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Contrast- vs. non-contrast enhanced MR data sets for characterization of perianal fistulas

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Abstract

Purpose: To evaluate the diagnostic efficacy between pre- and post-contrast MRI sequences in perianal fistulas using intra-operative findings as the gold standard.
Materials and methods: Retrospective analysis of 50 patients with a history of perianal fistula and MRI performed between January 2006 and January 2018 was performed. The inclusion criteria were patients who underwent MRI prior to surgery and had a detailed surgical report available. Pre- and post-contrast MR data sets were evaluated by two radiologists at two-week-intervals, assessed fistula type, internal/external opening, presence of abscess/secondary tracts, and confidence scores. The area under the curve (AUC) was used for comparison the diagnostic ability. The sensitivity and specificity were compared using the McNemar's test.
Results: The confidence scores in detecting perianal fistulas were significantly higher in the post-contrast MR data set ($p < 0.003$). The post-contrast MR data set had similar ability to classify perianal fistulas as combined T2-DWI and isolated T2 data sets in 49/50 cases. For internal/external opening, the post-contrast MR, combined T2-DWI, and isolated T2 data sets had 100% concordance with intra-operative reports. For perianal abscess, there was no significant difference in sensitivity or AUC value between the isolated T2 or combined T2-DWI data sets and post-contrast MR data set ($p > 0.05$). All MR data sets correctly identified secondary tracts in all 50 cases.
Conclusions: Although contrast-enhanced MR studies can improve a radiologist's confidence, non-contrast MR studies had similar diagnostic efficacy in identifying perianal fistulas and their complications. Therefore, a non-contrast study may suffice in selected patients such as those with renal impairment.

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Key words: Perianal fistula—MRI—Crohn's disease—Contrast agent

Perianal fistula is an uncommon condition with a challenging treatment and patient morbidity. It is defined as the connection between the mucosal layer of the anal canal and the perianal skin [1]. The mean estimated incidence in the European Union countries per 10,000 population ranges from 0.8 to 2.3 and predominantly affects young adults with a male-to-female ratio of 1.8:1 [2, 3]. The cryptoglandular hypothesis is the most widespread theory for the cause of this idiopathic fistula and represents the chronic phase of intramuscular anal gland sepsis [4]. Other inflammatory conditions, such as Crohn's disease, pelvic infection, diverticulitis, tuberculosis, trauma during childbirth, pelvic malignancy, and radiation therapy can also cause a perianal fistula. The most common presentation is discharge and local pain [5].

In 1976, Parks et al. proposed an anatomically precise classification system for perianal fistulas and is used widely in surgical practice [4]. Perianal fistulas are classified into four groups (i.e., intersphincteric, transsphincteric, suprasphincteric, and extrasphincteric) by considering the external sphincter as the central point of reference (Table 1). In 2000, the St James's University Hospital classification was proposed by radiologists as the MR imaging-based grading system on the basis of imaging findings. The grading system consists of five grades and relates the Parks surgical classification to the

Table 1. Parks classification for perianal fistula [4]

Fistula type	Course of the perianal fistula
Intersphincteric	The tract passed the internal sphincter and confined in the intersphincteric space, did not pass through the external sphincter
Transsphincteric	The tract passed the internal and external sphincters to the skin
Suprasphincteric	The tract penetrated the levator ani muscle before tracking down to the skin
Extrasphincteric	The internal opening at rectum and penetrated the levator ani muscle down to the skin

anatomy seen on MR imaging in both axial and coronal planes: grade 1 = simple linear intersphincteric; grade 2 = intersphincteric with abscess or secondary tract; grade 3 = transsphincteric; grade 4 = transsphincteric with abscess or secondary tract in the ischiorectal or ischioanal fossa; and grade 5 = supralevator and translevator [5, 6]. Another classification most commonly used in clinical practice was proposed by the American Gastroenterological Association (AGA) which classifies fistulas into simple and complex [7].

Although most perianal fistulas can be treated surgically, around 35% of patients will develop recurrent disease after the initial presentation of perianal abscess [8]. The significant factors associated with recurrence are non-identification of internal opening and complex fistulas [5, 9]. Therefore, successful surgical management requires accurate pre-operative assessment of the course of the primary/secondary fistulous tracts and site of perianal abscess.

Magnetic resonance (MR) imaging has become the modality of choice for evaluation in treatment planning due to its high accuracy and non-invasiveness, especially in patients with a complex perianal fistula and Crohn's disease [10, 11]. Contrast-enhanced T1-weighted MR imaging has an advantage over non-contrast imaging in anatomic and pathologic depiction of fistulas [12] and has become a frequently used sequence in a perianal fistula protocol. However, the use of gadolinium contrast agent leads to increased cost and has the associated risk of nephrogenic systemic fibrosis in patients with renal insufficiency [13]. Furthermore, multiple studies have shown the evidence of deposition of the gadolinium in the deep nuclei of the brain with repeat administration [14, 15]. Therefore, the purpose of our study was to evaluate the diagnostic efficacy between non-contrast- and contrast-enhanced MR imaging sequences in perianal fistula using the intra-operative findings as the gold standard.

Materials and methods

Study population

The institutional review board approved our retrospective study which was compliant with the Health Insurance Portability and Accountability Act. The requirement for informed consent was waived. We searched our radiology database using Render software, which acquired radiologic image data from the diagnostic Picture Archiving and Communication System workstations (AGFA Impax; AGFA Technical Imaging Systems, Ridgefield Park, NJ, USA) for consecutive patients with clinically suspected perianal fistula between January 2006 and January 2018. The inclusion criteria were patients with perianal fistula who underwent MR imaging prior to surgery and had a detailed surgical report. The exclusion criteria were: (a) no available MR imaging before surgery ($n = 153$); (b) no available diffusion weighted image (DWI) sequence ($n = 25$); (c) patients who had negative MR imaging ($n = 298$); (d) patients who underwent medical treatment and did not undergo operation ($n = 288$); and (e) incomplete operative reports (no defined internal/external openings) ($n = 8$). A total of 50 of 822 cases were identified (Fig. 1).

MRI technique

MRI scans were performed either on a 1.5-Tesla (Signa, GE Healthcare or Avanto, Siemens Healthcare) or in a 3.0-Tesla (Discovery MR750w, GE Healthcare or Skyra, Siemens Healthcare) scanner. No bowel preparation, laxative or spasmolytic agent as a premedication was required before the MR imaging examination. The patients were positioned supinely with the pelvic coil centered on the pelvis to fully cover the anal canal. A

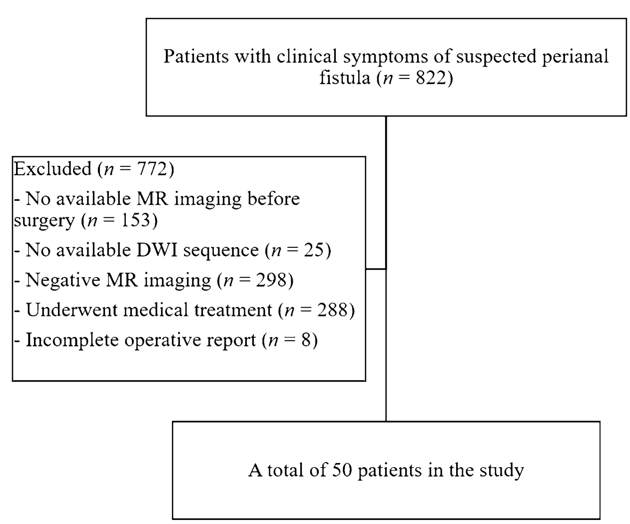

Fig. 1. Flow chart of our retrospective study design.

dedicated MR imaging protocol for perianal fistula was considered when at least the following sequences were available: (a) sagittal T2-weighted fast spin echo (T2-weighted FSE); (b) oblique axial T2-weighted FSE image with small field of view (FOV); (c) oblique axial fat-suppressed T2-weighted sequences (short tau inversion-recovery or fat-saturated T2-weighted FSE) with small FOV; (d) oblique axial DWI using b-value between 0 and 800 s/mm^2; (e) oblique coronal T2-FSE; (f) oblique coronal fat-suppressed T2-weighted sequences, oriented orthogonal and parallel to anal canal long axis; and (g) axial and (h) coronal fat-saturated contrast-enhanced T1-weighted sequences (CE-T1WFS) using gadoterate meglumine (Dotarem®, Guerbet, Paris, France).

Image analysis

Two radiologists with 3 and 8 years of experience in abdominal imaging confirmed that appropriate images were obtained and there was a definitive perianal fistula. They also recorded all of the features analyzed in the study. The two radiologists were aware that all patients had clinical suspicion of perianal fistulas; however, they were blinded to the surgical findings and radiological reports.

The radiologists separately evaluated four imaging data sets: (1) DWI data set (apparent diffusion coefficient and DWI sequences); (2) isolated T2 data set (FSE and fat-suppressed sequences); (3) combined isolated T2 data set with DWI data set (combined T2-DWI data set); and (4) combined isolated T2 data set with DWI data set with CE-T1WFS sequences (combined T2-DWI-CE data set) at 2-week intervals. The cases were randomized in each data set during evaluation. Note that the DWI data set, isolated T2 data set, and combined T2-DWI data set were considered as pre-contrast MR data sets. The combined T2-DWI-CE data set was considered as a post-contrast MR data set.

For each MR imaging data set, they recorded fistula type, simple/complex fistula, internal opening position, external opening position, presence of abscess, presence of secondary tracts, and their diagnosis confidence score. Since our institute used the Parks classification to record the fistula type from the operative findings, the readers decided to also use the Parks classification to classify the fistula type from the MR imaging. All disagreements were resolved by consensus.

Qualitative analysis

Diagnosis confidence score

The diagnosis confidence scores of the perianal fistula were rated on a 5-point scale in each data set [16]: 1 = < 25% confidence; 2 = 25%–50% confidence; 3 = 50%–75% confidence; 4 = 75%–90% confidence; and 5 near 100%.

Fistula type per Parks classification

The perianal fistulas were classified into four groups: intersphincteric; transsphincteric; suprasphincteric; and extrasphincteric, using the external sphincter in the coronal plane as the reference point. The fistula which traversed the intersphincteric space and did not pass through the external sphincter was considered intersphincteric type (Fig. 2). If the fistulous tract crossed the external sphincter, it was considered transsphincteric fistula (Fig. 3). For suprasphincteric fistula, the tract would have to penetrate the levator ani muscle before tracking down to the skin (Fig. 4). Lastly, the extrasphincteric type would have an internal opening at the rectum and penetrate the levator ani muscle down to the skin (Fig. 5) [4].

Simple/complex fistulas

Fistulas were also classified according to the AGA classification into simple or complex fistulas. A simple fistula was low (superficial or low intersphincteric or low transsphincteric origin of the fistulous tract), had a single external opening, and had no evidence of perianal abscess or rectovaginal fistula. A low fistula involved only the lower one-third of the sphincter complex. A complex fistula was high (high intersphincteric or high transsphincteric or extrasphincteric or suprasphincteric origin of the fistulous tract), possibly had multiple external openings or was associated with a perianal abscess or the presence of a rectovaginal fistula [7].

Internal and external opening position

The internal and external opening positions were determined in the axial or coronal images or both as anterior/posterior midline, left/right anterior, left/right lateral, left/right posterior, or adjacent organs.

Presence of perianal abscess

Perianal abscess was defined as potential anorectal spaces more than 3 mm in diameter which showed hyperintensity on T2-weighted image, peripheral enhancement on CE-T1WFS, and restricted DWI [17].

Presence of secondary fistulous tracts

Secondary fistulous tracts were defined as other tracts extending from the primary fistulous tract.

Reference standard

The intra-operative findings were used as the reference standard for the presence of perianal fistulas. The type of

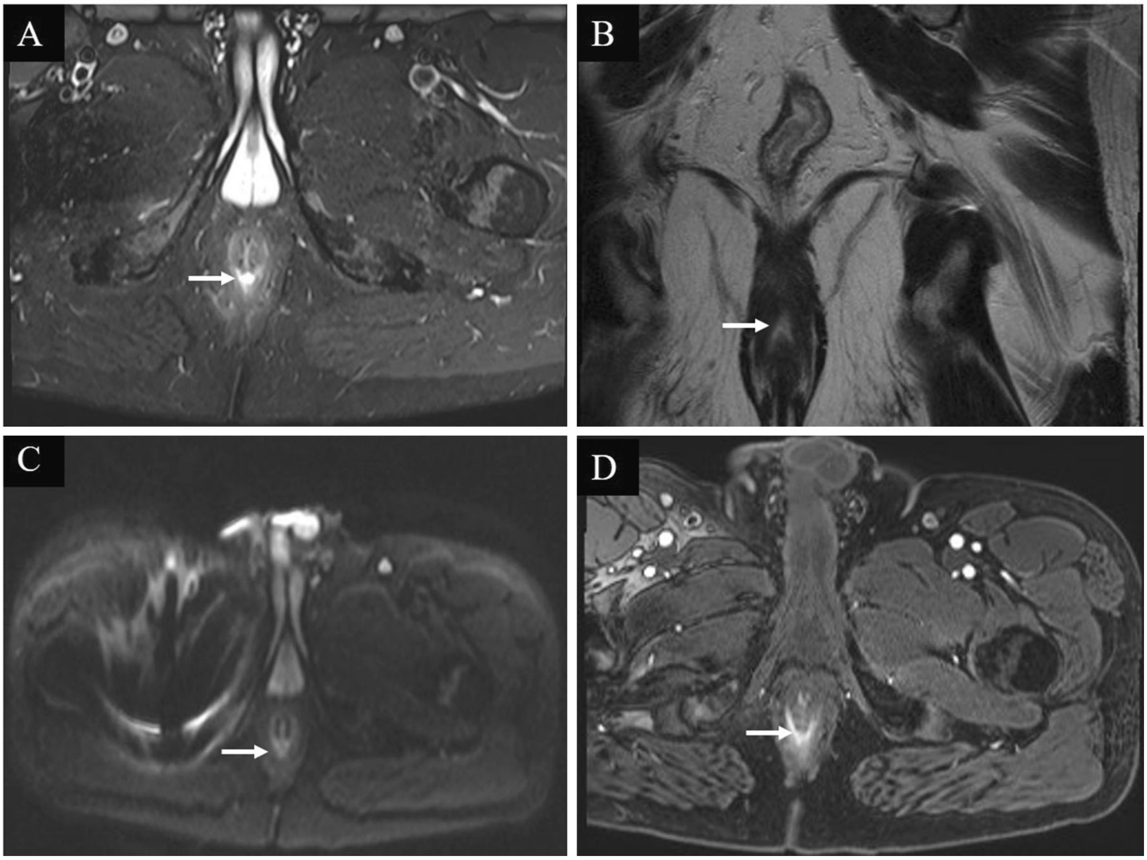

Fig. 2. An intersphincteric perianal fistula with abscess in a 47-year-old man. Axial STIR (**A**) image, coronal T2W (**B**) image, axial DWI (*b* value of 800 s/mm^2) (**C**), and axial (**D**) post-contrast T1WFS images showed an intersphincteric fistula with a small intersphincteric abscess (arrow).

fistula per Parks classification, the presence of abscess, and secondary tracts, which were noted during the surgery, were considered as correctly identified by MR imaging when both the classification and location agreed with the findings in the intra-operative reports. The internal and external opening positions were considered as correctly depicted when they were at the correct level in the anal canal and within the correct quadrant [18]. Simple and complex fistulas were classified according to the AGA classification.

Statistical analysis

Normally distributed continuous data are presented as mean ± standard deviation. Non-parametric data are presented as numbers of cases and percentages. The Cohen's kappa (κ) statistic was used to define the level of interobserver agreement. The scale used for interpretation of weighted κ statistics was: slight agreement 0–0.20; fair agreement 0.21–0.40; moderate agreement 0.41–0.60; substantial agreement 0.61–0.80; and almost perfect agreement 0.81–1.00. The Wilcoxon test was used for comparisons of diagnostic confidence scores. The area under the receiver operating characteristics (ROC) curve (AUC) with 95% confidence interval (CI) was used to compare the diagnostic ability. The sensitivity and specificity were compared using the McNemar's test. A P value < 0.05 was considered to indicate statistical significance. All statistical analyses were performed using Stata software package (Stata/IC 15.0; Stata Statistical Software, College Station, TX, USA).

Results

Demographics of study population

Our final study population of 50 of 822 patients consisted of 30 males and 20 females and the mean age was 35 years. Twenty-eight cases (56%) had underlying inflammatory bowel disease including Crohn's disease (n = 26) and ulcerative colitis (n = 2). The most common type of perianal fistula was transsphincteric type (n = 27, 54%) followed by intersphincteric type (n = 19, 38%), extrasphincteric type (n = 2, 4%), and suprasphincteric type (n = 2, 4%), and 41 (82%) cases had complex perianal fistula. The most common internal opening position was posterior midline (n = 22, 44%) and the most common external opening position was left posterior (n = 13, 26%). Thirty-eight (76%) cases had

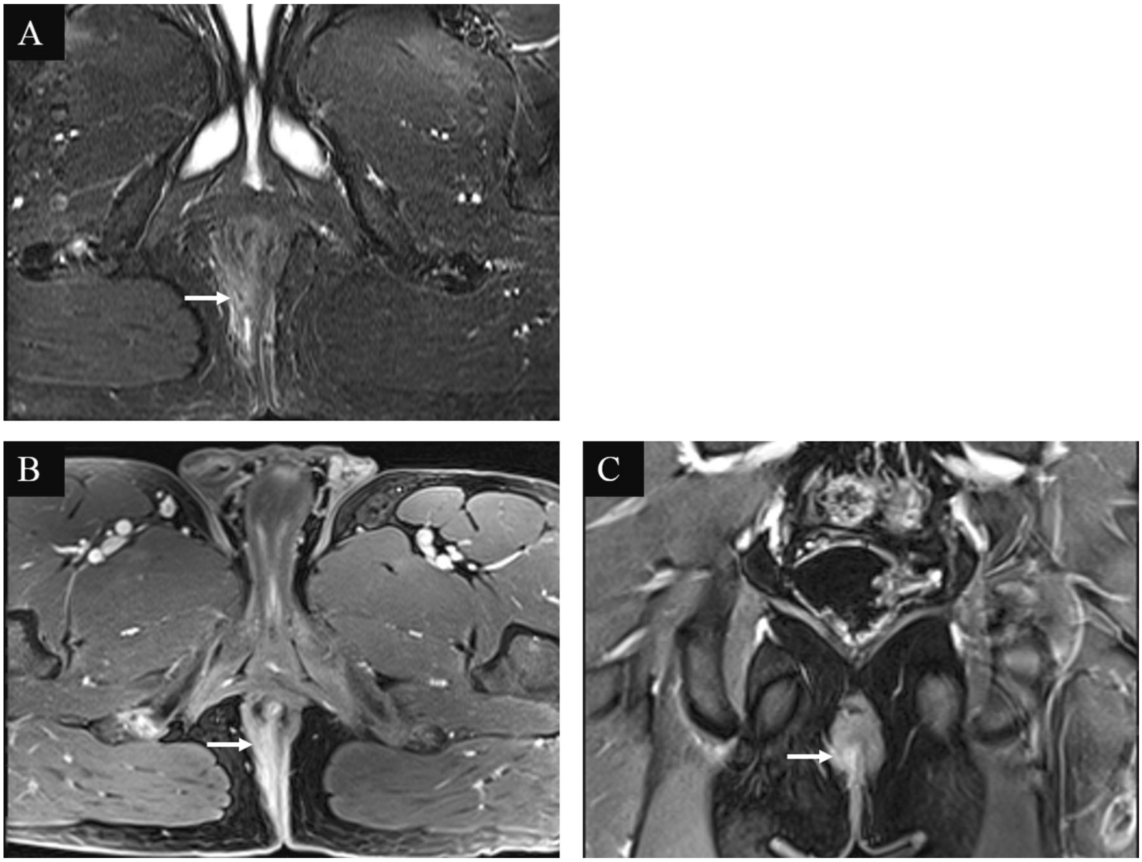

Fig. 3. A transphincteric perianal fistula in a 24-year-old man who was wrongly classified as intersphincteric perianal fistula. Axial STIR (**A**) image, axial (**B**), and coronal (**C**) post-contrast T1WFS images showed subtle involvement of right sided external sphincter (arrow).

perianal abscess and 21 (42%) cases had secondary tracts (Table 2).

MRI analysis

Interobserver agreement

Overall, the kappa coefficient between both readers to evaluate perianal fistula classifications, internal/external opening position, the presence of perianal abscess, and secondary tracts were almost perfect in all data sets. The combined T2-DWI-CE data set had the highest interobserver agreement values among all of the other data sets (Table 3).

Diagnostic confidence score

The diagnostic confidence score in detection of perianal fistulas and complications of both readers were significantly higher in the combined T2-DWI-CE data set (median 5, 95% CI 4.5–5.0 for reader 1 and median 4, 95% CI 4.0–4.0 for reader 2) compared with each pre-contrast data set: DWI vs. combined T2-DWI-CE; isolated T2 vs. combined T2-DWI-CE; and combined T2-DWI vs. combined T2-DWI-CE (Table 4).

Correlation with intra-operative findings

Perianal fistulas were equally correctly classified in 49 (98%) cases in the combined T2-DWI-CE data set, combined T2-DWI data set, and isolated T2 data set. In the DWI data set, 45 (90%) cases were correctly classified according to the Parks classification.

Regarding AGA classification, the combined T2-DWI-CE data set showed a 97.6% sensitivity, 100% specificity, 100% positive predictive value (PPV), and 90% negative predictive value (NPV) in classified simple/complex fistulas. The isolated T2 and combined T2-DWI data sets had similar sensitivity (92.7% vs. 92.7%), specificity (100% vs. 100%), PPV (100% vs. 100%), and NPV (75% vs. 75%). The DWI data set revealed the lowest sensitivity (90.2%), specificity (88.9%), PPV (97.4%), and NPV (66.7%). The combined T2-DWI-CE data set showed the highest AUC value of 0.988. However, in a comparison between the combined T2-DWI-CE data set and each of the pre-contrast data sets in classified simplex/complex fistulas, the AUC value had no significant difference (DWI vs. combined T2-DWI-CE [$P = 0.1199$], isolated T2 vs. combined T2-DWI-CE

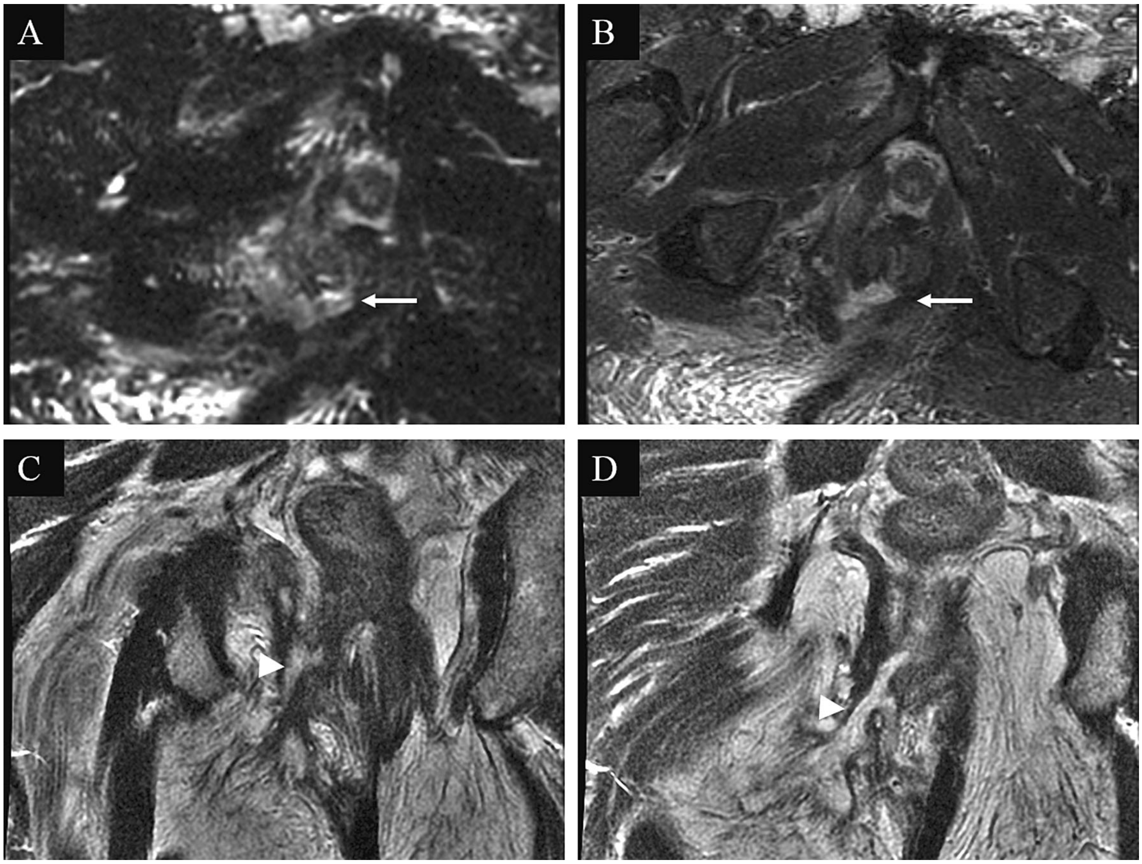

Fig. 4. A 48-year-old man with suprasphincteric perianal fistula. Axial DW (*b* value of 0 s/mm^2) image (**A**) and axial STIR image (**B**) showed a suprasphincteric fistula with internal opening at 6 o'clock (arrow). Coronal T2-weighted MR image (**C** and **D**) showed the fistulous tract crossed the right levator ani muscles (arrowhead) to right ischioanal fossa.

[$P = 0.1521$], and combined T2-DWI vs. combined T2-DWI-CE [$P = 0.1521$], respectively).

For the internal and external opening positions, the isolated T2, combined T2-DWI, and combined T2-DWI-CE data sets had 100% concordance with the intra-operative reports. The DWI data set correctly identified the internal opening position in 48 (96%) cases and the external opening position in 45 (90%) cases.

In terms of detection of perianal abscess, the combined T2-DWI-CE data set had the highest sensitivity (92%), specificity (91.7%), PPV (97.2%), NPV (78.6%), and AUC value (0.919, 95% CI 0.826–1.000) among other data sets. However, there was no significant difference in sensitivity or AUC value between the isolated T2 and combined T2-DWI-CE data sets ($P = 0.1573$ and 0.1521, respectively) or the combined T2-DWI data set and combined T2-DWI-CE data set ($P = 0.1573$ and 0.1521, respectively), in the detection of perianal abscess. On the other hand, the sensitivity and AUC value of the combined T2-DWI-CE data set were significantly higher than the DWI data set ($P = 0.0143$ and 0.0084, respectively). All MR data sets correctly identified the detection of secondary fistulous tracts in all 50 cases (Table 5).

Discussion

MR imaging has become the imaging of choice for preoperative evaluation of perianal fistulas due to its ability to demonstrate the hidden areas of infection, internal opening position, and secondary tracts which contribute to postsurgical recurrence and define the anatomic relationships of the fistula to avoid the side effects such as post-operative fecal incontinence [5]. The use of gadolinium contrast agents has been included in the routine MR imaging protocol in many institutes due to its advantage of rapid dynamic acquisition of data during enhancement of the inflammatory tracts and associated abscess [5, 12, 19]. However, the disadvantages of the gadolinium contrast agent are increased MR examination time, extra cost, deposition of the gadolinium contrast in the brain, and it can be a contra-indication for patients with renal insufficiency. Therefore, we evaluated the diagnostic efficacy between the post-contrast MR data set and each pre-contrast MR data set in perianal fistulas.

More than half of our patients in this study had underlying Crohn's disease (52%). A previous study by Irai S et al. showed that the MR imaging features of

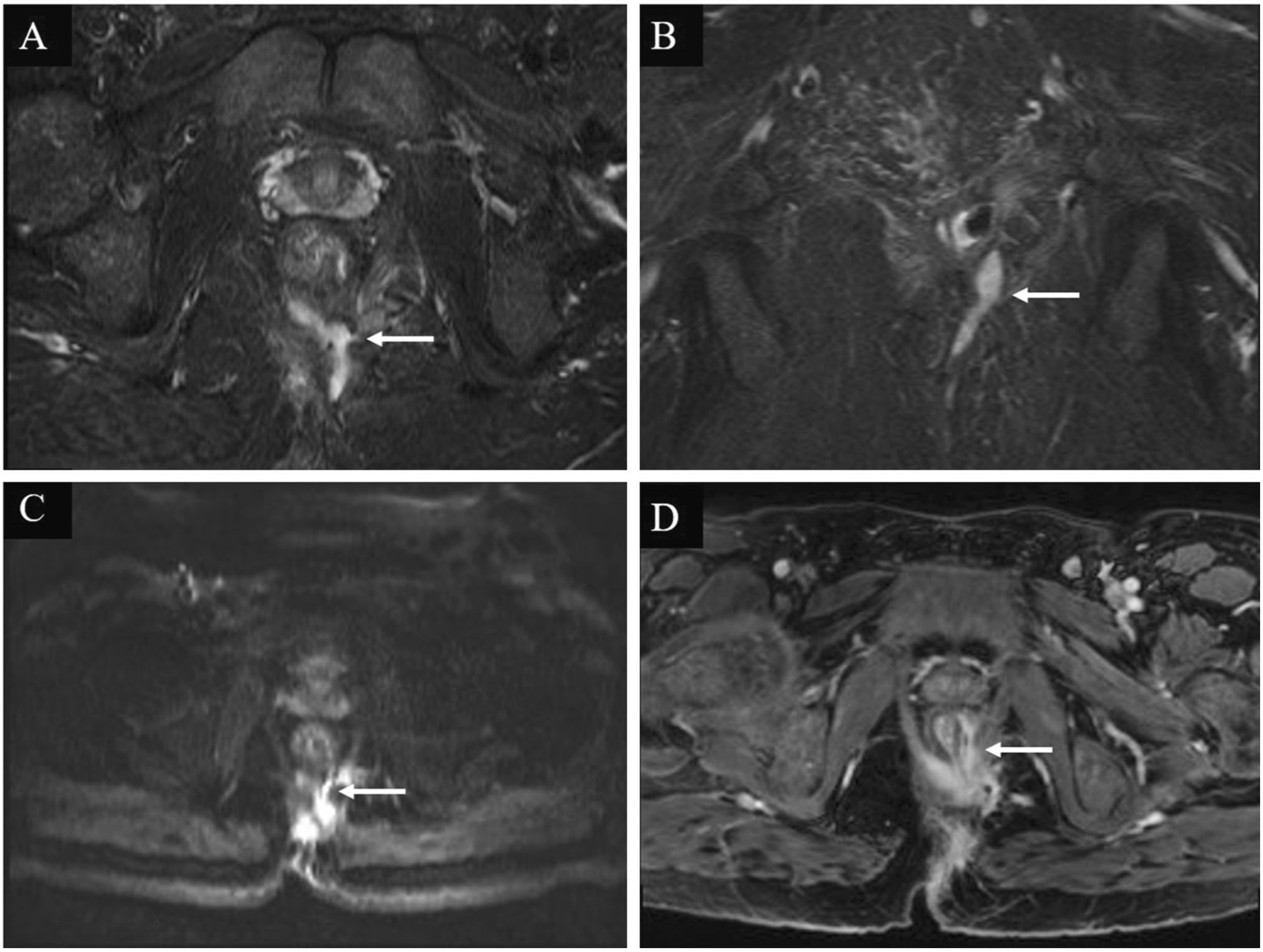

Fig. 5. An extrasphincteric perianal fistula in a 56-year-old man. Axial STIR (**A**) image, coronal STIR (**B**) image, axial DWI (*b*-value of 800 s/mm^2) (**C**), and axial (**D**) post-contrast T1WFS images showed a fistula tract with internal opening at rectum, penetrated levator ani muscle to the skin (arrow).

perianal fistulas in Crohn's and non-Crohn's disease were similar [20]. Therefore, we did not evaluate them separately. Our study found that the combined T2-DWI-CE (post-contrast) MR data set had significantly greater diagnostic confidence scores than other MR data sets in both experienced and less experienced readers. Cavusoglu et al. also showed that the confidence scores for the diagnosis of perianal fistula of the combined T2-DWI or T2-CE images were greater than T2 imaging alone [21].

In terms of the diagnostic ability to classify perianal fistula, our study showed that the post-contrast MR data set had similar ability to classify perianal fistula according to the Parks classification in the combined T2-DWI and isolated T2 data sets of 49/50 (98%) cases. Regarding AGA classification, the isolated T2, combined T2-DWI, and post-contrast MR data sets had overall high sensitivity of 93%–98% and specificity of 100% in detection of simple/complex fistulas. It correlated with a previous study by Baik et al. that reported the combined T2-DWI, isolated T2, and post-contrast MR images equally correctly identified perianal fistula in 89%–93% [22]. We retrospectively reviewed one case that had wrongly classified a transsphincteric fistula as an intersphincteric type and found that all MR sequences showed subtle involvement of the external sphincter, thus misleading the diagnosis (Fig. 3). On the other hand, the DWI data set showed the lowest diagnostic ability to classify a perianal fistula according to the Parks classification (90% vs. 98%) and had the lowest sensitivity (90%), specificity (88.9%), and AUC value (0.896, 95% CI 0.777–1.000) in the classification of perianal fistulas according to the AGA classification. These results were possible because of poor spatial resolution of the images and the images were in only one plane. Moreover, viewing DWI as the first set may account in part for the lower performance because learning occurs with subsequent passes through the data set.

In terms of internal and external opening positions, surprisingly we found that DWI alone had high diagnostic ability of 90%–98% in identification of the internal

Table 2. Baseline characteristics of the patients

Demographics	
Age (mean ± SD)	35.96 ± 13.87
Gender	
Male	30 (60)
Female	20 (40)
Crohn's disease	26 (52)
Ulcerative colitis	2 (4)
Type of perianal fistula per Parks classification	
Intersphincteric	19 (38)
Transsphincteric	27 (54)
Suprasphincteric	2 (4)
Extrasphincteric	2 (4)
Type of perianal fistula per AGA classification	
Complex	41 (82)
Simple	9 (18)
Internal opening position	
Anterior midline	7 (14)
Left anterior	6 (12)
Left lateral	1 (2)
Left posterior	5 (10)
Posterior midline	22 (44)
Right posterior	3 (6)
Right lateral	1 (2)
Right anterior	2 (4)
Rectum	2 (4)
Both sides	1 (2)
External opening position	
Anterior midline	1 (2)
Left anterior	6 (12)
Left lateral	1 (2)
Left posterior	13 (26)
Posterior midline	5 (10)
Right posterior	12 (24)
Right lateral	1 (2)
Right anterior	2 (4)
Both side	7 (14)
Perilabial space	2 (4)
Perianal abscesses	38 (76)
Secondary fistulous tracts	21 (42)

Values are expressed as *n* (%) unless otherwise noted
SD standard deviation

and external opening positions. This result used DWI in the low *b*-value image to identify the anatomical structure of the anal canal which improved the spatial resolution of the images (Fig. 4). However, in comparison with spin-echo or gradient-echo sequences, the DWI sequence had lower spatial resolution. Therefore, our study showed that isolated T2, combined T2-DWI, and post-contrast MR data sets correctly identified all of the internal and external opening positions in 50 cases. The findings of our study seem to be in contrast with the findings of Singh et al. who reported that T2 imaging had higher accuracy in the detection of the internal opening position than post-contrast MR imaging (91% vs. 85%) [23]. Hori et al. reported that DWI sequence improved the visualization of the external or internal opening in 25% of the cases compared to T2 imaging alone [24].

Since our study showed no significant difference in the AUC between the post-contrast MR data set and isolated T2 or combined T2-DWI data sets for the presence of perianal abscess, a contrast study could be omitted. However, we found that the DWI data set was significantly lower in sensitivity and AUC value in the detection of perianal abscess than other MR data sets (DWI vs. isolated T2 or combined T2-DWI [$P = 0.0455$ and $P = 0.0369$] and DWI vs. combined T2-DWI-CE [$P = 0.0143$ and $P = 0.0084$], respectively). In contrast, a study by Dohan et al. of 24 cases with perianal fistulas reported that the DWI sequence had higher sensitivity in the detection of perianal abscess than T2 imaging alone (100% vs. 91.2%). It can be assumed that using DWI alone to evaluate perianal abscess was statistically inconclusive.

In our study, all of the MR data sets correctly identified secondary fistulous tracts in all 50 cases. Therefore, we could avoid contrast agent for evaluation of the secondary fistulous tracts. Singh et al. also revealed that MR imaging had high sensitivity of 93.75%, specificity of 94.12%, PPV of 88.24%, and NPV of 96.97% in the detection of secondary fistulous tracts [23].

Based on our study, although the post-contrast MR data set significantly improved diagnostic confidence of both experienced and less experienced readers in the diagnosis of perianal fistula, the diagnostic efficacy of perianal fistula and its complications were similar between post-contrast MR data set and isolated T2 or combined T2-DWI data sets. Since many of these patients received multiple repeat examinations after percutaneous drainage and surgical treatment for treatment of the perianal fistula, contrast agent can be avoided in patients with renal insufficiency for the evaluation of perianal fistulas and in repeat imaging.

Table 3. Interobserver agreement between readers 1 and 2 for the detection of the perianal fistula and its complications in each MR data sets

	DWI	Isolated T2	Combined T2-DWI	Combined T2-DWI-CE
Type of perianal fistula per Parks classification	0.81	0.82	0.86	0.96
Internal opening position	0.81	0.95	0.92	0.95
External opening position	0.95	0.95	0.90	0.93
Simple/complex fistulas	0.88	0.93	0.83	1.00
Perianal abscesses	0.96	1.00	1.00	0.94
Secondary fistulous tracks	0.88	0.88	0.96	0.96

Values are expressed as weighted kappa

Table 4. Summary of the diagnostic confidence score

	DWI	Isolated T2	Combined T2-DWI	Combined T2-DWI-CE	*p* value		
					Combined T2-DWI-CE vs. DWI	Combined T2-DWI-CE vs. T2	Combined T2-DWI-CE vs. Combined T2-DWI
Reader 1	2 (2–2)	3 (3–4)	4 (3.5–4)	5 (4.5–5)	$<0.0001^{\dagger}$	$<0.0001^{\dagger}$	$<0.0001^{\dagger}$
Reader 2	2 (2–3)	3 (3–4)	4 (4–4)	4 (4–4)	$<0.0001^{\dagger}$	$0.0026^{\dagger}$	$0.0005^{\dagger}$

Values are expressed as median (95%CI) except *p* value
†Statistically significant

Table 5. Diagnostic efficacy in detection simple/complex perianal fistulas, perianal abscesses, and secondary fistulous tracts in each MR imaging data sets

MR imaging findings	Pre-contrast data set			Post-contrast data set
	DWI	Isolated T2	Combined T2-DWI	Combined T2-DWI-CE
Simple/complex				
Sensitivity	90.2 (76.9–97.3)	92.7 (80.1–98.5)	92.7 (80.1–98.5)	97.6 (87.1–99.9)
Specificity	88.9 (51.8–99.7)	100 (66.4–100)	100 (66.4–100)	100 (66.4–100)
PPV	97.4 (86.2–99.9)	100 (90.7–100)	100 (90.7–100)	100 (91.2–100)
NPV	66.7 (34.9–90.1)	75 (42.8–94.5)	75 (42.8–94.5)	90 (55.5–99.7)
AUC	0.896 (0.77–1)	0.963 (0.923–1)	0.963 (0.923–1)	0.988 (0.964–1)
Perianal abscess				
Sensitivity	76.3[a] (59.8–88.6)	86.8 (71.9–95.6)	86.8 (71.9–95.6)	92 (78.6–98.3)
Specificity	91.7 (61.5–99.8)	91.7 (61.5–99.8)	91.7 (61.5–99.8)	91.7 (61.5–99.8)
PPV	96.7 (82.8–99.9)	97.1 (84.7–99.9)	97.1 (84.7–99.9)	97.2 (85.5–99.9)
NPV	55 (31.5–76.9)	68.8 (41.3–89)	68.8 (41.3–89)	78.6 (49.2–98.3)
AUC	0.84[b] (0.733–0.946)	0.893 (0.794–0.991)	0.893 (0.794–0.991)	0.919 (0.82–1)
Secondary tracks				
Sensitivity	100 (83.2–100)	100 (83.2–100)	100 (83.2–100)	100 (83.2–100)
Specificity	100 (88.4–100)	100 (88.4–100)	100 (88.4–100)	100 (88.4–100)
PPV	100 (83.2–100)	100 (83.2–100)	100 (83.2–100)	100 (83.2–100)
NPV	100 (88.4–100)	100 (88.4–100)	100 (88.4–100)	100 (88.4–100)
AUC	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)

Values are expressed as percent (95% CI) except AUC
[a]The sensitivity in DWI data set was significantly lower than the combined T2-DWI-CE data set ($p = 0.0143$)
[b]The AUC of DWI data set was significantly lower than the combined T2-DWI-CE data set ($p = 0.0084$)

Our study had several limitations. First, the retrospective study design should be considered. Second, we included patients who had surgery which can cause selection bias. Third, although we used surgical findings as the reference standard, surgery may miss some fistulas. Fourth, our results were based on pre-operative patients; therefore, our results cannot be applied to post-operative cases. Fifth, due to the short period of the 2-week interval between each data set and the multiple passes through the cohort (4 data sets), recall bias is a possibility.

In conclusion, although contrast-enhanced MR studies can improve the confidence of a radiologist in the diagnosis of perianal fistulas, non-contrast MR studies, such as isolated T2 or combined T2-DWI sequences, had similar diagnostic efficacy to identify perianal fistulas and the complications. Therefore, contrast-enhanced MR studies can be avoided in patients with a history of renal impairment.

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Compliance with ethical standards

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Ethical approval This article does not contain any studies with human participants performed by any of the authors.

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