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COMPUTATIONAL FLUID DYNAMIC STUDY IN THE CASE OF NEUROVASCULAR CONFLICT IN TRIGEMINAL NEURALGIA AND FACIAL SPASM

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CFD – computational fluid dynamic
CN – cranial nerve
CT – computed tomography
CTA – computed tomography angiography
DSA - digital subtraction angiography
HFS – hemifacial spasm
ICA – internal carotid artery
ICG-VA – indocyanine green videoangiography
MRI – magnetic resonance imaging
MVD – microvascular decompression
NVc – neurovascular contact
NVCd – side distal to NVC NVCp – side proximal to NVC
NVCs – neurovascular conflict syndrome
PICA- posterior inferior cerebellar artery
SCA – superior inferior cerebellar artery
SL- Stream line
TN – trigeminal neuralgia
WP – wall pressure
WSSm- wall shear stress magnitude
WSSv – wall shear stress vectors

ABSTRACT

Background. In this study authors analyzed hemodynamic features of offending vessels with CFD study in hemifacial spasm and trigeminal neuralgia and compared with 3D Fusion images and real time surgery findings.

Materials and methods. 9 cases of NVCs in trigeminal neuralgia and hemifacial spasm were studied at Fujita Health University Banbuntane Hotokukai Hospital during fellowship training from August to October 2019. CFD analyzes of offending vessels was carried out preoperatively and compared with real time surgery findings. All patients were evaluated by 3D

MR cisternography, 3D MR angiography (MRA) and 3D CT angiography (CTA) to analyze fluid dynamic on Hemoscope 2. Rertosigmoid approach with microvascular decompression was performed using surgical microscope OPMI Pentero 900 (Carl Ziess, Germany).

Results. All cases represented with high WSSm, SL, and altered WSSv but in 55% increased WP, 33,4% moderate WP, 12% decreased WP were seen at NVC site. At both NVCp and NVCd, there were low WSSm, SL and normal WSSv in all Cases, However, in 5 cases we identified more than one NVc representing with either increased or moderate WP that were more increased at NVCp than NVCd. In one case preoperative MRI confirmed meningiomas of Meckel's cave. During endoscopic removal of meningioma, CSA compressing V nerve was observed and MVD with transposition was performed. After surgery, we analyzed preoperative CTA of SCA via CFD and identified that there was NVCs with increased WP, High WSSm, SL and altered WSSv which corresponded to findings of real time surgery.

Conclusion. Offending vessels in NVCs represents with high WSSm, SL, increased WP and altered WSSv at contact site that are useful to identify exact location of compression parts of offending vessels before surgery.

Keywords: neurovascular conflict, trigeminal neuralgia, hemifacial spasm, microvascular decompression, computational fluid dynamic.

INTRODUCTION

Neurovascular conflict syndrome (NVCs) is defined as a direct contact with mechanical irritation of cranial nerves (CNs) by adjacent blood vessels. Currently, the literature describes neurovascular conflict with all cranial nerves except olfactory nerve [1,2]. The most common neurovascular compression syndrome is trigeminal neuralgia, followed by hemifacial spasm. Less well known are glossopharyngeal neuralgia, nervus intermedius neuralgia, and vestibular nerve. Very rarely, the oculomotor nerve or the abducens nerve is involved [3,4]. The vascular structures in anatomical relation to the nerve root at the lateral pontine aspect of the brainstem should be examined and maximally decompressed to minimize the risk of recurrent NVC. There are several methods of treatment of NVCs such as conservative treatment, radio surgery, percutaneous decompression technique with balloon, percutaneous risotomy with glycerol, alcohol and water, partial risotomy and micro vascular decompression (MVD) [5]. Detailed preoperative evaluation of CNs and offending vessels are required to achieve effective decompression of affected CNs in MVD surgery. MRI and CT has been used to confirm trigeminal or facial nerve neuralgia for long years. CFD is recently introduced golden methods to evaluate dynamic features of offending vessels to identify NVc in preoperative period. In neurovascular conflict syndrome (NVCs), CFD of offending vessels was reported by many authors to be effective in identifying which part offending vessels compress the nerve [6].

Based on finding on preoperative 3D fusion images, hemodynamic features of offending vessels were analyzed by CFD study in hemifacial spasm and trigeminal neuralgia as crucial preoperative decision making tool and real time surgery findings, 3D fusion images findings and CFD results were compared.

MATERIALS AND METHODS

The study was conducted on 9 patients with trigeminal neuralgia and hemifacial spasm who underwent MVD surgery at the department of neurosurgery

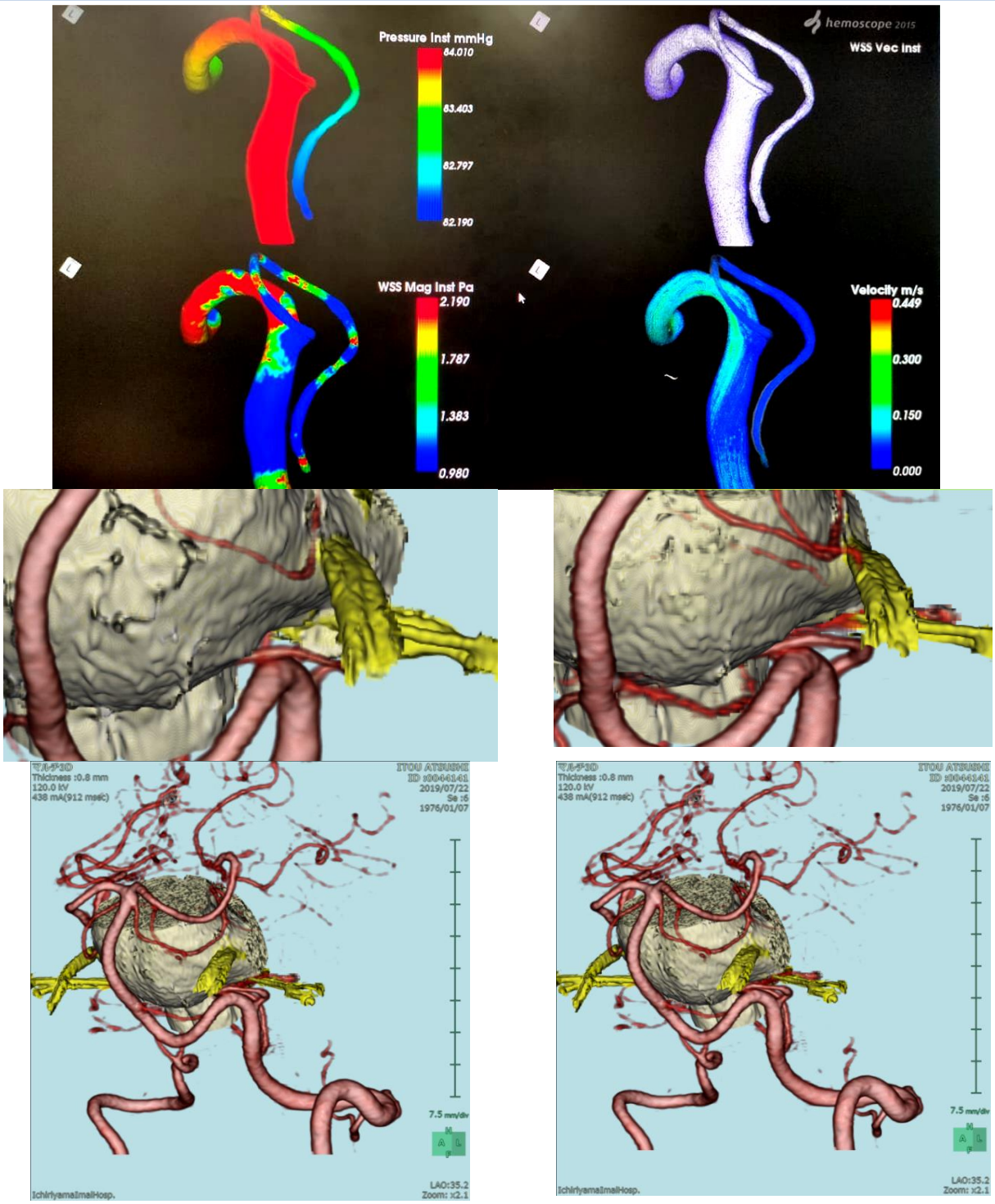
of Fujita Health University Banbuntane Hotokukai Hospital during 3 months' fellowship training period from August October 2019. All patients were evaluated by 3D MR cisternography, 3D MR angiography (MRA) and 3D CT angiography (CTA) to analyze fluid dynamic on Hemoscope 2. 3D fusion images were helpful to visualise root entry zone (REZ). Computational fluid dynamic study was carried out with Hemoscope 2 (Ziosoft Corporation, Minato ward, Tokyo Japan). CFD study measures 4 parameters; wall shear stress magnitude –WSSm, wall shear stress vector –WSSv, stream line flow and velocity, pressure (circumferential). In preoperative period offending vessels were assisted via CFD study and compared to intraoperative findings.

RESULTS

Among all 9 patients, incidence of facial spasm was seen in 34% while 66% patients suffered from trigeminal neuralgia. Male to female ratio was 2:1 with mean age 66. Preoperative evaluation of offending vessels showed that in all cases there was high WSSm, SL, and altered WSSv but in 55% increased WP, 33,4% moderate WP, 12% decreased WP were seen at NVC site. At both NVCp and NVCd, there were low WSSm, SL and normal WSSv in all Cases, However, in 5 cases we identified more than one NVC site representing with either increased or moderate WP that were more increased at NVCp than NVCd. In one case preoperative MRI confirmed meningiomas of Meckel's cave. During endoscopic removal of meningioma loop of SCA compressing V nerve were observed and MVD with transposition was performed. After surgery, we analyzed preoperative CTA of SCA via CFD and identified that there was NVCs with increased WP, High WSSm, SL and altered WSSv which corresponded to findings of real time surgery. In other 8 cases, preoperative findings of CFD confirmed by real time surgery findings. In all offending vessels were SCA and PICA for TN and HFS respectively. In one recurrent HFS, we identified Teflon granuloma compression nerve and artery and in one case there was compression of VII nerve by PICA which itself compressed by VA.

Illustrative case 1

78-year-old male admitted to neurosurgery department due to her left sided facial spasm and numbness in left face which does not have any symptom regress with medicine. Preoperative MRI, CT, DSA confirmed compression of VII c.n. by PICA which itself was compressed by left vertebral artery (VA). Preoperative detailed CFDanalyzes illustrated that there was 2 NVc with PICA compressed by left VA leading in altered WSSv, high WSSm, SL and increased WP. As an option we performed left retrosigmoid craniotomy in which we found Teflon granuloma compressing VII nerve. NVc and location of Teflon granuloma corresponded with the location of NVc identified with CFD. MVD was performed by removing Teflon Granuloma at first NVc location and interpositioning with Teflon at second NVc location (Figure 1).

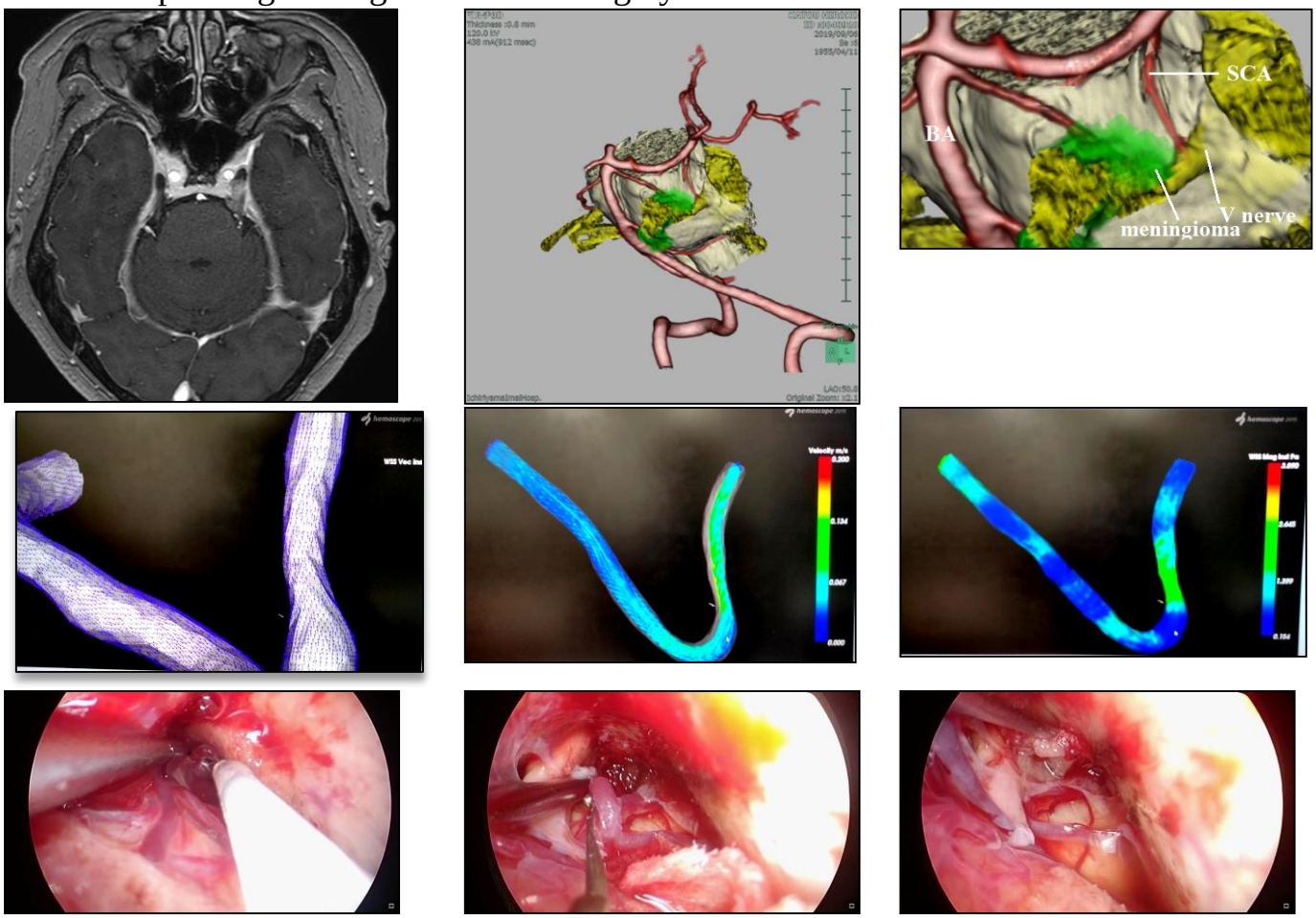


Figures 1. Pre and postoperatrive fusion images in recurrent hemifacial spasm illustrating complete decompression of left facial nerve.

Illustrative case 2.

64-year-old female with trigeminal neuralgia caused by Meckel's cave meningioma underwent endoscopic removal of Meckel's cave meningioma, during surgery, SCA was found compressing V nerve with its loop (Figure 2). We thought that apart from meningioama, even SCA might be cause of compression and therefore we decided to perform MVD via transposition of SCA. To confirm our concern, after surgery we analyzed hemodynamics of SCA on CFD in which there

was one NVc represented with high WSSm, SL, altered WSSv and moderate WP corriesponding finding of real time surgery.



MRI shows meningioma im Meckel' s cave, preoperative 3D fusion image of meningioma and SCA compressing root exist zone of V nerve, CFD illustrates altered WSSv, increased volume of SL, and WSSm that correspond to neurovascular contact of intraoperative findings.

DISCUSSION

Hemifacial spasm characterized by by frequent involuntary contractions (spasms) of the muscles on one side (hemi-) of the face (facial) which gradually spreads to the muscles of lower face. An intermittent twitching of the eyelid muscle is earliest symptoms of HFS which results in forced closure of the eye and involvement of muscles of lower face leading to one sided pulled mouth. Spasm usually occurs involuntarily, irregularly, with clonic and tonic movements of facial muscles [7,8]. The etiology of HFS is VII c.n. injury due to external factors such as compression of surrounding structure, tumors, and trauma. In the case of hemifacial spasm offending vessels usually compress affected VII c.n. [9]. The National Institute of Neurological Disorders and Stroke (NINDS) suggest that HFS is the most common in Asian population. Correct diagnosis of HFS leads to better outcome. It should be differentiated from other disorders which have similar symptoms as HFS. These disorders are blepharospasm, oromandibular dystonia,

facial nerve tic, hemimasticatory spasm, focal seizures and synkinesias after facial nerve paralysis [10].

Trigeminal neuralgia (Fothergill's disease) initially described by John Fothergill in 1773 [11] is a condition mostly presents with neuropathic pain due to NVCs caused trigeminal nerve compression at the level of it existing zone. A painful symptom in TN is usually unilateral. Only TN caused by multiple sclerosis can be bilateral. As diagnosis of possible TN, pain distribution within the facial or intraoral territory of TN and paroxysmal character of pain which lasts from few seconds to 2 minutes and triggered by typical maneuvers such as mechanic stimuli are required [12,13]. Classic TN is caused by vascular compression can be diagnosed with CFD studies. 3-D MR multi-fusion imaging technique by compositing co-registered data sets of a 3-D MR cisternogram, a 3-D MR angiogram (non-contrasted and contrast-enhanced), and a 3-D computed tomographic (CT) angiogram in a single 3-D image is new tool to diagnosis of HFS due to NVCs [14].

Neurovascular compression result in morphological changes in vessel wall such as its deformation, and dysfunction of haemodynamics of blood flow. These changes are well described by Satoh et al developing simulation fusion images to confirm adherence of nerve to vessel wall [15]. According to their report, average flow rate was varied among the individual patients, and WSSm values of offending vessels at the NVCs were high during peak systolic, end-diastolic and cycle average phase. Furthermore, the WSSm values at the NVC-j and NVC-s were higher than those at the NVC-p and NVC-d, magnitude of the WSS of the offending vessels increased at the are of th NVC leading aterosclerotic remodeling of the vessels as a mechanotransduction response of vascular endotelial cells. In addition to this WSS vectors were also altered, there was less movement of WSSv at the contacting side compared to frequent and unstable movement of WSSv on the vessel wall which was lateral and contralateral to the compressed nerve. In the case of NVC syndrome, high WSSm, altered directon of vectors (WSSv), high pressure and increased streamline at contact site, reported to be a reliable indicator of a neurovascular conflict zone. Satoh et al. studied WSSm and WSSv as two specific features. They demonstrated that WSSm increased at proximal, just beginning, contact site and distal areas of the neurovascular conflict.

Similar results were obtained in our series; in both TN and HFS cases there were high WSSm, high WP, SL and altered WSSV at neurovascular contact site of offending vessels. Moreover, multiple NVCs sites were identified and those findings corresponded with findings of 3D simulation images and real time surgery findings.

CONCLUSION

Identification of exact location of neurovascular contact zone on CFD analyse of offending vessels in neurovascular conflict syndrome such as trigeminal neuralgia and hemifacial spasm decreases overall period of surgery, intra and postoperative complication by avoiding extra manipulation in surgical field.

Neurovascular contact zone represents with High WSSm, WP, SL and altered WSSv.

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