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CASE REPORT

# Two-point Dixon fat-water swapping artifact: lesion mimicker at musculoskeletal T2-weighted MRI

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**Abstract**
Fat-water swapping is an artifact specific to chemical shift encoded MRI and so-called Dixon methods. It is more frequent using the 2-point than the multi-point (> 2) Dixon method. Actually, fat-water swapping on the 2-point Dixon sequences partly triggered the development of the multi-point techniques. Fat-water swapping occurs on post-processing calculated fat- and water-only images, but not on the directly acquired in-phase and out-of-phase source images. It originates from a natural ambiguity between fat and water peaks that may cause inverted calculation between fat- and water-only voxels. Fat-water swapping artifact over large areas encompassing multiple tissues can easily be recognized, but it may be confusing when the calculation errors are limited to a single anatomic structure or a small area, especially on T2-weighted images. We report four cases with 2-point Dixon fat-water swapping artifacts mimicking musculoskeletal lesions at T2-weighted MRI and propose hints to avoid misinterpretation.

**Keywords** MRI · Dixon · Chemical shift encoded · Artifact · Fat · Water · Spine · Hip · Ankle · Disc · Bone marrow · Soft tissue

## Introduction

We report four cases with 2-point Dixon fat-water swapping artifacts mimicking musculoskeletal lesions on T2-weighted MR images. The radiologist must be aware of their existence to avoid false-positive findings. We propose hints to avoid misinterpretation.

### Case report 1 (Fig. 1)

MR examination of the left hip of a 39-year-old woman with chronic hip pain was obtained by using a 1.5 T MRI scanner. Transverse T2-weighted 2-point Dixon water-only (i.e., fat-suppressed) images demonstrated abnormal high signal intensity of the fat tissue surrounding the left hamstring tendons which were initially interpreted as hamstring tendon tears with soft tissue edema-like changes. However, the tendons appeared normal and there was no edema on sagittal fat-saturated proton density images. The T2-weighted Dixon sequence was repeated with exactly the same acquisition parameters and showed normal hamstring tendons and surrounding tissues. Retrospectively, fat-only (i.e., water-suppressed) images obtained from the initial T2-weighted Dixon sequence demonstrated abnormal low signal intensity of the fat tissue surrounding the hamstring tendons with the same sharp delineation as the edema-like changes seen on the water-only images characteristic of a fat-water swapping artifact.

### Case report 2 (Fig. 2)

MR examination of the thoracic spine was obtained in a 34-year-old man with chronic back pain by using a 1.5 T MRI scanner. On coronal T2-weighted 2-point Dixon water-only images, a single intervertebral disc demonstrated decreased signal intensity that differed from the relatively high signal intensity of the other discs. Vertebral end-plate marrow adjacent to the abnormal T10-T11 disc demonstrated high signal intensity, mimicking disc disease with end-plate marrow signal alteration. The corresponding calculated fat-only images demonstrated sharply delineated high signal intensity in the T10–T11 disc and low signal intensity in the adjacent bone marrow. Comparison of the two calculated images showed

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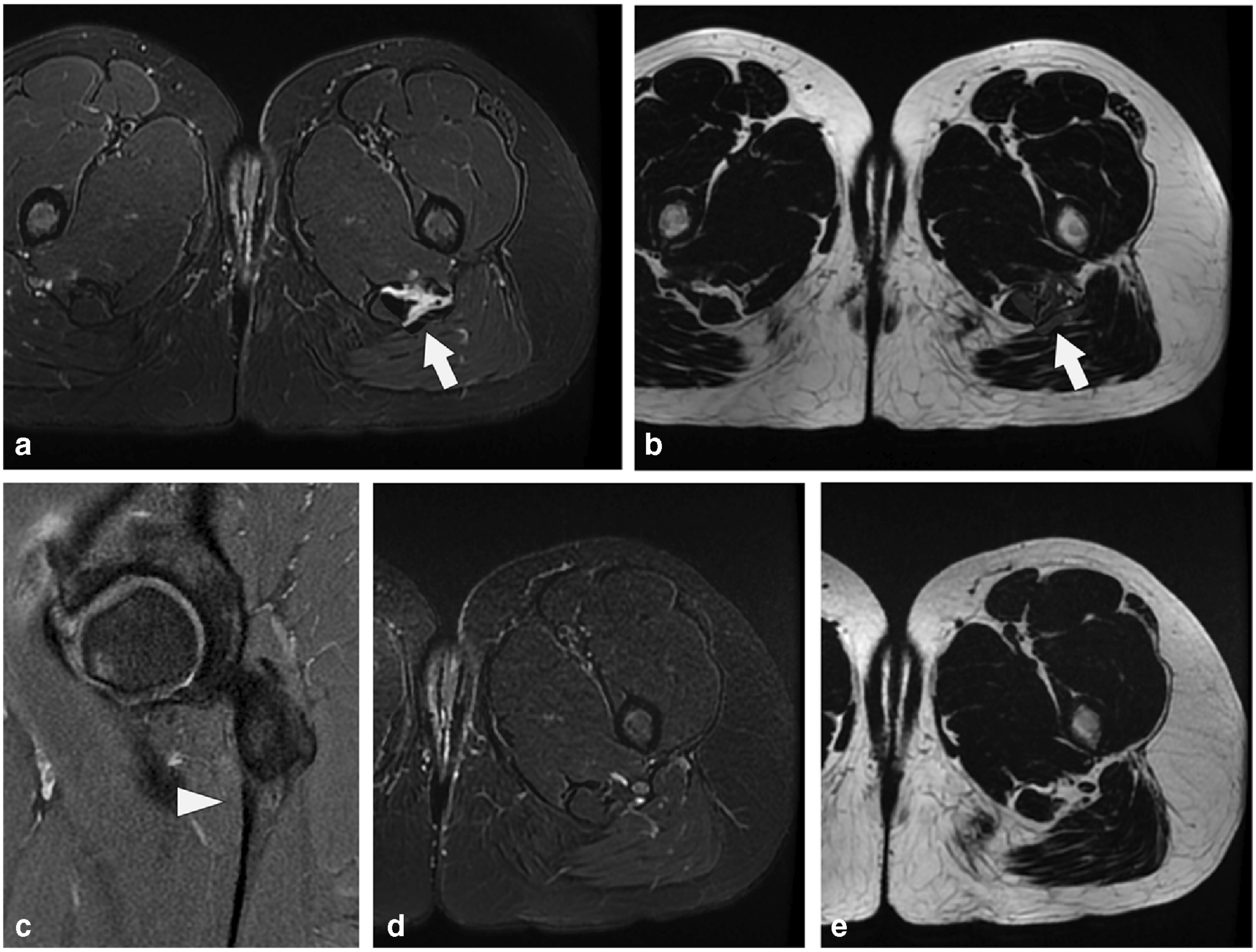


**Fig. 1** Fat-water swapping artifact mimicking hamstring tendinopathy at 1.5 T MRI of the hip in a 39-year-old woman. **a** Transverse T2-weighted 2-point Dixon water-only images demonstrated high signal intensity around the hamstring tendons (arrow). **b** Corresponding fat-only images which were not analyzed by the on-duty attending radiologist demonstrated the disappearance of fat surrounding the hamstring tendons (arrow) compatible with a fat-water swapping artifact. **c** Tendons and adjacent soft tissues were normal on the sagittal fat-saturated proton density-weighted images (arrowhead). Therefore, the T2-weighted 2-point Dixon sequence was repeated with exactly the same parameters and tendons and adjacent soft tissues returned to normal on the repeated **d** water- and **e** fat-only images

that the signal intensity of the T10–T11 disc on the water-only images was identical to that of the other discs on the corresponding fat-only images suggestive of a fat-water swapping artifact. Moreover, all discs had normal signal on in-phase source images. Sagittal T2-weighted 2-point Dixon source and calculated images demonstrated normal signal intensity in all discs including the T10–T11 disc that appeared abnormal on the calculated coronal images.

## Case report 3 (Fig. 3)

MR examination of the lumbar spine was obtained in a 36-year old woman with chronic back pain by using a 3.0 T MRI scanner. On the sagittal T2-weighted 2-point Dixon water-only images, the L5-S1 disc had an unexpected low signal intensity mimicking disc disease. Analysis of the water-only and fat-only images indicated a fat-water swapping artifact limited to the L5-S1 disc. The T2-weighted Dixon sequence was repeated with exactly the same acquisition parameters, and the fat-water swapping artifact was not present in the L5-S1 disc anymore but occurred in the L4-L5 disc. In-phase source images of both Dixon sequences as well as additional sagittal Short Tau Inversion Recovery (STIR) sequence demonstrated normal L4-L5 and L5-S1 discs.

## Case report 4 (Fig. 4)

MR examination of the right hindfoot was obtained in a 37-year-old woman with pain after calcaneal osteotomy by using a 3.0 T MRI scanner. Sagittal T2-weighted 2-point Dixon sequence demonstrated high signal intensity of the calcaneal tuberosity around the metallic screw on the water-only images

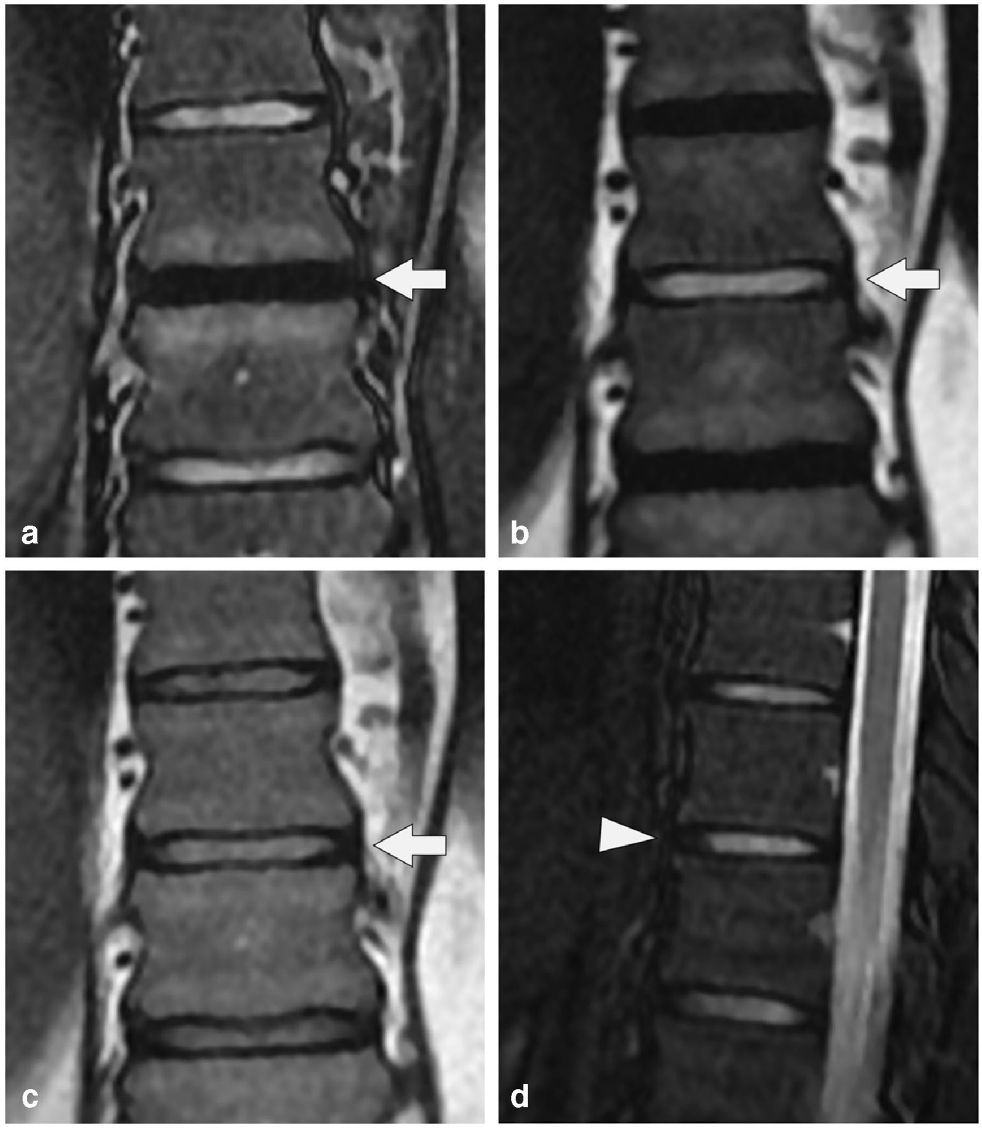


**Fig. 2** Fat-water swapping artifact mimicking disc disease at 1.5 T MRI of the spine in a 34-year-old man. **a** Coronal T2-weighted 2-point Dixon water-only images demonstrated decreased signal intensity of the T10–T11 disc (arrow) along with high signal intensity of adjacent vertebral end-plate marrow. Adjacent discs had normal appearance with high signal intensity. **b** The corresponding fat-only images demonstrated high signal intensity in the T10–T11 disc (arrow) and low signal in the other discs. **c** On the corresponding in-phase images, all discs had normal signal intensity including the T10–T11 disc (arrow) with abnormal signal intensity on calculated images suggestive of a fat-water swapping artifact. **d** A sagittal T2-weighted 2-point Dixon sequence was also obtained and demonstrated normal signal in all discs on water-only images including the T10–T11 disc (arrowhead)

and low signal intensity on the fat-only images which could have been related either to bone marrow "edema-like" changes or a fat-water swapping artifact. Additional STIR sequence in the sagittal plane showed no edema-like changes and demonstrated that signal changes on calculated Dixon images were related to a fat-water swapping artifact.

## Discussion

The Dixon method, formally called chemical shift encoded imaging, has become a solid alternative to fat-saturated and STIR sequences at musculoskeletal MRI [1, 2]. Numerous studies demonstrated the robustness of the fat signal suppression obtained with the Dixon method [3–8]. Dixon sequences may also yield more effective metal artifact reduction than fat-saturated sequences [9, 10] and similar reduction to that of STIR sequences in the absence of additional artifact reduction techniques [11]. Finally, recent studies demonstrated the value of T2-weighted Dixon sequences to replace either T1-weighted images or T2-weighted fat-saturated and STIR images [12–15].

The 2-point Dixon method first described by Dixon in 1984 [16] is based on the simultaneous acquisition of in-phase and out-of-phase images and commonly referred to as in-phase/out-of-phase imaging. "Water-only" fat-suppressed and "fat-only" water-suppressed images are generated by post-processing calculation based on the addition and subtraction of the in-phase and out-of-phase source images [17]. The 2-point Dixon method is insensitive to $B_1$ field heterogeneity if a spin echo sequence is used but is quite sensitive to $B_0$ heterogeneity. The sensitivity to the $B_0$ field heterogeneity exposes the 2-point Dixon sequences to a natural ambiguity between fat and water peaks which may cause inverted

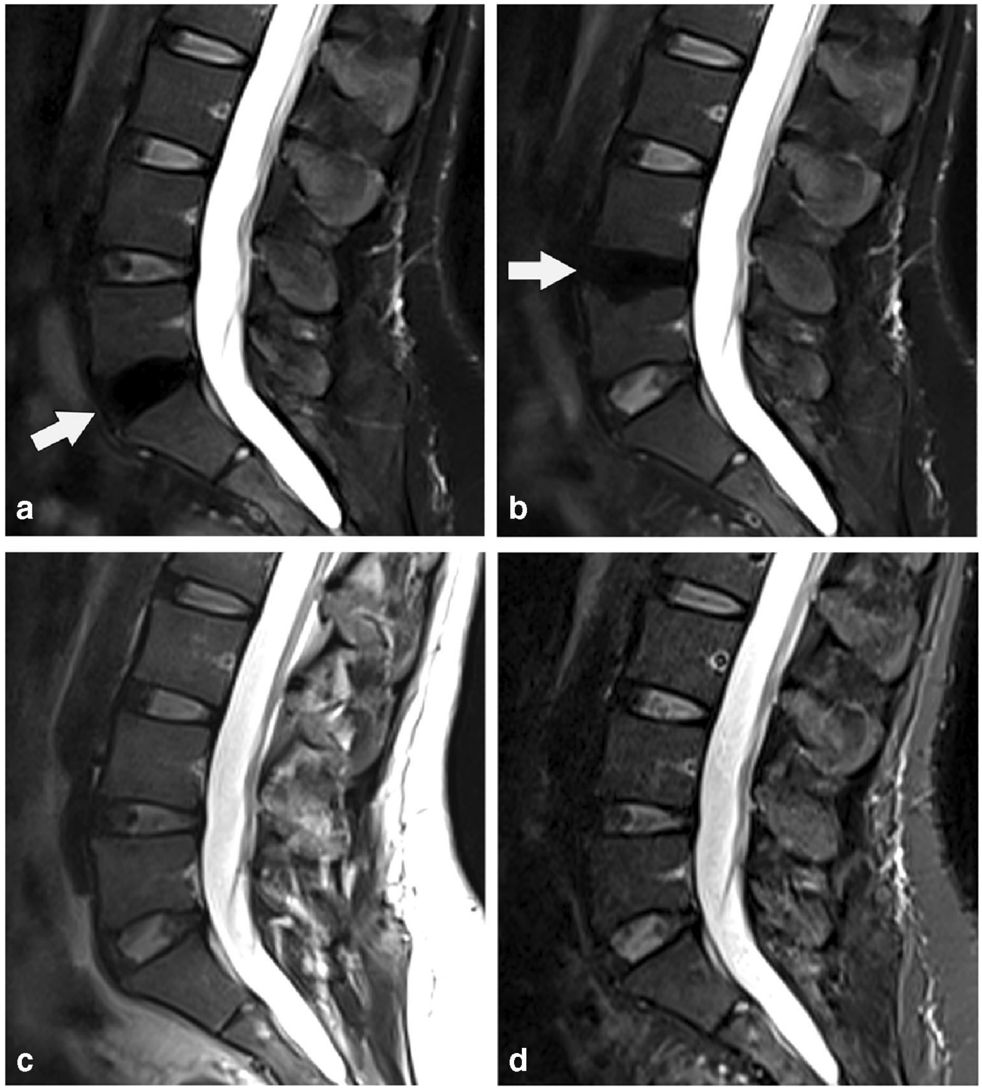


**Fig. 3** Migrating fat-water swapping artifacts mimicking intervertebral degenerative disc disease at 3.0 T MRI of the spine in a 36-year-old woman. Sagittal T2-weighted 2-point Dixon water-only images demonstrated very low signal intensity in L5-S1 disc (arrow) and normal signal intensity in L4-L5 disc. **b** The same sequence repeated 14 min later showed disappearance of the decreased signal in L5-S1 disc and appearance of a similar fat-water swapping artifact in L4-L5 disc (arrow). Sagittal **c** T2-weighted Dixon in-phase and **d** STIR images were normal

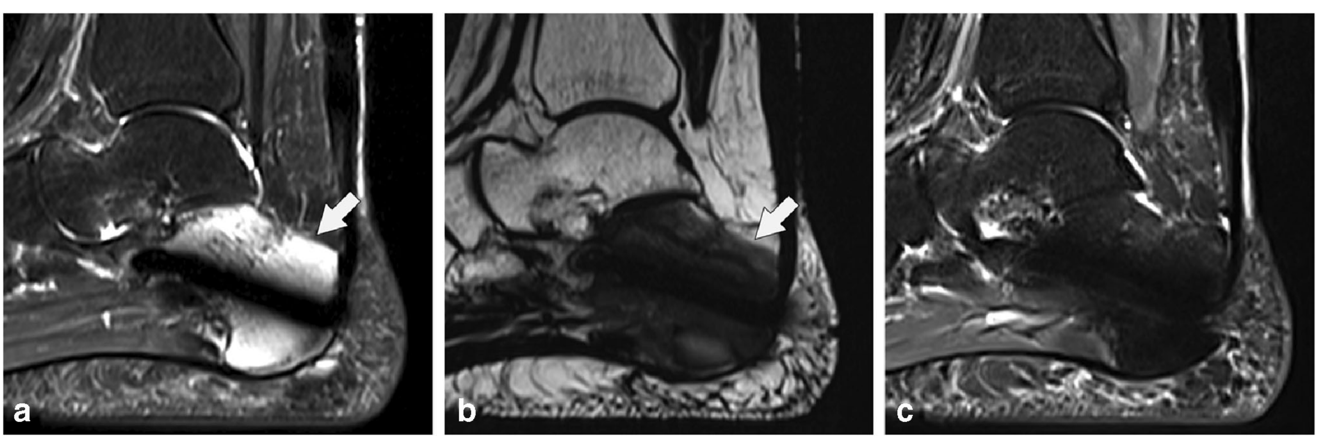


**Fig. 4** Fat-water swapping artifact mimicking bone marrow “edema-like” changes at 3.0 T MRI of the hindfoot of 37-year-old woman with previous calcaneal osteotomy and screw fixation. Sagittal T2-weighted 2-point Dixon sequence demonstrated signal change in the calcaneal tuberosity around the metallic screw with **a** high signal intensity on water-only images (arrow) and **b** low signal intensity on fat-only images (arrow) suggestive of bone marrow edema-like changes. Note that the signal intensity change is limited to the calcaneum. **c** A sagittal STIR sequence demonstrated no abnormal signal of the calcaneum confirming the fat-water swapping artifact

calculation between fat-only and water-only voxels [18, 19]. This miscalculation generates images with sharply delineated areas of inverted fat- and water-only calculation known as "fat-water swapping artifact" (Figs. 1a, b and 2a, b). Fat-water swapping artifacts can involve one to all images of the fat- and water-only series with partial or complete involvement of each image. This Dixon-specific artifact does not affect the source in-phase and out-of-phase images, but only the calculated fat- and water-only images (Fig. 2c). Fat-water swapping occurs randomly (Fig. 3a, b) with reported frequencies between 2 and 21% of the MR examinations depending on the acquisition parameters and investigated anatomical regions [8, 18, 20]. The risk of fat-water swapping artifacts increases in areas with higher magnetic field heterogeneity such as tissue around metal implants (Fig. 4a, b) or in regions with high magnetic susceptibility such as near air-filled sinuses, bowel, or in the neck [19]. However, the exact cause of the random occurrence of the fat-water swapping artifacts is not determined. There is no preference between high and low magnetic field strengths for Dixon sequences as both bring advantages and disadvantages and are at risk of fat-water swapping unlike fat-saturated sequences which benefit from wider spectral separation between water and fat and shorter spaces between radiofrequency pulses at 3.0 T than at lower field strength [17].

The 2-point Dixon method was later improved with the multi-point (> 2) Dixon technique [6–8, 19, 21] and with manufacturer-specific application schemes and algorithms to reduce its sensitivity to the $B_0$ field heterogeneity and the risk of fat-water swapping artifact [18, 21]. However, the gain obtained with the multi-point Dixon method comes at a cost of a longer acquisition time than the 2-point technique [17]. For this reason, 2-point Dixon sequences are still proposed by manufacturers and used by radiologists in clinical practice.

Fat-water swapping artifact over large areas encompassing multiple tissues can easily be recognized, but it may remain unrecognized when the calculation errors are limited to a single anatomic structure or a small area. In that case, artifact-related signal intensity changes can be confused with lesions, mainly on T2-weighted images. Indeed, fat-water swapping occurring in fat-containing tissue may mimic edema-like changes on T2-weighted Dixon water-only images.

Multi-point Dixon sequences should be used instead of 2-point Dixon sequences. However, multi-point Dixon sequences are not widely available for musculoskeletal applications and come at the cost of longer acquisition times when small field-of-view imaging is needed. To limit misinterpretation of fat-water swapping artifacts as pathology, the radiologist must always archive the source in-phase and out-of-phase images when 2-point Dixon sequences are used. In cases of unexpected or poorly understood findings on water- or fat-only images, radiologists should review all image acquisitions and regard the calculated images as least reliable. In our practice, our MRI protocols readily include either two Dixon T2-weighted sequences or at least one non-Dixon robust fat-suppressed acquisition to help with the interpretation of such cases.

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