Guidewires and catheters are used during minimally invasive interventional procedures to traverse in vascular system and access the desired position. Computer models are increasingly being used to predict the behavior of these instruments. This information can be used to choose the right instrument for each case and increase the success rate of the procedure. Moreover, a designer can test the performance of instruments before the manufacturing phase.”


Abstract:

Guidewires and catheters are used during minimally invasive interventional procedures to traverse in vascular system and access the desired position. Computer models are increasingly being used to predict the behavior of these instruments. This information can be used to choose the right instrument for each case and increase the success rate of the procedure. Moreover, a designer can test the performance of instruments before the manufacturing phase. A precise model of the instrument is also useful for a training simulator. Therefore, to identify the strengths and weaknesses of different approaches used to model guidewires and catheters, a literature review of the existing techniques has been performed. The literature search was carried out in Google Scholar and Web of Science and limited to English for the period 1960 to 2017.
For a computer model to be used in practice, it should be sufficiently realistic and, for some applications, real time. Therefore, we compared different modeling techniques with regard to these requirements, and the purposes of these models are reviewed. Important factors that influence the interaction between the instruments and the vascular wall are discussed. Finally, different ways used to evaluate and validate the models are described. We classified the developed models based on their formulation into finite-element method (FEM), mass-spring model (MSM), and rigid multibody links. Despite its numerical stability, FEM requires a very high computational effort. On the other hand, MSM is faster but there is a risk of numerical instability. The rigid multibody links method has a simple structure and is easy to implement. However, as the length of the instrument is increased, the model becomes slower. For the level of realism of the simulation, friction and collision were incorporated as the most influential forces applied to the instrument during the propagation within a vascular system. To evaluate the accuracy, most of the studies compared the simulation results with the outcome of physical experiments on a variety of phantom models, and only a limited number of studies have done face validity. Although a subset of the validated models is considered to be sufficiently accurate for the specific task for which they were developed and, therefore, are already being used in practice, these models are still under an ongoing development for improvement. Realism and computation time are two important requirements in catheter and guidewire modeling; however, the reviewed studies made a trade-off depending on the purpose of their model. Moreover, due to the complexity of the interaction with the vascular system, some assumptions have been made regarding the properties of both instruments and vascular system. Some validation studies have been reported but without a consistent experimental methodology.

Reference:

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