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Editorial

Predicting the behavior of cerebral aneurysms, a different approach is necessary

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Cerebral aneurysms are complex and understanding their behavior is important to effectively manage the patients afflicted with them. Moreover, given that reductionist (linear) approach has provided limited benefits, a nonlinear approach is necessary to study cerebral aneurysms. Such approach requires an intense data collection effort and advanced computation (e.g., deep learning).

The cerebrovascular system is a complex biological system. It is influenced by several factors (e.g., genetic profile, hemodynamics, and hormones) that interact among themselves and with the environment. As a result, the pathogenesis of any cerebrovascular disease (e.g., cerebral aneurysms) is a complex process. For example, the interaction between the blood flow and the endothelial mechanosensitive molecules (e.g., integrins) plays a major role in the development and progression of cerebral aneurysms. This interaction controls inflammatory responses within the vessel wall and results in structural changes to the cerebral vasculature. Moreover, the dynamic interaction between the environment and human body affects the system as well. These interactions are continuous and evolve over time, which means that the status of the system is continuously changing.

Despite multiple efforts, not much progress has been made to accurately predict the occurrence, formation, and rupture susceptibility of cerebral aneurysms. We attribute that to the use of reductive (linear) approach in studying these processes, such as studying one or limited number of factors to predict the behavior of a complex system. Other scientific disciplines were successful in using complex systems approach to study biological systems.[2,3]

Gross *et al.* developed a rule-based model that they used to predict the behavior of a complex signaling network. They used the model to study the Wnt signal transduction network which has a multitude of functions in several organisms. Specifically, they evaluated whether the Wnt signal is transduced at the level of phosphorylation of β-catenin or at the level ubiquitination. The authors compared their results to those obtained using a well-studied and validated methods. They concluded that their model was accurate in predicting that Wnt signal transduction occurs through inhibition of β-catenin phosphorylation.[2]

Machine learning is a computer science field, in which computers are programmed to recognize data patterns. The process entails the use of a set of mathematical rules and statistical assumptions to develop predictive models that can predict a range of outputs.

The use of machine learning is increasing exponentially in biology. A key advantage is that machine-learning methods can examine large volumes of data to detect patterns that would be missed otherwise.[1]

A complex system approach is necessary to accurately predict the behavior of cerebral aneurysms. Below is an overview of the necessary steps to implement such approach:

1. Identify the components of the system (e.g., cerebral flow dynamics, genetic profile, inflammation of the aneurysm wall, hormonal factors, and others)
2. Collect longitudinal data for each component
3. Create a mathematical model that integrates the system's components and their interaction
4. Create a deep learning algorithm based on the mathematical model
5. Run several rounds of simulation to assess the validity of the model and modify it accordingly
6. Initially, the model can be validated against historical data
7. Further validation of the model can be performed based on the newly collected data.

The proposed approach is complex and requires intense data collection effort and broad collaboration among clinicians, computer scientists, and biologists. Moreover, this approach needs access to advanced technology (e.g., artificial intelligence). The needed resources can potentially prevent or slow down the implementation of the proposed approach. Therefore, obtaining the support of a large funding agency such as the National institute of health (NIH) could prove helpful. A complex system approach can result in a significant shift in our understanding of the behavior of cerebral aneurysms and other disease processes and can potentially alter the existing treatment paradigms. Moreover, in the age of enormous biological data, machine learning can be instrumental in generating predictive patterns in complex biological system.

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