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T Stages of Tumors of the Tongue and Floor of the Mouth: Correlation between MR with Gadopentetate Dimeglumine and Pathologic Data

Marcello Crecco, Antonello Vidiri, Oronzo Palma, Roberto Floris, Ettore Squillaci, Marco Mattioli, Francesco Marzetti, and Saverio Squillaci

PURPOSE: To define MR accuracy in the evaluation of the T stages of tumors of the tongue and floor of the mouth. **METHODS:** Fifty-two patients affected by squamous cell carcinoma were studied with a superconductive system at 1.5 T. The study was performed with spin-echo T1- and T2-weighted images before contrast and short spin-echo T1-weighted and gradient-echo sequences after gadopentetate dimeglumine administration. The results obtained with MR were compared with pathologic data. **RESULTS:** Good correlation of T stages (TNM system) was obtained in 45 of 52 cases. MR did not show four superficial lesions. In one case, infiltration of the cortical bone of the mandible was not demonstrated (MR, T2; pathologic, T4), and in another the lesion was classified as T2 instead of T3, as it was pathologically. One lesion was classified as T4 on MR because of infiltration of the alveolar ridge but was classified as T2 at surgery. In 46 patients who underwent surgery, the accuracy of MR was excellent for predicting the relationship of tumor to midline and oral floor musculature. The results obtained with gadopentetate dimeglumine were better than those obtained in noncontrast studies in 32 (62%) of 53 cases. **CONCLUSION:** MR showed high accuracy in the study of tumors of the tongue and floor of the mouth.

Index terms: Magnetic resonance, comparative studies; Mouth, magnetic resonance; Mouth, neoplasms; Tongue, magnetic resonance; Tongue, neoplasms

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The diagnosis of tumors of the tongue and floor of the mouth is made by clinical examination and biopsy (1). Computed tomography (CT) and magnetic resonance (MR) assess deep extent of disease (2–4).

MR and CT are comparable for evaluation of tumors of the oral cavity and oropharynx. MR provides better soft-tissue detail and gives direct coronal or sagittal image planes (1, 5–7). For these reasons MR is now considered by many the imaging study of choice in the evaluation of these areas (1, 7).

The purpose of this study was to define the diagnostic accuracy of MR with gadopentetate dimeglumine infusion in the determination of T stages of tumors of the tongue and floor of the mouth, using the TNM classification (American Joint Committee Cancer Staging, 1988) (8).

Methods

Fifty-two patients (30 men and 22 women) 18 to 73 years of age were studied. All had histologically proved squamous cell carcinoma of the tongue (24 cases), base of the tongue (9 cases), or floor of the mouth (19 cases). Table 1 reports the clinical (6 cases) and the pathologic (46 cases) T stages of the tumors evaluated in this study. The clinical stage is indicated for patients who did not undergo surgery. These cases included 4 carcinomas of the tongue, 1 of the base of the tongue, and 1 of the floor of the mouth.

Images were acquired on a 1.5-T (Magnetom, Siemens, Iselin, NJ) superconductive system. A neck coil, 5-mm-

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TABLE 1: T stage of 52 tumors of the tongue and floor of the mouth evaluated clinically (6 cases) and pathologically (46 cases)

T Stage	Tongue	Base of the Tongue	Floor of the Mouth
T1	2	2	1
T2	8	3	8
T3	6	. . .	2
T4	8[a]	4[b]	8[c]
Total	24	9	19

[a] Four cases.
[b] One case.
[c] One case.

TABLE 2: Comparison of MR and clinical and pathologic T stage

MR T Stage	n	Clinical (6 cases) or Pathologic (46 cases) T Stage				
		T0	T1	T2	T3	T4
T0	4		1	1		2
T1	4		4			
T2	19			17	1	1
T3	7				7	
T4	18			1		17

Note.—No positive correlation was found in seven patients between MR and pathologic T stage.

thick sections, and a matrix of 256 × 256 were used. In the study, spin-echo T1-weighted (550/15/2 [repetition time (TR)/echo time/excitations]) and T2-weighted sequences (2500/15-90/1) were performed before contrast administration in axial plane. The protocol also included a spin-echo T1-weighted sequence in the sagittal plane. In some cases, sagittal T2-weighted sequences were carried out for the simultaneous evaluation of the extension to muscles of the floor of the mouth and posterior structures (preepiglottic space and valleculae). For the study of tumor extension to the mandible, gradient-echo sequences (190/20, 25° flip angle) in the axial planes were used. In all cases gadopentetate dimeglumine was administered at 0.2 mmol/kg. In the first part of this work, the gradient-echo technique (30/12, 70° flip angle, 17-second acquisition time) was performed after gadopentetate dimeglumine infusion. In the last 32 patients of the study, a spin-echo technique with a very short TR (180/15/2) was performed after gadopentetate dimeglumine infusion. Acquisition time was 90 seconds (with an imaging matrix of 192 × 192). Five sections were done in this sequence.

T stages were determined in all patients. For the staging of tumors of the oral tongue (anterior two thirds of the tongue) and floor of the mouth, the American Joint Committee Cancer Staging criteria for oral cavity tumors were used. The criteria for staging oropharynx tumors were used for the evaluation of tumors of the base of the tongue. The results, obtained with MR, were compared with clinical data in 6 cases (patients not undergoing surgery) and pathologic data in 46 cases.

In the patients who underwent surgery, the results were compared with pathologic findings for the evaluation of: relationship between tumor and midline; extension of the tumor to muscles of the floor of the mouth; involvement of bone of the alveolar ridge (referring to the superior aspect) and cortical bone of the mandible (gingival and buccal surfaces); and involvement of the tonsillar bed, valleculae, preepiglottic space, and hyoid bone. The evaluation of these correlations was obtained by dissection of the tissue removed en bloc at surgery.

This was a prospective study; the exams were evaluated by two independent observers and the results consensually determined.

Results

In the evaluation of T stage, there was good correlation between MR, clinical (6 cases), and pathologic data (46 cases) in 45 of 52 cases. MR allowed accurate prediction of the stages in all patients with clinically determined T stages. In 7 patients, MR did not correlate well with pathologic T stages (Table 2).

Four superficial lesions were not shown by MR. Two tumors of the anterior floor of the mouth, each approximately 1.5 cm, infiltrated the alveolar ridge (MR, T0; pathologic, T4). Two tumors of the tongue, 0.5 cm (MR, T0; pathologic, T1) and 2.5 cm (MR, T0; pathologic, T2), were not visible on MR.

In one patient, a lesion of the tongue was classified T2 with MR but T3 at pathologic examination. Part of the lesion was superficial. MR indicated a smaller size than that found at surgery, thus accounting for the difference in staging.

In one case, MR did not show the infiltration of the cortical bone of the mandible by a carcinoma of the floor of the mouth (MR, T2; pathologic, T4).

In one patient, MR indicated that a lesion of the tongue and the floor of the mouth was T4, because of infiltration of the alveolar ridge. The alveolar ridge was not involved at surgery, and the lesion was therefore classified as T2 pathologically.

The accuracy of MR in showing involvement of surrounding structures is summarized in Table 3. MR had an accuracy of 98%, a sensitivity of 95%, and a specificity of 100% in the evaluation of relationship with the midline (Fig 1). In one case of a patient with tongue carcinoma, MR did not show the presence of multiple superficial nodules crossing the midline.

In two cases, of carcinoma of the floor of the mouth, MR did not demonstrate the infil-

TABLE 3: Correlation between MR and pathologic findings in the evaluation of relationships between tumors and surrounding structures in 46 patients who underwent surgery

	Cases				MR, %		
	TP	TN	FP	FN	Ac	Se	Sp
Midline	19	24	. . .	1	98	95	100
Floor of the mouth	4	21	. . .	2	92	66	100
Muscles							
Alveolar ridge	3	12	1	2	83	60	92
Mandible	2	12	. . .	1	93	66	100
Tonsillar bed, valleculae							
Preepiglottic space	6	3	. . .	1	90	86	100
Hyoid bone							

Note.—TP indicates true positive; TN, true negative; FP, false positive; FN, false negative; Ac, accuracy; Se, sensitivity; and Sp, specificity.

tration of muscles of the floor of the mouth. MR had an accuracy of 92%, a sensitivity of 66%, and a specificity of 100% (Figs 2 and 3) in showing infiltration of the muscles of the floor of mouth.

MR did not demonstrate the infiltration of the alveolar ridge in two patients; in one case MR showed apparent infiltration not confirmed at surgery. For assessment of the alveolar ridge, the accuracy of MR was of 83%, the sensitivity 60%, and the specificity 92% (Fig 4).

For assessment of tumor invasion of cortical bone, MR had an accuracy of 93%, a sensitivity of 66%, and a specificity of 100%. In one patient MR did not show the infiltration of the cortical bone of the mandible.

In all patients MR demonstrated the extension of the carcinoma to the valleculae, preepiglottic space, and tonsillar bed. In one case MR did not show the infiltration of the hyoid bone from a carcinoma of the tongue. The accuracy of MR in the evaluation of relationships between tumors and these structures was 90%, the sensitivity 86%, and the specificity 100% (Figs 5 and 6).

The diagnostic information of MR images obtained with gadopentetate dimeglumine was considered better than of those obtained without in 32 (62%) of 52 cases (Fig 7). In the other 20 cases, no significant difference was seen. In tongue tumors, gadopentetate dimeglumine

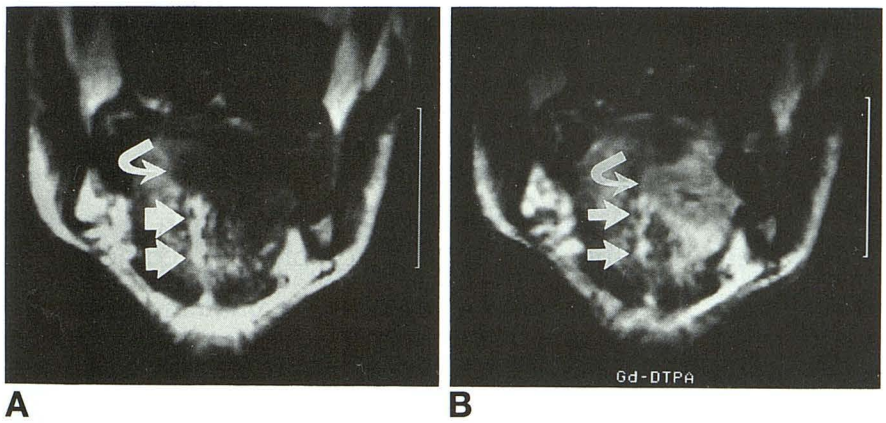

Fig 1. Tumor of the left hemitongue: stage T3 by pathology.

A, Coronal plane shows a lesion with low signal intensity in a spin-echo T1-weighted (550/15) sequence, crossing the midline (lesion margin, *curved arrow*; midline, *straight arrows*).

B, After gadopentetate dimeglumine infusion, with a short-TR spin-echo T1-weighted sequence (180/15), the lesion shows a marked enhancement and is not exceeding the midline.

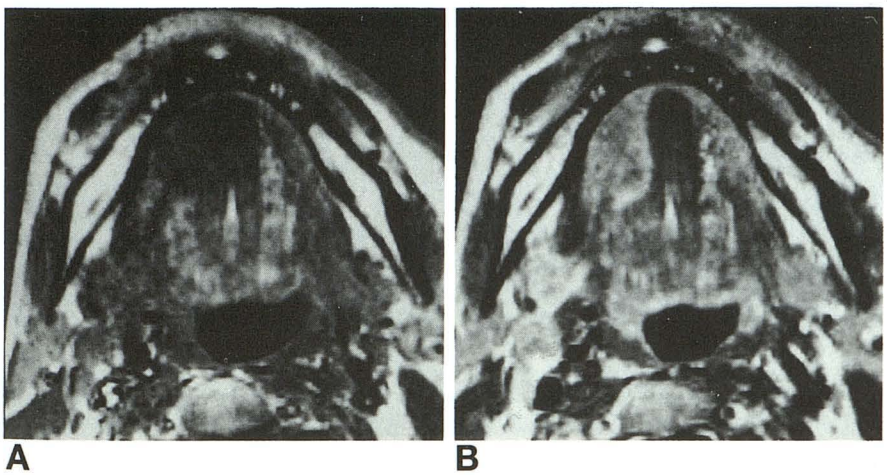

Fig 2. Tumor of the right floor of the mouth: stage T4 by pathology.

A, Spin-echo T1-weighted sequence (550/15) in the axial plane shows the presence of a lesion of the right floor of the mouth invading the sublingual space; this image does not allow definition of the relationships between lesion, muscle, and midline.

B, These relationships are well demonstrated after gadolinium infusion.

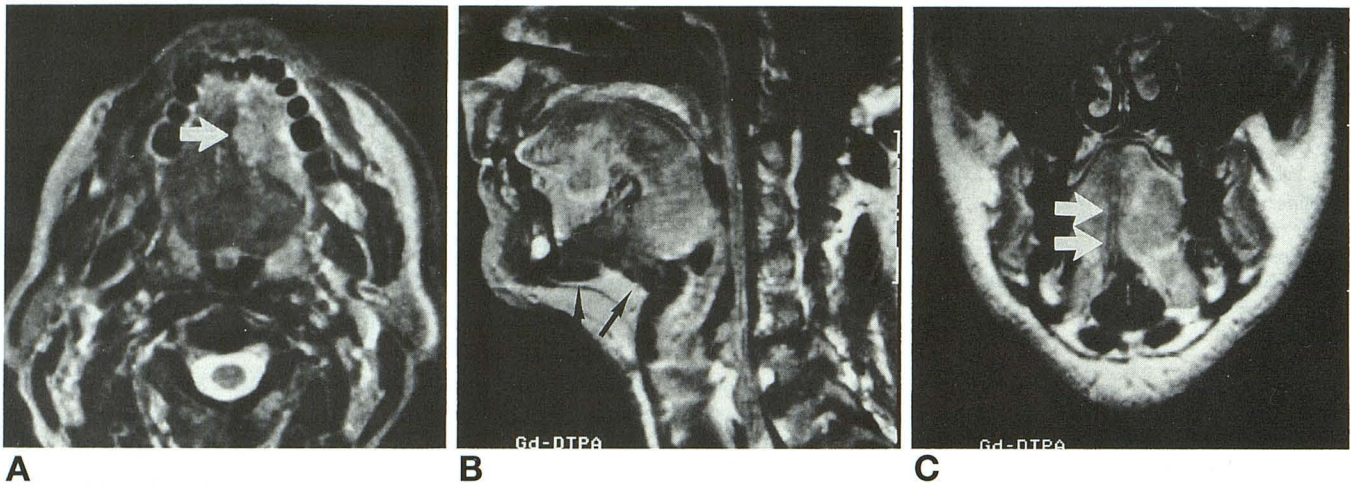

Fig 3. Tumor of the left tongue: stage T2 by pathology.

A, Spin-echo T2-weighted sequence (2500/30) in axial planes shows a hyperintense lesion (*white arrow*) of the left hemitongue. The hyperintensity of the lesion is not distinguishable from the sublingual space.

B and *C*, The administration of gadopentetate dimeglumine with short-TR spin-echo T1-weighted sequences, in sagittal (*B*) and coronal (*C*) planes, shows the lesion extending to the floor of the mouth without infiltration of the muscles of the floor of mouth (*black arrows*). This lesion does not infiltrate the mandible, as demonstrated in the sagittal plane (*B*), and is not exceeding the midline (*white arrows*), as demonstrated in the coronal plane (*C*).

gave better diagnostic information in 13 (54%) of 24 cases, better demonstrating the relationships between tumors and midline, the sublingual space, and intrinsic/extrinsic muscles. In tumors of the floor of the mouth, gadopentetate dimeglumine was considered superior in 12 (62%) of 19 cases, better demonstrating the relationships of tumor to the sublingual space, styloglossus, and hyoglossus muscles and the cortical bone of the mandible. In tumors of the base of the tongue, gadopentetate dimeglumine was found to be superior in 7 (78%) of 9 cases, better showing relationships with the valleculae.

Discussion

The most accurate tumor staging, in tumors of the oral cavity and oropharynx, comes when

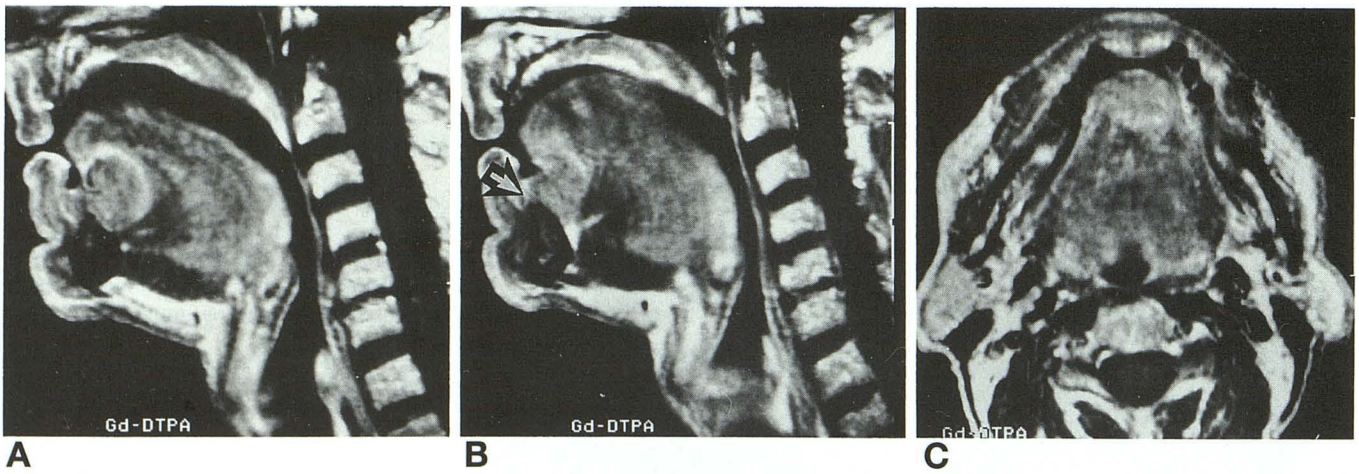

Fig 4. Tumor of the anterior floor of the mouth: stage T4 by pathology. Short-TR spin-echo T1-weighted sequences (180/15) in the sagittal plane (*A* and *B*) and in the axial plane (*C*) after gadopentetate dimeglumine infusion show a lesion of the anterior floor of the mouth, involving the alveolar ridge (*arrow*) but not infiltrating the cortical bone of the mandible.

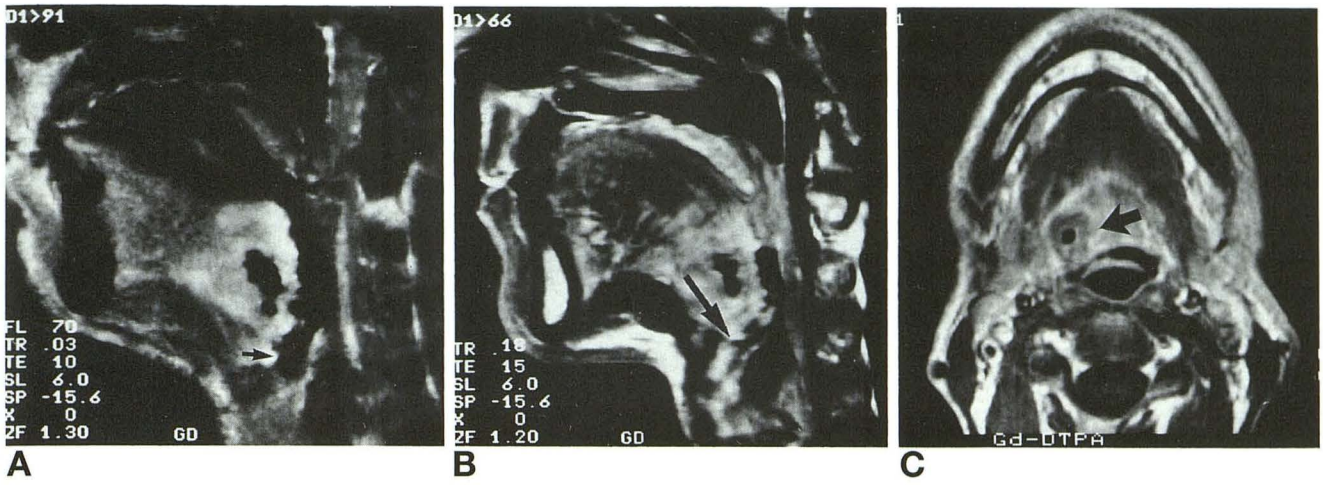

Fig 5. Tumor of the base of the tongue: stage T2 by pathology.

A, Gradient-echo fast low-angle shot (30/10, 70° flip angle) and *B*, spin-echo short-TR T1-weighted (180/15) sequences show a lesion of the base of the tongue, pointing out marked enhancement with central necrosis. The tumor reaches the anterior wall of the vallecula (*arrow*) but not the bottom and the posterior wall, as demonstrated both in the gradient-echo sequence in the sagittal plane (*A*) and in spin-echo sequences in the sagittal (*B*) and axial (*C*) planes. The lesion (*arrow*) extends toward the preepiglottic space as demonstrated in the axial plane (*C*).

the clinical mucosal extent, based on visual and tactile observations, is matched with the radiographic evaluation of deep-tissue extent. In tumors of the tongue and floor of the mouth, the size and extent of the primary tumor is critical in planning surgery and/or radiation therapy (9, 10). Hemiglossectomy is possible when the lesion has not crossed the midline. Partial glossectomies require the preservation of one lingual artery and hypoglossal nerve. When the tumors extend more than 1 cm across the midline, the opposite lingual arteries also must be sacrified, resulting in a functional total glossectomy (9). A total glossectomy with supraglottic laryngectomy or partial pharyngectomy is required when the tumor extends to valleculae, the preepiglottic space, the tonsillar bed, or the hyoid bone (1, 3, 9, 10).

Either CT or MR can be used to stage primary tumors: with either method one can stage any T2 or larger squamous cell carcinoma of the tongue and floor of the mouth objectively. MR offers the advantage of multiplanar views and gives high contrast between tumors and fat in T1-weighted sequences and between tumors and muscles in T2-weighted sequences (11–13). Some authors have suggested that the use of gadopentetate dimeglumine permits a

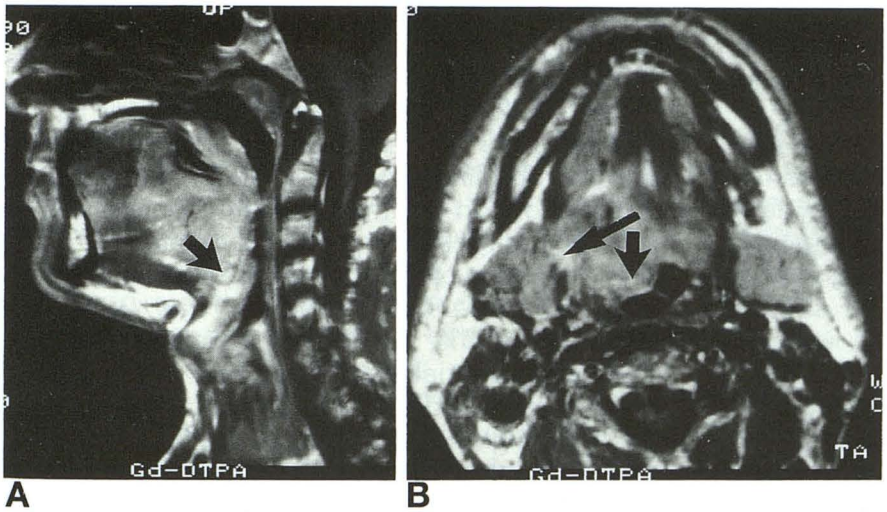

Fig 6. Tumor of the base of the tongue: stage T4 at pathology.

A, Spin-echo T1-weighted sequence (550/15) in the sagittal plane shows a lesion of the base of the tongue with a marked enhancement.

B, The axial plane shows the lesion extending posteriorly, infiltrating the right vallecula (*short arrows*) and the submandibular gland (*long arrow*). The axial plane image was performed later than the sagittal, so the lesion shows less enhancement.

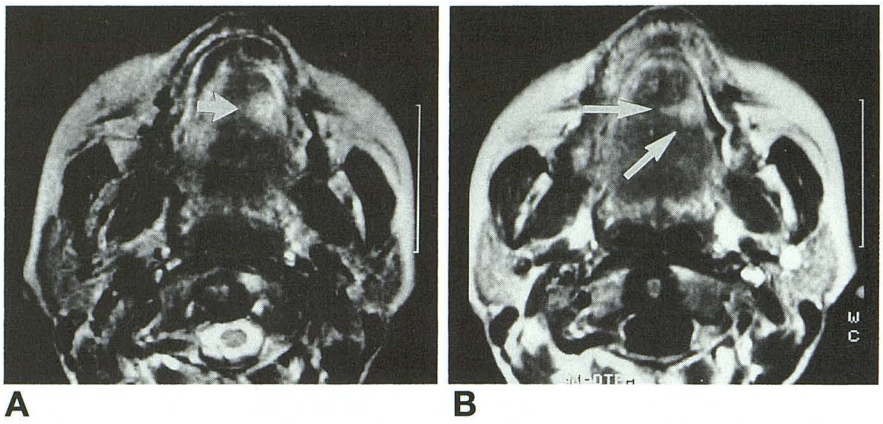

Fig 7. Tumor of the left hemitongue: stage T1 by pathology.

A, T2-weighted sequence (2500/90) on the axial plane shows a hyperintense lesion involving the left hemitongue (*short arrow*).

B, With short-TR spin-echo T1-weighted sequence (180/15) in the same plane, after gadopentetate dimeglumine infusion, the strong enhancement permits a better identification of the tumor (*long arrows*), which did not cross the midline.

more precise determination of tumor volume, differentiating the neoplastic tissue from edema (3, 7, 14).

In our experience, MR gave high accuracy in the evaluation of T stages of tumors of the tongue and floor of the mouth. However, as reported by various authors (1, 3, 7, 12, 15), MR failed to show superficial spreading tumors in four patients, either before or after gadopentetate dimeglumine infusion. In these cases, however, MR, although not demonstrating the lesion, can exclude infiltration into the muscle bundles or deep fascial planes.

In the evaluation of tumor volume, using gadopentetate dimeglumine was considered better than not. T1-weighted sequences with short TRs must be used, because these tumors show quick enhancement, as reported by other authors (4, 9). We have used gradient-echo sequences with acquisition times of 17 seconds in apnea, and short-TR, spin-echo T1-weighted sequences with acquisition times of 90 seconds. We use these last sequences more frequently, because these have a greater contrast resolution, and because in these patients it is often difficult to obtain apnea, which is necessary to perform the scans with the gradient-echo technique.

Gradient-echo sequences with bolus injections of gadopentetate dimeglumine were used at the beginning of this work for the dynamic studies in 20 patients. We have demonstrated that these neoplasms have enhancement peaks of about 120 to 180 seconds. The short-TR spin-echo T1-weighted sequences with 90-second acquisition timed and five sections allowed an optimal evaluation of the neoplasms, showing clearly 5 lesions of 6 at stage T1. We noticed that the use of gadopentetate dimeglumine with a TR of 560 shows a reduction of the contrast between tumors and surrounding tissue with a loss of diagnostic information owing to diffusion of contrast medium into the interstitial space.

We used T2-weighted sequences to locate the tumors to target the short-TR spin-echo T1-weighted gadolinium-enhanced sequences, which were limited to a few sections.

In our study the gadopentetate dimeglumine–enhanced sequences were considered better than unenhanced sequences in 32 of 52 cases, the two sequences being comparable in 20 patients. Spin-echo T1-weighted sequences with short TRs, after gadopentetate dimeglumine infusion, gave superior diagnostic information to T2-weighted sequences, because they allowed a better definition of the relationships between tumors and surrounding structures. Short imaging times allowed the study of the lesions in multiple planes, without increase of examination time and with reduction of motion artifacts. When edema is present, gadopentetate dimeglumine can suggest a differentiation between edema and the neoplastic tissue with a more precise definition of tumor size. More investigation of this effect is required before conclusive statements can be made.

MR has demonstrated high accuracy in the evaluation of the relationships between tumors and surrounding structures. This has important implications in treatment of the disease and in planning surgery, as previously stated (2, 10). The accuracy of determination of relationships between tumors and midline was 98%, the sensitivity 95%, and the specificity 100%. Coronal and axial planes are best in the evaluation of the midline, which has a high signal on T1-weighted sequences, because of fat. The sagittal and coronal planes demonstrate the relationship between tumors and muscles

of the floor of the mouth, resulting in an accuracy of 92%, a sensitivity of 66%, and a specificity of 100%.

In the study of tumors of the floor of the mouth, it is very important to define infiltration of the geniohyoid and mylohyoid muscles. The relationship between tumors and the alveolar ridge and the mandible is particularly important. A partial mandibular resection may be required for carcinomas that are immediately adjacent to these structures (1, 10), because microscopic invasion often cannot be excluded. In these cases we use the gradient-echo sequences. The diagnosis of involvement of the alveolar ridge was made when the tumor was spreading on the gingival mucosa covering the alveolar ridge and there was irregularity of the cortical bone. The diagnosis of the infiltration of the cortical bone of the mandible was made on the basis of the loss of the low-signal line of the cortical bone. In our study the alveolar ridge and cortical bone of the mandible were considered distinctly different regions. The term *alveolar ridge* referred only to the superior aspect of the tooth-bearing regions of the mandible. MR evaluation of the alveolar ridge is more difficult than evaluation of the cortical bone of the mandible. In our experience MR had an accuracy of 83%, a sensitivity of 60%, and a specificity of 92% in the evaluation of the alveolar ridge, compared with an accuracy of 93%, a sensitivity of 66%, and a specificity of 100% for the evaluation of the cortical bone of the mandible.

In the evaluation of bone involvement, MR is considered better than CT in following tumor extension through the bone marrow. The involvement is indicated by the presence of low signal intensity in the marrow cavity on the spin-echo T1-weighted sequences (6). CT is better than MR in the evaluation of the involvement of the cortical bone of the mandible because of the higher spatial resolution (1, 6, 15). We use CT in all cases in which there is a close connection between tumor and mandible.

In tumors of the floor of the mouth, the coronal plane is very important for evaluation of the hyoglossus and styloglossus muscles. The coronal plane allows evaluation of the relationship between tumors and mylohyoid muscle, separating the sublingual from the submandibular space.

Sagittal, coronal, and axial planes permit a precise evaluation of the relationship between tumors of the base of the tongue and oropharynx structures. In our experience MR had an accuracy of 90%, a sensitivity of 86%, and a specificity of 100%. MR failed to show infiltration of the hyoid bone in one case. In the study of relationships between tumors and valleculae, gradient-echo and short-TR spin-echo T1-weighted sequences after administration of gadopentetate dimeglumine are important, because spin-echo T2-weighted sequences are often altered by motion artifacts. The evaluation of the valleculae is important, because infiltration of only the anterior wall, without extension of the tumor to the posterior wall, allows preservation of the epiglottis at surgery.

In conclusion, MR showed a high accuracy both in the evaluation of T stage and in the evaluation of the relationships between tumors and surrounding structures. The use of gadopentetate dimeglumine was very important in the determination of the tumor volume and extent, but it must be used with short-TR spin-echo T1-weighted or gradient-echo sequences. We think that MR with gadopentetate dimeglumine should be considered the image modality of choice in the study of tumors of the tongue and floor of the mouth.

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