Placenta Vasculature 3D Printed Imaging and Teaching Phantoms

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In recent years, the use of three-dimensional (3D) printing has greatly increased in biotechnology, medical science, neuroscience and others due to its capabilities of direct formation of any shapes. [1,2] This has enabled the production of complex anatomical geometries such as patient-specific parts that can be used for teaching, training and surgical planning. [3–5] 3D printing is also of interest for developing ultrasound or optical imaging phantoms. [6,7] In this work, we apply 3D printing technology to create both teaching models and imaging phantoms of the human placenta.

Human placenta is an organ that has a complex vasculature system that passes oxygen and nutrients from the mothers' blood supply to the fetus. For clinical trainees, understanding the anatomy of the placenta is a pre-requisite to properly acquire and read placenta ultrasound images and even more so for trainees aiming at becoming fetal surgeons. 3D models of the placenta could facilitate in teaching while imaging phantoms could be used for procedure training and validation of new imaging modalities. It is particular important for successful treatment of twin-to-twin transfusion syndrome (TTTS) of monochorionic twins. This syndrome is associated with the anastomosing placental vessels that cause a net transfusion of blood between identical twins sharing a placenta and can lead to death one or both fetuses. [8–10]

Ultrasound imaging can provide information about the anatomy and physiology of the placenta. It is safe for both the mother and the embryo. Ultrasound imaging phantoms have proven to be useful for training doctors to perform interventional procedures. Training with realistic phantom provides invaluable experience and confidence before performing the first in-human procedures, and eventually reduces operational time.

In this context we developed two phantoms of human placenta using 3D printing technology: an ultrasound imaging phantom and a teaching model.

The ultrasound phantom was realised using a high-resolution DSLR picture of a full-term healthy human placenta (Fig. 1a). Traces of the artery and venous vessels were created using Inkscape. The final vasculature moulds were designed using FreeCAD computer aided design software and printed by Objet printer (Stratasys, UK) (Fig. 1.b). To address the lifetime limitation of typical Agar-based phantoms observed in previous studies, we used oil-based gel wax. This material proved not to degrade even after 6 months. In order to create a complex vasculature, two 3D printed moulds were filled with gel wax material with red or/and blue colour ink (Fig. 1d).

To evaluated realism in terms of ultrasound imaging, the imaging phantom was inserted in a box that was filled up half-way with water to ensure that the vasculature was in contact with water. Cooling gel was then placed on the exposed side of the placental model and ultrasound images were taken using L14-5 clinical probe (Fig. 1c).

The teaching model was developed by scanning a human placenta donated for research using a 3D scanner (Artec Space Spider, Artec 3D, Luxembourg). The acquired stl file was sent to the printer (Ultimaker, UK). The model is made from PLA and decorated with acrylic paints to highlight the vasculature of human placenta (Fig. 1 e). The phantom was compared to the real placenta.

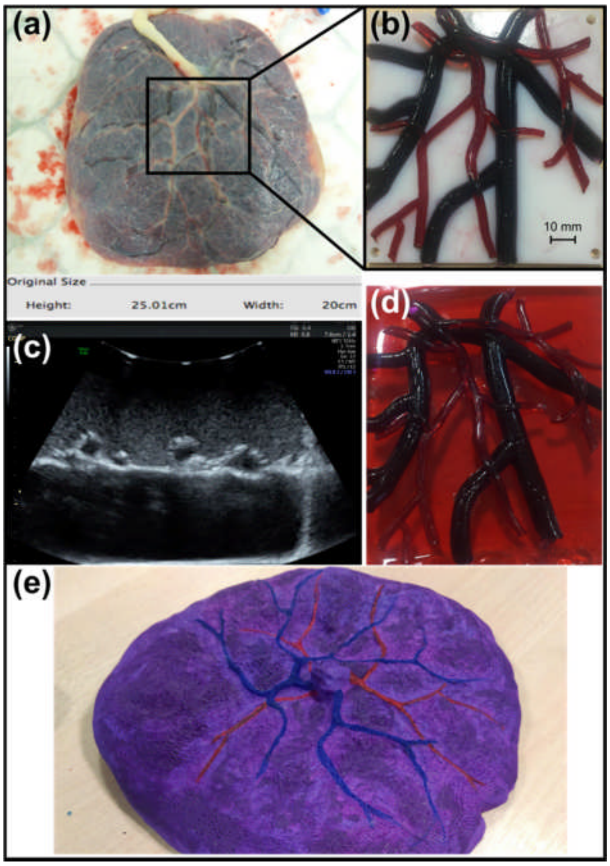

Fig.1 (a) A photograph of human placenta, (b) 3D printed moulds with the gelwax vasculature of human placenta, (c) an ultrasound image of the phantom, (d) the imaging phantom, (e) the teaching model of human placenta.

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Keywords

3D printing, human placenta, ultrasound imaging phantom

Biography

Daniil Nikitichev has earned a PhD degree from University of Dundee (2012) in Laser Physics. The same year he joined the University College London in London, UK. He has been working with a photoacoustic ultrasound system for ex-vivo and in-vivo imaging of the tissues and organs. His research topics include 3D printing, acoustic properties of 3D printed materials, acoustic sensors, photoacoustic imaging, optical and photoacoustic phantoms.