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Abstract

Hybrid-manufactured silicone vessels

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Surgical and radiological interventions require extensive training, for experienced and inexperienced operators alike. To circumvent the usage of cadavers and preserve the realism, synthetic vessels can be used [1]. For example, polymer molding allows the use of various materials to mimic the mechanical properties of a blood vessel. However, molding restricts the possible vessel geometries due to the necessity to remove the core forming the hollow vessel. 3D-printing allows for greater geometric freedom, but the material choice is limited: materials that are both flexible and transparent are uncommon. However, one material that unifies both characteristics is silicone – however, for hollow models, significant support structures are required. Combining different fabrication methods allows for the combination of the individual advantages and simultaneously overcomes the drawbacks.

In order to represent the inner geometry, a hollow sacrificial core of water-soluble polyvinyl alcohol (PVA) is produced using an Ultimaker 3 3D-printer (Ultimaker, Utrecht, Netherlands). The outer part of the form is produced of a common stiff material like “Clear” using a Form 3B 3D-printer (Formlabs, Somerville, USA). The mold is assembled and filled with a liquid transparent silicone (with a possibility to add dye to mimic the color of a vessel). After the polymerization, the core is dissolved in flowing water. The hollow core increases the contact surface, and thus the dissolving process only takes several hours.

Vasculature relevant for neuroradiological interventions includes the aortic arch, subclavian arteries and carotid arteries, all of which were produced using the method described [2]. The transparent silicone we used for the production allows for the visual observation of the position of a catheter inside the vessel, allowing for the supervision during the training. The realism of the training is increased due to the mechanical properties of the vessel wall as well as the fluid perfusing the vessel.

Our method might be used to produce different anatomical models, not limited to the arterial vasculature. Using different silicones, one can represent different tissues and organs [3]. Combining the silicone with stiff materials, one can also build complex models including bones or bone fragments – for example, for traumatological training.

AUTHOR’S STATEMENT

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