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Editorial

Explaining the Cerebral Aneurysm's Shape and Timing of Rupture – Unlocking the Mystique Using Theoretical Physics

Image-based computational fluid dynamics (CFD) holds a prominent position in the patient-specific evaluation of intracranial aneurysms with enormous potential to provide objective, quantitative, and mechanism-based markers of aneurysm rupture risk. Patient-specific *in vivo* flow dynamic simulation can be routinely performed from the existing medical imaging modalities (digital subtraction angiography, computed tomography angiogram, and magnetic resonance angiography). Conversely, tensile stress calculation requires knowledge of patient-specific, *in vivo* wall thickness and material properties, which are unavailable from the current imaging capabilities. Without the means to monitor wall stress and wall strength, it is impossible to predict when an aneurysm will rupture. However, because pathologic remodeling is partially mediated by abnormal wall shear stress (WSS), it may be the only suitable clinical application to predict rupture.

Although many hemodynamic parameters are used to interpret CFD such as WSS, velocity, vector flow, direction and pressure gradient, inflow concentration index, shear concentration index, viscous dissipation ratio, and kinetic energy ratio, WSS is the most commonly used because of its clinical significance. Initiation of intracranial aneurysms is induced by a high WSS and a positive WSS gradient.

With an increase in internal pressure, the best available shape to reduce the tension is to acquire the shape of a sphere. However, with each reduction in the tension and the formation of an aneurysm, there is also a subsequent reduction in the wall thickness. As the wall tension further increases, and moreover within the vessel and inside the aneurysm, there is a further modification in the shape of the aneurysm, which again tries to reduce its wall tension, thereby forming another spherical structure from an aneurysm. This sequence of events will keep on occurring and the wall thickness too reduces with each such change. Further, with approximately the third such event, the reduction in wall thickness and the increase in tension inside the aneurysm increase to an extent that the aneurysm ruptures. We call this the ``Kato-Ansari`` explanation. For the same internal pressure, the downward component of the tension must be the same. It can be explained by an analogy that to hang a mass on a cable with less sag, one needs to put more tension in the cable.

The Laplace's law dictates that wall stress in spherical coordinates is half of the stress in cylindrical systems and, as a result, all vessels under stress will naturally seek a new spherical set point. This can be considered the most valid explanation of most, if not all aneurysms taking the spherical shape. However, there are others which are not quite the shape of a sphere, which can be considered a manipulative change in the tension inside the aneurysm causing it to take different shapes. The only possible limitation of this explanation lies in its idealism. The laws hold true in an ideal condition, and human body nevertheless is any close to it.

Using the same laws and CFD studies, the characteristic of the site of bleb hemodynamics prior to an aneurysm rupture are: (1) concentrated inflow jet, (2) small impaction zone on the body (side wall) of the aneurysm, (3) elevated WSS, and (4) asymmetric flow division from the parent artery.

The need at the moment is a proper combination of an out-of-the-box thinking and correlation with other sciences in order to gain an even better understanding and explanation of this complexity.

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