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FULL PAPER

Evaluation of shoulder pathology: three-dimensional enhanced T_1 high-resolution isotropic volume excitation MR vs two-dimensional fast spin echo T_2 fat saturation MR

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Objective: To evaluate the diagnostic accuracy of three-dimensional (3D) enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) shoulder MR for the detection of rotator cuff tears, labral lesions and calcific tendonitis of the rotator cuff in comparison with two-dimensional (2D) fast spin echo T_2 fat saturation (FS) MR.

Methods: This retrospective study included 73 patients who underwent shoulder MRI using the eTHRIVE technique. Shoulder MR images were interpreted separately by two radiologists. They evaluated anatomic identification and image quality of the shoulder joint on routine MRI sequences (axial and oblique coronal T_2 FS images) and compared them with the reformatted eTHRIVE images. The images were scored on a four-point scale (0, poor; 1, questionable; 2, adequate; 3, excellent) according to the degree of homogeneous and sufficient fat saturation to penetrate bone and soft tissue, visualization of the glenoid labrum and distinction of the supraspinatus tendon (SST). The diagnostic accuracy of eTHRIVE images compared with routine MRI sequences was evaluated in the setting of rotator cuff tears, glenoid labral injuries and calcific tendonitis of the SST.

Results: Fat saturation scores for eTHRIVE were significantly higher than those of the T_2 FS for both radiologists. The sensitivity and accuracy of the T_2 FS in diagnosing rotator cuff tears were >90%, whereas sensitivity and accuracy of the eTHRIVE method were significantly lower. The sensitivity, specificity and accuracy of both images in diagnosing labral injuries and calcific tendonitis were similar and showed no significant differences. The specificity of both images for the diagnosis of labral injuries and calcific tendonitis was higher than the sensitivities.

Conclusion: The accuracy of 3D eTHRIVE imaging was comparable to that of 2D FSE T_2 FS for the diagnosis of glenoid labral injury and calcific tendonitis of SST. The 3D eTHRIVE technique was superior to 2D FSE T_2 FS in terms of fat saturation. Overall, 3D eTHRIVE was inferior to T_2 FS in the evaluation of rotator cuff tears because of poor contrast between joint fluid and tendons.

Advances in knowledge: The accuracy of 3D eTHRIVE imaging is comparable to that of 2D FSE T_2 FS for the diagnosis of glenoid labral injury and calcific tendonitis of SST.

Decreasing MR examination time is important for improving patient comfort and reducing motion artefact.¹ Three-dimensional (3D) MRI with isotropic resolution can create multiplanar reformatted (MPR) images and enable the creation of similar sequences with different image planes, resulting in decreased scan time.^{2–4} 3D isotropic MR can minimize partial volume artefact using thin slice thickness (SL), which can analyse lesions without interslice gaps.⁵ Recently, a new 3D imaging sequence called 3D enhanced T_1 high-resolution isotropic volume excitation

MR (eTHRIVE) was developed.⁶ The eTHRIVE is a 3D T_1 weighted gradient sequence with dual half-scan and improved fat suppression that enables fast dynamic scanning with submillimetre in-plane resolution.⁷ Lee et al⁶ reported that eTHRIVE has the advantage of high-contrast resolution that reveals better diagnostic results through multiplanar reconstruction. These techniques were used to evaluate ligaments of the wrist within a shorter imaging time. However, to the best of our knowledge, no preliminary study has used eTHRIVE to

Table 1. Imaging parameters for routine MR sequences

Parameter	Coro T_2 FSE	Coro T_2 FS FSE	Coro T_1 FSE	Sag T_2 FSE	Axial FS PD FSE	Axial T_2 FS FSE
Repetition time (ms)	3200–3500	3200–3500	600–1000	2800–3000	3000	3200–3500
Echo time (ms)	60–90	60–80	10	60–90	30	60
Flip angle (°)	90	90	90	90	90	90
Matrix size (pixels)	356 × 262	356 × 262	340 × 250	356 × 250	340 × 250	356 × 260
Field of view (cm)	16	16	16	16	16	16
Slice thickness (mm)	3	3	3	4	4	4
Interslice gap (mm)	1	1	1	1	1	1
Bandwidth (kHz)	290	290	290	360	290	290
Echo train length	15	15	23	16	14	15
Signal average	2	2	2	2	2	2
Scan time (min:s)	2:48	2:50	2:50	2:05	2:30	2:30

Coro, coronal; FS, fat saturation; FSE, fast spin echo; PD, proton density; Sag, sagittal.

evaluate shoulder joint pathology. The purpose of this study was to evaluate the diagnostic accuracy of eTHRIVE shoulder MR regarding the detection of rotator cuff tears, labral lesions and calcific tendonitis of the rotator cuff in comparison with two-dimensional (2D) fast spin echo T_2 fat saturation (FS) MR.

METHODS AND MATERIALS

Case selection

Our institutional ethics review board approved this study and waived the requirement for informed consent owing to the retrospective study design. We retrospectively evaluated 73 patients who consecutively underwent shoulder MRI using the eTHRIVE technique. The study population comprised 35 (48%) males and 38 (52%) females (mean age, 50 ± 14 years; range, 22–84 years). Clinical indications for shoulder MR included unbearable shoulder pain and impaired mobility. Two radiologists and a clinician determined the final diagnosis for each

patient based on clinical impression, physical examination findings and plain radiography findings (for calcific tendonitis). Corresponding symptoms of rotator cuff injury included pain worsened by overhead shoulder movement, as well as loss of motion and weakness in the affected shoulder. Positive physical examination findings indicating a rotator cuff injury included Neer's sign and Hawkins's sign, both of which indicate pain when a physician elevated the patient's arm.⁸ Exclusion criteria included pyogenic arthritis (four cases), osteomyelitis (three cases), surgical history (two cases) and bone tumour (one case).

MR parameters

MR examinations were performed using a 3.0-T MR scanner (Achieva; Philips Healthcare, Best, Netherlands) with an eight-channel shoulder coil. Routine imaging parameters and sequences are summarized in Table 1. The eTHRIVE images were obtained using the following parameters: repetition

Table 2. Mean scores for anatomic identification and image quality

Image	Fat saturation		Labrum		Supraspinatus		Total	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
eTHRIVE	2.89 (± 0.31)	2.89 (± 0.31)	2.62 (± 0.54)	2.68 (± 0.50)	1.92 (± 0.55)	2.05 (± 0.57)	7.42 (± 0.78)	7.49 (± 0.75)
T_2 FS	2.32 (± 0.52)	2.38 (± 0.54)	2.90 (± 0.34)	2.93 (± 0.25)	3.00 (± 0.00)	2.96 (± 0.20)	8.22 (± 0.67)	8.27 (± 0.71)
<i>p</i> -value	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001

eTHRIVE, enhanced T_1 high-resolution isotropic volume excitation; fat saturation, homogeneous and sufficient fat saturation through bone and soft tissue; labrum, discrimination of the glenoid labrum; supraspinatus, discrimination of the supraspinatus tendon; T_2 FS, fast spin echo T_2 fat saturation. Data in parentheses are standard deviations.

Figure 1. The scores for anatomic identification and image quality of fat saturation in a 50-year-old female with shoulder pain. (a, c) An oblique coronal and axial fat saturated T_2 weighted images (repetition time/echo time, 3200/60 ms) showing non-homogenous fat saturation in the subcutaneous fat layer (arrows). Fat saturation in the bone marrow appears homogeneous. The score was 2. (b, d) Oblique coronal and sagittal images reformatted from enhanced T_1 high-resolution isotropic volume excitation MRI demonstrating homogeneous fat saturation in the soft tissue and bony structures (arrows). The score was 3.

time/echo time (TR/TE) = 12/7 ms; flip angle = 12°; SL = 0.6 mm; overlap = 0; matrix = 270×270 pixels; field of view = 160×160 mm; number of acquisitions = one; and average scan time = 3 min 30 s.

Figure 2. The scores for anatomic identification and image quality of the labrum in a 65-year-old female with shoulder pain. (a) Axial images reformatted from enhanced T_1 high-resolution isotropic volume excitation MRI demonstrating poor delineation of the glenoid labrum (arrows). The score was 2. (b) Axial fat saturated T_2 weighted images (repetition time/echo time, 3200/60 ms) demonstrating apparent shapes of the glenoid labrum (arrows). The score was 3.

Figure 3. The labrum scores for anatomic identification and image quality in a 29-year-old male with shoulder pain after exercise. (a) An axial fat saturated T_2 weighted image (repetition time/echo time, 3200/60 ms) demonstrating poor differentiation between the anterior glenoid labrum (long arrow) and middle glenohumeral ligament (short arrow). The score was 2. (b) Axial images reformatted from enhanced T_1 high-resolution isotropic volume excitation MRI demonstrating a tear of the anterior glenoid labrum (arrow). The score was 3.

The isovolumetric multiplanar images were generated along oblique coronal, oblique sagittal and axial planes with 3-mm SL immediately at the operating console and then transferred to the picture archiving and communication system. The time required for image reformation was about 2 min.

Image analysis

Two fellowship-trained musculoskeletal radiologists with 6–13 years of clinical experience offered separate interpretations of shoulder MR images; they were blinded to any radiographic reports or clinical history of the subjects. The analysis included anatomic identification and image quality evaluation of shoulder joints on

Figure 4. An example of a false-negative partial tear of the supraspinatus tendon (SST) on enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) in the same patient from Figure 2. (a) An oblique coronal image reformatted from eTHRIVE MRI demonstrating an intact SST in the setting of poor contrast between the joint fluid and tendon (arrow). (b) Oblique coronal fat saturated T_2 weighted image (repetition time/echo time, 3200/60 ms) demonstrating a partial tear of the SST (arrow).

Table 3. Interobserver agreement and diagnostic accuracy (kappa value)

Image	Rotator cuff tear	Labral injury	Calcific tendinitis
eTHRIVE	0.853 (<0.001)	0.805 (<0.001)	0.940 (<0.001)
T_2 FS	0.887 (<0.001)	0.888 (<0.001)	0.916 (<0.001)

eTHRIVE, enhanced T_1 high-resolution isotropic volume excitation; T_2 FS, fast spin echo T_2 fat saturation. Numbers in parentheses are p -values.

routine MRI sequences (axial and oblique coronal T_2 FS images), as well as reformatted eTHRIVE images. Subjective scoring of the images was performed using the degrees of homogeneous and sufficient fat saturation through bone and soft tissue, discrimination of the shape of glenoid labrum and discrimination of the shape of the SST according to a four-point scale (0, poor; 1, questionable; 2, adequate; 3, excellent).^{9,10} Scoring of fat saturation was determined as follows: (a) if homogeneous fat saturation was seen in the bone and soft tissue, then the score was 3; (b) if heterogeneous fat saturation was seen in the soft tissue, then the score was 2; (c) if heterogeneous fat saturation was seen in the bone and soft tissue, then the score was 1; and (d) if little or no fat saturation was seen, then the score was 0. First, the readers evaluated subjective scoring of eTHRIVE images only. Then, to prevent recall bias, they evaluated subjective scoring of routine MR images 1 week later at the next session. Diagnostic accuracy of eTHRIVE images and routine MRI sequences was evaluated based on whether a rotator cuff tear, glenoid labral injury or calcific tendinitis of the SST was identified. Each evaluation was performed at different times with at least a week interval. Full thickness tear of the SST comprised visualization of a complete defect from the articular aspect to the bursal side of the tendon.¹⁰ If a partial defect was seen in the SST extending along either the articular or bursal surface, then the diagnosis was a partial tear of the SST.⁹ The diagnosis of calcific tendinitis was based on visualization of a partially torn, swollen tendon with a signal void. Glenoid labral tear was diagnosed in cases of full thickness tear, avulsion from the glenoid or being crushed.¹¹

Statistical analysis

The two radiologists graded anatomic identification and image quality on routine and eTHRIVE images, which were then compared. To determine the statistical significance of image quality and anatomic identification scoring, Wilcoxon signed-rank tests were used. Interobserver agreement of diagnostic

accuracy was analysed using kappa statistics. Kappa values were interpreted as follows: poor ($k \leq 0.1$), slight ($0.1 < k \leq 0.2$), fair ($0.2 < k \leq 0.4$), moderate ($0.4 < k \leq 0.6$), substantial ($0.6 < k \leq 0.8$) and near-complete agreement ($0.8 < k \leq 1$).¹² Diagnostic accuracy values of eTHRIVE and routine images were evaluated based on sensitivity, specificity and accuracy for diagnosing rotator cuff tears, glenoid labral injury or calcific tendinitis of SST. Arthroscopic or clinically confirmed diagnoses were used as a reference standard, and values were statistically analysed using the McNemar test. p -values ≤ 0.05 were considered to be statistically significant, and statistical analyses were performed using PASW® Statistics for Windows software v. 18.0 (IBM Corporation, Armonk, NY).

RESULTS

The mean scores for anatomic identification of the shoulder joint and p -values are summarized in Table 2. For both readers, the fat saturation scores for eTHRIVE were significantly higher than those for T_2 FS (Figure 1). Labrum discrimination scores and SST discrimination scores for eTHRIVE were significantly lower than the corresponding scores of T_2 FS (Figures 2–4). Regarding labral discrimination, all but one patient evaluated by T_2 FS had higher scores than by eTHRIVE. Interobserver agreement for diagnostic accuracy between the two readers was near complete for both eTHRIVE and T_2 FS (kappa values, 0.805–0.940) (Table 3). We found three cases of full thickness tear of SST and 27 cases of partial tear of SST arthroscopically and clinically. 43 cases had normal SST. We found 21 cases of labral tear and 52 cases of intact labra arthroscopically and clinically. There were 12 cases of calcific tendinitis on plain radiography and had clinical symptoms. Four patients had multiple lesions. 20 patients underwent an arthroscopic procedure (27%). 30 patients were diagnosed as having an intact rotator cuff and glenoid labra (41%). The final diagnoses of those who were diagnosed as total negative included adhesive capsulitis (17

Table 4. Sensitivity, specificity and accuracy of enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) and fast spin echo T_2 fat saturation (T_2 FS) in diagnosing rotator cuff tears

Image	Sensitivity (%)		Specificity (%)		Accuracy (%)	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
eTHRIVE	50.0 (15/30)	53.3 (16/30)	95.3 (41/43)	93.0 (40/43)	76.7 (56/73)	76.7 (56/73)
T_2 FS	93.3 (28/30)	96.7 (29/30)	100 (43/43)	93.0 (40/43)	97.3 (71/73)	94.5 (69/73)
p -value	0.002	<0.001	1.000	1.000	0.001	0.002

Numbers in parentheses are the number of patients used to calculate the percentages.

Figure 5. A false-negative case of a full thickness tear of the supraspinatus tendon (SST) per enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) in a 61-year-old male with shoulder pain while driving. (a) Oblique coronal image reformatted from eTHRIVE MRI showing no definite tear of the SST likely owing to poor contrast between the joint fluid and tendon (arrow). (b) Oblique coronal fat saturated T_2 weighted imaging (repetition time/echo time, 3500/60 ms) demonstrating a full thickness tear of the SST (arrow).

cases), cervical radiculopathy (10 cases) and lateral epicondylitis (3 cases). The sensitivity and accuracy of T_2 FS for the diagnosis of rotator cuff tears were $>90\%$, whereas those of eTHRIVE were significantly lower (Table 4, Figure 5). The specificity values of both images were similar. The sensitivity, specificity and accuracy of both images in diagnosing labral injury were similar and showed no significant differences (Table 5). The sensitivity, specificity and accuracy of both images in diagnosing calcific tendinitis were also similar and showed no significant differences (Table 6, Figures 6 and 7). The specificity of both images in diagnosing labral injuries and calcific tendinitis was higher than the sensitivity. In cases of partial tears of the supraspinatus tendon (SST), T_2 FS images appeared normal, whereas eTHRIVE images identified the correct diagnosis (Figure 8). In two cases, both images suggested normal tissue when in fact there was calcific tendonitis of the SST.

DISCUSSION

The advantage of 3D eTHRIVE sequence over 2D FSE imaging is a reduction in total scan time (3 min 30 s in eTHRIVE vs 7 min 30 s in T_2 FS axial, sagittal and coronal images) for isovolumetric imaging.⁶ Using the proposed method, we produced $0.6 \times 0.6 \times 0.6$ -mm-sized isovolumetric MPR images.

To acquire an ultrafast scan, eTHRIVE uses a small flip angle (in our study 12°) and short TR, which results in poor T_1 weighted contrast. To overcome this problem, eTHRIVE uses a 180° inversion pulse for the magnetization preparation delay between acquisition of the k-space lines and the inversion pulse.⁶ The eTHRIVE technique has been performed for imaging of the liver, breast and MR cholangiography. It is essentially a 3D T_1 weighted fast spin echo sequence with spectral attenuated inversion recovery fat suppression using the sensitivity encoding (SENSE) technique.¹³ The 3D eTHRIVE provides high resolution, contrast-enhanced imaging with thin-slice images and excellent fat saturation. Furthermore, 3D use yields multiplanar images, providing useful information in the evaluation of tendons.¹⁴ In our evaluation of anatomical identification and image quality, eTHRIVE was superior to T_2 FS regarding fat saturation but inferior in the discrimination of the shape of the labrum and SST. We found inhomogeneous fat saturation patterns in T_2 FS images, especially in soft tissues; however, fat saturation of the bone marrow was sufficient (Figure 1). In the evaluation of the labrum and SST, mean scores were lower in eTHRIVE than in T_2 FS, likely because of poor contrast between the joint fluid and labrum, as well as between the subdeltoid fluid and SST. Moreover, the fibre bundle of the distal SST in eTHRIVE imaging was not as apparent as in T_2 FS. Margin sharpness of the glenoid labrum and SST in eTHRIVE images was less apparent than in T_2 FS. We investigated whether eTHRIVE was comparable to T_2 FS in sensitivity, specificity and accuracy of diagnosing rotator cuff tears, labral injuries and calcific tendinitis. The kappa values of interobserver agreement for diagnosis were >0.80 in both images, indicating nearly complete agreement. Table 4 reveals lower sensitivity and accuracy of eTHRIVE in the evaluation of rotator cuff tears, suggesting an inferior diagnostic ability, except for specificity. We assume that inferior demarcation of the tendon margin and poor contrast between fluids (or haematoma) and ruptured tendon of eTHRIVE might result in lower sensitivity and accuracy. In two cases of partial SST tears, one full thickness tear was undetected owing to poor contrast (Figures 4 and 5). On the contrary, in one case of a partial SST tear combined with calcific tendonitis, the partial tendon tear was not seen on T_2 FS but was prominent on eTHRIVE. This result may have been owing to focal enhancement of the tendon in the setting of inflammatory changes of the injured tendon at the bursal side (Figure 8). In our study, we did not find any significant differences between eTHRIVE and T_2 FS in diagnosing labral

Table 5. Sensitivity, specificity and accuracy of enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) and fast spin echo T_2 fat saturation (T_2 FS) in diagnosing labral injury

Image	Sensitivity (%)		Specificity (%)		Accuracy (%)	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
eTHRIVE	61.9 (13/21)	71.4 (15/21)	96.2 (50/52)	94.2 (49/52)	86.3 (63/73)	87.7 (64/73)
T_2 FS	76.2 (16/21)	76.2 (16/21)	100 (52/52)	94.2 (49/52)	93.2 (68/73)	89.0 (65/73)
p-value	0.581	1.000	1.000	1.000	0.302	1.000

Numbers in parentheses are the number of patients used to calculate the percentages.

Table 6. Sensitivity, specificity and accuracy of enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) and T_2 fat saturation (FS) MR in diagnosing calcific tendinitis

Image	Sensitivity (%)		Specificity (%)		Accuracy (%)	
	Reader 1	Reader 2	Reader 1	Reader 2	Reader 1	Reader 2
eTHRIVE	83.3 (10/12)	75.0 (9/12)	100 (61/61)	100 (61/61)	97.3 (71/73)	95.9 (70/73)
T_2 FS	50.0 (6/12)	50.0 (6/12)	100 (61/61)	98.4 (60/61)	91.8 (67/73)	90.4 (66/73)
<i>p</i> -value	0.125	0.250	1.000	1.000	0.125	0.125

Numbers in parentheses are the number of patients used to calculate the percentages.

injuries or calcific tendinitis (Tables 5 and 6). We concluded that 3D eTHRIVE had comparable accuracy to that of 2D FSE T_2 FS, at least in the diagnosis of glenoid labral injuries and calcific SST tendonitis; however, 3D eTHRIVE was superior to 2D FSE T_2 FS in fat saturation. The 3D isotropic images can be used in clinical practice because they produce MPR images and can shorten the total acquisition time by obviating the need to acquire the same sequence in different planes.¹⁵

Therefore, the more important issue is the scan time of eTHRIVE. Our mean scan time for eTHRIVE was about 3 min 30 s, whereas the total scan time for three sequences of 2D FSE T_2 FS was about 7 min 30 s. This amounted to a 53% reduction in scan time. Thus, if we replaced routine T_2 FS with 3D eTHRIVE, the scan time benefit would be >50%. We can consider 3D eTHRIVE imaging as a substitute for three sequences of T_2 FS as long as the main purpose of MR is to

Figure 6. A case of calcific tendinitis involving the supraspinatus tendon (SST) seen on both images in a 59-year-old female with shoulder pain after a motor vehicle accident. (a) Oblique coronal imaging reformatted from enhanced T_1 high-resolution isotropic volume excitation (eTHRIVE) MRI demonstrating a prominent low-signal lesion in the distal portion of the SST (arrow). (b) Oblique coronal fat saturated T_2 weighted imaging (repetition time/echo time, 3200/60 ms) with a low-signal lesion in the SST not prominently seen on eTHRIVE imaging (arrow). (c) Plain radiography demonstrating an apparent calcific lesion in the SST, suggestive of calcific tendonitis (arrow).

Figure 7. A case of calcific tendinitis involving the supraspinatus tendon (SST), which was not seen on fast spin echo T_2 fat saturation, in a 64-year-old male who complained of shoulder pain with no history of trauma. (a) Oblique coronal fat saturated T_2 weighted imaging (repetition time/echo time, 3200/60 ms) with no definite signal void lesion in the SST. Instead, focal tendon irregularities suggest a partial tear (arrow). (b) Oblique coronal imaging reformatted from enhanced T_1 high-resolution isotropic volume excitation MRI demonstrating clustered irregularly shaped low-signal lesions suggestive of calcific lesions in the distal portion of the SST (arrow). (c) Plain radiography demonstrating a calcific lesion in the SST (arrow).

Figure 8. A case of a partial supraspinatus tendon (SST) tear combined with calcific tendonitis not seen on fast spin echo T_2 fat saturation in a 67-year-old female who complained of shoulder pain with no history of trauma. (a) Oblique coronal imaging reformatted from enhanced T_1 high-resolution isotropic volume excitation MRI demonstrating a partial tear of the SST (arrow). A calcific lesion just distal to the tear is also seen. (b) Oblique coronal fat saturated T_2 weighted imaging (repetition time/echo time, 3200/60 ms) with no definite partial tear of the tendon (arrow) except a calcific lesion in the distal portion.

diagnose glenoid labral injury or calcific tendonitis, although the technique should not be used to detect a rotator cuff injury.

Some limitations of this study should be mentioned. First, our study included a small number of patients with each positive finding, although the total number of positive findings was significant. Our second limitation stems from the lack of sufficient surgical confirmation. Only 27% of patients underwent arthroscopic surgery. However, great care was taken to overcome this problem and to diagnose the best possible standard of reference in non-surgical cases using clinical findings, as well as other imaging modalities including other available MR sequences, plain radiography and consensus reading. The third limitation was that our study lacked objective quantitative analysis of the anatomic identification and image quality evaluation. We adopted a subjective scoring method, and the three categories for evaluation had different variables including different weights; therefore, the value of the total score was limited.

In conclusion, 3D eTHRIVE had comparable accuracy to 2D FSE T_2 FS in diagnosing glenoid labral injuries and calcific SST tendinitis. Finally, 3D eTHRIVE was superior to 2D FSE T_2 FS in terms of fat saturation but was inferior to T_2 FS in the evaluation of rotator cuff tears, most likely owing to poor contrast between joint fluid and tendons. We acknowledge that our research is based on a small-sized study that limits the value of the conclusion.

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