Detection of Modic Changes in an Ovine Model of Intervertebral Disc Degeneration

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Introduction: Modic changes (MCs) are pathological magnetic resonance imaging (MRI) signal intensity changes in the vertebral bone marrow, typically adjacent to degenerated IVDs (1). MCs have gained relevance in the last few decades due to different researchers showing a direct association between the presence of MCs and the diagnosis of Intervertebral Disc Degeneration (IDD), one of the main causes of low back pain (2). Generally, MCs are classified in 3 types. MCs type 1 (hypointense on T1-weighted (T1W), hyperintense on T2-weighted (T2W)), when fibrous and vascularized tissue replaces normal bone marrow and edema of the endplates can be observed. Type 2 MCs (hyperintense on T1W and T2W) are considered to represent the conversion of normal into fatty bone marrow. MCs type 3 (hypointense on T1W and T2W) are assumed to represent subchondral bone sclerosis (3). Given that tissue samples from human subjects are rare, animal models become crucial to understand the development and relevance of MCs (3). The process of identifying and categorizing MCs can be influenced by the strength of the MRI field utilized which could be a limitation due to cost and equipment required. Additionally, current research literature suggests that, up until now, the investigation of these changes in large animal models remains limited and warrants further exploration. The objective of this study was to describe the types of MC’s noted on MRI of skeletal mature sheep undergoing IDD. Sheep are highly relevant large animal model of IDD and may serve to be useful in our understanding of how MCs vary according to the progression of IDD.

Methods: Three sheep were evaluated to describe the degeneration progression following the induction of IDD via a partial discectomy at the L2-L3, L3-L4, and L4-L5 levels. Animal use was approved by the Colorado State University Animal Care and Use Committee (IACUC #3382). MRI (3 Tesla) was conducted both pre-operatively and at 8, 16, and 30 weeks post-operatively to monitor the progression of disc degeneration and the presence/change of MCs. The imaging employed T1W and T2W sequences in sagittal view from L1 caudal to S1 cranial endplate (=36 endplates). A blinded observer analyzed the images using an imaging software (Horos). The collected data was subjected to a variance analysis between the different time points (GraphPad Prism 10).

Results: Upon initial MRI analysis of the 36 endplates (L1 caudal to S1 Cranial), only 2 endplates displayed MCs of type 2 at baseline. However, as time progressed, a noticeable increase in these changes was observed. At the 8-week, 4 endplates manifested type 2 MC’s. This number doubled by 16 weeks, with 8 endplates exhibiting MCs type 2. By the 30-week interval, 11 endplates presented with MCs type 2. This data reflects a consistent progression in the number of endplates showing MCs over the study period. Intriguingly, these changes were not uniformly distributed across the spine; they were localized predominantly within the concluding lumbar segments, specifically the L4-L5, L5-L6 and L6-S1 intervertebral spaces. Statistical differences were noted in the number of MCs in time, specifically between baseline (0 weeks) and the endpoint of the study (30 weeks) (Figure 1). Evolution of these MRI findings over a relatively short span underscores the potential dynamic nature of MCs in the studied model.

Discussion: The temporal evolution of MCs observed in this study offers valuable insights into the dynamic nature of spinal degenerative alterations. From a mere 2 out of 36 endplates exhibiting type 2 MCs at baseline, there was a marked increment in this count over the subsequent weeks, with 30-week assessments showing almost six times the initial count. It’s particularly noteworthy that these changes were not diffuse or generalized across the entire spine; rather, they presented a predilection for the lower lumbar regions (Figure 2). This focal nature of progression, observed primarily in the concluding lumbar regions, might hint at biomechanical or anatomical factors predisposing these specific segments to MCs. As MCs have been linked with symptoms and degenerative processes in human studies, understanding their swift emergence and localized distribution, as revealed in our model, becomes crucial for both diagnostic and therapeutic strategies in clinical settings. Sheep are frequently considered a suitable model for studying IDD in humans for several reasons; such as: a) anatomical similarities: anatomy and size of sheep intervertebral discs closely resemble those of humans, making surgical procedures and imaging techniques more translatable, b) biomechanical similarities: sheep spinal biomechanics, particularly in the lumbar region share resemblances with human spine biomechanics, thus offering insights that are relevant to human spinal conditions; c) ethical and practical Considerations: while still requiring ethical oversight, sheep are more accepted in the research community as a model for large-scale animal studies compared to other large animals like dogs. Given the parallels in disc anatomy and biomechanics between the studied animals and humans, our findings suggest a potential rapid evolution of such MCs in certain clinical scenarios. MCs, particularly of type 2, have been historically associated with back pain in humans (4). If these changes can indeed develop or progress in such a swift manner, as indicated by our study, it underscores the need for timely diagnostic interventions and therapeutic approaches in patients presenting with back pain symptoms. Furthermore, the localization of these changes to specific lumbar levels, can guide clinicians in their diagnostic assessments, potentially aiding in more targeted treatment strategies.

Significance/clinical relevance: This research provides pivotal insights into the rapid progression of Modic changes type 2, highlighting the dynamic nature of spinal degenerative alterations. Furthermore, the specific localization of these changes offers valuable guidance, shaping targeted therapeutic strategies for optimal patient outcomes.

References:

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