Automated Arterial Input Function Detection in Ascending Aorta for Breast DCE-MRI

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Target Audience: Physicists and radiologists interested in automated arterial input function (AIF) detection in breast dynamic contrast enhancement (DCE)-MRI.

Purpose: DCE-MRI and pharmacokinetic (pK) model parameters derived from the DCE data have been commonly used for characterizing tumor vascular properties quantitatively. The accuracy of pK parameters depends on the choice of AIF [1]. In breast DCE-MRI, AIF may be selected from voxels within the internal mammary artery or axillary artery or lateral thoracic branch of the axillary artery, since they supply blood to the breast. Previously, a semi-automated method based on seed-input for AIF detection within axillary artery has been proposed [2]. However, partial volume effects due to horizontal course of the axillary artery in the axial plane, motion from pulsation and breathing may reduce the accuracy of the AIF selected from the axillary arteries. The internal mammary artery and the lateral thoracic artery are small in caliber. Motion due to pulsation may result in the position of the voxel(s) selected for AIF detection being located outside the artery during the time course. Consequently, AIF measured in the ascending aorta (AAO) may be used. Previously, a method to automatically detect AIF in the descending aorta was proposed [3]. The descending aorta (DAO) may sometimes be excluded from (or be partially present in) the field-of-view of the imaging volume. Additionally, intensity of MR signal at the location of DAO may be low due to increased distance from the surface coil, compared to AAO. In this work, we demonstrate a fully automated method based on contrast dynamics and anatomical prior for AIF detection within the AAO for breast DCE-MRI.

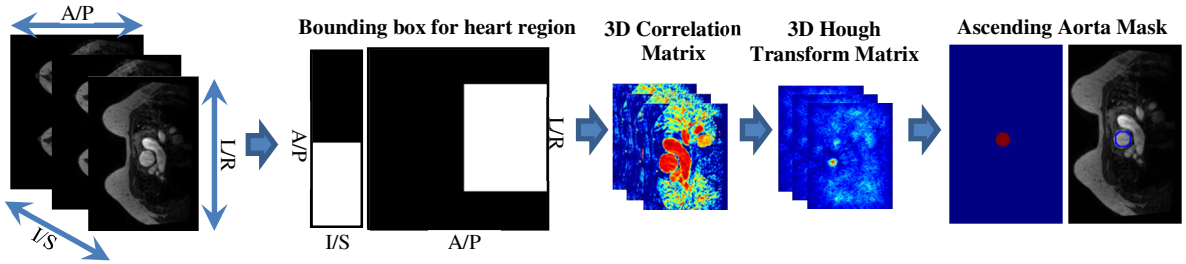

***Figure 1**: Flow chart for ascending aorta segmentation. Model AIF correlation matrix based Hough Transform with in a heart bounding box was used to generate the ascending aorta mask.*

Methods: ***Imaging:*** Seven subjects were scanned on 1.5T GE Signa HDxt and 3T GE Discovery MR750 systems (GE Healthcare, Waukesha, WI) using HD breast coil. An appropriate IRB approved the studies. The imaging parameters include: TE = 1.7 to 1.87ms, TR = 3.7 to 4.1ms, FA = 11° to 20°, FOV = 300mm×300mm to 336mm×336mm, slice-thickness = 1.2mm to 4mm, 256×256 to 512×512 matrix size, temporal resolution from 20s to 30s, and 20 to 45 bolus volumes. 3 cases were with Dixon fat supersession (FS) and 4 without fat suppression. ***AIF Detection:*** The different steps for automated detection of AIF within AAO are: **i)** Identify the slice in the anterior-posterior orientation which separates the breast and heart regions. **ii)** Generate a 3D bounding box for the heart region **iii)** Find the correlation of DCE signal intensity time course at each voxel in the 3D heart bounding box with model AIF to generate a 3D correlation matrix. The model AIF was derived from a population AIF [4] after global bolus arrival time adjustment and interpolation. **iv)** Compute 2D Hough transform for each axial slice in the 3D correlation matrix to generate a 3D matrix of concatenated 2D Hough transforms. Since average AAO is approximately 30 to 40 mm in diameter [5], the circular shape diameters between 30mm to 45mm were used for Hough transform. **v)** Select the first five voxels with highest values in the 3D Hough transform matrix. These voxels are typically located close to the center of the Hough circular regions. **vi)** For each of the voxels selected in step 5, generate a circular region-of-interest (ROI) of diameter 25mm around the voxel in the axial orientation. **vii)** From within the above mentioned ROIs, select the top 20 voxels with highest correlation with model AIF to generate 20 candidate AIFs. **viii)** Compute mean of the 20 candidate AIFs to compute the final AIF (Auto-AIF). ***Validation*:** An experienced radiologist marked a single AIF location in the AAO after evaluating multiple DCE signal curves for each case. The correlation-coefficient between the manually marked AIF and the corresponding automatically detected AIF was computed. The bolus arrival times (BAT) and time-to-peak (TTP) indices of the manual and automated AIF were also compared.

Results and Discussion: Figure 1 shows the results of automated ascending aorta segmentation in a representative case along with the intermediate steps. The use of Hough transform allows distinguishing AAO from other high model AIF correlation regions in the heart and pulmonary artery. The AAO was distinguished from DAO using high correlation threshold (>0.9) and high diameter range of 30mm to 45mm in the Hough transform. The use of contrast dynamics resulted in reliable AAO detection even in presence of varied tissue contrast such as FS and non-FS. The algorithm is independent of acquisition orientation, because the data can be reformatted to axial orientation. The automated algorithm consistently segmented ascending aorta in the seven cases that were evaluated. Strong correlation (0.96±0.03) was observed between the Auto-AIF and the manually determined AIF. There was also excellent agreement between the shape characteristics (BAT and TTP) of the model and Auto AIFs. The results demonstrate the potential of the proposed automated method to replace manual or user assisted methods for AIF selection.

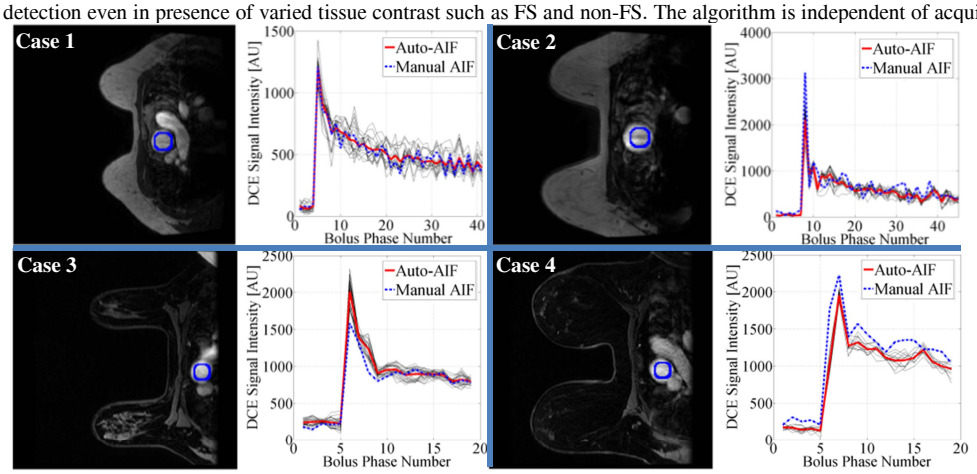

***Figure 2**: Comparison of Auto-AIF computed from ROI (blue line) within AAO with AIF selected manually by the experienced radiologist (Manual-AIF) in four representative cases (two with and two w/o fat suppression). The black lines indicate 20 candidate AIFs. The mean of candidate AIFs is presented as the final Auto-AIF.*

Conclusions: We have demonstrated a completely automated method for consistent detection of AIF in the ascending aorta for breast DCE MRI. The proposed automated AIF detection method may be useful in reliable estimation of pK parameters in breast DCE-MRI data.

References: [1]. Tofts et.al. JMRI 1999;10:223-232**. [2].** Li et.al. Phys. Med. Biol. 56 (2011) 5753–5769. **[3].** Chen et.al. MICCAI, 2008; 11: 594-601**. [4].** Morgan et al., Br. J Cancer 2006;94:1420-1427. [5]. Acad Radiol. 2008 July; 15: 827–834, Table 3.