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Research Paper

# Utility of opposed-phase magnetic resonance imaging in differentiating sarcoma from benign bone lesions

Barry E. Kenneally [a], Christina J. Gutowski [b,*], Alan W. Reynolds [c], William B. Morrison [d], John A. Abraham [a]

[a] Rothman Institute at Jefferson, Philadelphia, PA, United States
[b] Thomas Jefferson University Hospital, Department of Orthopaedic Surgery, Philadelphia, PA, United States
[c] Penn State University College of Medicine, Hershey, PA, United States
[d] Thomas Jefferson University Hospital, Department of Radiology, Philadelphia, PA, United States

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ABSTRACT

*Purpose:* To investigate the utility of opposed-phase magnetic resonance imaging (OP MRI) in differentiating malignant from benign bone lesions.

*Materials and methods:* MRI scans of musculoskeletal lesions including opposed-phase imaging sequences were reviewed by both an experienced musculoskeletal attending radiologist, and a second year radiology resident. The change in signal from IP to OP images was measured. The reviewers' evaluation of the lesions based on T1 and T2-weighted images was compared to their evaluation with inclusion of the OP sequences.

*Results:* Twenty-seven lesions in bone were analyzed: 4 malignant primary bone lesions, 3 malignant soft tissue lesions to bone, 3 metastases from visceral malignancies, and 17 benign bone lesions. Benign lesions of bone dropped in signal on OP imaging by an average of 37.1%. Five of the benign lesions decreased in signal by less than 20%, and two increased. Malignant bone lesions dropped in signal by an average of 0.69% with one of the ten lesions showing a greater than 20% drop.

When OP sequences were included, concern for malignancy decreased in benign lesions and increased in malignant lesions, for both the resident and attending. Compared with standard MRI, inclusion of these sequences increased the overall confidence in diagnosis for both reviewers.

*Conclusion:* Opposed-phase imaging is helpful in differentiating benign from malignant lesions in bone. Confidence in diagnosis rose for both the attending and the resident as result of the inclusion of OP sequences.



## 1. Introduction

Magnetic resonance imaging (MRI) has great utility in evaluating musculoskeletal tumors. However, some lesions have an appearance on MRI that make it challenging to differentiate benign from malignant lesions. Even intravenous (IV) contrast sometimes does not allow differentiation of benign from malignant lesions: hemangiomas, Schmorl's nodes, and degenerative vertebral endplate changes all enhance with IV contrast. Opposed-phase MRI (also termed chemical shift imaging, or in-and-out of phase imaging) has shown value in this setting based on its ability to detect small amounts of fat, suggestive of a benign process. In these opposed-phase sequences, signal characteristics consistent with normal fat tissue are not found in malignant, marrow-replacing bone lesions [1,2].

This imaging technique exploits the difference in signal seen on in-phase (IP) and out-of-phase (OP) sequences: this difference is based on the phenomenon that hydrogen atoms attached to water and lipid precess at different frequencies. On the in-phase imaging, fat and water signals are additive when these tissues are in the same voxel. On OP images, the two vectors are opposite, resulting in the two signals canceling. When lipid and water exist simultaneously in a benign lesion, the result is a drop in signal on OP images when compared to IP images of the same lesion (see Fig. 1a–d). IP and OP sequences are easily acquired during a standard musculoskeletal protocol, using a dual gradient-echo technique with T1 weighting. Protocol for IP and OP MRI differs depending on the strength of the magnetic field: with a 1.5 T magnet, the interval on TE (time to echo) between IP and OP

* Correspondence to: 1025 Walnut St. College Building, Room 516, Philadelphia, PA 19107, United States. Fax: +1 215 503 0530.
*E-mail addresses:* barry.kenneally@rothmaninstitute.com (B.E. Kenneally), gutowski1@gmail.com (C.J. Gutowski), areynolds1@hmc.psu.edu (A.W. Reynolds), William.morrison@jeffersonhospital.org (W.B. Morrison), john.abraham@rothmaninstitute.com (J.A. Abraham).

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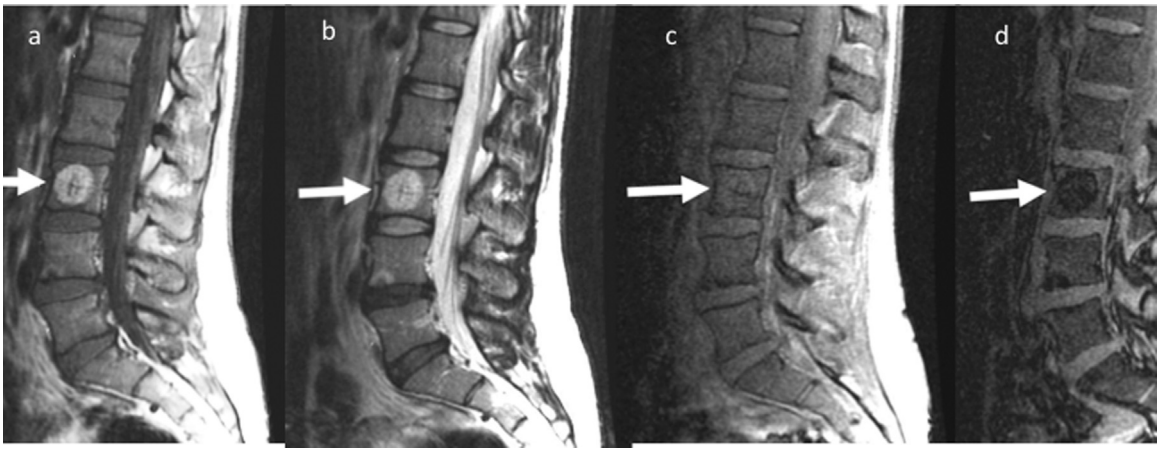


**Fig. 1.** a–d: 1a – Sagittal T1-weighted spin echo (SE); TR: 500 ms, TE: 9 ms. 1b – T2-weighted fast spin echo (FSE); TR: 4600 ms, TE: 88 ms. 1c – In-phase gradient-recalled echo (GRE): TR: 125 ms, TE: 4.6 ms, flip angle: 90°. 1d – coronal opposed-phase gradient-recalled echo (GRE): TR: 125 ms; TE: 2.3 ms, flip angle: 90°.

images is 2.3 ms. The images for both opposed and in-phase-imaging can be taken in about 20–30 s, or a single breath hold.

Many benign bone lesions contain variable amounts of fat, while malignant bone lesions replace or destroy the fatty bone marrow. A drop in signal on OP images indicates at least some fat content in the lesion, suggestive of a benign process (see Fig. 2a–d). Imaging software uses a region of interest (ROI) to measure the drop in signal, thus yielding a quantitative result. Previous studies have determined a drop in signal of 20% or more to be suggestive of a benign lesion [3]. A drop of 20% on OPI was found to capture all malignant lesions in the study, although this cut-off did allow for some benign lesions being included in the malignant category [3]. This 20% threshold seems to maximize the sensitivity and specificity of the test. A malignant lesion tends to contain little or no fat, resulting in little drop in signal from in-phase to out-of-phase sequences (see Fig. 3a–d). Previous research has shown that this correlates to the histology of the lesions [3]. The hypothesis of our study is that these sequences may play an important role in the imaging of musculoskeletal tumors, enhancing the ability to differentiate benign from malignant disease states and in some cases obviating the need for biopsy. Our goal is to investigate and quantify the extent of this capability, using data collected from blinded radiologists regarding their concern for malignancy, accuracy in diagnosis, and confidence in reading these imaging studies.

## 2. Materials and methods

Institutional review board approval was obtained for this study; informed consent was waived as this is a retrospective review. A keyword search of our institutional radiology information system was performed, querying for the phrases, “opposed phase” and “in and out of phase.” A senior musculoskeletal radiologist reviewed all MRIs to determine that the OP images were adequate for analysis. Twenty-seven lesions meeting these criteria were found.

Clinical records were examined to determine whether the lesions were benign or malignant. Inclusion criteria were either biopsy confirmation of lesions or at least 9 months of radiologic surveillance. In patients who underwent biopsy, tissue diagnosis was recorded; in those who did not undergo biopsy, documentation of clinical follow-up was utilized. Fifteen of the 27 patients had a biopsy-proven diagnosis of malignancy; only 10 of these exhibited bony involvement. Five of these were bone sarcoma and another five were soft tissue sarcoma or visceral carcinoma. One of the malignant lesions in bone represented direct, local invasion from a soft tissue mass. Of the 17 benign lesions, two were biopsy-proven (osteoid osteoma) and the other 15 were deemed benign based on lack of progression with follow-up imaging and examination of at least nine months. Duration of follow-up imaging ranged from nine to twenty-three months.

A senior musculoskeletal radiologist screened all cases and presented them to two other radiologists in a blinded fashion. These two radiologists were of different experience levels: one was a musculoskeletal radiologist with 5 years of experience and the other was a second-year radiology resident. The screening radiologist had access to the patient records and radiology reports. The two reviewers were blinded to the previous radiology reports as well as the clinical diagnoses.

All MR imaging was performed by using a 1.5 T unit (various vendors) and a phased-array surface coil. The following pulse

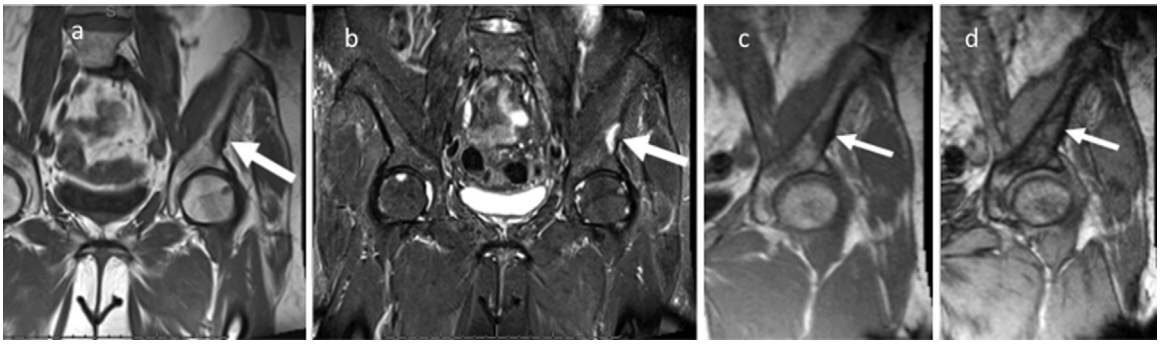


**Fig. 2.** a–d: 2a – Coronal T1-weighted SE; TR: 547 ms, TE: 12 ms. 2b – Coronal short tau inversion recovery (STIR); TR: 3830 ms, TE: 50 ms, inversion time (TI): 150 ms. 2c – Coronal in-phase GRE; TR: 206 ms, TE: 4.6 ms, flip angle: 70°. 2d – Coronal opposed phaseGRE; TR: 206 ms, TE: 2.3 ms, flip angle: 70°.