Visualization platform for real-time, MRI-guided cardiac interventions

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Introduction: Guidance of electrophysiological (EP) procedures by MRI is attractive compared with x-ray fluoroscopy because MRI has good tissue contrast and can be used to visualize arrhythmogenic regions of heterogeneous scar and healthy tissue ("gray zone"). The Vurtigo software presented here is designed to enhance guidance of radio-frequency (RF) ablation therapies with visualization of prior volume roadmaps, tracked catheters and EP recordings.

Materials and Methods: Experiments with an aortic arch phantom and healthy porcine subjects provided data for development. In each experiment there was a cine SSFP MR scan (7-13 slices, 20 cardiac phases), followed by an EP mapping procedure. MR imaging was performed on a 1.5 T scanner (CV/i, GE Healthcare) using a 5" surface coil. The software was designed for 4D (3D + cardiac phase) visualization and programmed with threaded C++ for computational performance. It utilizes the multi-platform Qt interface toolkit, DCMTK toolkit for DICOM image reading support, and VTK 5.6 visualization library. A plug-in structure supports the extension with new functionality. Functionality includes simultaneous, mono or stereo display of multiple 2D real-time MRI planes, 3D/4D prior volumes and tracked devices (e.g. active catheter coils) with spatial alignment. Vurtigo supports GPU-accelerated volume and maximum intensity projection (MIP) rendering for CUDA NVIDIA graphics cards. CARTO (Biosense-Webster) EP mapping data files or custom EP data files (XML format) can be imported for alignment of recordings with a prior volume. Automatic segmentation contours of the left ventricle can be imported and utilized for endocardial surface display, and this surface can be painted with color coded information from EP recordings (e.g. bi-polar voltage).

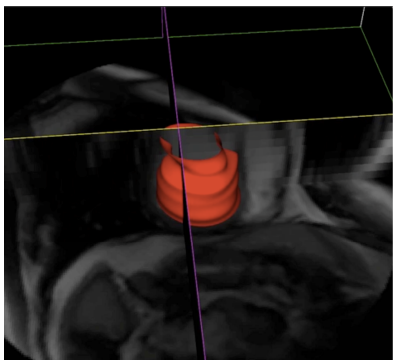

Fig. 1. Automatically segmented left ventricular endocardial surface fused with MR prior volume, displayed with three orthogonal cut planes.

Results: In our in-vivo experiments the LV endocardial surface generated from automatically segmented cine SSFP images was visualized with the fused prior volume to provide a target for EP catheters (Fig. 1). The history (track) of catheter positions was also visualized to support the interventionalist monitoring the advance toward the therapy target (Fig. 2). During in-vivo EP procedures, the software provided visualization of the EP recording locations and the actively tracked catheter within the prior volume roadmap (Fig. 3). The latency of transmitting reconstructed images to Vurtigo was 56 ± 59 ms. A 415×415 pixels render window of a three plane prior volume view with one real-time MRI plane was rendered at 340 ± 107 frames/s (8 core, 32-bit MacPro (Apple) with Ubuntu 8.04 OS, 2GB RAM) without GPU-acceleration.

Discussion and Conclusions: We have presented an open-source, cross-platform, freely available application that is an advanced visualization platform to support MR-guided interventions, especially arrhythmia therapy by EP ablation. The open source software is available for download from www.vurtigo.ca.

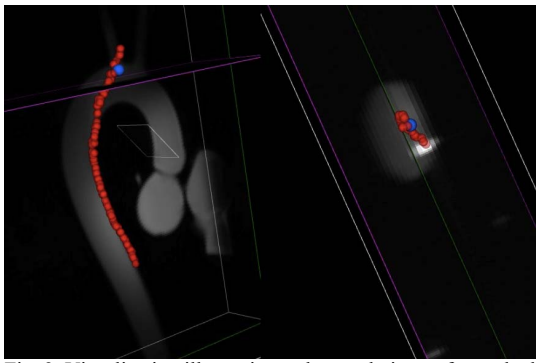

Fig. 2. Visualization illustrating orthogonal views of a tracked catheter tip (blue point) in a aortic arch phantom. Red points indicate the track of the catheter along the phantom wall.

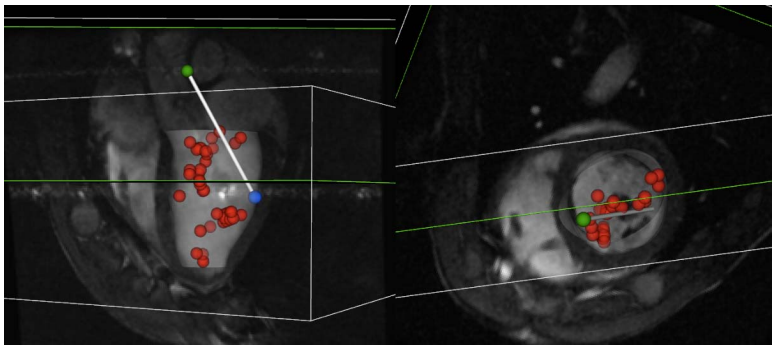

Fig. 3. Visualization illustrating EP recording locations (red), catheter tip coil (blue), secondary catheter coil (green) in prior MR roadmap with simultaneous 4-chamber (left) and short axis views (right).