Radiología. 2010;**52(3):**234-240

RADIOLOGÍA

www.elsevier.es/rx

ORIGINAL

Can MRI analysis determine whether there are predisposing acute or chronic conditions in spontaneous osteonecrosis of the knee?

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Received 25 May 2008; accepted 29 December 2009

KEYWORDS
Spontaneous osteonecrosis;
Avascular necrosis;
Knee;
Subchondral lesion;
Stress fracture;
Osteoarthritis;
Magnetic resonance imaging

Abstract

Objective: The purpose of this study was to analyze the possible underlying causes of spontaneous osteonecrosis of the knee in adults according to the lesion's behavior on magnetic resonance imaging (MRI): acute lesion (insufficiency fractures) or chronic lesion (osteoarthritic degeneration).

Material and methods: We retrospectively evaluated the MRI studies of the knee in 48 patients who fulfilled criteria for spontaneous osteonecrosis. A total of 51 subchondral lesions were included and classified in two groups: those in which linear images were present (group A) and those in which linear images were not present (group B). We recorded the location and size of the lesions, their signal intensity, their relation to bone marrow edema, ipsilateral meniscal tear and abnormalities in the adjacent cartilage, as well as the presence of osteoarthritis.

Results: We studied 28 men and 20 women (mean age, 55.1 ± 18.0 years). Linear images were present in 58.5% of lesions (group A) and absent in 41.2% (group B). The most common location in both groups was the internal femoral condyle (56.7% in group A and 52.4% in group B). 88.2% of lesions were hypointense on T1-weighted and fat suppressed proton density sequences. The mean size of the anteroposterior and transverse diameters was 11.9 ± 3.6 × 9.4 ± 3.9 mm in group A and 10.9 ± 5.1 × 10.5 ± 4.5 mm in group B. The predominant bone marrow edema was severe (grade 2-3) in group A and mild (grade 0-1) in group B ($p = 0.033$). Cartilage defects ipsilateral to the subchondral lesion were more common in group B than in group A, although this difference was not statistically significant (76.2% and 56.7%, respectively; $p = 0.33$). The frequency of ipsilateral meniscal tear was similar in the two groups (56.7% in group A and 57.1% in group B; $p = 0.97$).

Conclusion: Knowledge of the MRI findings of spontaneous osteonecrosis and evaluation of associated data (type of lesion, bone edema, meniscal tear, and ipsilateral cartilage defects) can help determine the primary predisposing process. Linear lesions may be related to an acute process (insufficiency fractures) and non-linear lesions to a chronic process (osteoarthritis).

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PALABRAS CLAVE
Osteonecrosis espontánea;
Necrosis avascular;
Rodilla;
Lesión subcondral;
Fractura de estrés;
Artrosis;
Resonancia magnética

Resonancia magnética de la osteonecrosis espontánea de la rodilla: ¿existe un proceso agudo o crónico predisponente?

Resumen
Objetivo: Analizar la posible etiología subyacente de la osteonecrosis (ON) espontánea de la rodilla en adultos, según su comportamiento en la resonancia magnética (RM): lesión aguda (fracturas por insuficiencia) o crónica (degeneraciones artrósicas).
Material y método: Se realizó un estudio retrospectivo en el que se evaluaron las RM de rodillas de 48 pacientes que cumplían criterios de ON espontánea. En total, se incluyeron 51 lesiones subcondrales, que se dividieron en 2 grupos según la presencia de imágenes lineales (grupo A) o no (grupo B). Recogimos la localización y el tamaño de las lesiones, su intensidad de señal, su relación con el edema óseo, la rotura meniscal ipsolateral y las anomalías del cartílago adyacente, así como la existencia de artrosis.
Resultados: Estudiamos a 28 hombres y a 20 mujeres con una edad media de 55,1 ± 18,0 años. La morfología más frecuente fue la lineal (grupo A) frente a la no lineal (grupo B) (el 58,8 y el 41,2%, respectivamente). En ambos grupos, la localización más frecuente fue el cóndilo femoral interno (el 56,7% en el grupo A y el 52,4% en el grupo B), y la intensidad de señal predominante (88,2%) fue hipointensa en T1 y DP con supresión grasa. El tamaño medio en milímetros de las lesiones en los diámetros anteroposterior y transversal fue en el grupo A de 11,9 ± 3,6 × 9,4 ± 3,9 y en el grupo B de 10,9 ± 5,1 × 10,5 ± 4,5. El edema óseo predominante fue grave (grado II-III) en el grupo A y leve (grado 0-I) en el grupo B ($p = 0,033$). Los defectos del cartílago ipsolateral a la lesión subcondral fueron superiores en el grupo B que en el grupo A (el 76,2 y el 56,7%, respectivamente; $p = 0,33$), mientras que la incidencia de rotura meniscal ipsolateral fue similar en ambos grupos (el 56,7% en el grupo A y el 57,1% en el grupo B; $p = 0,97$).
Conclusión: Al conocer los hallazgos de la ON espontánea de la rodilla en la RM y valorar otros datos (tipo de lesión, edema óseo, rotura meniscal y defectos del cartílago ipsolateral), podemos intentar determinar un proceso primario predisponente. Las lesiones lineales podrían relacionarse con un proceso agudo (fracturas por insuficiencia) y las no lineales con un proceso crónico (artrosis).

Introduction

Osteonecrosis (ON) or avascular necrosis is a relatively common disease that causes death by ischemia of the cellular components of the bone and marrow in the subchondral region. The most common location is the femoral head, followed by the humeral head and the knee, where it can affect the femoral condyles or the tibial plateau[1].

In the knee, there are two very distinct forms of ON: spontaneous ON of the knee (SONK) and secondary osteonecrosis (SON) (bone infarction). In the latter, predisposing factors for ON are identified, and with magnetic resonance imaging (MRI), a subchondral area of variable signal intensity is observed, delineated by a serpiginous hypointense rim on T1-weighted images. On T2-weighted images, an inner parallel hyperintense line can also be depicted (double halo sign)[1,2].

Ahlback described the first case of SONK in 1968[1,3]. It is a disease that usually occurs in elderly patients, especially in women, who report strong and sudden pain, normally when resting and without a clear traumatic injury[4]. It is typically located in the weight-bearing area of the subchondral bone of the internal femoral condyle[1-5]. On MRI, a hypotense focal subchondral area is observed on T1 and T2-weighted images[1,2,4]. The etiopathogeny of SONK is not clear. In recent publications, its spontaneous origin has been questioned, and it has been postulated that it may be an acute process related to a subchondral stress fracture[3-8] or a chronic event associated with osteoarthritis[3].

The objective of this study was to analyze the MR findings of patients diagnosed with SONK and determine its association with subchondral stress fractures or osteoarthritis.

Materials and methods

Patients

Between January 2001 and February 2005, 91 patients diagnosed by MRI with subchondral disease of the knee, were evaluated in a retrospective study. Patients (n = 43) excluded from the study were those with a history of trauma or surgery, predisposing factors for ON (alcoholism, corticosteroid treatment, pancreatitis and hematological or rheumatological disease), lesions compatible with bone infarction (hypotense serpiginous rim), osteochondritis dissecans or isolated bone marrow edema.

The final study group consisted of 48 subjects: 28 men and 20 women, with an average age of 55.1 ± 18.0 years (range

of 18-78 years). They presented rapid-onset, incapacitating knee pain with poor response to medical treatment, and showed MRI findings consistent with SONK. Three patients had two subchondral lesions in the same knee, giving a total number of 51 lesions analyzed.

MRI technique

All studies were performed in the same 1.5 T magnet (, General Electric Medical Systems) and with the same protocol: sagittal FSE PD (TR/TE 2,400/47 ms), sagittal and coronal FSE PD with frequency selective fat suppression (TR/TE 2,700/27 ms) and axial GRE (TR/TE 3,300/38 ms); 4-mm, section thickness; intersection gap, 0.4-mm; field of view 18x18 cm; matrix,512x256; NEX, 2.

Data collection

All MR images of the 48 patients involved in the study were evaluated (until consensus) by three radiologists with extensive experience in the musculoskeletal system (C.N, M.F, and B.B). The subchondral lesions were divided into two groups: group A (presence of hypointense subchondral linear images parallel to the articular surface) and group B (absence of linear images). Three morphological sub-types were classified in group B: oval lesion (OL), cortical irregularity (CI), and subchondral collapse (SC) (fig. 1).

The following parameters were collected:

- Location: this was based on a system already used by other authors[3], which consisted of dividing the femoral condyles and the tibial plateaus into three zones in the coronal and sagittal planes. They were numbered from 1 to 3 in the coronal plane from the internal to the external third, and in the sagittal plane from the anterior to the posterior third.
- Size: the length, in millimeters, of the anteroposterior and transverse axes was measured.
- Adjacent bone edema: a grading system of the coronal plane that has previously been employed by other authors, was used[3]. It included the following classifications: grade 0 if no edema was present, grade I (mild) if it occupied less than one third of the condyle or tibial plateau surface, grade II (moderate) if it occupied between one and two thirds, and grade III (severe) if it occupied more than two thirds.
- Ipsilateral meniscus rupture.
- Anomalies of the adjacent cartilage: the presence of focal chondral defects (FCD) or degenerative chondrosis (DC) (thinning or irregularity of the cartilaginous surface), adjacent to the subchondral lesions was also evaluated. Those cases with osteoarthritis (narrowing of articular surface, subchondral sclerosis and presence of marginal osteophytes) were also recorded. Although previous histological studies[9] showed that these patients may have small foci of fibrosis or necrosis and MRI findings similar to SONK, they were included in the study, given that they showed a subchondral lesion (linear or not) that met the established criteria.

Statistical analysis

The quantitative variables were expressed as means ± standard deviation and range, and the qualitative variables as a number and percentage. The comparison between two qualitative variables was made using a Pearson chi-square test or a linear tendency chi-square test (if one of the variables was ordered and had more than two categories) and a Fisher's exact test. The initial comparison between dichotomous qualitative and quantitative variables was made by testing the normal quantitative variable distribution through the Kolmogorov Smirnov test. If the variable was normally distributed, a student's T-test or single-factor ANOVA was applied, and if not, the Mann Whitney U test or Kruskal Wallis test were used. All contrasts were performed with 2-tails, and a p-value smaller than 0.05 was considered significant. For the statistical calculations, the program SPSS (version 15.0, Windows) was used.

Results

Of the three patients with two subchondral lesions, two linear lesions were observed in one subject, and one linear

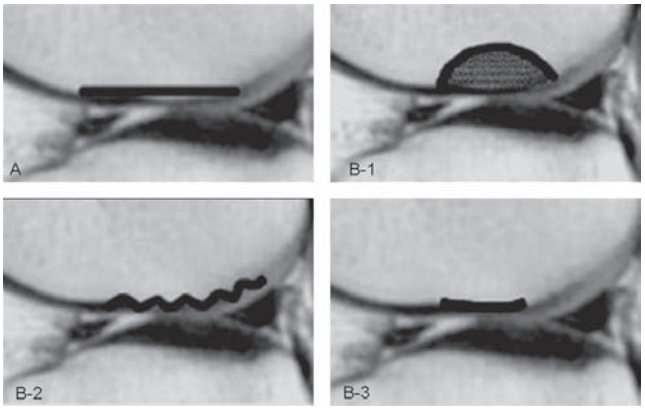

Figure 1 Representation of all types of lesions: A) Linear lesion, B) Non-linear lesion: B1) oval lesion; B2) cortical irregularities; B3) subchondral collapse.

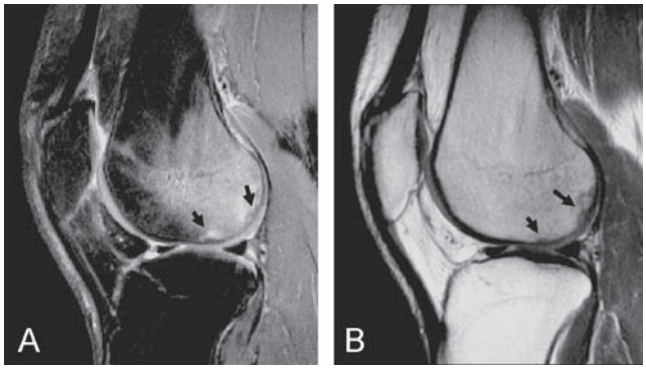

Figure 2 Bone edema in the internal femoral condyle with 2 non-linear oval lesions (arrows). A) Sagittal fat-suppresed proton density-weighted MR image. B) Sagittal proton density-weighted MR image.

and one non-linear lesion in the other two subjects (fig. 2). These lesions were independently included in the groups.

Group A (linear lesions)

In 29 patients, 18 men and 11 women with an average age of 56.5 ± 18.9 years, thirty subchondral lesions with linear morphology were observed. The most common location was zone 2, in both the coronal and sagittal planes of the medial femoral condyle (fig. 3). The average size of the lesions in the anteroposterior axis was 11.9 ± 3.7 mm (range: 7.2-19.8 mm) and in the transversal axis it was 9.4 ± 3.9 mm (range: 1.3-18 mm). The intensity of the predominant signal was hypointense in the T1 and fat-suppressed PD sequences (93.9%). In one case (3.3%), no bone marrow edema was observed adjacent to the lesion, while in the others, grade II was predominant (46.6%) (table 1, figs. 4 and 5). In 17 of the 30 cases (56.7%), a rupture of the ipsilateral meniscus was observed (table 2). In 17 of the 30 cases (56.7%), anomalies of the cartilage adjacent to the subchondral lesion were identified and 4 cases were observed with FCD, 6 cases with DC, and 7 cases with osteoarthritis. In 13 of the 30 cases (43.3%) the articular cartilage was normal.

Group B (non-linear lesions)

In this group (n = 21), three types of lesions were identified: oval subchondral lesions (n = 11, 6 men and 5 women), CI (n = 4, 3 men and 1 women), and SC (n = 6, 3 men and 3 women).

The older patients showed SC (average age: 59.3 ± 18.9 years, range: 21-69), while patients with OL had an average age of 56.1 ± 13.6 years (range: 22-72).CI was observed in younger patients (average age: 33.6 ± 18.4years, range: 18-65) (p = 0.015).

As in group A, the most common location for the lesions was zone 2 (coronal and sagittal planes) of the medial femoral condyle (fig. 3). The average size in the anteroposterior plane of the OL was 12.4 ± 5.3 mm, CI was 12.8 ± 2.1 mm, and SC was 6.7 ± 4.1 mm (p = 0.05), while in the transversal plane these values were 3.2 ± 0.9, 6.6 ± 3.3 and 1.1 ± 0.7 mm, respectively (p = 0.103). The intensity of the predominant signal, as in group A, was hypointense in the T1 and fat-suppressed PD sequences (85.7%). In two cases (9.5%), no bone marrow edema adjacent to the lesion was evident. In the OL, the most common grade of associated edema was grade III (45.4%), and grade I was observed more frequently in the CI and the SC (75% and 50%, respectively) (table 1, fig. 4). In 12 of the 21 lesions (57.1%) a rupture of the ipsilateral meniscus was observed, associated at a higher frequency with CI (83.5%), followed by SC (75%), and OL (63.6%) (table 2). Cartilage anomalies were identified in 15 of the 21 lesions (71.4%) (table 3). 8 cases with FCD (predominant in the OL), one case with DC (associated with SC), and 6 cases with osteoarthritis (especially with OL) were also observed. In all cases with CI, cartilage anomalies were evident (75% with FCD and 25% with osteoarthritis). In 6 of the 21 cases (28.5%), the articular cartilage was normal.

Group A versus group B

- Location: in both groups, the most common location of lesions was position 2 of the internal femoral condyle. In group A, 53.3% were observed in the coronal plane, 20% in the external sagittal plane, and 53.3% in the internal sagittal plane. In group B, 38.1% in the coronal plane, 33.8% in the external sagittal plane, and 42.8% in the internal sagittal plane were detected.

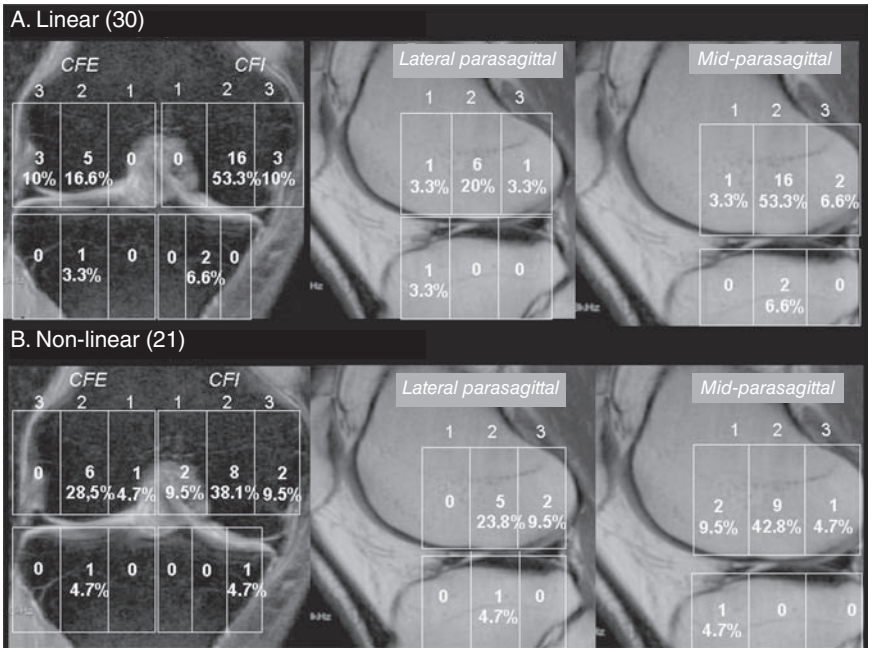

Figure 3 Distribution of lesions in the zones 1-2-3 in the coronal plane, external parasagittal plane, and internal parasagittal plane. A) linear lesions. B) non-linear lesions.

Table 1 Degree of bone marrow edema associated with subchondral lesions

Edema	Grade 0, n (%)	Grade I, n (%)	Grade II, n (%)	Grade III, n (%)
Group A (n = 30)	1 (3)	6 (20)	14 (46.6)	9 (30)
Group B (n = 21)				
OL (n = 11)	1 (9)	3 (27,2)	2 (18.1)	5 (45.4)
CI (n = 4)	1 (25)	3 (75)	0	0
SC (n = 6)	0	3 (50)	1 (16.6)	2 (33.3)

C: subchondral collapse; CI: cortical irregularities; OL: oval lesion.

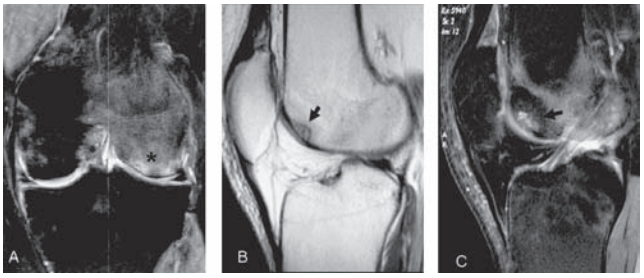

Figure 4 Patient with a linear lesion in the external femoral condyle (asterisk) and a non-linear oval shaped lesion in the internal femoral condyle (arrow) with grade III bone marrow edema. A) fat-suppresed proton density-weighted MR image. B) proton density-weighted MR image. C) Sagittal fat-suppresed proton density-weighted MR image.

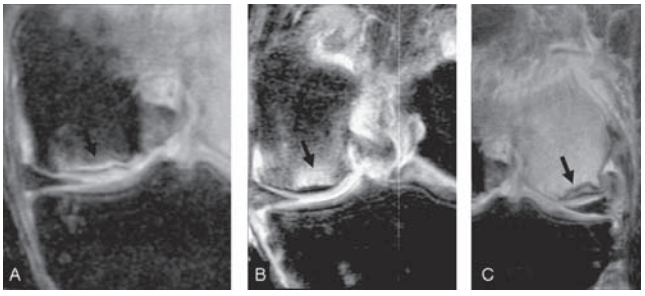

Figure 5 Grades of bone marrow edema associated with linear lesions. Coronal fat-suppresed proton density-weighted MR image. A) Linear lesion in the internal femoral condyle (arrow) associated with mild bone marrow edema (grade I). B) Linear lesion in the internal femoral condyle (arrow) with moderate bone marrow edema (grade II). C) Linear lesion in the external femoral (arrow) with severe bone marrow edema (grade III).

Table 2 Meniscus rupture associated with subchondral lesions

	Yes, n (%)	No, n (%)
Group A (n = 30)	17 (56.7)	13 (43.3)
Group B (n = 21)		
OL (n = 11)	4 (36.3)	7 (63.6)
CI (n = 4)	3 (75)	1 (25)
SC (n = 6)	5 (83.3)	1 (16.6)

SC: subchondral collapse; CI: cortical irregularity; OL: oval lesion.

- Size: There were no significant differences between the size of the lesions in both groups in the anteroposterior (p = 0.39) or transversal (p = 0.37) axes.
- Gender: both groups of lesions were more common in men (63.3% in group A and 57.1% in group B) (p = 0.65).
- Signal intensity: 46 of the 51 lesions (90.2%) were hypointense in T1 and PD-weighted images (56.7%), with no significant differences between group A (93.3%) and group B (85.7%) (p = 0.63).
- Bone marrow edema: the linear lesions were most commonly associated with moderate to severe bone edema (II-III) (76.7%) (fig. 5), whereas the predominant bone marrow edema in non-linear lesions (52.4%) (p = 0.03) was mild (0-I).
- Ipsilateral meniscus rupture: in 29 of the 51 lesions (56.9%), the meniscus rupture was adjacent to the SONK, which was practically equal in groups A and B (56.7% and 57.1%, respectively). No significant difference was observed between both groups (p = 0.97).
- Cartilage abnormalities: in 33 of the 51 cases (64.7%) cartilage abnormalities and osteoarthritic changes were observed in 13 patients. Although these abnormalities were predominant in group B, as compared to group A (76.2 and 56.7%, respectively), no significant differences were found (p = 0.33).

Discussion

Spontaneous osteonecrosis of the knee (SONK) presents some characteristic findings on MRI and, together with appropriate clinical information (surgery history, trauma, and the existence of risk factors), enable proper diagnosis to be made. Until 2000, little published information existed on the use of MRI in SONK[1]. Of recent, several studies have appeared relating to SONK characteristics on MRI and its arthroscopic aspect[2,3]. Narváez et al.[1] published a study in 2000 which described the clinical and imaging characteristics of patients with SONK and SON, emphasizing their differences. While SONK manifested clinically as a sudden pain in the knee, (usually in women older than 60, unilaterally and more frequent in the medial femoral condyle), SON did so gradually and in a younger population, and was generally bilateral with greater involvement of the external femoral condyle. MRI diagnosis of ON was based on the presence of a subchondral or focal lesion with variable signal intensity.

The etiopathogeny of SONK is unclear, but two theories have been postulated in recent studies: an insufficiency

Table 3 Abnormalities of the cartilage adjacent to the subchondral lesion and its association with osteoarthritis

	FCD, n (%)	DC, n (%)	Osteoarthritis, n (%)	Normal cartilage, n (%)
Group A (n = 30)	4 (13.3)	6 (20)	7 (23.3)	13 (43.3)
Group B (n = 21)				
OL (n = 11)	4 (36.3)	0	3 (27.2)	4 (36.3)
IC (n = 4)	3 (75)	0	1 (25)	0
CS (n = 6)	1 (16.6)	1 (16.6)	2 (33.3)	2 (33.3)

DC: degenerative chondrosis; SC: subchondral collapse; FCD: focal chondral defect; CI: cortical irregularity; OL: oval lesion.

fracture of the of subchondral bone[3-8] or the existence of subchondral abnormalities realated to osteoarthritic changes[3,12]. Several authors[3-11] agree that the subchondral stress or insufficiency fractures have common characteristics with those of SONK on MRI. Both have a predilection for the medial articular compartment of the knee, are associated with ipsilateral meniscus ruptures, and occur most frequently in older individuals. Several published studies agree that lesions associated with stress mechanisms have signs of ON and reversible bone marrow edema on MRI[13-15].

As in the study published by Rammath et al.[3], we intended to highlight the MRI findings for SONK and determine the underlying etiological factors. The general characteristics of the lesion were assessed and the results obtained showed similarities to a study by Narváez et al.[1]: the most common location was the internal femoral condyle, the patients average age was 55, and MRI behavior indicated a focal subchondral lesion, hypointense on long TR sequences.

We emphasized the morphology of the lesions by classifying them as linear and non-linear. We also assessed the existing associations between the presence and degree of bone marrow edema, meniscus rupture and degeneration of the cartilage. As Rammath et al.[3], we found statistically significant differences between the morphology of the lesion and the degree of bone marrow edema. Morphologically linear subchondral lesions are associated most frequently with large bone marrow edema, whereas non-linear forms are associated with smaller edema. As other authors have mentioned, it is possible that the linear morphology may reflect an insufficiency fracture and the greater degree of bone marrow edema may be evidence of an acute nature.

Bone marrow edema, although present in almost all of our patients in varying degrees, is a non-specific finding possibly related to other entities, as is reflected in recent publications[13-15].

Regarding the existence of a meniscus rupture or degeneration of the cartilage ipsilateral to the subchondral lesion, we observed that the cartilage defects were more frequently associated with non-linear lesions (group B). The incidence of ipsilateral meniscus tears was similar in both groups, without a statistically significant difference. Therefore, it was not possible to establish a clear association with any type of lesion, although, in agreement with other authors[3,10,11], it could be interpreted that both the meniscus and cartilage lesions may be predisposing factors favoring the necrotic process.

By differentiating the type of cartilage alteration, it was observed that FCD was more frequently associated with the non-linear lesions (group B), whereas DC was associated mostly with linear lesions (group A). The cases associated with osteoarthritis were practically the same in number between both groups.

In contrast to the study by Rammath[3], the most frequent lesions in our sample were linear. Our patients exhibited incapacitating knee pain and a poor response to medical treatment, possibly due to associated bone edema, which, as already mentioned, was observed more frequently in this type of lesion.

Current publications[15] are giving importance to early diagnosis of SONK and the prognostic criteria established by MRI. Yates et al.[15] devised MRI criteria indicative of a benign prognosis so that conservative treatment was recommended. These included the absence of a focal depression of the epiphyseal contour, and of deep lines of low signal intensity in the femoral condyles. In our study, the non-linear lesions, especially oval shaped and CI, were frequently associated with joint degeneration and supported the chronic processes and poor prognosis according to the criteria defined by Yates et al.

One of the limitations of our study was the lack, in all cases, of MRI checkups to assess the process evolution and determine the lesion's acute or chronic nature. Another constraint was, in cases of advanced osteoarthritis, we were unable to histologically confirm if the subchondral lesion corresponded to an ON, although we selected those cases that met the MRI criteria for ON.

However, taking our results into account and those of other recent publications[3-12] that show an association between SONK, osteoarthritis, and insufficiency fractures, it may be concluded that this is not a primary process, and that perhaps there is a predisposing condition that may be elucidated through the use of MRI. This could be of acute (subchondral insufficiency fracture) or chronic (osteoarthritis) nature.

Authors

M.F. Cegarra Navarro: elaboration of general text and coordination of the sections.

M. Martínez Fernández: writing of the materials and methods section.

A. Blanco Barrio: writing of the results and bibliography sections.

Francisco Lloret Estañ: preparation of the tables and statistical analysis

All authors have read and approved the final version of this article.

Conflict of interests

The authors declare not to have any conflict of interests.

Acknowledgments

We would like to thank Dr. Andrés Carrillo for his help in performing the statistical analysis for this study.

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