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MAGNETIC RESONANCE

Now is the time to start routinely using chemical shift imaging in the spine

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I am a musculoskeletal radiologist. For the first 20 years of my specialty, before the advent of MRI, we basically were skeletal radiologists. For the last 20 years, many of us have been primarily articular radiologists. What we lost in those two decades was the granular study of bones.

The ignored granularity was marrow. Marrow is a complex, evolving structure. It is this unfolding over time that makes the study of marrow particularly intriguing. Much of this evolution is related to increases in the relative fat content, especially following childhood but continuing as we age. Fat also is replaced by both systemic hematological diseases as well as by malignant processes, making the investigation of marrow fat particularly important.

In malignant processes fat is replaced in a distinctly different fashion than it is in benign disorders. Secondary malignancies in bone begin as embolic phenomena and grow from that initial seed. Because this growth occurs in a modified centrifugal fashion, the local fat is displaced by the growing mass. Hence, each pixel will show limited fat, which is difficult to discern visually, using traditional sequences.

Vertebral fractures are extremely common, with a prevalence of about 50%. Most of these are fairly low energy injuries; thus they may be diagnosed incidentally in somewhat more than half of cases. The USA has among the highest frequencies of vertebral fractures in the world. In Europe, Sweden and then Germany have the highest prevalence. Overall women have more than twice the frequency as men, with this differential widening with increasing age. The most common locations for vertebral fractures are T12 and L1, followed by L2 and L3, then T9 through L4. Osteoporotic fractures in other locations are fairly rare [1].

This distribution of spinal fractures is quite similar to that of vertebral metastases, which are rare in the cervical spine and rarely lead to fractures in the upper to mid thoracic spine. Although overall the vast majority of fractures are benign, a not insignificant percentage are related to an underlying malignancy. Hence, whether a given vertebral fracture is benign or malignant has been and remains, to a large degree, a continued clinical conundrum.

Thus, the clinician has to choose between following up, performing an elaborate work-up or requesting a biopsy. None of these options are desirable.

Chemical shift imaging was first described by Dixon in 1984 in a landmark paper, cited nearly 2000 times [2]. He utilized this technique at low field strength and termed it a spectroscopic technique, which indirectly it is. Although quickly applied to the musculoskeletal system, this out-of-phase technique reached its fasted widespread application in abdominal imaging.

It had been well known histologically that the adrenal adenomas contained microscopic fat. Adrenal adenomas are quite common lesions and were often noted incidentally on the lower images of chest CTs done to stage lung cancer. The application of out-of-phase techniques revolutionized the work-up of these lesions and allowed many more lung cancer patients to undergo curative treatments [3]. With the global epidemic of diabetes, the study of liver fat fraction became increasingly important, and chemical shift techniques are currently the norm in the study of chronic liver disease by MR [4].

Many years ago, our group among others applied the principles of chemical shift imaging as a functional route to determine if microscopic fat was present in suspicious marrow lesions [5–8]. The principle was the fat was displaced by neoplasms out of the voxel studied. These papers showed quite promising results, and numerous others started using these techniques clinically.

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Initially Dixon techniques were done with two echoes. This worked adequately in the adrenal glands. However, in marrow, trabecular bone causes specific issues. As most chemical shift techniques utilize variations of gradient techniques, the absence of a refocusing pulse influences the fat and water signal. These multiecho chemical shift techniques have been optimized in the liver, where similar perturbations of susceptibility are seen as may be noted in vertebral marrow [9]. In the Schmeel paper a six-echo Dixon technique was implemented [9].

Most of the papers on chemical shift imaging of marrow have either studied small numbers, had imperfect reference standards, used somewhat skewed patient populations, or failed to provide detailed quantitative analysis. What Schmeel et al. have performed is an excellent, acutely clinically important study that addresses nearly all the limitations of the prior works.

They studied 66 patients prospectively. All underwent more traditional MR imaging as well as a multiecho chemical shift sequence. There was a relatively even proportion of benign and malignant fractures. Their reference standard was histology in the malignant fractures, and rigid imaging appearance and follow-up criteria for the benign fractures, thus avoiding confirmation bias.

But what was particularly impressive, was the quality and extent of the statistical analysis. Fat fractions are presented for each different benign process and for myeloma, primary tumours and metastases separately. The excellent box and whiskers graph in Fig. 3 is particularly illuminating. Lastly, after developing ROC curves they provide meaningful, clinically useful cut-offs. These cut-offs would be easily implemented when presented with this problem "at the viewbox".

Hence, when one sees a vertebral body fracture and either by clinical or by imaging criteria we are concerned that it might be malignant, Schmeel's work would lead us to add a multiecho gradient echo sequence and use the fat fraction cut-off of 6.40% to determine whether this fracture might be malignant or not. This well-done study is a very useful addition to the growing literature on the use of chemical shift imaging as a functional biomarker. This application using multiple echoes to compensate for dephasing related to trabecular bone and blood products optimizes the Dixon technique for the use in vertebral bodies. To add this sequence fairly routinely would seem to be 1 min well spent.

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Methodology
• Opinion

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