Diagn Interv Radiol 2018; 24:175–180

MUSCULOSKELETAL IMAGING

ORIGINAL ARTICLE

FSE T2-weighted two-point Dixon technique for fat suppression in the lumbar spine: comparison with SPAIR technique

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PURPOSE

Fat suppression magnetic resonance imaging (MRI) technique has been used to improve the diagnostic confidence in lumbar spine diseases. We aimed to compare T2-weighted water-fat separation technique (T2 Dixon) with spectral attenuated inversion recovery (SPAIR) image for fat suppression.

METHODS

Lumbar spine MRI examinations were performed in 79 patients by using a 3.0 T machine. We compared T2 Dixon water-only image and SPAIR image for the evaluation of fat suppression quality and lesion conspicuity. For qualitative evaluation, two radiologists scored the images from Dixon and SPAIR for fat suppression uniformity and lesion conspicuity. Quantitative assessment was also performed for 39 lesions in 26 patients who had lesions in their spine bodies. Contrast ratio (CR) and contrast-to-noise ratio (CNR) were calculated by signal intensity measurement of the lesions, adjacent bodies, and background noise. The Wilcoxon's signed-rank test and paired sample t-test were used to assess the statistical significance of qualitative and quantitative data, respectively.

RESULTS

For qualitative assessment, T2 Dixon water-only image showed higher mean scores for fat suppression quality and lesion conspicuity than SPAIR (2.99±0.11 vs. 2.18±0.38 and 2.84±0.37 vs. 2.28±0.51, respectively). For quantitative measurement, the CR and CNR values of the lesions were higher on T2 Dixon than on SPAIR. Both qualitative and quantitative results showed statistically significant differences between T2 Dixon and SPAIR ($P < 0.01$ in all).

CONCLUSION

T2 Dixon sequence was superior to SPAIR for the quality of fat suppression and for the delineation of lumbar spine lesions.

Fast spin-echo (FSE) T2-weighted imaging is currently an essential part of the spine MRI examination because it results in considerably reduced scan time, providing similar contrast properties as conventional spin echo (1–3). However, the train of 180° rephasing pulses in FSE and short T1 relaxation time of fat affect J-coupling modulation, which produces bright signal of the fat on T2-weighted image (4). Increased signal of the fat on T2-weighted image can obscure underlying pathology with elongated T2 signal such as edema, bone marrow infiltration, and metastasis (5). Thus, additional T2-weighted image with fat suppression is necessary to improve visualization of abnormalities in an anatomical region with abundant fat component such as the lumbar spine.

Several fat suppression techniques have been developed and widely used: chemical shift-selective saturation (CHESS), short-tau inversion recovery (STIR) and spectral attenuated inversion recovery (SPAIR) (6–8). The CHESS and STIR have advantages and disadvantages. Although CHESS has advantages of selectivity for fat and high signal-to-noise ratio (SNR), it is vulnerable to magnetic field inhomogeneity. STIR is insensitive to magnetic field inhomogeneity; however, it is not specific for fat. SPAIR is a hybrid technique combining the fat selectivity of CHESS and the inversion radiofrequency pulse of STIR. Thus, it has advantages of high fat selectivity and low vulnerability to the magnetic field inhomogeneity (7, 9).

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Received 9 August 2017; revision requested 19 September 2017; last revision received 15 February 2018; accepted 16 February 2018.

DOI 10.5152/dir.2018.17320

You may cite this article as: Lee S, Choi DS, Shin HS, Baek HJ, Choi HC, Park SE. FSE T2-weighted two-point Dixon technique for fat suppression in the lumbar spine: comparison with SPAIR technique. Diagn Interv Radiol 2018; 24:175–180.

Dixon sequence is known as a class of chemical shift based water-fat separation method. Unlike other fat suppression methods, two-point Dixon technique relies on the phase shifts made by fat–water resonance frequency differences to separate water from fat. By strategically acquiring images at specific echo time (TE) values, two separate images can be acquired in which water and fat signals are located in-phase and out-of-phase, respectively. By addition and subtraction of the two images, Dixon method provides both water-only and fat-only images (5, 7, 10, 11). As FSE T2-weighted two-point Dixon sequence (T2 Dixon) generates both T2 and fat-suppressed T2-weighted images at a single acquisition, it could reduce the total scan time compared with the conventional techniques. If the fat suppression quality of T2 Dixon is superior to that of conventional techniques, T2 Dixon is expected to demonstrate its clinical usefulness as it not only reduces the scan time but also obtains a better quality fat suppression image. There have been several reports comparing T2 Dixon and conventional fat suppression techniques in the evaluation of the lumbar spine (3, 8, 12). However, to our best knowledge, there has been no comparative study of T2 Dixon and SPAIR which are more advanced fat suppression techniques. This study was aimed to compare T2 Dixon with SPAIR image for fat suppression in the lumbar spine.

Methods

Patients

This study was approved by our institutional review board. Informed consent was waived because of the retrospective study design. Between May 2014 and July 2014, 79 consecutive patients (36 male and 43 female patients; mean age, 61.1 years; age range, 18–90 years) underwent lumbar spine MRI examinations, including T2-weighted Dixon and SPAIR sequences. The patients underwent MRI examinations for lower back pain or radiculopathy. We retrospectively evaluated fat suppression uniformity and lesion conspicuity. All 79 patients were included in the evaluation of fat suppression uniformity. Twenty-six patients who had lesions in their spine bodies were included for the evaluation of lesion conspicuity.

Main points

- T2-weighted two-point Dixon (T2 Dixon) sequence generates both T2-weighted and fat-suppressed T2-weighted images in a single acquisition.
- T2 Dixon provided superior fat suppression uniformity and lesion conspicuity compared with SPAIR technique for the evaluation of the lumbar spine.
- T2 Dixon can be a highly efficient and robust technique for the evaluation of the lumbar spine because it provides superior fat suppression quality and lesion conspicuity with reduced total scan time.

MRI protocol

All MRI studies were performed by using a 3 T scanner (Ingenia; Philips Healthcare) with a SENSE (sensitivity encoding) spine coil. Imaging studies included sagittal SPAIR sequence (TR/TE, 2538 ms/70 ms; TI, 110 ms; echo train length, 19; FOV, 280 mm; matrix, 320×218; NEX, 1; acquisition time, 1:33 min; slice thickness/gap, 4 mm/0.4 mm) and T2 Dixon sequence (TR/TE, 2208 ms/10 ms; echo train length, 22; FOV, 283 mm; matrix, 380×262; NEX, 1; acquisition time, 2:20 min; slice thickness/gap, 4 mm/0.4 mm). For the T2 Dixon technique, a modified FSE sequence was used to acquire two images (one in-phase and the other out-of-phase).

Qualitative evaluation

Two independent radiologists performed the qualitative analysis for fat suppression uniformity and lesion conspicuity on T2 Dixon water-only and SPAIR images. One was a neuroradiologist with 20 years of experience and the other was a general radiologist with 3 years of experience. Both radiologists were blinded to the imaging sequences and knowledge of the diagnosis.

A three-scale scoring system (1=poor; 2=fair; 3=good) was used to grade the fat-suppression quality and lesion conspicuity. For fat suppression quality, a score 1 was assigned when it prevented lesion characterization or when it was obviously not homogeneous in a large region of the image. A score 2 was assigned when fat suppression inhomogeneity was present in a small region of the image and when it did not prevent lesion characterization. A score 3 was assigned if homogeneous fat suppression was achieved. For lesion conspicuity, a score 1 was given to images where the contrast between the lesion and the surrounding structures was poor. A score 2 was given to images where the contrast between the lesion and the surrounding structures was moderate, whereas if the lesion was clearly distinguished, score 3 was assigned. In case of discrepancy, two reviewers reached a consensus later.

Wilcoxon's signed-rank test was used to evaluate the score differences between the Dixon and SPAIR. Averages were used to represent the degree of fat suppression or lesion conspicuity. Significance was determined at a *P* value of less than 0.05.

Quantitative evaluation

Region-of-interest (ROI) analysis was performed for T2 Dixon and SPAIR images by a single investigator. The signal intensities (SI; mean value of a ROI) of the lesion (SI_{lesion}), adjacent normal vertebral body (SI_{normal}), and the background noise (SI_{noise}) were measured on a workstation in ROIs with an electronic cursor encompassing a large representative area removed from any source of artifact. The ROIs ranged from 0.21 to 113.9 cm^2. Contrast ratio (CR) and contrast-to-noise ratio (CNR) were calculated as follows:

$$CR = (SI_{lesion} - SI_{normal})/SI_{normal}$$
$$CNR = (SI_{lesion} - SI_{normal})/\text{Standard Deviation}(SI_{noise})$$

The paired sample t-test was used to assess the statistical significance of quantitative data. Significance was assessed at a *P* value of less than 0.05.

Results

Among the 79 patients, 26 patients had 39 body lesions of the lower thoracic or lumbar spines, which were included in the evaluation of lesion conspicuity. Eleven patients had multiple lesions. The lesions included recent fracture (n=19), spondylitis (n=14), metastasis (n=5), and hemangioma (n=1), respectively, which were diagnosed on the basis of their radiologic and clinical findings.

Regarding the fat suppression quality, mean scores were 2.99±0.11 (mean ± standard deviation) and 2.18±0.38 for T2 Dixon and SPAIR, respectively (Table).

For the evaluation of lesion conspicuity, the mean scores showed 2.84±0.37 for T2 Dixon and 2.28±0.51 for SPAIR, respectively (Table). T2 Dixon showed more homogeneous fat-suppression and superior lesion conspicuity when compared with SPAIR (*P* < 0.01 in all).

The quantitative results of lesion-to-normal CR and CNR are summarized in the Table. Both of the CR and CNR values were higher in the T2 Dixon than in the SPAIR im-

Table. Qualitative assessment for fat suppression uniformity and lesion conspicuity and CR and CNR values of the lesions

		T2 Dixon	SPAIR	Z value or 95% CI	*P*
Qualitative assessment of fat suppression uniformity and lesion conspicuity	Fat suppression uniformity (n=79)	2.99±0.11	2.18±0.38	-8.00	<0.01
	Lesion conspicuity (n=39)	2.84±0.37	2.28±0.51	-4.69	<0.01
Quantitative assessment of lesion CR and CNR (n=39)	CR	1.98±0.81	1.58±0.74	(0.23, 0.58)	<0.01
	CNR	80.7±41.9	30.8±15.4	(37.8, 61.9)	<0.01

Data are presented as mean ± standard deviation.
CR, contrast ratio; CNR, contrast-to-noise ratio; SPAIR, spectral attenuated inversion recovery; CI, confidence intervals.

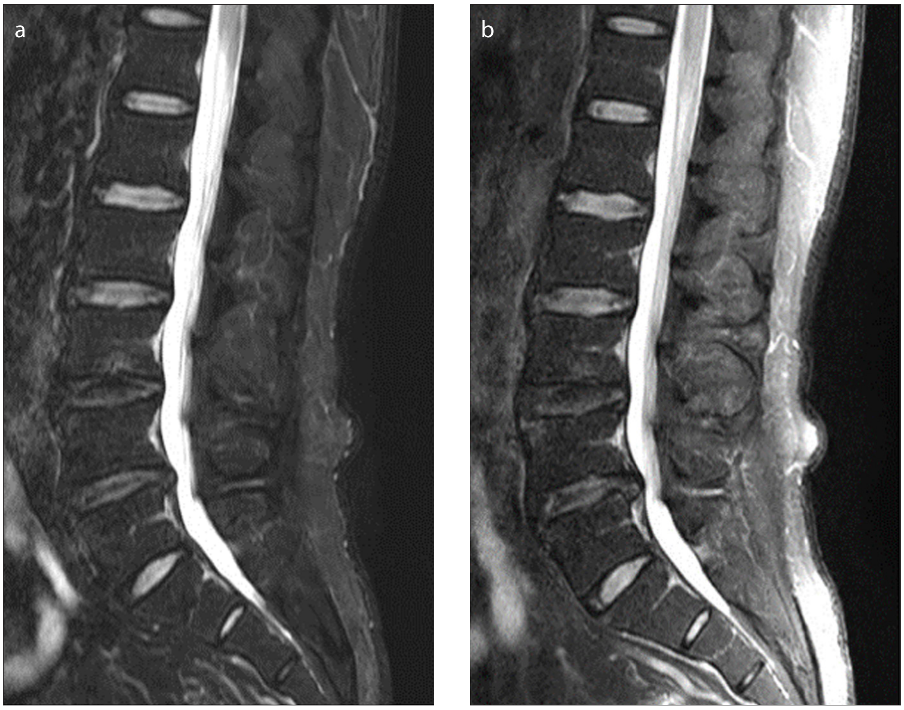

Figure 1. a, b. A 56-year-old male patient. Sagittal T2 Dixon water-only **(a)** and SPAIR images **(b)** show that fat suppression is more homogeneous on T2 Dixon than on SPAIR for both bone marrow and soft tissues.

ages and they were statistically significant ($P < 0.01$ in all).

Discussion

Our study aimed to determine the practical role of Dixon as a fat suppression technique in the lumbar spine compared with SPAIR. In the qualitative evaluation of fat suppression quality and lesion conspicuity, two radiologists reviewed T2 Dixon and SPAIR images side by side and did a subjective comparison. The T2 Dixon images accomplished more uniform fat suppression (Figs. 1, 2) and superior lesion conspicuity than SPAIR (Figs. 3, 4). Previous investigators have insisted that multipoint Dixon techniques show more uniform fat suppression than other conventional techniques (e.g., CHESS, STIR) in the presence of field inhomogeneity (3, 8, 12, 13). SPAIR is relatively insensitive to B1 inhomogeneity compared with CHESS, and it has higher SNR than STIR. In other words, SPAIR is a combination of the advantages of CHESS and STIR. However, the adiabatic pulse of the SPAIR is designed to inverse selective fat signal, and it has been causing prominent drawbacks of B_0 sensitivity, resulting in heterogeneous fat suppression, especially in high susceptibility regions (e.g., geometric anatomic regions, air-tissue interface) and regions far from the isocenter, especially near the edge of the FOV (14). Thus, SPAIR requires a good separation between fat and water signals to provide effective fat suppression. Compared with SPAIR, the Dixon technique has the advantage of fat suppression that is relatively insensitive to B0 heterogeneity. Thus, Dixon can achieve uniform fat suppression and good lesion conspicuity.

Even though Wohlgemuth et al. (15) found that the multipoint Dixon technique shows superior SNR and CNR than STIR, to our knowledge, no prior report has demonstrated a direct comparison of the quantitative parameters between Dixon and SPAIR techniques applied to lumbar spine lesions. As our study showed, T2 Dixon was also superior to SPAIR in quantitative parameters (better CR and CNR, $P < 0.01$ for both). B0 inhomogeneity may hinder enough fat suppression or can make fat-selective radiofrequency pulse fall outside the fat frequency range in SPAIR (7). However, T2 Dixon is based on the phase difference between water and fat spins rather than selective excitation of only fat spins in SPAIR. Successful fat suppression of T2 Dixon preserves water signal of lesion from high signal of fat. This provides high SNR of the lesion and lower SNR of the normal vertebral body. Therefore, lesion conspicuity, CR, and CNR were shown to be improved on T2 Dixon.

A technique that is less sensitive to field inhomogeneity and provides rapid T2 spine imaging with and without fat suppression would be practically desirable. Typically, the longer acquisition time prevented widespread acceptance of multipoint Dixon techniques (12, 16). With significant advances in Dixon technique (e.g., modified Dixon, Philips in our institution), the total acquisition time can be reduced by a third relative to that of previous three-point Dixon acquisitions. With a single acquisition, T2 Dixon provides multiple images including water, fat, in-phase, and out-of-phase images. Therefore, it can replace two separate scans with and without fat saturation (e.g., SPAIR and T2-weighted FSE), which can save on the total scan time. In the present study, two-point Dixon acquisition (2 min 20 s) produced T2-weighted images with and without fat suppression resulting in a 45% reduction in scan time compared with the combined SPAIR (1 min 33 s) and conventional T2 FSE (2 min 42 s) acquisitions which were routine default settings in our institution. The efficiency of the T2 Dixon approach in spine imaging could result in significant time savings (1 min 55 s) if it could replace both T2 and SPAIR acquisitions. In our institution, we now routinely perform T2 Dixon with equivalent resolution and obtain image series with and without fat saturation in less time than the time needed for the traditional STIR or SPAIR sequences.

In addition, Dixon technique showed fewer artifacts than SPAIR in the lumbar region (Figs. 2, 5). Our results are consistent with those of several previous studies (3, 8, 15). Lumbar region has difficulty in successful fat suppression at geometric anatomical features and air-tissue interface, and it is prone to susceptibility artifacts induced by metallic implants. In the present study, six patients had spinal fixation screws. And the degree of susceptibility artifact was less on T2 Dixon than on SPAIR (Fig. 5). Dixon method repeatedly samples the composite signal at different TEs, followed by the complex sum of water and fat signals. Although patient's movement between the different TEs may cause severe artifact (17), relatively less motion occurs in the lumbar region than other body regions, which can minimize motion artifacts. In the present study, motion artifacts occurred in 8 of 79 patients. However, the motion artifact was mild enough so that it did not affect the diagnosis and there was little difference between T2 Dixon and SPAIR. Therefore, T2 Dixon is a more suitable fat suppression technique for the lumbar spine where there is a high susceptibility difference and it is difficult to obtain good field homogeneity.

There are some limitations to our study. First, the number of subjects was relatively small. Further studies with a larger number of patients are necessary to confirm our results. Second, only the lumbar spine was evaluated. Dixon sequence could certainly be useful for the evaluation of other anatomic regions where T2-weighted image with reliable fat suppression is needed.

In conclusion, on the basis of qualitative and quantitative assessments, T2 Dixon sequence was superior to SPAIR for the quality of fat suppression and for the delineation of lumbar spine lesions. T2 Dixon can be a highly efficient and robust technique for the evaluation of the lumbar spine because

Figure 2. a, b. A 77-year-old female patient with multiple metastases from lung cancer. Sagittal T2 Dixon water-only image **(a)** provides uniform fat suppression and shows clear extent of metastases at L3, L5, S1, S2, and S3. SPAIR image **(b)** fails to show the full extent of metastases due to incomplete fat suppression at coccyx region.

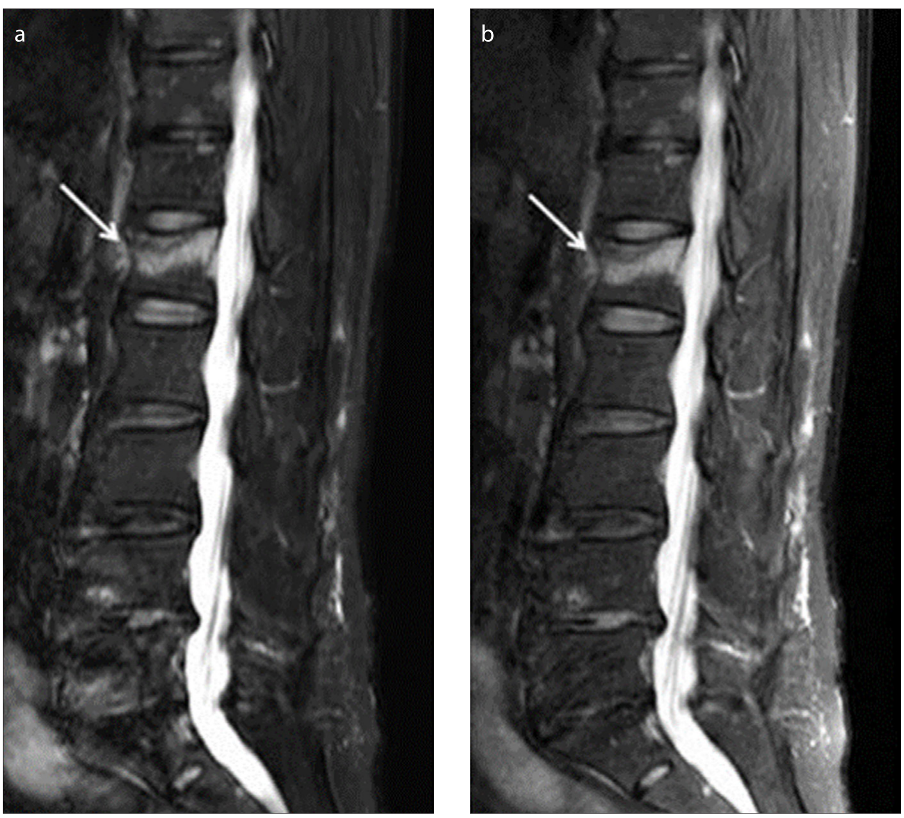

Figure 3. a, b. A 74-year-old female patient with compression fracture at L1 body. Sagittal T2 Dixon water-only image **(a)** shows clear fracture line *(arrow)* and bone marrow edema. SPAIR image **(b)** reveals relatively indistinct fracture line as well as bone marrow edema compared with T2 Dixon image.

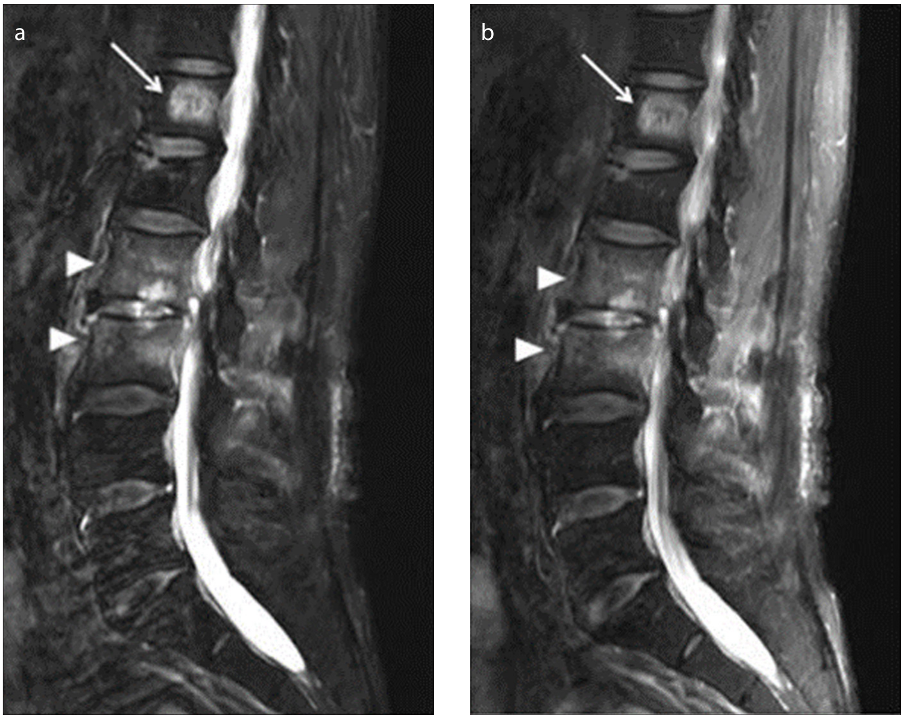

Figure 4. a, b. A 70-year-old male patient with hemangioma of T12 *(arrow)* and pyogenic spondylitis of L2-3 *(arrowheads)*. Sagittal T2 Dixon water-only image **(a)** shows superior contrast, lesion conspicuity, and uniform fat suppression when compared with SPAIR **(b)**.

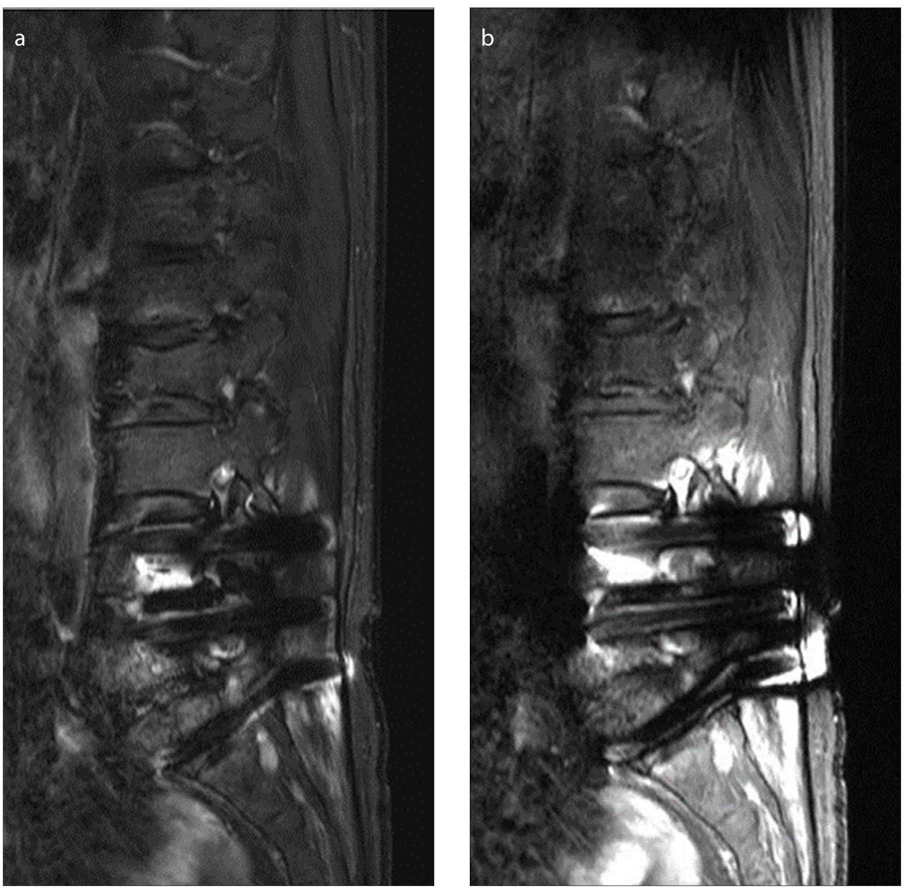

Figure 5. a, b. A 75-year-old female patient with posterior screw fixation state extending from L4 to S1. Sagittal T2 Dixon water-only **(a)** and SPAIR **(b)** images. Geometric distortion and incomplete fat suppression are worse for SPAIR **(b)** when compared with T2 Dixon **(a)**. Less susceptibility artifact is present on the T2 Dixon image.

it provides superior fat suppression quality and lesion conspicuity with reduced total scan time.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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