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AJNR Am J Neuroradiol 1994, 15 (4) 767-773

<http://www.ajnr.org/content/15/4/767>

This information is current as
of August 19, 2025.

MR of the Head and Neck: Comparison of Fast Spin-Echo and Conventional Spin-Echo Sequences

Robert Fulbright, David Panush, Gordon Sze, Robert C. Smith, and R. Todd Constable

PURPOSE: To compare conspicuousness of head and neck lesions on fast spin-echo sequences and conventional spin-echo sequences. **METHODS:** Forty consecutive patients with 61 head and neck lesions were evaluated. Lesion conspicuousness was qualitatively compared on conventional spin-echo and fast spin-echo sequences, using both spin-density and T2-weighted images. Thirty-six lesions had surgical or pathologic confirmation, and 25 were assigned a presumptive diagnosis based on clinical evaluation and imaging findings seen on conventional spin-echo T1- and T2-weighted sequences. Forty lesions were related to neoplasms; 21 lesions consisted of infectious, vascular, or inflammatory abnormalities. **RESULTS:** Fast spin-echo sequences provided improved lesion conspicuousness in 91% of spin-density images, in 77% of T2-weighted images, and in 84% of the combined spin-density and T2-weighted images. **CONCLUSION:** By providing shorter imaging times and equal or superior lesion conspicuousness, long-repetition-time fast spin-echo sequences can replace long-repetition-time conventional spin-echo sequences in evaluation of the head and neck.

Index terms: Head, magnetic resonance; Neck, magnetic resonance; Magnetic resonance, comparative studies; Magnetic resonance, technique

AJNR Am J Neuroradiol 15:767-773, Apr 1994

In magnetic resonance (MR) imaging of the head and neck, both T1-weighted and T2-weighted sequences help characterize normal and diseased tissues. With conventional spin-echo sequences, the longer imaging times of T2-weighted images and the inherent motion of the head and neck can result in motion artifacts that degrade image quality.

A fast spin-echo technique has been developed that produces long repetition time (TR) images with similar quality and tissue contrast as long-TR conventional spin-echo sequences, but with substantially shorter imaging times, and thus less artifact from physiologic motion (1-4). Compared with conventional spin-echo, fast spin-echo has demonstrated superior image quality in the pelvis (5-6) and has shown promise in imaging the brain

(7, 8), head and neck (9, 10), and spine (2, 11). To determine whether fast spin-echo sequences can replace conventional spin-echo sequences in evaluation of the head and neck, we compared the conspicuousness of 61 lesions on long-TR conventional spin-echo and long-TR fast spin-echo sequences.

Materials and Methods

The study group consisted of 40 consecutive patients referred for MR imaging with suspected abnormalities of the head and neck. The 27 male and 13 female patients ranged in age from 11 months to 90 years, with a mean age of 42 years.

Imaging was performed with a 1.5-T superconductive magnet (GE Signa, Milwaukee, Wis). All patients were scanned using a conventional spin-echo T1-weighted (600/201 [TR/echo time (TE)]) sequence, followed by long-TR conventional spin-echo and long-TR fast spin-echo sequences in the same scanning plane as the conventional spin-echo T1-weighted sequence (axial or coronal). Parameters for the long-TR conventional spin-echo sequences included 2000-2850/30, 80-84; 2 excitations were used in 11 patients, 1 in 29 patients. No phase wrap was used; first-order gradient moment nulling in the frequency encoding and section selection directions, and inferior and

Received March 30, 1993; accepted after revision July 6.

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AJNR 15:767-773, Apr 1994 0195-6108/94/1504-0767

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superior saturation pulses were used. For long-TR fast spin-echo sequences, the parameters were 2000–2500/14, 84 (effective TE) with 2 excitations. The echo spacing was 14 msec, and the echo train length was 8; the first four echoes generated spin-density images with an effective TE of 14; the last four echoes generated T2-weighted images with an effective TE of 84. No phase wrap was used. Both sequences used a 24-cm field of view, a 256 × 192 matrix, and a section thickness of 4 mm or 5 mm with interspace gaps of 1 mm or 2.5 mm, respectively. The section thickness and intersection gap were constant for conventional spin-echo and fast spin-echo sequences in each individual patient. Twenty patients were studied with a 25-cm head coil and 20 patients with an anterior neck coil. For conventional spin-echo sequences, the number of sections averaged 39; the scan time averaged 12 minutes, 4 seconds with 2 excitations (11 cases); and 8 minutes, 30 seconds with 1 excitation (29 cases). The double-echo fast spin-echo technique used 2 excitations in all cases and provided an average of 36 sections in an average time of 4 minutes, 22 seconds.

For each case, patient data and imaging parameters displayed on the films were covered from sight by opaque adhesive paper, the conventional spin-echo and fast spin-echo sequences randomly labeled A or B, and the films mounted on the viewing board side-by-side. Two experienced neuroradiologists, blinded to the type of pulse sequences and clinical history, examined both sequences together at the same time. Each physician independently gave a qualitative rating of lesion conspicuousness. A grading system for each finding consisted of: 1) A superior to B; 2) A equal to B; or 3) A inferior to B. The spin density and T2-weighted images of both sequences were compared separately, and an overall grade of lesion visibility using both sequences was also given. With each lesion, therefore, there were three comparisons of conventional spin-echo and fast spin-echo lesion conspicuousness: spin-density images alone, T2-weighted images alone, and spin-density and T2-weighted images together. For each reviewer's comparison, the cases scored as A equal to B were discarded and the remaining cases tested for statistical significance by means of a one-tailed binomial distribution. A value of $P \leq .05$ represented statistical significance. We used a weighted kappa statistic to evaluate interobserver variability (12).

There were 61 head and neck lesions in the 40 patients. Thirty-six lesions had pathologic or surgical confirmation,

including neoplasms (34 lesions). The remaining 25 lesions were assigned a presumptive diagnosis based on clinical evaluation and imaging findings seen on the conventional spin-echo T1- and T2-weighted sequences. These lesions consisted of benign adenopathy (eight lesions), benign-appearing sinus and mastoid inflammation (five lesions), fatty atrophy of the tongue in patients with proved squamous cell involvement of the hypoglossal nerve (two lesions), skin and salivary gland changes after radiation therapy (two lesions), Sjögren involvement of the parotid gland (one lesion), neck cellulitis (one lesion), neck hemangioma (one lesion), neck arteriovenous malformation (one lesion), mucocele (one lesion), nasopalantine canal cyst (one lesion), and a neurofibroma and an optic nerve glioma in a patient with clinically proved neurofibromatosis (two lesions).

Results

Except for adipose tissue, which had high signal on fast spin-echo sequences, the signal characteristics of normal tissue such as bone, muscle, salivary glands, and fluid appeared similar on conventional spin-echo and fast spin-echo sequences. In addition, the spectrum of lesions including cystic masses, neoplasms, infections, and inflammatory processes had the same signal characteristics on both sequences. For example, if the lesions appeared hyperintense on conventional spin-echo sequences, they were also hyperintense on fast spin-echo sequences.

Table 1 summarizes the comparison of lesion conspicuousness on fast spin-echo and conventional spin-echo sequences. Fast spin-echo provided superior lesion conspicuousness in 48% of the spin-density images, in 44% of the T2-weighted images, and in 48% of combined spin-density and T2-weighted images. Conventional spin-echo sequences resulted in superior lesion visibility in 9% of the spin-density images, in 23% of the T2-weighted images, and 16% of the combined spin-density and T2-weighted images. Lesion conspicuousness was equal on both sequences in 43% of the spin-density images, in

TABLE 1: Comparison of lesion conspicuousness between fast spin-echo and conventional spin-echo sequences, number (percentage) of lesions

	Spin-Density			T2-Weighted			Spin-Density and T2-Weighted		
	Reviewer 1	Reviewer 2	Average %	Reviewer 1	Reviewer 2	Average %	Reviewer 1	Reviewer 2	Average %
Fast spin-echo superior to conventional spin-echo	28 (46)	30 (49)	(48)	25 (41)	29 (48)	(44)	27 (44)	31 (51)	(48)
Fast spin-echo equal to conventional spin-echo	27 (44)	26 (43)	(43)	22 (36)	18 (29)	(33)	24 (39)	20 (33)	(36)
Fast spin-echo inferior to conventional spin-echo	6 (10)	5 (8)	(9)	14 (23)	14 (23)	(23)	10 (16)	10 (16)	(16)
P value	.0003	.00001		.05	.02		.004	.0007	

33% of the T2-weighted images, and in 36% of the combined spin-density and T2-weighted images. Each comparison had statistical significance ($P \leq .05$), with near-perfect interobserver agreement ($0.81 \leq \kappa \leq 1.0$). All lesions were seen on both sequences.

Figure 1 is an example of improved lesion visibility on fast spin-echo sequences. Because of decreased motion artifact, the margins of the paraganglioma and its abnormal vessels appear sharper.

For lesions with high signal and adjacent to fat, fast spin-echo sequences resulted in decreased conspicuousness in three cases: a parotid hemangioma (Fig 2), an optic nerve glioma, and a peripheral neurofibroma. In each of these cases, conventional spin-echo T1-weighted sequences provided signal contrast between lesion and fat.

The cystic lesions in our study were easily identified; however, small cystic lesions adjacent to fat may be harder to see on fast spin-echo

sequences. Other lesions surrounded by fat did not have decreased conspicuousness on fast spin-echo sequences; those lesions with intermediate signals on long-TR sequences, especially the spin-density images, were easily seen next to the high signal of fat. We observed this in squamous cell carcinoma metastatic to the parotid gland (Fig 3), epidermoid carcinoma of the parotid gland, parotid fibrosis, Sjögren involvement of the parotid gland, and radiation changes of the skin.

If the abnormalities contained fat and were adjacent to muscle or other soft tissue, T2-weighted fast spin-echo sequences showed them clearly as a high signal next to intermediate signal of muscle (Fig 4). Similarly, obliteration of normal fat planes by tumor was more easily detected on fast spin-echo sequences; the asymmetric loss of the normal high signal of fat indicated the presence of a neoplastic or inflammatory process (Fig 4).

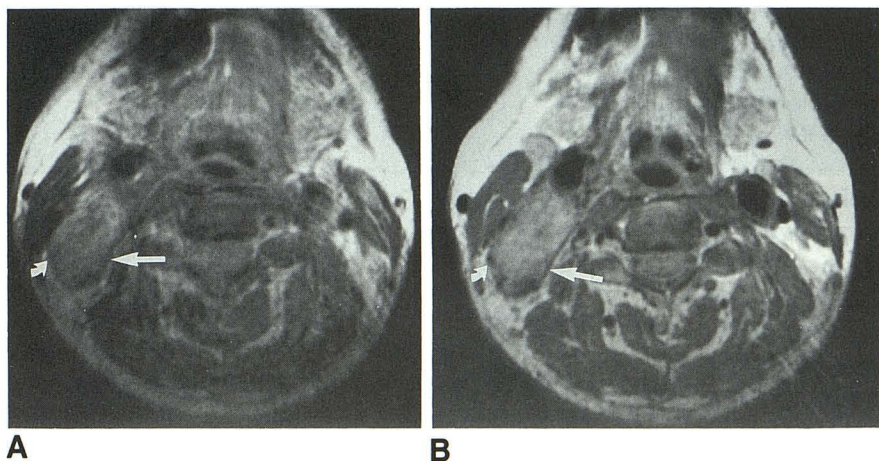


Fig. 1. Forty-two-year-old man with a paraganglioma.

A, Conventional spin-echo spin-density (2000/30) image.

B, Fast spin-echo spin-density (2500/14) image. The fast spin-echo image has less motion artifact; normal structures are better delineated. Although the paraganglioma is easily seen on conventional spin-echo, the fast spin-echo image provides better definition of vessels (curved arrows) and lesion margins (straight arrows, A and B).

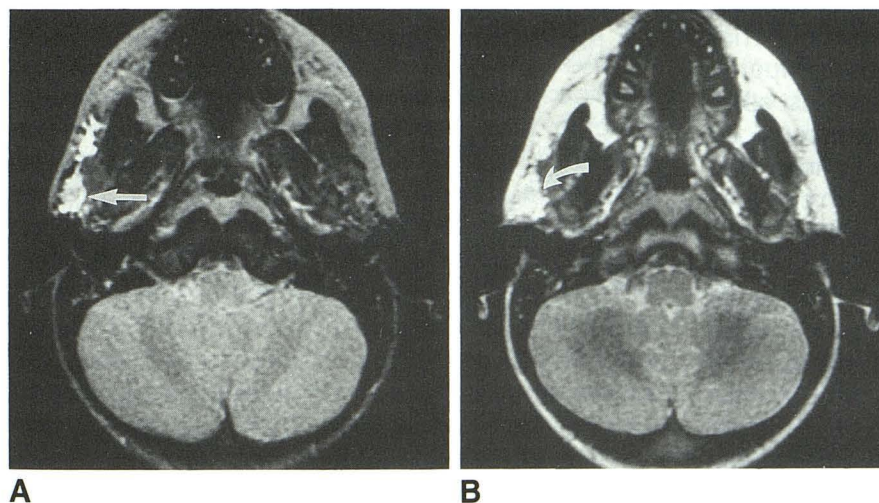


Fig. 2. Two-year-old girl with a hemangioma.

A, Conventional spin-echo T2-weighted (2000/80) image.

B, Fast spin-echo T2-weighted (2000/84) image. The hemangioma is easily seen on the conventional spin-echo image (straight arrow, A). In the fast spin-echo image, the high signal of adjacent fat decreases conspicuousness of the high signal of the hemangioma (curved arrow, B).

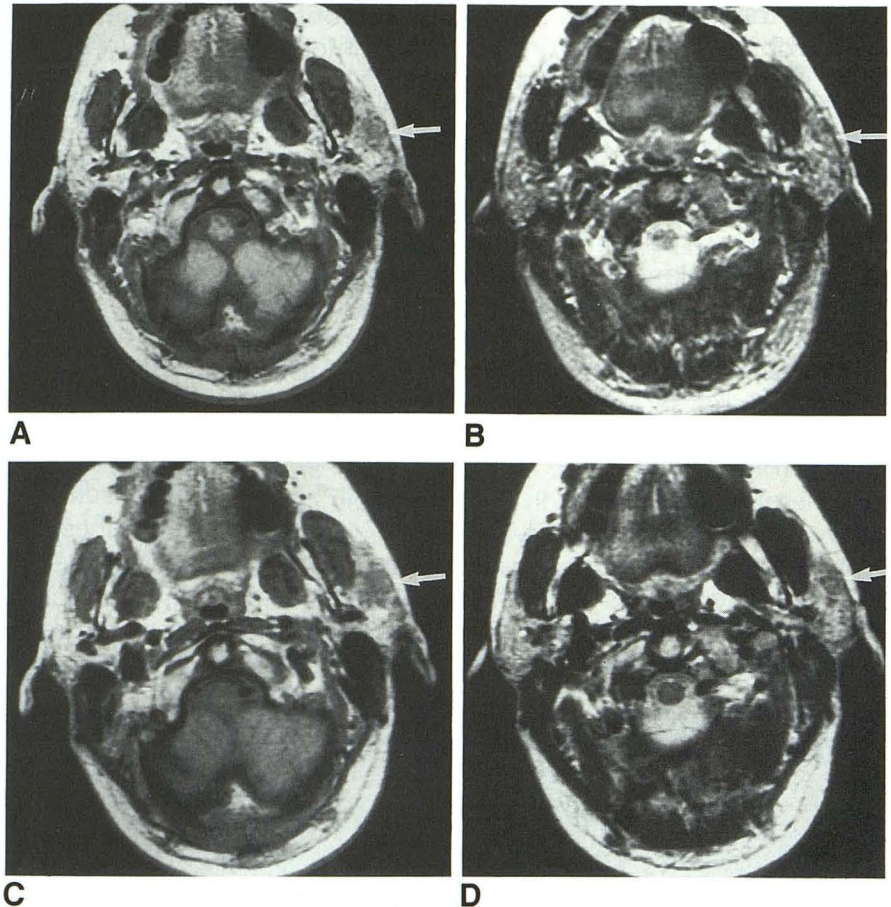
Fig. 3. Sixty-six-year-old man with squamous cell carcinoma metastatic to left parotid.

A, Conventional spin-echo spin-density (2000/30) image.

B, Conventional spin-echo T2-weighted (2000/80) image.

C, Fast spin-echo spin-density (2500/14) image.

D, Fast spin-echo T2-weighted (2500/84) image. With an intermediate signal, the lesion (*straight arrow, A-D*) is highlighted against the signal of fat; lesion margins appear sharper on fast spin-echo images (C and D).

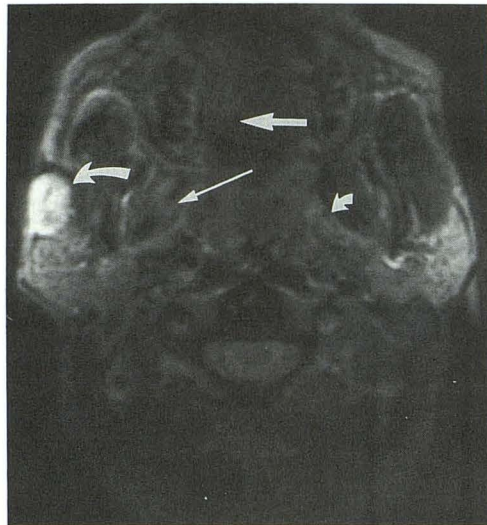


Discussion

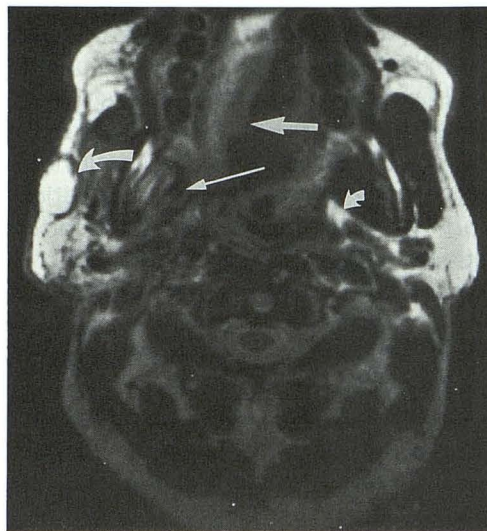
Long-TR sequences play an integral role in MR imaging, because many pathologic processes have a long T2 relaxation time that results in a conspicuous, bright signal. Motion artifacts, however, can limit the utility of MR imaging in the head and neck region. By providing shorter imaging times, fast spin-echo represents a technique that counters image degradation caused by motion yet offers long-TR images. When compared with conventional spin-echo sequences, fast spin-echo sequences provided improved or equal lesion conspicuousness in a majority of head and neck lesions (Table 1) and did not miss any lesions seen on conventional spin-echo sequences.

Fast spin-echo sequences increase the number of lines of k-space data acquired within the TR interval by applying a series of 180° pulses after each 90° pulse. The number of 180° pulses represents the echo train length; the time between pulses is the echo spacing. Each 180° pulse generates a spin-echo, with each spin-echo phase encoded by a distinct phase-encoding gradient (3, 4, 7). Those echoes collected with low-mag-

nitude phase-encoding gradients contribute the majority of image signal and contrast (13–15). The order in which the echoes are phase encoded determines the effective TE. The application of low-magnitude phase-encoding gradients to the early echoes of each echo train results in spin-density images. If the low-magnitude phase-encoded gradients are applied to the late echoes of the echo train, the images appear T2 weighted. Because each echo of the echo train fills a different line of k-space, fast spin-echo reduces the imaging time by a factor equal to echo train length for single-echo sequences; for double-echo sequences, imaging time is reduced by a factor of echo train length/2. In conventional spin-echo sequences, imaging time equals $TR \times NEX \times NPE$, where NEX represents the number of excitations and NPE represents the number of phase-encoding steps. For a double-echo fast spin-echo sequence similar to the one used in our study, imaging time equals $TR \times NEX \times NPE / (\text{echo train length} / 2)$. In clinical practice, the shorter imaging times of fast spin-echo sequences allow adjustments in parameters that improve image



A



B

Fig. 4. Fifty-eight-year-old man with spread of squamous cell carcinoma into the masticator space and fatty atrophy of the tongue.

A, Conventional spin-echo T2-weighted (2500/80) image.

B, Fast spin-echo T2-weighted (2150/84) image. Both sequences depict tumor infiltration into the right pterygoid muscle (*long arrows*). Because fat remains bright on long-TR fast spin-echo sequences (see text), the fast spin-echo image better shows the normal parapharyngeal space fat on the left, thus making asymmetry more easily seen (*short curved arrows*). Similarly, the fatty atrophy of the tongue (*short straight arrows*), a result of tumor spread into the sublingual space, is better seen on the fast spin-echo image. Note the large lymph node adjacent to the right masseter muscle (*curved arrows*).

quality: a larger matrix improves spatial resolution; longer repetition and echo times lead to better signal intensity and tissue contrast; and an increase in signal averages optimizes the signal-to-noise ratio. In order to provide a direct com-

parison, however, we used similar parameters for both fast spin-echo and conventional spin-echo sequences.

T2-weighted fast spin-echo and conventional spin-echo images have similar tissue contrast except that fat has a substantially increased signal on fast spin-echo images (16), attributable primarily to the decoupling effect of multiple 180° pulses on lipid protons (Wright GA, Lipid Signal Enhancement in Spin-echo Trains, presented at the meeting of the Society of Magnetic Resonance in Medicine, August 1992; Rutt BK, Lipid Signal Enhancement in CPMG MRI: Effect of Field Strength, presented at the meeting of the Society of Magnetic Resonance in Medicine, August 1992). The protons of long-chain fatty acids are coupled in the sense that the local magnetic field experienced by one proton is affected by the orientation of protons on adjacent carbon atoms. Coupling results in splitting of frequency peaks of lipid protons on nuclear MR spectroscopic studies. On T2-weighted conventional spin-echo sequences, coupling leads to more rapid T2 decay of lipid protons with a relative decrease in the signal of fat. In T2-weighted fast spin-echo sequences, however, the multiple, repetitive 180° pulses decouple lipid protons. This prolongs the T2 relaxation times of fat, causing it to have a relatively increased signal on long-TR sequences. Increasing the echo train length and decreasing the echo spacing contribute to a prolonged T2 value of coupled protons (17). Although imaging parameters were concealed when the reviewers graded lesion visibility, the increased signal of fat seen on fast spin-echo images limited the degree to which a strict, blinded comparison of conventional spin-echo and fast spin-echo sequences could be done.

The combination of increased signal of both lesion and surrounding fat caused decreased visibility of three lesions (parotid hemangioma, optic nerve glioma, and a peripheral neurofibroma) on fast spin-echo images. Small, cystic lesions adjacent to fat may also be more difficult to see with fast spin-echo sequences. In these cases, fast spin-echo sequences combined with fat suppression by an inversion recovery fast spin-echo sequence increase lesion conspicuousness by highlighting the bright signal of the lesion against a darker background of fat suppression (10). For fatty lesions that lie adjacent to muscle, no fat suppression is needed because fast spin-echo sequences render the lesion easily seen as increased signal adjacent to muscle of interme-

diate signal. In the parotid gland, the relative fat content increases with age; lesion conspicuousness may thus be affected on both conventional spin-echo and fast spin-echo sequences, depending on the composition of the mass.

If fat surrounds a lesion, its conspicuousness is not necessarily decreased on fast spin-echo sequences. Lesions with intermediate signal on long-TR sequences stand out against the high signal of fat, explaining in part why fast spin-echo spin-density sequences provide excellent lesion visibility. In addition, lesions that have short-T2 relaxation times and low signal on T2-weighted sequences are seen well on fast spin-echo sequences if surrounded by tissues that are hyperintense. An inverted papilloma in the nasal vault with a relatively low signal was easily visible because of surrounding high signal of sinus secretions. Other lesions with short T2 relaxation times and low signal on T2-weighted fast spin-echo sequences that may be highlighted by surrounding hyperintense tissue include cellular lesions (sarcoidosis and lymphoma), fibrocollagenous stroma (orbital pseudotumor), low-spin-density tissue (calcium), and paramagnetic tissue (fungal infections, melanotic melanoma, and blood products). T1-weighted conventional spin-echo sequences also help detect and characterize lesions that contain fat or protein or that have intermediate or dark signal on T2-weighted fast spin-echo sequences. For lesions that have similar signal as fat on both short- and long-TR sequences, fat or water chemical suppression techniques may help; however, routine fat suppression for all lesions with bright signals on short-TR images is not required.

Fast spin-echo imaging has potential disadvantages. First, image blurring in the phase-encoding direction with loss of small lesion contrast has been observed (7, 13, 18). Certain imaging parameters and tissue characteristics exacerbate blurring, including a long echo train length, a short effective TE, and small lesions with short T2 relaxation times. Because we used a short echo train length and a larger matrix size, blurring did not limit the quality of fast spin-echo images. Second, for an equal TR, fast spin-echo provided an average of three fewer section locations compared with conventional spin-echo. In clinical use, the shorter imaging times of fast spin-echo allow an increased TR; this results in more sections along with improved signal intensity and tissue contrast. Third, discontinuities in raw data acqui-

sition inherent in fast spin-echo sequences cause ghosting-like artifacts that degrade image quality (7, 13). To limit this artifact, an increased matrix size (ie, greater than 128 phase matrix) and decreased echo spacing can be used. Finally, with short interecho spacing of fast spin-echo sequences, diffusion-related dephasing induced by paramagnetic iron-containing molecules is decreased, leading to fewer magnetic susceptibility artifacts (7). Although this study had no hemorrhagic lesions, they might appear less conspicuous on fast spin-echo sequences.

In conclusion, compared with conventional spin-echo sequences, fast spin-echo sequences provided superior or equal lesion conspicuousness in a majority of head and neck lesions. Imaging times with fast spin-echo sequences were markedly reduced. The high signal of fat on fast spin-echo images did not substantially limit lesion visibility except in a minority of lesions. In these cases, T1-weighted conventional spin-echo and fat suppression techniques such as inversion recovery fast spin-echo sequences will help detect and characterize the lesions. In evaluation of the head and neck, we advocate replacing long-TR conventional spin-echo sequences with long-TR fast spin-echo sequences. A routine protocol therefore includes T1-weighted conventional spin-echo and spin-density and T2-weighted fast spin-echo sequences, supplemented with inversion recovery fast spin-echo and gadolinium-enhanced conventional spin-echo T1-weighted sequences as needed. If all four sequences and a T1-weighted or inversion recovery fast spin-echo locator scan are used, and accounting for time setting up before and during the exam, the exam time approximates 30 minutes.

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This issue marks the appearance of a new feature in the *AJNR*, the Imaging Quiz. The quiz can be found on page 658 and the diagnosis on page 774. We welcome other original submissions for this feature. This feature must fit on no more than two journal pages: a quiz page and a diagnosis page. Therefore, the approximate length of submissions should be two to three double-spaced pages of text, including references, and up to 10 figures. The submissions will undergo peer review. We look forward to receiving your contributions for this feature.