



Case Report

Ingenuity using 3D-MRI fusion image in evaluation before and after microvascular decompression for hemifacial spasm

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ABSTRACT

Background: Hemifacial spasm (HFS) is most often caused by blood vessels touching a facial nerve. In particular, responsible vessels compress the root exit zone (REZ) of the facial nerve. Although we recognize these causes of HFS, it is difficult to evaluate the findings of precise lesion in radiological imaging when vessels compress REZ. Hence, we tried to obtain precise images of pre- and postoperative neuroradiological findings of HFS by creating a fusion image of MR angiography and the REZ of facial nerve extracted by magnetic resonance imaging (MRI) diffusion tensor image (DTI).

Case Description: A 52-year-old woman had a 2-year history of HFS on the left side of her face. It was confirmed that the left vertebral artery and anterior inferior cerebellar artery were presented near the facial nerve on MRI. REZ of the facial nerve was visualized using DTI and fusion image was created with vascular components, making it possible to recognize the relationship between compression vessels and REZ of the facial nerve in detail. She underwent microvascular decompression and her HFS completely disappeared. We confirmed that the REZ of the facial nerve was decompressed by MRI imaging, in the same way as before surgery.

Conclusion: We describe that the REZ of facial nerve and compressive vessels was delineated in detail on MRI and this technique is useful for pre- and postoperative evaluation of HFS.

Keywords: Diffusion tensor fusion image, Hemifacial spasm, Magnetic resonance image, Microvascular decompression, Root exit zone

INTRODUCTION

Hemifacial spasm (HFS) has been reported to be related to vascular compression of the facial nerve at its root exit zone (REZ) in the majority of patients.^[6,10,15] Jannetta *et al.* had identified that culprit neurovascular compression was consistently present on the most proximal portion of the affected nerve in HFS and trigeminal neuralgia.^[6,11] Recently, magnetic resonance imaging (MRI) sequences have been developed, enabling preoperative analysis of the neurovascular anatomy in the cerebellopontine angle cistern.^[12,14,23,25] Although useful for determining the offending artery, it is not yet useful for simulating actual surgery due to image resolution issues. In particular, it is often difficult to depict in detail the segment of the facial nerve. To have a successful surgery,

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it is important to understand the neurovascular structure involved in the facial nerve preoperatively. This study evaluated and described the technical considerations of preoperative neuroradiological findings.

METHODS

Facial nerve anatomy

Campos-Benitez and Kaufmann classified the facial nerve into four segments based on their location and their relationship to myelination; route exit point (REXP), attachment segment (AS), root detachment position (RDP), and cisternal portion (CP).^[1] REXP, which is myelinated with oligodendrocyte-derived myelin, is the point of the facial nerve emerging to the brainstem surface from the pontomedullary sulcus at the upper edge of the supraolivary fossa. AS is the segment that strongly adheres to the surface of the pons for 8–10 mm and includes the centrally myelinated axons exposed anywhere.^[24] RDP is the point separating from the brainstem. The dome-shaped terminal zone (TZ), which is called the Obersteiner-Redlich zone, is located approximately 2 mm distal to the RDP with the transition from the central myelination to peripheral myelination of axons.^[4,24] In the previous reports, the length of the TZ appeared to be about 0.96 mm (range, 2.86–1.9 mm).^[5,24] In this region, in the proximal part of the lateral TZ, a thin peripheral myelin covers the central myelin such that the facial nerve myelin sheath in this area is composed primarily of the central myelin with little superficial peripheral myelin.^[24] Inside, the facial nerve touches the pons through the pia mater and connective tissue. CP was the area from the TZ to the entrance of the internal auditory meatus and was 17.93 mm long (range, 14.8–20.9 mm).^[24] The facial nerve, which is susceptible to pulsatile vascular compression, has not only the root exit point but also somewhere from REXP to TZ where it is about 10 mm long and exposed to CSF central myelination.^[1,7] If the running of the facial nerve in the AS part could be identified, it would be useful for preoperative simulation.

Radiographic technique

We performed pre-/postoperative MRI using a 3.0T MR imager (MRI, Achieva 3.0T TX Quasar, Philips) with parameters (T2-weighted image three-dimensional drive: echo time [TE] 2.8 ms, repetition time [TR] 1.45 ms, flip angle 90, band width 11.0, field of view [FOV] 13 cm, reconstruction slice thickness 0.6 mm, matrix 240*432, and number of excitations 1.00, MR angiography [MRA]: TR 25 ms, TE 3.45 ms, FOV 23 cm, reconstruction slice thickness 1.1 mm, matrix 512*512, and number of excitations 1.00).

For diffusion tensor image (DTI), we used a single-shot spin echo sequence (TR 3000 ms, TE 63 ms, and FOV 224 mm)

and marked facial nerve in volume data after the facial nerve fiber tracking.

Image processing

We used the SYNAPSE VINCENT medical imaging system (Fujifilm Medical, Tokyo, Japan) for 3D visualization. We extracted the desired structure from the preoperative T2 drive and pre- and postoperative MRA. The vascular and brainstem models were visualized using surface rendering with automatic thresholding. Because the facial nerve has a very fine structure and it was difficult to extract it automatically, we manually extracted the 2D image. The AS and REXP parts of the facial nerve touch the brainstem with the same signal value, we extended 10 mm after contacting the brain stem in the direction of the medulla oblongata. In extracting the facial nerve, we referred to DTI. In this way, we were able to create separate 3D models by color coding for easy identification.

CASE ILLUSTRATION

A 52-year-old woman with intractable left HFS for 2 years was admitted for operation. She previously underwent botulinum toxin injections twice, resulting in only temporary improvement. MRI T2 drive and SPGR images confirmed that the left vertebral artery (VA) and anterior inferior cerebellar artery (AICA) were close to the facial nerve, but the detailed relationship with the REZ of the facial nerve was difficult to understand [Figure 1]. MRA and DTI fusion images revealed compressed left facial nerve at the portion of AS, secondary to tortuous and elongated VA, and AICA [Figure 2]. She underwent the microvascular decompression (MVD) with transposition of VA and interposition of AICA was performed [Figure 3]. After operation, the spasm disappeared immediately. We could recognize the

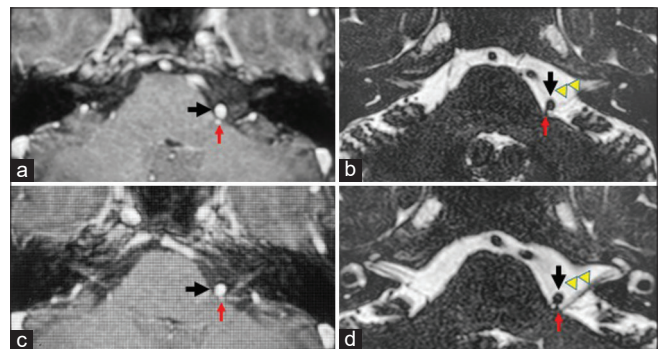


Figure 1: Preoperative MRI. MRI SPGR (left side) and T2 drive (right side) images confirmed that the left vertebral artery (black arrow) and anterior inferior cerebellar artery (red arrow) were close to the facial nerve (yellow arrow heads), but the detailed relationship with REZ of facial nerve was difficult to understand. a: left upper, b: right upper, c: left lower, d: right lower.

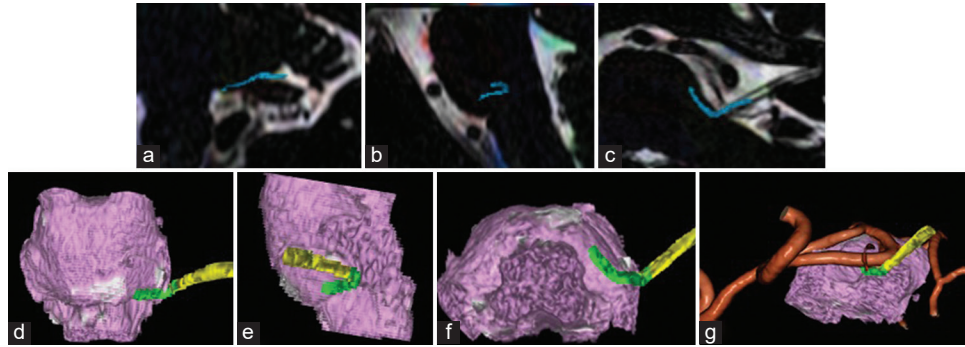


Figure 2: Depiction of the facial nerve by MRI diffusion tensor image (DTI). We have created 3D images of the facial nerve and brainstem (d: coronal; e: sagittal; and f: axial view) by extracting REXZ and AS (green) and RDP and CP (yellow) of the facial nerve with reference to DTI (a, coronal; b: sagittal, c: axial view, blue line: diffusion tensor image) d, e, f: purple: brainstem. g; Preoperative image: the left vertebral artery and anterior inferior cerebellar artery compressed REZ of the left facial nerve (green).

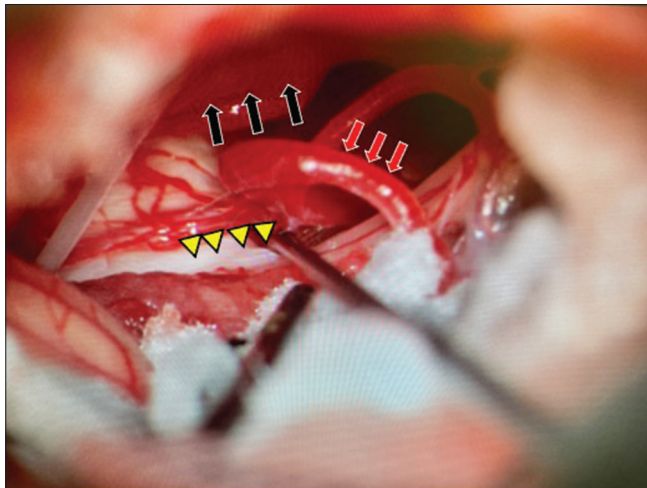


Figure 3: Intraoperative view. REZ (yellow arrow heads) of facial nerve was decompressed by transposition of the left vertebral artery (black arrows) and interposition of anterior inferior cerebellar artery (red arrows).

decompressed facial nerve using the created images in the manner we described [Figures 4a and 4b].

DISCUSSION

HFS is caused by the compression of the facial nerve by blood vessels located at the AS or REXZ. Histologically, the central myelin and the peripheral myelin suggest that the latter is more resistant to vascular contact.^[24] The central myelin portion of the nerves could be the incidences of the corresponding cranial dysfunctional syndromes caused by compression of some mechanism as the nerve fibers of these portions with the central myelin would be vulnerable to demyelination.^[8] MVD surgery is intended to displace the offending vessels impinging on the cranial nerve. Hence, it is important to identify the AS or REXZ preoperatively for successful MVD.

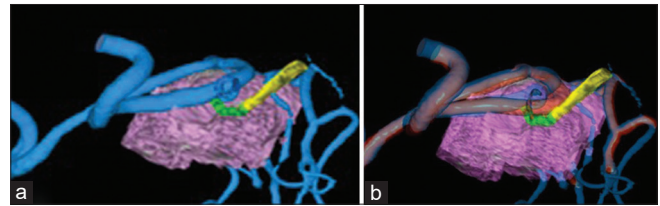


Figure 4: Perioperative fusion images. Brainstem (purple), the AS and REXZ parts of the facial nerve called REZ (green), other parts of the facial nerve (yellow) and MRA (preoperative [red] and postoperative [blue] vertebralbasilar system). (a) Postoperative image: vascular compression on REZ has been released. (b) Fusion image of pre- and postoperative examination could allow us to evaluate the extent of decompression easily. Preoperative vascular image (translucent blue), postoperative vascular image (red), and REZ of facial nerve (green).

The previous reports attempted preoperative simulations using 3D images to ascertain the exact locations of complexly intertwined arteries. Shigematsu *et al.* and Ishimori *et al.* used virtual endoscopic imaging and they could recognize vessels containing the parenchyma of the pons.^[9,21] Samala *et al.* and Granata *et al.* depicted the complex anatomical relationship using advanced virtual MRI techniques, such as image fusion and virtual cisternography. They could simulate with no risk to the patient with this technology.^[3,19] Satoh *et al.* reconstructed 3D MR cisternograms and 3D MR angiograms using a perspective volume rendering algorithm to compensate for errors between modalities that arise on fusing CT and MRI.^[20] Ohtani *et al.* elected the method of a tubular model for creating certain arteries and nerves to remove the noise from the models. However, they had to use anatomic knowledge to identify arteries that were intricately intertwined.^[17] Recently, integrated 3D computed models can clearly illustrate anatomic structures, such as nuclei and fibers, that radiological images do not.^[13] Our ingenuity is to extract the facial nerve in contact with the brain stem with a 3D model for the purpose of revealing the exact location

of neurovascular compression and to make a fusion image of the artery and nerve before surgery to facilitate postoperative evaluation.

We consider that there are the three points to understand the exact compression site and devise a preoperative simulation.

Extraction of facial nerve

We had extracted the facial nerve by the following procedure based on the heavily T2 images with reference to the above anatomical features of the facial nerve. The CISS sequence used to extract the facial nerve (called the Philips T2 drive at our center) has excellent spatial resolution. Therefore, various detailed anatomical structures could be analyzed.^[14,23] We manually extracted the facial nerve at every 0.6 mm slice to create a volume-rendered image. First, we identified the facial nerve and auditory nerve at the internal auditory canal. Next, we depicted the facial nerve from the internal auditory canal to the part in contact with the brain stem as CP and RDP. In addition, we extracted the brainstem, tracing the brainstem about 10 mm to the medulla oblongata and further proximal to the brainstem as AS and RExP. We created a 3D model by fusing with the blood vessel image extracted by MRA and by color coding this part to distinguish easily from CP/RDP. In each case, we identified that the offending artery was in contact with the AS and the 3D fusion images were similar to the intraoperative findings.

Facial nerve DTI

We referred to the findings of facial nerve tractography to extract the facial nerve more accurately. DTI is an MRI technique based on the principle that water molecule diffusion is anisotropic in white matter tracts.^[16] Taoka *et al.* first reported the use of tracing the facial nerve with DTI in patients with VS.^[22] Since then, several researchers have reported the experience of applying this technique to reconstruct the facial nerve canal in patients with VS and parotid gland cancer.^[18,19] However, to the best of our knowledge, there are no reports that use DTI for the perioperative evaluation of the HFS. It was impossible to depict how the facial nerve runs in the brainstem. However, by devising parameters, it was possible to depict the part in contact with the brainstem. It would be worth noting that the AS part could be identified by DTI.

Fusion image with facial nerve and offending vessels pre- and post-MVD

We performed the MVD with transposition in all cases and then confirmed that the offending artery was separated from the facial nerve in intraoperative findings. By creating fusion images pre- and post-MVD, it was possible to easily understand the minute changes in transposition of the

offending vessels. In the previous reports, it was challenging to neuroimage for the precise identification of the pathologic contact between the nerves and vessels.^[2] Our method had some limitations. If the entire vertebrobasilar system is displaced, it is difficult to accurately align it with the preoperative and postoperative images and to extract minute blood vessels (such as AICA's penetrating branch). Moreover, our article is a case report and further research is needed such as a prospective study. However, our method is particularly useful for understanding the pathophysiology of HFS, and we consider it to be a valuable method in clinical practice.

CONCLUSION

We extracted the RExZ and AS of facial nerve with a 3D model by MRA and DTI and created a fusion image of the pre-/postoperative artery and nerve. It was considered to be useful in facilitating postoperative evaluation.

Ethical approval

For this type of study, formal consent is not required. This article does not contain any studies with human participants performed by any of the authors.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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