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Bone bruise in the acutely injured knee

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Abstract We used MRI to study the lesions in a consecutive group of 64 patients with an acute trauma of the knee and normal plain radiography during the winter season. Bone bruise was present in 35 of the patients, and these were referred to subsequent MRI 4 and 12 months later. After 4 months bone bruise was still present in 69% of the patients and after 12 months in 12%. Soft tissue lesions, for example, lesion in the meniscus, ACL rupture, or MCL lesion was present in 94% of the patients with bone bruise. Interobserver agreement varied from good to excellent. Soft tissue lesions are found in almost all patients with bone bruise, and these generally resolve 4–12 months after the injury. In the patients with no bone bruise the number of ligament injuries was lower.

Keywords Knee injury · Acute · Magnetic resonance imaging · Bone bruise

Introduction

In recent years magnetic resonance imaging (MRI) has been used frequently in patients with acute musculoskeletal trauma, especially in the knee [3], as it is superior to other radiological modalities such as plain radiography, computed tomography, and ultrasonography in revealing bone and soft tissue lesions. The term bone bruise injury or bone contusion has been used synonymously for areas in cancellous bone with a high signal intensity on MRI fat-suppression sequences [1, 4, 8]. It has been suggested that these areas represent a spectrum of radiographically occult bone injuries, ranging from bleeding, infarction, and edema to microscopic compression fractures of cancellous bone [4, 7, 12] without disruption of compact bone within cortex, unlike a fracture, which involves both cancellous and compact cortical bone. Bone bruises may be associated with more serious injuries, for example, ligament injuries [9, 16], but isolated bone bruise abnormalities may also account for clinical symptoms and require prolonged rest of the knee. However, the clinical significance and prevalence of bone bruise in patients with acute trauma of the knee are poorly elucidated.

We carried out a prospective study of lesions on MRI in a random group of patients with an acute trauma of the knee during a winter period.

Design and patients

The study included all 64 patients presenting at one of our causalty wards with an acute trauma of the knee between January and March 1998 (33 men, 31 women; mean age 36 years, range 15–68). One patient was excluded due to technical problems. In the

63 patients bone bruise was found in 35 (56%). The patients were offered an extremity MRI of the injured knee in addition to clinical examination. To be included any kind of trauma, twist, or contusion of the knee must have occurred within the previous 24 h and no fracture on plain radiography.

MRI was performed on average 5 days after the visit to the causalty ward. If bone bruise abnormalities were present at the first examination, the patient was referred to two more MRI examinations. The second examination, which we call the early follow-up examination, was performed approximately 4 months after the injury (range 2.5–5.5, mean 3.5). 16 patients returned to the early follow-up MRI. The third and last examination, the late follow-up, was performed approximately 1 year after injury (range 11–16 months, mean 12.5); 25 patients had the late follow-up MRI. Of the 16 patients who had an early follow-up 15 returned to the late follow-up, and there were 10 patients who had a late follow-up but no early follow-up.

Extremity MRI

MRI of the knee was performed with an extremity scanner (Artoscan 0.1 T Esaote, Genova, Italy) with a linear coil and an 11 cm field of view. The imaging time was less than 30 min. The following five sequences were performed:

- Turbo-multi echo (TME; T2 and proton weighted), TR 2400 ms, TE 34/90 ms, flip angle 90°, sagittal plane, slice thickness 5.0 mm, gap 0.5 mm
- TME, TR 2400 ms, TE 34/90 ms, transversal plane, slice thickness 5.0 mm, gap 0.5 mm
- Three-dimensional gradient echo (GE), TR 200 ms, TE 14 ms, sagittal plane, slice thickness 5.0 mm, gap 0.5 mm
- Three-dimensional GE, TR 200 ms, TE 14 ms, coronal plane, slice thickness 5.0 mm, gap 0.5 mm
- Short tau inversion recovery (STIR), TR 1200 ms, TI 85 ms TE 28 ms, two acquisitions, flip angle 90°, coronal plane, slice thickness 5.0 mm, gap 1.0 mm

Evaluation

All the extremity MRI sequences were analyzed independently and blinded by two senior radiologists using a standardized questionnaire. All examinations were evaluated with regard to presence or no presence of (a) abnormalities of menisci including tear lesions, (b) ligament injuries (anterior and posterior cruciate ligaments, medial and lateral collateral ligaments), and (c) cartilage and osteochondral lesions including bone bruise lesions including locations. The MRI sequences performed 4 months and 1 year after trauma were evaluated in conjunction with the review of the initial images, and the extent of bone bruise was compared.

In this study we used the definition of bone bruise by Mink and Deutsch [8] as a traumatically involved, geographic, and nonlinear area of signal loss involving the subcortical bone, detected on T1-weighted images. On T2-weighted and STIR images most or all of the lesions had increased signal intensity (Fig. 1A, B). Bone bruises were divided into three types [5]: In a type I lesion there is a loss of signal intensity on short TE images that is located primarily within the medullary cavity of the bone without cortical interruption. The type II lesion is defined as a loss of signal intensity associated with an interruption of the black cortical line, also on short TE images; in this study we define this type of abnormality as a fracture combined with bone bruise. The type III lesion is defined as a signal intensity loss on short TE images that is restricted primarily to the region of bone immediately adjacent to the cortex without a definite cortical interruption.

Vellet et al. [18] offer a classification based on the structure of bone injuries. Reticular injuries are regions of reticular, serpiginous stranding of diminished signal intensity on T1-weighted images within the high signal intensity of marrow. Such lesions may be associated with focal cortical impaction. Geographic injuries are occult subcortical fractures characterized by their contiguity to the subjacent cortical bone that may show focal cortical impaction. The geographic injuries can show variable degrees of depression of the articular or osteochondral surface. Linear lesions are discrete linear regions of T1 diminished signal and unassociated with evidence of significant perifocal reticulation.

Osteochondral lesions, which is a geographic injury involving the osteochondral surface, were diagnosed as discrete adherent of distracted cortical fractures associated with variable quantities of marrow fat, shown as a low signal on GE sequence and a high signal intensity on STIR images [18].

A meniscal tear was diagnosed on TME and GE sequences when the images showed an irregular high-intensity signal of vertical or horizontal lines extending to the margin of the surface of the meniscus, causing a disruption of the typical triangular low-intensity signal contour of the meniscus. If no tear lesion was visible, but the images showed an increased signal intensity in the central area, or the contour of the meniscus was blurred at the TME and GE sequences, the meniscal lesion was diagnosed as an increased

Table 1 Other lesions found in 35 patients with bone bruise and in 28 patients without bone bruise at the MRI performed shortly after the injury (*ISI* increased signal intensity lesion, *ACL* anterior cruciate ligament, *PCL* posterior cruciate ligament, *LCL* lateral collateral ligament)

Lesion	All 63 patients	35 patients with bone bruise		28 patients without bone bruise		Patients with lesion and bone bruise	
		n	%	*n*	%	*n*	%
No other lesion	7	2	6	5	18	2/7	29
Medial meniscus lesion (ISI/tear)	50	30	86	20	71	30/50	60
Lateral meniscus lesion (ISI/tear)	30	19	54	11	39	19/30	63
Partial ACL rupture	6	3	9	3	11	3/6	50
Total ACL rupture	18	12	34	6	21	12/18	67
Partial PCL rupture	0	0	–	0	–	0	–
Total PCL rupture	0	0	–	0	–	0	–
MCL lesion	18	12	34	6	21	12/18	67
LCL lesion	9	8	23	1	4	8/9	89
Osteochondral lesion	28	28	80	0	–	28/28	100
Fracture	1	1	3	0	–	1/1	100

signal intensity lesion (ISI). These lesions could be due to degeneration or a crush lesion.

A cruciate ligament injury was diagnosed on TME as a partial lesion when some continuous fibers were present, and as a complete lesion when there were absence of any intact fibers along the normal course of the ligament.

An injury of the collateral ligaments was diagnosed as a lesion when STIR and TME (axial plane) images showed increased signal intensity in the ligament.

The interobserver agreement was expressed in terms of the κ statistic, as a two-level κ result, with extremity MRI interpreted as positive or negative for bone bruise. To determine the interobserver agreement for lesions of the menisci the extremity MRI was interpreted as positive or negative ISI. Interobserver agreement was defined as almost perfect (κ>0.80), good (κ=0.80–0.61), moderate (κ=0.60–0.41), fair (κ=0.40–0.21), or poor (κ<0.21) according to Davies et al. 1982 [2].

Nonparametric statistics were used to compare the patients with themselves using Wilcoxon's signed test. The level of significance was set at P<0.05.

Results

Bone bruise

Both investigators found bone bruise in 35 patients (56%), including one patient in whom a fracture of the lateral tibia condyle was detected on MRI despite normal radiography. No bone bruise were diagnosed in 28 patients (44%) at the first examination. Interobserver agreement was almost perfect (κ=0.936, 95% limits 0.848–1.0).

Of the patients with bone bruise 94% had other lesions as well (Table 1, Fig. 1A). Only two patients had bone bruise as the only abnormality at the first examination. Bone bruise was found in all condyles and in more than one condyle in 18 patients (Table 2). In the 35 patients with bone bruise we found 22 (63%) with bone bruise in the lateral tibial condyle, 18 (51%) with bone bruise in the lateral femural condyle, 12 (35%) with bone bruise in the medial tibial condyle, and 9 (26%) with bone bruise in the medial femural condyle (Table 2).

At the early follow-up approx. 4 months after trauma the bone bruise had resolved in 5 of 16 patients (31%) who returned to early follow-up. In the other 11 patients (69%) the bone bruise was more diffuse but less intense (Fig. 1B). At the late follow-up after approx. 12 months the bone bruise had resolved in 22 of 25 (88%; Figs. 1C, 2). The disappearance rate was statistically significant (P=0.013). In the remaining 3 patients (12%) bone bruise was still detectable but was more diffuse and less intense than at the early follow-up.

At early follow-up the investigators disagreed in one patient over diagnosing bone bruises. The observed agreement rate was slightly lower (κ=0.862; 95% confidence limits 0.60–1.0) due to the low number of patients [15]. At the late follow-up (1 year after trauma) the agreement was good (κ=0.779; 95% confidence limits 0.354–1.0); also here the readers disagreed over one patient regarding presence of bone bruises. In one patient bone bruise was diagnosed only at the first examination and the late fol-

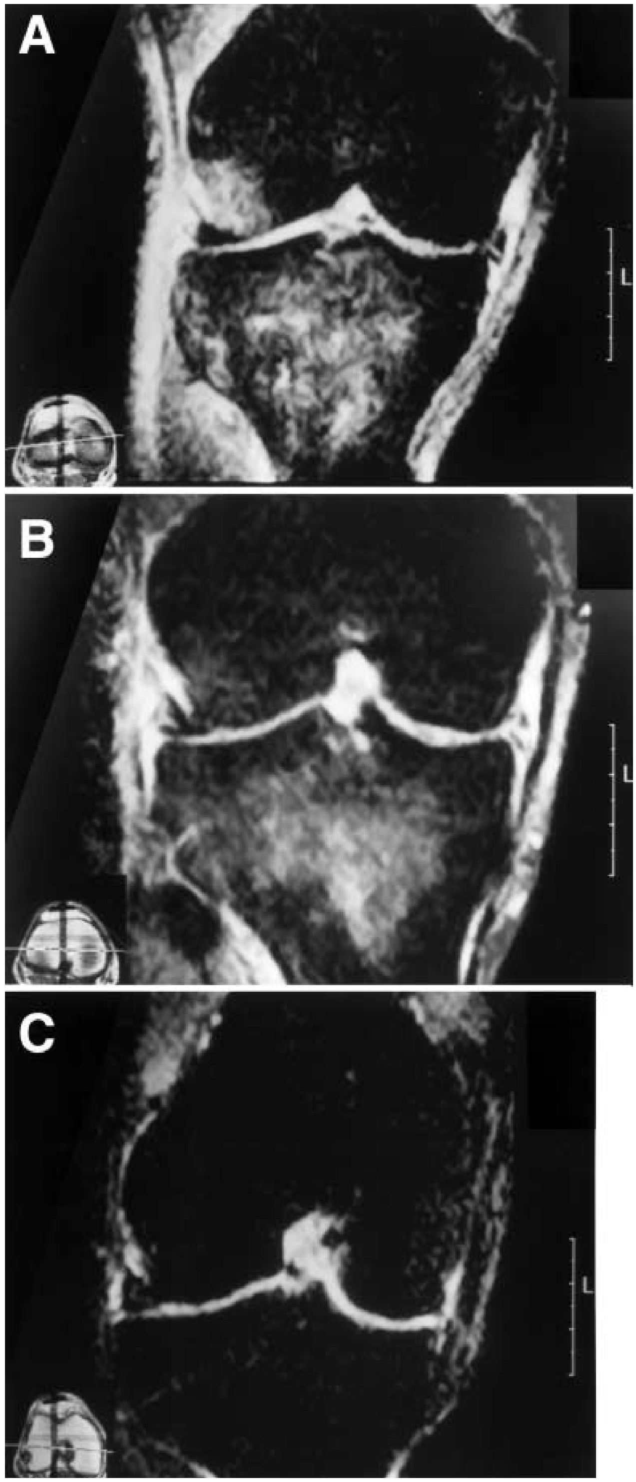

Fig. 1A–C A First examination in a patient with bone bruise. **A** diffuse area within the bone, with increased signal intensity at the short tau inversion recovery sequence is found in both medial and lateral tibia condyle and in the lateral femur condyle. **B** Second examination approximately 3 months later. The areas with bone bruise are now more diffuse but less intense. **C** Third examination approximately 1 year after trauma. Bone bruise areas are no longer visible

Table 2 Showing the locations of bone bruise in 35 patients; 33 patients had more than one other lesion, and 18 had bone bruise in more than one condyle

Lesion	35 patients with bone bruise	Bone bruise in the medial femural condyle	Bone bruise in the lateral femural condyle	Bone bruise in the medial tibial condyle	Bone bruise in the lateral tibial condyle
No other lesion	2 (6%)	0	1	1	0
Medial meniscal lesion (ISI/tear)	30 (86%)	6	11	6	14
Lateral meniscal lesion (ISI/tear)	19 (54%)	6	10	6	11
Partial ACL rupture	3 (9%)	1	1	2	1
Total ACL rupture	12 (34%)	4	7	6	11
Partial PCL rupture	0	0	0	0	0
Total PCL rupture	0	0	0	0	0
MCL lesion	12 (34%)	5	6	1	6
LCL lesion	8 (23%)	1	5	3	6
Osteochondral lesion	28 (80%)	9	17	9	15
Fracture	1 (3%)	0	0	0	1

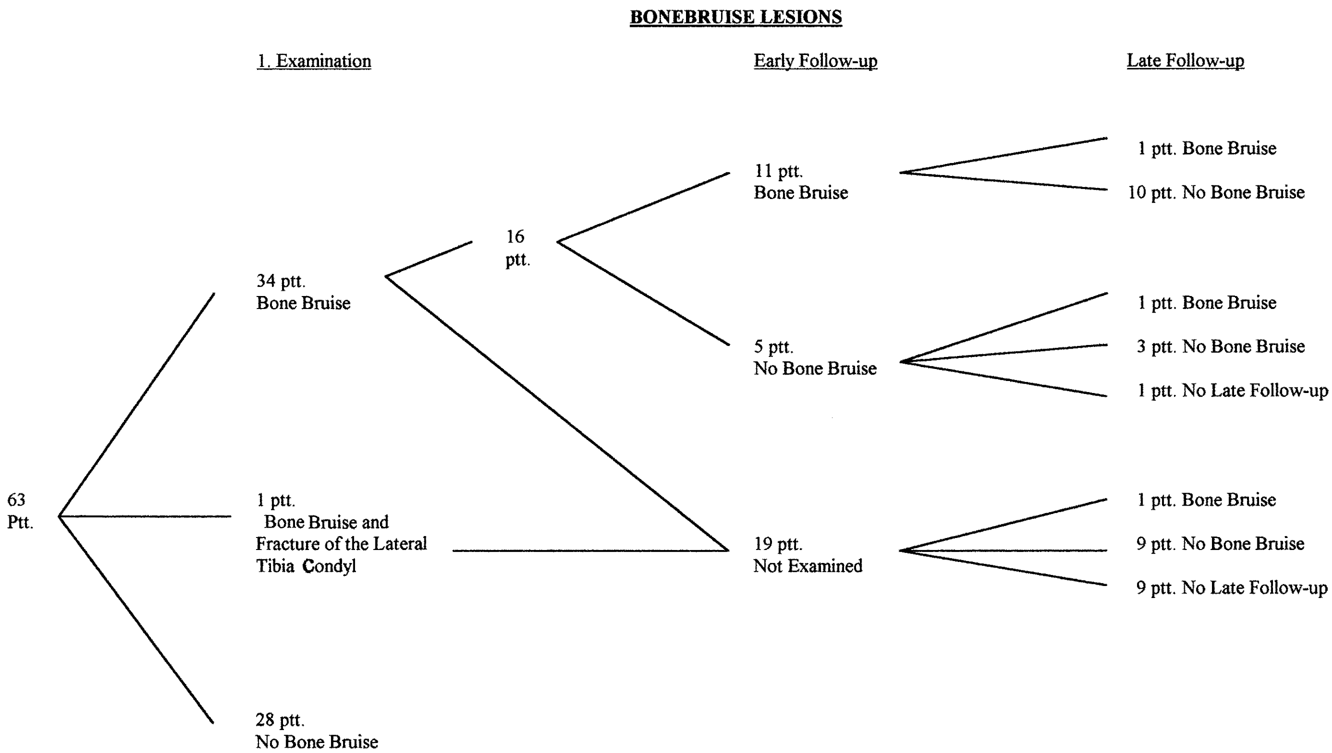

Fig. 2 An algorithm showing the bone bruise results of the three examinations

low-up; he experienced a second distortion after the early follow-up MRI.

The results of the three examinations are shown in an algorithm (Fig. 2).

Meniscal lesions

At the first examination ISI in the medial meniscus were diagnosed in 50 patients (79%) by one or both readers. In only 13 patients (21%) both readers diagnosed the menisci as normal. In 26 patients both ISI and a meniscal tear were found while the other 24 only ISI was reported. Interobserver agreement was good (κ=0.732; 95% confidence limits 0.545–1.0). Bone bruise was also present in 30 (60%) patients with a lesion of the medial meniscus. One or both readers diagnosed ISI in the lateral meniscus in 30 patients (48%), and in 33 (52%) patients no changes were diagnosed. In only two patients with ISI was a meniscal tear also detected. No meniscal tear was detected in the patients without ISI. Interobserver agreement was slightly lower (κ=0.318; 95% confidence limits 0.062–0) compared to the value for the medial meniscus. Bone bruise was also present in 19 of 30 (63%) patients with a lesion of the lateral meniscus.

Ligament lesions

At the first examination a lesion of the anterior cruciate ligament was detected in 24 of 63 patients (38%). In 18 patients the lesion was a complete rupture and in the other 6 a partial rupture. The interobserver agreement was almost perfect (k=0.827; 95% confidence limits 0.682–0.973). No lesion of the posterior cruciate ligament was found. Of the 18 patients with total anterior cruciate ligament (ACL) rupture 12 (67%) had bone bruise (Table 1). Extremity MRI detected 18 patients with lesion of medial collateral ligament and 9 with a lesion of the lateral collateral ligament. Interobserver agreement was moderate (k=0.465; 95% confidence limits 0.228–0.7). Only 2 of the 35 patients (6%) had bone bruise with no other detectable lesion.

Discussion

The terms “bone bruise” and “bone marrow edema” have been known for at least a decade and seem to be used synonymously. In 1988 Wilson et al. [19] found ill-defined bone marrow hyperintensities on T2-weighted MRI in patients with knee and hip pain. The corresponding radiographs were normal. Wilson et al. believe that the findings on MRI represent a transient increase in bone marrow water content and the findings resolved spontaneously in all cases in 12 –36 months. For lack of a better term and to emphasize the generic character of the condition the authors termed this condition “the transient bone marrow edema syndrome.”

To our knowledge, only a few articles describe the pathological-radiological correlation in patients with ill-defined bone marrow abnormalities at the MRI. Rangger et al. [12] evaluated the histopathological and cryosectional appearance of bone bruise injuries of the knee detected on MRI in five cases. The authors found microfractures of cancellous bone, edema, and bleeding in the fatty marrow corresponding to the MRI findings. Plenk et al. [11] investigated specimens from core decompression in patients with hip pain. They found interstitial edema between bone marrow elements in the intertrabecular spaces that corresponding to the ill-defined high-signal intensity zones on MRI. However, they also found a certain amount of fragmented necrotic fat cells and regions with necrosis in hematopoietic marrow. This led to the discussion of a continuum between bone marrow edema and avascular necrosis. In 2000 Zanetti et al. [20] examined the correlation between MRI findings of bone marrow edema with histological findings in osteoarthritic knees and concluded that bone marrow edema in such knees represents a number of noncharacteristic histological abnormalities. In addition to edema of the bone marrow, the authors also found necrosis and fibrosis of the marrow. This could represent a trauma localized to the bone marrow. Despite this, ill-defined hyperintensities seen on the STIR images and on T2-weighted, fat-suppressed MRI sequences are commonly considered to represent bone marrow edema [13, 23] because the changes commonly are reversible, or due to altered biomechanics [15].

The subject in this study were an unselected group of patients presenting at our causalty ward. They all had recent trauma to the knee, i.e., a contusion and/or distortion. Thus also patients with very minor trauma of their knee were included, but even so we found that more than one-half of the patients had bone bruise. A reason for this could be that patients with very minor trauma and no pain after a few days did not present at the first MRI examination. This bone bruise resolved in most cases 4–12 months after the trauma. This is in agreement other studies [7, 18] that demonstrate evidence of osteochondral sequelae but resolution with no apparent sequelae at the site of the associated localized bone bruise in all cases, and resolution within 4 months.

The interobserver agreement in this study was almost perfect in diagnosing bone bruises. The slightly lower k value at the second examination could be due to the low number of patients (n=16). One weakness of this study is that several patients did not return to early and late follow-up examinations, and we must emphasize that statistical treatment of the small amount of data, especially in the early and late follow-up examinations is less reliable. In addition to bone bruise changes, we found other lesions, as shown in Table 1, and the injuries seemed to be more serious if bone bruise was present. Only two patients had bone bruise changes as the only detectable lesion.

The association between bone bruise and ACL injury is well known. The prevalence of bone bruise in patients with ACL injuries has been reported to be more than 70–80%[21], predominantly where the ACL is attach to the bone, i.e., the middle portion of the lateral femoral condyle and the posterior portion of the lateral tibial plateau. In our study we found 18 patients with a total ACL lesion, 12 of whom (67%) also had bone bruise (Fig. 1A, B). A partial ACL lesion was detected in 6 patients, 3 of whom (50%) also had bone bruise. This is a much higher rate than that in a previous study [21], but, again, we emphasize that the size of the dataset is very small. However, the presence of bone bruise in a patient with a partial ACL lesion is noteworthy because it may suggest that the forces creating the lesion are more severe than in those patients without bone bruise, which eventually can lead to a functionally total ACL rupture. Because bone bruise is seen in a higher rate in patients with a total ACL rupture, one must presume that the forces creating a total ACL rupture are greater than those producing a partial rupture.

Medial collateral ligament injury has recently also been associated with the occurrence of bone bruise in 35–40%of cases [7, 16, 22]. This difference can be explained by the difference in force at the two types of injury. It appears from Table 1 that bone bruise was most often located in the lateral condyles of the knee. This is in accordance with other studies [8, 17] and can be a result of a valgus stress on the knee with the femur in external rotation relative to a fixed tibia both in cruciate and meniscal trauma. In the patients with medial collateral ligament lesions the location of bone bruise changes in the lateral condyle could be a result of an impaction force opposite the ligamentous injury. A recent study shows an association between bone bruises involving the posterior lip of the medial tibial plateau and an ACL tear lesion, which also might be explained by a kind of contrecoup lesion, as the tibia reduces following an ACL rupture [10].

At present it is unknown whether bone bruise has any clinical significance in the long turn. It has been suggested that bone bruise represents a kind of microfractures of the trabecular bone structure [14]. It cannot be excluded that these fractures have some effect on microcirculation in the bone and hereby cause an earlier onset of, for example, arthrosis [6]. Studies with a long clinical follow-up (>10 years) of patients having a trauma causing bone bruise is strongly warranted.

We conclude that bone bruise is frequent in patients with knee injuries without radiographically detectable fractures, and that it resolves in most cases 4–12 months after the injury. Soft tissue lesions are found in almost all patients with bone bruise. Finally, the injuries seems to be more serious if bone bruise is present, especially the ligament injuries.

References

1. Bonel H, Helmberger T, Sittek H, Reiser M (1997) A comparison of pulse sequences in the detection of post-traumatic bone marrow abnormalities at low field strength MRI. Skeletal Radiol 26:538–543
2. Davies M, Fleiss JL (1982) Measuring agreement for multinomial data. Biometrics 38:1047–1051
3. Haygood TM, Monu JU, Pope TL Jr (1994) Magnetic resonance imaging of the knee. Orthopedics 17:1067–1072
4. Kier R, McCarthy S, Dietz MJ, Rudicel S (1991) MR appearance of painful conditions of the ankle. Radiographics 11:401–414
5. Lynch TCP, Crues JV III, Morgan FW, et al (1989) Bone abnormalities of the knee: prevalence and significance at MR imaging. Radiology 171:761–766
6. Mathis CE, Noonan K, Kayes K (1998) “Bone bruises” of the knee: a review. Iowa Orthop J 18:112–117
7. Miller MD, Osborne JR, Gordon WT, Hinkin DT, Brinker MR (1998) The natural history of bone bruises. A prospective study of magnetic resonance imaging-detected trabecular microfractures in patients with isolated medial collateral ligament injuries. Am J Sports Med 26:15–19
8. Mink JH, Deutsch AL (1989) Occult cartilage and bone injuries of the knee: detection, classification, and assessment with MR imaging. Radiology 170:823–829
9. Newberg AH, Wetzner SM (1994) Bone bruises: their patterns and significance. Semin Ultrasound CT MR 15: 396–409
10. Phoebe A, Kaplan, Randall H, Gehl, Robert G, Dussault, Mark W, Anderson, David R. Diduch (1999) Bone contusions of the posterior lip of the medial tibial plateau (contrecoup injury) and associated internal derangements of the knee at MR. Imaging Radiology 211:747–753
11. Plenk H Jr, Hofmann S, Eschberger J, Gstettner M, Kramer J, Schneider W, Engel A (1997) Histomorphology and bone morphometry of the bone marrow edema syndrome of the hip. Clin Orthop 334:73–84
12. Rangger C, Kathrein A, Freund MC, Klestil T, Kreczy (1998) Bone bruise of the knee: histology and cryosections in 5 cases. Acta Orthop Scand 69:291–294
13. Reinus WR, Fischer KC, Ritter JH (1994) Painful transient tibial edema. Radiology 192:195–199
14. Resnick D, Kang HS (1997) Internal derangements of joints emphasis on MR imaging. Saunders, Philadelphia, pp 94–99
15. Schweitzer ME, White LM (1996) Does altered biomechanics cause marrow edema? Radiology 198:851–853
16. Schweitzer ME, Tran D, Deely DM, Hume EL (1995) Medial collateral ligament injuries: evaluation of multiple signs, prevalence and location of associated bone bruises, and assessment with MR imaging. Radiology 194:825–829
17. Tung GA, Davis LM, Wiggins ME, Fadale PD (1993) Tears of the anterior cruciate ligament: primary and secondary signs at MR imaging. Radiology 188:661–667
18. Vellet AD, Marks PH, Fowler PJ, Munro TG (1991) Occult posttraumatic osteochondral lesions of the knee: prevalence, classification, and short-term sequelae evaluated with MR imaging. Radiology 178:271–276
19. Wilson AJ, Murphy WA, Hardy DC, Totty WG (1988) Transient osteoporosis: transient bone marrow edema? Radiology 167:757–760
20. Zanetti M, Bruder E, Romero J, Hodler J (2000) Bone marrow edema pattern in osteoarthritic knees: correlation between MR Imaging and histologic findings. Radiology 215:835–480
21. Zeiss J, Paley K, Murray K, Saddemi SR (1995) Comparison of bone contusion seen by MRI in partial and complete tears of the anterior cruciate ligament. J Comput Assist Tomogr 19: 773–776
22. Yao L, Dungan D, Seeger LL (1994) MR imaging of tibial collateral ligament injury: comparison with clinical examination. Skeletal Radiol 23:521–544
23. Yu JS, Cook PA (1996) Magnetic resonance imaging (MRI) of the knee: a pattern approach for evaluating bone marrow edema. Crit Rev Diagn Imaging 37:261–303