

Original Article

Prevalence of bone marrow edema in a study population with foot and/or ankle pain

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ABSTRACT

Bone marrow edema (BME) is an imaging diagnosis defined by an abnormal accumulation of intraosseous interstitial fluid within a bone on magnetic resonance imaging (MRI) investigation. The aim of this study was to determine the prevalence of BME in patients with foot and/or ankle pain studied using MRI. This was a retrospective observational work on patient cases and controls studied through MRI of the foot and/or ankle at our Foot and Ankle Unit (FAU). An analytical statistical analysis and a multivariate analysis were performed to eliminate possible confounding factors. 1950 foot and/or ankle MRI cases were reviewed, of which 451 presented bone edema (23% prevalence). The average patient age was 51.8 (range, 7–87); the talus bone was most frequently affected: post-traumatic in 43.5% of cases, degenerative in 34.7% and there was no specific cause identified in 6.3% (these cases were termed ‘idiopathic’). With regards to risk factors, in the case of gender, the odds ratio (OR) of men suffering bone oedema was 1.5 times higher than that of women ($P = 0.003$); for immunosuppression the OR was 3.4 times higher ($P = 0.001$); while among those with a smoking habit it was 0.59 ($P = 0.001$), meaning that after ruling smoking out as a possible confounding factor, it was, in fact, revealed to be a protective factor. The prevalence of bone edema in MRI in patients with foot and/or ankle pain was 23%. The average patient was male, aged approximately 50, with traumatic or degenerative origin talus bone oedema.

Level of Evidence: Level IV, revision observational study.

1. Introduction

Bone marrow edema (BME) is a purely imaging diagnosis, characterised by a signal change in the magnetic resonance imaging (MRI) which is related to an abnormal accumulation of interstitial fluid within a bone [1]. The characteristic pattern of BME seen in MRI is an area that differs from the bone, showing hypointensity in the T1 sequence and hyperintensity in the T2 sequence, preferably with fat saturation, or a short-time inversion recovery (STIR) sequence [2,3] (Fig. 1).

The etiology of BME is not known, although some predisposing factors have been described, including vitamin D deficiency, osteoporosis, microtrauma, pregnancy (especially in the third trimester), cirrhosis, diabetes mellitus (DM), peripheral arterial disease, immunosuppression, and toxin abuse [3–6]. In the majority of cases it affects the lower limbs, especially load-supporting joints including, in decreasing order of frequency, hips, knees, and ankles. The male–female ratio of affected patients is 3:1, with a higher prevalence in middle-aged men (aged 30–60) and young women (aged 20–40) [7].

In clinical practice, it is common to deal with patients in a Foot and Ankle Unit (FAU) whose MRI reports include the term BME, even though the origin of their discomfort cannot be exactly related with this condition. On the other hand, the recovery evolution of patients with foot and/or ankle complaints and a bone marrow edema usually is slower than in non-sufferers.

The aim of this study was to determine the prevalence of BME in patients studied in a FAU; and as a secondary objective, to identify the possible risk factors associated to BME.

2. Methods

Institutional review board approval was obtained prior to the initiation of this study. A revision observational study was conducted using MRI reports of patients being studied for foot and ankle complaints in our FAU between 2006 and 2016. The following inclusion criteria were applied:

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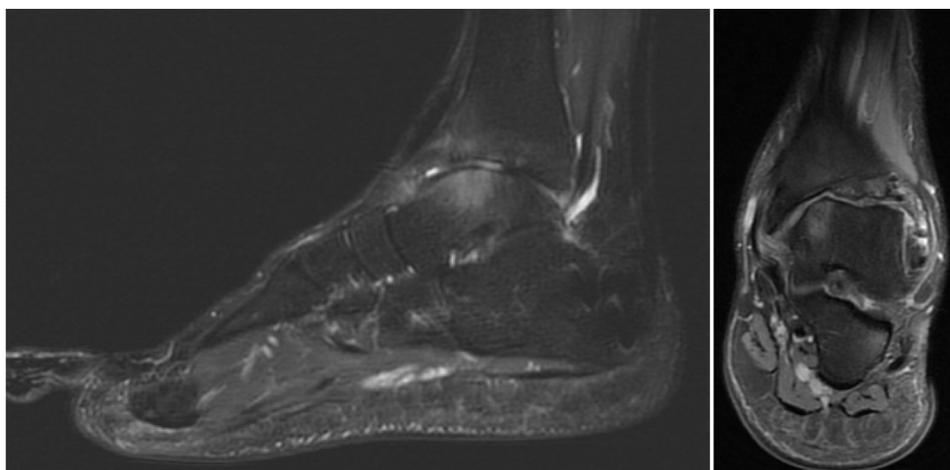


Fig. 1. A 42-year-old man with degenerative origin BME in the talus bone secondary to tibiotalar osteoarthritis.

- Patient studied for any cause in the FAU.
- MRI of the foot and/or ankle-area.
- The only exclusion criteria was:
- Patients with a radiological report that did not include the words 'bone edema'.

The clinical history of each patient in the 'cases' study sample group was reviewed using the institutional database to collect the following variables: age and gender, personal history (osteoporosis, cirrhosis, third trimester pregnancy, DM, immunosuppression, trauma, micro-trauma, alcoholism, smoking, drugs, obesity, etc.), diagnosis (primary/secondary BME —trauma, degenerative, infectious, ischemic, neoplastic, neuropathic, or iatrogenic) and affected bone (distal tibia, talus, calcaneus, cuboids, scaphoids, cuneiform bones, or metatarsals and phalanges).

2.1. Statistical analysis

The patient characteristics are summarised in Table 1 using frequencies and their respective percentages. The mean and standard deviations are given for the uncategorised age variable. Comparison of the different epidemiological characteristics analysed, in terms of their correlation with the presence of bone oedema, was carried out using chi-square tests, implementing the Yates correction where 2×2 tables were used (Table 1). Age, which was treated as a continuous variable, was compared using Student t-tests. A multivariate study was also carried out using logistic regression (Table 2) to analyse the influence of the different epidemiological characteristics on the appearance, or not, of bone oedema. The significant variables that had to be introduced into the model were selected using the Wald backward elimination method, utilising the model's standard input values and output variables, i.e., 0.05 and 0.10, respectively. All analyses were carried out using SPSS v.25 package (IBM SPSS Statistics) and Microsoft Excel 2016 software. The result was considered significant when the P-value was less than 0.05.

3. Results

1950 patients were considered from our database and, after applying the inclusion and exclusion criteria, 451 patients were identified as 'cases'. For the statistical analysis, 451 patients were chosen randomly from the total study population who did not show evidence of bone edema, and were defined as 'controls'. The mean age of the total patient cohort (451 cases and 451 controls) was 51.8 years (range, 4–87 years). In the control group, 181 (40%) were men and 270 (60%) were women. In the cases group, 221 (49%) were men and 230 (51%) were

Table 1
Univariate analysis.

	Group		P-value	Total (N = 813)
	Control (N = 451)	Bone oedema (N = 451)		
Gender			0.007	
Male	181 (40%)	221 (49%)		402 (45%)
Female	270 (60%)	230 (51%)		500 (55%)
Age			0.962	
≤ 14	18 (4%)	15 (3%)		33 (4%)
(14–25)	23 (5%)	21 (5%)		44 (5%)
(25–45)	106 (24%)	103 (23%)		209 (23%)
(45–65)	204 (45%)	213 (47%)		417 (46%)
> 65	100 (22%)	99 (22%)		199 (22%)
Pathologies				
Osteoporosis	41 (9%)	38 (8%)	0.732	79 (9%)
Cirrhosis	4 (1%)	3 (1%)	0.707	7 (1%)
3T Pregnancy	–	2 (0.4%)	0.249	2 (0.2%)
DM	64 (14%)	58 (13%)	0.568	122 (14%)
IAP	8 (2%)	9 (2%)	0.803	17 (2%)
Microtrauma	21 (5%)	22 (5%)	0.870	43 (5%)
Trauma	107 (24%)	131 (29%)	0.067	238 (26%)
Immunosuppression	11 (2%)	30 (7%)	0.002	41 (5%)
Smoker	143 (32%)	105 (23%)	0.005	248 (28%)
Alcohol	101 (22%)	92 (20%)	0.476	193 (21%)
Drugs	17 (4%)	15 (3%)	0.724	32 (4%)
Obesity	111 (25%)	92 (20%)	0.134	203 (23%)
Others	239 (53%)	208 (46%)	0.220	447 (50%)

women, and this difference was statistically significant ($P = 0.003$).

In both case and control-patient clinical histories, significant differences were found in those with a history of trauma (29%; $P = 0.067$) and immunosuppression (7%; $P = 0.002$). Additionally, a higher percentage of smokers was observed in the control group (32%; $P = 0.005$). The other aspects of medical history studied showed no statistical significance or relationship with this radiological finding.

Table 2 shows that the odds ratio (OR) for male patients with BME was 1.5 times higher than for female patients ($P = 0.003$); for immunosuppression the OR was 3.4 times greater ($P = 0.001$), and for smoking it was 0.59 ($P = 0.001$). Trauma was also part of the model, although its p-value was slightly higher than 0.05 (the standard criterion for discarding variables for use in regression models is $P = 0.10$) with an OR of 1.33 ($P = 0.061$).

Table 3 shows the diagnosis of bone edema in the case group. From the study sample, 43.5% (193 patients) presented BME secondary to trauma; 34.7% (154 patients) secondary to a degenerative pathology; and in 6.3% (28 patients) no specific cause could be identified (these cases were termed 'idiopathic' or 'primary' BME). The average number

Table 2
Multivariate analysis.

	B	Standard error	Wald	df	Sig.	Exp(B)	95% CI for EXP (B)	
							Upper	Lower
Gender = Male	0.414	0.138	9.012	1	0.003	1.512	1.154	1.981
Trauma	0.289	0.154	3.509	1	0.061	1.335	0.987	1.806
Immunosuppression	1.225	0.365	11.276	1	0.001	3.404	1.665	6.958
Smoker	-0.526	0.155	11.524	1	0.001	0.591	0.436	0.801
Constant	-0.171	0.105	2.637	1	0.000	0.843		

Table 3
BME etiology.

	Frequency	%
Degenerative	154	34.7
Primary BME	28	6.3
Infectious	24	5.4
Ischemic	23	5.2
Neoplastic	16	3.6
Neuropathic	1	0.2
Trauma	193	43.5
Iatrogenic	5	1.1

Table 4
Total bones affected.

Nº affected bones	Frequency	Percentage
1	302	67.0
2	95	21.1
3	34	7.5
4	15	3.3
5	4	0.9
6	1	0.2
Total	451	100.0

of affected bones in the cases was 1.51 (range, 1–6 bones) (Table 4).

Finally, the most commonly affected bone was the talus, in 197 patients (43.6%), secondary to trauma (40.6%), followed by degenerative disease (38%) and ischemic disorders (9%; Table 5). In BME patients diagnosed with an infectious etiology, the most commonly affected bones were the metatarsals and phalanges (45.8%). The other locations affected by BME was distributed as follows: 7 patients (1.6%) os trigonum; 125 patients (27.7%) metatarsals and phalanges; 111 patients (24.6%) calcaneus; 72 patients (16%) distal tibia; 45 patients (10%) scaphoids; 45 patients (10%) cuneiform bones; 38 patients

Table 5
Etiology – affected bone.

	Distal tibia	Calcaneus	Cuneiform	Fibula	Metatarsals and Phalanges	Scaphoids	Talus	Cuboids	Os trig.
Degenerative	22	34	17	7	53	19	75	14	2
1st BME	14,3%	221%	110%	4,5%	344%	123%	487%	9,1%	1,3%
Infectious	3	7	2	2	7	5	11	1	1
Ischemic	10,7%	250%	7,1%	7,1%	250%	179%	393%	3,6%	3,6%
Neoplastic	6	5	3	1	11	3	6	3	0
Neuropathic	250%	208%	125%	4,2%	458%	125%	250%	125%	0,0%
Traumatic	2	1	3	0	5	0	18	0	0
Iatrogenic	8,7%	4,3%	130%	0,0%	217%	0,0%	783%	0,0%	0,0%
	1	5	3	0	5	1	5	0	1
	6,3%	313%	188%	0,0%	313%	6,3%	313%	0,0%	6,3%
	0	0	0	0	1	0	0	0	0
	0,0%	0,0%	0,0%	0,0%	1000%	0,0%	0,0%	0,0%	0,0%
	38	57	17	21	42	17	80	20	3
	19,7%	295%	8,8%	109%	218%	8,8%	415%	104%	1,6%
	0	2	0	1	1	0	2	0	0
	0,0%	400%	0,0%	200%	200%	0,0%	400%	0,0%	0,0%

(8.4%) cuboids; and 32 patients (7.1%) distal fibula.

4. Discussion

With regards to our first objective, the present study shows that prevalence of BME in a study population of patients with foot and/or ankle complaints is 23%. In recent decades, MRI has become the technique of choice for evaluating patients with persistent foot and/or ankle pain over normal simple radiographs. In many of these cases, BME is present, which may or may not be related to the patient's clinical profile.

Mirghasemi et al. [7] proposed a BME classification based on three causal mechanisms: ischemic (osteonecrosis and osteochondritis dissecans); mechanical (haematoma, microfracture, BME stress, or stress fracture); and reactive (osteoarthritis, postoperative oedema, or tumour) [7,8]. When there is no apparent cause, the disease is referred to as 'bone marrow oedema syndrome' (BMES) or 'idiopathic bone marrow edema', a self-limiting condition that is so uncommon even hospitals with a high burden of care only produce studies including few patients [9–12]. This condition is characterised by intense pain and increased interstitial fluid, presenting a BME pattern on MRIs, but with no evidence of focal injuries or any definable cause [4,12,13]. There is a great deal of published literature on BME syndrome, which is also referred to as 'transient osteoporosis', 'transient bone marrow oedema', 'algodystrophy', and 'early reversible osteonecrosis' [7].

The real impact the radiological finding has on the quality of life of patients or their ability to perform daily activities is difficult to quantify. However, what does seem clear is that both the prognosis and treatment response are completely unpredictable, and that bone oedema is often a cause of chronic pain and functional disability requiring long periods of convalescence. For this reason, the clinical condition is often disconcerting for both doctors and patients. Treatment involving clinical-radiological correlation is essential because many patients studied for foot and/or ankle pain may present BME in MRI but in the absence of any clinical correlations. Indeed, studies of elite athletes who

presented BME with no clinical significance were identified [14,15], while in other cases, bone oedema was associated with a significant loss of function [10,13,16].

In clinical practice, it is common to deal with patients in a FAU whose MRI reports refer to BME, even though the origin of their discomfort could not be confirmed. BME has been studied by professionals from various medical and surgical specialities [17–19] because, as described in the literature, it can be secondary to inflammatory or degenerative processes, and infectious or malignant diseases, as well as having a primary or idiopathic origin, with no identifiable cause. For this reason, a differential diagnosis should always be performed with a view to the need for an eventual multidisciplinary approach to this disease [7,20,21].

Laboratory tests cannot usually usefully contribute to the diagnosis of this condition, and histological analysis is usually unnecessary [22]. BME is not visible on normal radiographs or computed tomography scans, and although there is focal hypercaptation in scintigraphy it is highly non-specific. The diagnostic test of choice for BME is MRI, which can be used to give an early diagnosis, rule out associated causes (hidden fractures, tumours, infections, etc.), and monitor the progression of the oedema itself [23]. However, the usefulness of control MRIs is not clear, when it appears that clinical control of these patients is sufficient [22]. BME is non-specific, with a wide differential diagnosis, and so a detailed medical history is particularly important for these cases. In some cases, the disease location is indicative of a trauma mechanism and may help identify the origin of the trauma [20].

Most BME studies stated that, in decreasing order of frequency, the talus, scaphoid, cuneiform, and metatarsal and phalange bones of the forefoot are affected; [11,16,24] however, in our study BME was distributed, in decreasing order of frequency, between the talus, metatarsals and phalanges, and calcaneus bones. The fact that in our series there were a significant number of cases in which the forefoot bones were affected and the main etiology was infectious, could be related to the pathophysiology of DM and peripheral arterial disease: these areas of the extremities have worse distal irrigation and may be predisposed to a greater incidence of infection. Thus, the high number of cases of BME in the metatarsal bones in our sample might be explained by the high prevalence of DM in our community [25,26]. Several authors suggested that the simultaneous involvement of several foot and/or ankle bones is common; [5,12,27] this was confirmed in our work, where 2 or more bones were affected in a third (33%) of cases.

With regards to the secondary objective of this work, several risk factors have been identified in the literature [7,11,28]. The etiology of BME is not known, although some predisposing factors have been described, including vitamin D deficiency, osteoporosis, microtrauma, pregnancy (especially in the third trimester), cirrhosis, diabetes mellitus (DM), peripheral arterial disease, immunosuppression, and toxin abuse [3–6]. Corticosteroid therapy is stated to be an accepted risk factor for developing BME, a premise with which our data concurs (OR = 3.4). Trauma is thought to be the main cause of BME, which also seemed to be confirmed in our study, with 43.5% of cases resulting from this. Previously published work insisted that tobacco use is a risk factor [7,11], however, after ruling it out as a confounding factor, a stratified analysis by age in our study revealed that it could be a protective factor (OR = .59), although this can be considered to be just a statistical artefact no previous studies have linked tobacco use to BME. On the other hand, no significant differences were found in this study that would suggest osteoporosis, cirrhosis, DM, peripheral arterial insufficiency, alcohol, drugs, or obesity either predispose or protect patients against developing BME.

Some studies claimed that the clinical and radiological findings of bone edema and early-stage osteonecrosis are sometimes very similar [19,28–30], but it is currently unclear if these conditions are isolated or not. Several studies [31–33] (particularly those performed on hip and knee joints) have used MRI to focus on the clinical and radiological evolution of bone trauma. In most cases, clinical symptoms resolve at 6

weeks and radiological changes can be seen at around 3 months. Less than 5% of cases persisted beyond this period, and these were probably due to recurring trauma [31–33].

Published data on the clinical relevance of bone edema is contradictory. In this sense, some authors have shown that patients who present less bone marrow oedema have better outcomes after arthroscopic treatment of osteochondral lesions of the talus, indicating that the presence of bone oedema is a factor contributing to a poor end-result prognosis among these patients [34]. However, Nakasa et al. more recently attributed a positive prognostic factor to the presence of bone oedema, relating it to increased metabolic turnover, less cartilage degradation, and subchondral bone sclerosis [35].

4.1. Strengths and limitations

This study has several limitations that should be considered. First, several different profiles patients who were referred to our FAU were included. The etiology of traumatic, degenerative, infectious, ischemic, neoplastic, neuropathic, or iatrogenic conditions are changeable and can therefore be difficult to unify. To determine whether, in our series of patients, finding BME in the MRI was incidental or the actual cause of the clinical symptoms is very complicated, although this is not the main objective of our work. Second, although vitamin D deficit has been identified as a risk factor for BME, its level was not measured in our series.

On the other hand, the uniqueness and main strength of this study lies in the fact that, although many studies have been published on BME in other anatomical locations [8,36,37], none has specifically studied the epidemiology of BME in the foot and/or ankle area, and, therefore, to the best of our knowledge this is the first work to present a specific analysis.

5. Conclusions

In our series, the prevalence of BME among patients who underwent MRI studies in their feet and/or ankles in a FAU, was 23%. On the other hand, being male, of around 50 years old, receiving immunosuppressive treatments, or having suffered a trauma, are statistically significant risk factors.

Declaration of conflicting interests

None of the authors of this article have any conflicts of interest to declare.

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