PRESENCE OF A STENOSIS AND AN ANEURYSM AT THE VERTEBROBASILAR ARTERY

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INTRODUCTION

The presence of a stenosis in a vertebral artery or of an aneurysm in the basilar artery is not uncommon. The formation of a stenosis results from atherosclerotic narrowing and is related to low flow shear on the vessel wall (1-2), while the development of an aneurysm is thought to be related to a local weakening of vessel wall structure (3-4). However, to our knowledge, the co-existence of a stenosis and an aneurysm in close proximity has never been examined. A phenomenon that a vascular disease may present or be related to the development of another vascular disease can be overlooked when planning a treatment (surgery or endovascular procedure). A numerical study that investigates possible mechanism of disease development for an aneurysm at the basilar artery was conducted. Results suggest a possible sequence of disease development and may be applicable to other vascular territory.

METHOD

A subject being evaluated for treatment of a giant fusiform basilar aneurysm was imaged with contrast enhanced magnetic resonance angiography (MRA), in which a contrast agent is injected to provide good coverage and resolution. The flow rate into each vertebral artery and the basilar artery was measured with phase contrast magnetic resonance angiography during the MRI study. Since few treatment alternatives were available, the subject was not treated. The subject was imaged again one year later, and no significant change or growth of the aneurysm was observed.

The geometry of the vertebrobasilar artery was extracted from the three-dimensional MRA images of the subject, and the flow was simulated with FLUENT 6.0 (Lebanon, NH). Grid independence was tested to ensure the flow was resolved properly. The artery segment that was modeled included the basilar trunk, sections of the vertebral arteries proximal to the junction and the cerebral arteries distal to the basilar tip.

Since the basilar artery in Figure 1 is highly deformed, a simplified vertebrobasilar artery, representing the pre-diseased condition, was constructed by maintaining the size of each branch with a symmetric configuration. Another configuration was obtained by morphing between the healthy and diseased geometries, representing a likely geometry that occurred during mid-development of the aneurysm.

RESULTS

A volume rendered picture of the MRA of the vertebrobasilar artery is shown in Figure 1, in which the vertebral and basilar arteries are clearly depicted. A stenosis is found at the right vertebral artery proximal to the junction. An aneurysm is also noted of the basilar artery, which deforms to the left - opposite to the stenosis.

A comparison of pressure distributions at the mid-plane for the basilar artery before aneurysm development (A), mid-development (B), and post-development (C) is presented in Figure 2. For all the configurations, the flow rate in the vertebral arteries was fixed at 1ml/s, a similar level to that measured with phase contrast MRA.

In Figure 3, the total flow rate into the basilar artery was kept fixed at 2ml/s, but the ratio of flow into two vertebral arteries was varied by reducing the flow through the stenosed vertebral artery. The flow rate ratio at downstream branches has also been adjusted to evaluate its influence, and it was determined that the downstream flow rate ratio affects less to the flow pattern and pressure distribution than the upstream flow rate ratio does.

DISCUSSION

Higher pressure is observed in the aneurysm in Figure 2, where the flow rate through the right vertebral artery is maintained at a fixed level. Though there is no direct evidence that the hemodynamic pressure is linked to the aneurysm development, the pressure appears to be the force that deforms the basilar trunk. The elevated pressure is not seen in Figure 3, indicating that a variable flow rate scenario may not produce the deformation of aneurysm that was seen in the MRA images. Thus, the change of flow rate may occur in a short period of time in the end phase of aneurysm formation rather than gradually.

Because of the relative position of the stenosis to the aneurysm, the flow jet resulting from the narrowed vertebral artery could contribute to the growth and deformation of the aneurysm. As the stenosis becomes tighter and the resulting flow jet stronger, the impinging fluid force is also stronger, which may promote the deformation of the basilar artery and aneurysm growth. In fact, the displacement of the basilar artery also deforms the adjacent cerebral arteries and circle of Willis.

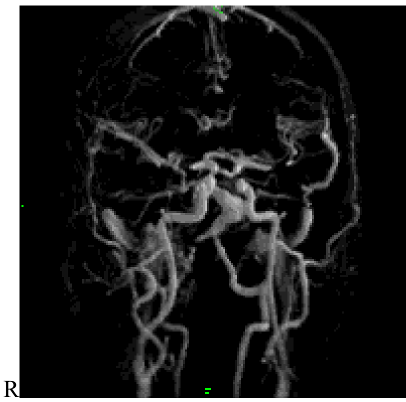

Figure 1. Contrast enhanced magnetic resonance angiography image of a vertebrobasilar artery that has a stenosis in the right vertebral artery and a fusiform aneurysm in the basilar trunk.

From the in vivo velocity measurement, the flow rate through the stenosed vertebral artery is less than 5% of the total flow rate through the basilar artery, indicating a high flow resistance through the stenosis. However, the deformation of the basilar artery and adjacent cerebral arteries appears to be permanent despite the decrease of the flow jet intensity. This might indicate that growth and deformation of the aneurysm occurred simultaneously during development; thus, the deformation of the aneurysm becomes permanent even though the initiating hemodynamic factor (flow jet) is removed. The aneurysm ceases to grow when the intensity of the flow jet is reduced and the likelihood of rupture is reduced.

Although the exact cause and mechanism of aneurysm formation is still unknown, it appears that the flow jet distal to a vertebral stenosis could play an important role because it coincides with the location of aneurysm growth and the direction of aneurysm deformation. The co-existence of a stenosis and an aneurysm in this case presents us a unique opportunity to examine the hemodynamics in basilar aneurysm development.

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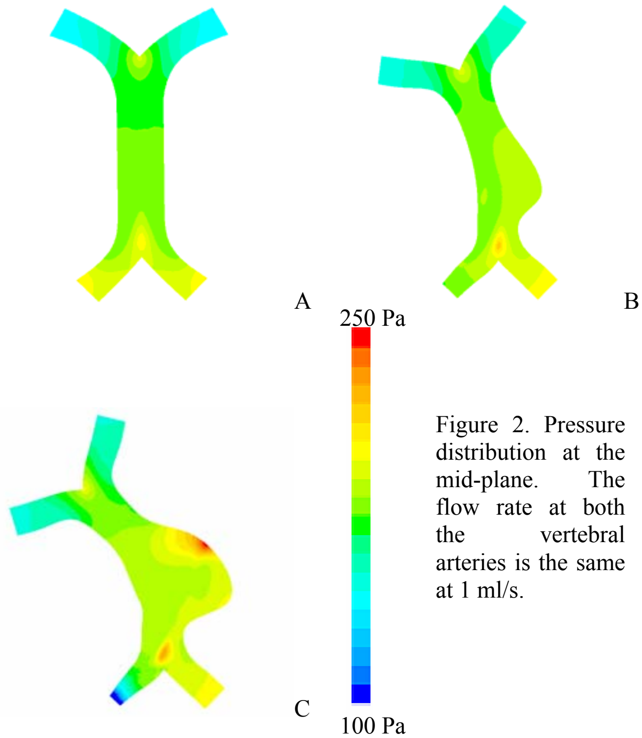

Figure 2. Pressure distribution at the mid-plane. The flow rate at both the vertebral arteries is the same at 1 ml/s.

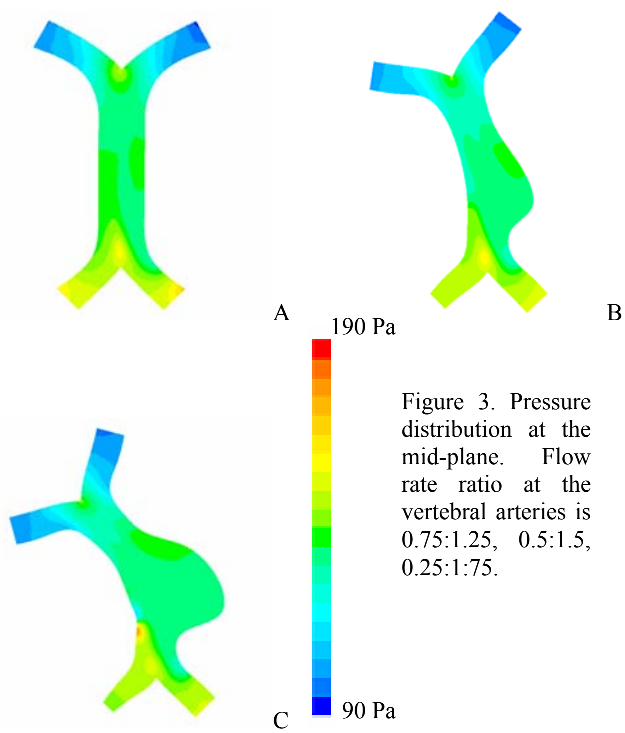

Figure 3. Pressure distribution at the mid-plane. Flow rate ratio at the vertebral arteries is 0.75:1.25, 0.5:1.5, 0.25:1:75.