]. The literature on non-operative treatment of low-grade injuries is sparse. Good results have been reported for non-surgical treatment for low-grade injuries [13, 23], which was the case in the majority of our patients who were treated non-operatively (5/7). This is in contrast to adult case series on arcuate fractures, which have a high incidence of operative intervention ranging from 66% [22] to sometimes up to 100% of patients [7]. The mean time for return to sports in a pediatric collateral ligament case series was 2.2 months [16], which is similar to our patient series.

Limitations of our study include a small cohort of patients precluding us from conducting inferential statistical analysis as it would be underpowered. However, it is still the largest case series in the pediatric population, which renders the descriptive analysis meaningful. Multicenter studies with larger patient populations could possibly be done in the future.

## Conclusion

Pediatric patients presenting with a radiographic “arcuate sign” tend to have low-grade injuries to the posterolateral corner structures with low frequency of meniscal or cruciate ligament injuries. Treatment is predominantly non-operative in contrast to literature reported in adults.

## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

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