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GASTROINTESTINAL

Diffusion-weighted MR imaging for the diagnosis of abscess complicating fistula-in-ano: preliminary experience

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Abstract
Objective To investigate the role of diffusion-weighted magnetic resonance imaging (DWMRI) in the diagnosis of abscess-complicating fistula-in-ano.
Methods This retrospective study was approved by our Institutional Review Board and informed consent was waived. MRI examinations, including fat-suppressed T2-weighted turbo spin-echo (T2-TSE) MRI and DWMRI, of 24 patients with a fistula-in-ano, were reviewed by two independent readers for the presence and number of visible fistulas, conspicuity and apparent diffusion coefficient (ADC) measurement of suspected fistula tracks and pelvic collections. The reference standard was surgical with follow-up findings.
Results Sensitivity was 91.2 % [95 % CI: 76 %-98 %] for T2-weighted TSE MRI and 100 % [95 % CI: 90 %-100 %] for DWMRI detecting fistulas. ADC values were lower in abscesses than in inflammatory masses (P=0.714.10^{-6}). The area under the ROC curve was 0.971 and the optimal cut-off ADC value was 1.186×10^{-3} mm^2/s, yielding a sensitivity of 100 % [95 % CI: 77 %-100 %], a specificity of 90 % [95 % CI: 66 %-100 %], a positive predictive value of 93 % [95 % CI: 82.8 %-100 %] and a negative predictive value of 90 % [95 % CI: 78 %-100 %] for an abscess diagnosis. Fistula conspicuity was greater with DWMRI than with T2-TSE MRI for the two observers (P=0.0034 and P=0.0007).
Conclusion DWMRI shows high sensitivity and specificity for the diagnosis of perianal abscesses and helps discriminate between an abscess and inflammatory mass. Conspicuity of fistulas-in-ano is greater with DWMRI than with T2-weighted TSE MRI.
Key Points
- *DWMRI can differentiate between pelvic abscess and inflammatory mass.*
- *DWMRI helps avoid gadolinium-chelate administration in patients with a suspected fistula-in-ano.*
- *DWMRI provides high degrees of conspicuity for fistula-in-ano.*

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• *Conspicuity of fistulas is better with DWMRI imaging than with T2-TSE-weighted MRI.*

Keywords Diffusion-weighted MR imaging · Crohn's disease · Perianal fistula · Fistula-in-ano · Anopelvic fistula

Introduction

Magnetic resonance imaging (MRI) has an undisputed role in the evaluation of fistula-in-ano owing to a sensitivity of up to 100 % and a specificity of 86 % for the depiction of a fistula track [1, 2]. In addition, MRI has a sensitivity of 96 % and a specificity of 97 % in the diagnosis of abscesses [1, 2]. The association of MRI with examination under anaesthesia (EUA) has been shown to have an accuracy of 100 % (95 % IC: 88 %-100 %) for the diagnosis of perianal complications in patients with Crohn's disease [3, 4]. Moreover, preoperative MRI helps decrease the recurrence rate of anal fistula by 75 % and its use correlates with a better outcome [5].

Perianal fistula and abscess are common complications of Crohn's disease and occur in 30 to 50 % of Crohn's disease patients during their lifetime [6]. Crohn's disease patients have repeated MRI examinations for the evaluation of the perineum and anal canal and many studies have suggested that MRI can be used for the assessment of disease activity and follow-up after treatment [7–9].

Current MRI protocols commonly used to investigate perianal fistulas uniformly include fat-suppressed T2-weighted turbo spin-echo (TSE) and, at a lesser degree, gadolinium chelate-enhanced T1-weighted MR sequences [10, 11]. Fat suppressed T2-weighted TSE MRI is very accurate at depicting a fistula track but some reports have emphasized the difficulty in distinguishing between actual abscesses that require surgical drainage and inflammatory masses that are not drainable and require adequate medical anti-inflammatory treatment. The adjunct of gadolinium chelate-enhanced T1-weighted MR images is often needed as a problem solving tool [1, 5, 12–14]. DWMRI has recently been used successfully in the field of rectal and perirectal inflammation as well as in that of Crohn's disease [12, 13, 15]. Surprisingly, only two studies have evaluated the potential role of DWMRI in the evaluation of patients with perirectal inflammation [9, 15]. However, the main limitation of these two studies is the lack of surgical correlation.

The goal of our study was to retrospectively evaluate the capabilities of DWMRI in detecting fistula-in-ano, assessing fistula activity and in distinguishing between an abscess and an uncomplicated inflammatory mass, using fat-suppressed T2-weighted MR imaging, clinical examination, surgery and follow-up as reference.

Material and methods

Patients

This study included MRI examinations of 24 patients who were referred to our department from April 2012 to August 2013 for a preoperative MRI examination before surgical management of a fistula-in-ano with a suspected coexisting pelvic abscess. There were 18 men and 6 women with a median age of 35 years (Q_1=26.8; Q_3=42.5) [range: 20 - 73 years]. Seventeen patients had Crohn's disease; of which 12 were under immunosuppressive therapy when MRI was performed. Two patients had ulcerative colitis, one patient had colorectal anastomosis after colorectal cancer resection, one had type II diabetes and three had no underlying disease. This study was approved by our Institutional Review Board and informed consent was waived.

MRI acquisition

All MRI examinations were performed with the same protocol, using a 1.5-T clinical MR unit (Magnetom Avanto, VB15 software version, Siemens Healthcare, Erlangen, Germany) with 9 receiver channels, using one anterior torso phased-array coil with six channels and a posterior spine cluster with three channels; the patient was in supine position. Gradient strength of the magnet was 45-mT/m with a maximal gradient slope of 200-mT/m/s using super quantum gradients. No specific bowel preparation was used before MRI examination and no antispasmodic agents were administrated to the patients. For all patients, the MRI protocol included frequency-selective fat-suppressed T2-weighted TSE MRI in the axial, coronal and sagittal planes and DWMRI in the axial plane. The MRI protocol is detailed in Table 1. Axial ADC maps were created using three *b*-values (0, 600 and 1000 s/mm^2) with a mono-exponential algorithm.

MRI analysis

All MRI examinations were evaluated retrospectively by two independent, board-certified abdominal radiologists with 5- and 20-years of experience in reading abdomen and pelvis MRI examinations. They were blind to clinical history and to the results of surgery, blood tests, endoscopic examinations and follow-up MRI examinations. MRI examinations where evaluated on a picture archiving and communication system (PACS) viewing station (Directview®, 11.3 sp1 version, Carestream Health Inc., Rochester, NY, USA) using a standardized form created for the study including all the information further described hereafter.

Qualitative analysis Three different reading sessions were performed with sessions being separated by two week

Table 1 MR Imaging parameters

	T2-TSE	T2-TSE	T2-TSE	DW-MRI
Plane	Axial	Coronal	Sagittal	Axial
TR/TE (ms/ms)	6180/112	4310/112	2350/109	5300/91
Field of View	180 mm	180 mm	240 mm	380 mm
Reconstruction matrix size	192×172	256×230	320×288	192×182
Voxel size (mm^3)	1.0×0.9×4.0	0.8×0.7×4	1.0×0.9×4	1.1×2.0×5
Intersection gap	20 %	20 %	20 %	10 %
Number of signal averages	4	3	3	4
Echo train length	4	16	17	NA
Echo spacing (ms)	8.02	8.02	10.9	0.83
Receiver bandwidth (Hz/pixel)	190	195	130	1302
Number of slices	28	20	20	35
Slices thickness (mm)	4	4	4	5
Turbo factor	23	23	17	N.A.
Grappa	2	N.A.	N.A.	2
Acquisition time (s)	211	166	105	166
EPI factor	N.A.	N.A.	N.A.	182
Diffusions directions	N.A.	N.A.	N.A.	3
b-values (s/mm^2)	N.A.	N.A.	N.A.	0, 600, 1000

Note: N.A. indicates not applicable

intervals in order to avoid recall bias. Each reading session was performed blind to the results of the others. During the first reading session the radiologists analyzed a set that consisted of the DWMRI sequence alone (“Set 1”). During the second reading session the radiologists analyzed the T2-weighted TSE MR images alone (“Set 2”). During the third reading session the radiologists analyzed the two previous sets together (“Set 1” and “Set 2,” hereafter referred to as “Set 3”).

For each MR imaging set the two radiologists recorded the number of visible fistulas-in-ano and graded their conspicuity semi-quantitatively according to a subjective 3-point scale, from 0 to 2; if there were primary and/or secondary fistula their location and topography was recorded according to the anal clock. Conspicuity was defined as the ease by which the radiologist could clearly distinguish the fistula tract along its entire length (0 = not visible, 1 = difficult to depict and 2 = easily depicted). Internal and external openings were not recorded. The presence of an abscess was suspected when there was a loculated pelvic collection or a pooling of fluid with high signal intensity on T2-weighted TSE MR images or on DWMR images obtained at b=0.

Quantitative analysis After qualitative analysis “Set 3” was reviewed by the two radiologists working in consensus. Any loculated collection (i. e., area with non-parallel borders) with a high signal intensity and larger than 20 mm^2 was measured for each patient at the slice level where the largest dimensions were found (Fig. 1). The corresponding surface and signal intensity on the fat-suppressed T2-weighted TSE MR images were tabulated. This value was normalized using the signal of the quadriceps muscle as a reference organ. Then a region of interest (ROI) was placed on the diffusion MR images (b=0) to cover the largest area of the suspected region and copied to the ADC map corresponding to this area and the lowest value of ADC was recorded (Fig. 1). The smallest ROI was 20 mm^2; ROI sizes are reported in Table 2.

Then one of the readers manually placed ellipsoidal ROIs on the fistula tracks using the DWMR image obtained at b=0 and the ROI was copied on the ADC map (Fig. 2). An ADC value and ROI surface were then tabulated.

Finally the two radiologists quantified pelvic inflammation according to the MRI classification as described by Van Assche et al. [16].

Standard of reference

Surgery was performed under general anaesthesia in all patients and included visual inspection, manual exploration and a methylene blue test after catheterization of the primary orifice and drainage of pelvic abscess. Extrasphincteric fistulas were sectioned whereas transsphincteric and intersphincteric fistulas were treated using a draining seton. Bacteriological examination was performed in 17 patients because of the presence of pus in the fistula and an histopathological examination was performed in 4 patients. All MR images and reports were available to the surgeon in the

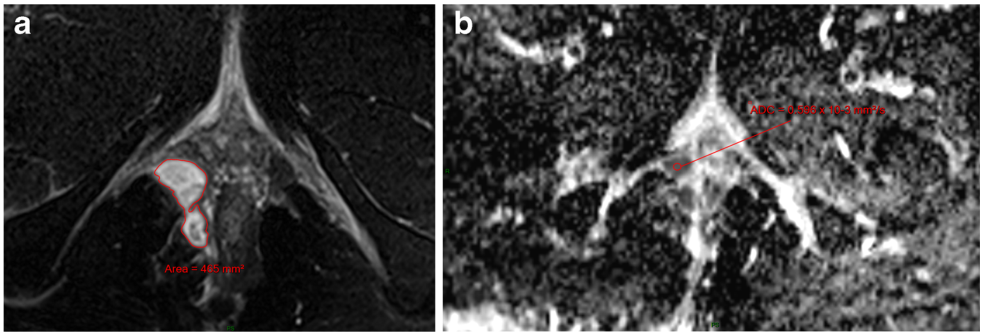

Fig. 1 32-year-old woman with diabetes presenting with transsphincteric fistula and large perianal abscess. **a**. T2-weighted TSE MR image (TR/TE=6180/112) in the axial plane shows an area of high signal intensity (arrow). **b**. ADC map in the axial plane. The ADC value of the pelvic perianal collection is: 0.586×10^{-3} mm^2/s, corresponding to an actual perianal abscess

operating room. Diagnosis of an abscess was made when a purulent mass was found in the corresponding suspected area during MRI.

For all patients fistulas were classified by the two radiologists and the surgeon in consensus using the classification of Parks et al. [17].

All patients had blood tests including a blood count and a C-reactive protein count. All patient (n=19) with inflammatory bowel disease were examined by a gastroenterologist specialized in inflammatory bowel diseases who evaluated disease activity and introduced an immunosuppressive therapy or increased the dose of immunosuppressive treatment already given in cases of suspected active disease.

All patients had a clinical follow-up of at least 6 months and 18 had a new MRI examination within 6 months after surgery. If MRI showed an extension that was not found at the time of surgery a second intervention was performed and if the extension remained unfound it was considered a false positive for MRI. In cases of unfound collection the radiologist performed an ultrasound examination during intervention for guiding the surgeon. When a fistula was external and considered to be inaccessible to surgical examination the fistula was considered a false-positive finding of the MRI if it was not found during the follow-up MRI.

Statistical analysis

Statistical analysis was performed using the following software: SAS, version 9.2, SAS Institute, Cary, NC; R, version 2.8; GraphPad Prism, version 5.03, GraphPad softwares, Inc, R Foundation, http://www.r-project.org/ Descriptive statistics were calculated for all variables obtained with the two sequences and reported as medians, first quartiles (Q_1), third quartiles (Q_3) and ranges.

The Mann-Whitney U test was used to compare the ADC values, the signal intensities and the surfaces areas of high signal intensity on T2-weighted TSE MR images between patients with abscesses and those with inflammatory mass. The Wilcoxon-signed rank test was used to compare the conspicuity of the fistula between T2-weighted TSE MRI and DWMRI. A logarithmic fitting method was used to calculate the correlation coefficient (R^2) between ADC values in the main fistula track and the MRI activity score. Linear regression analysis was used to calculate the correlation

Table 2 Quantitative MR imaging findings in 14 patients with abscess and 10 patients with inflammatory mass

		Abscess (n=14)	Inflammatory mass (n=10)	*P* value*
ADC value of the collection (x10^{-3} mm^2/s)	Median	0.976	1.412	*P*<0.0001
	Q_1; Q_3	0.937; 1.021	1.366; 1.534	
	Range	[0.587 – 1.371]	[1.286 – 1.603]	
Size of ROIs (mm^2)	Median	49.7	71.3	
	Q_1; Q_3	36.3; 64.1	43.8 ; 92.0	
	Range	[27.6 – 93.3]	[20 – 143.9]	
Area of high signal intensity on fat-suppressed T2-TSE (mm^2)	Median	202	146.5	*P*=0.285
	Q_1; Q_3	137.5; 551.5	67.5; 404.75	
	Range	[72 - 1064]	[26 - 903]	
Normalized signal intensity in the area of high signal intensity on fat-suppressed T2-TSE	Median	11.035	13.46	*P*=0.235
	Q_1; Q_3	8.25; 13.60	10.52; 15.65	
	Range	[2.25 – 15.61]	[6.38 – 17.44]	

Note. * indicates Mann-Whitney U test

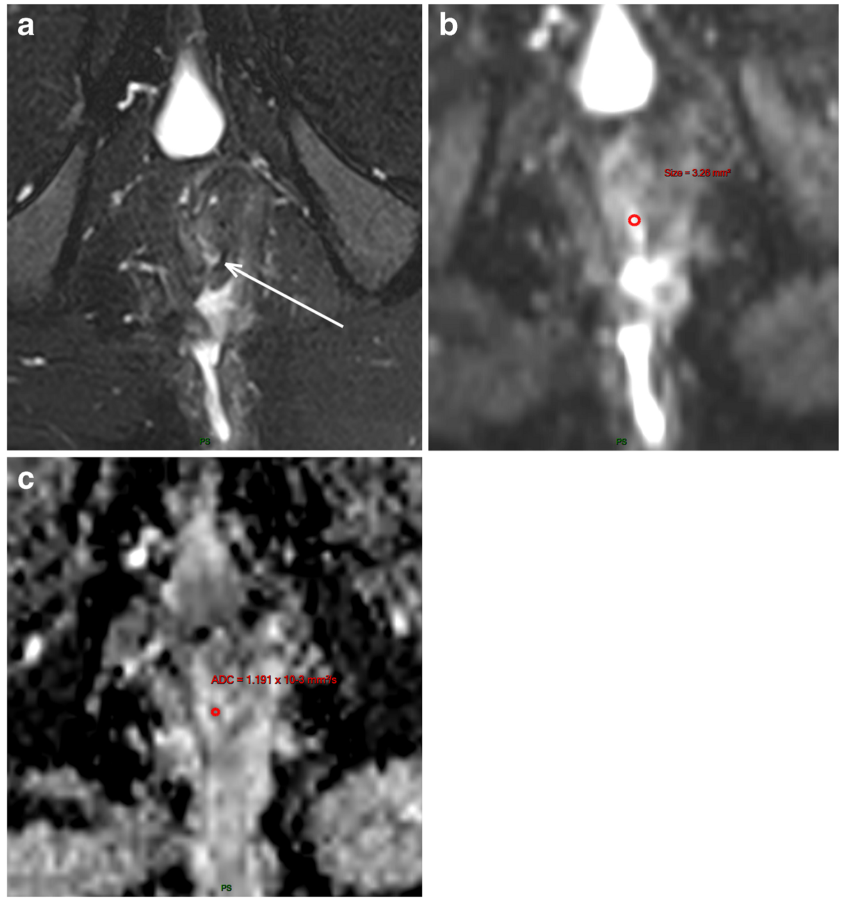

Fig. 2 28-year-old man with Crohn's disease, transsphincteric fistula at 6 hours with a horseshoe perianal collection. **a**. The fistula track is visible on T2-weighted TSE MR image in the axial plane (arrow). **b**. On diffusion-weighted images in the axial plane (b= 1000), only the track and the collection have a high signal intensity. **c**. A ROI is traced on the diffusion MR image (b=1000) and copied on the ADC map. ADC value did not correlate with MRI activity score (Van Assche classification)

coefficient R^2 between signal intensity in the main fistula track on T2-weighted TSE MR images and the MRI activity score.

A McNemar test was used to compare the number of fistulas depicted on each MRI set. A Fisher exact test was used to search for differences in sensitivity between the three MRI sets. A *P* value of less than 0.05 was considered significant.

Receiver operating characteristic (ROC) analysis was performed to determine the area under the ROC curve and the optimal ADC cut-off value with a corresponding sensitivity, specificity and positive and negative predictive value.

Agreement in scoring with the 3-point scale between the two readers was assessed with weighted Cohen κ (kappa) statistics. Degrees of agreement were categorized as follows: κ values of 0.00 - 0.20 were considered to indicate poor agreement; κ values of 0.21 - 0.40, fair agreement; κ values of 0.41 - 0.60, moderate agreement; κ values of 0.61 - 0.80, good agreement; κ values of 0.81 - 0.99, excellent agreement; and, κ value of 1, perfect agreement [18].

Results

Classification of fistulas according to the classification system of Parks et al. is reported in Table 3. The median time interval between MRI and surgery was 1.6 days (Q_1=1; Q_2=2.25; range: 0-8 days). We did not evaluate the ability of DWMRI to classify fistula according to the classification of Parks et al. because of well-established high degrees of accuracy for T2-weighted TSE MRI especially in evaluating the relationships between the fistulas and the sphincter complex. Moreover, DWMRI is performed in only one plane and we assumed that T2-weighted TSE MR would outperform it.

A loculated collection larger than 20 mm^2 and of high signal intensity on T2-weighted TSE MR images was found in all cases.

Quantitative evaluation

Table 4 shows results of the quantitative analysis. Thirty-one fistulas were depicted on the T2-weighted TSE MR images,

Table 3 Fistula type in 24 patients with fistula-in-ano according to Park et al.

Type of fistula	Number of fistulas
Transsphincteric	15
Superficial	5
Intersphincteric	3
Suprasphincteric	4

Table 4 Number of fistulas depicted by each MR imaging set and corresponding sensitivity

	Fat-suppressed T2-TSE alone	DWI alone	Fat-suppressed T2-TSE + DWI
Number of fistulas depicted	31/34	34/34	34/34
Sensitivity	91.2 % [76–98]	100 % [90–100]	100 % [090–100]

Note: No differences were found between fat-suppressed T2-weighted TSE alone and the combination of fat-suppressed T2-TSE with DWMRI (P= 0.239, Fisher's exact test). Numbers in brackets indicate 95 % CI

34 via DWMRI and 34 were deemed present using the standard of reference, corresponding to a sensitivity of 91.2 % [95 % CI: 76 %-98 %] for T2-weighted TSE MRI and 100 % [95 % CI: 90 %-100 %] for DWMRI but the difference was not significant (P=0.239). Concordant findings between DWMRI, T2-weighted TSE MRI and surgery regarding location of the fistulas according to the anal clock were found in 32 fistulas (32/34; 94 %) and discordant findings in the remaining two (2/34; 6 %). In these 2 cases the fistula was depicted via DWMRI and not on fat-suppressed T2-weighted TSE MR images. However, all fistulas initially missed via T2-weighted TSE MRI and seen on DWMRI were surgically proven and were visible via the T2-weighted TSE MRI in retrospect. Agreement between the two independent readers for the number of fistulas was good to excellent with kappa values ranging between 0.65 and 1.

ADC values in suspected pelvic collections were significantly lower in patients with an abscess (n=14) than in patients with an inflammatory mass (n=10; $P=0.714\times10^{-6}$; Table 2; Fig. 3). The area under the ROC curve was 0.971 and the optimal cut-off ADC value was 1.186×10^{-3} mm^2/s. This optimal ADC cut-off value yielded a sensitivity of 100 % [95 % CI: 77 %-100 %], a specificity of 90 % [95 % CI: 66 %-100 %], a positive predictive value of 93 % [95 % CI: 82.8 %-100 %] and a negative predictive value of 90 % [95 % CI: 78 %-100 %] for the diagnosis of perianal abscess (Fig. 4). No

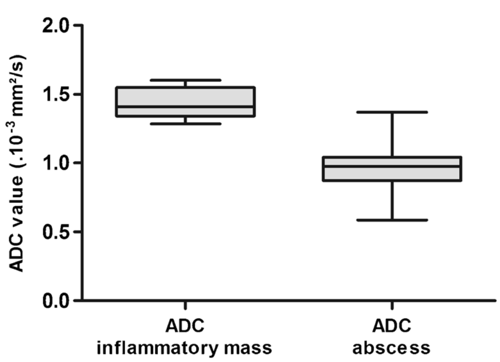

Fig. 3 Box and whisker plots of ADC values, which differ significantly between abscess and inflammatory mass. Boxes stretch across the interquartile range (IR), i.e., from lower quartile (Q1) to upper quartile (Q3); whiskers show smallest data point that is greater than (Q1×1.5\IR) and largest data point that is smaller than (Q3×1.5\IR). The horizontal line through each box represents the median value. ADC values of abscesses overlap with those of inflammatory mass in only one case. Lower ADC values are associated with a perianal abscess.

differences in surface area values of high signal intensity were found between abscesses and inflammatory masses on T2-weighted TSE MRI (P=0.285; Fig. 5). Similarly, no differences in signal intensity were found between abscesses and inflammatory masses on T2-weighted TSE MRI (P=0.259; Table 2).

The Van Assche classification median value was 14 (Q_1= 10.5, Q_3=16.5; range: 4-20). Neither ADC values nor values of signal intensity on T2-weighted MR images in the fistula track correlated with the Van Assche classification, with a correlation coefficient R^2 of 0.1084 for ADC and R^2 of 0.0031 for signal intensity on T2-weighted MR images (Figs. 6 and 7).

Qualitative evaluation

Conspicuity of the fistulas was significantly greater via DWMRI than T2-weighted TSE MRI for the two observers (P=0.003 and P=0.0007, respectively), with fair agreement between the two observers using a T2-weighted TSE MRI sequence (kappa=0.355) and moderate agreement with DWMRI (kappa=0.747).

Discussion

We found that DWMRI shows high degrees of sensitivity and specificity for diagnosis of a perianal abscess and helps discriminate between an abscess and an inflammatory mass (100 % sensitivity and 90 % specificity using a ADC threshold value of 1.186×10^{-3} mm^2/s) and may avoid gadolinium-chelate administration. Moreover, conspicuity of a fistula-in-ano is greater with DWMRI than with T2-weighted TSE MRI. Another result of our study is that ADC values better correlate with disease activity than does signal intensity on T2-weighted MR images, although correlation remains weak for both sequences.

Accuracy of pelvic MRI for the preoperative staging of fistula-in-ano has already been evaluated in large studies [3, 4]. The basic protocol for MRI evaluation of fistula-in-ano uniformly includes fat-suppressed T2-weighted TSE MR in three planes including a strict axial plane, a sagittal plane and a plane parallel to the anal canal; the latter is of great value for

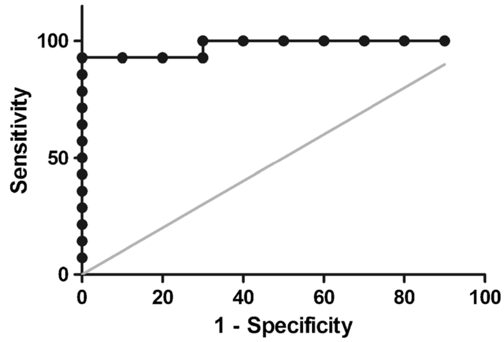

Fig. 4 Graph shows ROC curves for ADC values in the differentiation between an abscess and an inflammatory mass. Area under the curve is 0.971

depicting fistula tracks, perianal collections and sphincter involvement [19]. The added value of gadolinium chelate-enhanced T1-weighted MRI has been investigated [19]. In this regard, researchers have shown that intravenous administration of gadolinium-chelate is helpful for the diagnosis of pelvic collections and helps discriminate between abscesses and inflammatory masses [19]. However, these advantages are obtained at the penalty of an increased MR examination time and extra cost. Moreover, it has been shown that gadolinium-chelate-enhanced T1-weighted MRI may overestimate the number of active lesions or the degree of lesion activity, especially when persisting quiescent fistulas are present [10]. Occasionally, quiescent fistula tracks may show gadolinium-chelate uptake and may thus be erroneously considered as active lesions [10].

The sensitivity of DWMRI in the depiction of malignant or inflammatory lesions in the abdomen has been well demonstrated in several studies [20–23]. It is assumed that ADC values in abscesses is lower than than in normal tissues because the presence of pus reduces free diffusion of water molecules [24].

The depiction of a perianal abscess in patients with inflammatory bowel diseases is a critical issue because it may have substantive impact on the treatment option. In this regard MRI has a pivotal role because it helps determine which patient should have antibiotics or surgical drainage and those who require medical immunosuppressive therapy [5]. The results of our study suggest that MRI can be used to discriminate between abscesses and an inflammatory mass. Although an improvement in the diagnostic capabilities of MRI has been shown using gadolinium-chelate, this is at the penalty of an overestimation of pelvic lesions and the need for an intravenous injection with its potential complications [10]. Our study suggests that DWMRI is highly accurate in differentiating between abscess and inflammatory mass and does not overestimate the number of lesions present. The preoperative depiction of inflammatory mass in very helpful for the surgeon who will not be able to catheterize the inflammatory tracks and insert a draining seton. Moreover, surgical excision of an inflammatory mass may be aggressive whereas medical treatment is sufficient. In addition, the acquisition time of DWMRI is similar to those reported in the literature for a gadolinium-chelate enhanced T1-weighted spoiled gradient echo MR sequence. DWMRI may thus be used instead of gadolinium-chelate enhanced T1-weighted MRI, particularly in patients with contra-indications to intravenous administration of gadolinium-chelate.

Of interest in our study, we found that a subset of patients with an abscess had a very low ADC value (i. e., $<1.0\times10^{-3}$ mm^2/s). In these patients the diagnosis of a perianal abscess was easy without any overlap with the ADC values of patients with an inflammatory mass. In some cases, the signal of the collections may be heterogeneous and the ADC values range between a value around 1.100×10^{-3} mm^2/s and 2.300×10^{-3} mm^2/s. We assume that high ADC values are due to internal heterogeneity of the abscess, which may contain gas-polluting ADC measurement. This is the reason why we decided to consider the region of the collection with the lowest ADC value instead of the ADC value of the whole collection.

Our results show that the use of DWMRI results in better conspicuity of the fistula tracks by comparison with T2-weighted TSE MRI. Conversely, in our study DWMRI did

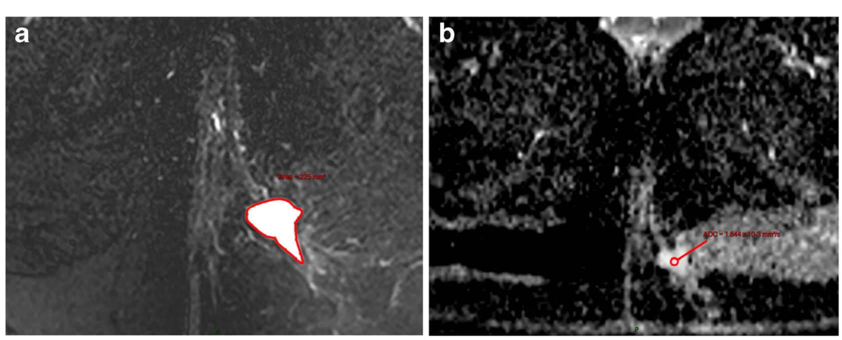

Fig. 5 41-year-old man with Crohn's disease, transsphincteric fistula and a large perianal collection. a. The collection is highly suggestive of abscess on T2-weighted TSE MR image in the axial plane. b. On ADC map, ADC value is 1.844×10-3 mm2/s, above the cut-off value for discriminating between inflammatory mass and abscess. Surgical examination confirmed the diagnosis of inflammatory mass

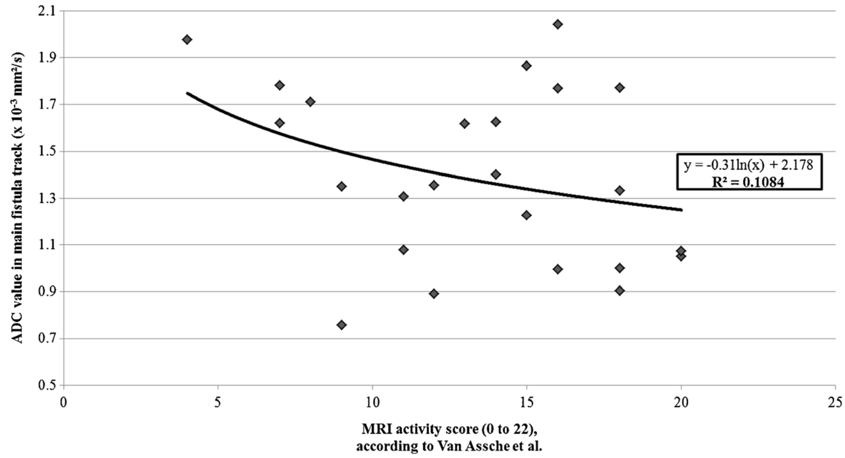

Fig. 6 Diagram shows correlation between ADC values in fistula tracks and MRI activity score (Van Assche classification) with a logarithmic fitting method (R^2=0.1084)

not show more fistula tracks than T2-weighted TSE MRI did, which is consistent with the results Hori et al. obtained with a more limited patients population [15]. However, it can be assumed that our study was underpowered and thus statistically inconclusive. Yoshizako et al. evaluated the ability of DWMRI to depict active inflammatory disease using ADC measurement in the fistula track [9]. Our results show a poor correlation between ADC values in fistula tracks and lesion activity according to Van Assche's classification [16]. Our results are consistent with those reported by Yoshizako et al. and carry the same limitation that relates to the inaccurate standard of reference used. Indeed, a definite diagnosis with respect to the status of the disease (i. e., quiescent vs. active) is difficult to make in retrospect. We consider that our results need further prospective investigation to be confirmed.

DWMRI provides a quantitative evaluation of the restriction of diffusion via use of an ADC map, even in retrospect. Conversely it is very difficult to obtain a quantitative evaluation of the degree of gadolinium enhancement on T1-weighted dynamic MRI because this would require subtle and refined analysis with dedicated software and time-consuming acquisitions [7]. This is the reason why studies evaluating inflammatory activity via gadolinium-enhanced T1-weighted MRI mainly use a semi quantitative approach that is simple and does not require any specific software for post-processing [25].

Our study has several limitations. First, the small sample size does not allow us to draw definitive conclusions, but to date no studies have evaluated the value of DWMRI using surgery as a standard of reference. In addition, in our study MRI examinations were performed less than 8 days before surgery in all patients. The second limitation is due to the difficulty to obtain a strong and valid standard of reference for pelvic evaluation of fistula-in-ano and abscesses, which today includes examination under general anaesthesia and MRI without DWMRI [4]. The third limitation relates to the fact that we did not try to search for correlation between ADC values and the perianal disease activity index (PDAI) because of the lack of prospective clinical data acquisition. However, we tried to overcome this limitation by making a correlation

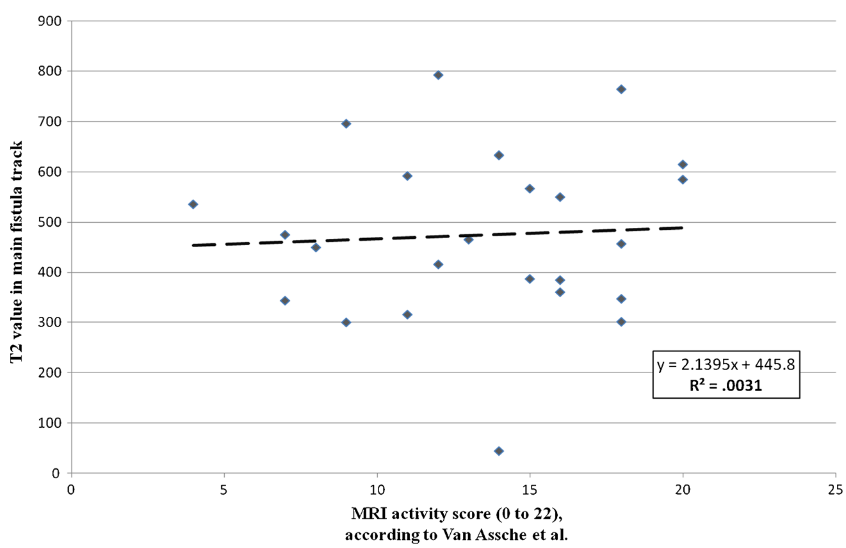

Fig. 7 Diagram shows correlation between T2 values in fistula tracks on fat-suppressed T2 TSE weighted MR images and MRI activity score with a linear regression (R^2=0.0031)

with Van Assche MRI classification. Nevertheless, there is no ideal reference standard to determine disease activity in perianal Crohn's disease and several authors have already underlined the poor accuracy of PDAI and other indexes to evaluate the actual degree of inflammation [7]. The fourth limitation of our study is that we used a 3 point scale to evaluate the conspicuity of fistula. It may be thus argued that the use of a 5 point scale might have resulted in a different result regarding conspicuity of fistulas with DWMRI. Finally, we did not evaluate the added value of gadolinium-enhanced T1-weighted MRI nor compare it to DWMRI. We agree upon the fact that further studies are still needed to evaluate the added value of gadolinium-chelate enhanced T1-weighted MRI, but it can be reasonably assumed that DWMRI may be sufficient in the majority of cases.

In conclusion, we found that DWMRI is very accurate at distinguishing between a perianal abscess and an inflammatory mass while fat-saturated T2-weighted TSE MRI is not able to do so. DWMRI could thus obviate the need for gadolinium-chelate administration for this purpose. This is of interest because of recent concern raised by the use of gadolinium-chelate and also because of a resulting decreased examination time and cost [26]. In addition, we found that conspicuity of fistulas-in-ano is greater with DWMRI than with T2-weighted TSE MRI. As a limitation, however, we did not find any correlation between ADC values and disease activity. Moreover, DWMRI does not help depict more fistula tracks than T2-weighted TSE MRI did, which is already very accurate. According to our results, we suggest that DWMRI should be part of the routine MRI protocols for patients with a suspected perianal abscess especially for protocols without gadolinium-chelate administration.

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References

1. Beets-Tan RG, Beets GL, van der Hoop AG et al (2001) Preoperative MR imaging of anal fistulas: does it really help the surgeon? Radiology 218:75–84
2. Caprilli R, Gassull MA, Escher JC et al (2006) European evidence based consensus on the diagnosis and management of Crohn's disease: special situations. Gut 55:36–58
3. Haggett PJ, Moore NR, Shearman JD, Travis SP, Jewell DP, Mortensen NJ (1995) Pelvic and perineal complications of Crohn's disease: assessment using magnetic resonance imaging. Gut 36:407–410
4. Schwartz DA, Wiersema MJ, Dudiak KM et al (2001) A comparison of endoscopic ultrasound, magnetic resonance imaging, and exam under anesthesia for evaluation of Crohn's perianal fistulas. Gastroenterology 121:1064–1072
5. Buchanan G, Halligan S, Williams A et al (2002) Effect of MRI on clinical outcome of recurrent fistula-in-ano. Lancet 360:1661–1662
6. Keshaw H, Foong KS, Forbes A, Day RM (2010) Perianal fistulae in Crohn's disease: current and future approaches to treatment. Inflamm Bowel Dis 16:870–880
7. Horsthuis K, Lavini C, Bipat S, Stokkers PCF, Stoker J (2009) Perianal Crohn disease: evaluation of dynamic contrast-enhanced MR imaging as an indicator of disease activity. Radiology 251: 380–387
8. Villa C, Pompili G, Franceschelli G et al (2012) Role of magnetic resonance imaging in evaluation of the activity of perianal Crohn's disease. Eur J Radiol 81:616–622
9. Yoshizako T, Wada A, Takahara T et al (2012) Diffusion-weighted MRI for evaluating perianal fistula activity: feasibility study. Eur J Radiol 81:2049–2053
10. Morris J, Spencer JA, Ambrose NS (2000) MR imaging classification of perianal fistulas and its implications for patient management. Radiographics 20:623–635
11. Yildirim N, Gokalp G, Özturk E et al (2012) Ideal combination of MRI sequences for perianal fistula classification and the evaluation of additional findings for readers with varying levels of experience. Diagn Interv Radiol 18:11–19
12. Colosio A, Fornes P, Soyer P, Lewin M, Loock M, Hoeffel C (2013) Local colorectal cancer recurrence: pelvic MRI evaluation. Abdom Imaging 38:72–81
13. Loock MT, Fornes P, Soyer P, Graesslin O, Lafont C, Hoeffel C (2012) MRI and pelvic abscesses: a pictorial review. Clin Imaging 36:425–431
14. Nguyen TL, Soyer P, Barbe C et al (2013) Diagnostic value of diffusion-weighted magnetic resonance imaging in pelvic abscesses. J Comput Assist Tomogr 37:971–979
15. Hori M, Oto A, Orrin S, Suzuki K, Baron RL (2009) Diffusion-weighted MRI: a new tool for the diagnosis of fistula in ano. J Magn Reson Imaging 30:1021–1026
16. Van Assche G, Vanbeckevoort D, Bielen D et al (2003) Magnetic resonance imaging of the effects of infliximab on perianal fistulizing Crohn's disease. Am J Gastroenterol 98:332–339
17. Parks AG, Gordon PH, Hardcastle JD (1976) A classification of fistula-in-ano. Br J Surg 63:1–12
18. Landis JR, Koch GG (1977) An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. Biometrics 33:363–374
19. Halligan S, Stoker J (2006) Imaging of fistula in ano. Radiology 239: 18–33
20. Soyer P, Boudiaf M, Place V et al (2011) Preoperative detection of hepatic metastases: comparison of diffusion-weighted, T2-weighted fast spin echo and gadolinium-enhanced MR imaging using surgical and histopathologic findings as standard of reference. Eur J Radiol 80:245–252
21. Kyriazi S, Collins DJ, Messiou C et al (2011) Metastatic ovarian and primary peritoneal cancer: assessing chemotherapy response with diffusion-weighted MR imaging–value of histogram analysis of apparent diffusion coefficients. Radiology 261:182–192
22. Murtz P, Krautmacher C, Traber F, Gieseke J, Schild HH, Willinek WA (2007) Diffusion-weighted whole-body MR imaging with background body signal suppression: a feasibility study at 3.0 Tesla. Eur Radiol 17:3031–3037
23. Thoeny HC, Forstner R, De Keyzer F (2012) Genitourinary applications of diffusion-weighted MR imaging in the pelvis. Radiology 263:326–342
24. Park HJ, Kim SH, Jang KM, Lee SJ, Park MJ, Choi D (2013) Differentiating hepatic abscess from malignant mimickers: value of

diffusion-weighted imaging with an emphasis on the periphery of the lesion. J Magn Reson Imaging 38:1333–1341

25. Zappa M, Stefanescu C, Cazals-Hatem D et al (2011) Which magnetic resonance imaging findings accurately evaluate inflammation in small bowel Crohn's disease? A retrospective comparison with surgical pathologic analysis. Inflamm Bowel Dis 17:984–993
26. Chopra T, Kandukurti K, Shah S, Ahmed R, Panesar M (2012) Understanding nephrogenic systemic fibrosis. Int J Nephrol 2012: 912189