3D Power Doppler Imaging using a Mechanically Translating Linear Array Transducer

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Introduction

Doppler imaging is routinely used for visualizing vascularisation and quantifying blood flow. Conventional Doppler is subjected to low temporal resolution and low sensitivity for detecting low-velocity flows. The development of ultrafast ultrasound extensively increases the temporal resolution, and in combination with eigen-based filtering it can also improve Doppler sensitivity for low velocity blood, as demonstrated in 2D images. We extended this technique to 3D by acquiring data during mechanical translation of a linear-array probe to enable sensitive visualization of vascularisation within fast volume scanning.

Method

We designed a prototype of mechanical 3D power Doppler in which an L7-4 transducer is driven by a stepper motor to translate at a constant speed. While being translated, the transducer transmits 9-angles compounded plane wave packages at 600 fps rate. Acquired datasets are filtered through singular value decomposition (SVD) to separate the slow blood signals from tissue clutter and noise. A theoretical model was developed for considering the effects of beam slice thickness, translation speed, signal features and SVD setting. It was derived that a slower translating speed and a larger slice thickness allow longer transition time for more accurate slow-flow imaging, although the slice thickness limits the elevational resolution. The prototype was tested on a flow phantom containing two perpendicular 15°-tilted tubes filled with fluid flowing at 5 cm/s and 10 cm/s. Additionally, an in vivo acquisition of renal perfusion was performed. Data was obtained with translating speeds of 5 and 10 mm/s, with a stationary 2D image as reference.

Results and Discussion

For the phantom, the fluid flowing velocity 5 cm/s presents Contrast to Noise ratios (CNR) of 3.65, 3.03 and 2.72 dB, for translating speeds of 0, 0.5 and 1 cm/s, respectively. When the flow velocity is 10 cm/s, corresponding CNRs are 2.84, 2.54 and 2.15. For the renal perfusion, slices of the power Doppler volumes are presented in Fig. 1. CNRs are 7.09, 6.14, 4.56 for the 3 translating speeds. It can be also observed that the elevational resolution is limited due to the slice thickness. In conclusion, mechanical 3D Doppler imaging based on ultrafast ultrasound and eigen-based filtering is more accurate at lower translation speeds and for higher flow velocities.

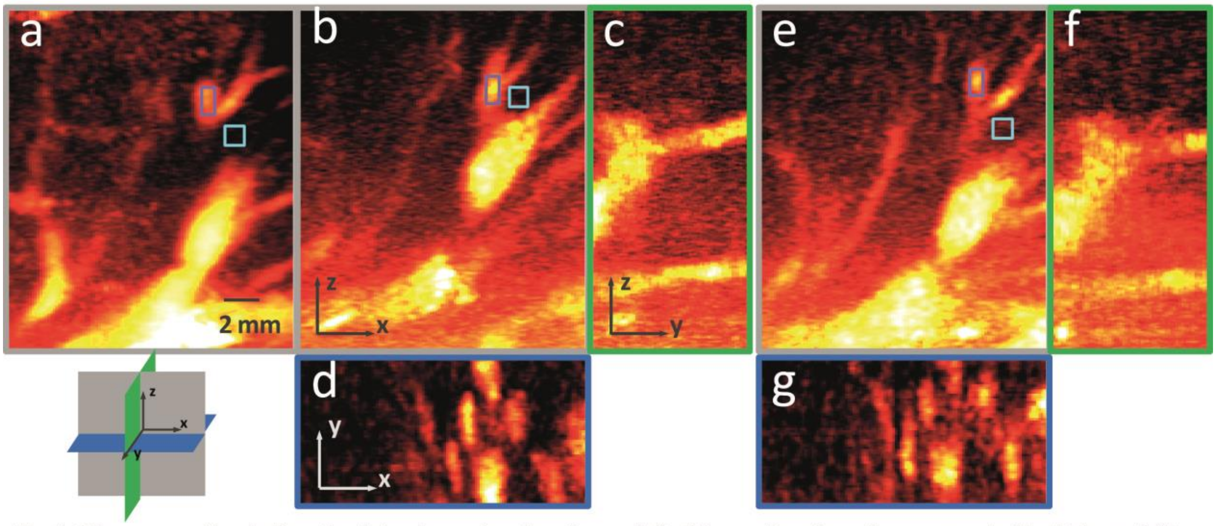

Fig. 1. 3D cross-sectional slices (x – lateral, y – elevational, z - axial) of Power Doppler volume presented in dB form. (a) is the 2D image of 0 mm/s translating speed as a reference. (b-d) and (e-g) are groups of lateral-axial, elevational-axial and lateral-elevational slices, respectively for translating speeds of 5 and 10 mm/s. In (a), (b) and (e), CNRs are calucated for Doppler values between labeled regions.