Microscopic measurement of the facial nerve root exit zone from central glial myelin to peripheral Schwann cell myelin

MASATO TOMII, M.D., HISASHI ONOUE, M.D., MASAHARU YASUE, M.D., SHOGO TOKUDOME, M.D., and TOSHIKI ABE, M.D.

Department of Neurosurgery, Jikei University School of Medicine, Tokyo; and Department of Legal Medicine, Dokkyo University School of Medicine, Tochigi, Japan

Object. The authors have attempted to define the exact borders of the root exit zone (RExZ) of the facial nerve, measure the distribution of myelin histologically, and examine the relationship between contact vessels and the RExZ.

Methods. Seventy-five facial nerves were obtained from brainstems excised from 44 adult patients at autopsy. The arteries and veins associated with the facial nerve were counted and measured. The facial nerves, associated vasculature, and adjoining portions of the brainstem were then removed en bloc. These tissues were serially sectioned and stained, and a photomicrograph of each section was obtained. The distribution of myelin on each section was measured from the upper edge of the supraolivary fossa, and the relationship between contact vessels and the RExZ was examined.

The lateral transitional zone of the facial nerve began 8 mm distal to the upper edge of the supraolivary fossa and had a mean length of 1.9 mm. The root detachment point (RDP) of the facial nerve at the medial side was located very close to the beginning of the mediolateral transitional zone. In more than 80% of the nerves that were examined, vascular structures compressed the central glial myelin of the nerve.

Conclusions. The authors propose the use of the terms “RExP,” “RDP,” and “transitional zone,” instead of RExZ, which cannot be well defined. The RDP appears to be a good landmark for use during microvascular decompression.

KEY WORDS • facial nerve • root exit zone • myelin

It is generally accepted that HFS is caused by compression of the facial nerve (the seventh cranial nerve) by blood vessels located at the RExZ.6,16 Janetta and colleagues6 have reported that myelin defects exist in the RExZ at the point at which the central glial myelin extending into the facial nerve from the brainstem meets the peripheral myelin composed of Schwann cells, the transitional zone. The transitional zone is generally thought to lie within 2 to 3 mm from the site at which the facial nerve emerges from the brainstem. Because the RExZ, transitional area, and exit point of the facial nerve have not been defined clearly, however, the locations of the RExZ and the transitional zone are reported differently by each investigator. The aim of the present study was to define the exact location of the RExZ, measure the distribution of myelin histologically, and examine the relationship between contact vessels and the RExZ of the facial nerve.

Materials and Methods

All procedures were conducted in accordance with the institutional guidelines of Jikei University and the Tokyo Medical Examiner’s Office.

Forty-four brains were obtained during the autopsies of 33 men and 11 women, whose ages were between 18 and 87 years (mean 56.5 years) at the time of death. Our findings were based on 75 facial nerves that had been removed from these brains. The remaining 13 facial nerves were not used because curving deformities were created during fixation.

The calvaria was opened and the brain was removed en bloc. The facial and acoustic nerves were severed at the internal auditory canal. The arteries and veins associated with the facial nerve were counted and their locations were recorded before dissection of the arachnoid membrane. Vascular compression of the facial nerve was observed macroscopically, and the distance from the compression to the most proximal point of the facial nerve was measured. The brain was then fixed in formalin and a tissue block consisting of the facial nerve, associated vasculature, and adjoining brainstem was removed on each side. Each tissue block was embedded in paraffin and serially sectioned. Slices cut through the center of the facial nerve were stained with LFB and PAS. After staining, photomicrographs of each section were obtained and the distribution of myelin was observed. The distances shown in Fig. 1 were measured using a millimeter rule. We defined the exit of the lateral side of the facial nerve from the brainstem as the upper edge of the supraolivary fossa, which has been defined by Matsushima and colleagues3 as the cavity formed by the lateral portions of the pons and the medulla oblongata.

In this paper distances are expressed as the mean values ± standard deviations. To correct for shrinkage of brain tissue during fixation and embedding, we treated each oculomotor nerve of the same side and embedding, we treated each oculomotor nerve of the same brain in the same way and calculated the percentage of shrinkage. We then substituted the percentage of shrinkage of the oculomotor nerve for that of the facial nerve.

Results

In photomicrographs of facial nerves stained with LFB and PAS, light blue myelin (central myelin) and dark blue myelin (peripheral myelin) could be clearly distinguished
The fasciculated shape of the facial nerve and the cone-shaped termination of the central myelin were also visible. On the lateral side of the facial nerve, the transition from central to peripheral myelin began 8 ± 2.79 mm distal to the exit of the nerve, and the transition to peripheral myelin was complete at a mean point of 9.9 ± 3.03 mm distal to the exit (Table 1). The lengths of the lateral and medial transitional zones (where both central and peripheral myelin are present) were 1.9 ± 1.14 mm and 0.58 ± 0.32 mm, respectively. The difference between the lengths of the lateral and medial transitional zones was significant (p < 0.05, Student t-test for unpaired observations). Thin peripheral myelin covered the central myelin in the proximal part of the lateral transitional zone (Figs. 1 and 2), and therefore in this part, the myelin sheath of the facial nerve consisted predominantly of central myelin and little peripheral myelin. We did not observe this morphological feature on the medial side and thus a substantial difference in myelin components exists between the lateral and medial sides. On the medial side, the facial nerve strongly adhered to the pons through the pia mater and connective tissue. The distance to the exit (Table 1). The lengths of the lateral and medial transitional zones (where both central and peripheral myelin are present) were 1.9 ± 1.14 mm and 0.58 ± 0.32 mm, respectively. The difference between the lengths of the lateral and medial transitional zones was significant (p < 0.05, Student t-test for unpaired observations). Thin peripheral myelin covered the central myelin in the proximal part of the lateral transitional zone (Figs. 1 and 2), and therefore in this part, the myelin sheath of the facial nerve consisted predominantly of central myelin and little peripheral myelin. We did not observe this morphological feature on the medial side and thus a substantial difference in myelin components exists between the lateral and medial sides. On the medial side, the facial nerve strongly adhered to the pons through the pia mater and connective tissue.

**Fig. 1.** Schematic diagram of a magnified facial nerve and the adjacent brainstem showing how distances relating to the transitional zone were measured.

**Fig. 2.** Photomicrograph demonstrating a fasciculated structure of the facial nerve. The cone-shaped central myelin of the facial nerve extends from the brainstem. There is connective tissue between the pons and the medulla oblongata. LFB and PAS, original magnification × 10.
from the point at which the nerve detached from the pons to the proximal part of the medial transition zone was 0.28 ± 0.34 mm (Table 1). In 18 of the 44 brains examined, we found compression of 22 facial nerves by vasculature structures (Fig. 3). In nearly 80% (17 of 22) of the pressed nerves, the compressed portions were less than 6 mm distal to the point along the nerve that was macroscopically determined to be the most proximal. Because connective tissue was present at the suprailiminary fossa and the most proximal part of the facial nerve, the upper edge of the suprailiminary fossa was not well visualized macroscopically. The thickness of this connective tissue was approximately 2 mm, and thus most facial nerves were compressed by vascular structures within 8 mm distal to the upper edge of the suprailiminary fossa. In all compressed nerves, the lateral side of the nerve was compressed. As a result, in approximately 80% of the compressed nerves, the compression was proximal to the transition zone. This indicates that vascular structures usually compress central glial myelin, rather than myelin composed of Schwann cells.

Discussion

Root Exit Zone

We defined the site at which the facial nerve exited the brainstem as the upper end of the suprailiminary fossa. We call this point the RExP. This point is the most concave area just below the facial nerve around the pontomedullary sulcus. After exiting the brainstem, the facial nerve strongly adheres to the pons through the pia mater and connective tissue, although it is easily distinguishable from the pons. Yoneda and associates noted that the length of adhesion is longer than 10 mm. We call the point at which the medial side of the facial nerve detaches from the brain the RDP. We believe the use of the terms “RExP” and “RDP” in referring to an area of nerve compression is preferable to the use of “RExZ,” whose limits have never been clearly defined.

Transitional Zone

Previous investigators have used various terms to refer to the transitional zone, the region of transition from central to peripheral myelin. Because no clear description of the relationship between the RExZ and the transitional zone has been published, these terms have often been confused with each other.

We defined the transitional zone of the facial nerve as the region where the myelin sheath is composed of both central glial and Schwann cell myelin. We found the medial part of the transitional zone to be shorter than the lateral part. This observation has not been reported previously. Skinner observed that the oligodendroglial dome of the facial nerve extended as far as 2.6 mm from the plane of the nerve’s superficial origin. Adams reported that the transitional zone is only 1 to 3 mm in length, a range that encompasses the value we obtained in the present study (1.9 ± 1.14 mm). The distance from the RDP to the most proximal part of the transitional zone on the medial side was 0.28 ± 0.34 mm. These points are therefore very close to each other. During surgery, the exact location of the RDP could almost always be determined if a mirror or neuroendoscope were used. This point should offer a good landmark during procedures for HFS to locate the transitional zone.

Vascular Compression of the Facial Nerve

Many researchers have investigated compression of the facial nerve. In patients with HFS, areas of compression correspond to the transitional zone, the anterocaudal REXZ, and the most proximal part of the nerve. The location of compression has been reported to be within 3 mm of the brainstem and within 5 mm on either side of the REXZ. In autopsy cases, Stibbe reported that arteries in patients without HFS did not attach to the proximal part of the facial nerve. Conversely, Matsushima, et al., reported that an arterial attachment at the REXZ was evident in 69% of patients without HFS. Clinical records for the patients...
whose brains were examined were not available and thus we
could not correlate anatomical changes with symptoms
that had existed during life. Nevertheless, the annual inci-
dence of HFS is only 0.74 per 100,000 men and 0.81
per 100,000 women; it is therefore unlikely that many
of the brains we examined came from patients with HFS.
Our study of vascular compression of the facial nerve was
not conducted under conditions in which the cerebellum
was located within the cranium; our model could not rep-
resent vascular position and compression with perfusion,
and thus some differences between live conditions and
our own results might exist. Regardless, it is possible to
say that in more than 80% of our cases, vascular structures
compressed the central glial myelin and not the peripheral
Schwann cell myelin. Jannetta has commented that some
areas of the facial nerve strongly adhere to the pons from
the pontomedullary junction, and vessels compressing the
brainstem in this region are a frequent cause of classic HFS.

Our study was conducted using material obtained from
random cadavers. Next we will focus on the autopsy speci-
mens obtained in patients with a history of HFS. First, we
will inspect electron micrographs of the compressed portion
of the facial nerve transitional zone for demyelination, re-
genation, and other processes. Anatomical changes may
be present. Second, we will estimate the lateral transitional
zone by observing the RDP during microvascular decom-
pression, a procedure widely performed to treat HFS. We
Can then determine whether the transitional zone coin-
cides with the portion compressed by the vasculature.

Conclusions

In the lateral portion of the facial nerve, the transition
from central to peripheral myelin occurred between 8 and
9.9 mm from the upper edge of the supraolivary fossette.
We propose the use of the terms “RExP,” “RDP,” and “tran-
sitional zone” instead of “RExZ,” which cannot be well de-

References

1. Adams CBT: Microvascular compression: an alternative view and
   hypothesis. J Neurosurg 70:1–12, 1989
2. Auger RG, Whisnant JP: Hemifacial spasm in Rochester and
   Almsted County, Minnesota, 1960 to 1984. Arch Neurol 47:
   1233–1234, 1990
3. Digre K, Corbett J: Hemifacial spasm: differential diagnosis,
4. Fukushima T: [Posterior cranial fossa neurovascular decompres-
   sion (Jannetta method) for trigeminal neuralgia and facial spasm.] No
   Shinkei Geka 10:1257–1261, 1982 (Jpn)
5. Gardner WJ: Concerning the mechanism of trigeminal neuralgia
6. Gardner WJ: Cross talk—the paradoxical transmission of the
   Neurosurgery 14:89–92, 1984
   other than neuralgias, in Wilkins RH, Rengachary SS (eds): Neuro-
   3227–3333
10. Jannetta PJ: Treatment of trigeminal neuralgia by micro-operative
decompression, in Youmans JR (ed): Neurological Surgery: A Compre-
   microsurgical treatment of hemifacial spasm. Operative tech-
   compression of cranial nerves—role of changes of vertebrobasilar
   vasculature.] Neurol Med Chir 21:287–293, 1981 (Jpn)
   pression of cranial nerves, particularly of the 7th cranial nerve.
   Neurol Med Chir 20:739–751, 1980
14. Matsushima T, Inoue T, Fukui M: Arteries in contact with the cis-
   ternal portion of the facial nerve in autopsy cases: microsurgical
   anatomy for neurovascular decompression surgery of hemifacial
   of the ccellobellopontine angle, in Surgical Anatomy for Micro-
   neurosurgery VI. Cerebral Aneurysms and Skull Base Les-
16. Möller AR, Jannetta PJ: On the origin of synkinesis in hemifacia-
   l spasm: result of intracranial recordings. J Neurosurg 61:
   569–576, 1984
17. Neagoy DR, Dohn DF: Hemifacial spasm secondary to vascular
18. Ruby JR, Jannetta PJ: Hemifacial spasm: ultrastructural changes
   in the facial nerve induced by neurovascular compression. Surg
   Neurol 4:369–370, 1975
19. Skinner HA: Some histologic features of the cranial nerves. Arch
   Neurol Psychiatry 37:356–372, 1931
20. Stibbe EP: Surgical anatomy of the subtemporal angle. With spe-
   cial reference to the acoustic and trigeminal nerve. Lancet 1:
   859–862, 1939
21. Tarlov IM: Structure of the nerve root. II. Differentiation of sen-
   sory from motor roots: observations on identification of function
   in roots of mixed cranial nerves. Arch Neurol Psychiatry 37:
   1338–1355, 1937
   sion for hemifacial spasm.] Neurosurg Lett 8:39–45, 1998 (Jpn)

Address reprint requests to: Masato Tomii, M.D., Department of
Neurosurgery, Jikei University School of Medicine, 3-25-8 Nishi
shimbashi, Minato-ku, Tokyo 105-8461, Japan. email: masato2770
@hotmail.com.