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MR of Denervated Tongue: Temporal Changes after Radical Neck Dissection

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PURPOSE: **The purpose of this study was to evaluate the temporal changes of MR imaging in the denervated tongue after a radical neck dissection.**

METHODS: **One hundred seventy-four consecutive MR studies in 116 patients with radical neck dissections for malignant tumors of the head and neck were evaluated retrospectively. Patients with tumors involving the tongue or hypoglossal nerve were not included in this study.**

RESULTS: **Abnormal signal intensity and/or hemiatrophy on the side of the tongue operated on was seen in 22 patients who had hypoglossal paralysis after radical neck dissection. The denervated side of the tongue appeared hypointense to hyperintense relative to the normal side on T1-weighted images and hyperintense on T2-weighted images. Signal intensity ratios of the abnormal to normal muscles were 0.9—1.6 on T1-weighted images and 1.3—2.8 on T2-weighted images. High signal intensity on T1-weighted images appeared 5 months or more after the dissection, whereas on T2-weighted images, the most prominent increases in signal intensity appeared in the first several months after denervation. Hemiatrophy of the tongue was observed on MR images obtained more than 6 months after surgery.**

CONCLUSION: **MR findings in the denervated tongue are compatible with histologic changes and are characterized by an enlarged extracellular fluid space or fatty infiltration. The pattern of signal intensity and the degree of hemiatrophy suggest the duration of denervation.**

Denervation muscle atrophy signals a pathologic condition involving the motor nerves. The usefulness of magnetic resonance (MR) imaging in the diagnosis of denervation has been reported experimentally and clinically (1–5). However, clinical studies of the temporal changes in MR findings in the denervated muscle are limited, because the time of onset of motor nerve injury is usually not known with certainty (1, 2).

Hemiatrophy of the tongue is an indirect sign of damage to the hypoglossal nerve, suggesting the possibility of a head and neck neoplasm or a brain stem abnormality (6–8). Hypoglossal paralysis occurring after radical neck dissection has been reported otorhinolaryngologically as a complication of surgery (9, 10). In patients who have undergone neck dissection for a malignant process, the denervated tongue suggests the likelihood not only of recurrence with involvement of the hypoglossal nerve but also of postoperative changes. Previously, we described the MR findings in seven cases of denervated tongue occurring after a radical neck dissection (11). In the present study, we evaluated the temporal changes of MR findings in the denervated tongue in a large population.

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Methods

One hundred seventy-four consecutive MR studies in 116 patients with radical neck dissections were evaluated retrospectively. The subjects included 88 men and 28 women who had been treated surgically, with or without radiation therapy, for malignant tumors of the head and neck with metastasis to the cervical lymph nodes. Patients with tumors involving the tongue or hypoglossal nerve were not included in the study. No patient had evidence of tumor recurrence, and there was no radiologic evidence of soft-tissue enlargement along the course of the hypoglossal nerve up to the skull base. Seven patients reported in our previous study (11) are included in the current study.

MR imaging was performed with one of two 1.5-T MR units as follow-up studies 1 to 82 months after neck dissection. T1-weighted spin-echo images (600–670/14–15/1–2 [repetition time/echo time/excitations]) were obtained before and after intravenous injection of 0.1 mmol/kg gadopentetate dimeglumine. T2-weighted images were obtained with either conventional spin-echo (2300/90/1) or fast spin-echo (4000–4500/96/1–2) sequences.

Abnormal signal intensity and hemiatrophy of the tongue were established visually by consensus of three of the authors, who were unaware of the clinical findings. The degree of

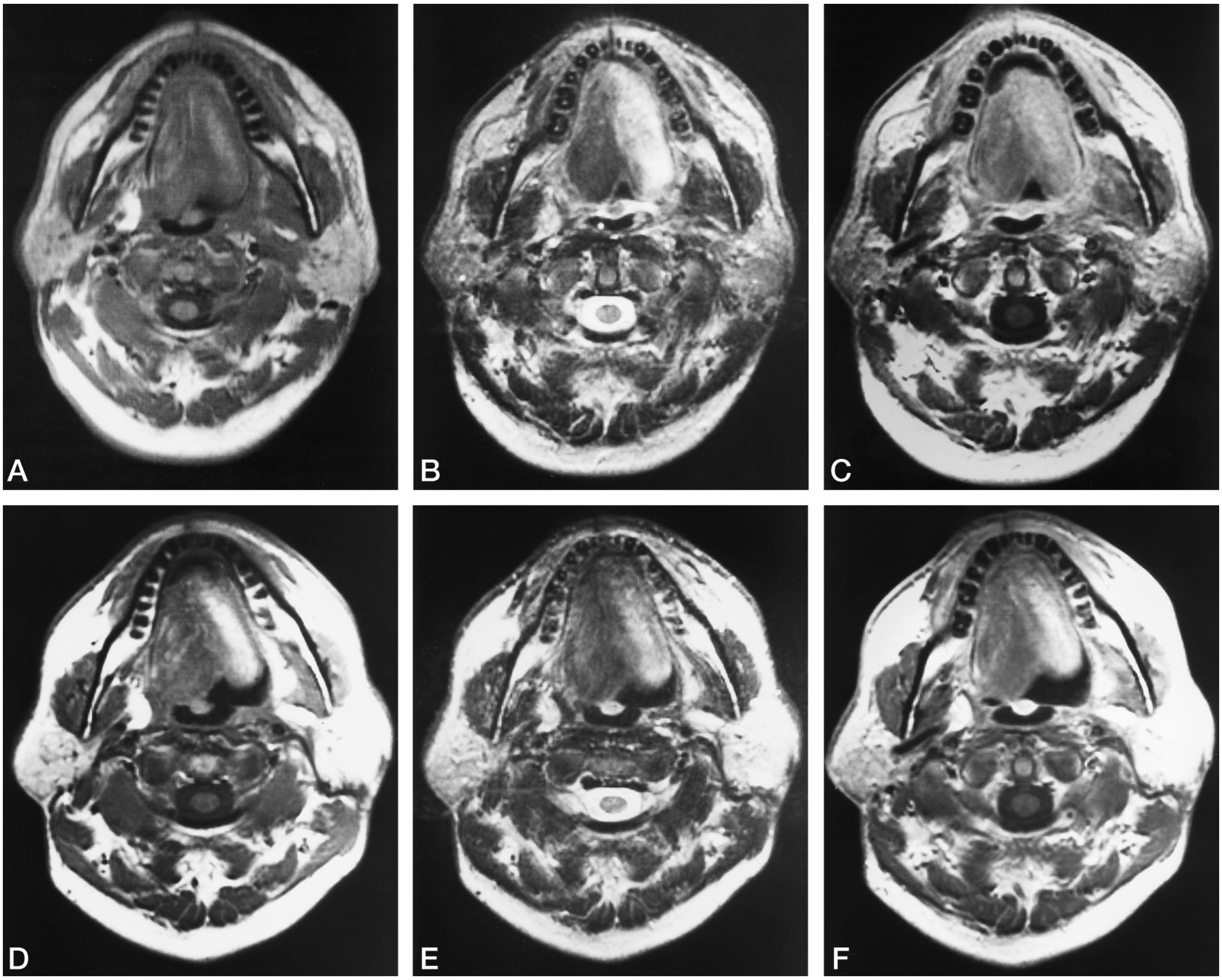

FIG 1. Serial MR studies in a 43-year-old man with left-sided denervated tongue after radical neck dissection and myocutaneous reconstruction of a neck flap.

A, Unenhanced T1-weighted image (670/14/1) 3 months after surgery shows normal signal (signal intensity ratio = 1.0) of the tongue.

B, T2-weighted image (4500/96/1) 3 months after surgery clearly shows prominent hyperintensity (signal intensity ratio = 2.8) of the left half of the tongue.

C, Contrast-enhanced T1-weighted image (670/14/1) 3 months after surgery shows prominent enhancement in the corresponding area (signal intensity ratio = 1.4).

D, Unenhanced T1-weighted image (670/14/1) 12 months after surgery shows increased signal (signal intensity ratio = 1.7) with mild hemiatrophy on the left side of the tongue.

E, T2-weighted image (4500/96/1) 12 months after surgery shows hyperintensity (signal intensity ratio = 2.0) of the tongue.

F, Contrast-enhanced T1-weighted image (670/14/1) 12 months after surgery shows no apparent abnormal enhancement in the corresponding area (signal intensity ratio = 1.6).

hemiatrophy was subjectively defined as none, mild, or marked. To quantify the visual observations, signal intensity of both the denervated and normal sides of the tongue was measured over the regions of interest, and signal intensity ratios of the abnormal to normal muscles were calculated according to the following equation: Signal intensity (SI) ratio = (SI in denervated muscles − SI of background noise)/(SI in normal muscles − SI of background noise). The correlation between MR findings in the denervated tongue and the interval since radical neck dissection was evaluated by means of the signal intensity ratios and the subjective degree of hemiatrophy.

Results

Abnormal signal intensity on the side of the tongue operated on was present, with or without hemiatrophy, on 33 MR studies obtained in 22 patients 1 to 26 months after radical neck dissection. (Six patients were studied serially with two to four MR examinations.) The group included 18 men and four women in whom hypoglossal paralysis occurred after surgery. T1-weighted images showed the denervated side of the tongue as hypointense relative to the normal side on four MR studies, isointense on 10 studies, and hyperintense on 19 studies. On T2-weighted images, the lesion appeared hyperintense relative to the normal side on all 33 studies (Fig 1). Signal intensity ratios of the abnormal to normal muscles were 0.9—1.6 on T1-weighted images and 1.3—2.8 on T2-weighted images. Contrast enhancement was more prominent on the denervated side of the tongue than on the normal side in 15 of 33 studies. The time

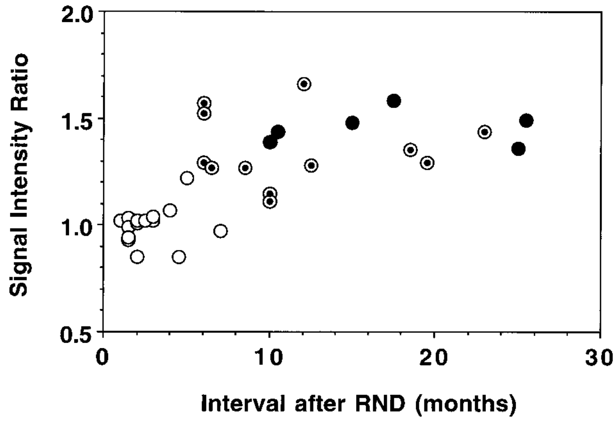

FIG 2. Signal intensity ratios of T1-weighted images. Degree of hemiatrophy is indicated as none (*open circles*), mild (*open circles with central dot*), or marked (*solid circles*); *RND* indicates radical neck dissection.

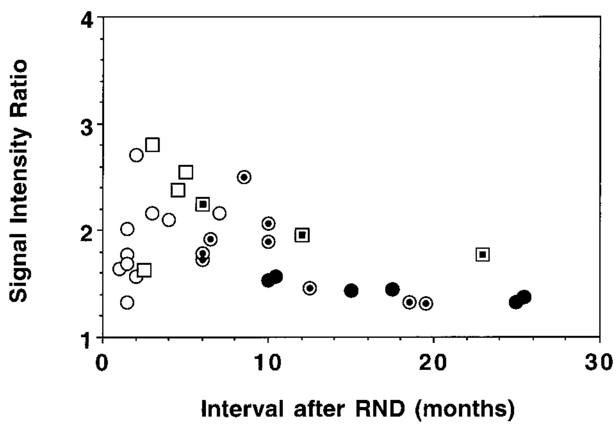

FIG 3. Signal intensity ratios of T2-weighted images obtained with conventional (*circles*) and fast (*squares*) spin-echo techniques. Degree of hemiatrophy is indicated as none (*open circles*), mild (*open circles with central dot*), or marked (*solid circles*); *RND* indicates radical neck dissection.

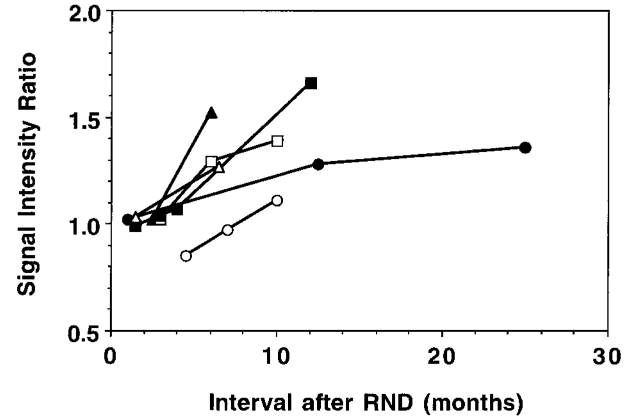

FIG 4. Serial changes of signal intensity ratios on T1-weighted images in six patients, each indicated by a different symbol; *RND* indicates radical neck dissection.

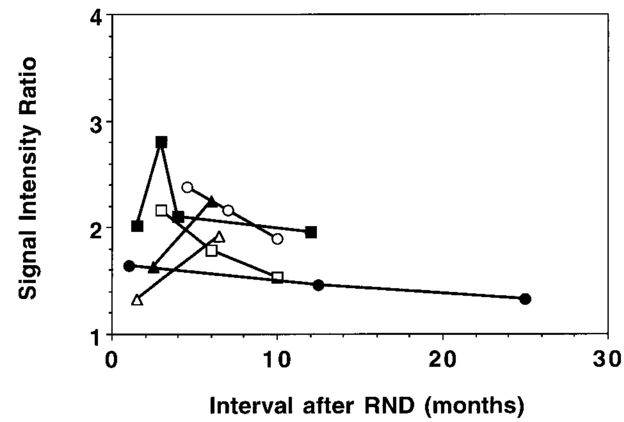

FIG 5. Serial changes of signal intensity ratios on T2-weighted images in six patients, each indicated by a different symbol; *RND* indicates radical neck dissection.

course of signal intensity, as well as serial MR studies in six patients, revealed that high signal intensity ratios (>1.0) on T1-weighted images appeared 5 months or more after neck dissection, whereas the most pronounced increase in signal intensity ratios (>2.0) on T2-weighted images occurred in the first several months after denervation (Figs 1–5).

We found no correlation between the prominent contrast enhancement of the denervated tongue and the interval since neck dissection. Hemiatrophy of the denervated tongue was seen on 18 MR studies obtained more than 6 months after surgery, and marked atrophy was observed on six studies obtained more than 10 months after surgery (Figs 1–3).

Discussion

Radical neck dissection is the standard treatment for cervical lymph node metastases, although the cranial and cervical nerves are at risk of injury during the operation (9, 10). Reportedly, the frequency of unintentional injury to the nerves is less than 5%, with the risk increasing as the disease progresses (9). The hypoglossal nerve courses over both internal and external carotid arteries, and is crossed twice by the digastric muscle at the submandibular triangle, where injury to the hypoglossal nerve may occur during neck dissection (11). In patients whose primary tumor or lymph node metastases involve the submandibular triangle, there is the increased possibility of hypoglossal paralysis after surgery. In our study, denervated tongues were shown in 19% of the patients. This higher rate of occurrence can probably be attributed to the fact that our MR studies were performed as follow up studies for patients with progressed disease.

Polak et al (3) experimentally investigated early MR findings in samples of rat muscle 15 days after denervation, and found prolongation of both the T1 and T2 relaxation times. They suggested that the relaxation times correspond to the tissue water in enlarged extracellular fluid spaces. Uetani et al (1), in a clinical study, observed high signal intensity on T2-weighted images and normal signal intensity on T1-weighted images 15 days or more after the onset of paralysis. However, they acknowledged that the interval between onset of paralysis and MR imaging may not have been known precisely, since time of onset was designated as that reported by the patient. In another clinical study, Fleckenstein et al (2) examined traumatic peripheral nerve injury as a model of denervation, but the muscle edema caused by the direct trauma was a potential limitation of their investigation. In that study, MR imaging showed poor sensitivity within 1 month after onset of nerve injury, whereas denervated muscles showed prolonged T1 and T2 relaxation times between 1 and 12 months after the injury, and conspicuous fatty infiltration was evident on T1-weighted images more than a year after that. Recently, a fat-suppression short-inversion-time inversion recovery (STIR) sequence has been suggested as a useful technique for evaluating denervated muscle (2, 4). In the meantime, the results of previous studies also suggest that denervated muscles are detectable on T1- and/or T2-weighted images more than 1 month after injury (1–3). In our study, all MR images were obtained in the detectable phase of denervation, because no MR examinations were performed earlier than 1 month after neck dissection.

Previous reports of MR findings of the denervated tongue are limited, and have described denervation with fatty infiltration due to tumor invasion, without reference to the exact onset of nerve damage (8). In our study, the date of a radical neck dissection could be regarded as the onset of hypoglossal nerve injury; however, the surgery itself, with or without radiation therapy, is one of the limitations of our study, because we cannot ignore the effects on the vascular circulation, in addition to radiation-induced damage. Although the temporal changes in MR findings in the denervated muscle may vary from muscle to muscle and with the degree of nerve damage, our results are compatible with those of previous investigations (1–3). MR findings reflect the histologic changes of the denervated tongue as follows: between 1 and 5 months after onset, the tongue appears isointense to hypointense relative to normal muscle on T1-weighted images and prominently hyperintense on T2-weighted images as a result of edema and increased extracellular water. More than 5 months after denervation, fatty infiltration is detected as an area of hyperintensity relative to normal muscle on both T1- and T2-weighted images, and hemiatrophy is observed subsequently.

If the denervated tongue is seen without hemiatrophy or high signal intensity on T1-weighted MR images 1 year after a radical neck dissection, the findings are incompatible with the postoperative changes and the possibility of tumor recurrence with involvement of the hypoglossal nerve should be considered.

Contrast enhancement of denervated muscles is sometimes more prominent than that of normal muscles (5, 11). Although our results suggest no relationship between enhancement and duration of denervation, the concentration or number of capillaries per volume of muscle may increase as atrophy progresses. Furthermore, contrast material accumulates in the extracellular fluid spaces, which are more prominent in denervated muscles.

Conclusion

In the presence of abnormal MR findings in the tongue, the possibility of denervation must be considered in order to avoid a misdiagnosis of an inflammatory or neoplastic process. The MR appearance of the denervated tongue is nonspecific, but the pattern of distribution of abnormal signal intensity and the degree of hemiatrophy may be diagnostic and should suggest the duration of denervation.

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