Ultrasound super-resolution imaging algorithm for a curved array transducer for human kidney imaging

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Background, Motivation, and Objective:

Ultrasound super-resolution (USR) imaging is an emerging technology that can visualize microvessels with unprecedented high spatial resolution compared to conventional ultrasound imaging methods. USR imaging can be a promising diagnostic tool for kidney disease by evaluating the changes of microvasculature. Most previous studies have shown its feasibility of in vivo kidney vasculature imaging on small animal models using high frequency linear array transducers. However, for translating USR into clinical applications on human subjects, a deeper imaging depth, as well as a larger imaging field of view is required. Few studies have been conducted to develop USR technique using a curved array transducer, which is used for kidney imaging in clinics. In this pilot study, we configured the deconvolution-based USR algorithm on a clinical curved array transducer and applied on a healthy human subject.

Statement of Contribution/Methods

Under the IRB approval, a bolus of 2mL microbubbles (Definity) at concentration of 13% was intravenously injected over 10 seconds to the healthy human subject followed by a 10mL saline flush. A clinical curved array probe (C5-2, ATL, centered at 3 MHz) connected to Verasonics Vantage system was used for imaging the entire right kidney in long axis. About thirty seconds after injection, multi-angle (-3°, -1.5°, 0°, 1.5°, 3°) ultrasound plane wave imaging with two cycles per pulse was applied to acquire the raw data of 2000 frames (500 frames/s), while the subject held breath. The raw data were processed with beamforming, rigid body motion compensation, SVD filter, and Richardson-Lucy deconvolution algorithm that was adapted and optimized to the curved array acquisition. The final USR image was reconstructed by summation of 250 consecutive frames with minimized physiologic motion artifact.

Results/Discussion

The USR image of the human kidney vasculature network (Fig. b) in the maximum long axis view was successfully reconstructed. Combining the B-mode (Fig. a) and USR images (Fig. b), the overall vascular network and individual microvessels in different regions of the kidney were identified with high resolution. The smallest renal microvessel identified, which marked by white solid line in zoomed ROI (Fig. c), is estimated to be 0.14mm (<λ/3) (Fig. d).

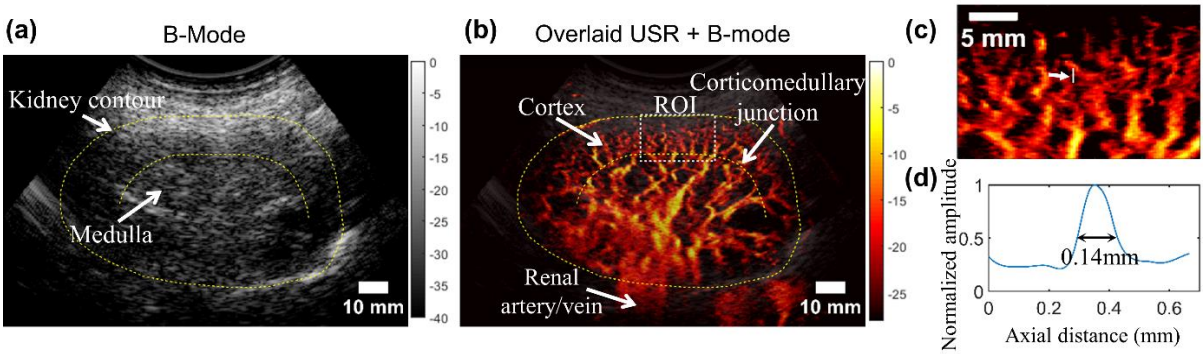

Fig. (a) B-mode image of the human kidney. (b) Overlaid USR and B-mode images of the kidney. (c) Zoomed in USR image of the ROI indicated by white dashed rectangle in (b), with detectable smallest vessel marked by white arrow. (d) Spatial profile of the selected vessel. FWHM is estimated at 0.14 mm (<λ/3).