Feasibility of longitudinal monitoring of atherosclerosis with Pulse Wave Imaging in a swine model

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Background, Motivation and Objective

Pulse Wave Imaging (PWI) is a characterization technique of the local mechanical properties of arteries. This method has been validated in phantoms, human aortas, carotids and murine models. Its capability to track the growth of atherosclerotic plaques is yet to be assessed. Swine models are considered the most appropriate human mimicking model of this pathology. Several parameters such as weight gain, changing anatomy or fat layer aberrations, could hinder the PWI quality. In this study, feasibility to monitor the properties of pig carotids with PWI is evaluated. The repeatability of PWI in hypercholesterolemic pigs is also investigated.

Statement of Contribution/Methods

The left common carotid of 3 hypercholesterolemic Wisconsin miniature pigs, fed an atherogenic diet, was ligated (~80%). Left and right carotids were imaged once a month over 5 months post-surgery at a high-frame rate (1800Hz) with a 5-plane wave compounding sequence and a 5MHz-linear array. Each PWI acquisition was repeated after probe repositioning over 2 cardiac cycles. The beamformed RF data were processed with a 1D cross-correlation algorithm to estimate the axial wall displacements. Spatiotemporal maps were then generated to analyze the pulse wave propagation. The local PWV was estimated by tracking the 50% upstroke of the PW. Vector Doppler images were simultaneously obtained by estimating 1D flow velocity for 3 different angles and combining the 3 axial components. 3D CT angiograms were acquired at the 5-month time point.

Results/Discussion

On day 0, the average difference in PWV between acquisitions and between cardiac cycles were low and highly similar (12.43 vs 12.36%) showing good repeatability. The arterial compliance was found to be lower ($5.31\pm2.60e^{-10}$ m^2/Pa) than in humans (~$3e^{-9}m^2/Pa$ [Li 2019]). Doppler measurements indicated a 3-fold decrease in flow on the day of ligation and subsequent partial restoration. Despite a weight gain of 25.7±1.7 kg, PWI could be performed throughout the entire 5 months (Fig1a). The stenosis, confirmed by CT, can be identified by a decrease in the wall motion. In 2 out of 3 pigs, the ligated carotid became stiffer while the contralateral carotid became softer (Fig1b). This study indicates the feasibility of using PWI to monitor the properties of carotids of atherosclerotic swine. The animals are currently survived to 9 months, when histology will be performed.

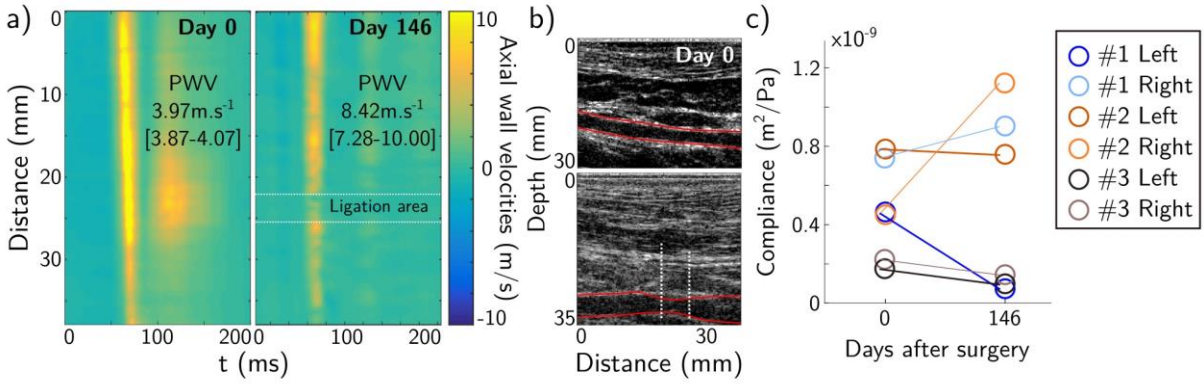

Fig. 1. a) Spatiotemporal maps depicting the pulse wave propagation in the left carotid of pig #1 before surgery and 146 days post-surgery. At day 146, the ligated area can be identified by the reduction in axial wall velocities. b) Bmode images for the same animal with the segmented carotid walls in red. At day 146, the ligated area can be identified by the reduction of diameter. c) Evolution of the carotid compliance between 0 and 5 months after surgery for each of the 3 animals. The left carotid was ligated after day 0 while the right carotid was left intact.