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Case Report

Intraoperative Rupture Cerebral Aneurysm and Computational Flow Dynamics

Abstract

Intraoperative aneurysmal rupture (IAR) is the most fearsome complication of aneurysm surgery. IAR associates with high morbidity and mortality. In recent years, we have many studies regarding using computational fluid dynamics (CFD) in aneurysm surgery. CFD helps in calculating the velocity of blood flowing in the aneurysm sac, the pressure in the aneurysm sac, and wall shear stress (WSS). CFD also helps in predicting nature of aneurysm wall and thus may warn about different intraoperative microscopy findings in aneurysms. Using its application, surgeon may become more careful in doing microsurgical sharp dissection. A 40-year-old female admitted with diagnosis of unruptured anterior communicating artery aneurysm. CFD analysis demonstrated high intra-aneurysmal pressure and divergent WSS in dome. During sharp dissection, there was intraoperative rupture aneurysm twice which was managed with cotton tamponade and glue and temporary clipping aneurysm. Indocyanine green video angiography showed working parent arteries and nonfunctioning aneurysm. After operation, the patient recovered fully and had a modified Rankin score of 1. This case demonstrated importance of preoperative planning of aneurysm surgery using CFD analysis. IAR is associated with an increased risk for an unfavorable outcome. Accurate preoperative planning with studying flow dynamics and structure of aneurysm may help in use sharp microsurgical dissection more cautiously.

Keywords: *Cerebral aneurysm, computational fluid dynamics, intraoperative aneurysmal rupture*

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Introduction

Intraoperative aneurysmal rupture (IAR) is the most dramatic complication of aneurysm surgery. IAR associates with high morbidity and mortality. Incidence of IAR during open surgery ranges from 5% to 50%.[1] Assessment risk factors for IAR of aneurysm will reduce the incidence of this complication and improve the outcome the treatment. Computational fluid dynamics (CFD) helps in predicting nature of aneurysm wall and thus may warn about different intraoperative microscopy findings in aneurysms.[2]

Case Report

A 40-year-old female had a 3-year history of headache. Magnetic resonance imaging (MRI) discovered small anterior communicating artery (ACoA) aneurysm 2 years ago. The patient was again admitted with increasing headache and MRI showed same aneurysm. Computed tomography (CT) angiography showed an ACoA aneurysm with maximum diameter of 3.3 mm [Figure 1]. Computational flow dynamics in aneurysm was analyzed using Haemoscope Software, AMIN corp., Tokyo, Japan. Intra-aneurysmal pressure was high [Figure 2a] and wall shear stress (WSS) magnitude in aneurysm was low [Figure 2b]. Furthermore, CFD analysis showed WSS divergent vectors in dome with spiral streamline patterns [Figure 2c and d].

Procedure

After orotracheal intubation, head of the patient was fix in 45° right rotated and up to the cord line with zygoma in the top. The right pterional approach was used to do craniotomy. The dura was opened in a curved fashion and temporary suspended. Using the lateral transsylvian approach, we dissected M1 segment left middle cerebral artery and left internal carotid artery. After that, we dissected A1 segment left anterior cerebral artery (ACA) and traced the ACoA. This part of ACA was temporary clipped to dissect the aneurysm. The aneurysm was localized in angle between left ACA and

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ACoA and it was of more size (9 mm) than seen on the CT angiography. During sharp dissection, aneurysm ruptured at thin area predicted by CFD. Bleeding was controlled using aspirator, and point of rupture was tamponade by cotton and glue [Figure 3]. Bleeding was stopped.

After that, we made final aneurysm dissection. Aneurysm had combined direction dome where the most part of aneurysm localized between A2 segment anterior cerebral arteries. With using temporary clipping left A1 segment, we clipped aneurysm two fenestrated clips. However, after clipping aneurysm, indocyanine green (ICG) video angiography showed not working left ACA. After reposition clips left ACA restored permeability [Figure 4].

After operation, the patient recovered full and had a modified Rankin score of 1. Postoperative CT was normal [Figure 5]. The patient was discharged on postoperative day 10. Overall postoperative course was uneventful.

Discussion

Cerebral aneurysms which rupture intraoperative show worse outcome. The majority of IAR occurs either during aneurysm dissection or clip application. Among aneurysms at all sites, ACoA aneurysm demonstrates a higher frequency of IAR (30%), followed by posterior communicating artery aneurysm (26%) and middle cerebral

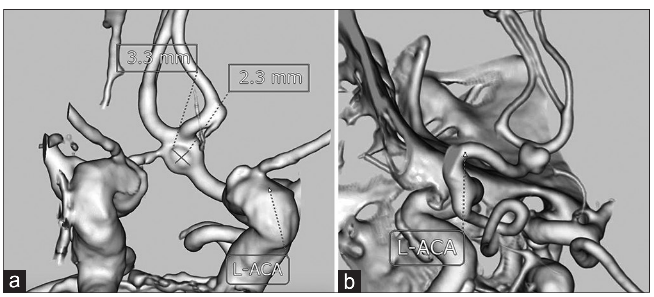

Figure 1: (a and b) Computed tomography angiography intracranial artery. Aneurysm anterior communicating artery

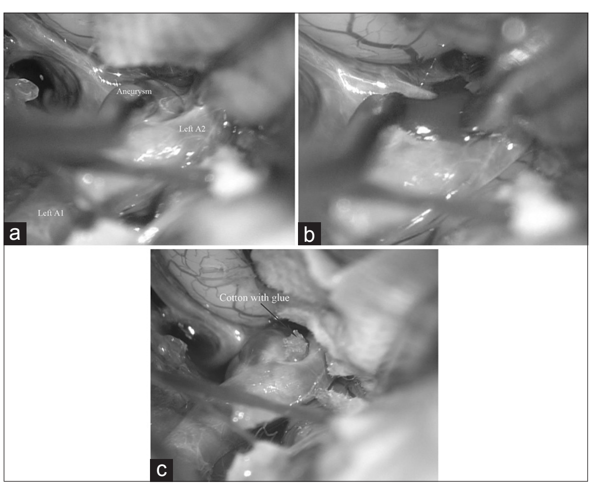

Figure 3: Intraoperative view after left transsylvian approach. (a) Anterior communicating artery aneurysm with red thin wall, (b) intraoperative rupture during aneurysm dissection, (c) temporary tamponade point of rupture by cotton

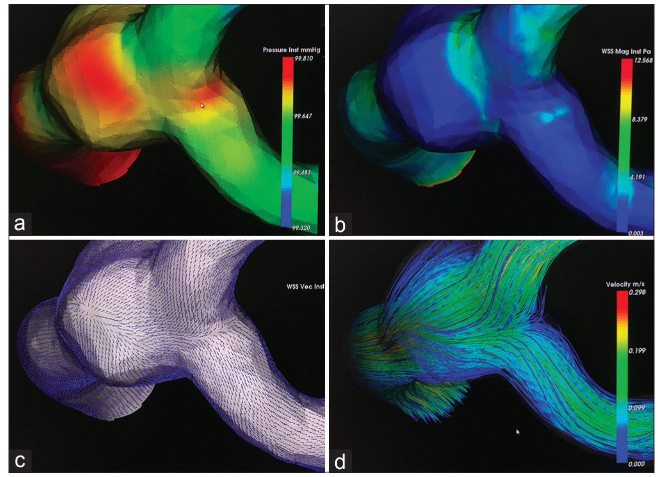

Figure 2: Computational flow dynamics in aneurysm anterior communicating artery. (a) Pressure, (b) wall shear stress magnitude, (c) wall shear stress vectors, (d) streamlines pattern

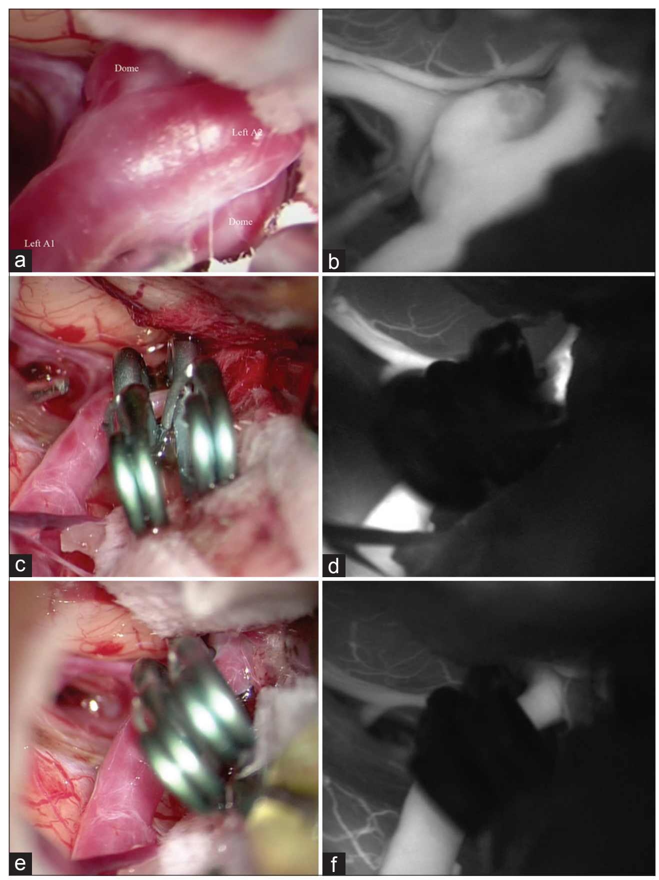

Figure 4: Clipping anterior communicating artery aneurysm with indocyanine green video angiography control. (a) anterior communicating artery aneurysm with combined direction dome, (b) indocyanine green video angiography preclipping control, (c) clipping anterior communicating artery aneurysm two fenestrated clips, (d) indocyanine green video angiography control after clipping, left anterior cerebral artery not filling, (e) reposition clips, (f) indocyanine green video angiography control after reposition, filling left anterior cerebral artery is good

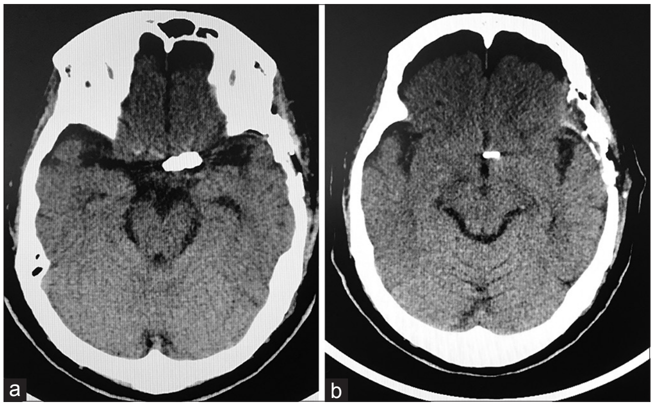

Figure 5: (a and b) Postoperative computed tomography

artery aneurysm (18%) in descending order.[3] IAR must be better avoided than treated. Leipzig *et al*. and Pang *et al*. reported on significantly lower rates of IAR that were attributed to the increased use of temporary clipping.[1,3] Adequate exposure, proximal control, use of temporary clip, and sharp dissection permit to avoid IAR.

Many efforts have focused on analyzing the effects of hemodynamic forces on initiation, growth, and rupture of cerebral aneurysms. The used CFD explains the increasing number of investigations in this field. CFD studies apply mathematical model to simulate blood flow conditions, the shapes of vessels and aneurysms, velocity, and forces such as tension or shear stress. Direction blood flow depends from neck diameter, angle with respect to the parent artery, the parent vessel caliber, the caliber or the angle of efferent vessels, and aneurysm shape.[4] The mechanical stress imposed on the vessel wall by blood flow and pressure can be divided into two main components: WSS that is tangential to the lumen and caused by friction, and wall tension caused by circumferential stretch created by pulse pressure wave and transmural pressure difference, which leads to distension and tension of the aneurysmal wall. It is tension of the wall that leads to rupture when it exceeds the tensile strength of the wall matrix. Nevertheless, WSS and other stress vectors also have an affect on vessel wall remodeling since they affect the function and phenotype of endothelial cells, smooth muscle cells, and fibroblasts and can induce wall inflammation.[5]

CFD shows association of data that often correlate with intraoperative findings. CFD has potential to allow prediction about aneurysm wall weakness.[2] Fukazawa *et al*. (2013) and Kadasi *et al*. studied the association of WSS and aneurysm wall observed during microsurgical clipping. They found that low WSS is associated with thin and most likely fragile walls.[6,7] Cebral *et al*. found that secondary blebs form at sites of high WSS.[8] Too-high or too-low WSS or otherwise aberrant WSS not only leads to dysfunction of endothelial cells but also may cause complete loss of the endothelial layer. Endothelial cells act as a barrier between the aneurysm wall and plasma, and loss of this barrier function and subsequent free diffusion of plasma components into the aneurysm wall can trigger wall degeneration that eventually leads to rupture.[5]

We have many controversies about CFD findings and aneurysm growth, rupture, and intraoperative findings. We need multicentric comparative trials about different flow dynamic parameters and structure of aneurysm.

Our clinical case demonstrated important of preoperative evaluation of CT angiography and CFD in aneurysm. Careful planning and strategic clipping of aneurysms will allow to avoid intraoperative misadventures. Today, understanding flow dynamics and morphology of aneurysm have an influence on operative strategy, for example, using preventive temporary proximal clipping or avoiding thin red wall during aneurysm sharp dissection.

Conclusion

IAR associates with an increased risk for an unfavorable outcome. Accurate preoperative planning with studying flow dynamics and structure of aneurysm might warn us to do sharp microsurgical dissection more cautiously.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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