

Nonspecificity of Short Inversion Time Inversion Recovery (STIR) as a Technique of Fat Suppression: Pitfalls in Image Interpretation

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Short inversion time inversion recovery (STIR) and the rapid acquisition with relaxation enhancement (RARE) version of STIR are commonly used pulse sequences that are sensitive enough to detect a broad range of pathologic conditions. In addition to suppressing the signal from fat, the STIR sequence achieves additive T1-weighted, T2-weighted, and proton density-weighted contrast to facilitate lesion conspicuity [1, 2]. Fat suppression with STIR sequences is based on short T1 relaxation rates and therefore is not tissue specific. The signal from any tissue with a short T1, similar to that of fat, may be nulled as well. The signal from tissues that accumulate paramagnetic contrast agents also may be suppressed with STIR sequences when an appropriate degree of T1 shortening results.

The purpose of this pictorial essay is to present a series of cases in which the signal from a variety of nonfatty tissues and fluids was nulled on STIR imaging. Awareness of the nonselective signal suppression achieved with STIR pulse sequences may help practitioners avoid errors in image interpretation.

Physics

The STIR sequence uses an initial 180° RF pulse to invert spins in the longitudinal plane. After a short time delay (known as inversion time [TI]), this initial RF pulse is followed by a conventional spin-echo or RARE sequence. The RARE technique uses a train of 180° RF pulses that follow an initial 90° excitation pulse [2]. To achieve fat suppression, a TI should be

selected such that the longitudinal magnetization of the fat spins is zero when a subsequent 90° pulse is applied. The TI that will negate the signal from fat is equal to 0.69 times the T1 relaxation time of fat, provided that the selected TR is significantly greater than T1 [1]. Because T1 relaxation times are proportional to the applied magnetic field, the appropriate TI with STIR for nulling the signal from fat must be adjusted for a given magnet strength. For example, at 1.0 T, the T1 of fat is about 200 msec and the appropriate TI with STIR is 135–150 msec; at 1.5 T, the T1 of fat is approximately 250 msec and the TI used to achieve fat suppression is 155–175 msec [3]. Even at a given magnetic field strength, the TI that maximally nulls the fat signal varies slightly from patient to patient, possibly because of differences in fat composition [4].

STIR pulse sequences rely on the relatively short T1 relaxation time of adipose tissue to achieve fat suppression. This technique is quite different from the frequency-selective fat suppression technique, in which the signal from fat protons is selectively nulled on the basis of the intrinsic chemical shift differences between lipid and water protons. Because STIR sequences will suppress the signal from any tissue or fluid that—like fat—has a short T1 relaxation time, this technique of fat suppression may be considered nonselective.

Postgadolinium STIR

STIR sequences used after the administration of gadolinium chelates can produce misleading results, depending on

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the concentration in regional tissue of the paramagnetic agent and the resulting degree of T1 shortening. If the T1 of any tissue, normal or pathologic, is reduced to that of adipose tissue, the signal from that tissue will be appropriately nulled by STIR (Figs. 1 and 2). This nulling may result in decreased conspicuity of pathologic conditions or a misinterpretation of signal suppression as constituting fat. For these reasons, STIR sequences should be used before the administration of gadolinium chelates; after gadolinium chelate

administration, an alternative fat suppression technique that is independent of T1 relaxation times should be used to produce images on which enhanced tissue is conspicuous.

Suppression of Nonfatty Tissue with Similar T1 Values

A variety of biological tissues and fluids may have a short T1 and therefore can be suppressed by STIR sequences. The most commonly suppressed are blood breakdown prod-

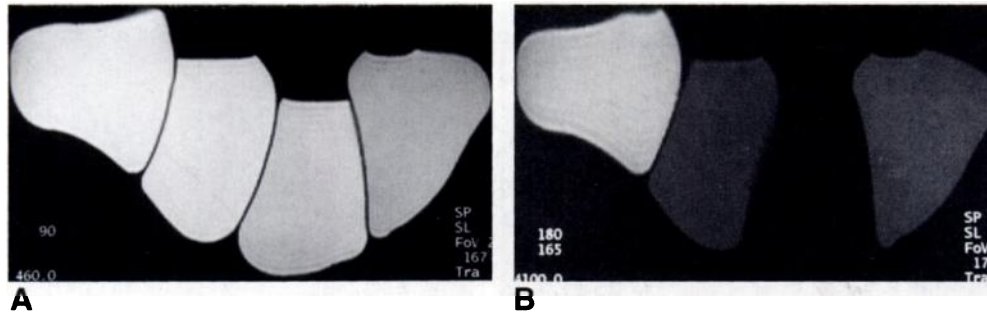


Fig. 1.—Serial dilutions of gadopentetate dimeglumine (Magnevist; Berlex Laboratories, Wayne, NJ) in 0.9% normal saline solutions result in solutions with concentrations of 2×10^{-3} , 1×10^{-3} , 5×10^{-4} , and 2.5×10^{-4} mmol/ml (from left to right, respectively, in A and B).

A, T1-weighted spin-echo MR image (460/20 [TR/TE]) shows progressively increased signal as gadolinium concentration is increased.

B, Turbo-short inversion time inversion recovery MR image (4100/60/165 [TR/TE/inversion time]) shows suppression of signal at gadolinium concentration of 5×10^{-4} mmol/ml.

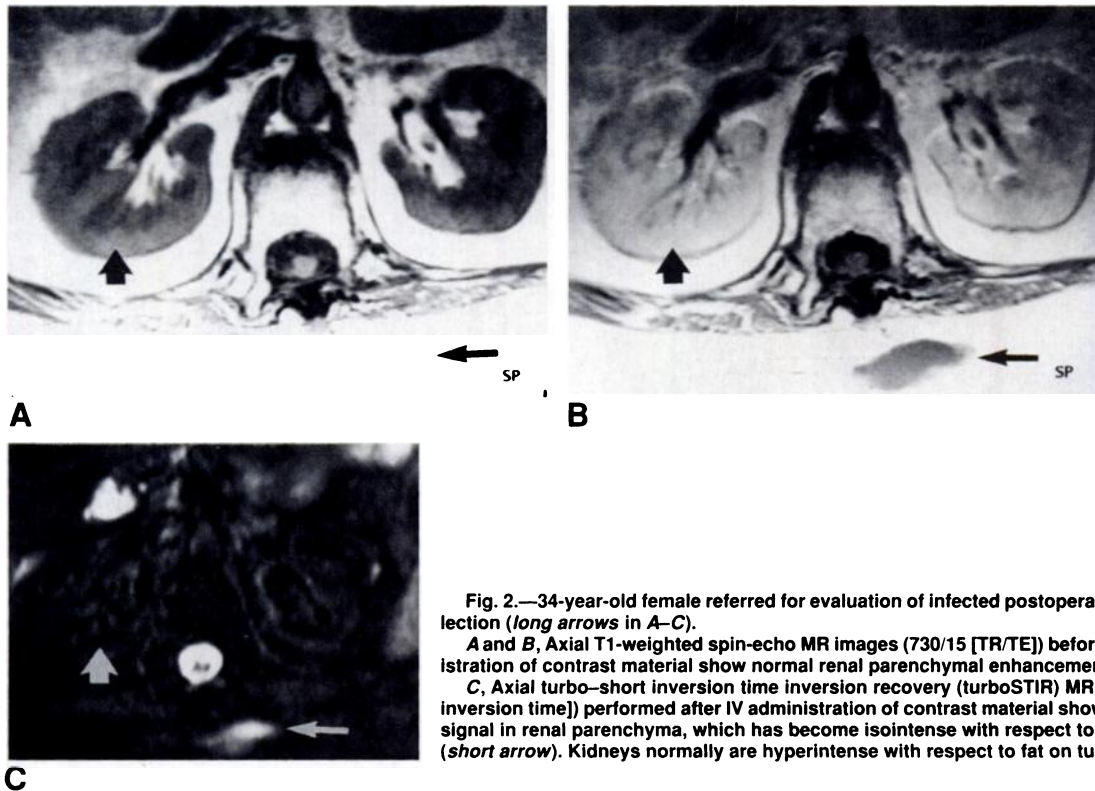


Fig. 2.—34-year-old female referred for evaluation of infected postoperative subcutaneous fluid collection (long arrows in A–C).

A and B, Axial T1-weighted spin-echo MR images (730/15 [TR/TE]) before (A) and after (B) IV administration of contrast material show normal renal parenchymal enhancement (short arrows).

C, Axial turbo-short inversion time inversion recovery (turboSTIR) MR image (8184/60/165 [TR/TE/inversion time]) performed after IV administration of contrast material shows complete suppression of signal in renal parenchyma, which has become isointense with respect to adjacent retroperitoneal fat (short arrow). Kidneys normally are hyperintense with respect to fat on turboSTIR images.

ucts, especially methemoglobin, which may be isointense with respect to fat on both T1- and T2-weighted images. Methemoglobin is common in hemorrhagic cysts but also can be seen in endometriomas and neoplasms that have bled (Figs. 3 and 4).

Because proteinaceous fluids and mucoid material also may have a T1 similar to that of adipose tissue, they may be suppressed by STIR sequences (Fig. 5). Other paramagnetic substrates that may shorten T1 include melanin, copper, and manganese. Therefore, melanoma—because of the presence of melanin or blood products (Fig. 6)—and certain hepatocellular carcinomas that contain copper [5] may show signal suppression with STIR sequences. Any tissue in which a contrast

agent accumulates can exhibit similar properties that shorten T1 relaxation times.

Conclusions

Signal suppression by STIR pulse sequences is based on T1 relaxation times and therefore is not tissue specific. To ensure effective characterization of tissue, a selective fat suppression technique should be used whenever a substrate is isointense with respect to fat on multiple pulse sequences and the substrate is suppressed on STIR imaging. In addition, STIR sequences should be used before the administration of contrast agents that facilitate T1 shortening.

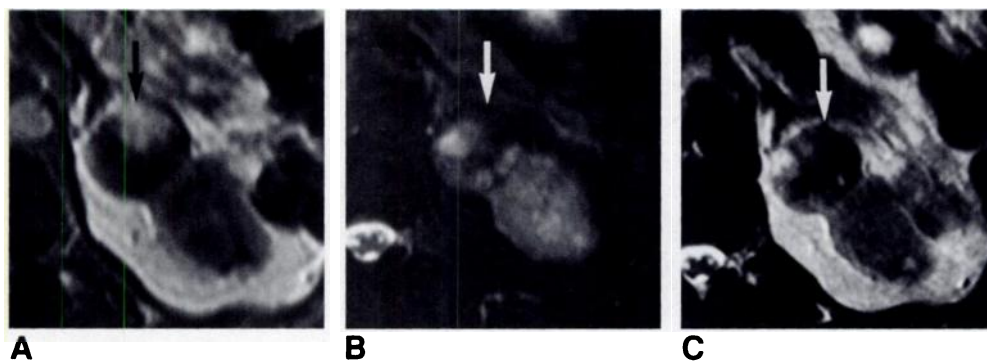


Fig. 3.—Left renal mass incidentally discovered on CT of patient referred for evaluation of liver lesions (*not shown*).

A, Axial T1-weighted spoiled gradient-echo MR image (200/4.8/60° [TR/TE/flip angle]) shows well-margined renal mass with focal area of increased signal intensity that is same as that of perinephric fat (*arrow*).

B, Axial turbo—short inversion time inversion recovery (turboSTIR) MR image (6820/60/165 [TR/TE/inversion time]) shows complete suppression of high-signal-intensity area seen on **A** (*arrow*). On basis of assumption that signal suppression with short inversion time recovery constitutes fat, suggested diagnosis is renal angiomyolipoma.

C, Axial turbo T2-weighted spin-echo MR image (5000/120 [TR/TE]) shows that corresponding portion of renal mass is not adipose tissue (*arrow*). Mass enhanced after IV administration of contrast material. Surgery revealed renal cell carcinoma with large area of hemorrhage that corresponded to this suppressed area on turboSTIR image.

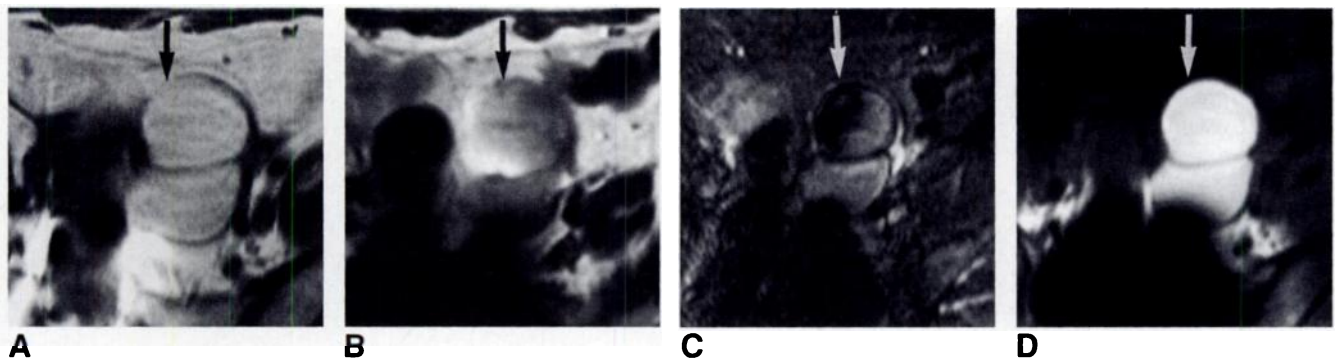


Fig. 4.—48-year-old woman referred for MR imaging to evaluate cystic pelvic mass seen on sonography.

A and B, Axial turbo T1-weighted spin-echo MR image (760/12 [TR/TE]) and turbo T2-weighted spin-echo MR image (3000/99) show bilobar left adnexal mass that is isointense with respect to adipose tissue on both images (*arrows*). Susceptibility artifacts adjacent to spine are attributable to orthopedic hardware for vertebral stabilization.

C, Axial turbo—short inversion time inversion recovery MR image (4100/60/165 [TR/TE/inversion time]) shows complete suppression of signal in medial aspect of adnexal mass (*arrow*), suggesting fat within dermoid plug.

D, Axial turbo T1-weighted spin-echo MR image with chemical shift selective fat suppression shows uniformly high-signal-intensity mass (*arrow*) to be consistent with hemorrhagic cyst or endometrioma; surgery revealed bilobar endometrioma.

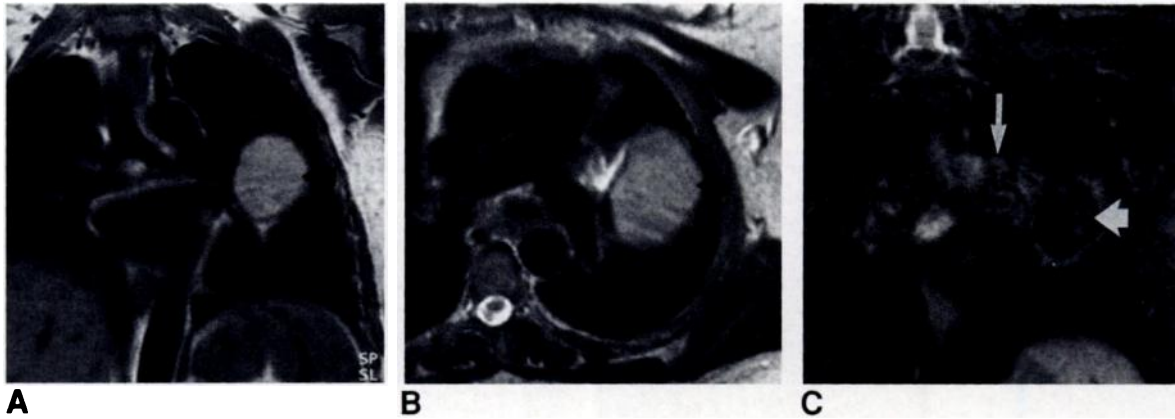


Fig. 5.—52-year-old woman referred for evaluation of fluid-density mass seen on contrast-enhanced chest CT.

A and B, ECG-triggered, coronal turbo T1-weighted spin-echo MR image (993/12 [TR/TE]) and axial turbo T2-weighted spin-echo MR image (3750/90) show well-circumscribed left hilar mass that is isointense with respect to adipose tissue on both images (arrows).

C, ECG-triggered, coronal turbo-short inversion time inversion recovery MR image (3750/60/165 [TR/TE/inversion time]) shows complete suppression of signal in hilar mass (short arrow). Note ghosting artifact (long arrow) in phase-encoding direction (left to right). Hilar mass failed to enhance after IV administration of contrast material. Surgical resection revealed infected bronchogenic cyst. Without preoperative CT evaluation, hilar mass may have been misinterpreted as fatty neoplasm.

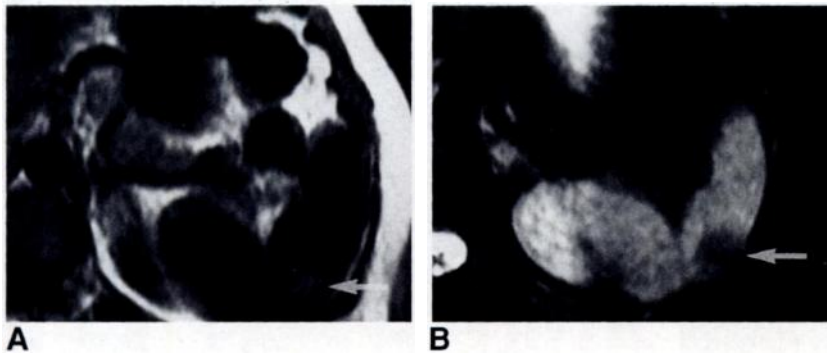


Fig. 6.—72-year-old woman with diffuse metastatic melanoma.

A, Axial T1-weighted spoiled gradient-echo MR image (137/4.4/80° [TR/TE/flip angle]) shows hyperintense splenic lesion (arrow).

B, Axial turbo-short inversion time inversion recovery MR image (7000/60/165 [TR/TE/inversion time]) shows complete suppression of signal in lesion (arrow), which had dramatically increased in size from prior examination, consistent with metastatic melanoma in spleen.

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