Magnetization transfer contrast MR in lesions of the head and neck.

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Magnetization Transfer Contrast MR in Lesions of the Head and Neck

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PURPOSE: To compare lesion-to-background contrast with and without magnetization transfer (MT) in lesions of the head and neck. **METHODS:** Twenty lesions (16 malignant, 4 benign) were evaluated in 17 patients (11 men, 6 women; mean age, 58 years; age range, 39–76 years). In 13 patients, MR imaging was performed at 0.1 T with continuous-wave, off-resonance MT; in 4 patients, MR imaging was performed at 1.5 T with on-resonance, binomial MT prepulses. Fifteen sequences were conducted before the administration of gadopentetate dimeglumine; 13 were conducted after the administration of that contrast material. The ratio of signal intensity with the MT pulses (Ms) to signal intensity without the MT pulses (Mo) was calculated, as were the lesion-to-background contrast and the contrast-to-noise ratios. **RESULTS:** Ms/Mo showed both wide variability and considerable overlap among different lesion types. Images from MT sequences showed better contrast than those from non-MT sequences in 23 of 28 lesions (12 of 15 before and 11 of 13 after the administration of contrast material). The mean contrast improvement percentages (± standard deviation) were 165.5% (±58%) on unenhanced images and 186.6% (±84.8%) on contrast-enhanced images. The mean improvements in contrast-to-noise ratios were 156% (±60%) on unenhanced images and 171.6% (±98.1%) on contrast-enhanced images. **CONCLUSION:** MT improved contrast between nodes or tumors showing an MT effect and background tissue (usually fat) not showing an MT effect. MT also improved contrast between contrast-enhanced neoplastic lesions and background tissue that showed an MT effect.

Index terms: Head, magnetic resonance; Magnetic resonance, magnetization transfer; Neck, magnetic resonance

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The concept of magnetization transfer (MT) and its application to magnetic resonance (MR) imaging have been described in detail elsewhere (1, 2). In brief, selective magnetization of protons associated with macromolecules may be transferred to the water proton population that constitutes the MR image. Where an efficient transfer mechanism exists between the two proton populations, a strong MT effect is observed. In the resultant image, the MT effect is seen as a reduction in signal intensity. Examples of tissues that exhibit a strong MT effect include muscle, cartilage, and brain parenchyma (3). Little or minimal MT effect is seen in fat, fluid, or moving blood (3); therefore, MT can be used to improve contrast between mass lesions that demonstrate an MT effect and background tissue that does not (eg, fat). Furthermore, a combination of gadopentetate dimeglumine and MT contrast can improve contrast between enhancing lesions and background tissues that exhibit an MT effect (4). The degree of the MT effect observed will be directly proportional to T1, and contrast-enhanced T1 shortening will result in a smaller MT effect. The combination of increased signal from T1 shortening and a reduced MT effect is additive. The addition of MT to contrast-enhanced sequences has been shown to improve contrast in enhancing breast lesions and in intracranial lesions (5–7). Normative data for the head and neck have already been published (8). The aim of this study was to evaluate the impact of MT on the background-to-lesion contrast in lesions of the head and neck.

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Materials and Methods

All patients who were referred for MR imaging to delineate the extent of a clinically known or suspected lesion and who were prepared to participate in the study were recruited. Seventeen patients with a variety of head and neck lesions were studied. There were 11 men and 6 women (mean age, 58 years; range, 39 to 76 years). Malignant lesions were present in 14; 4 of these patients had squamous cell carcinoma of the tongue, 1 had nasopharyngeal carcinoma, 1 had laryngeal carcinoma, 1 had carcinoma arising from the buccal mucosa, 4 had pharyngeal carcinoma, and 5 had malignant cervical lymphadenopathy (in 2 patients, this was associated with a visualized primary lesion). Three patients had nonmalignant lesions. Cervical lymphadenopathy related to human immunodeficiency virus was present in 2; 1 of these also had parotid lymphadenopathy. One patient had a postoperative inclusion cyst. The median lesion size was 4 cm (range, 1–15 cm).

At the start of the study, MT was only available on a low-field system. Later, when MT became available on the high-field system, patients were studied on that system also. Thirteen patients underwent MR imaging on a 0.1-T system (Picker International, Highland Heights, Ohio); a continuous-wave, off-resonance radio frequency (RF) MT prepulse was applied, followed by a T1-weighted gradient-echo sequence. Typical imaging parameters were 250/30 (repetition time/echo time), 90° flip angle, and 5-mm to 6-mm section thickness. Typical MT parameters were an RF pulse of 6000 Hz off-resonance, with a duration of 50 milliseconds and strength of 13 μT.

The other four patients had MR imaging on a 1.5-T system (Philips, Shelton, Conn) and with MT generated by using on-resonance prepulses (9). The prepulses were as follows: four 180° pulses of 1-millisecond duration in a "jump and return" or "binomial configuration." The prepulses were followed by a spoiler gradient and then the standard spin-echo sequence. Imaging parameters were 900/20, with a 5-mm or 6-mm section thickness.

The MT sequences were performed after intravenous administration of contrast material (gadopentetate dimeglumine) in 2 patients, before intravenous administration of contrast material in 4 patients, and both before and after intravenous administration of contrast material in 11 patients. To allow measurement of the MT effect and calculation of the ratio of (signal intensity with the MT pulses to signal intensity without MT) (Ms/Mo), the same sequence with identical imaging parameters but without the MT pulses was also performed. The same section positions were used whenever possible, but sometimes patient movement during the injection of contrast material precluded this.

At the start of the study, a control test tube of manganese chloride ($MnCl_2$)–doped water, known not to show any MT effect, was included in the imaging volume to act as a reference. After it was established that there was very little change in the measured signal intensity of the $MnCl_2$, this step was omitted. The contrast material was given intravenously in standard dosage (ie, 0.1 mL/lb [0.22 mL/kg]). The order of the sequences with and without MT after administration of contrast material was varied, effectively minimizing the effect of the relationship of the observed contrast to the timing of the bolus of contrast material.

Region-of-interest measurements were made in the lesion, in muscle, and in the tissue adjacent to the lesion. The relative contrast (ie, [signal of lesion − signal of background tissue]/signal of background tissue) with and without MT was calculated and expressed as a percentage. For maximum accuracy, the largest possible region of interest was used in each case, and the mean of three measurements was used. The standard deviation of the background noise was measured, and the contrast-to-noise ratio (CNR) was calculated.

Results

The amount of MT experienced by different lesions is given in Table 1. For each lesion, the ratio of signal intensity with MT pulses (Ms) to signal intensity without MT pulses (Mo) is shown. Also shown is the ratio of MT in the lesion to that in nearby normal muscle. A wide range of MT values was recorded for all lesion types, both before and after administration of contrast material.

Quantitative contrast analysis was done before or after administration of contrast material for a total of 28 data sets. In 23 of the 28 data sets, the contrast between the lesion and the background tissue was better on MT sequences than on non-MT sequences (Figs 1 and 2).

TABLE 1: Ms/o by lesion type

Lesion	Ms/Mo of Lesion	Ms/Mo of Lesion / Ms/Mo of Muscle*
Benign HIV adenopathy (before contrast material)	0.74 (0.72–0.77) (n = 3)	1.53 (1.07–1.64) (n = 3)
Malignant nodes (before contrast material)	0.8 (0.76–0.88) (n = 4)	1.22 (1.04–1.6) (n = 4)
Malignant nodes (after contrast material)	0.91 (0.8–1.18) (n = 5)	1.2 (0.96–1.36) (n = 3)
Primary malignant (before contrast material)	0.89 (0.64–1.06) (n = 7)	1.08 (0.87–1.23) (n = 8)
Primary malignant (after contrast material)	0.87 (0.64–1.1) (n = 8)	1.21 (0.89–1.5) (n = 6)

Note.—Ms indicates signal intensity with magnetization transfer pulses; Mo, signal intensity without magnetization transfer pulses; and HIV, human immunodeficiency virus. The contrast material used was gadopentetate dimeglumine. Values given are medians, with the range in parentheses.

*Ms/Mo varied with imaging sequence and field strength; the median was 0.72, and the mean was 0.7 (range, 0.5–0.87).

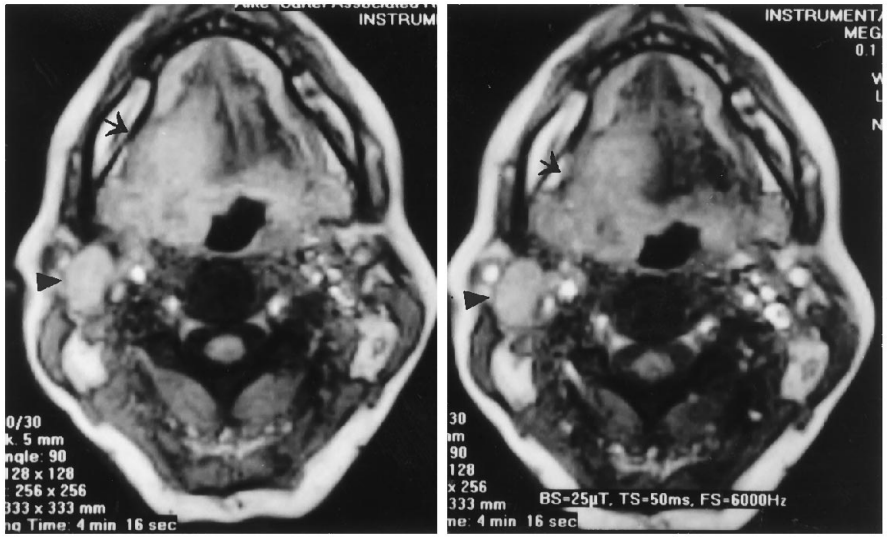

Fig 1. Axial T1-weighted 0.1-T MR images after administration of gadopentetate dimeglumine (250/30; flip angle, 90°) show squamous cell carcinoma of the tongue (*arrows*) with ipsilateral lymphadenopathy (*arrowheads*). The contrast between tumor and adjacent tongue muscle is better on the MT image (*B*) than on the non-MT image (*A*).

The MT sequence before the administration of contrast material improved the contrast differential between lymph nodes, which showed an MT effect, and background fat (either in the neck or parotid gland), which did not show an MT effect. Similarly, the wall of the inclusion cyst did not show an MT effect, but the adjacent muscle did, so MT improved the contrast in that case as well. MT also improved the contrast between malignant tissue, which in general exhibited a mild MT effect, and background tissues (eg, muscle), which showed a good MT effect (Table 2). The mean improvement in contrast (± standard deviation) before the administration of contrast material was 165.5% (±58%), and the mean improvement of the CNR was 156% (±60%). Analyses of the data by field strength showed that, for the particular parameters used in this study, MT was more effective at 0.1 T. Mean contrast improvement in the patients studied at 0.1 T was 182% versus 121% for those studied at 1.5 T; the CNR improved 176% at 0.1 T versus 117% at 1.5 T.

Improved contrast with MT after administration of contrast material was seen in 13 lesions in 12 patients (Fig 3). All these lesions were malignant and showed some degree of enhancement with gadopentetate dimeglumine (Table 3). Mean improvement in contrast with MT after administration of contrast material was 186.6% (±84.8%); the mean improvement in

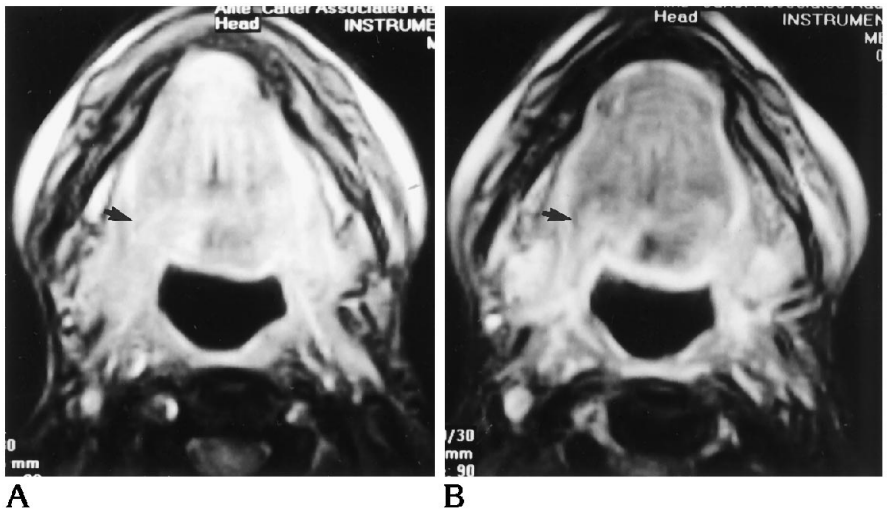

Fig 2. Axial 0.1-T MR images after administration of gadopentetate dimeglumine (250/30; flip angle, 90°) show enhancing, biopsy-proved squamous cell carcinoma of the tongue (*arrows*). The contrast is better on the MT image (*B*) than on the non-MT image (*A*).

TABLE 2: Improved contrast with MT before administration of contrast material

Lesion	Background Tissue	Contrast without MT	Contrast with MT	% Change
Inclusion cyst	Muscle	16	28	175
Malignant LN*	Muscle	1	33	3300*
Malignant LN	Muscle	23	34	148
Malignant LN	Muscle	10	24	240
HIV LN	Fat	65	74	114
HIV cervical LN	Fat	57	66	116
HIV parotid LN	Parotid	40	53	133
Nasopharyngeal Ca	Brain	18	24	133
Pharyngeal Ca	Muscle	20	49	245
Tongue Ca	Muscle	146	185	127
Tongue Ca	Muscle	44	53	120
Laryngeal Ca	Muscle	16	4	269

Note.—MT indicates magnetization transfer pulses; LN, lymphadenopathy; HIV, human immunodeficiency virus; and Ca, carcinoma. These data represent 11 of 14 patients (12 of 15 lesions) studied. The contrast material used was gadopentetate dimeglumine.

*Excluded from calculation of mean and standard deviation.

TABLE 3: Improved contrast with MT after administration of contrast material

Lesion	Background Tissue	Contrast without MT	Contrast with MT	% Change
Tongue Ca	Muscle	7	29	414
Tongue Ca	Muscle	57	117	205
Tongue Ca	Muscle	570	649	114
Tongue Ca	Muscle	67	121	181
Buccal Ca	Muscle	40	53	133
Nasopharyngeal Ca	Brain	37	43	116
Pharyngeal Ca	Muscle	38	67	176
Pharyngeal Ca	Muscle	58	122	210
Malignant LN	Muscle	46	62	135
Malignant LN	Muscle	99	224	226
Malignant LN	Muscle	54	77	143

Note.—MT indicates magnetization transfer pulses; Ca, carcinoma; and LN, lymphadenophathy. These data represent 10 of 12 patients (11 of 13 lesions) studied. The contrast material used was gadopentetate dimeglumine.

CNR was 171.6% (±98.1%). Analyzing the data from the different field strengths showed greater-mean contrast improvement in the patients studied at 0.1 T (190% versus 172%); the change in CNR was 183% at 0.1 T versus 128% at 1.5 T (Fig 4).

MT failed to improve contrast in 3 of 15 lesions before the administration of contrast material and in 2 of 13 lesions after administration of contrast material. All 5 lesions involved were malignant. They showed various degrees of MT effect and were depicted against background tissues that also showed an MT effect. The varying MT effect in the neoplastic lesions and the varying contrast enhancement after administration of contrast material resulted in either no change or a slight reduction in contrast in the MT sequences.

Discussion

MT contrast provides a readily implemented method for improving delineation of lesions in the head and neck. Contrast between the lesion and its background improved in 23 of 28 lesions either before or after intravenous administration of the contrast material. The most important mechanisms for improved contrast were (a) a high-signal lesion enhanced by the contrast material against a background tissue showing reduced signal from an MT effect and (b) an MT effect in lymphadenopathy (median Ms/Mo,

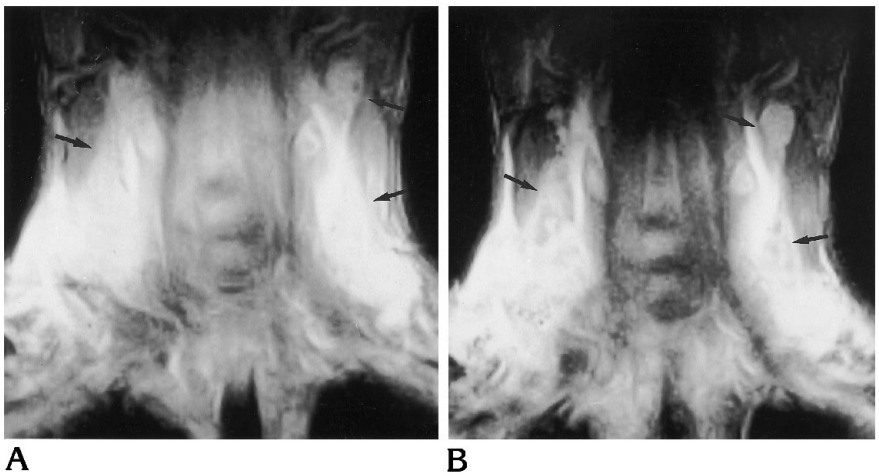

Fig 3. Coronal 0.1-T MR images after administration of gadopentetate dimeglumine show enhancing, biopsy-proved metastatic lymphadenopathy (*arrows*). The contrast is better on the MT image (*B*) than on the non-MT image (*A*).

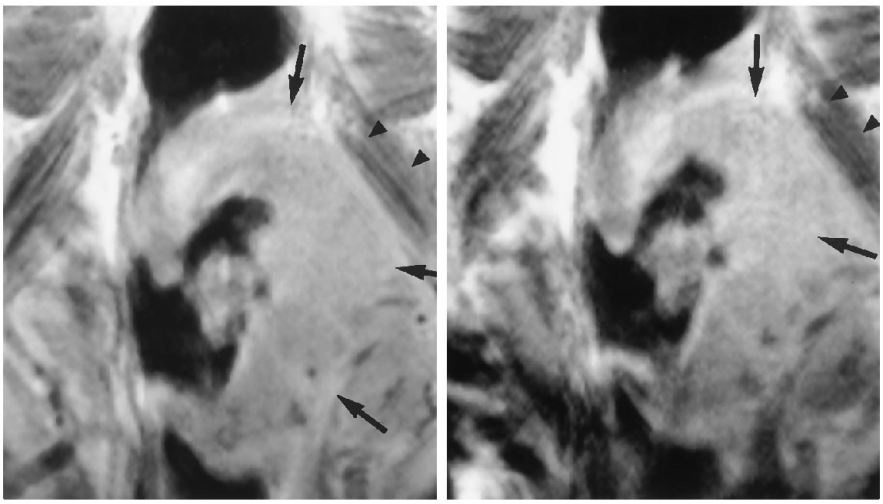

Fig 4. Coronal T1-weighted 1.5-T MR images after administration of gadopentetate dimeglumine show pharyngeal carcinoma (*arrows*). The contrast between the enhancing tumor and the pharyngeal musculature (*arrowheads*) is better on the MT image (*B*) than on the non-MT image (*A*).

0.79) against a background of either fat in the cervical region or the fatty tissue of the parotid gland.

Although the numbers are small and therefore the comparison may be misleading, there was a difference in the degree of benefit provided by MT at 0.1 T compared with MT at 1.5 T. MT was much more beneficial at 0.1 T, and this difference was more marked before the administration of contrast material. This might be thought to have been caused by the specific absorption rate limitations at 1.5 T, restricting the amount of MT that could be implemented. However, using the Ms/Mo of muscle as a reference, this did not appear to be the case.

The Ms/Mo of the lesion was calculated, and the ratio of that calculated value to the Ms/Mo of normal muscle (Table 1) permitted a comparison between the different techniques. Ms/Mo showed a wide range of values in pathologic lesions, with overlap among different lesion types. Ms/Mo did not prove to be specific to any particular type of lesion. For example, benign lymphadenopathy and malignant lymphadenopathy showed overlapping Ms/Mo values. This concurs with other studies of Ms/Mo in neoplastic lesions (10, 11). Further marked variability (1 standard deviation = 0.10 [1 − Ms/Mo]) has been reported in side-to-side comparisons of normal healthy tissue in any given volunteer or patient (8). Variable Ms/Mo values in pathologic lesions resulted in no improvement in contrast in a small percentage of lesions.

In the application of MT, we must balance maximizing contrast with maintaining an adequate signal-to-noise ratio (SNR). This was particularly true at 0.1 T, at which more MT effect could have been produced without RF power deposition problems. The imaging protocol was therefore modified to provide as much MT as possible without sacrificing too much SNR. The amount of MT effect that was considered optimal for imaging considerations was that which produced an Ms/Mo of muscle between 0.65 and 0.75. At 1.5 T, SAR limitations restricted the use of MT such that SNR problems are not often encountered.

Section thickness and section gap were varied according to the size of the lesion and the particular information required from the study. The overall aim was maximum resolution within the confines of a reasonable imaging time and SNR. MT prepulses do increase the imaging time by about 15% to 20%, or the number of sections can be decreased to compensate for the extra time. Further SAR problems are more likely if saturation slabs are used in conjunction with MT. This was particularly noticeable at 1.5 T, but it was not a major consideration because saturation slabs were not routinely used. The choice of coil may have implications for the delivery of MT prepulses and therefore may determine how much MT contrast can be implemented. A mild increase in sensitivity to magnetic susceptibility artifacts was also noted on the MT sequences. All these various factors should be considered when selecting the required protocol and the MT parameters to be used.

In conclusion, use of MT improved contrast between head and neck lesions and background

tissue in most cases studied. MT can be used to good advantage to improve depiction of lesions enhanced by contrast material and adjacent to tissue that has a strong MT effect; it will also aid unenhanced MR imaging in the delineation of tumors or lymph nodes in the parotid gland. MT is not really indicated either for cystic lesions, because they are generally well shown on a T2-weighted image, or for cervical lymphadenopathy in fat, because that does not usually pose an imaging problem. A formal comparison of MT with other imaging sequences (eg, fat suppression) is the next step in evaluating the role of MT in improving imaging results.

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