MR Appearance of Trigeminal and Hypoglossal Motor Denervation

Craig P. Russo, Wendy R. K. Smoker, and Jane L. Weissman

PURPOSE: To illustrate and describe the appearance of both long-standing and relatively recently occurring motor denervation of the hypoglossal nerve and of the third (mandibular) division of the trigeminal nerve (V3), with emphasis on findings particular to MR imaging. METHODS: Findings from 11 patients with V3 denervation and from seven patients with hypoglossal denervation resulting from a variety of abnormalities were reviewed retrospectively. The motor denervation appearance and functional compromise of the affected musculature are described in terms of the chronicity of the denervation process. RESULTS: The appearance of V3 and hypoglossal motor denervation varies with the chronicity of the process. Long-standing denervation results in extensive fatty replacement and a decrease in the size of the affected musculature. Relatively recently occurring denervation results in abnormal contrast enhancement and edemalike signal changes in the denervated musculature. Fatty replacement was observed acutely in hypoglossal denervation but did not manifest until the subacute stage in V3 denervation. Increased volume of the denervated musculature may also accompany acute denervation signal changes. CONCLUSION: V3 and hypoglossal denervation have a variable appearance depending on the chronicity of the process. Recognition of MR imaging patterns of denervation may allow earlier diagnosis of a denervating lesion and may help to distinguish denervation from similar-appearing processes, such as infection or neoplasia.

Index terms: Nerves, hypoglossal (XII); Nerves, magnetic resonance; Nerves, trigeminal (V)

Magnetic resonance (MR) imaging has greatly expanded the capacity to image the cranial nerves directly and to evaluate sequelae of cranial nerve denervation. Harnsberger and Dillon (1) described patterns of cranial nerve motor denervation atrophy seen at computed tomography (CT) and emphasized that these patterns may be the only clue to underlying cranial nerve disease. Recognition of these patterns on CT scans is based on the presence of atrophy and fatty replacement of particular muscle groups. The pathologic process must, therefore, be present for sufficient duration to result in appreciable fatty infiltration and volume loss of the denervated musculature. MR imaging, with its superior soft-tissue characterization, facilitates recognition of more subtle, earlier fatty infiltration and can show other findings of denervation, such as abnormal muscle enhancement, which are not apparent on CT scans (2, 3).

In our practices we most commonly encounter patients with denervation of the hypoglossal (12th) nerve or of the third (mandibular) division of the trigeminal (fifth) nerve (V3). These nerves are affected by a variety of pathologic processes and the innervated muscle groups are readily recognizable. The purpose of this article is to review the more common MR manifestations of V3 and hypoglossal denervation and to describe the less common manifestations of denervation that are apparent only with MR imaging.

Anatomy

A schematic diagram of the course of the third division of the trigeminal nerve is shown in Figure 1. V3 provides motor innervation to the
muscles of mastication (temporalis, masseter, medial, and lateral pterygoid) and to two of the muscles of the floor of the mouth (anterior belly of the digastric and mylohyoid). V3 also provides motor innervation to the tensor veli palatini muscle, which regulates eustachian tube patency, and to the tensor tympani muscle, which provides acoustic dampening. Figure 2 is a schematic diagram of the course of the hypoglossal (12th) nerve, which provides motor innervation to the extrinsic muscles of the tongue (genioglossus, hyoglossus, styloglossus, and geniohyoid) and to the intrinsic tongue muscles.

**Materials and Methods**

We retrospectively reviewed the clinical and teaching files of our institutions and identified 11 cases of V3 denervation and seven cases of hypoglossal denervation. A summary of the cases is presented in Tables 1 and 2, respectively. Imaging patterns were described as acute (less than 1 month), subacute (1 month to 20 months), or chronic (greater than 20 months). Although other authors have arbitrarily defined subacute and chronic differently, our definitions are based on the observation of specific imaging patterns for each of these designations, as described in the “Results” section. Duration of denervation was based on either onset of symptoms or onset of a known pathologic insult (eg, surgical trauma). T2 prolongation of denervated muscles was determined qualitatively by comparing T1- and T2-weighted MR images. T1-weighted images were assessed for fatty infiltration. If the T2-weighted images showed increased signal intensity in addition to, or in a different distribution from, areas of fatty infiltration seen on T1-weighted images, T2 prolongation was considered present. All imaging was done with either a 1.0-T or 1.5-T superconducting magnet, and most examinations included both T1- and T2-weighted images. In several of the cases presented here, contrast material was not administered; and in some cases, only T1- or T2-weighted images were available for review. T2-weighted images were obtained with a conventional spin-echo technique in all but two patients. Fast spin-echo T2-weighted images were obtained in case 7 (Table 1) and fat-suppressed T2-weighted images were obtained in case 6 (Table 2). The greater signal intensity of fat on fast spin-echo images as compared with conventional spin-echo images was not a confounding factor in estimating the presence of T2 prolongation in these patients. In the former patient, T1-weighted images showed no evidence of fatty infiltration; in the latter patient, fat-suppression was used (see Figs 6 and 8). Imaging parameters varied and are provided in the figure legends.
Images of patients with V3 denervation exhibited one of four patterns: 1) long-standing chronic denervation, characterized by extensive fatty infiltration and volume loss of denervated musculature, without evidence of abnormal muscle enhancement or T2 prolongation; 2) early/mild chronic denervation, characterized by mild fatty change of the affected musculature without appreciable volume loss, evidence of T2 prolongation, or abnormal enhancement; 3) subacute denervation, characterized by abnormal enhancement, T2 prolongation, and fatty replacement of the denervated muscles, without increase in muscle volume; or 4) acute denervation, characterized by abnormal muscle enhancement, T2 prolongation, increase in muscle volume, but no fatty infiltration.

Four of 11 patients (Table 1, cases 1–4) had findings consistent with long-standing chronic denervation.
denervation atrophy (Fig 3). Three of these patients had symptoms of a known disease process of greater than 2 years’ duration. Clinical history was not available in one patient. Three of the four patients with the long-standing chronic denervation pattern were examined with T1-weighted imaging with and without contrast enhancement and with T2-weighted imaging. Contrast-enhanced images were not available in case 3.

Only one patient (case 5) had findings consistent with earlier or less severe chronic denervation (Fig 4). Although the available clinical history was inadequate to determine the chronicity of the process in this patient, the size of the meningioma responsible for the denervation indicated a duration of months to years (Fig 4).

In four of 11 patients (cases 6 and 9–11), symptom duration ranged from 6 to 20 months, and the images showed a subacute denervation...
pattern (Fig 5). In case 11, postoperative follow-up imaging at 20 months revealed persistent masticator muscle atrophy with resolution of the abnormal enhancement observed at 8 months, consistent with transition to a chronic denervation appearance.

The remaining two of 11 patients (cases 7 and 8) presented acutely, after 2 days and 2 weeks of symptoms, respectively, and had findings of acute denervation (Fig 6).

Indirect findings of V3 denervation were also observed. One patient had a small torus tubarius on the affected side and ipsilateral mastoiditis, both consistent with loss of tone at the opening of the eustachian tube, related to tensor veli palatini dysfunction (Fig 5).

**Hypoglossal Denervation**

Images of patients with hypoglossal denervation showed patterns similar to those observed for trigeminal denervation, although fatty infiltration appeared to occur earlier in hypoglossal denervation. No distinct early/mild chronic hypoglossal denervation pattern was identified. Two of the seven patients with hypoglossal denervation had findings consistent with long-standing chronic denervation. One of these patients (case 2, Table 2) had symptoms of several years’ duration, related to a long-standing hypoglossal schwannoma. The second patient had a long-standing densely calcified skull base meningioma; clinical history was insufficient to specify a more exact duration of symptoms. Images in both these patients showed extensive fatty replacement of the affected hemitongue, with loss of normal tongue muscle volume (Fig 7). Prolapse of the affected hemitongue into the oropharynx was consistent with loss of normal tongue muscle tone. There was no edemalike T2 prolongation of the tongue in either case, and the one contrast-enhanced study showed no abnormal enhancement.

Five of seven patients (cases 3–7), with symptom duration ranging from 2 to several weeks, had findings consistent with acute/subacute denervation. Acute and subacute hypoglossal denervation are considered together, as these stages exhibited the same imaging pattern. One patient (case 6) was examined with T1-weighted imaging, with and without contrast enhancement, and with fat-suppressed T2-weighted imaging. This patient’s images showed fatty infiltration of the denervated hemitongue as well as abnormal enhancement and edemalike T2 prolongation (Fig 8). Three other patients with subacute symptom duration were examined with T1-weighted imaging without contrast administration. Images in all three patients showed varying degrees of fatty replacement of the denervated hemitongue. T2-weighted images were available in three (cases 3, 6, and 7) of the five patients with acute/subacute denervation, and edemalike T2 prolongation was observed in all three cases. Hemitongue swelling was observed in cases 4 and 7 (Fig 9). Increased signal intensity was seen on contrast-enhanced T1-weighted images in case 7. It could not be determined whether this represented enhancement or fatty infiltration, given
that no unenhanced T1-weighted images were obtained.

Discussion

MR signal abnormalities in denervated skeletal muscle have been described for both peripheral (4–7) and cranial (2, 3, 8) nerves. Some findings, such as extensive fatty infiltration, seen in long-standing denervation atrophy may be readily apparent on CT scans (1). MR images, however, can show findings that occur earlier in the denervation process, before severe muscle atrophy is apparent. On the basis of our own observations, along with findings from previous experimental and clinical studies, we have categorized the appearance of denervation roughly according to the chronicity of the process. Both V3 and hypoglossal denervation can be described in terms of chronic, subacute, or acute denervation, each with a distinctive set of imaging features.

Long-standing chronic V3 and hypoglossal denervation were manifested by marked loss of volume of the affected musculature with extensive fatty replacement (Figs 3 and 7). These findings are identical to those observed on CT scans (1). Secondary findings of ipsilateral mastoiditis and asymmetry of the torus tubarius were also observed in V3 denervation (Fig 5). Mastoiditis is consistent with loss of regulation of the eustachian tube related to tensor veli
palatini denervation. The pathogenesis of torus
tubarius asymmetry is unclear given that most
of the torus is made up of fibers from the levator
veli palatini, which is innervated by the vagus
nerve. There was no evidence of vagus nerve
denervation in the case illustrated. Perhaps loss
of tone in tensor veli palatini muscle fibers in-
serting at the eustachian tube altered the ap-
pearance of the torus tubarius. Prolapse of the
hemitongue into the oropharynx on axial supine
imaging was observed in hypoglossal denerva-
tion and was consistent with loss of normal
tongue muscle tone. In those cases of V3 and
hypoglossal denervation in which there was ex-
tensive fatty replacement of the affected mus-
culature, neither abnormal muscle enhance-
ment nor increased signal intensity on T2-
weighted images was observed. The exact
duration of denervation necessary to produce
this pattern of atrophy is unclear. One patient,
with findings of subacute denervation at 8
months, had a chronic denervation pattern on a
repeat MR examination at 20 months. Long-
term serial scanning was not performed in our
remaining cases and we were, therefore, unable
to follow patients through the stages of dener-
vation beginning at the onset of disease or of
symptoms. Also, the clinical history that was
available in patients with a pattern of long-
standing chronic denervation atrophy was insuffi-
cient to allow accurate determination of the
onset of clinical symptoms. Studies of exper-
imentally created denervation in animal models
have focused on early biochemical and MR
changes in denervated muscle, but serial stud-
ies of the appearance of denervated muscle
over a period of months to years have not been
performed (9–12). Clinical studies that define
the beginning of denervation as the onset of
symptoms are also inherently limited given that
the temporal relation of the denervation process
to the onset of symptoms is variable (6). In our
series, all patients with a pattern of long-stand-
ing chronic denervation and determinable clin-
ical history had symptoms or a known patho-
logic process of at least 20 months’ duration.
The minimum duration necessary for this ap-
pearance could not be determined.

We also observed a more subtle, but similar,
appearance of V3 denervation atrophy, consis-
tent with early or mild chronic denervation (Fig
4). In both long-standing and early chronic
denervation, images showed evidence of fatty re-
placement of the denervated musculature, but
fatty replacement in the latter was much less
extensive. Muscle volume was relatively pre-
served in early chronic denervation and there
was no evidence of abnormal muscle enhance-
ment or edemalike increased signal intensity on
T2-weighted images.

In patients with symptoms ranging from 2
days to 20 months duration, we observed im-
ing patterns consistent with acute/subacute
denervation, as has been described by other
authors (2, 4, 7). One feature of these patterns
was T2 prolongation of the denervated muscu-
lature. Polak et al (5) observed similar T2 pro-
longation in an animal model 2 weeks after
sciatic nerve ligation. Analysis of the dener-
vated muscle revealed no change in overall wa-
ter content, but there was a relative increase in
extracellular water with a concomitant decrease
in intracellular water, which coincided with a
decrease in muscle fibril size. An increase in
extracellular water, which has a longer T2 than
intracellular water, most likely accounts for in-
creased T2 signal intensity in the acute/sub-
acute stage. As emphasized by Fleckenstein et
al (4), it may be useful to consider the T2 pro-
longation observed in acute/subacute denerva-
tion to be edemalike rather than as reflecting
true edema, given that true edema implies an
absolute increase in tissue water content. On
the other hand, the increased muscle volume
seen in several of our cases of acute/subacute
trigeminal and hypoglossal denervation sug-
gests there may be a component of true edema.
as well. STIR (short-tau inversion-recovery) imaging appears to be especially sensitive to T1 and T2 prolongation associated with acute/subacute denervation (4, 7). For example, West et al (7) found increased STIR signal as early as 4 days after onset of clinical symptoms of denervation, which preceded changes on electromyography. Other authors have observed a similar pattern of masticator subacute denervation several months after the onset of denervating disease (2, 8).

The presence of increased contrast enhancement in acute/subacute denervation may also be attributable to an increase in extracellular space. Contrast material normally distributes between the intravascular and extracellular spaces. The expanded extracellular space in acutely/subacutely denervated muscle therefore allows for more contrast accumulation (2). Animal studies have also found that denervated muscle has relatively increased vascularity per volume of muscle, although this luxury perfusion is somewhat diminished by capillary necrosis (9–12). This relatively increased perfusion may also contribute to increased contrast enhancement.

In our series, the images of the two patients with acute symptoms of V3 denervation showed abnormal enhancement, increased volume, and T2 prolongation of the muscles of mastication, but no fatty replacement. Images in the patients with subacute V3 denervation showed fatty replacement as well as abnormal enhancement and T2 prolongation of the denervated musculature without increase in muscle volume. Images of the patients with subacute V3 denervation, therefore, had an appearance of combined features of the acute and chronic stages. This suggests that there is a continuum in the patterns of denervation such that fatty replacement gradually develops and abnormal enhancement decreases with increasing duration of the process. Indeed, in one patient with a typical pattern of subacute denervation at 8 months, images showed a typical appearance of chronic denervation at 20 months.

Imaging findings in acute/subacute hypoglossal denervation were similar to those observed in V3 denervation, although fatty replacement appeared earlier (Fig 8). Abnormal enhancement and an edemalike appearance were also observed, although the limited imaging in our small number of patients prevents any conclusions about the frequency of these findings.

Familiarity with findings in acute/subacute denervation is important in that inflammatory or neoplastic processes may have a similar appearance. Awareness of the presence of abnormal enhancement and an edemalike appearance in acute/subacute denervation should direct one to look for a denervating lesion. Denervation may appear almost identical to inflammatory or neoplastic processes when muscle swelling is present. Denervation pseudohypertrophy, characterized by an increase in muscle volume attributable to fatty infiltration, may also appear similar to acute/subacute denervation as described here, especially in the tongue (13). In our series, T2-weighted images in patients with increased muscle volume showed edemalike features, which are not characteristic of denervation pseudohypertrophy. True denervation hypertrophy, characterized by muscle enlargement without signal abnormality, has been reported in the radiologic literature (13). In contradistinction to findings in true denervation hypertrophy, the images in our patients with muscle enlargement all showed signal abnormality.

In summary, imaging findings in V3 and hypoglossal denervation depend on the chronicity of the process. In the acute to subacute stage, the denervated muscles may show increased signal intensity on T2-weighted images, increased muscle volume, and abnormal contrast enhancement. Fatty infiltration was not observed in V3 denervation in the acute stage but was present in subacute V3 denervation and in both acute and subacute hypoglossal denervation. Chronic denervation may be divided into early/mild and long-standing, depending on the amount of fatty infiltration present. In early chronic denervation, mild fatty replacement may be seen without appreciable muscle volume loss, abnormal enhancement, or T2 prolongation. Long-standing chronic cases demonstrated extensive fatty replacement and volume loss of the denervated musculature. Further research may more definitively define the time course of these changes.

References