Posterolateral tibial plateau bone bruises in anterior cruciate ligament (ACL) injuries and its association with lateral meniscal injuries

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ABSTRACT

Introduction: This study examined the prevalence of posterolateral tibial bone bruising in isolated anterior cruciate ligament (ACL) injuries, prevalence of meniscal injuries in ACL injuries, as well as the association between posterolateral tibial bone bruising and lateral meniscal tears among those with ACL injury undergoing Primary ACL Reconstruction.

Materials and Methods: Retrospective data on 130 patients who underwent primary ACL reconstructions was analysed. Their preoperative magnetic resonance images (MRI) were reviewed for the presence of posterolateral tibial bone bruise. The presence of meniscal injuries was recorded based on the arthroscopic findings from the operative records.

Results: 95 patients were recruited into the study. The prevalence of posterolateral bone bruise in this study was 41%. There was a statistically significant difference when comparing the prevalence of bone bruising to the time of injury to MRI ($p<0.001$). The prevalence of an injury to at least one meniscus at the time of ACLR surgery was 83.2%. The prevalence of lateral meniscus injuries in patients with bone bruise was found to be 53.9%. The crude odds ratio of a patient having a lateral meniscal tear in the presence of bone bruising was 1.56 (0.68, 3.54). This figure was even higher when it was adjusted for time to MRI and was 2.06 (0.77, 5.46).

Conclusion: Prevalence of posterolateral tibial bone bruising in our study was 41%, and the prevalence of meniscal injury to either meniscus at the point of surgery was 83.2%, out of which the lateral meniscus tears were identified during ACLR surgery in 47.3% of the patients. We found there was no association between posterolateral tibial bone bruising to sex, age and mode of injury, but was sensitive to the interval between time of injury and MRI. The overall prevalence of lateral meniscal tears was higher in patients with posterolateral bone bruising but was not statistically significant with a P value of 0.31; however, the Crude odd ratio was 1.56 (0.68, 3.54) and was higher when adjusted to time of injury to MRI 2.06 (0.77, 5.46). We suggest for MRI to be done as soon as possible after injury in regard to bone bruising identification. We should be vigilant to look for lateral meniscal tears and anticipate for its repair in ACL injuries, especially so when we identify posterolateral tibial bruising on the preoperative MRI.

KEYWORDS:
Bone bruise, ACL injury, Meniscus tear, Bone Edema, Posterolateral tibia

INTRODUCTION

The anterior cruciate ligament (ACL) is a band of dense connective tissue which courses from posterior medial aspect of the lateral femoral condyle in the intercondylar notch to the anterior aspect of the intercondylar eminence of the tibia.[1] The ACL is a key structure in the knee joint, as it resists anterior tibial translation and rotational loads.[2,3] The ACL has a critical role in the stability of the knee.[4] Anterior cruciate ligament (ACL) injuries represent more than 50% of knee injuries and affect more than an estimated 200,000 people in the United States each year, with direct and indirect costs of more than $7 billion annually.[5,6] Most of these ACL injuries occur during sports activity, and up to 70% of all incidents are non-contact injuries.[7-9]

The terms bone bruise and bone contusion have been used synonymously and represent a spectrum of occult bone injuries, including bleeding, infarction and oedema due to microscopic compression fractures of cancellous bone.[10] It is sometimes referred to as occult or non-displaced impaction fracture.[11] Its occurrence in the knee is commonly associated with more serious ligament injuries such as rupture of the ACL where bone bruises are commonly found in the lateral compartment of the knee and are theorized to indicate a higher energy pivoting injury.[11-15] The location of bone bruises within specific compartments of the tibia and femur can provide evidence about the potential injury mechanism.[16]

Bone bruise is best diagnosed by the increased signal intensity seen on T2-weighted images, with decreased signal intensity on T1-weighted images. T2-weighted images reflect the presence of free water (oedema, hemorrhage or inflammatory response) and therefore are useful to determine how acute the injury is. Clinically, it can cause pain and tenderness.[15] MRI studies of acute ACL injury have reported bone bruises, contusions or edema in the subchondral tibia and femur in more than 80 % of subjects with a complete ACL disruption.[12,13,16] In a study by Mink and

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Deutsch, bone signal abnormalities were present laterally in 92% of ACL tears (tibia or femur) [17] and in 100% (tibia or femur) in another study by Murphy et.al.[18] Avulsion fractures of the posterior aspect of the lateral tibial plateau were present in 40% of the acute ACL tears in the study by Stallenberg et al.[19] Bone bruises that were depicted in these regions were usually in accordance with acute ACL tears.

During ACL injury, large external forces in combination with the patient's ligament vulnerabilities during certain loading conditions cause a violent impact between the tibial and femoral articular cartilage that is transferred to the bone, resulting in bone bruises.[16] The typical pattern of bone bruising during ACL rupture involves the lateral femoral condyle (LFC and the lateral tibial plateau (LTP). This pattern of distribution reflects the mechanism of injury during ACL rupture, with the lateral plateau subluxating more laterally than medially, which causes an impact on the anterolateral rim of the femur and the posterolateral rim of the tibia.[20,21] These resultant bone bruises are seen on MRI of the ACL-injured knee as hyperintense signals in the subchondral tibia and femur.[16] When the knee is imaged longer after the ACL injury has occurred, the incidence of bone bruising decreases, ranging from 40-56 % on MRI.[22-24]

Bone bruises evolve over time from the acute injury time and intensify or resolve after varying periods of time. Significant time differences between time of injury and date of MRI collection could potentially lead to inaccurate comparisons of bone-bruise prevalence and location among studies. Tung et al. reported an average MRI collection period of 4.3 weeks for all subjects who demonstrated at least one bone bruise on their MRI[24] while in another study by Graf et al., it was reported that their subjects only expressed bone bruises when MRIs were collected within six weeks post-ACL injury[22] Bone-bruise studies classify ACL injury mechanisms by the location of bone bruises within the anterior, posterior and/or middle aspects within each lateral and medial compartment of the tibia and femur.[25,26]

Isolated ACL tears are uncommon, with approximately 55-65% accompanied by meniscal tears due to the close anatomic and functional relationships of these structures.[27] The menisci are important structures within the knee, with complex biomechanical functions. They are thought to carry 40-70% of the load across the knee, and they have a role in shock absorption, proprioception, and enhancement of stability.[28] The lateral meniscus is injured more often in acute ACL tears, and the medial meniscus is more likely involved in chronic ACL tears.[13,29] Some studies have demonstrated unique gender and sport-specific meniscal injury patterns associated with acute ACL tears.[30-32]

The objectives of this study were to determine the prevalence of posterolateral tibial bone bruises in isolated ACL injuries, the prevalence of meniscal injuries in ACL injuries and to determine the association between between posterolateral tibial plateau bone bruising and lateral meniscal tears among those with ACL injuries.

MATERIALS AND METHODS

Retrospective demographic information and data from the medical records were collected on all patients who underwent primary ACL reconstructions by a single surgeon (M.M.) between the 1st January 2013 and 31st August 2022 at Hospital Sultan Abdul Halim, Kedah, Malaysia. The presence of meniscal injury was recorded based on the arthroscopic findings during the surgery only as obtained from the operative records (meniscal tears confirmed by arthroscopy). Patients whose preoperative magnetic resonance imaging (MRI) images or digitized MRI were unavailable in the local hospital Information system, patients who had sustained more than one ligament injury, and patients who underwent any previous tibial plateau fractures or surgery which could possibly alter the findings of the bone bruise had been excluded from this study. For patients who had met the criteria, their preoperative MRI scans were analyzed via CentricityTM Universal Viewer Zero Footprint Client (GE Healthcare) software and reviewed to determine the presence of posterolateral tibial bone bruise. Bone bruising was considered as present when there was increased signal present specifically in the subcortical or cancellous bone of the Posterolateral tibial condyle on T2-weighted images. Approval for the study was obtained from the Malaysian Research and Ethical Committee, Ministry of Health Malaysia.

RESULTS

A total of 130 patients were recruited into the study of which 35 of them were excluded from the study as they did not meet the inclusion criteria (Figure 1). Of the 95 patients included in the study, 76 of them were males and 19 were female. The mean age of the study patients was 26.6 years, and their ages ranged from 15 to 50 years. (Table I). Sports-related injuries were the main cause of the ACL injury in the study participants accounting for 69.5% (Table I). Field soccer accounted for 60% of the study patients with sports injuries. Other sports-related injuries included futsal, badminton, netball, rugby and other sports accounted for the remaining 40 %. Non-sports injuries, such as motor vehicle accidents and traumatic falls, accounted for the remaining 30.5% of injuries. The median time from the time of injury to the time the MRI was performed was 5 months (Q1–Q3) 2–12 (Table I). Out of 95 patients, 35 patients (37.2%) had their MRI performed within 3 months,16 patients (17%) had their MRI performed between 4 and 6 months after the injury and 22.3% between 6-12 months post-injury. Out of 95 patients, 22 patients (23.4%) had their MRI performed 12 months after the injury (Table I).

The prevalence of posterolateral tibia bone bruising in this study was 41% (39/95) (Table II). The prevalence of posterolateral bone bruising was 42.1 % in females and 40.8 % in males (Table II). There was no statistically significant difference in the prevalence of posterolateral tibia bone bruising patients when compared for sex, age and mode of injury. There was, however, a statistically significant difference when comparing the prevalence of bone bruising to the time of injury to MRI. There was no statistically significant difference between the time intervals <3 and >3–6 months, with a prevalence of 62.9% and 62.5%, respectively.

Table I: Demographic data of the patients including mechanism of injury and the time lapse between the injury and date of MRI

Characteristics	n (%)
Sex	
Female	19 (20.0)
Male	76 (80.0)
Age (years), mean±SD	26.6±8.6
Sports injury	
No	29 (30.5)
Yes	66 (69.5)
Type of sports	
Field Soccer	40 (60.6)
Futsal	8 (12.1)
Badminton	4 (6.1)
Netball	4 (6.1)
Rugby	3 (4.5)
Sepak Takraw	2 (3.0)
Other sports	5 (7.6)
Time to MRI	
Median (Q1-Q3)	5 (2-12)
≤3 months	35 (37.2)
>3-6 months	16 (17.1)
>6-12 months	21 (22.3)
>12 months	22 (23.4)

Table II: Prevalence of posterolateral tibial bone bruise by age, sex, mode and time of injury

	Posterolateral tibial bone bruise		P value
	No, n (%)	Yes, n (%)	
Overall	56 (59.0)	39 (41.0)	
Sex			0.99
Female	11 (57.9)	8 (42.1)	
Male	45 (59.2)	31 (40.8)	
Age, mean±SD	26.6±8.9	26.6±8.4	0.99
Mode of injury			0.82
Other	18 (62.1)	11 (37.9)	
Sports-related	38 (57.6)	28 (42.4)	
Time of injury			<0.001
≤3 months	13 (37.1)	22 (62.9)	
>3-6 months	6 (37.5)	10 (62.5)	
>6-12 months	17 (81.0)	4 (19.0)	
>12 months	20 (90.9)	2 (9.1)	

Table III: Prevalence of meniscal tears at time of ACL reconstruction surgery

Presence of meniscal tear	n (%)
No	16/95 (16.8)
Yes	79/95 (83.2)
Medial meniscus torn	61/95 (64.2%)
Lateral meniscus torn	45/95 (47.3%)
Only involving medial meniscus	34/79 (43.0)
Only involving lateral meniscus	18/79 (22.8)
Both menisci torn	27/79 (34.2)

Table IV: Prevalence of lateral meniscus tear and its association with posterolateral tibial bone bruise

Posterolateral tibial bone bruise	Prevalence, n (%)			Associations, OR (95% CI)	
	No	Yes, n (%)	P value	Crude	Adjusted*
Lateral Meniscus Tear			0.31		
No	32 (57.1)	18 (46.1)		1.00	1.00
Yes	24 (42.9)	21 (53.9)		1.56 (0.68, 3.54)	2.06 (0.77, 5.46)

*Adjusted for time of injury to time of MRI.

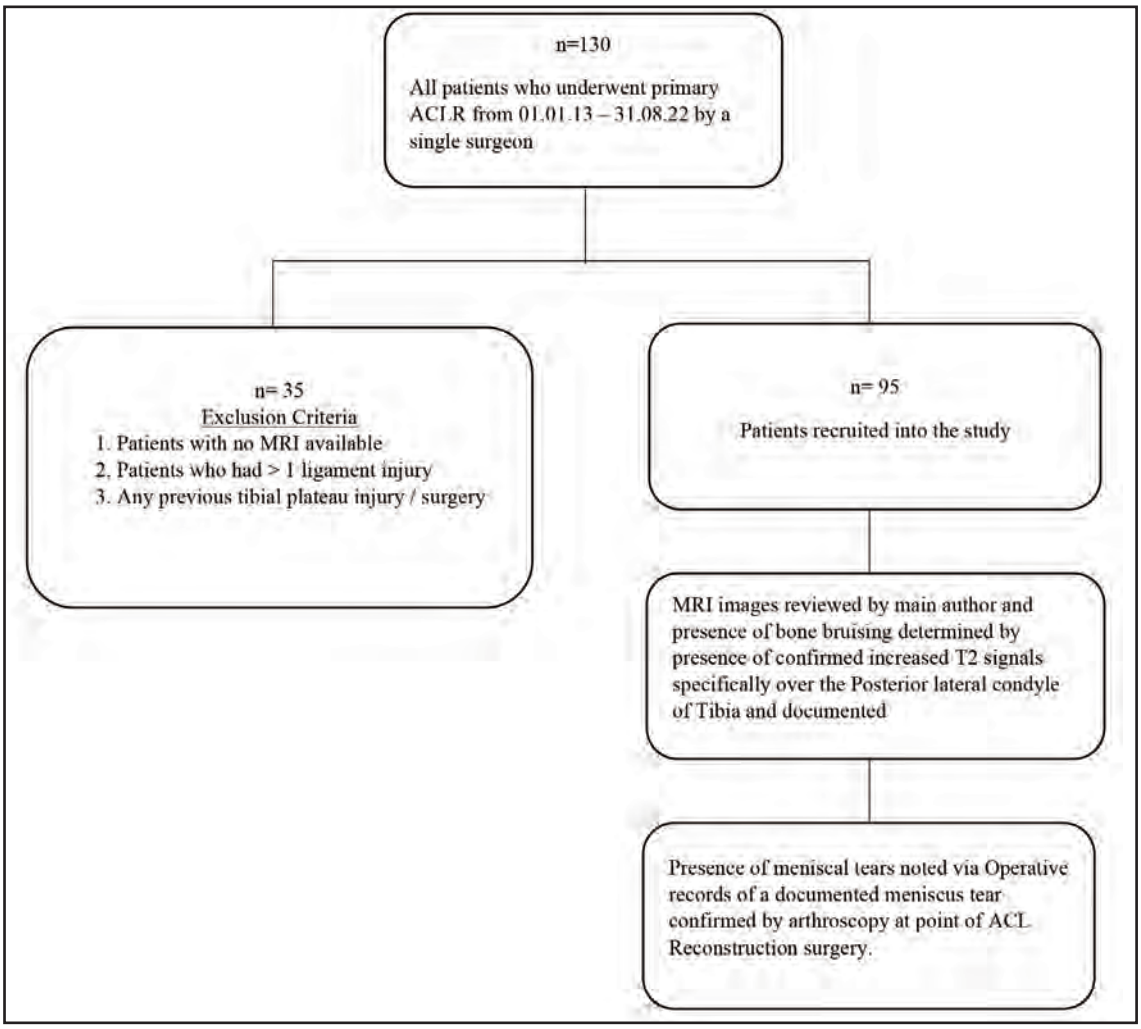

Fig. 1: Flowchart of patient selection.

The prevalence of bone bruising reduced significantly with time to MRI between 6 and 12 months (19.1%) and further reduced with time to MRI above 12 months (9.1%) (Table II).

Prevalence of an injury to at least one meniscus at the time of ACLR surgery was 83.2%. In 28.4% (27/95) of the patients, both the medial and lateral menisci were injured (Table III).

The prevalence of lateral meniscus injuries in patients with bone bruise was 53.9% (Table IV). Although this was higher compared to patients without bone bruise (46.1%), it was statistically not significant with a P value of 0.31 (Table IV). However, when comparing the association between the presence of lateral meniscus tear in posterolateral bone bruising using Fischer's Analytical testing, it was noted that the crude odds ratio with (95%CI) was 1.56 (0.68, 3.54) and was even higher when it was adjusted for time of injury to MRI 2.06 (0.77, 5.46) (Table IV).

DISCUSSION

The prevalence of posterolateral tibia bone bruising in the patients in this study was found to be 41%. Other similar studies have reported a prevalence of bone bruise of 48% with approximately 30% of them in the lateral tibial plateau.[22] A systematic review also reported that ACL-injured subjects showed an increased prevalence of lateral compartment bone bruises, more specifically in the posterior aspect of the lateral tibial plateau and lateral compartment of the femur.[16] This study showed no statistically significant difference in the prevalence of posterolateral tibia bone bruising when compared for sex, age and mode of injury (p>0.05). However, Fayad et al.,[33] and Engebretsen et al.,[34] reported a higher percentage of females demonstrated lateral tibial and medial tibial plateau bone bruises compared to males.

There was no statistically significant difference between the time to MRI intervals <3 and 3-6 months, which both showed a prevalence of about 62%. Other MRI studies have reported bone bruises, contusions or edema in the subchondral tibia and femur in more than 80 % of subjects with a complete ACL disruption.[12,13,16] However, the prevalence of bone bruising was significantly reduced for the group of patients with time to MRI performed between 6 and 12 months after injury to 19.1%. This prevalence was even lower for those patients in which MRI was performed after 12 months from

time of injury (9.1%). This is consistent with the fact that bone bruising is a haemorrhagic/oedematous response to the traumatic injury during an event resulting in ACL tear. These injuries tend to heal over time and may resolve within a year but may persist longer in some cases. These time differences between the time of the injury and the time MRI were performed may lead to inaccurate comparisons of bone-bruise prevalence and location among studies. Some studies have reported bone bruise on MRI performed in a period of 4-6 weeks after the injury[24,22] while other studies have identified persistent bone bruising up to 14 weeks after the injury.[35] The results from this study, however, showed a decline in the incidence of bone bruising after 6 months. 45.7% of the patients had an MRI performed >6 months from the time of injury and this could be a contributing factor for the lower overall prevalence of bone bruising among the patients in this study. The average waiting time for an MRI at the study hospital ranged from 1 to 6 months depending on the number of MRI requests, and this was one of the limitations of this study.

The prevalence of meniscal injury at the time of ACLR surgery among the patients in this study was 83.2% (79/95), of which involving the medial meniscus was 77.2% and that involving the lateral meniscus was 57%. The overall incidence of lateral meniscal tears in this study was 47.3% at the time of ACLR surgery. These findings are consistent with other studies which have shown the presence of lateral meniscal tears between 38.2 and 49.5%.[32,36] The higher incidence of medial meniscus tears in this study patients of 64.2% may be attributed to the chronicity of these injuries. Most of the surgeries for these patients were performed after 1 year from the initial ACL injury. The risk of developing a medial-sided meniscus injury in an ACL-deficient knee increases with time as demonstrated by the findings in this study. In a study of associated injuries in paediatric and adolescent ACL tears, it was also concluded that a delay in surgical treatment was associated with a higher incidence of medical meniscal tears.[36] Chhadia et al.,[37] and Vavken et al.,[38] also similarly reported a significant association between delayed surgery and the risk of medial meniscal injuries as well. The overall prevalence of lateral meniscus injuries in patients with bone bruise was 53.9% compared to 46.1% in patients without bone bruise. Although the percentage was higher, it was statistically not significant with a P value of 0.31. However, when comparing the association between the presence of lateral meniscus tear in posterolateral bone bruising, it was found that the crude odds ratio with (95% CI) was 1.56 (0.68, 3.54) and was even higher when it was adjusted for time of injury to MRI 2.06 (0.77, 5.46).

CONCLUSION

Prevalence of posterolateral tibial bone bruising in our study was 41%, and the prevalence of meniscal injury to either meniscus at the point of surgery was 83.2%, out of which the lateral meniscus tears were identified during ACLR surgery in 47.3% of the patients. We found there was no association between posterolateral tibial bone bruising to sex, age and mode of injury, but was sensitive to the interval between time of injury and MRI. The overall prevalence of lateral meniscal tears was higher in patients with posterolateral bone bruising but was not statistically significant with a P value of 0.31; however, the Crude odd ratio was 1.56 (0.68, 3.54) and was higher when adjusted to time of injury to MRI 2.06 (0.77, 5.46).

We suggest that an MRI has to be done as soon as possible after injury regarding bone bruising identification. We should be vigilant to look for lateral meniscal tears and anticipate for its repair in ACL injuries, especially when we identify posterolateral tibial bruising on the preoperative MRI.

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This study is not funded by any organisation.

CONFLICT OF INTEREST

This study has no conflict of interest.

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