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# Fluid structure interaction analysis reveals facial nerve palsy caused by vertebral-posterior inferior cerebellar artery aneurysm

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ABSTRACT

Cranial nerve palsy caused by aneurysmal compression has not been fully evaluated. The main causes of symptoms are considered to be direct mechanical compression and aneurysm pulsations. Recent studies indicate that nerve dysfunction is mainly induced by pulsation rather than by direct compression, and successful cases of endovascular surgery have been reported. We describe a patient with an unruptured vertebral artery-posterior inferior cerebellar artery (VA-PICA) aneurysm compressing the facial nerve at the root exit zone (REZ). The patient presented with peripheral facial nerve palsy but not hemifacial spasm and was successfully treated by coil embolization. To investigate the mechanisms underlying peripheral facial nerve palsy, fluid structure interaction (FSI) analysis can approximate displacement and the magnitude of aneurysmal wall motion due to hemodynamic forces. In our case, maximum mesh displacement was observed at the aneurysmal wall attached to the facial nerve inside the pons rather than the REZ, which explains the clinical manifestation of facial nerve palsy in the absence of hemifacial spasm. This preliminary report demonstrates the utility of FSI analysis for investigating cranial nerve neuropathy.



## 1. Introduction

Cranial nerve palsy caused by aneurysmal compression is considered to result from direct compression and aneurysm pulsations against the nerve. Recent studies indicate that nerve dysfunction is mainly induced by pulsation rather than direct compression, and successful endovascular surgeries have been reported [1–3]. Improvement of radiculopathy is considered to result from reduced intra-aneurysmal flow, which in turn attenuates pulsation. Even though aneurysm size is not reduced after coil embolization, symptom resolution is observed [1]. Flow diverters have recently been used to treat symptomatic unruptured aneurysms [4]; therefore, it has been proposed that symptomatic improvement may be related to hemodynamic changes inside the offending aneurysm. However, the correlation between cranial nerve palsy and aneurysmal pulsations has not been fully elucidated.

While there are relatively few reports of hemifacial spasm due to neurovascular conflicts caused by cerebral aneurysm [5–7], facial nerve palsy in these cases is even more rare. We treated a patient with an unruptured vertebral artery-posterior inferior cerebellar artery (VA-PICA) aneurysm that contacted the facial nerve at its root exit zone (REZ). The patient presented with peripheral facial nerve palsy without hemifacial spasm and was successfully treated with coil embolization. To further investigate the cause of nerve palsy, we carried out fluid structure interaction (FSI) analysis, which allowed us to assess aneurysm wall motion magnitude by calculating the total mesh displacement [8–10]. We hypothesize that the location most affected by aneurysm pulsation was at the point of maximum total mesh displacement, and this may have caused the observed nerve dysfunction. Using FSI, we

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attempted to determine if stimulation of the elastic aneurysmal wall coupled with its pulsation was a cause of cranial nerve palsy in this patient. Our findings highlight the clinical usefulness of FSI analysis in investigating cerebral aneurysm pulsation as a potential cause of cranial nerve palsy.

## 2. Case and methods

### 2.1. Case presentation

A 59-year-old female was admitted to our hospital with sudden onset left-side peripheral facial nerve palsy (House-Brackmann grade III) without other neurological deficits. She had no medical history and was taking no medications. We initially suspected Bell's palsy; however, magnetic resonance imaging (MRI) revealed an unruptured VA-PICA aneurysm 8-mm in diameter wedged in the left side of the pons at the facial nerve REZ (Fig. 1a and b). A small bleb was also found on three-dimensional rotational angiography (3-DRA; (Fig. 1c and d). Considering the aneurysm's location, it was clear that it caused the patient's palsy. Furthermore, the sudden symptom onset indicated impending rupture, and immediate surgical treatment was considered. Given the aneurysm's shape and location, both clipping and coiling were viable treatment options. After explaining the situation to the patient, she selected coil embolization. The procedure was performed under general anesthesia 3 days after symptom onset. A series of bare coils were placed in the aneurysm, and total occlusion was achieved without any perioperative complications (Fig. 2). Her facial weakness had gradually resolved 1 week after the procedure, and she was fully recovered after 1 month. A follow-up MRI showed no evidence of aneurysm recanalization.

### 2.2. Fluid domain model

To investigate the mechanism underlying the patient's palsy, we generated fusion image reconstructions from 3-DRA and constructive image in steady state magnetic resonance imaging (MRI CISS) and visualized the anatomical position of the VA-PICA aneurysm and facial nerve using Amira software (FEI/VSG-division, Bordeaux, France). For analysis, the digital imaging for communication in medicine (DICOM) format for 3DRA was used, and blood vessels were extracted using Real Intage software (Cybernet System, Tokyo, Japan), allowing us to export data for meshing using ICEM CFD 15.0 software (ANSYS, Inc., Canonsburg, PA, USA) in the stereolithography (STL) file format. Using the triangulated surface from STL file as a base, a computational volumetric mesh was constructed. The mesh mainly comprised tetrahedrons with seven layers of prism elements near the wall surface to increase the analytic precision of the boundary layer. The maximum Reynolds number of aneurysm model was based on the inlet diameter and ranged between 300 and 600; thus, the flow was treated as

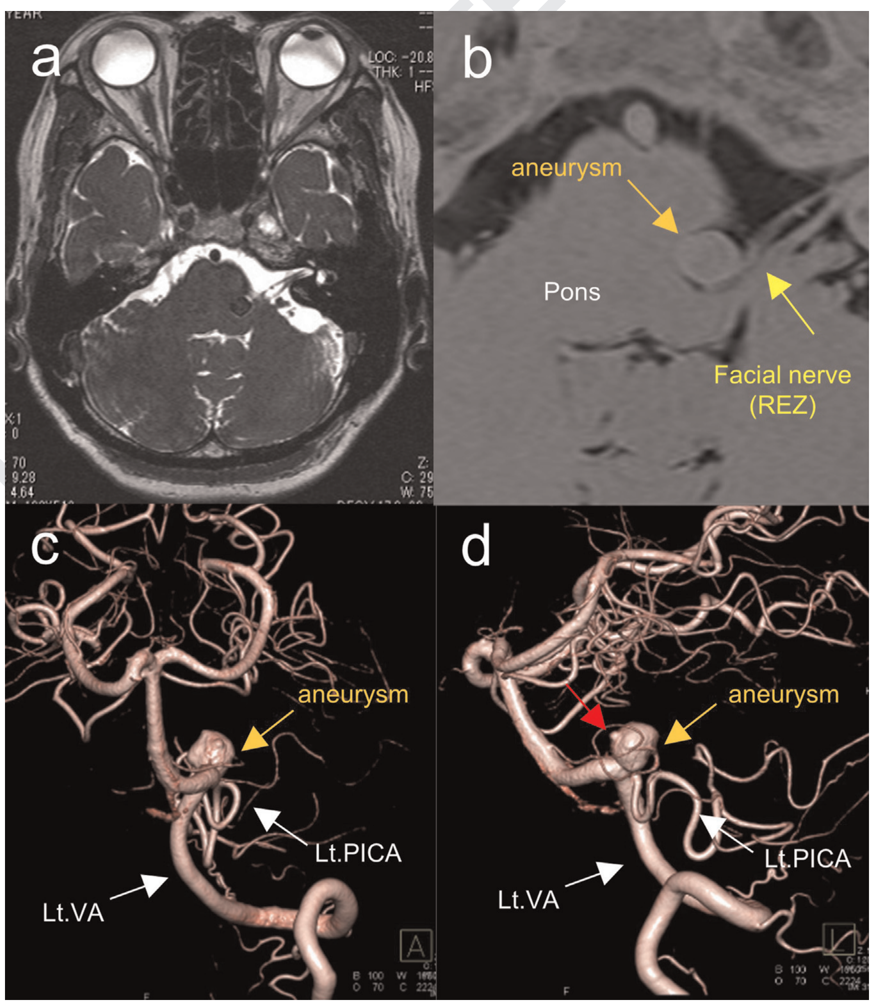


**Fig. 1.** MRI CISS and 3DRA imaging of the aneurysm. (a) Axial image generated by MRI CISS imaging from the ventral view. (b) Magnified view of the image in (a). (c) Antero-posterior view generated by 3DRA imaging. (d) Left lateral view generated by 3DRA imaging (the bleb is indicated by the red arrow) PICA: posterior inferior cerebellar artery; REZ: root exit zone; VA: vertebral artery. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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