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Abstract

Hydrogel vascular models for investigating vessel wall motion

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Vessel wall stiffening is a clinically significant parameter in many pathologies, serving as both an adjustable target for disease prevention and a marker of treatment outcomes. Reliable assessment of arterial stiffness is crucial for patient welfare. One promising method for determining vascular stiffness is through the study of vessel wall motion; however, such methods have not yet been fully validated. Elastic vascular models can facilitate the development and optimization of these methods under standardized conditions, though they are not yet widely established. The goal of this work was to develop a fabrication method for elastic vascular models based on hydrogel, utilizing casting and 3D printing techniques. First a straight vessel model was designed and fabricated to demonstrate and test the proposed approach. For this a casting mold was designed (Inventor, Autodesk) and 3D-printed with water-resistant material (Form 3, Formlabs). The casting mold consists of three parts, two outer parts encase an inner lumen in the shape of a cylinder with a diameter of 6 mm. The gap between the inner lumen and the outer parts of the mold is in the shape of a hollow cylinder. The inner lumen was designed in a way that it could be inserted into the outer parts such that the bottom of the mold was closed. To create the hydrogel model, a $1\ wt\%$ sodium alginate solution was poured into the assembled mold from the top opening. Once the inner part of the casting mold was filled, a $200\ mM\ CaCl_2$ solution was added on top of it to facilitate the solidification process [1]. After 24 hours once the hydrogel stabilizes, the vessel mold was opened revealing the soft hydrogel structure, the vessel lumen was removed from the hydrogel vessel by pulling it out. Two different wall thicknesses, 0.75 mm and 1.5 mm were tested. Both vessel models exhibited wall pulsations in response to a pulsatile flow when connected to a pulsatile pump. However, the 1.5 mm wall thickness was more durable in comparison to 0.75 mm vessel. Additionally, a bifurcated vessel model was fabricated employing a dual-printing strategy: the outer structure of the mold was printed with the water-resistant material, while the inner structure with water-soluble filaments (PVA and BVOH, Prusa i3 MK3S+). The soluble inner part was subsequently dissolved, leaving a hollow bifurcated hydrogel structure. To prevent the inner part of the bifurcated vessel model from dissolving during the hydrogel formation, it was coated with a thin water-resistant layer containing nitrocellulose. The developed fabrication protocol demonstrates the potential for these 3D-printing aided hydrogel models to be used in optimizing methods for detecting vascular wall motion.

Author's statement

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This research was conducted without human or animal experiments

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