

Estimation of Respiratory Tracking Factor between Pulmonary Vein and Right Hemi-Diaphragm For Free-breathing PV LGE

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Introduction: High spatial and temporal resolution cardiac MRI necessitates a free-breathing acquisition using diaphragmatic or self-gating navigators. In diaphragmatic navigators, the motion of right-hemi-diaphragm (RHD) is commonly monitored using a pencil-beam navigator. Motion of the heart is then estimated relative to the RHD motion using a constant tracking factor of 0.6 [1]. This constant factor is based on data from coronary arteries and may be different for pulmonary veins (PVs) due to their relative position with respect to the RHD [2]. In this study, we sought to determine the respiratory tracking factor between PV and RHD for PV imaging.

Materials and Methods: 3 healthy volunteers (3 males, 20±1 years old) and 16 patients (7 female, 53±16 years) referred to our CMR center for assessments of atrial fibrillation (AF), were recruited. From each subject, we acquired real-time coronal two-dimensional (2D) images covering both the right lower PV and RHD for estimating their displacements. Sequence parameters for the real-time 2D images were: ECG triggered at the end diastole, 270×337 mm² field of view (FOV); 188×133 acquisition matrix size; 1.5×3 mm² in-plane spatial resolution; TE/TR = 1.49/3; flip angle 60°; SENSE with acceleration factor 3, temporal resolution of 90 ms; number of dynamics = 100. Images were then transferred to Matlab (The MathWorks, Natick MA) for off-line processing. Two regions of interest, as shown in Fig.1, were defined at the RHD and right lower PV on the first acquired 2D image. The regions of interest were then overlaid along the superior-inferior (SI) direction on the next acquired 2D images for calculating 2D normalized cross-correlations. The positions where the normalized cross-correlations were maximized, were chosen as the tracked positions of the RHD (x_{RHD}) and PV (x_{PV}) at different respiratory cycles. A linear regression model was then applied to the estimated PV and RHD's displacements for calculating the tracking factor α for each subject as follows:

$$\alpha = \frac{N \sum_{i=1}^N x_{RHD}^i x_{PV}^i - \sum_{i=1}^N x_{RHD}^i \sum_{i=1}^N x_{PV}^i}{N \sum_{i=1}^N x_{RHD}^i x_{RHD}^i - \sum_{i=1}^N x_{RHD}^i \sum_{i=1}^N x_{RHD}^i},$$

where $N=100$ is the total number of acquired 2D images. The estimated tracking factor was then used in a three-dimensional (3D) PV late gadolinium enhancement (LGE) sequence for acquiring PV images of 5 patients with the following parameters: ECG triggered at end diastole, TE/TR/α = 2.5 ms/5.2 ms/25°, field-of-view (FOV) of 320×320 mm², 40 slices, spatial resolution of 1.4×1.4×4 mm³ reconstructed to a resolution of 1.25×1.25×2 mm³ using zero-padding, and 25 shots in each cardiac cycle, navigator acceptance window of 7 mm with a tracking factor of 0.45.

Results: Fig.2 shows the relative displacements of PV with respect to that of the RHD. The PV displacements can be linearly approximated by the respiratory displacements of RHD (slope = 0.45). Fig.3 shows the estimated tracking factor between the PV and RHD's displacements for each of the subject. Tracking factor is subject-dependent, and ranges from 0.3 to 0.63 (mean±standard deviation =0.45±0.1). Fig.4 shows a slice of the reconstructed LGE images using 0.45 as tracking factor from an AF patient.

Conclusions: Respiratory tracking factor between PV and RHD displacements is subject-dependent. A mean respiratory tracking factor of 0.45 should be used in PV imaging for improving estimation of its motion from the motion of RHD.

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References: [1] Wang, MRM, 1995; [2] Wagner, ISMRM, 2009.

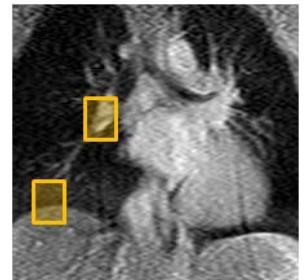


Fig.1: Acquired real-time 2D image and defined regions of interest around PV and RHD for calculating tracking factor between their displacements.

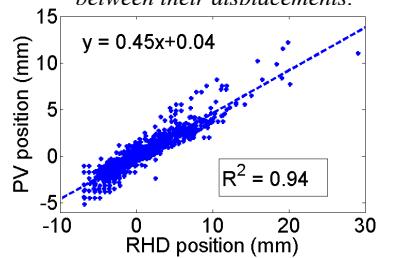


Fig.2: Respiratory displacements of PV with respect to that of RHD.

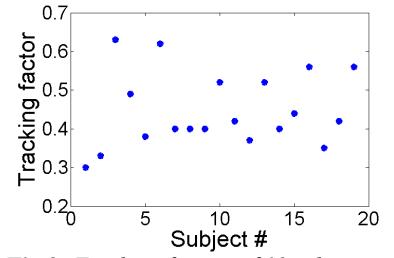


Fig.3: Tracking factors of 19 subjects.

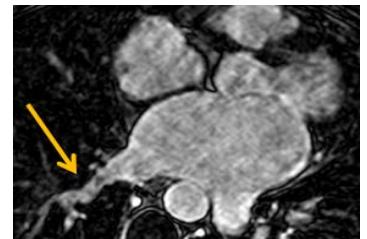


Fig.4: Reconstructed PV LGE images of an AF patient in sinus rhythm using tracking factors of 0.45. The arrows display the lower right PV branch.