3D printed ultrasound phantoms for clinical training

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Ultrasound is a ubiquitous, portable structural imaging technique used to provide visual feedback for a heterogeneous range of diagnostic and surgical techniques[1]. Preparatory training for these techniques therefore demands a range of teaching models tailored for each application. Existing anatomical models are often overly simple or prohibitively expensive, causing difficulties in obtaining patient or procedure specific models. In this study we present ultrasound phantoms for clinical teaching and training purposes, fabricated by extruding and "photopolymerization" three-dimensional (3D) printing technologies.

3D printing is increasingly used in medicine, neuroscience and biotechnology due to its affordability and the ability to create complex anatomical geometries[2]. 3D printed imaging phantoms have been successfully demonstrated in the past but they were relatively simple[3][4]. In order to create patient-specific models from medical image data, image-processing software is required. In recent years, a number of image-processing methods have been developed that allow the rapid generation of anatomically accurate 3D models from population or patient specific data[5][6]. There is a growing interest in the application of these techniques in a clinical context for the creation of anatomically accurate 3D printed models from medical images for therapeutic, research and teaching applications [7-9].

For this study, clinical partners identified a requirement for practical rib and kidney imaging phantoms for use in surgical teaching and planning of complex cases. We produced a series of high quality 3D printed functional models of selected sets of ribs and a partial kidney model suitable for use in clinical training for ultrasound guided therapy and diagnostics. Clinical partners advised on specific design considerations for these models.

To produce these models, X-Ray CT data were segmented to extract volumes of interest. These segmentations were transferred to MeshMixer software for refinement, before being exported as stereolithography (STL) files for 3D printing software (Figure. 1.a). A rib models was printed in enhanced PLA extruding material using an Ultimaker printer (Ultimaker, UK) while a kidney model was fabricated in digital material (DM9860, Stratasys) using a polyjet Objet printer (Stratasys, UK) (Figure 1.b,c). These models were combined in an ultrasound imaging phantom (Figure 1.c).

The ultrasonic profiles of the imagining phantom were obtained and compared with pre-existing ultrasound images of the areas and organs of interest. These images were used to gauge suitability of the phantom for teaching and surgical planning, and to determine the optimal 3D printing material for use in realistic phantom production. Following review the final model design will be of use to clinicians and educators for medical training purposes as the final STL files can be easily shared between centres. Furthermore, the optimised production technique will be of interest for anyone wishing to design a similar phantom for alternative medical applications.

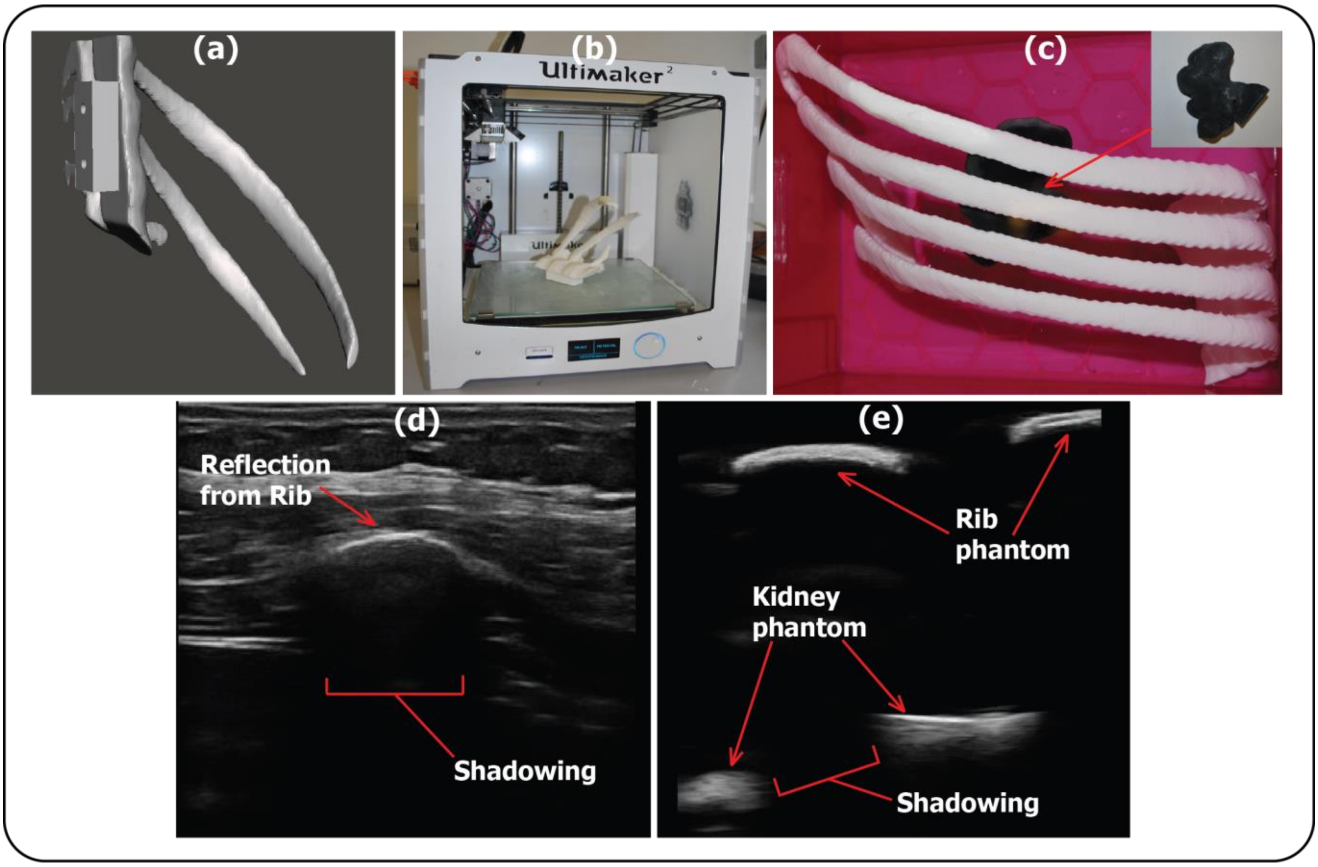

Figure 1. a) Medial view of completed rib mesh in MeshMixer environment following segmentation in Seg3D b) Completed 3D print of Rib model in Polylactic Acid (PLA) on Ultimaker 2 3D printer c) Reduced scaled rib phantom with partial kidney phantom in fluid bath (insert: detail of kidney phantom) d) Ultrasound scan of human rib *in-situ*, with reflection and shadowing from the rib highlighted e) Ultrasound scan of imaging phantom showing shadowing and reflections from rib and kidney phantoms.

Keywords

Ultrasound phantom, clinical training, image processing

Biography

James Robertson obtained an undergraduate degree in Biomedical Science with Medical Physics from University College London in 2013 in part completion of an MBBS in Medicine (on hiatus). He is currently reading for a PhD in Medical Physics at the Biomedical Ultrasound Group of the Dept. of Medical Physics and Biomedical Engineering of UCL, under Dr Bradley Treeby. His research is based on the use of numerical simulation of ultrasound for the transcranial focusing of ultrasonic therapy, and includes the creation and validation of multiple ultrasonic bone phantoms.

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