Preoperative Three-Dimensional Diagnosis of Neurovascular Relationships at the Root Exit Zones During Microvascular Decompression for Hemifacial Spasm

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■ OBJECTIVE: **Hemifacial spasm occurs when a blood vessel compresses against an area near the root exit zone of the facial nerve. Developments in diagnostic neuroimaging have allowed three-dimensional (3D) observation of artery and nerve locations, an effective aid for treatment selection. However, an accurate interpretation of the 3D data remains challenging because imaging representations of complex small vessels are drowned out by noise. We used a noise elimination method to analyze artery and nerve locations and to determine their 3D relationship.**

■ METHODS: **Fifteen patients treated for hemifacial spasm were included. Images fused from 3 modalities of magnetic resonance imaging, 3D computed tomography, and angiography were used as source images.**
Using the images, models of the nerve and candidate vessels were created and shown in 3D to observe how the arteries were compressing the nerve and to identify the portions of the offending vessels that were closest to the nerve. These preoperative results were then compared with operative field observations during surgery. 3D models of the unaffected side were created and evaluated as controls.

■ RESULTS: **We confirmed that these models were accurate reconstructions of the source images as the tubular nerve and artery cross-sections showed good alignment onto magnetic resonance imaging axial slice images. The preoperative diagnoses of the compression sites and offending arteries all matched intraoperative findings.**

■ CONCLUSIONS: **An accurate identification of the offending arteries and compression sites was possible, and this method is anticipated to offer effective means of preoperative simulation.**

INTRODUCTION

Neurovascular compression (NVC) is a syndrome caused by the compression of a nerve by an artery. Hemifacial spasm, a type of NVC, is believed to arise when one of the facial arteries, such as the posterior inferior cerebellar artery (PICA), the anterior inferior cerebellar artery (AICA), or the vertebral artery (VA), compresses against a site in the vicinity of the root exit zone (REZ) of the facial nerve,[1,2] causing characteristic clinical symptoms, including persistent eyelid and lip spasms. Because a dramatic improvement is obtained with successful neurovascular decompression, it is important to accurately identify the site of compression.[3] In addition to clinical diagnosis, detailed diagnostic imaging plays a major role in treatment selection and in accurately identifying the site of compression. Recent developments in imaging techniques include magnetic resonance (MR) imaging (MRI) and advances in image reconstruction techniques, thereby enabling physicians to obtain a three-dimensional (3D) view of the locations of blood vessels

Key words
- Hemifacial spasm
- Microvascular decompression
- Three-dimensional surgical simulation

Abbreviations and Acronyms
3D: Three-dimensional
AICA: Anterior inferior cerebellar artery
CISS: Constructive interference in steady state
CSF: Cerebrospinal fluid
CT: Computed tomography
MR: Magnetic resonance
MRI: Magnetic resonance imaging
NVC: Neurovascular compression
PICA: Posterior inferior cerebellar artery
REZ: Root exit zone
TOF: Time of flight
VA: Vertebral artery

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and nerves. However, difficulty in ascertaining the exact locations of complexly intertwined arteries remains, and several methods of showing 3D data and image-processing methods have been attempted. We report an attempt to conduct a 3D analysis of the locations of blood vessels and nerves using a method that used generic 3D visualization software to intuitively and accurately determine the 3D relationships of these structures.

METHODS

Fifteen patients diagnosed with hemifacial spasm who underwent neurovascular decompression at our institution from April 2010 onward were included in the study. Tests were conducted using 2 modalities comprising MRI (3D cisternography), MRI (magnetization-prepared rapid acquisition gradient echo), 3D MR angiography (time-of -flight [TOF]), and 3D computed tomography (CT) angiography, and images fused using 3D visualization and manipulation software (Amira [FEI, Hillsboro, Oregon, USA]) were used as source images. 3D models of the affected nerves and surrounding arteries were then created from these source images and used in the preoperative diagnosis. The MRI apparatus used was the Discovery MR750 3.0 T (GE Healthcare Japan, Tokyo, Japan).

Model Creation

Before surgery, evaluations were performed using the following 2 modalities and 4 sequences: 1) MRI (3D cisternography), 2) MRI (magnetization-prepared rapid acquisition gradient echo), 3) 3D MR angiography (TOF), and 4) 3D CT angiography. To allow the manipulation of source images containing the same image location data on a common coordinate system, images were automatically fused by affine transformation.[4]

Steady-state T2 high-resolution MR cisternography was primarily used to depict facial nerves. Facial nerves appeared as low MRI signals surrounded by cerebrospinal fluid (CSF) with long T2 values. These data were exported to the visualization software Amira, and subsequent data processing was performed in Amira.

The center point of the facial nerve on each axial slice was closely plotted approximately every 3 mm, missing points were interpolated, and a curved line connecting each consecutive point was drawn. When we plotted the center point, to prevent arbitrary error, we had set software setting only can plot defined range of image density. The diameter of the nerve was then measured on the images. Thereafter, we plotted the center point of nerves/vessels and created the spline interpolated center line. We drew a circle denoting the center point of the nerves/vessels and diameter of the nerves/vessels and created spline interpolated circles. We created the tube model as shown in Figure 1A and B.

For the arteries, 3D MR angiography (TOF) and heavily T2-weighted images were used to plot center points on axial cross-sectional images using the same method as that used for the nerves. A tubular artery model was then created (Figure 2).

In some cases, it was difficult to distinguish the nerve from the artery on heavily T2-weighted images, including those constructed using the fast imaging with steady-state acquisition, constructive interference in steady-state (CISS), and balanced fast field echo; however, the use of arterial phase 3D CT angiography with 3D MR angiography (noncontracted TOF) and contrast medium allowed the arteries, veins, and nerves to be differentiated.

In all cases, we created 3D models with a surface rendering method as a conventional method by way of comparison. In surface rendering method, image processing consists of segmentation and surface rendering. The structures other than microvascular and nerve remained, and this is noise. Therefore, we removed them from the volume date. Surface rendering processing with the appropriate threshold was then performed.

To ensure that the nerve and artery models were accurate and did not deviate from the source image, all tubular models were rendered as volume data and their cross-sections were superimposed on the source axial images to confirm that they lined up

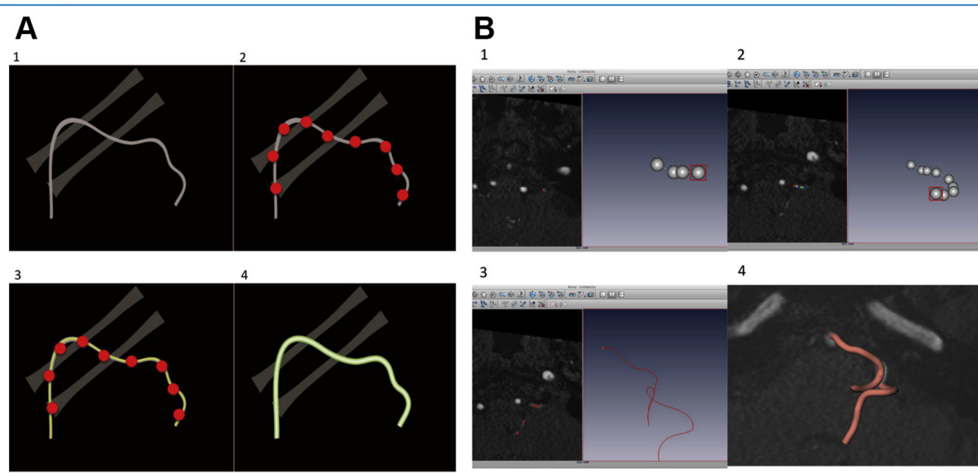

Figure 1. (**A**) 1) The method of constructing three-dimensional models in a schematic way. 2) Tracking the center point of vessels side by side. 3) Interpolating the center points to the centerline. 4) Constructing the tube model from the centerline and measured nerve width. (**B**) How the three-dimensional model is constructed.