2015 ELyT lab Workshop

Matsushima, Japan
February 18-21, 2014

Introduction of Three Strut Optimization Strategies towards the Design of Efficient Flow-Diverter Stents

Project ELyT lab : Poster Session

	*Mingzi Zhang Graduate School of Engineering, Tohoku University Sendai, Japan*		*Hitomi Anzai, FRIS, Tohoku University Sendai, Japan*		*Makoto Ohta Institute of Fluid Science, Tohoku University, 2-1-1 Katahira, Aoba-ku Sendai, Japan*

Abstract:

1. Introduction

Intracranial aneurysm is a cerebrovascular defect of localized bulge in the wall of a blood vessel. Without treatment, it may result in subarachnoid hemorrhage (SAH) due to rupture, and severely disrupt the quality of patient's life. Flow diverter (FD) implantation, as an emerging endovascular treatment, intends to block intra-aneurysmal inflow and induce thrombotic occlusion by implanting a stent into the parent artery, eventually leading to the local hemodynamic rehabilitation. In our previous study, by using the combination of Lattice Boltzmann Simulation (LBS) and Simulated Annealing Procedure (SAP), a two dimensional plane with discretized stent struts was implemented to explore the factors that lead to an efficient FD structure design.

In order to stretch our previous optimization work to a general practical stage, we presented three FD strut definition methods and their corresponding random modification strategies in this abstract to enable the two to possibly meet the manufacture requirements. We consider the basic rule for a practical and manufacturable stent design is the connectivity of stent struts. Thus all the cases presented have connected strut structures and the continuity cannot be damaged by random modification.

2. Method

2.1 Random Strut Alteration

This method was designed based on the sub-domain of a 2D strut plane. We assumed that the strut domain was a flat, which was comprised of several same shape sub-domains and fully covered the aneurysm neck. By arranging the strut shape in one sub-domain, we can get the stent structure by duplicating the sub-domain into the whole neck plane according to a pre-defined logic. During the random modification process, one strut was randomly selected and then altered from its original position to an empty position (as depicted in Fig. 1) according to a procedure as shown in Fig. 1, which resulted in a slight alteration of the whole stent structure.

2.2 Random Route Generation

Based on the previously described 2D strut sub-domain and duplicating logic, we generated the strut structure by defining a method to randomly create the strut trajectory. In this method, we firstly randomly selected three points inside the sub-domain; then create the shortest route from the one corner to its opposite corner via the three points (refer to Fig. 2); finally, overstrike the route by filling struts into the trajectory's positions' neighbors and maintain the stent's original porosity.

2.3 Strut generation based on Bezier Curves

This method is an improvement for the route random generation. In this method, the route of the strut structure was controlled by control points of Bezier Curve equation. After randomly selecting the control points (P1, P2, and P3), a trajectory equation passing through the start point (P0) and end point (P4) could be generated (refer to Fig. 3). Then we discretized the continuous function into connected strut coordinates.

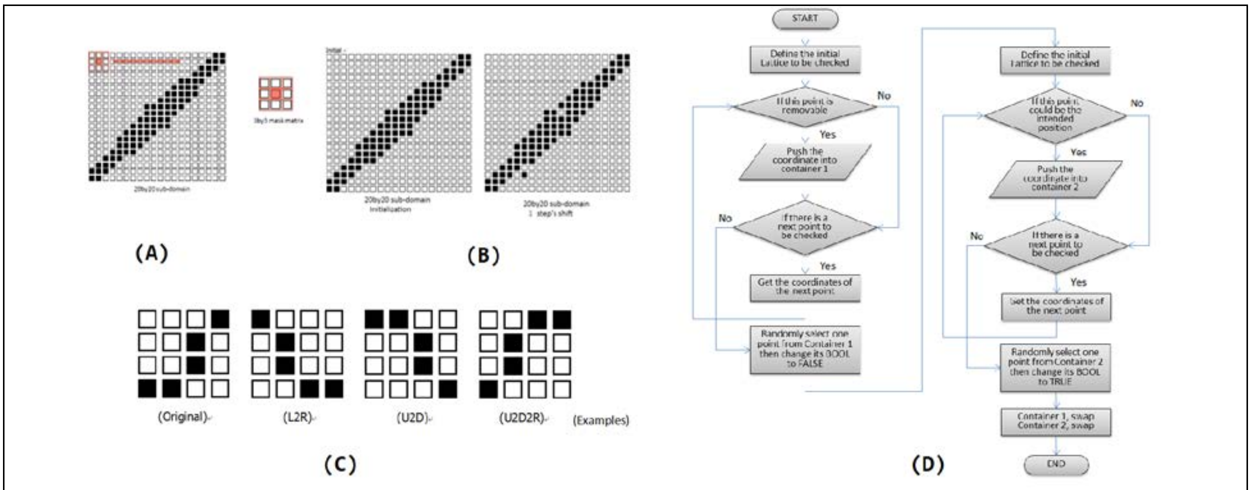

Fig. 1 Schematic of random strut alteration. (A) Initial Sub-domain and scanning direction; (B) The sub-domain before and after random alteration; (C) Duplicating logic; (D) Strut and Position detecting logic

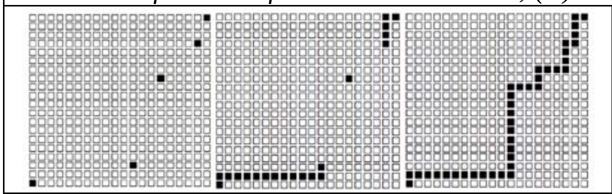

Fig. 2 Example of Random Route generation

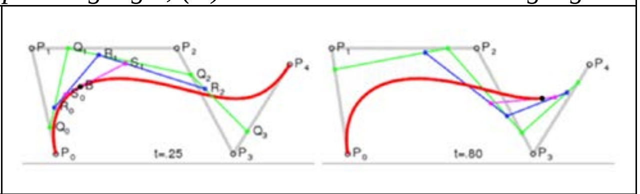

Fig. 3 Schematic of Bezier Curve generation

3. Preliminary Results

All the methods listed above can be blended with our previous developed optimization strategy. The random strut alteration method has been preliminarily tested. After 300 steps' random modification, an optimized structure with Intra-aneurysmal average (IAA) flow of 0.000637 m/s was achieved. Compared to the initial structure (IAA=0.001135 m/s), the flow reduction (FR) rate experienced a dramatic increase of 20.88%. (FR=73.29% for initial structure; FR=52.41% for optimized structure)

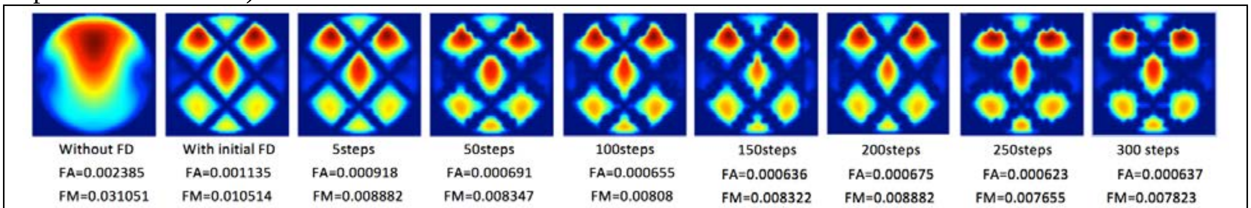

Fig. 4 Preliminary results of velocity contour after 300 steps' random strut alteration

4. Conclusion

This study presented three methods of stent struts modification which can be potentially applied to the optimization design of advanced FD devices. Each method was able to randomly alter the strut structure and keep the device porosity at the meantime.

Acknowledgements:

This study was supported by the MEXT, Grant-in Aid for Scientific Research (B), 2013-2015 (25282140, Makoto Ohta) and was partly supported by the JSPS Core-to-Core Program, A. Advanced Research Networks, International research core on smart layered materials and structures for energy saving".