Article published online: 2023-10-10

Comparison of Contrast-Enhanced 3D Imaging with 2D Imaging in the Evaluation of Perianal Fistula at 3T: A Prospective Observational Study

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Indian J Radiol Imaging 2024;34:95–102.

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Abstract

Introduction Perianal fistula and its recurrence is a challenging entity for surgeons. It is a well-establi1shed fact that magnetic resonance imaging (MRI) findings influence surgical procedures and reduce the rate of recurrence. In this study, we assessed the contrast-enhanced (CE) three dimensional T1 sequences [sampling perfection with application optimized contrast using different flip angle evolution (SPACE) and volumetric interpolated breath-hold examination (VIBE)] in a 3T MRI system to evaluate perianal fistulas and compared them with two-dimensional (2D) sequences.

Materials and Methods Forty-four patients (mean age, 38.8 ± 15.3 [standard deviation]; 32 males, 12 females) with perianal fistula were included in this prospective study. The patients underwent conventional noncontrast, 2D sequences, diffusion-weighted imaging, followed by postcontrast, 2D T1 images in both axial and coronal planes, and 3D sequences at 3T. Acquisition times were recorded for each sequence. Each postcontrast sequence was evaluated in terms of image quality, presence of artifacts, fistula type, presence of an abscess, visibility, and number of internal orifices. The surgical findings were considered the gold standard. The imaging findings were compared with the surgical findings.

Results In all three sequences, the fistula type and abscess were identified correctly in all patients. The sensitivity value for identification of ramifications utilizing CE 3D T1 VIBE sequence, CE 3D T1 SPACE, and CE 2D T1 images was 100, 86, and 36%, respectively. The number of internal orifices was identified by the CE 3D T1 VIBE and CE 3D T1 SPACE sequences in 100 and 92% of patients, respectively. CE 2D T1 images correctly identified internal orifices in 80% of patients. The overall scan time for each 3D sequence was shorter than for the combined postcontrast 2D sequences.

Conclusion CE 3D T1 SPACE and CE 3D T1 VIBE sequences outperformed conventional CE 2D sequences in the evaluation of perianal fistulas in terms of visibility and the number of internal orifices with a shorter scanning time. Among the 3D sequences, CE 3D T1 VIBE is slightly superior to CE 3D T1 SPACE sequence.

Keywords
- 3 Tesla
- 3D sequence
- abscess
- perianal fistula
- ramification
- VIBE

article published online
October 10, 2023

DOI https://doi.org/10.1055/s-0043-1775738.
ISSN 0971-3026.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

The perianal fistula is an abnormal tract between the perianal skin and the anal canal. Multiple secondary tracts may also exist and extend from the same primary opening. It is characterized by chronic purulent discharge or cyclic pain associated with reaccumulation of the abscess followed by spontaneous intermittent decompression.[1] Because of their high propensity to recur, perianal fistulas significantly contribute to morbidity,[2] particularly when it comes to incontinence and poor quality of life that necessitates recurrent surgical procedures. Of all patients with an initial perianal abscess, up to 65% will develop a chronic or recurrent perianal fistula.[3]

Recurrence usually occurs because of secondary tracts that cannot be detected during surgery and, therefore, cannot be fully treated.[4] Therefore, accurate preoperative assessment is essential for surgical success.

Until recently, imaging methods played a limited role in evaluating perianal fistulas. Magnetic resonance imaging (MRI), on the other hand, now offers more accurate details on the anatomical makeup of the anal canal, the anal sphincter complex, the relationship between the fistula and the pelvic floor organs, and the levator ani muscle. MRI can also accurately delineate the fistulous tract and detect additional tracts or abscesses. This reduces the risk of recurrence and prevents side effects such as fecal incontinence by providing precise information for appropriate surgical treatment.

Currently, conventional sequences for MRI scans of anal fistulas include two-dimensional (2D) T2-weighted imaging (T2WI), 2D T1-weighted imaging (T1WI), inversion recovery (IR), diffusion-weighted imaging, and postcontrast 2D T1WI. Perianal anatomy is best evaluated using the 2D T1WI sequence, whereas a fistula or abscess is best evaluated using the 2D T2WI and 2D T1WI postcontrast sequence.[5] There are still many things that need to be improved in conventional MRI sequences. Because of their secretive-filled nature, perianal fistulas and perianal structures demonstrate strong signals in non-fat T2WI, resulting in poor image contrast and risking a poor diagnosis. Suppression of fat signals can significantly improve the contrast of the fistula in fat-suppressed (FS) T2WI but leads to poor visualization of the perianal anatomy.[2,6]

In contrast, three-dimensional (3D) sequences provide high-quality multiplanar reconstruction images. It also has the advantage of reducing the total imaging time and eliminating the need for additional 2D images in other planes.[7] A 3D model can help surgeons understand the complex relationship between sphincter anatomy and fistula, guiding surgical decisions, and improving outcomes. In a study by Cerit et al, they observed that contrast-enhanced (CE) 3D sequences (T1 SPACE and CE 3D T1 VIBE) outperform conventional 2D sequences in the preoperative evaluation of perianal fistulas with a shorter scanning time.[8] In the study done at our tertiary care center, we assessed the role of volumetric MRI sequences (CE 3D T1 SPACE and CE 3D T1 VIBE) over conventional (CE 2D T1WI) MRI sequences in the presurgical assessment of perianal fistula.

Materials and Methods

This prospective observational study was conducted in the department of radiology in a tertiary care hospital after obtaining approval from the hospital's ethics and scientific committee. The patients presented to our hospital with perianal pain, fever, tenderness, redness, and discharge, whose physical examination findings were consistent with perianal fistula, and those who underwent CE MRI of anorectum followed by surgery within 2 weeks, from December 2020 to July 2022 were included in the study. Patients who had previously undergone perianal fistula surgery and those unwilling to undergo surgery were excluded. A total of 44 patients were enrolled in this study. Among these 44 patients, 12% were associated with Crohn's disease, and 2 patients had anal fissures.

MRI Technique

MRI was performed in a 3T (Siemens 3T MAGNETOM Skyra). 2D and 3D MRI protocols were performed on all the patients. Conventional (2D) sequences followed by postcontrast 2D sequences (in coronal and axial planes) orthogonal to the anal canal and 3D T1W sequences were taken (►**Table 1**). To prevent bias, the postcontrast sequences were performed in random order. This was done by implementing a randomized block design for MRI sequences. The sample population was divided into distinct blocks based on variables and within each block, a randomization method (computer-generated random numbers) was used to assign the postcontrast sequences (2D T1, 3D VIBE, and 3D SPACE) in a random order. The random sequence assignment process for each block was repeated independently. MRI scans were done

Table 1 MRI sequence parameters for CE T1WI, CE 3D T1 VIBE, and T1 SPACE

	FOV (cm)	TR (ms)	TE (ms)	Voxel size	TA
T1WI (axial)	25	636.0	12.0	$0.8 \times 0.8 \times 3.0$ mm	3 min 56 s
T1WI (coronal)	25	654	12	$1.0 \times 1.0 \times 3.0$ mm	3 min 55 s
VIBE	17	4.26	1.58	$0.7 \times 0.7 \times 0.9$ mm	2 min 56 s
SPACE	20	504	24	$0.8 \times 0.8 \times 1.0$ mm	3 min 56 s

Abbreviations: CE, contrast-enhanced; FOV, field of view; MRI, magnetic resonance imaging; TA, time of acquisition; TE, echo time; TR, repetition time; T1WI, T1-weighted imaging; 3D, three-dimensional.

according to the randomized sequence order for each participant, and the results and relevant data were recorded.

Evaluation of MRI Findings

The MRI was evaluated by a radiologist with more than 15 years' experience in abdominal MR reporting. Following the assessment of conventional MRI, the results of postcontrast MRI were evaluated in series. In all the patients, CE 2D T1WI, CE 3D T1 SPACE, and CE 3D T1 VIBE sequences were analyzed in random orders to avoid bias. All findings were assessed and scored. The confidence scores of all three datasets were recorded in terms of artifacts, overall image quality, the type of the fistula, visibility of internal orifices, presence of ramifications, the number of detectable internal orifices, and the presence of abscesses. The types of fistula-in-ano are intersphincteric, transsphincteric, suprasphincteric, and extrasphincteric fistulas.[9] Ramifications or secondary tracts are the tracts from the primary tract that cross from one side to the other (horseshoe type) or may be visualized as a side track within the ipsilateral intersphincteric plane in a patient with an intersphincteric fistula. They can also be seen as a tract from the primary tract extending into the ischioanal/ischiorectal fossae in trans/suprasphincteric fistulas. Scan time was recorded for every sequence. The performance of each sequence in terms of image quality, presence of artifacts, fistula type, presence of abscess, and visibility of internal orifice were compared.

The surgery was done immediately after the MRI scan in simple fistulas and after 1 to 2 weeks of antibiotic therapy in complex cases by a surgeon with more than 20 years of experience. After the surgery, surgical reports were recorded. The postsurgical findings were defined as the reference standard. Finally, an agreement between MRI findings and intraoperative findings was evaluated.

Qualitative Analysis

The visibility of the origin point in the anal channel (visibility of the internal orifice) is defined, and the rating system was as follows: 0, not visible; 1, visible. The number of internal orifices was also counted. A five-point scale was used for the confidence level of image artifacts: 1, unreadable artifacts, images of nondiagnostic quality; 2, severe artifacts, images degraded but interpretable; 3, moderate artifacts with a few but not serious effects on diagnostic quality; 4, minimal artifacts, no effect on diagnostic quality; and 5, no artifacts.[10] A five-point scale was also used for the confidence level of overall image quality: 1, unacceptable; 2, faint; 3, acceptable; 4, fine; and 5, perfect or ideal.

Statistical Analysis

Statistical analyses were performed using SPSS Statistical Software, version 20.0. Categorical and quantitative variables were expressed as frequency (percentage) and mean ± standard deviation, respectively. Sensitivity and specificity were calculated to determine the diagnostic accuracy of MRI sequences. The chi-square test was used to determine the association between categorical variables. For all statistical interpretations, $p < 0.05$ was considered the statistically significant threshold.

Results

A total of 44 patients were included in the study. The sample group's mean age was 38.8 years, with a range between 13 and 59 years. Among 44 patients, males were more in number accounting for 72% of the total and females were 28% of capacity.

Fistula Type

Among 44 patients, intraoperatively the majority showed transsphincteric (44%) and intersphincteric (44%) fistula types (i.e., 19 patients each). Suprasphincteric kind of fistula is seen in two patients. Four patients showed both transsphincteric and extrasphincteric types of fistula. There was 100% agreement of above-mentioned intraoperative findings with preoperative MRI findings in all three sequences (►**Fig. 1**).

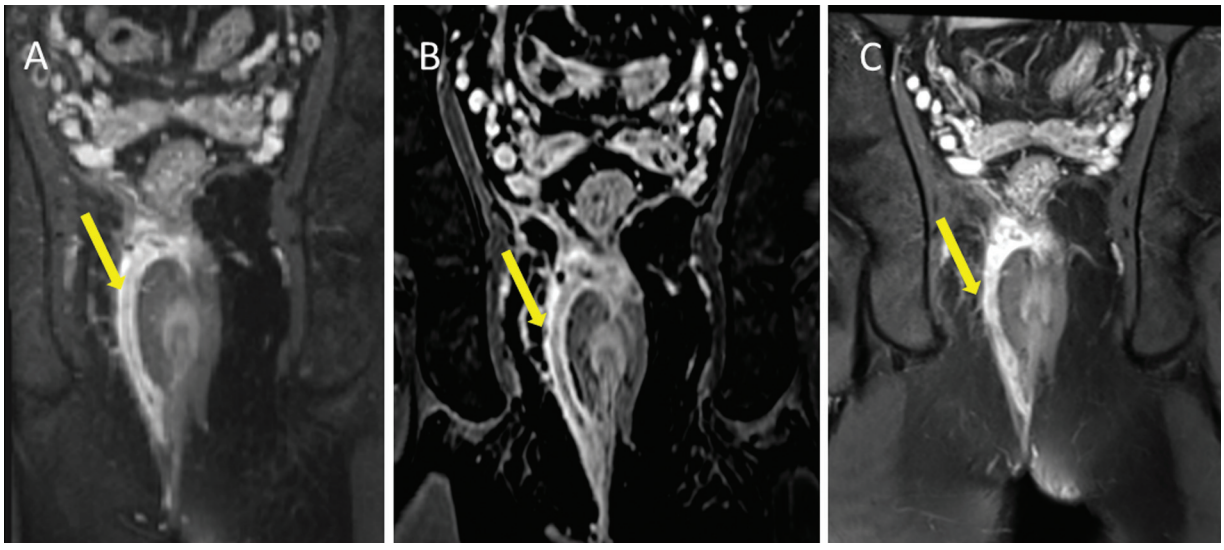

Fig. 1 Postcontrast images in coronal plane: transsphincteric fistula (yellow arrow) on right side seen on 3D T1 space (A), 3D T1 VIBE (B), and 2D T1 (C) sequences. 2D, two-dimensional; 3D, three-dimensional.

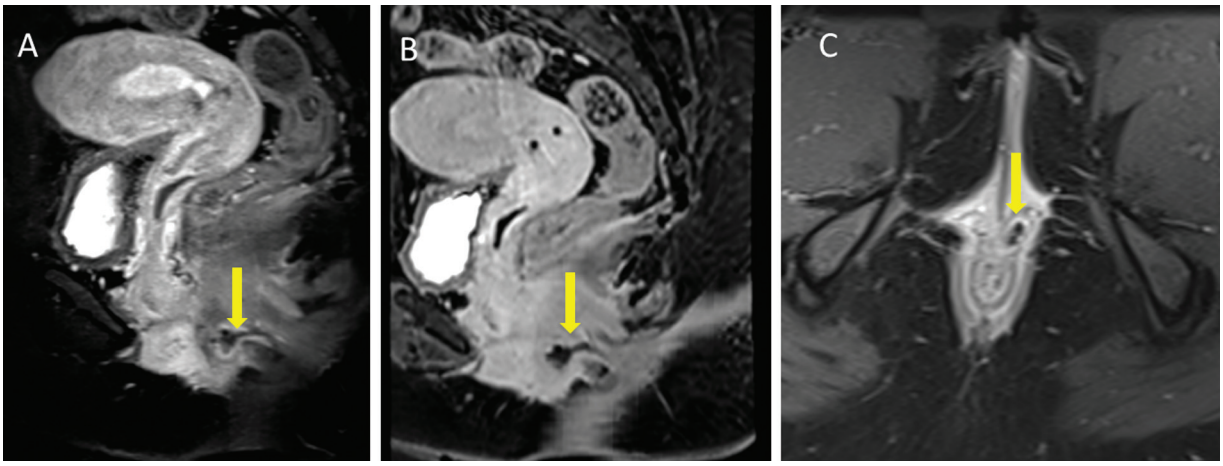

Fig. 2 Extrasphincteric abscess (yellow arrow) demonstrated as nonenhancing focus with peripheral enhancement on 3D T1 space (A, sagittal plane), 3D T1 VIBE (B, sagittal plane), and 2D T1 (C, axial plane) sequences. 2D, two-dimensional; 3D, three-dimensional.

Abscess

Abscesses were identified in 28 patients (64%) intraoperatively, and the remaining 16 patients (36%) did not have any abscesses.

Among the 28 patients with abscesses, 16 patients were detected to have abscesses in all three sequences in preoperative MRI (►**Fig. 2**). The presence or absence of abscess was identified correctly in 41 patients out of 44 in preoperative MRI, with a sensitivity of 89% and specificity of 100% in all three sequences (►**Table 2**). In the rest of the three complex patients, since abscess was not picked up in any of the conventional/postcontrast sequences, abscess was thought to have developed between the MRI acquisition and surgery.

Ramifications

Ramifications were seen in 14 patients (32%) intraoperatively, and the remaining 30 patients (68%) did not show any ramifications. Among the 14 patients with ramifications in preoperative MRI, 14 patients showed ramifications in CE T1 VIBE and 11 patients in CE T1 SPACE (►**Figs. 3** and **4**). However, in the CE 2D TIWI sequence, only five patients showed ramifications. CE 3D VIBE, CE 3D SPACE, and CE 2D T1WI had a sensitivity of 100, 86, and 36%, respectively, for identifying ramifications. All three sequences had a specificity of about 100% (►**Table 2**).

Number and Visibility of Internal Orifices

In this present study population of 44 patients, surgery revealed that all 44 patients had internal orifices. In surgery, 33 patients had a single internal orifice, and the remaining 11 patients had more than one internal orifice (seven patients—two internal orifice; two patients—three internal orifice, and two patients—four internal orifice).

Table 2 Agreement of abscess and ramifications in MRI with intraoperative findings

MRI sequence	Finding on MRI	Intraoperative findings		Sensitivity	Specificity
		Present	Absent		
Presence of abscess					
T1 VIBE	Present	25	0	89.29%	100%
	Absent	3	16		
T1 SPACE	Present	25	0	89.29%	100%
	Absent	3	16		
2D T1WI	Present	25	0	89.29%	100%
	Absent	3	16		
Presence of ramifications					
T1 VIBE	Present	14	0	100%	100%
	Absent	0	30		
T1 SPACE	Present	12	0	85.71%	100%
	Absent	2	30		
2D T1WI	Present	5	0	35.71%	100%
	Absent	9	30		

Abbreviations: MRI, magnetic resonance imaging; T1WI, T1-weighted imaging; 2D, two-dimensional.

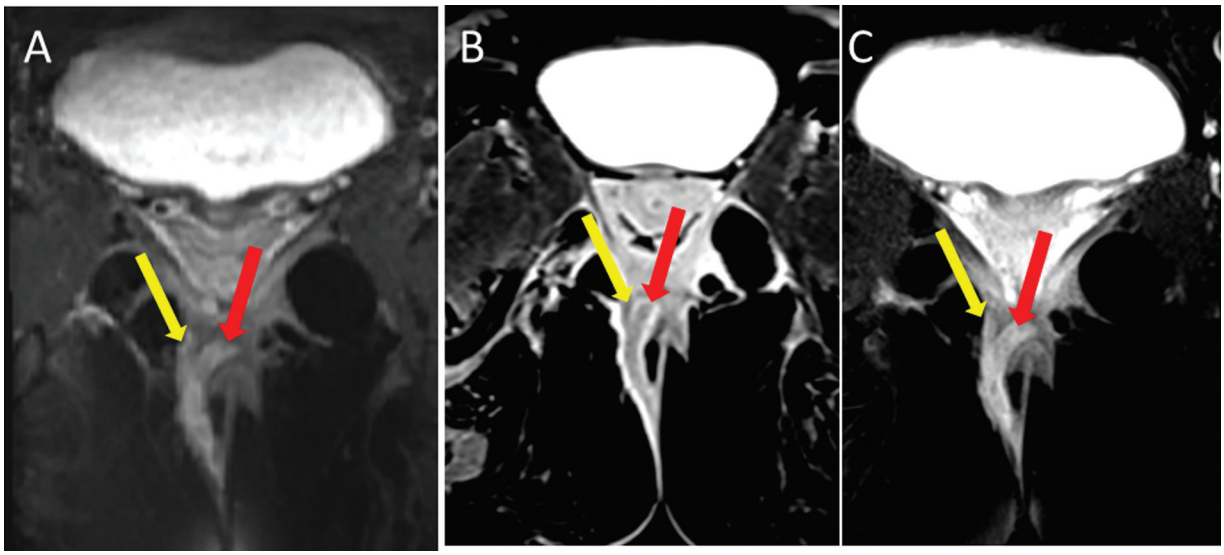

Fig. 3 Transsphincteric fistula with two ramifications (yellow and red arrows) demonstrated on 3D T1 space (A), 3D T1 VIBE (B), and 2D T1 (C) sequences in coronal plane. 2D, two-dimensional; 3D, three-dimensional.

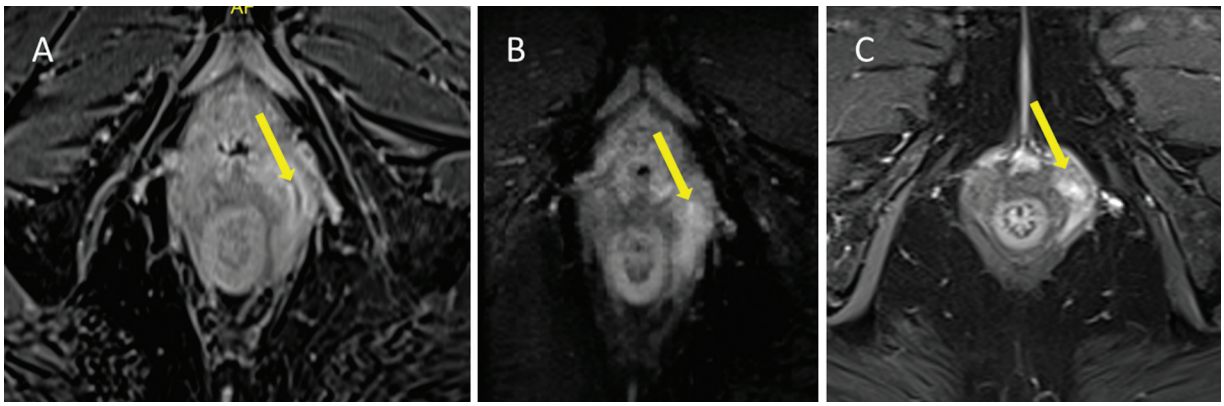

Fig. 4 Postcontrast images in axial plane: Secondary ramification with adjacent inflammation (yellow arrow) in the left anterolateral aspect of anal canal clearly visualized on 3D T1 VIBE sequence. 3D T1 space (B) and 2D T1 (C) sequences demonstrate inflammatory changes at the site of secondary ramification. The tract was not clearly demonstrated in these sequences. 2D, two-dimensional; 3D, three-dimensional.

In preoperative MRI, the number of internal orifices was identified correctly for all 44 patients (100%) in the CE TI VIBE sequence and 40 patients (92%) in the CE T1 SPACE sequence. However, the number of internal orifices was identified correctly in only 35 patients (80%) in the CE 2D T1WI sequence (►**Fig. 5**).

The surgery revealed more than one internal openings in 11 patients. On preoperative MRI evaluation, all internal orifices were visible in all 11 patients in CE T1 VIBE sequence cases (sensitivity—100%). However, the number of internal orifices was same as in surgery in seven patients in CE T1 SPACE sequence and only in four patients in the CE 2D TIWI sequence. The sensitivity of 3D SPACE and 2D T1 images in identifying more than one internal orifice were 63 and 36%, respectively.

Image Artifacts

Overall artifact scores are higher in CE 2D T1WI sequence than CE T1 SPACE and CE T1 VIBE sequences, with no significant difference in artifact scores between CE T1 SPACE and CE T1 VIBE sequences, as detailed in ►**Table 3**. The higher degree of CE 2D T1WI sequences artifacts could be due to increased scanning time and patient movements.

Acquisition Time

In this present study, the acquisition time for each CE T1 SPACE and CE T1 VIBE sequences was shorter compared with combined CE 2D T1WI sequences with no compromise in image quality.

Mean acquisition time for CE T1 SPACE and CE T1 VIBE sequences were found to be 3 minutes 56 seconds and 2 minutes 56 seconds, respectively, whereas the mean acquisition time for CE 2D T1 sequences (axial and coronal planes) was found to be 7 minutes and 54 seconds, which is more than the time required for both CE T1 SPACE and T1 VIBE combined.

Image Quality

There is no significant difference in overall image quality between sequences (►**Table 3**).

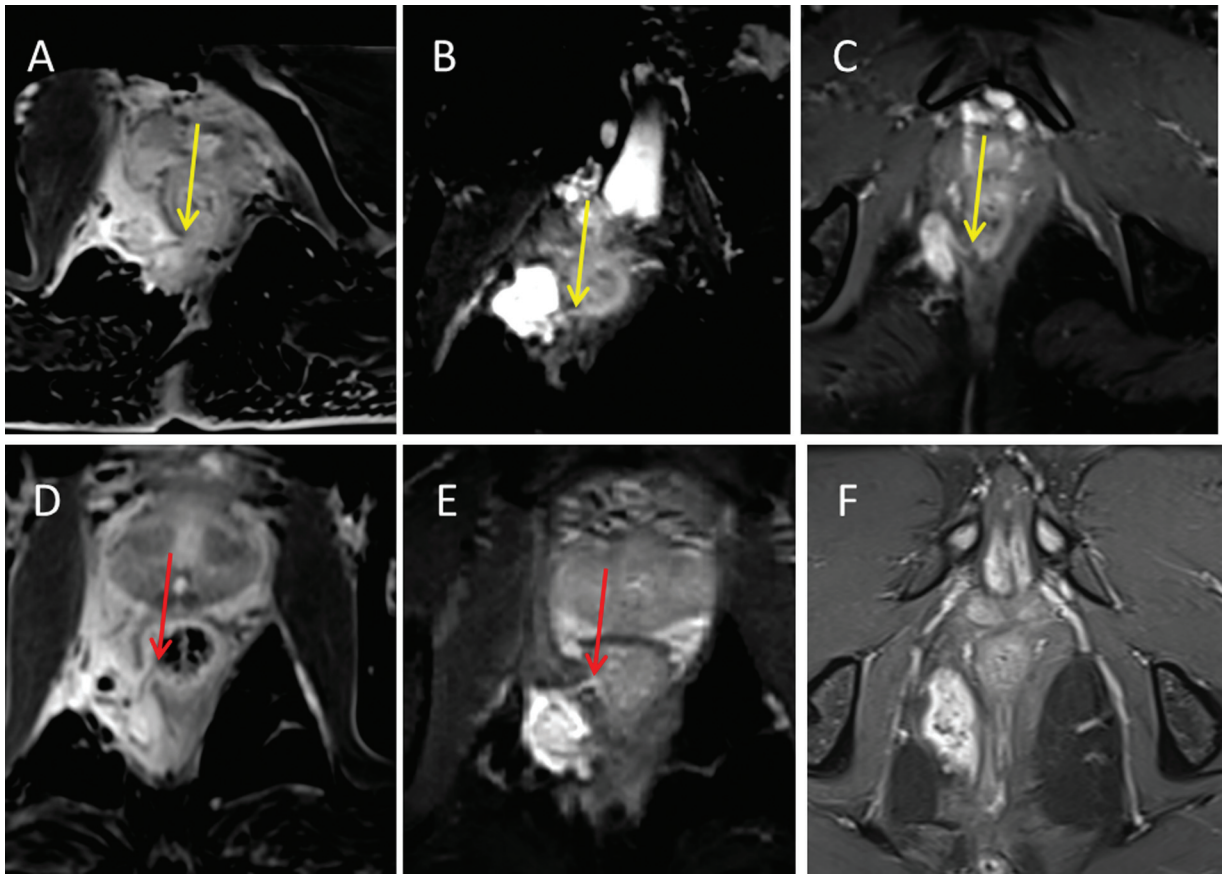

Fig. 5 Postcontrast oblique axial images: Internal opening at 7'o clock position (yellow arrow) demonstrated in on 3D T1 VIBE (A), 3D T1 space (B), and 2D T1 (C) sequences. The internal opening at 9'o clock position (red arrow) was demonstrated on 3D T1 VIBE (D) and 3D T1 space (E) sequences and not in 2D T1 image (F). 2D, two-dimensional; 3D, three-dimensional.

Table 3 Distribution of the sample according to image quality and artifacts

MRI	Number of patients		
	T1 VIBE	T1 SPACE	2D T1WI
Image quality			
Acceptable	0	2 (4%)	0
Fine	14 (32%)	7 (16%)	14 (32%)
Perfect	30 (68%)	25 (80%)	30 (68%)
Artifacts			
Moderate	2 (4%)	2 (4%)	0
Minimal	9 (20%)	11 (24%)	19 (44%)
None	33 (76%)	31 (72%)	25 (56%)

Abbreviations: MRI, magnetic resonance imaging; T1WI, T1-weighted imaging; 2D, two-dimensional.

Discussion

MRI has a significant role in presurgical assessment of perianal fistula because it can demonstrate the tract of a primary fistula, associated pelvic structures, hidden areas of sepsis, and secondary extensions, thereby increasing the success rate of surgical treatment.

The introduction of 3T MRI has been a game changer, as it introduced high spatial resolution isotropic 3D data acquisition, which is invaluable for perianal fistula mapping.[11] The main advantages of 3D compared with 2D imaging techniques are free slab positioning, operator independence, coverage of a larger area with thinner sections without intersection gaps, and increased signal-to-noise ratio (SNR) achieved with reduced imaging time. Every manufacturer has their 3D imaging technology: Siemens (VIBE, SPACE), GE (LAVA), and Philips (THRIVE, VISTA).

VIBE and SPACE were used in the present study. VIBE is a spoiled gradient-echo sequence that can produce T1WI with high contrast and spatial resolution in a relatively short acquisition time.[12] 3D SPACE is another volumetric MRI sequence that has recently been used in 1.5 and 3 Tesla scanners to produce different imaging weighting, including T1, T2, proton density, T1W fluid-attenuated inversion recovery (FLAIR), T2-FLAIR, double IR, and phase-corrected IR techniques.[13,14] SPACE sequence has a low specific absorption rate value because of low flip angles. A low flip angle results in higher spatial and contrast resolution.[15]

CE 2D T1WI requires multiple planes for precise perianal fistula mapping. Oblique coronal and oblique axial images must be acquired to assess the fistula tract's anatomical details and show supralevator and skin extension. Retrospective postprocessing of CE 2D T1WI is impossible in case of

errors in the field of view or imaging planes. However, CE 3D SPACE and 3D VIBE imaging overcome those limits. They are used to perform isotropic data acquisition on a single slab, allowing multiplanar reformatting in different imaging planes to improve examination efficiency. Free slab positioning, operator independence, and increased SNR are other advantages of 3D imaging. The 3D acquisition has the ability to cover a larger area with thinner sections without intersection gaps in a shorter imaging time. In the present study, the overall acquisition time for each 3D sequence was shorter compared with combined 2D lines (oblique axial and oblique coronal), with no significant difference in image quality. The results mentioned earlier were similar to the study done by Cerit et al.[8]

Image artifacts are less in 3D sequences than 2D sequences, possibly due to increased table time in 2D sequences leading to patient movement. In this study, the type of fistula was correctly categorized in all patients (100%) on the CE 3D T1 SPACE, CE 3D T1 VIBE, and CE 2D T1WI sequences. Thus, in assessing the type of fistula, this study did not show any statistically significant differences between 2D and 3D sequences.

Similarly, in a study conducted by Yildirim et al,[16] the contribution of various MRI sequences in determining the type of perianal fistula and for obtaining critical information for surgical decisions, as well as defining the optimal combination of sequences for readers with varying levels of experience were assessed. In their study, for all three readers, a statistically significant concordance was obtained between fistula classifications and surgical findings with the postcontrast FS T1WI. The *p*-values were 0.022, 0.011, and 0.043, respectively. The authors concluded that a high-resolution MRI of the perianal fistula with FS CE T1WI sequence showed statistically significant agreement with surgical findings in perianal fistula classification and had a low interobserver variance.

The precise identification and localization of internal orifices have an important role in reducing the recurrence rate and guiding surgical treatment in the perianal fistula. In this study, all internal orifices could be viewed on CE 3D T1 VIBE. On CE 3D T1 SPACE sequences, internal orifices were correctly depicted in 92% of the cases, and on CE 2D T1WI sequences, internal orifices were defined only in 80% of the cases. In support of our study, various researchers have shown that 3D MRI sequences are superior to 2D sequences in representations of the internal orifice of the perianal fistula. A study done by Torkzad et al[17] stated that postcontrast 3D T1-weighted gradient echo sequence with fat saturation (THRIVE) is superior to 2D T1 fat saturation (spectral presaturation with inversion recovery) in the depiction of the internal orifice. In their study, postcontrast 3D T1-weighted sequence showed better agreement compared with postcontrast FS 2D T1 sequences in the description of fistulae (Cohen's kappa = 0.94 or strong agreement), identifying internal openings (Cohen's kappa = 0.97 or perfect agreement), and evaluating inflammation (Cohen's kappa = 0.94 or strong agreement). The corresponding counts for the postcontrast 2D FS T1 sequences were 0.71 (good concordance), 0.66 (good concordance), and 0.87 (strong concordance), respectively. In another study by Zhao et al, they compared the CE FS 3D T1-weighted VIBE and FS T1-weighted turbo spin echo (TSE) sequence in characteristics of anal fistula.[18] They concluded that 3D T1 VIBE was more accurate and more valuable than 2D TSE T1 images in the assessment of anal fistula on evaluating the position of internal opening, secondary tracts, and classification of the complex fistula.

In our study, the ramifications were correctly identified in all patients in the 3D T1 VIBE sequence and 11 out of 14 patients in the 3D T1 SPACE sequences. Ramification was identified in only five patients in postcontrast 2D T1 sequences. Consequently, 3D sequences played a major role in treatment planning in our study. Similarly, Schaefer et al[19] demonstrated that high-resolution subtraction MRI fistulography consisting of high-resolution 3D T1-weighted gradient echo sequences (3D FLASH) and the image subtraction technique were important complements to surgical exploration, especially in the case of complex perianal fistulas. The study found that 90% of cases had complete agreement between MR fistulography and surgery.

Beyond the different study designs characterizing all the studies mentioned earlier, a common result is represented, that is, in the evaluation of perianal fistula, especially in complex fistulous tracts with ramifications and multiple internal orifices, the higher accuracy is for CE 3D T1 sequences over CE 2D T1WI sequence. The main limitation of our study was the smaller sample size. Further research with a large number of participants is necessary. The cases were examined by only one radiologist. It would have been beneficial if two experienced radiologists had seen it and analyzed the interreader agreement. In addition, there is a possibility of bias because all the contrast sequences were read during the same session.

Conclusion

In conclusion, CE 3D T1 sequences outperformed CE 2D T1 sequences, particularly in the evaluation of complex perianal fistulas in terms of visibility of internal orifices, number of internal openings, and identification of ramifications with a shorter scanning time in our study. Of the 3D sequences, CE 3D T1 VIBE was slightly better than the CE 3D T1 SPACE sequence in our study. However, the relatively small number of patients in this study requires this statement be validated by further research involving a larger number of patients.

Funding
None.

Conflict of Interest
None declared.

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