Original Investigation

Accuracy of Opposed-phase Magnetic Resonance Imaging for the Evaluation of Treated and Untreated Spinal Metastases

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Rationale and Objectives: To assess whether the accuracy of opposed-phase magnetic resonance (MR) imaging to differentiate spinal metastases from benign lesions is influenced by treatment.

Materials and Methods: We retrospectively evaluated 25 benign lesions, 25 untreated spinal metastases, and 89 treated spinal metastases in 101 patients who underwent opposed-phase MR spine imaging at our institution. The largest possible region of interest was placed over the lesion in question on out-of-phase and in-phase MR sequences, and the signal intensity ratio (SIR) of the lesions was calculated. The SIRs were compared between benign, untreated, and treated lesions. Receiver operator characteristic (ROC) curves were used to identify the optimal threshold to differentiate benign lesions from untreated spinal metastases, and the accuracy of this threshold was assessed for treated spinal metastases, chemotherapy-treated spinal metastases, and radiated spinal metastases.

Results: Benign lesions had lower mean SIR than untreated ($P = 2.4 \times 10^{-8}$, 95% confidence interval [0.29, 0.51]) and treated spinal metastases ($P = .51$; 95% confidence interval [–0.13, 0.06]). A cutoff SIR of 0.856 had an accuracy of 88.00% for untreated lesions, 77.48% for previously treated lesions, and 70.45% for previously radiated lesions. The ROC curve to differentiate benign lesions from radiated spinal metastases was significantly different from the ROC curve to differentiate benign lesions from untreated spinal metastases ($P = .0180$). The ROC curve to differentiate benign lesions from lesions treated with chemotherapy only was significantly different from the ROC curve to differentiate between benign lesions and radiated spinal metastases ($P = .041$).

Conclusions: Opposed-phase imaging is less accurate for treated spinal metastases, in particular after radiation.

Key Words: Magnetic resonance imaging; cancer; neoplasm metastasis; staging; spine.

INTRODUCTION

Differentiating benign lesions from spinal metastases is sometimes a challenge for radiologists using conventional magnetic resonance imaging (MRI) (1). This is of tremendous clinical importance because spinal metastases represent advanced stage disease and portends poor prognosis. Mistakenly proposing that a lesion is a spinal metastasis when it is a benign lesion may result in biopsy of the lesion or, in some cases, may alter the potential therapy available to the patient and consequently affect patient survival. Therefore, it is important that a radiologist accurately differentiate benign lesions from spinal metastases. Different MRI techniques have been used to evaluate suspected spinal metastases including routine spin echo sequences, contrast enhancement, and diffusion-weighted imaging (1).

Of the techniques used, opposed-phase MRI may be the most promising (2). Opposed-phase MRI uses chemical shift to detect intracytoplasmic lipid. Because fat- and water-associated protons resonate at different frequencies, imaging can be obtained when fat and water protons are aligned in the same direction (in-phase) and when they are aligned in opposite directions (out-of-phase). When these protons are "in-phase," there is an additive effect increasing the signal intensity (SI) produced in the corresponding voxel. When the protons are "out of phase," the signal from fat and water protons are in opposite directions, resulting in decreased SI in the corresponding voxel. Benign osseous lesions often have intracellular fat and higher lipid content, and as a result have decreased SI on out-of-phase images (3,4). Opposed-phase MRI has been used in imaging to differentiate benign from malignant lesions of the adrenal gland on the basis of intracellular lipid content (4). Opposed-phase MRI has been used for the evaluation of lesions of the spine to differentiate benign lesions from spinal metastases (5). The ratio of the SI on out-of-phase imaging

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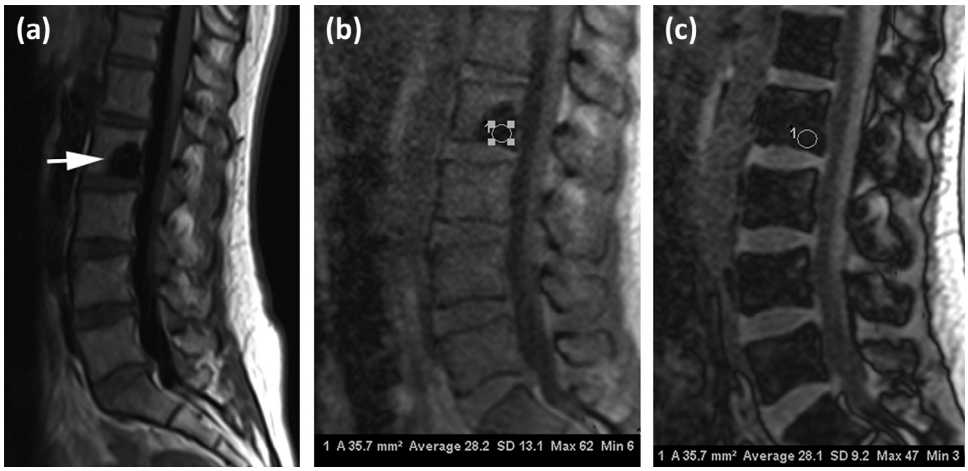

Figure 1. Forty-one–year-old female with oligometastatic breast cancer and L2 lesion. **(a)** Sagittal proton density-weighted magnetic resonance (MR) sequence (repetition time [TR] 1690 ms, echo time [TE] 8.7 ms) demonstrates a T1-hypointense lesion in the L2 vertebral body. White arrow shows the L2 metastatic lesion. **(b)** In-phase (TR 140 ms, TE 5.04 ms) and **(c)** out-of-phase images (TR 140 ms, TE 2.56 ms) demonstrate method of region of interest (ROI) measurement; SIR = 0.993.

to the SI on in-phase imaging is the signal intensity ratio (SIR). An SIR less than 0.80 has been used as a threshold to diagnose benign lesions (5), and lesions that have an SIR between 0.80 and 1.00 are often designated as indeterminate in clinical practice. Previous studies have shown that opposed-phase imaging can be used to differentiate benign from pathologic vertebral body fractures (6–9). Kenneally et al. also reported that opposed-phase imaging may be useful in differentiating benign from malignant primary tumors of bone (10).

In many cases, the patient's complete treatment history is unavailable to the interpreting radiologist. Anecdotally, we have noticed a number of indeterminate lesions (SIR between 0.80 and 1.00) using opposed-phase MRI of the spine, which we hypothesized may represent treated (radiated or chemotherapy-treated) spinal metastases. After radiation, there is normal fatty marrow replacement (6). Our goal was to assess whether treated spinal metastases could be accurately categorized as metastases using opposed-phase MRI. We hypothesized that after radiation, the treated spinal metastasis undergoes fatty infiltration that may increase SI loss on opposed-phase imaging, thereby giving the treated spinal metastasis an SIR similar to a benign lesion. We hypothesized that chemotherapy may also result in similar changes.

Therefore, the aim of this study is to compare the accuracy of opposed-phase MRI for evaluation of treated and untreated spinal metastases, and to assess how the accuracy of opposed-phase MRI is affected by prior chemotherapy or radiation therapy.

MATERIALS AND METHODS

We used MONTAGE software to identify patients who underwent opposed-phase MRI of the cervical, thoracic, or lumbar spine at our institution between January 1, 2006 and November 10, 2016. MRI studies that did not contain opposed-phase sequences or were motion-degraded were excluded from the study.

Patient age at time of MRI, sex, history of malignancy, history of systemic chemotherapy preceding MRI study (including immunotherapy, anti-androgen therapy, bisphosphonate therapy), preceding radiation therapy to the specific lesion in question, and results of histologic sampling if available were obtained from the electronic medical record.

All examinations were performed on 1.5-T (General Electric [GE] Optima, GE Signa HDxt, Siemens Aera, Siemens Espree, and Siemens Symphony) or 3-T (Siemens Skyra, Siemens TrioTim, Siemens Verio, and GE Discovery) systems. Opposed-phase gradient recalled-echo images were performed in the sagittal plane, 1.5-T (repetition time [TR] 140–350 ms, echo time [TE] out-of-phase 2.204–2.54 ms, TE in-phase 4.373–5.04 ms, slice thickness 4 mm, interslice gap 0.4–0.8 mm); 3-T (TR 4.82–173 ms, TE out-of-phase 1.24–1.28 ms, TE in-phase 2.48–2.56 ms, slice thickness 4 mm, interslice gap 0.4–0.8 mm).

All images were reviewed using a GE Centricity Picture Archiving and Communication System (PACS) workstation. Region of interest (ROI) measurements were obtained using the PACS ellipse ROI markup tool. The largest possible ROI was placed over the lesion and the mean SI was recorded on out-of-phase and in-phase sequences (Fig 1). An approximately similar-sized ROI (same area) was placed on the out-of-phase and in-phase sequences. Care was taken to avoid vessels and vertebral body cortex when obtaining ROIs. The SIR of out-of-phase SI to the in-phase SI was then calculated (SIR = mean lesion SI on out-of-phase MRI sequence/mean lesion SI on in-phase MRI sequence).

Lesions were determined to be spinal metastases if there was histologic confirmation of spinal metastases from percutaneous or surgical biopsies; if there was progression of disease (increase in size of lesion) on subsequent imaging over 2 years;