MODELLING LYMPH PROPULSION IN A 3D RECONSTRUCTED MURINE COLLECTING VESSEL

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1. INTRODUCTION

The lymphatic system transports the excess fluid from the interstitium and ultimately returns it to the venous circulation against an adverse pressure gradient and gravitational force. The spontaneous contractions of lymphangions (i.e. the building blocks of collecting vessels) and unidirectional valves play key roles in lymphatic propulsion [1]. Currently, higher dimensional models of lymphatic transport are scarce. Furthermore, the morphology of the lymphatic system has proven to be very difficult to capture. In this study, we aim to investigate and model lymph propulsion in a collecting vessel with contracting lymphangions in a 3D reconstruction of collecting lymphatics from the hind limb of mice. We then performed a parametric study to better understand the factors impacting lymph propulsion.

2. MATERIALS AND METHODS

First, ex-vivo animal experiments were performed to collect morphological information from the collecting lymphatic vessels which were approved by the ethical committee of the faculty of medicine and health sciences of Ghent University Hospital and were conducted with respect to the animal welfare. A total of 18 C57BL/6 mice were sacrificed. The mice were imaged by high resolution µ-CT scans after interstitial contrast injection. The images, with a resolution of 40 µm, were then 3D reconstructed using Mimics (®Materialise, Leuven, Belgium). The 3D computational model was further developed and computed using COMSOL Multiphysics®. Computational methods were used to study the behavior of flow within the collecting vessel, the deforming vessel wall, and the poroelastic interstitium (Figure 1a). The four valves were modelled as porous media and the vessel wall as linear elastic material. The total length of the vessel was 1.83 mm with maximum and minimum diameters of 130 µm and 50 µm, respectively. Lymphangion contractions were implemented as boundary loads and the porous unidirectional valves by a transvalvular pressure dependent permeability function.

3. RESULTS AND DISCUSSION

Figure 1b shows the deformations of the collecting vessel wall as the result of lymphangion contractions. Figure 1c shows a representative pressure-volume (P-V) loop of lymphangion 1, as well as the definition of some significant points throughout its contraction cycle.

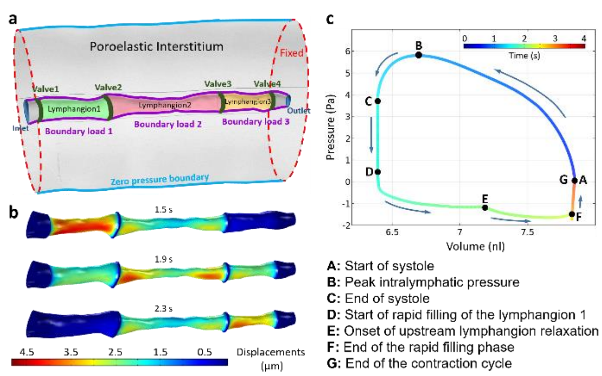

Figure 1: The different domains and boundary conditions of the model, (a), the deformation contours of the vessel wall, (b), and the P-V loop of lymphangion 1, (c).

The parametric study proved the significant impact of the maximum valve permeability and the elastic modulus of the interstitium on the accumulated volume propelled by the collecting vessel. Very high values of permeability as well as increased interstitial elastic modulus drastically reduced the conveyed volume.

References

[1] Reddy, N.P., Krouskop, T.A. and Newell Jr, P.H., 1975. Microvascular research, 10(2), pp.214-216.