Towards Vascular Ultrasound Super-Resolution Without Contrast Agents

Avinoam Bar-Zion[1], Oren solomon[2], David Maresca[1], Mikhail G. Shapiro[1], and Yonina C. Eldar[3]

[1] Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA, USA.

[2] Technion - Israel institute of technology, Haifa, Israel

[3] The Weizmann Institute of Science, Rehovot, Israel

Background, Motivation and Objective:

The emergence of super-resolution methods has revolutionized ultrasound imaging, enabling an order of magnitude improvement in spatial resolution by localizing echoes from single separable microbubbles. However, currently, the majority of ultrasound scans, including blood flow measurements, are still performed without contrast agents. In parallel to the development of super-localization methods, compressed sensing techniques have gained popularity in optical imaging, and recently in contrast-enhanced ultrasound, producing super-resolution images without the need to obtain separable targets. Inspired by the Sparsity-based Ultrasound Super-resolution Hemodynamic Imaging (SUSHI) framework, this work aims to produce super-resolved images of blood flow without injecting contrast agents.

Statement of Contribution/Methods:

After applying an SVD clutter filter, each ultrasound clip was decomposed into sub-scans according to the direction of the blood flow. The PSF of the scanner was estimated from the tissue related SVD component. Super-resolved images were produced by exploiting the sparsity of the vasculature in the pixel-wise temporal autocorrelation images. Two types of blood flow simulations were used in this study. In the first one, two parallel blood vessels with blood flowing in the same direction were positioned next to each other to measure the resolution improvement and separation capabilities of this technique. The second one simulated blood flow through a bifurcation. In order to test our method experimentally, we acquired 0.5 s long mouse cortex scans at a 1.5 kHz framerate using a Verasonics scanner connected to an 18MHz transducer.

Results, Discussion and Conclusions:

Simulations of two close-by vessels showed a full width half max (FWHM) improvement by a factor of 5.5 compared to the PSF and a factor of 4 compared to the autocorrelation image (Fig. 1a). At the same time, the structure of the bifurcation was successfully estimated, demonstrating the ability to reconstruct arbitrary vascular structures without any shape priors. The vascular map estimated from the *in-vivo* scan (Fig. 1b, c) showed fine vessels that could not be resolved in the original data, including bifurcations. By improving the spatial resolution of vascular scans without using contrast agents, this technique could facilitate direct and fast super-resolution imaging of blood flow.

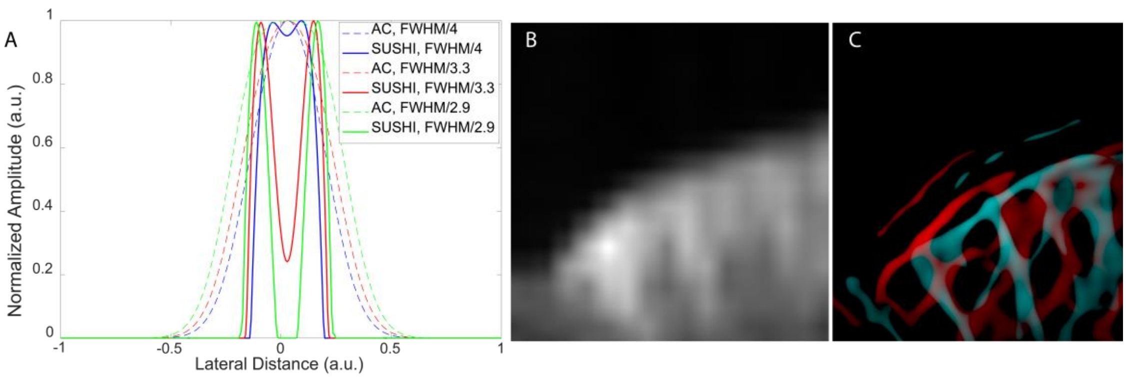

Fig. 1. Cross sections from numerical simulations of blood vessels separation compared to the autocorrelation (AC) image. The distance between the vessels is presented as a function of the original FWHM (A). Detail from a mouse cortex scan: autocorrelation image (B), and compressed sensing result (C).