課題番号（Project number）７４

Interactive analysis of arterial stent and artificial hemodynamic reconstruction between CFD and animal experiments

［1］組織（Research group）
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（（注）以下，分担者全員を記載する。）

研究費(Expenditure report of research funds)：
物件費 400000YEN

［2］研究経過（Research setup）

Purpose: The process of designing new aortic stenting procedure is to be related to local blood flow circulation as well as the biological evaluation. In this project, we examined the flow distribution in the lesion of the aorta or arteries by CFD analysis based on the animal experimental hemodynamic examination. Arterial wall stresses caused by the interaction of the stent with the flow structure in the vicinity of aneurysm lesion of arteries and possibly stress induced stent strut structure might be two important parameters for the optimal design for the stents. The basic knowledge of these parameters after stent deployment in the subjects derived and modelled by arteries might give insights in the recognition of biomedical parameters of the optimal control of stent deployment and in the understanding of the feasibility of these stent procedures in each patient.

Methods: In the project, we established a new collaborative platform for the biomedical analysis in between the animal or human hemodynamics and the numerical investigations. The research plan of the project was as follows:

Animal experimental procedures (at IDAC):
- Aortic dissection reproduction in descending aorta using goats (IDAC, Yasuyuki Shiraishi, Tomoyuki Yambe)
- Stent delivery and deployment in the lesion of the aorta in the animal experiments as well as in the mechanical circulatory model systems

Computational fluid dynamics processing (at Macquarie, partly in IDAC):
- Numerical reproduction of false and true lumens in the goat's dissected aorta
- Blood velocity mapping in the vascular cavities
- Shear stress distribution in the false lumen and the flow recovery after the stent deployment
- Feasibility studies associated with the CFD results and clinical investigations for the elimination of risks related with the stenting procedures and results integration for preclinical requirements using animal hemodynamics and CFD (Macquarie/IDAC)

For the feasibility of the animal data and CFD analyses, we focused on the two specific topics: a) computer simulation of virtual stent deployment, and b) haemodynamic simulation for cerebrovascular stent using the method of modelling the flow-diverting stent as a porous

medium.

In FY2016, we performed animal experiments for the 3-D reconstruction of aortic aneurysms in goats in IDAC. All the animal experimental procedures were allowed by the Institutional Animal Experimental Committee in Tohoku University (2016-AcA-034).

For the discussion of the assessment and progress of the project, the meetings were set on:

- 26th April, 2016
- 10th September, 2016
- 9th November, 2016
- 24th February, 2017

Project summary assembly has been conducted on 4th May, 2017.

［3］成果（Research outcomes）

（3－1）研究成果（Results）

1) Reproduction of the aortic aneurysms for the analysis of stent deployment

A new aortic stent had been designed, and its characteristics of deploying in the aorta could be tested in the aortic dissected aneurysm model using goats. Prior to the hemodynamic tests of stents, we made an exfoliation in the aortic wall to separate lumens into true and false ones. Consequently, we performed an installation and deployment test with the stents with aortic aneurysms which could represent a flow separation and vortex in the false lumen.

2) Computer simulation of virtual stent deployment

Flow-diverting (FD) compaction is a newly developed method to improve the wire density across the aneurysm neck, thereby promoting the clotting inside the aneurysm with less flow entering the aneurysm dome. Nonetheless, how much difference in the aneurysmal haemodynamics influenced by the alteration of FD stent compaction level remains unclear. Therefore, we seek to obtain the changes in aneurysmal haemodynamics when virtual FD stents in difference device diameters deployed at various compaction levels. In this study, we virtually deployed FD stents with three device sizes, at four compaction level with each case into two patient-specific aneurysms. With the simulation results, we discussed haemodynamic parameters like velocity, mass flow rate, energy loss and flow pattern. We found significant information about metal coverage rate in aneurysms with different morphology.

3) Haemodynamic Simulation for Cerebrovascular Stent using the Method of Modelling the Flow-Diverting Stent as a Porous Medium

Using porous medium as a computational model of the real flow diverting stent geometry in computational fluid dynamics (CFD) improves the simulation efficiency. Adjustment of simulated permeability level of the porous medium will result in various projected flow resistance force, which impact flow dynamics around and inside the aneurysm dome. Diversity in patient-specific aneurysm geometry and flow diverting stent property also contribute to the difference in both the resistance force and the aneurysmal haemodynamics. However, few studies have discussed the relationship between the setting of permeability and the intra-aneurysmal haemodynamics. As a result, we provided future porous-medium stent simulations with information on the parametric sensitivities, by altering the permeability and initial resistance factor of the porous medium model.

（３－２）波及効果と発展性など（Future perspectives）

The joint research project in the preclinical studies had started based on the collaboration between the Faculty of Medicine, Macquarie University, and the IDAC. The academic exchange program between the institutes has been expanded to the program between the universities. As for this research project, the international cooperation for quantitative analyses in preclinical research will be implemented to support the new standardization of surgical approaches on establishing the common standards worldwide.

［4］成果資料（List of Papers）

Mingzi Zhang, et al. Which stent diameter and compaction ratio would benefit the patient the most?, Proc. Medical Engineering & Preclinical Studies, Vol.2, 8-9, Nov, 2016.