

## Fast Spin Echo STIR Imaging

Robert C. Smith, R. Todd Constable, Caroline Reinhold, Thomas McCauley,  
Robert C. Lange, and Shirley McCarthy

---

**Objective:** Our goal was to evaluate the image quality, contrast characteristics, and possible clinical utility of STIR images obtained using a fast SE (FSE) technique.

**Materials and Methods:** The signal and contrast characteristics of FSE STIR images were evaluated using a lipid/water phantom and normal volunteers. Based upon these results, optimal FSE STIR imaging parameters were chosen. Conventional STIR and FSE STIR images were then obtained (while maintaining an equal number of section locations between the two sequences) in a series of 14 patients with known musculoskeletal abnormalities. These images were compared side by side by two experienced MR radiologists for image quality and lesion detection.

**Results:** There were no statistically significant differences between the FSE STIR images and conventional STIR images in lesion detection, image quality, motion artifact, or final diagnosis.

**Conclusion:** STIR imaging provides optimal contrast for detection of many pathologic abnormalities. This is especially true for musculoskeletal tumors and infection. The long imaging time and reduced number of sections obtainable with conventional SE (CSE) STIR sequences limit their routine use. Our results show that FSE STIR images of the musculoskeletal system can be obtained up to seven times more rapidly than CSE STIR images without compromising lesion detection or image quality.

**Index Terms:** Magnetic resonance imaging, techniques—Muscles—Bones.

---

In MRI most pathologic abnormalities have increased T1 and T2 relaxation times. With conventional SE (CSE) sequences, these characteristics result in a relatively hypointense appearance on T1-weighted images and relatively hyperintense appearance on T2-weighted images.

Inversion recovery sequences apply a 180° inversion pulse prior to the 90° pulse of an SE sequence. The time between the inversion pulse and the 90° pulse is referred to as TI or  $\tau$ . When a short value of TI is used, the sequence is referred to as a STIR sequence. In STIR sequences the increase in both the T1 and the T2 relaxation times of most patho-

logic abnormalities is used to produce increased signal intensity. In addition, lipid signal is suppressed on STIR images. Therefore, STIR images usually provide optimal contrast for lesion detection (1,2).

While the acquisition time of STIR sequences is comparable with that of conventional T2-weighted sequences, the number of section locations that can be obtained is reduced because of the addition of TI to the intrasequence time. This is a major disadvantage of the STIR technique. A prior study evaluated STIR-like images obtained more rapidly by using a short TR and short TI with CSE sequences (3). By adding an inversion pulse to the beginning of a fast SE (FSE) sequence (4), STIR-like images can also be obtained with markedly reduced imaging times.

This study compares the imaging characteristics of the FSE STIR sequence with those of a conventional STIR sequence and compares FSE STIR and conventional STIR images in a series of patients undergoing MRI for known musculoskeletal abnormalities.

---

From the Department of Diagnostic Imaging, Yale University School of Medicine, New Haven, Connecticut, U.S.A. (R. C. Smith, R. T. Constable, T. McCauley, R. C. Lange, and S. McCarthy); and Department of Radiology, Montreal General Hospital, Montreal, Quebec, Canada (C. Reinhold). Address correspondence and reprint requests to Dr. R. C. Smith at Department of Diagnostic Imaging, Yale University School of Medicine, 333 Cedar St., New Haven, CT 06510, U.S.A.

## MATERIALS AND METHODS

All imaging was performed using a 1.5 T MRI system (GE Signa, Milwaukee, WI, U.S.A.). The STIR sequence we have routinely employed on this system using a CSE sequence consists of TR = 2,000 ms, TE = 43 ms, TI = 140 ms, two signal averages, 256 × 128 matrix, and a bandwidth of ±6 kHz. This sequence provides nine section locations in 9 min.

To generate STIR images more rapidly, we modified a standard FSE sequence (4) by adding a 180° inversion pulse to the beginning of the sequence. We initially compared the FSE STIR sequence with the conventional STIR sequence using a lipid/water phantom consisting of a tube of corn oil and a tube of distilled water. The FSE STIR sequence used an echo train length (ETL) = 8 or 16, echo spacing (ESP) = 18 ms, TR = 2,250 or 4,500 ms, effective TE = 36–126 ms (in 18 ms increments), TI = 60–160 ms (in 20 ms increments), two signal averages, 256 × 128 matrix, and a bandwidth of ±16 kHz. The TR and ETL were chosen such that the number of section locations was held constant between the conventional and FSE STIR sequences. Thus, a TR of 2,250 ms was used with an ETL of 8, and a TR of 4,500 ms was used with an ETL of 16. This yields nine section locations for all sequences.

The phantom was evaluated for the degree of elimination of lipid signal, signal-to-noise ratio (S/N), and contrast-to-noise ratio of the lipid and water components. Based upon these results, a limited number of variations of the FSE STIR sequence were then tested on healthy volunteers. The S/N and contrast characteristics of these images resulted in the selection of parameters of an FSE STIR sequence to be used for clinical studies.

An equal number of section locations can be obtained with an FSE sequence by halving both the TR value and the ETL. This does not affect the imaging time. Phantom studies compared FSE STIR images using TR = 2,250 ms and ETL = 8 with a sequence using TR = 4,500 ms and ETL = 16. The water signal increased by 50–60% when using the longer TR value. We therefore chose TR = 4,500 ms for our clinical imaging sequence to maximize lesion signal.

Following approval by the university human investigation committee, a series of 14 consecutive patients (excluding patients referred for routine examinations) referred for clinical MRI were studied. The specific abnormalities and the number of patients with each are shown in Table 1. In addition to our routine imaging, each of these patients underwent STIR imaging using both a conventional STIR and an FSE STIR sequence. The FSE STIR sequence used TR = 4,500 ms, effective TE = 126 ms, TI = 100 ms, ETL = 16, and echo spacing = 18 ms. This sequence yields nine section locations

TABLE 1. *Musculoskeletal lesions of patients imaged*

Ganglion cyst (1)
Bone infarct (2)
Osteomyelitis (3)
Myositis/cellulitis (1)
Neurofibromatosis (1)
Bone bruise (1)
Ewing sarcoma (1)
Avascular necrosis (1)
Cellulitis (2)
Osteogenic sarcoma (1)

Values in parentheses are numbers of patients.

in 1 min, 15 s. Both sequences were performed in the same plane, using the same coil, with identical field of view, section thickness, and intersection spacing.

After removing all image identification data, the STIR images for each patient were randomly labeled as A or B. The images were then compared side by side by two experienced MR radiologists for lesion detection, overall quality, motion artifact, and final diagnosis. For each case, the images were scored as A > B, A = B, or B > A. Those cases scored as A = B were discarded and the remainder compared using a two-tailed binomial distribution. Due to obvious differences in signal intensity of muscle between the two sequences, it was impossible to completely blind the interpreters.

For each case, the signal intensity from a representative portion of the detected lesion as well as the signal intensity of background noise and muscle were calculated.

## RESULTS

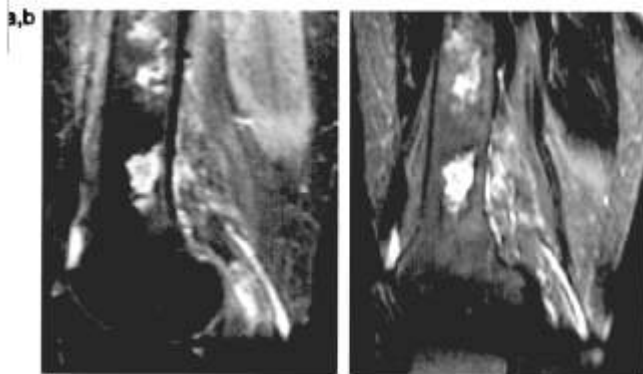
Phantom studies showed the lipid signal to be nulled with the FSE sequence when TI was 110–120 ms. Imaging of volunteers showed the signal of subcutaneous fat to be nulled when TI was 130–140 ms.

Phantom studies with the FSE sequence showed that the degree of image blurring in the phase direc-

TABLE 2. *Results of individual scorers*

	STIR	FSE STIR	Equal
Reader 1			
Better overall quality	7	3	4
Less motion artifact	4	2	8
Better lesion detection	0	1	13
Reader 2			
Better overall quality	7	4	3
Less motion artifact	7	4	3
Better lesion detection	0	2	12

The numbers represent the number of cases (of a total of 14) scored as STIR images superior (STIR), fast SE (FSE) STIR images superior (FSE STIR), or STIR images and FSE STIR images equal (Equal). In all cases, the final diagnosis was the same for the images obtained with both sequences.



**FIG. 1.** Conventional STIR image (a) and fast SE (FSE) STIR image (b) in a patient with bone infarcts involving the distal femur. Note the relative higher signal intensity of skeletal muscle and slightly lower relative signal intensity of subcutaneous fat in (a). The signal intensities of lesion/noise/muscle for the STIR image are 340/3/141 and for the FSE STIR image 326/3/23.

tion decreased for increasing values of effective TE. This blurring was readily apparent on imaging of volunteers obtained using a TE of 36 or 54 ms.

Imaging of volunteers showed that the relative signal from skeletal muscle decreased with increasing values of effective TE. The S/N for skeletal muscle approached 1 for effective TE values of >90 ms. At these same long values of effective TE, anatomic landmarks were no longer discernible when TI was chosen to null the signal from subcutaneous fat.

Phantom studies showed that for identical value of effective TE, increasing the TR from 2,250 to 4,500 ms (and at the same time increasing the ETL

from 8 to 16 to keep imaging time constant) resulted in a 50–60% increase of the water signal.

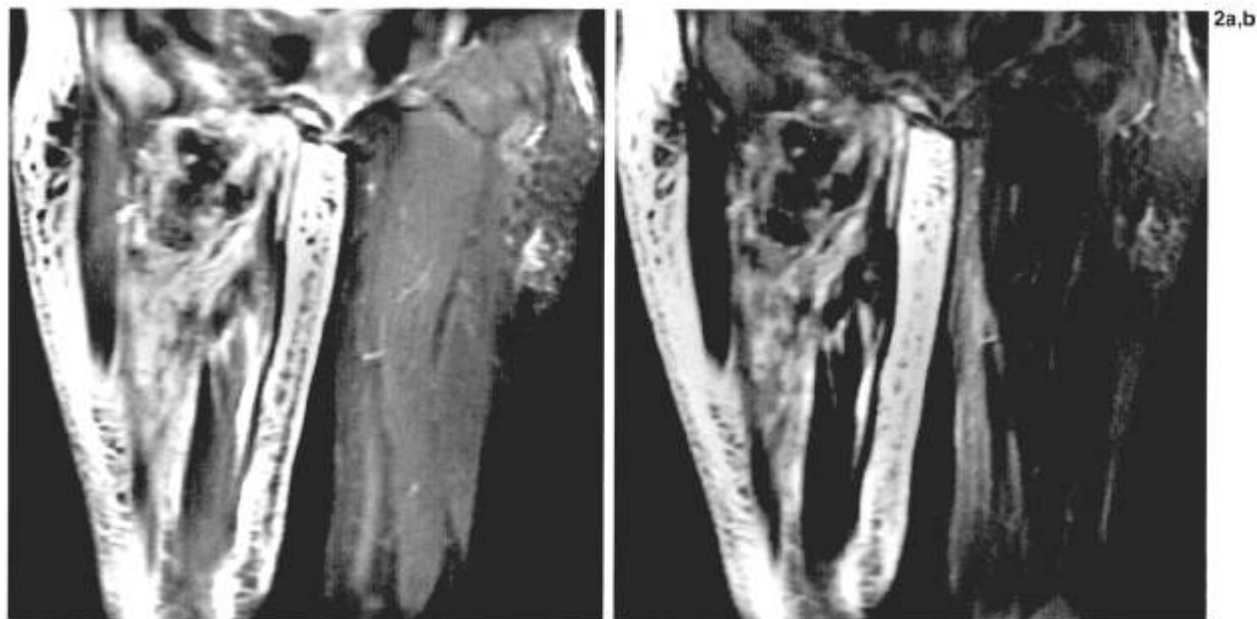
Clinical imaging performed on 14 patients with known musculoskeletal abnormalities showed no statistically significant differences in image quality, motion artifact, lesion detection, or final diagnosis between the FSE and conventional STIR sequences (Table 2). The FSE STIR images showed substantially lower signal intensity of skeletal muscle compared with the conventional STIR images. Several examples comparing conventional and FSE STIR images are shown in Figs. 1–5.

The S/N for all lesions was comparable between the conventional STIR and FSE STIR images. The ratio of the signal intensity of lesion to muscle was greater on the FSE STIR sequence in all cases. The values for representative cases are shown in the legends of Figs. 1, 3, and 5.

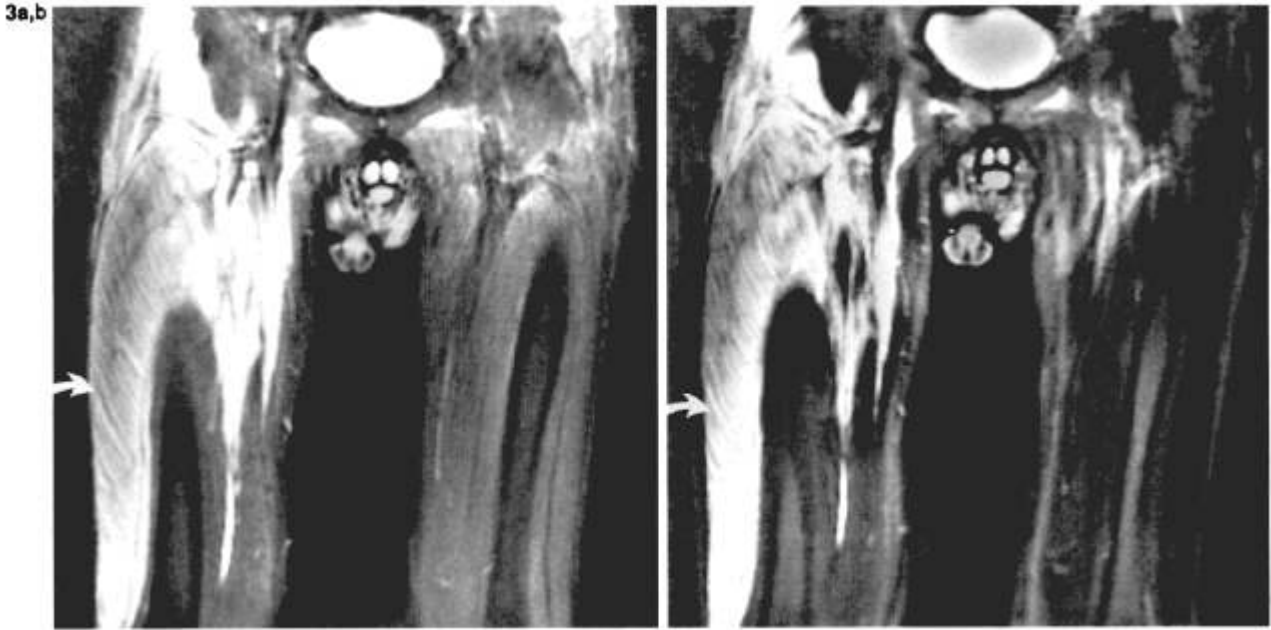
## DISCUSSION

By adding a 180° inversion pulse to an FSE sequence, STIR images can be obtained with substantially reduced imaging times. Following evaluation of phantoms and volunteers, this study compared images from a 9 min conventional STIR sequence with images from a 1 min, 15 s FSE STIR sequence in a series of 14 patients with known musculoskeletal abnormalities. Evaluation of these images showed equal lesion detection and conspicuity in all cases. There were no statistically significant differences in image quality or motion artifact.

The parameters for the FSE STIR sequence were



**FIG. 2.** Conventional STIR image (a) and fast SE (FSE) STIR image (b) in a patient with cellulitis with extensive edema of the subcutaneous tissues of the right upper thigh.



**FIG. 3.** Conventional STIR image (a) and fast SE (FSE) STIR image (b) in a patient with cellulitis of the right lower extremity and myositis of the vastus lateralis muscle (arrows). The signal intensities of lesion/noise/muscle for the STIR image are 154/5/90 and for the FSE STIR image 231/6/35.

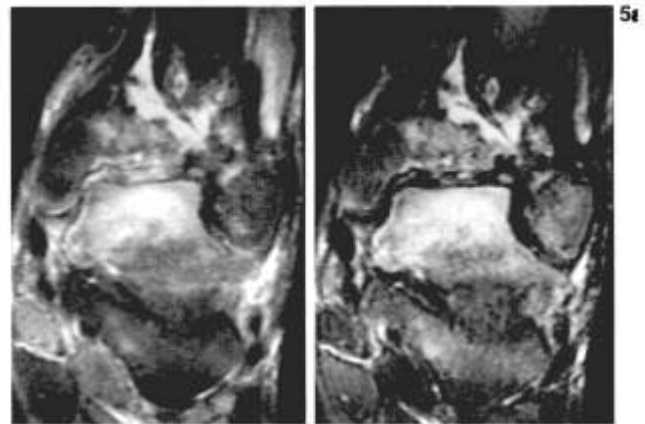
chosen to minimize imaging time while providing an equal number of section locations as the conventional sequence. A relatively long effective TE was chosen to minimize both image blurring and loss of small object contrast that can occur when using

FSE sequences (5,6). In this context, "small" means an object that spans only a few pixels in the phase encoding direction. Loss of small object contrast is most apparent for short T2 objects. Thus, theoretically, small lesions with short T2 may not be as apparent on FSE STIR images as on conventional STIR images. This difference can be minimized by use of a shorter ETL and shorter echo spacing. None of the lesions imaged in this study would be considered small and all had a long T2.

When using FSE sequences, there is no loss in the number of section locations with longer effec-



**FIG. 4.** Fast SE STIR image (a) and conventional STIR image (b) in a patient with Ewing sarcoma of the first metatarsal bone. The cystic changes present were unchanged over several years and were thought to represent changes secondary to radiation and chemotherapy.



**FIG. 5.** Conventional STIR image (a) and fast SE (FSE) STIR image (b) in a patient with osteomyelitis of the talus. Both images show diffuse abnormal increased signal of the marrow of the talus. The signal intensities of lesion/noise/muscle for the STIR image are 364/10/139 and for the FSE STIR image 239/7/27.

tive TE values. If we had used a TE of 126 ms with the conventional STIR sequence, only six section locations would have been obtainable.

Imaging of volunteers showed markedly diminished signal from skeletal muscle on FSE STIR images when using an effective TE of 126 ms (likely due to the short T2 value of muscle). Therefore, when using a value of TI that completely nulled the signal from fat, normal anatomic landmarks were difficult to discern. For this reason, we chose a TI of 100 ms so that a small fat signal persisted. The lower signal intensity of muscle with the FSE STIR sequence should provide greater contrast between lesion and muscle.

Since performing this study, we have anecdotally noted improvement in image quality and artifact reduction with the FSE STIR sequence by using a 192 instead of a 128 phase matrix. This increases imaging time by a factor of 1.5; however, there is still a significant time saving compared with conventional sequences. Additionally, since performing this study, the minimum value of the echo spacing has been reduced to 13 ms with commercially available versions of the FSE software. The shorter echo spacing reduces blurring and reduces loss of small object contrast.

We routinely use the FSE STIR sequence as a localizing sequence in all patients with suspected musculoskeletal tumor or infection. An additional high resolution FSE STIR sequence can be performed once an abnormality is identified. The higher resolution sequence can be obtained using decreased section thickness, smaller field of view and a higher phase matrix. The FSE STIR sequence is particularly useful when imaging with a surface

coil or multicoil (7,8). Under these circumstances, the high signal from subcutaneous fat immediately adjacent to the coils is eliminated. This markedly reduces ghost artifact.

In conclusion, the results of this study indicate that the FSE STIR sequence can provide STIR images much more rapidly than conventional sequences without compromising image quality or lesion detection.

## REFERENCES

1. Dwyer AJ, Frank JA, Sank VJ, Reinig JW, Hickey AM, Doppman JL. Short-TI inversion recovery pulse sequence: analysis and initial experience in cancer imaging. *Radiology* 1988;168:827-36.
2. Shuman WP, Patten RM, Baron RL, Liddell RM, Conrad EU, Richardson ML. Comparison of STIR and spin-echo MR imaging at 1.5 T in 45 suspected extremity tumors: lesion conspicuity and extent. *Radiology* 1991;179:247-52.
3. Fleckenstein JL, Archer BT, Barker BA, Vaughan JT, Parkey RW, Peschock RM. Fast short-tau inversion recovery MR imaging. *Radiology* 1991;179:499-504.
4. Smith RC, Reinhold C, Lange RC, McCauley T, Kier R, McCarthy S. Fast spin echo MR imaging of the female pelvis, part I. Use of a whole volume coil. *Radiology* 1992;184:665-9.
5. Constable RT, Anderson AW, Zhong J, Gore JC. Factors influencing contrast in fast spin-echo MR imaging. *Magn Res Imag* 1992;10:497-511.
6. Constable RT, Gore JC. The loss of small objects in variable TE imaging: implications for FSE, RARE, and EPI. *Magn Res Med* 1992;28:9-24.
7. Constable RT, Smith RC, Gore JC. Signal to noise and contrast in fast spin echo (FASE) imaging and inversion recovery. FAS imaging. *Comput Assist Tomogr* 1992;16:41-7.
8. Smith RC, Reinhold C, McCauley T, et al. Multicoil high resolution fast spin echo MR imaging of the female pelvis. *Radiology* 1992;184:671-5.