STEVENS INSTITUTE OF TECHNOLOGY 1870

Ph.D. DISSERATION DEFENSE

Candidate:	**Yang Xu**
Degree:	Doctor of Philosophy
Department/School:	Mechanical Engineering, Schaefer School of Engineering & Science
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Time/Location:	2:00~4:30pm, Zoom link: https://stevens.zoom.us/j/98617043803?from=addon
Title:	Contact Forces of Guidewire on Vascular Artery Considering its Physical and Mechanical Properties
Chairperson: Prof.	**Yong Shi, Department of Mechanical Engineering**
Committee Members:	Sundeep Mangla, Neurointerventional Medicine, PLLC Johannes Weickenmeier, Department of Mechanical Engineering Long Wang, Department of Mechanical Engineering Xiaojun Yu, Department of Biomedical Engineering

ABSTRACT

Studies investigating the contact force between a guidewire and the vascular artery are crucial for enhancing the efficiency and safety of robotic-assisted neurointervention. Due to the high flexibility and small cross-section of the guidewire, coupled with the complex contact process with the vascular surface, estimating the contact force presents numerous challenges.

The research objective of this work is to investigate the contact force between a guidewire and the vascular surface by considering the deformation of the vascular wall, topography and adhesion of the vascular surface, and the compliance of the guidewire. Both analytical analysis and experimental measurement or validation were used to achieve the objective. Initially, the sizes of the micro-asperities on the vascular surface were measured using Optical Coherence Tomography (OCT) and Atomic Force Microscopy (AFM). The height distribution of asperities was fitted with a Gaussian function. The mechanical properties of the vascular surface were measured using AFM.

An improved contact mechanics model was developed to predict the adhesive contact force between the guidewire tip and the vascular artery. This model utilizes a dual-spring system to represent the asperity and vascular substrate. The asperity spring model was derived from an approximation of the Johnson-Kendall-Roberts (JKR) model, while the vascular artery spring model was based on Hertzian stress distribution. The guidewire tip was assumed to be a rigid sphere. The model's validity was confirmed through indentation tests in both air and Phosphate Buffered Saline (PBS), demonstrating high precision when the indentation strain is less than 10%. Compared with classic contact models like the Hertzian and JKR models, the proposed model showed more accurate contact force prediction by accounting for the height distribution of asperities. On the other hand, the proposed model was also more accurate due to accounting for vascular wall deformation compared with multi-asperity contact models like the Fuller-Tabor (FT) model.

In the second part of this work, the compliance of the guidewire was taken into consideration. The guidewire was assumed to be a deformable cantilever in 2D space. The contact forces applied on the guidewire were assumed to be point loads. The physical and mechanical properties of the vascular artery were neglected in this model. By utilizing the curvature changes of the guidewire, the contact force applied on it can be estimated. The contact points can also be determined through the local maximum of the second derivatives of the curvature distribution curve. By analyzing the

curvature between contact points, the magnitudes and directions of the contact forces can be calculated. An experiment was conducted to validate the method. The error between the actual and estimated forces at most contact points is approximately 10%. Additionally, the relative error between the actual and estimated locations of contact points is about 6%. A shape-based force estimation method was derived based on this research. Compared with other shape-based force estimation methods, the proposed method has higher computational efficiency. since it does not require segmentation of the guidewire for modelling purposes. The developed contact force model has significantly improved our understanding of the interaction between guidewire and vascular artery and would minimize the risk during such operations performed by either medical robots or surgeons.