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Editorial

Neoplastic and Non-Neoplastic Vertebral Marrow Pathologies: Can the Conventional and Advanced MRI Sequences Provide a Definitive Answer?

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Vertebral marrow lesions are quite frequently detected in magnetic resonance imaging (MRI) of the spine referred for various clinical scenarios. Although MRI is highly sensitive for detecting marrow lesions, the specificity can be improved by understanding and choosing appropriate sequences. Relative distribution of fat and water in the vertebral marrow lesions, estimation of cell density, and analysis of edema or vascularity using various MRI sequences are increasingly used to improve the specificity of lesion characterization. MRI plays the main role in avoiding the biopsy of benign vertebral lesions or tumor mimics. In this regard, conventional sequences like T1-weighted, T2-weighted, and short tau inversion recovery (STIR) sequences can be combined with problem-solving sequences like diffusion-weighted imaging (DWI), chemical shift imaging (CSI), or Dixon-based fat quantification and dynamic contrast studies.

Vertebral lesions can be broadly categorized into three groups based on the most common patterns we encounter in daily practice. Group I includes vertebral collapse, which can be osteoporotic or neoplastic, and group II includes single or multiple focal vertebral benign or malignant lesions, which can be detected incidentally or in patients with known underlying malignancy. Group III lesions are diffusely heterogeneous marrow signal changes that can be for various reasons like hematological, metabolic disorders, marrow reconversion related, and chemoradiation induced. Although patterns are varied, the principles of distinguishing the above groups of lesions remain the same.

Acute and subacute vertebral collapse poses diagnostic challenges to distinguish from malignant causes mainly due to variable marrow signal changes. Although there are many distinguishing features of benign and malignant collapse in conventional sequences, the most specific feature to rule out malignancy is the preserved fat signal within the collapsed vertebra. Whereas pedicle involvement; and soft-tissue components are fairly specific for metastasis. The sensitivity, specificity, and accuracy of conventional MRI sequences to detect metastatic compression fracture are 100, 93, and 95%, respectively.[1,2] The total predictive value to detect metastatic fracture is between 94 and 97.3%.[3,4]

Whenever there are equivocal findings, DWI, CSI, Dixon-based fat quantification, and dynamic contrast can be used. CSI and Dixon imaging are based on the detection of the amount of marrow fat replaced by the lesion. CSI with in-phase and out-phase sequences can be used to quantify the fat signal drop. The cutoff value ratio of 0.8 resulted in a sensitivity of 95% and a specificity of 89 to 95% for detection of neoplasm.[5,6] Ragab et al[6] used 35% as a cutoff and found the sensitivity and specificity of the out-of-phase images was 95% and 100%, respectively. The multi-echo Dixon method is now very popular for rapid and more accurate quantitative assessment of the fat content as compared with CSI. The fracture fat fraction cutoff value is 5.2% with a sensitivity of 95.8% and a specificity of 95%. However, several cutoff values are suggested by various studies with a sensitivity of 93 to 95% and specificity of 82 to 100%.[7] DWI can quantify the water mobility in tissues with ADC value as a substitute providing indirect estimates of cellularity. Malignant lesions show low ADC values due to high cellularity. Various studies in the literature have mentioned cutoff values of less than 1.7 to 0.8 and collective sensitivity and specificity for osteoporotic and metastatic vertebral fractures of 0.92 (95% confidence interval [CI]: 0.82–0.97) and 0.91 (95% CI: 0.87–0.94), respectively.[8] We should be aware that the DWI acquisitions are not uniform across the world; however, high *b* value and thin sections are recommended. When compared with fat fraction by CSI and ADC, fat fraction had excellent repeatability and was a superior discriminator than ADC as reported by a study by Donners

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et al.[9] There can be overlap in the values, especially in sclerotic lesions, which has to be considered when relaying on CSI. In completely collapsed vertebrae, chronic infection may also give false-negative results for metastasis in both CSI and DWI. Dynamic contrast-enhanced MRI[10] is another problem-solving tool that is reported to be of use. The increased cost, acquisition time involved, and multiple flow parameters to be analyzed make it a less popular sequence to be included in routine clinical use.

Both vertebral marrow metastatic lesions and heterogeneous marrow pose different diagnostic challenges since the imaging features in routine MRI overlap with many benign lesions including red marrow islands. T1-weighted sequences are quite sensitive to detect the marrow lesions with lesions having a signal intensity lower than disks or muscles, indicating the malignant nature.[11] These lesions are less bright on fat-saturated images and do not show contrast enhancement. However, when conventional sequences are indeterminate, CSI or Dixon and DWI may be useful. Studies have shown CSI provides a sensitivity of 91.7%, specificity of 73.3%, and accuracy of up to 82%. A signal drop of more than 20% almost rules out malignancy with up to 91% sensitivity and high negative predictive value; however, the lesion that shows a signal drop of $\leq$20% has to be followed up or biopsied.[12] DWI with quantitative ADC value estimation is more accurate than visual estimation of restricted diffusion. Pooled sensitivity and specificity of quantitative ADC values ($1.01 \pm 0.22\,mm^2/s$) for marrow lesions are 89% and 87%, respectively.[8] Hypercellular focal red marrow may have overlapping values with metastasis on ADC. CSI is ideal for diagnosing atypical hemangioma and focal red marrow hyperplasia with good certainty, reducing the need for biopsies. Sclerotic metastasis, lesions with small foci of metastasis, and infiltrative pathologies with preserved trabeculations especially myeloma or lymphoma might show greater signal drop-off, falsely indicating benignity. Lesions with hypercellular hematopoietic marrow like spindle cell hemangioma and extensive fibrosis in chronic osteomyelitis might show false-positive results.

Predicting vertebral lesions as benign or malignant using conventional imaging sequences can be inconclusive in a small number of cases. Problem-solving sequences greatly enhance the confidence of radiologists to categorize these lesions. These are now routinely included in scanning protocols, of which Dixon sequences are more popular due to ease, good repeatability, and rapid acquisition. Biopsy or close follow-up with clinical evaluation is still standard practice in lesions with overlapping imaging features in spite of problem-solving sequences.

Conflict of Interest
None declared.

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