Beat-specific estimate of PVC-compromised cardiac function via non-gated free-breathing MRI

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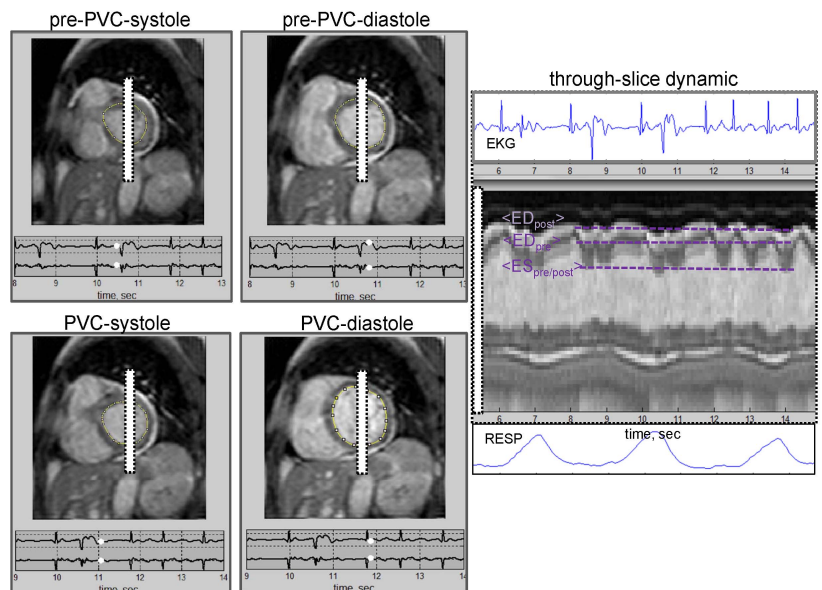
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Introduction: Frequent premature ventricular contractions (PVCs) can result in a reversible form of cardiomyopathy [1]. Improved image acquisition and analysis are needed to accurately assess left ventricular (LV) function in patients with PVC [1,2]. Current procedures designed to reject irregular heart beats from analysis are imperfect in assessing ejection fraction (EF) in patients with frequent PVCs [2]. Real time cardiac MRI [3-6] enables continuous acquisition of cardiac phases with acceptable temporal resolution. This study evaluates real-time non-gated free-breathing images retrospectively synchronized with physiological data to determine beat-specific cardiac function in the presence of PVCs.

Methods: Non-gated b-TFE MRI [3,4] with true dynamic resolution of 68-82 ms was acquired using Philips Achieva 1.5T clinical scanner with $\theta = 40°$, TR/TE = 3.35/1.68 ms, SENSE factor 3 and slice thickness of 8 mm. Continuous acquisition of 700-800 dynamic scans per base, mid, and apex (short-axis) slices spanned ~one minute of cardiac activity under free-breathing. Retrospective analysis was performed for four patients: two with infrequent PVCs (< 6/min) and two with ventricular trigeminy (> 12/min). Real time images were synchronized and combined with the auto-saved EKG waveforms into DICOM cine-frames for beat-specific selection of heart phases for ROI measurements. The closest end-diastolic (ED) and end-systolic (ES) phases were visually identified for beats preceding PVC (pre-PVC), PVC, as well as first, and second post-PVC by scrolling through the frames graphically linked to EKG-traces (Fig.1). The sum of manual ROI area measurements performed for similar heart phases on separate slices was used to approximate end-diastolic volume (EDV) and end-systolic volume (ESV). The estimated EF was compared to clinically-measured LV ejection fraction [4], which was obtained from standard (segmented k-space, breath-hold) cine-MRI acquired for 10-15 slices with 30 reconstructed phases per cardiac cycle.

Results: The ROI area measurements repeated for the same type of beat along real time cine [3,4] were reproducible within ±5%. When compared to post-PVC beats, pre-PVC beats for all patients had a 15-25% lower EDV with a similar ESV (Fig.1) resulting in a lower EF of 25-35%. Most PVC beats exhibited ~20% higher ESV with EDV similar to post-PVC beats and a corresponding EF of 35-45%. For all patients, the average EF of individual post-PVC beats (40-65%) was within ±3% of the corresponding clinical measurement from standard cine MRI. For patients with frequent (trigeminal) PVCs, the measured EF of the PVC beats was close to the corresponding clinically measured EF, while pre-PVC EF was substantially (~40%) lower. Consistent with previous observations [1,2], ES-to-ED interval of the PVC beat was ~50% longer than that of the pre-PVC beat, returning to normal length after the first post-PVC beat. Non-uniform changes of the heart wall during diastolic and systolic phases of different beats were directly detectible from the dynamic (temporal-spatial) image stack (Fig.1).

Figure 1: Synchronized short-axis MRI cine-frames and EKG traces for base slice of a pre-PVC (top) and PVC beat, indicating spline-fit ROIs (yellow) used to measure ES and ED areas. Left images: systole, right images: diastole. The small white circle on the EKG trace corresponds to the dynamic time for the image above it. The vertical white pencil-beam indicates the through-slice pixel selection for temporal-spatial dynamic stack on the right (with EKG and RESP signals). The visible differences in average position of heart wall for ED and ES of pre-PVC versus PVC and post-PVC beats are marked by horizontal (dashed purple) lines.

Conclusion: Non-gated free-breathing real time MRI acquisition with retrospective synchronization to physiological signals enables beat-specific analysis of cardiac phases. Sufficient time resolution and signal-to-noise are achieved for quantitative estimate of cardiac function on a beat-to-beat basis. The proposed methodology provides higher accuracy and specificity than standard cine-MRI for EF measurement in the presence of frequent PVCs.

References: [1] Cha Y-M, et al, *Adv Arrhythmia and Electrophys*, v.5:229 (2012); [2] Sarrazin J-F, et al, *Heart Rhythm*, v.6:1543(2009); [3] Kellmann P, et al, *Magn Res Med*, v.62: 1557 (2009); [4] Beer M, et al, *Int J Card.*, v.145: 380 (2010); [5] Feng L, et al, *Magn Res Med*, v.70:64 (2013); [6] La Gerche A, et al, *Circ Cardiovasc Imaging*, v.6:329 (2013).