Utilization of three-dimensional fusion images with high-resolution computed tomography angiography for preoperative evaluation of microvascular decompression: patient series

Takamitsu Iwata, MD, Koichi Hosomi, MD, PhD, Naoki Tani, MD, PhD, Hui Ming Khoo, MD, PhD, Satoru Oshino, MD, PhD, and Haruhiko Kishima, MD, PhD

Department of Neurosurgery, Osaka University Graduate School of Medicine, Suita, Osaka, Japan

BACKGROUND High-resolution computed tomography (CT), outfitted with a 0.25-mm detector, has superior capability for identifying microscopic anatomical structures compared to conventional CT. This study describes the use of high-resolution computed tomography angiography (CTA) for preoperative microvascular decompression (MVD) assessment and explores the potential effectiveness of three-dimensional (3D) image fusion with magnetic resonance imaging (MRI) by comparing it with traditional imaging methods.

OBSERVATIONS Four patients who had undergone preoperative high-resolution CTA and MRI for MVD at Osaka University Hospital between December 2020 and March 2022 were included in this study. The 3D-reconstructed images and intraoperative findings were compared. One patient underwent conventional CTA, thus allowing for a comparison between high-resolution and conventional CTA in terms of radiation exposure and vascular delineation. Preoperative simulations reflected the intraoperative findings for all cases; small vessel compression of the nerve was identified preoperatively in two cases.

LESSONS Compared with conventional CTA, high-resolution CTA showed superior vascular delineation with no significant change in radiation exposure. The use of high-resolution CTA with reconstructed 3D fusion images can help to simulate prior MVD. Knowing the location of the nerves and blood vessels can perioperatively guide neurosurgeons.

https://thejns.org/doi/abs/10.3171/CASE23330

KEYWORDS 3D fusion image; high-resolution CT angiography; microvascular decompression

Neurovascular compression syndromes, such as trigeminal neuralgia, hemifacial spasm, and glossopharyngeal neuralgia, are abnormal conditions that can substantially affect the quality of life of patients.1–3 Microvascular decompression (MVD) is an effective surgical treatment for drug-resistant cases.1–4 The overall success rate of MVD varies from 73% to 90%, and the most common complications include hearing loss, facial weakness or numbness, and cerebrospinal fluid leakage.3,5 However, the success of MVD depends on accurate preoperative imaging and localization of the offending vessel compressing the cranial nerve.6 Preoperative three-dimensional (3D) image fusion is an essential tool for identifying the precise location and orientation of a compressing vessel, allowing for a more specific and safe surgical approach.1,7,8

Traditionally, magnetic resonance imaging (MRI) with time-of-flight (TOF) magnetic resonance angiography (MRA) and constructive interference in steady state (CISS) sequences have been used for preoperative imaging.4–11 TOF MRA is an imaging technique that provides a high signal-to-noise ratio and contrast, allowing the identification of larger vessels that compress the nerve. CISS is another MRI technique that provides high contrast between different tissue types,
allowing visualization of the cranial nerves and their relationship with the surrounding vasculature.\(^6\) However, high-resolution computed tomography angiography (CTA) uses a detector with a range of 0.25 mm, providing a more detailed anatomical image than conventional CTA, which uses a detector with a range of 0.5 mm and TOF MRA.\(^{11,12}\) This higher resolution allows the visualization of vessels less than 1 mm in diameter that may be responsible for nerve compression and cannot be delineated by conventional imaging. With the advent of high-resolution CTA, 3D fusion images have become even more valuable for identifying small vessels and their relationship with the cranial nerve.

Herein, we introduce the use of high-resolution CTA for the preoperative evaluation of MVD and discuss its possible efficacy in combination with 3D fusion images with MRI compared to conventional imaging, presenting our experience with this technique.

**Study Description**

**Subjects**

Four consecutive patients (two with facial spasms and two with trigeminal neuralgia) who had undergone MVD at Osaka University Hospital between December 2020 and March 2022 were included in the study without any exclusion. The patient characteristics are shown in Supplemental Table 1. The study protocol was approved by the Ethics Committee of the Osaka University Hospital. The study was conducted in accordance with the tenets of the Declaration of Helsinki. The requirement for written informed consent from each patient was waived due to the retrospective nature of the study.

**High-Resolution CTA**

Our MRI protocol included whole-brain sagittal T2, axial T1, axial fluid-attenuated inversion recovery, TOF MRA, CISS, apparent diffusion coefficient maps, and diffusion-weighted imaging sequences. Thin sections of the T1 and T2 images were obtained through the brainstem in three planes. The MRA and CISS imaging parameters are summarized in Supplemental Table 2. In addition to preoperative brain MRI (iNGENIA, Philips Healthcare; SIGNA Architect, GE Medical Systems), high-resolution CTA (Canon Medical Systems) was equipped with a 0.25-mm detector, which has one-half the conventional section thickness, one-half the in-plane detector element width, and one-half the reconstructed pixel width compared to those of conventional CTA. The contrast medium volume was calculated based on the weight of each patient, and 250 mg/kg of iopamidol (Oypalolin 300, FujiPharma) was injected intravenously as a bolus for a fixed infusion duration of 10 seconds, followed by an intravenous bolus injection of 20 mL of physiological saline solution at the same rate as the contrast medium. Contrast-enhanced volume data for high-resolution CTA were acquired using a 160-detector row, high-resolution CT scanner (Aquilion Precision, Canon Medical Systems) with helical scanning. The scan parameters were as follows: section thickness 0.25 mm, tube voltage 120 kV, pitch factor 0.569, reconstructed field of view (FOV) size 240 mm, and gantry tilt 0°. The contrast medium, 75 mL of ioversol (Optiray 320, Guerbet Japan), was injected intravenously as a bolus for a fixed infusion duration of 10 seconds, followed by an intravenous bolus injection of 20 mL of physiological saline solution at the same rate as the contrast medium. The estimated volume computed tomography dose index (CTDIfvol) for the CTA displayed on the CT scanner console was recorded for each patient. The estimated dose-length product was calculated as CTDIfvol × scan length.

**Patient Informed Consent**

The necessary patient informed consent was obtained in this study.

**Discussion**

**Observations**

**Case 1**

A 39-year-old female experiencing spasms of the right orbicularis oculi and orbicularis oris muscles that had persisted for 4 years was referred to our hospital. MRI showed that the posterior inferior cerebellar artery (PICA), whose vascular supply extends into the region that is supplied by the anterior inferior cerebellar artery (AICA), was close to the right facial nerve. The patient was treated with botulinum toxin, but the treatment was ineffective, and MVD was performed.

Preoperative simulation using 3D fusion reconstruction images with high-resolution CTA and MRI showed that a branch of the PICA ramifying from the vertebral artery (VA) compressed the root exit zone (REZ) of the facial nerve anteriorly and inferiorly (Fig. 1). MVD was performed using an intrafriocellular approach, with the patient under general anesthesia in the lateral position. As simulated preoperatively, the PICA was compressing the REZ; therefore, a Teflon (polytetrafluoroethylene) felt was used to transpose the PICA toward the petrous bone, and a ball of Teflon was placed between the REZ and the PICA for interposition. The postoperative course was uneventful, and the patient had no symptom recurrence for 20 months.

**Case 2**

A 65-year-old female had experienced lower jaw pain during conversations, washing her face, and eating for more than 20 years. She received 400 mg of carbamazepine (CBZ); however, symptoms
such as facial pain during face washing and difficulty speaking persisted. The dose of CBZ was increased to 800 mg, but the symptoms remained unresolved. The patient was referred to our department, and an MVD was planned. Preoperative simulation with 3D-reconstructed images showed that the AICA, superior cerebellar artery (SCA), and petrous vein were in contact with the left trigeminal nerve (Fig. 2). The left AICA was strongly compressing the trigeminal nerve from the caudal side. MVD was performed with the patient in the lateral position and under general anesthesia and with auditory brainstem response (ABR) monitoring. As simulated, the AICA and SCA were compressing the trigeminal nerve; therefore, Teflon felt was used to transpose the AICA to the petrous bone side and the SCA to the tentorium side. The postoperative course was uneventful, and the patient had no symptom recurrence for 24 months.

Case 3

A 68-year-old female had been experiencing pain in her left upper back tooth for approximately 2 years. She was diagnosed with trigeminal neuralgia and treated with CBZ. However, her symptoms did not improve, and she was referred to our hospital. 3D fusion images from MRI and high-resolution CTA (Fig. 3) revealed the location of the cranial nerves around the brainstem and arteries in the posterior cranial region. The 3D fusion image showed that the SCA was exerting strong compression on the trigeminal nerve from the cranial side. A branch of the SCA was seen to originate near the site of compression and to run along the trigeminal nerve to the REZ with strong compression; therefore, Teflon felt was used to transpose the SCA to the petrous bone side and the AICA to the tentorium side. The postoperative course was uneventful, and the patient had no symptom recurrence for 24 months.

Comparison With Conventional CTA

The CTDIvol obtained using conventional and high-resolution CTA was 37.8 and 43.4 mGy, respectively. The estimated dose-length product range was calculated as CTDIvol × scan length, which was determined as 813.9 mGy · cm with conventional CTA and 959.5 mGy · cm with high-resolution CTA. However, the radiation doses for high-resolution CTA were still lower than the diagnostic reference level according to the Japan Network for Research and Information on Medical Exposures (85 and 1350 mGy · cm). At approximately the same dose, high-resolution CTA was superior to conventional CTA in demonstrating small blood vessels, and 3D

FIG. 1. Case 1. CISS MRI (A) and MRA (B) show that the PICA is located near the REZ of the facial nerve. 3D fusion images from MRI and high-resolution CTA (C) showing the locations of the cranial nerves around the brainstem and arteries in the posterior circulation. A magnified 3D fusion image (D) shows that a branch of the PICA strongly compresses the REZ of the facial nerve (blue). Intraoperative MVD image (E), similar to the preoperative 3D image, shows a branch of the PICA with a strongly compressed REZ of the facial nerve. Red, blue, and green arrowheads indicate the facial nerve, PICA, and lower cranial nerve, respectively.
reconstruction provided a high-resolution preoperative simulation image (Fig. 5).

**Lessons**

This study demonstrated the utility of 3D fusion imaging with high-resolution CTA for the preoperative evaluation of MVD surgery. Surgical simulation utilizing 3D fusion images in conjunction with high-resolution CTA facilitates the identification of intraoperative vessels and nerves before surgery. In particular, high-resolution CTA was more effective than conventional CTA in detecting smaller arteries without increasing radiation exposure.

Although numerous studies have reported that preoperative 3D fusion imaging is beneficial, they exclusively investigated MRA; thus, the utility of high-resolution CTA remains to be established.\(^8\)\(^–\)\(^10\)\(^,\)\(^13\)

Teton et al.\(^8\) showed that 3D fusion imaging with T2 and MRA may improve the long-term prognosis of MVD for facial spasms. Gamaleldin et al.\(^9\) showed that 3D TOF MRA and 3D CISS fusion imaging are reliable, noninvasive tools for assessing the offending vessels.

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**FIG. 2.** Case 2. CISS MRI (A) and MRA (B) show the SCA, AICA, and petrosal vein near the trigeminal nerve. 3D fusion images from MRI and high-resolution CTA (C) showing the locations of the cranial nerves around the brainstem and arteries in the posterior circulation. The magnified 3D fusion image (D) shows that the petrosal vein and SCA are in contact with the trigeminal nerve, and the AICA strongly compresses the trigeminal nerve from the caudal side. The intraoperative image of the MVD and the preoperative 3D fusion image (E) shows that the petrosal vein and SCA are in contact with the trigeminal nerve, and the AICA strongly compresses the trigeminal nerve from the caudal side. Red arrowheads point to the AICA, blue arrowheads point to the petrosal vein, yellow arrowheads point to the trigeminal nerve, and green arrowheads point to the SCA.

**FIG. 3.** Case 3. CISS MRI (A) and MRA (B) show the SCA and petrosal vein near the trigeminal nerve. 3D fusion images from MRI and high-resolution CTA (C) show the locations of the cranial nerves around the brainstem and vessels in the posterior cranial region. Magnified 3D fusion image (D) showing that the SCA exerts strong compression on the trigeminal nerve from the cranial side. A branch of the SCA (arrowhead) was seen to originate near the site of compression and to run along the trigeminal nerve to the REZ with strong compression, and it was determined preoperatively that this small artery was the offending vessel. Images show the state before transposition of the SCA (left, E) and the state after transposition of the SCA using instruments (right, E). These intraoperative MVD images, similar to the preoperative 3D image, show a branch of the SCA with a strongly compressed trigeminal nerve. Blue, yellow, and green arrowheads indicate the petrosal vein, trigeminal nerve, and SCA branch, respectively.
vessel and the degree of compression in patients with trigeminal neuralgia and facial spasm. Many centers use MRA rather than conventional CTA, which requires radiation exposure and contrast administration for MVD. In the past, CTA was linked to elevated radiation exposure; however, as imaging technology has progressed, high-resolution CTA has improved spatial resolution and partial volume effects, resulting in intracranial CTA images of higher quality compared to conventional CTA.\textsuperscript{11,12,14} Furthermore, although plain CT is widely utilized as a preoperative imaging modality for MVD to obtain anatomical information about the mastoid air cells, CTA can also provide essential information on the transverse sinus and sigmoid sinus location, which is important for lateral suboccipital craniotomy.\textsuperscript{15,16}

Our study highlighted the importance of obtaining detailed preoperative anatomical information to improve surgical safety and outcomes,

**FIG. 4.** Case 4. CISS MRI (A and B) showed that the VA and AICA are present near the REZ of the facial nerve. 3D fusion images from MRI and high-resolution CTA (C) showing the locations of the cranial nerves around the brainstem and arteries in the posterior circulation. Magnified 3D fusion image (D) showing that the AICA was wedged between the brainstem and VA by the tortuous VA. This AICA exerts significant pressure on the REZ of the facial nerve. Intraoperative image (E) of the MVD, similar to the preoperative 3D image, showing the AICA with a strongly compressed REZ of the facial nerve. Red, blue, green, and yellow arrowheads indicate the REZ of the facial nerve, VA, AICA, and lower cranial nerves, respectively.

**FIG. 5.** In comparing volume-rendered images of MRA (A), conventional CTA (B), and high-resolution CTA (C), conventional CTA shows the poorest delineation of the branching vessels of the AICA, whereas high-resolution CTA shows the best delineation. In comparing axial images from MRA (D), conventional CTA (E), and high-resolution CTA (F), conventional CTA provides the least clear representation of the internal auditory artery. Conversely, high-resolution CTA offers superior visualization of small arteries compared to MRA.
particularly because smaller arterial branches may compress nerves in addition to the main trunk artery. Our reasoning for recommending high-resolution CTA, despite its requirement for contrast and radiation exposure, is based on its ability to offer detailed preoperative identification of compressing vessels and their peripheral locations. Discerning the exact locations of the offending vessel and nerve before surgery can minimize the need for arachnoid incision and dissection of the nerve from nearby tissues during the procedure. However, as illustrated in Fig. 5, MRA struggles to achieve this level of clarity. In some cases, nerves can be compressed by not only the main trunk artery but also the smaller branch, which may be invisible or difficult to see intraoperatively, and detailed preoperative anatomical information helps to determine surgical strategy, improving surgical safety and outcomes.1,7

Our study had certain limitations, including its retrospective design, small sample size, and single-center experience. Further studies are intended to establish clearer criteria and incorporate larger and more diverse patient populations to more precisely evaluate the utility of high-resolution CTA in the preoperative evaluation of MVD surgery.

In conclusion, 3D-reconstructed images with high-resolution CTA may be beneficial for the preoperative assessment of MVD. Preoperative identification of the location of nerves and surrounding blood vessels aids proper intraoperative decision-making. Further studies are required to fully evaluate the potential benefits of high-resolution CTA in MVD surgery.

References


Disclosures

Dr. Hosomi received funding from the Japan Society for the Promotion of Science (JSPS; JP22K09206).

Author Contributions

Conception and design: Hosomi, Iwata, Kishima. Acquisition of data: Iwata, Tani, Khoo. Analysis and interpretation of data: Iwata, Tani. Drafting the article: Iwata. Critical revising of the article: Hosomi, Tani, Oshino, Kishima. Reviewed submitted version of manuscript: Hosomi, Tani, Oshino, Khoo, Kishima. Approved the final version of the manuscript on behalf of all authors: Hosomi. Administrative/technical/material support: Hosomi, Khoo. Study supervision: Hosomi, Kishima.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article. Supplemental Tables 1 and 2. https://thejns.org/doi/suppl/10.3171/2022/CASE23330.

Correspondence

Koichi Hosomi: Osaka University Graduate School of Medicine, Suita, Osaka, Japan. k-hosomi@nsurg.med.osaka-u.ac.jp.