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Review Article

A methodological review of data mining techniques in predictive medicine: An application in hemodynamic prediction for abdominal aortic aneurysm disease

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ABSTRACT

Modern clinics and hospitals need accurate real-time prediction tools. This paper reviews the importance and present trends of data mining methodologies in predictive medicine by focusing on hemodynamic predictions in abdominal aortic aneurysm (AAA). It also provides potential data mining working frameworks for hemodynamic predictions in AAA. These frameworks either allow the coupling between a typical computational modeling simulation and various data mining techniques, using the existing medical datasets of real-patient and mining it directly using various data mining techniques or implementing visual data mining approach to already available computed results of various hemodynamic features within the AAA models. These approaches allow the possibility of statistically predicting rupture potentials of aneurismal patients and ideally provide an alternate solution for substituting tedious and time-consuming computational modeling. Prediction trends of patient-specific aneurismal conditions via mining huge volume of medical data can also speed up the decision making process in real life medicine.

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1. Introduction

Aneurysms are abnormal swelling of any blood vessel. It is caused by the weakening of the vessel wall that ultimately results in morphological changes in the blood vessel. This morphological change generally takes the form of an abnormal bulge. According to the International Society for Cardiovascular Surgery, aneurysms are irreversible dilatations of an artery that experiences at least 50% rise in diameter as compared to a normal and healthy artery diameter [1].

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Apart from cystic medial degeneration and arteriosclerosis, malfunction of the aorta (biomechanical failure), genetic disorder, and mycotic infections can also contribute to the development of aneurysm. Besides these factors, natural aging due to reduction in elastin within the aortic wall can lead to stiffer vessel walls and subsequently causes the vessel to dilate [2].

Abdominal aortic aneurysm (AAA) is the weakening of the infrarenal abdominal aorta. It occurs between the renal bifurcation and the iliac branches. AAA can rupture if not treated on time. The rupture potential is often correlated to its size. Small AAAs (i.e. diameter <4 cm), medium sized AAAs (i.e. diameter between 4 cm and 5 cm) and large AAAs (i.e. diameter >5 cm) have potential rupture risks about 2%, 0.5% and 5–10% per year, respectively and subsequently may result in fatality [3]. About 9% of the population above 65 years old is affected by this pathologic condition. This may lead to rupture if remained untreated [4]. AAA size and expansion rate are parameters commonly linked with its risk of rupture [5].

The lack of precise rupture risk index makes the decision for surgery complicated. Historical clinical studies indicate that the peak transverse diameter (PTD) is commonly applied. Surgical intervention is proposed for PTD exceeding 5 cm. Contrary, small AAAs (i.e. PTD < 5 cm) rupture as well. In view of this, a non-invasive methodology to understand the rupture potentials of AAAs is needed.

To date, peak wall shear stress (WSS) values are referred as a benchmark value to determine the rupture potentials of AAAs [6]. The key challenge in this case is to identify critical WSS value limits as well as its yield stresses in various individuals. This is mainly due to the lack of *in vitro* measurements in AAA patients. As a result of this, the alternate approach would be to introduce *in vivo* methods such as computational simulation methodologies that involve structural analysis to aid in WSS simulations. A few examples of these computational tools are FIDAP, ABAQUS, ANSYS, ADINA, etc.

Biomechanical analysis that evaluates the level of stresses experienced by the arterial wall would prove to be a suitable option in assessing rupture potentials in AAAs. As a result of blood flow inside the artery, the inner walls of the artery experience stresses. These stresses are the consequences of both normal and shear forces generated by the flow of blood. Having the values of hemodynamic factors such as blood pressure, velocity, wall shear stress, residence time and impingement flow is valuable for understanding the formation and rupture of pathological changes on blood vessels and in the outcome of their endovascular and surgical treatment. There is a growing trend to practice minimally invasive endovascular procedures in measuring these valuable hemodynamic variables [7].

One famous way in obtaining these hemodynamic factors is through computational modeling. Computational methods have been vastly applied to study various complex systems of the human body [8–12]. A great deal of these studies involved understanding the characteristics of blood flows dynamics in the human arteries [13–17]. The behavioral prediction of AAAs has been successfully studied by biomedical engineers and research scientists by best applying the features of computational modeling techniques. These techniques have dramatically improved the ability of medical doctors and clinicians to design multi-level treatment plans based on patient specific cases. In addition to this, these techniques allow the clinicians to identify potential aneurysm initialization and development zones via monitoring WSS levels along the arterial walls.

A typical computational modeling study generates aneurismal hemodynamic characteristics such as blood velocity, temperature and flow-induced stresses and pressure values within an AAA model. Optimization techniques via parametric and initial boundary condition variations of the AAA model allow researchers to understand blood flow patterns and/or thermal distributions. Application of computational modeling techniques in biomedical engineering has grown from its infancy status to a well-established and accepted method today in helping predict and solve various medical-related diseases such as AAAs.

2. The need for methodological shift in predictive medicine

Although computational modeling techniques are noninvasive, display results of high levels of accuracy and more informative, adaptive as well as interactive compared to *in vitro* techniques, they do have some drawbacks. It requires a tedious approach of mathematical formulation and followed by huge computational efforts. Besides that, model preparations also involve time consuming efforts. In order to minimize computational run-time, certain assumptions have to be made in order to simplify the governing equations and hence expose a certain uncertainty in the results generated. Today, in order to run simulation models faster, parallel computing is introduced but its cost of operation can be expensive.

AAA is a complex chronic disease. Apart from its complexity in terms of its morphological characteristics, AAAs' pathological characteristics tend to be nonlinear as well. The wide range of variations between these two characteristics demands more accurate information for predicting its initialization, development and subsequent rupture potentials. The accuracy of decision making depends on the amount of information available. However, the drawback of having a large amount of information is that at one point of time it becomes apparent that extraction of these information, particularly, relevant information becomes a daunting task. As a result of this, the reliability of the clustering process becomes questionable.

In view of the level of tediousness of the computational modeling process as well as the complexity of the AAA disease, a logical approach to further enhance the understanding of AAA formation, development and rupture potential, is by assessing the disease statistically. The fundamental principle of the statistical approach is logic that arises from theories relating to complex biological systems. If viewed from this point of view, computer science is taking over this role from physicists and mathematicians. The marriage between computer science and medicine will enable the invention of intelligent tools that are capable of adapting dynamically on

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