A simple, realistic walled phantom for intravascular and intracardiac applications

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Introduction:

Ultrasound-compatible vascular phantoms are routinely used in clinical tool training, testing of intravascular devices, blood flow studies, and validation of algorithms for intravascular and intracardiac surgical systems. They are usually categorized as wall-only phantoms – with a prominent tube-like vessel layer but lack representation of surrounding tissue, and wall-less phantoms which are hollow on the inside and lack a vessel-layer. This work aims to develop a simple, anatomically and haptically realistic vascular phantom, compatible with intravascular and intracardiac ultrasound. The low-cost, dual-layered phantom bridges the gap between traditional wall-only and wall-less phantoms by showing both the vessel wall and surrounding tissue in ultrasound imaging.

Methods:

Polyvinyl alcohol cryogel (PVA-c) incorporating a scattering agent was used to obtain vessel and tissue-mimicking materials. Our specific design targeted the inferior vena cava and renal bifurcations which were modelled using CAD software. A custom mould and container were 3D-printed for shaping the desired vessel wall. Three phantoms were prepared by varying both the concentrations of scattering agent as well as the number of freeze–thaw cycles to which the phantom layers were subjected during the manufacturing process. Each phantom was evaluated using ultrasound imaging using the Foresight™ ICE probe. Geometrical validation was provided by comparing CAD design to a CT scan of the phantom.

Results:

The desired vascular phantom was constructed using 2.5% and 0.05% scattering agent concentration in the vessel and tissue-mimicking layers, respectively. Imaging of the three phantoms showed that increasing the number of freeze–thaw cycles did not significantly enhance the image contrast. Comparison of the US images with their CT equivalents resulted in an average error of 0.9 mm for the lumen diameter.

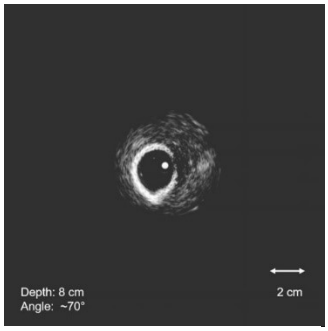

Fig 1 Ultrasound imaging of the third phantom

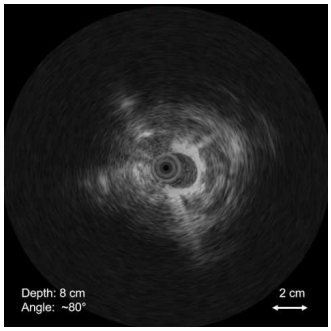

Fig 2 Ultrasound imaging of the animal IVC

Conclusion:

The phantom is anatomically realistic when imaged with intracardiac ultrasound and provides a smooth lumen for the ultrasound probe and catheter to maneuver. The vascular phantom enables validation of intravascular and intracardiac image guidance systems. The simple construction technique also provides a workflow for designing complex, multi-layered arterial phantoms.