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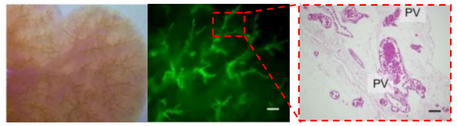
Prediction of vessel occlusion during recellularization using a computational fluid dynamics model

V.L. NGUYEN[1] **and H. OBARA**[1]
1Tokyo Metropolitan University, Tokyo, Japan

TOKYO METROPOLITAN UNIVERSITY

INTRODUCTION

To address the organ shortage crisis, a promising approach is to generate transplantable organs through decellularization and recellularization. In this approach, a human – sized organ is removed its cells (decellularization) and then reseed by patients' cells (recellularization) to generate a functional organ. To ensure the functions of the generated organ, a high uniformity of cell distribution is required. However, it is challenging to achieve a uniform distribution of cells.



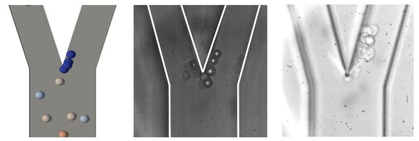
Cells stays inside portal after recellularization [1]

AIM

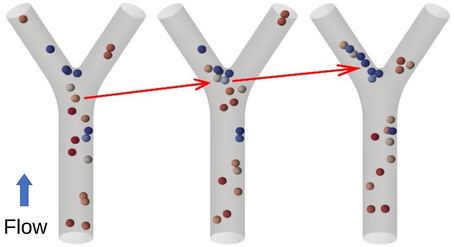
We aimed to quantify the occurrence of vessel occlusion during recellularization under different seeding conditions.

RESULTS

The occlusion process

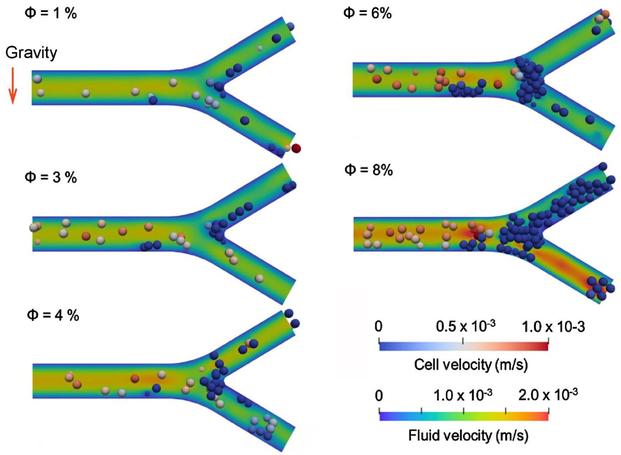


Cells that adhered around the apex of bifurcation trigger the occurrence of vessel occlusion.



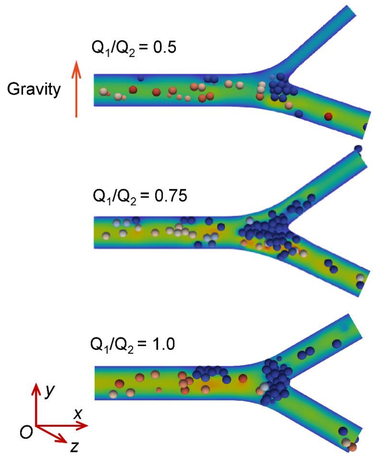
The formation of cell aggregates through the interactions between moving cells and wall or immobile cells [2].

The influence of seeding cell concentration



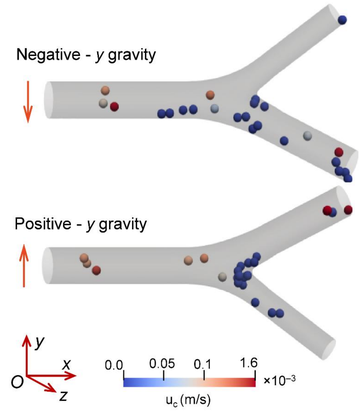
Vessel occlusion occurred as the cell concentration was above 4%.

The influence of branching patterns



The symmetric bifurcation resulted in early occlusion (Q_1/Q_2 = 1.0).

The influence of gravitational direction



As the ratio of Q_1/Q_2 = 0.5, under gravitational effect cells can be pushed to the lower flow rate branch.

METHOD

- A combined model that coupled computational fluid dynamics (CFD) and discrete element method (DEM) was employed to describe the vessel occlusion phenomenon.
- Cells were, presented as discrete phase, solved by DEM solver; and the culture medium was, modelled as fluid phase, solved by CFD solver.
- A vascular segment of blood vessel with different branching patterns was employed for the simulation model. (Fig. 1)
- Suspension of hepatocytes was modelled as cell suspension.

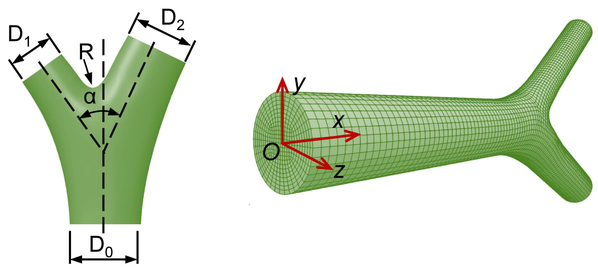


Figure 1. Structural parameters and illustrations of the bifurcation region with different ratios of D_1/D_2

CONCLUSIONS

In this study, the computational fluid dynamic model indicates different scenarios leading to the non – unform distribution of cells, where the bifurcating pattern of vessels plays is an important parameter. This computational model can be used to evaluate recellularization conditions for enhancing the distribution of cells.

ACKNOWLEDGEMENT

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Nguyen, V.L., Obara, H. Investigation of vessel occlusion during cell seeding process. Biomech Model Mechanobiol 20, 2437–2450 (2021).

CONTACT INFORMATION

Nguyen Van Lap
Tokyo Metropolitan University
Email: nguyen-van-lap@ed.tmu.ac.jp