Cerebral aneurysms and mathematical modeling: clinical and biological applications

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Abstract

Saccular cerebral aneurysms are focal bulgings of cerebral arteries whose prevalence is estimated to be around 5% of the general population. The main concern with cerebral aneurysms is that they are prone to rupture, which is frequently a catastrophic event, often resulting in death or severe disability, with a minority of patients ever returning to the previous clinical status. A frequent matter of dispute involves the natural history of incidentally diagnosed aneurysms and the decisions to undertake once the diagnosis is made.[1] With the widespread availability of diagnostic brain imaging, more and more aneurysms are being diagnosed each year on asymptomatic patients, raising the issue to the level of a public health question. The main interrogation is related to how many and which of these aneurysms should be treated; all the available treatment modalities, whether by surgical or endovascular techniques, involve significant risks (both have associated morbidity/mortality) and this group of patients is mostly neurologically intact and has no symptoms, making the need to have decision tools evident. Presently, the treatment algorithm has relied on the presence of risk factors for rupture, on the perceived treatment-associated risk (varies according to the center expertise) and on the data of the main prospective randomized study available, which is the ISUIA study. There is a pressing need for decision tools that take into account both mechanical, geometrical and biological factors (as well as their interplay), allowing us to predict the long-term evolution of the aneurysm and restricting treatment for those cases where it is indispensable.[2]

In this presentation, we give an account of the potential usefulness of mathematical applications in the clinical setting, when dealing with brain aneurysms. We will focus on the possibility of using results of computational fluid dynamics as predictive tools [3], but also as a tool to unravel the phenomena of mechanobiological response of vascular wall cells to mechanical stress. Certain hemodynamic stresses (such as elevated wall shear stress) may trigger physiologic vascular remodeling as an adaptive process; somewhere along this process, this response becomes maladaptative and the aneurysmal dilation ensues. If exaggerated hemodynamic stress is deleterious, we now know that cells, especially

endothelial, require a basal amount of such stress in order to exhibit an anti-thrombotic and anti-atherogenic phenotype. We hope to approach in the near future the study of this interplay by using real aneurysmal tissue in which phenomena such as extracelullar matrix degradation, endothelial disfunction, apoptosis and immunoinflammatory response can be measured and correlated to mathematical models of blood flow and rheology.[4].

Keywords: Cerebral aneurysms, mechanotransduction, CFD and medical imaging.

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