Original Research

Diffusion-Weighted MRI: A New Tool for the Diagnosis of Fistula in Ano

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Purpose: To retrospectively determine the additional value of diffusion-weighted magnetic resonance imaging (MRI) to T2-weighted imaging in the evaluation of anal fistulae in comparison with gadolinium (Gd)-enhanced imaging.

Materials and Methods: Thirteen patients (mean age, 35.2 years) with 20 anal fistulae were included. The protocol consisted of fat-suppressed T2-weighted fast spin-echo, diffusion-weighted single-shot echo-planar (b factors 0 and 800 s/mm^2), and fat-suppressed Gd-enhanced T1-weighted gradient echo sequences. Two radiologists evaluated images in consensus.

Results: Eighteen (90%) fistulae were detected on T2-weighted images, and 19 (95%) and 19 (95%) were detected on diffusion-weighted and T2-weighted images combined and on Gd-enhanced and T2-weighted images combined, respectively. There was no statistically significant difference in sensitivity of the techniques ($P > 0.5$ for all comparison pairs). Confidence scores with diffusion-weighted and T2-weighted images combined or those with Gd-enhanced and T2-weighted images combined were significantly greater than those with T2-weighted images alone ($P = 0.0047$ and 0.014, respectively).

Conclusion: Diffusion-weighted MRI of anal fistulae is a useful sequence and can be a helpful adjunct to T2-weighted imaging, especially in patients with risk factors for contrast agents.

Key Words: magnetic resonance imaging; diffusion; ano; rectal fistula; Crohn's disease
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ANAL FISTULA is a disorder of the anorectum with a prevalence of ≈1 per 10,000 of population with underlying causes of cryptoglandular infection, Crohn's disease, radiotherapy, or secondary malignancy (1). Although many anal fistulae are easy to treat surgically, some have a tendency to recur despite seemingly adequate surgery. Recurrence is most often due to infection that has escaped surgical detection and gone untreated. Therefore, the importance of preoperative imaging to evaluate the disease extent is now well recognized. Magnetic resonance imaging (MRI) is accepted as an accurate preoperative technique for the detection of fistulae and associated secondary tracts and abscesses. Preoperative MRI can impact surgical planning, diminish the chance of recurrence, and alter surgical outcome of fistulae (2–7). While noncontrast MR techniques such as T2-weighted or short tau inversion recovery (STIR) sequences can demonstrate many fistulae, it has been documented that gadolinium (Gd)-enhanced imaging sometimes performs better than noncontrast images in the anatomic depiction of fistulae and has become part of MR fistula protocols in some institutions (8). However, the use of contrast material leads to increased cost and its use may be contraindicated in a subset of patients with impaired renal function due to concerns about development of nephrogenic systemic fibrosis (NSF) (9,10). Especially after recognition of associated NSF risk, there is less willingness for using intravenous MR contrast agents, and it is desirable to develop alternative MRI methods that will provide the information previously obtained by the use of extracellular contrast material.

Diffusion-weighted MRI reflects the changes in the water mobility caused by interactions with cell membranes, macromolecules, and alterations of the tissue environment (11). Clinical application of the technique has expanded in the last decade. It has been applied recently to body imaging, mostly for detecting and characterizing tumors (12). Because inflammatory tissues can usually be seen as high signal areas on diffusion-weighted images (13), it may be a promising sequence for the diagnosis of anal fistulae. In addition, the technique does not require additional cost or pose increased risk for patients. To the best of our knowledge, no previous reports have shown the value of diffusion-weighted MRI in the diagnosis of anal fistula. The purpose of this study was to determine the incremental value of diffusion-weighted MRI to T2-weighted imaging in the diagnosis of anal fistulae

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and to compare it with the additional value of Gd-enhanced MRI.

MATERIALS AND METHODS

Institutional Review Board approval for reviewing medical records and images related to this retrospective study was obtained. Informed consent was not waived. A search in the Radiology database identified 17 patients who underwent MRI for the diagnosis of anal fistulae between November 2007 and October 2008. Two of these patients did not agree to be included in the study, and another two, who did not undergo Gd-enhanced MRI, were excluded from the study. The other 13 patients (mean age of 35.2 years; range, 19–61 years; seven men, six women) underwent MRI including T2-weighted, diffusion-weighted, and Gd-enhanced T1-weighted imaging, and constituted our study group. Informed oral consent was obtained from each patient. Concomitant diseases in the study group included Crohn's disease (10), diabetes (1), Hermansky–Pudlak syndrome (1), and no known underlying cause or associated diseases in one.

MRI was performed using a 1.5T superconducting system (Signa HDx 1.5T, GE Healthcare, Milwaukee, WI) and an 8-channel phased-array body multicoil. No bowel preparation or catheterization of anal canal or fistula was performed. The MRI protocol consisted of T2-weighted fast spin-echo (FSE) with fat suppression sequence (repetition time [effective TR] msec/echo time [effective TE] msec; 3000–5000/70–90, echo train length of 16–23, 224–256 × 220–276 matrix, field of view of 24–38 cm, received bandwidth of 64 kHz, 4 signals acquired, section thickness 5 mm, and section interval 5 mm); diffusion-weighted single-shot echo-planar sequence (TR/TE; 3000–10,000/70–80, b factors 0 and 800 s/mm^2, 128 × 128 matrix, field of view of 32–50 cm, received bandwidth of 64 kHz, 4 signals acquired, section thickness 5 mm, section interval 7 mm, and acquisition time of 2–4 minutes); and T1-weighted 3D gradient echo with fat suppression sequence (TR/TE; 4.2–4.6/2.0–2.3, 12–20° flip angle, 320 × 192 matrix, field of view of 30–38 cm, receiver bandwidth of 64 kHz, a parallel imaging reduction factor of 2, one signal acquired, section thickness 5 mm, section interval 2.5 mm) before and 70 seconds after intravenous gadolinium administration (gadodiamide, 0.1 mmol/kg of body weight: Omniscan, GE Healthcare). All images were obtained in axial plane. For T2-weighted imaging with fat suppression, coronal and sagittal images were also obtained.

Two experienced radiologists (each with over 10 years' experience in abdominal MRI) reviewed MR images in consensus. They have interpreted MR images of the anal fistula as part of their daily clinical practice, and have prior experience with abdominal diffusion-weighted MRI of more than 2 years. One of the radiologists was involved in the clinical care of some of these patients. The other radiologist was from another hospital and was not involved in the prospective clinical care of any of these patients. They knew that each patient had anal fistulae, but were blinded to more detailed clinical history including the findings of digital rectal examination. The review was conducted at two separate sessions at 2-week intervals. We did not have a training session before the two reviewing sessions. The patients were randomly divided into two groups to avoid order bias favoring either diffusion-weighted or Gd-enhanced imaging. The radiologists initially evaluated only fat-suppressed T2-weighted images (axial, coronal, and sagittal planes). This was followed by an evaluation of the T2-weighted images combined with either diffusion-weighted (group 1, seven patients) or Gd-enhanced images (group 2, six patients). Two weeks later, radiologists reviewed T2-weighted and Gd-enhanced images of patients in group 1 and T2-weighted and diffusion-weighted images of patients in group 2. In each evaluation the radiologists recorded the location of possible fistulae by consensus on an evaluation sheet on which cross-sectional drawings of the pelvis in seven locations were printed. Each possible fistula was scored by consensus in terms of the presence of fistulae using a four-point scale: 1, probably not a fistula; 2, uncertain; 3, possible fistula; and 4, definite fistula. Three evaluation sheets were used for each patient to record the findings of 1) T2-weighted images; 2) diffusion-weighted images and T2-weighted image combined; and 3) Gd-enhanced images and T2-weighted images combined.

Clinical and surgical records were collected by a third radiologist separate from the reviewing radiologists. The third radiologist initially did not have much experience in evaluating MR images of anal fistulae, but underwent a training session before the study. After the two reviewing sessions, the three radiologists reviewed all the images together with the clinical records of each patient. Two of the 13 patients underwent surgery, and surgical records were also reviewed for these patients. Locations of anal fistulae determined by consensus among the three radiologists based on MR images, clinical records, and surgical records were used as the reference standard in this study. Twenty anal fistulae were identified in the 13 patients. Fistulae were classified as intersphincteric (n = 10), transsphincteric (n = 6), suprasphincteric (n = 1), and extrasphincteric (n = 3) based on the Parks' classification (6,14). Seven patients also had perianal/rectal abscesses.

The three radiologists also subjectively evaluated in consensus if there were additional values of diffusion-weighted imaging or Gd-enhanced imaging to T2-weighted imaging for each case, in terms of visualization of fistula extension or of communication to external or internal opening.

The sensitivity in detecting fistulae was calculated by the confidence scores of fistulae using the above reference standard, and considering the confidence rating of 3 or 4 as positive diagnosis. Those values were compared between T2-weighted images alone, diffusion-weighted images and T2-weighted image combined, and Gd-enhanced images and T2-weighted images combined. McNemar's test with Bonferroni

Table 1
Results of Confidence Scores for 20 Fistulae in 13 Patients

Score	T2w	DW+T2w[a]	CE+T2w[b]
4	8 (40.0)	15 (75.0)	13 (65.0)
3	10 (50.0)	4 (20.0)	6 (30.0)
2	2 (10.0)	1 (5.0)	1 (5.0)
1	0 (0.0)	0 (0.0)	0 (0.0)

Data in parentheses are percentages.
T2w: T2-weighted images, DW+T2w: diffusion-weighted images and T2-weighted images combined, CE+T2w: Gd-enhanced T1-weighted images and T2-weighted images combined.
Confidence was graded in terms of presence of fistulae using a 4-point scale: 1) probably not a fistula; 2) a possible fistula; 3) a probable fistula; and 4) a definite fistula.
Sensitivity calculation was performed considering the confidence rating of 3 or 4 as positive diagnosis.
[a]Score was significantly greater than that with T2-weighted images ($P = 0.0047$).
[b]Score was significantly greater than that with T2-weighted images ($P = 0.014$).There was no significant difference in confidence scores between DW+T2w and CE+T2w ($P = 0.41$).

correction ($n = 3$) was used for multiple comparisons of sensitivities. The Wilcoxon signed-rank test with a Bonferroni correction ($n = 3$) was used for multiple comparisons of confidence scores. For all statistical analyses, a software package (SPSS 11.0 for Windows, Chicago, IL) was used. A two-tailed P-value of less than 0.017 (0.05/3) was considered to indicate a statistically significant difference.

RESULTS

Of the 20 fistulae, 18 (90%) were detected on T2-weighted images alone, and 19 (95%) and 19 (95%) were detected on diffusion-weighted images and T2-weighted images combined and on Gd-enhanced images and T2-weighted images combined, respectively. There were no false positives. One fistula, which was not detected on diffusion-weighted images and T2-weighted images combined, was detected on Gd-enhanced images and T2-weighted images combined. Another fistula, which was not detected on Gd-enhanced images and T2-weighted images combined, was detected on diffusion-weighted images and T2-weighted images combined. There was no statistically significant difference in sensitivity of the techniques ($P > 0.5$ for all comparison pairs). The results of the confidence scores in terms of the presence of anal fistulae using a four-point scale are given in Table 1. Confidence scores with diffusion-weighted images and T2-weighted images combined or those with Gd-enhanced images and T2-weighted images combined were significantly greater than those with T2-weighted images alone ($P = 0.0047$ and 0.014, respectively) (Figs. 1–3). There was no significant difference in confidence scores between diffusion-weighted images and T2-weighted images combined and Gd-enhanced images and T2-weighted images combined ($P = 0.41$).

Subjective evaluation by radiologists revealed that diffusion-weighted imaging improved the visualization

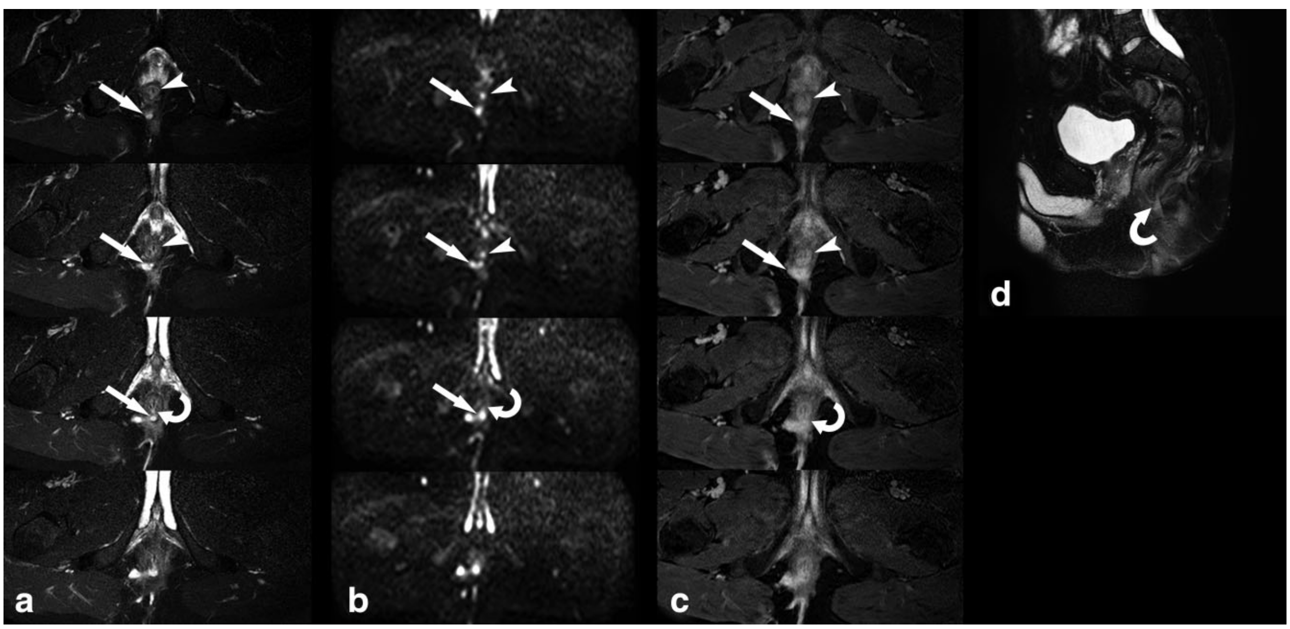

Figure 1. A 35-year-old man with Crohn's disease and suprasphincteric anal fistula. **a:** Fat-suppressed T2-weighted axial images show fistulous tract (arrows) and anal canal (arrowheads). Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is demonstrated as high-intensity area (curved arrow), but conspicuity is worse compared to diffusion-weighted images. **b:** Diffusion-weighted axial images also show fistulous tract (arrows) and anal canal (arrowheads). Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is demonstrated (curved arrow). Conspicuity is better compared to T2-weighted axial images. **c:** Gd-enhanced T1-weighted axial images also show fistulous tract (arrows) and anal canal (arrowheads). Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is demonstrated as enhanced area (curved arrow), but conspicuity is worse compared to diffusion-weighted images. **d:** Fat-suppressed T2-weighted sagittal image shows the communication between fistulous tract and anal canal (curved arrow). Careful reading is needed to identify the fistula on this image.

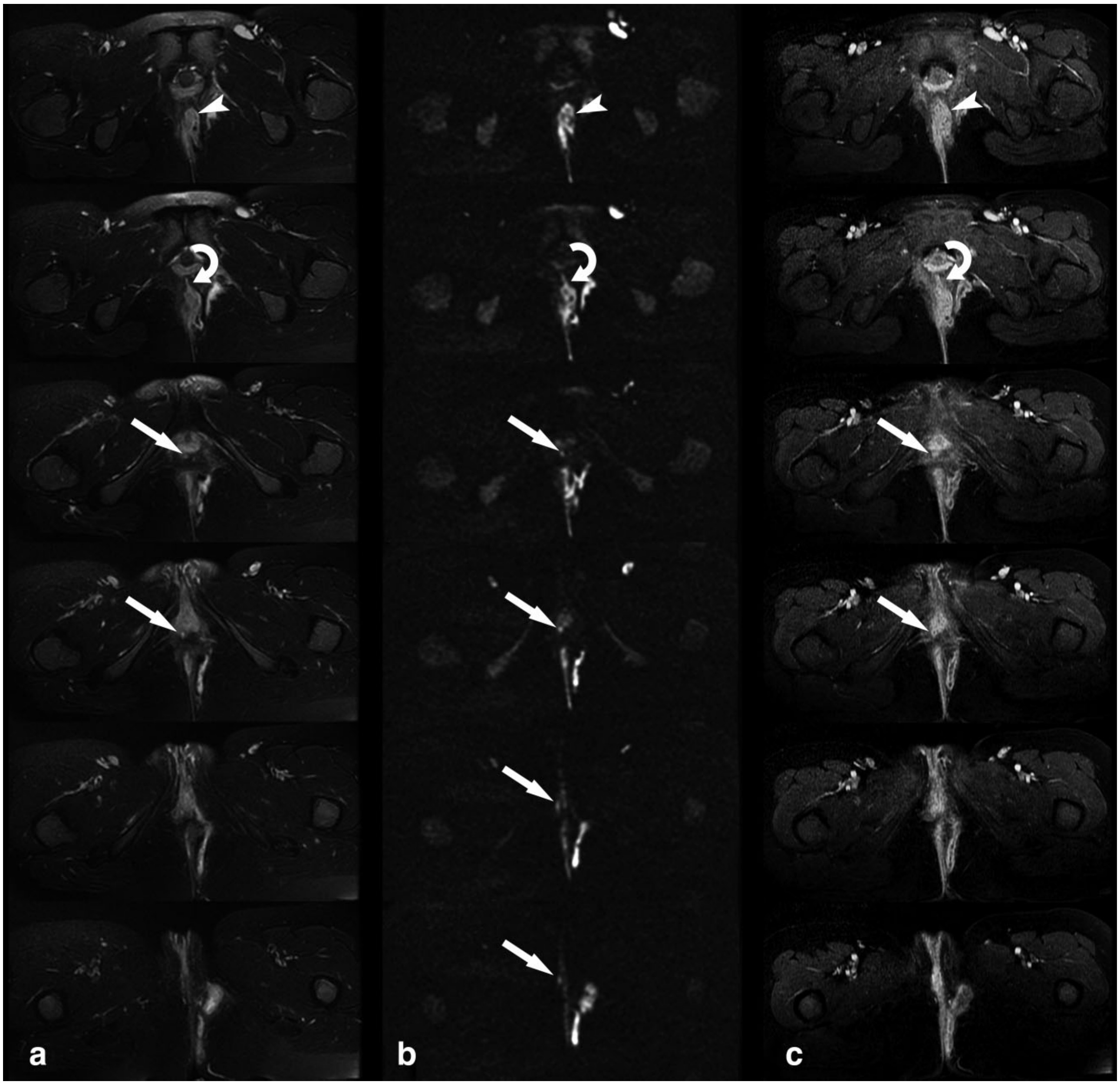

Figure 2. A 29-year-old woman with Crohn's disease and transsphincteric anal fistula. **a:** Fat-suppressed T2-weighted axial images show fistulous tract (arrows) and anal canal (arrowhead). Six slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is clearly demonstrated as high-intensity area (curved arrow). **b:** Diffusion-weighted axial images also show fistulous tract (arrows) and anal canal (arrowhead). Six slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is clearly demonstrated (curved arrow). Conspicuity of the communication is almost the same compared to T2-weighted axial images, but the course of the fistula in the periphery is more clearly observed on diffusion-weighted images (arrows) compared to T2-weighted or Gd-enhanced images. **c:** Gd-enhanced T1-weighted axial images also show fistulous tract (arrows) and anal canal (arrowhead). Six slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is demonstrated as enhanced area (curved arrow). Another large track is seen at the left.

of the extent of four fistulae (20%) in two patients (15%) and improved the visualization of the external or internal opening of five fistulae (25%) in four patients (31%) compared to T2-weighted images (Fig. 2). On the other hand, Gd-enhanced images improved the visualization of the external or internal opening of five fistulae (25%) in four patients (31%) compared to T2-weighted images (Fig. 3). Diffusion-weighted imaging showed better visualization of the external or internal opening of two fistulae in two patients in which Gd-enhanced images did not show better visualization compared to T2-weighted images, and Gd-enhanced images showed better visualization of the external or internal opening of another two fistulae in two patients in which diffusion-weighted images did not show better visualization.

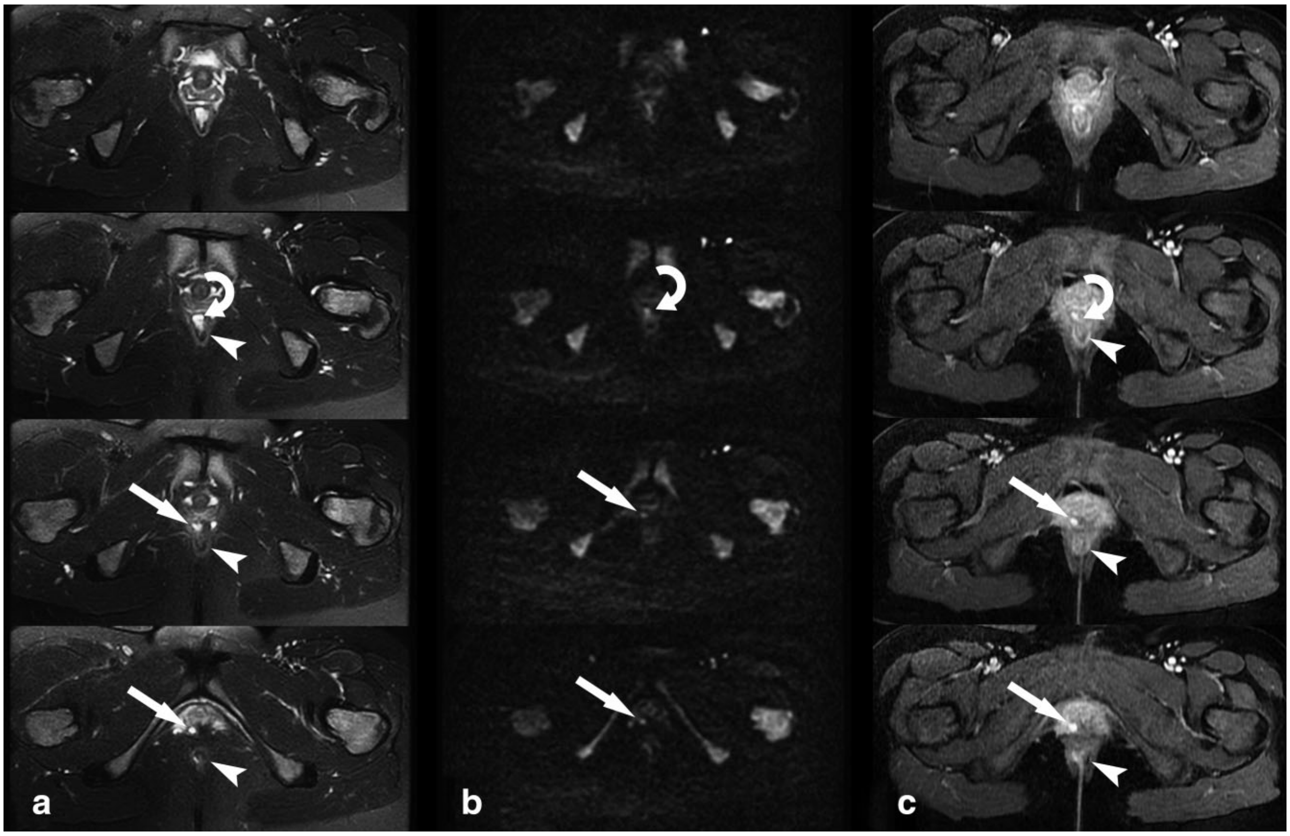

Figure 3. A 26-year-old woman with Crohn's disease and intersphincteric anal fistula. **a:** Fat-suppressed T2-weighted axial images show fistulous tract (arrows) and anal canal (arrowheads). Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is clearly demonstrated (curved arrow). **b:** Diffusion-weighted axial images also show fistulous tract (arrows) and anal canal. Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is demonstrated as high-intensity area (curved arrow). Conspicuity of the communication is worse compared to T2-weighted or Gd-enhanced images. **c:** Gd-enhanced T1-weighted axial images also show fistulous tract (arrows) and anal canal (arrowheads). Four slices are presented from cranial (upper) to caudal (lower) position. Communication between fistulous tract and anal canal is clearly demonstrated as marked enhanced area (curved arrow). Conspicuity is better compared to T2-weighted axial images.

DISCUSSION

Gd-enhanced imaging is sometimes employed for the evaluation of anal fistulae. The advantage of the technique over noncontrast imaging is that of increased conspicuity of the fistulous tract with vivid enhancement (8). However, utilizing Gd increases costs and has associated risks. Since we speculated that diffusion-weighted imaging could also be useful in increasing conspicuity of anal fistulae as Gd-enhanced imaging is, we conducted this study. Our results showed that the fistulous tract appears hyperintense, whereas the background signal is significantly suppressed on diffusion-weighted images. Some fistulae could be diagnosed with improved confidence by adding diffusion-weighted imaging to T2-weighted imaging. In addition, the extent of the fistula could be more clearly visualized on diffusion-weighted images in some cases. These improvements are probably due to the higher fistula/background contrast that was helpful to detect fistulae and follow their tracts on diffusion-weighted images. However, for preoperative planning it is also crucial to evaluate the course of the fistula with respect to adjacent structures. Therefore, high spatial resolution imaging would be required for anatomic orientation. In this regard, diffusion-weighted imaging has a disadvantage, because the technique has inherent poor spatial resolution compared to spin-echo or gradient-echo sequences. Therefore, we did not evaluate the role of diffusion-weighted imaging separately. Instead, we evaluated the additional value of the technique to fat-suppressed T2-weighted imaging.

Rapidly acquired, fat-suppressed Gd-enhanced images increase the conspicuity of the fistulous track with vivid enhancement, leading to better anatomic depiction of fistulae. Moreover, some researchers demonstrated that high-resolution subtraction MR-fistulography, which was composed of Gd-enhanced high-resolution 3D gradient-echo sequence and image subtraction technique, was useful for the diagnosis of anal fistula (15). In our study, some anal fistulae were also more clearly demonstrated on Gd-enhanced images than on fat-suppressed T2-weighted images, and were diagnosed with higher confidence after additional review of Gd-enhanced images. These findings show the efficacy of Gd enhancement. However, the incremental value of diffusion-weighted imaging in terms of improvement in the sensitivity, diagnostic confidence, and depiction of the fistula extent was similar to contrast-enhanced imaging. Diffusion-weighted imaging provides this additional value without a need for injection of contrast material, and it only requires an additional 2–4 minutes to total examination time. Diffusion-weighted sequences have already been added to the routine body MR protocols in many institutions, and as they have been used in neuroradiology applications for a long time, the technologists are familiar with the technique. Therefore, logistically they are not difficult to implement and we recommend routine use of diffusion-weighted imaging in the diagnosis of anal fistula, especially for patients who have risk factors for injection of Gd-based contrast agents.

Our study has several limitations. First, we made the reference standard by radiologists' consensus based on MR images, clinical records, and surgical records. Many of our patients did not undergo surgery. Some studies on imaging techniques for the diagnosis of anal fistula used surgical exploration as the reference standard (3). Therefore, this could be a major limitation in our study. However, it sometimes occurs that surgery misses some fistulae, and many investigators think that surgery is not regarded as a gold standard, but a competing procedure in detecting anal fistulae against imaging techniques (4,5,15). Second, this was a retrospective study with a relatively small size of 13 patients. Using a consensus reading of radiologists must also be noted as a study limitation. Prospective study using independent reading with a larger number of patients will obviously be needed to clarify the efficacy of diffusion-weighted imaging in diagnosing anal fistulae. Third, a slice thickness of 5 mm used for imaging was somewhat thick for detecting subtle findings. However, we think that our study protocol did not significantly differ from the current standard of MRI.

In conclusion, diffusion-weighted imaging showed additional value to fat-suppressed T2-weighted imaging in the diagnosis of anal fistulae as well as Gd-enhanced imaging by increasing the confidence level of radiologists. It is a good adjunct to T2-weighted imaging, especially for patients who have risk factors for intravenous contrast agents. Based on the results of our study, we are routinely using diffusion-weighted imaging in our anal fistula imaging protocol.

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