Bone marrow edema and results after cartilage repair

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Bone marrow edema (BME) has been described in several areas of both knee pathology and treatment, with the first reports dating back more than two decades ago. However, even though a very long time has passed since the first description by Wilson *et al.* in 1988 (1), BME remains a controversial entity not only in terms of clinical impact, but also for its still unknown significance in etiopathological processes.

BME is an MRI finding, defined as an alteration of the signal intensity of the bone marrow, seen on T1-weighted and T2-weighted images and best seen with fat suppression and short tau inversion recovery (STIR) sequences (2). However, although the imaging appearance is highly suggestive of an edema condition, very little true edema has been actually detected histologically, and conditions characterized by BME have instead been found to present non-characteristic abnormalities including bone marrow necrosis, bone marrow fibrosis, and trabecular alterations (3). Thus, in recent years, the more general term "bone marrow lesion" (BML) has been preferred (4-7) to describe the MRI findings and their heterogeneous underlying pathological elements.

BMLs are associated with multiple pathological conditions, both traumatic (bone contusion, osteochondral fracture, insufficiency and stress fractures, etc.) and atraumatic (avascular necrosis, spontaneous osteonecrosis, osteoarthritis-associated BML, etc.) (8). Whereas little is known about their exact physiopathological aspects, a common element among these pathologies presenting BML is likely to be a disequilibrium between the pathological stimulus and the ability of the bone to remodel and restore the physiological condition.

Although several studies have attempted to explore the meaning of BML for joint homeostasis and evolution of both osteonecrosis and osteoarthritis, more attention has been recently placed on the meaning of BML after cartilage treatments, due to an increasing awareness of the role played by the subchondral bone in cartilage lesions. In fact, understanding the importance of focusing on the entire osteochondral unit has led to the development of new osteochondral procedures (9) on one hand, whereas on the other it has increased attention on the imaging evaluation of the BML observed after cartilage treatment.

A recent study published by Niethammer et al. (10) documented prospectively the BME observed after thirdgeneration autologous chondrocyte implantation (ACI). They followed 38 knees in 30 patients, by a standardized MRI examination performed at 1.5, 3, 6, 12, 24, and 36 months. BME was seen in 78.9% of defects over the postoperative course. It was more common in femoral than patellar defects, but no correlation with the clinical outcome could be found in this series. This strong prospective study on a homogeneous cohort of patients supported similar findings previously suggested by other reports. In fact, other authors also found a high rate of bone marrow alterations after cartilage surgery. Takahashi et al. (11) showed a link between BML and 47% of the implants, and a similar rate was also reported by the studies of Henderson et al. (12), Dhollander et al. (13), and Tetta et al. (14), with half of the patients presenting MRI subchondral alterations. The evolution of post-surgical BML is less clear, with both evidence of reduction or increase over time. With regards to this, a recent study on a large cohort of patients shed some light on a possible explanation for these controversial findings. Filardo et al. (15) evaluated the MRIs of 116 patients treated with hyaluronic acid-based ACI, making a total of 248 exams performed from 6 to 108 months postoperatively. The high number and wide follow-up range of the MRIs studied enabled a specific trend to be found: BML was present in the first postoperative phases, markedly reduced at 2 and 3 years, and then again increased

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and steadily present at mid/long-term follow-up. The initial reduction may be explained by a maturation phase, which for such cartilage treatments is commonly acknowledged to stabilize at around 2 years with a parallel reduction of the MRI signal. On the other hand, the hyaline-like cartilage found as a result of ACI procedures may be not sufficient to protect the subchondral bone from mechanical forces, and thus lead to progressive bone marrow stimulation. The importance of the abnormal load applied seems to be supported by the distribution of BML, which was found to be more common in femoral condyles than in trochlea and patellae, or in joint compartments with combined meniscus damage and therefore further increased abnormal mechanical stress.

Worthy of note, no correlation was found between BML and the clinical outcome, as confirmed by the previously mentioned study by Niethammer et al. (10). The high MRI sensitivity might allow early changes to be detected, which may be a tissue reaction that is abnormal but still not severe enough to affect the clinical outcome, even at mid/long-term follow-up. Thus, although BML is a common finding after cartilage surgery, the interpretation of MRI abnormalities remains to be clarified. Prospective well designed studies with multiple evaluations at long follow-up are still needed for a better understanding of the evolution of post-surgical BML over time, as well as its importance as a prognostic factor at long-term follow-up, in order to better evaluate the potential of cartilage procedures and improve the management of patients undergoing surgery for the treatment of the articular surface.

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