Improved detection and delineation of head and neck lesions with fat suppression spin-echo MR imaging.

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Improved Detection and Delineation of Head and Neck Lesions with Fat Suppression Spin-Echo MR Imaging

To compare conventional and fat suppression MR imaging in their ability to detect head and neck lesions, we prospectively studied 17 patients with head and neck tumors and one normal volunteer. Five patients had benign tumors (one mixed cell tumor, one hemangioma, one lipoma, and two plexiform neurofibromas), 10 had malignant tumors (six squamous cell carcinomas, two minor salivary gland carcinomas, one lymphoma, and one malignant fibrous histiocytoma), and two had nonspecific lymphadenopathy. All subjects were studied with standard spin-echo T1- and T2-weighted images (T2-weighted imaging was done with and without fat suppression technique). In addition, T1-weighted images with contrast enhancement and fat suppression were obtained in nine patients. A four-point grading system was used for comparison of the conventional and fat suppression images. Grades ranged from 0 (unsatisfactory, the lesion cannot be seen) to 3 (excellent, the lesion and its margins can be seen clearly with sharp contrast from surrounding normal tissue).

We found that postcontrast fat suppression T1-weighted images and fat suppression T2-weighted images were most useful; these sequences obtained an average score close to grade 3 (2.77 and 2.85, respectively). On the other hand, the conventional T2-weighted images had an average score of about 2 (1.82) and the conventional T1-weighted image had a score of about 1 (1.33). Fat suppression T2-weighted sequences generally were superior in cases of lymphadenopathies. Postcontrast T1-weighted images were most useful in a case of plexiform neurofibroma, owing to their fibrous component and lower proton density.

Our preliminary data suggest that the addition of fat suppression to T2- and postcontrast T1-weighted pulse sequences improves the detection and delineation of head and neck lesions with no increase in scan time.

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Large amounts of fat and complex anatomy make the head and neck region one of the more challenging areas for MR imaging. The tumors in the head and neck region usually produce a signal with an intensity similar to that of muscle on T1-weighted images, and frequently the signals from muscle, fat, and other tissues cannot be distinguished without contrast enhancement. However, some contrast-enhanced tissue, including neoplasia, may have T1-weighted signal intensity similar to fat, which again results in diagnostic difficulty. Although conventional T2-weighted images may depict the lesions to a certain degree, the margins often are not well seen owing to adjacent fat. A fat suppression technique used in conjunction with paramagnetic contrast material ensures that the enhancing lesion will not be obscured by high signal from the surrounding fat on T1-weighted images. In addition, on conventional T2-weighted images the fat suppression technique should likewise be useful in differentiating fat from pathologic tissue. A prospective study was conducted to test this hypothesis.
Materials and Methods

We obtained MR images of the head and neck in 17 patients and one volunteer (12 males, six females) who ranged in age from 10 to 68 years (average, 42 years). This group included five patients with benign tumors, 10 with malignant tumors, and two with nonspecific lymphadenopathy (Table 1). Nine patients received gadopentetate dimeglumine (Magnevist, Berlex, Cedar Knolls, NJ). All MR studies were performed on a 1.5-T unit (Signa, GE Medical Systems, Milwaukie, WI). A head or neck coil was used depending on lesion location and the patient’s body habitus. The studies included conventional unenhanced T1-weighted, 600–800/20 (TR range/TE), proton-density, and T2-weighted, 2000–3000/30–80, images. The field of view and slice thickness varied in individual cases. Two to four excitations were used. In one patient, only a postcontrast T1-weighted image was obtained. Proton-density and T2-weighted fat suppression images were obtained in 14 patients and postcontrast T1-weighted fat suppression images were obtained in nine patients. The fat suppression technique, developed by Szumowsk1 et al. [1, 2], is a modification of chopper fat suppression. This hybrid method consists of a frequency-selective preparatory pulse to saturate the fat, followed by in-phase and out-of-phase chopper components. This sequence achieves high-level lipid suppression without increasing imaging time or image postprocessing [3]. Images were obtained in axial or coronal planes. The resultant conventional images and paired fat suppression images were carefully compared for demonstration of normal anatomic structures, depiction of lesion margins, lesion conspicuity, and interface between lesions and normal structures.

A four-point grading system was used for detection and delineation of the lesions. Grade 0, lesion could not be seen; grade 1, lesion was visible but margin could not be seen; grade 2, the margins of the lesions were seen but not clearly; and grade 3, the lesion and its margins could be seen clearly. Conventional and fat suppression MR images were evaluated and compared according to this system.

Results

The results from our normal volunteer confirmed that the fat suppression technique successfully diminished the fat signal on both T1- and T2-weighted images.

Based on the four-point grading system (Table 1), the conventional T1-weighted image had an average score of 1.33 and the conventional proton-density and T2-weighted images had an average score of 1.55 and 1.82, respectively. In one patient with oral hemangioma, a postcontrast T1-weighted image was obtained, and this failed to show the lesion (score of 0) (Fig. 1). The fat suppression T2-weighted image and the postcontrast T1-weighted images had an average score of 2.85 and 2.77, respectively (Figs. 2–6). Although the fat suppression T2-weighted image had a slightly better result than the fat suppression postcontrast T1-weighted image, the difference was not statistically significant. The fat suppression proton-density images had an average score of 2.1. However, in one case of plexiform neurofibroma, the fat suppression proton-density and T2-weighted images were not good and had a score of 1 (the lesion could be seen but margins were not visible), while the postcontrast fat suppression T1-weighted image had a score of 3 (the lesion and its margins could be seen clearly).

Discussion

CT has had enormous success in imaging head and neck lesions because of the high contrast between bone, fat, and other soft tissues. Nonetheless, CT has some difficulty dis-

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**TABLE 1:** Comparison of Conventional and Fat-Suppression MR Sequences in Evaluating Head and Neck Lesions

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Disease</th>
<th>Conventional&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Fat Suppression&lt;sup&gt;a&lt;/sup&gt;</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T1WI PD T2WI *T1WI</td>
<td>T1WI PD T2WI *T1WI</td>
</tr>
<tr>
<td>1</td>
<td>33</td>
<td>F</td>
<td>Mixed-cell tumor</td>
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<td>2 3 3</td>
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<tr>
<td>2</td>
<td>12</td>
<td>M</td>
<td>Hemangiom a</td>
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<tr>
<td>3</td>
<td>10</td>
<td>M</td>
<td>Plexiform neurofibroma</td>
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<td>1 1 3</td>
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<td>4</td>
<td>23</td>
<td>M</td>
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<tr>
<td>5</td>
<td>65</td>
<td>F</td>
<td>Lipoma</td>
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<td>2 2 3</td>
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<tr>
<td>6</td>
<td>52</td>
<td>M</td>
<td>Squamous cell CA</td>
<td>0 0 2 3 2</td>
<td>0 2 2</td>
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<tr>
<td>7</td>
<td>59</td>
<td>M</td>
<td>Squamous cell CA</td>
<td>1 1 1 3 3</td>
<td>1 1 3</td>
</tr>
<tr>
<td>8</td>
<td>53</td>
<td>F</td>
<td>Squamous cell CA</td>
<td>1 2 2 3 3</td>
<td>1 2 3</td>
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<tr>
<td>9</td>
<td>67</td>
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<td>Squamous cell CA</td>
<td>2 2 2 3 3</td>
<td>1 1 3</td>
</tr>
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<tr>
<td>12</td>
<td>47</td>
<td>M</td>
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<td>13</td>
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<tr>
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<tr>
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<td>53</td>
<td>F</td>
<td>Malignant fibrous histiocytoma</td>
<td>2 3 2 3 3</td>
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</tbody>
</table>

Average score = 1.33 1.55 1.82 0 2.1 2.85 2.77

<sup>a</sup> Grading system: 0 = unsatisfactory, lesion cannot be seen; 1 = lesion is visible but margin cannot be seen; 2 = the margins of the lesion can be seen but not clearly; 3 = the lesion and its margins can be seen clearly.

Note.—T1WI = T1-weighted images; PD = proton density images; T2WI = T2-weighted images; "*" = postcontrast studies; "**" = the signal of the mass was completely suppressed, no abnormal signal was noted.
Fig. 1.—Case 2: 12-year-old boy with surgically proved hemangioma.
A, Postcontrast T1-weighted (600/20) image fails to show the lesion (grade 0) except for a deformity of left canine tooth (arrow).
B, Postcontrast T1-weighted (600/20) image with fat suppression clearly delineates high-signal lesion involving left upper canine tooth and hard palate (grade 3) (arrow). Although there is no fat in the hard palate, the dynamic change of the gray scale after fat suppression makes the mildly enhancing lesion much more distinct.
C, On this unenhanced T2-weighted (2000/70) image with fat suppression, the lesion is easily seen (grade 3) (arrow). The information obtained from fat suppression T2-weighted images and contrast-enhanced T1-weighted images is comparable.

Fig. 2.—Case 16: 8-year-old boy with infectious mononucleosis.
A, T1-weighted (600/20) image shows multiple enlarged lymph nodes near the parapharyngeal and carotid spaces (arrows), but the signal intensity of lymph nodes and muscles is similar, and the extent of lymphadenopathy is uncertain. The margins of the nodes are not clearly delineated (grade 2).
B, T2-weighted (2800/70) image fails to reveal the lymphadenopathy (grade 0); the nodes and fat have similar signal intensity.
C and D, Proton-density image (C) and T2-weighted (2000/30, 70) image with fat suppression clearly show the number and margins of the nodes (grade 3) (straight arrows). The tonsillar lymphoid tissue also has high signal intensity (curved arrows).
Fig. 3.—Case 15: HIV-positive 29-year-old man with lymphadenopathy.
A, Axial T1-weighted (600/20) image shows small retropharyngeal nodes. Although the nodes are seen, the contrast between the nodes and adjacent muscles is low (grade 2) (arrows).
B, T2-weighted (2000/70) image with fat suppression clearly delineates the high signal lymph nodes with well defined margins (grade 3) (arrows).

Fig. 4.—Case 1: 33-year-old woman with surgically proved right parotid mixed cell tumor.
A, Coronal T1-weighted (800/200) image shows the right parotid lesion with an indistinct upper margin (grade 2) (arrow).
B, Coronal postcontrast T1-weighted (800/20) image with fat suppression increases the contrast between the enhancing tumor and surrounding structures (grade 3) (arrow).
C and D, Axial proton-density image (C) and T2-weighted (2800/30, 70) image with fat suppression clearly show the mass with smooth margins (grade 3) (short arrow). Also, bilateral reactive lymph nodes are well demonstrated (long arrows). Areas of incomplete fat suppression seen posteriorly are due to field inhomogeneity (arrowheads).
A B C

Fig. 5.—Case 14: 35-year-old man with lymphoma.
A, T1-weighted (600/20) image discloses thickened oropharyngeal tissue but the margins cannot be delineated (grade 1) (arrows).
B, T2-weighted (3000/80) image shows the abnormal tissue involving the oropharynx and diffusely infiltrating the superficial facial structures bilaterally (grade 3) (arrows).
C, Postcontrast T1-weighted (600/20) image with fat suppression also delineates the mass and its extent (grade 3) (arrows). The information is essentially equivalent to that obtained from the heavily T2-weighted image. Areas of incomplete fat suppression seen posteriorly are due to field inhomogeneity.

A B

Fig. 6.—Case 8: 53-year-old woman with squamous cell carcinoma of the tongue.
A, Postcontrast T1-weighted (600/20) image reveals a slightly inhomogeneous high signal area involving the right side of the tongue and floor of the mouth, with ill-defined lateral and posterior margins (grade 1) (arrow).
B, T2-weighted (2000/70) image with fat suppression has lower signal-to-noise ratio, but clearly demonstrates the abnormal high-signal lesion and its extent (grade 3) (straight arrows). High-signal region behind left mandible, which has indistinct signal intensity on T1-weighted image, was also sampled by biopsy and proved to be another site of carcinoma (curved arrows).

criminating pathologic processes in areas with lesser amounts of fat, such as the oropharynx, tongue, floor of the mouth, and hypopharynx. Because of its multiplanar capabilities, excellent soft-tissue definition, and lack of ionizing radiation, MR has been investigated as an alternative method for imaging the head and neck region, and some advantages have been noted [4, 5].

Fat also provides contrast for MR imaging, but the pulse sequences must be carefully selected to optimize contrast differences between pathologic lesions and fat, which is abundant in the head and neck regions. Moreover, the fat signal can predominate on the images and actually hinder image analysis. In some cases of lymphadenopathy and squamous cell carcinoma, the most common cancer in the head and neck, T2-weighted images can actually mask the abnormalities because the fat has intermediate to low signal on T2-weighted images and cannot be distinguished from pathologic lesions [4] (Fig. 2B). Robinson et al. [6] have reported that postcontrast T1-weighted images did not improve the clarity of tumors in the masseter or parotid spaces because the lesions were isointense with fat.

Our data showed that the fat suppression sequences were superior to conventional T1- and T2-weighted images. On the other hand, the anatomic detail of normal structures usually
were better appreciated on conventional images. In particular, anatomy often appeared unsatisfactory on the fat suppression T2-weighted image. The magnetic susceptibility artifact from dentures also was exaggerated on fat suppression images, especially the T2-weighted sequences.

The fat suppression technique we used is a modification of the chopper fat suppression technique, which does not increase the scan time or postprocessing. Although increased magnetic susceptibility artifact was noted, in most cases the quality of the images was not significantly affected. Recently, Vogl and coworkers [7] recommended conventional MR with gadopentetate dimeglumine enhancement for tumors that are small and difficult to detect on the initial unenhanced MR images or that show subtle infiltrations in the head and neck region. In addition, Simon and Szumowski [8] reported that fat suppression MR technique with gadopentetate dimeglumine enhancement was helpful in depicting lesions in and outside the CNS.

Our dedicated head and neck study was done to compare the conventional and fat suppression MR technique with and without paramagnetic contrast material and to determine what sequences were optimal. Our reasoning was that by eliminating the high signal from fat on T1-weighted images and by using gadopentetate dimeglumine to enhance the lesion, the images would display superior contrast between the lesions and normal structures.

We found that the postcontrast fat suppression T1-weighted images were excellent in most cases (average score of 2.77) (Figs. 1B, 4B, 5C). In addition, on conventional T2-weighted images, fat still had low or intermediate signal, similar to pathologic tissue, depending on the TR. However, on fat suppression T2-weighted images, the fat signal was totally suppressed and the muscle was of low signal intensity owing to short T2 relaxation time. Consequently, lesions that are rich in mobile protons, such as lymphadenopathies and most tumors, which may appear indistinct on conventional images [4, 8], were found to be more prominent and distinct on fat suppression T2-weighted images (Figs. 1C, 2C, 2D, 3B, 4C, 6B).

In a case of plexiform neurofibroma, fat suppression T2-weighted images were suboptimal but postcontrast fat suppression T1-weighted images showed the lesions clearly. A possible explanation for this is that plexiform neurofibromas are not rich enough in mobile water protons to produce very high signal on T2-weighted images, but they will enhance intensely after contrast administration.

The conventional T1-weighted image was not useful in most cases because most lesions of the head and neck have signal intensities very similar to those of adjacent muscle or mucosa. Even though in the majority of cases the lesion could be detected, its margins usually were not well seen (Figs. 2–6A).

Conventional T2-weighted images can show the lesions but, again, the margins generally are not well seen owing to signal similarities of fat, which commonly surrounds the lesion. In certain cases of lymphadenopathy, in which the nodes were totally surrounded by fat, the lesions were completely obscured on conventional T2-weighted images but became very obvious on fat suppression T2-weighted images (Figs. 2B–2D). Further study is required to determine the benefits of fat suppression techniques on T2-weighted images and postcontrast T1-weighted images for elucidating the internal morphology of nodes and the ability to distinguish inflammatory changes from metastatic disease.

There are some disadvantages to the fat suppression technique, such as increased magnetic susceptibility artifact, lower signal-to-noise ratio (the image is more grainy owing to lack of signal from fat), and areas of incomplete fat suppression due to field inhomogeneities induced by using a large field of view and shape variation in the area studied (Figs. 4–5C). However, these disadvantages are outweighed by the obvious advantages of increased contrast between lesions and soft tissue compared with conventional MR imaging methods. The problem of incomplete fat suppression may be reduced by magnetic field shimming, by changing the plane of section so that the imaged volume is more uniform, and by using more than one fat suppression mechanism. In a case of oral hemangioma involving the hard palate (Fig. 1), the pre- and postcontrast T1-weighted image failed to demonstrate the abnormality. However, the postcontrast fat suppression T1-weighted image clearly showed the lesion. Although there is no fat in the hard palate, there was a shift of gray scale after fat suppression that made the enhancing lesion much more distinct. This feature is an important advantage for fat suppression technique.

We recommend the use of postcontrast fat suppression T1-weighted imaging as a useful adjunct to conventional MR imaging in evaluating the head and neck region. Also, according to our preliminary data, fat suppression T2-weighted imaging improves lesion detection and shows promise as a means for evaluating cervical lymphadenopathy.

REFERENCES