Validation of a Vasculature-based Co-registration Technique of X-ray and MR Images for the Guidance of Cardiovascular Interventions

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Objective: Combined X-ray and MRI (XMR) guidance of interventions has been shown to offer considerable benefits by providing soft-tissue and functional information and real-time visualization of interventional devices. However, combining both types of information necessitates co-registration and fusion of MR and X-ray images. This study presents and validates a software solution, *FluoroFusion* (General Electric Healthcare), which does not require hardware calibrations, optical tracking, or external markers [1, 2].

Materials and Methods: Images were acquired on a combined XMR cardiac interventional suite, equipped with 1.5T Signa HDx MRI, Innova 2121-IQ Biplane X-ray and a dedicated motorized bed for transferring patients between the scanners located in adjoining rooms (GE Healthcare). 3D MRI data sets were acquired using T1w RF-spoiled fast GRE. Afterwards the subjects were transferred by the motorized bed to the X-ray imaging system, to minimize positioning differences between exams relative to the bed. Standard guide wires were introduced into selected landmark blood vessels or their phantom equivalents, and X-ray cine images were acquired (standard cardiac protocol). The MR images were post-processed semi-automatically using *Volume Viewer* software (GE Healthcare) to construct 3D segmented models of the landmark vessels and the chambers of interest (e.g. LV) for visualization.

FluoroFusion oriented the MR-derived 3D models of the vessel and chamber based on the angulation of the selected X-ray images, generated 3D rendering of the models, and displayed the approximately-fused XMR image. Final adjustment was made by manual translational co-registration of the MRI rendering of the vessel to the catheter and guide wire on two or more X-ray images simultaneously. These X-ray views were selected to be separated by >30° to improve 3D localization. A non-standard usage of Fluorofusion with only a single X-ray view for registration was also assessed. The fused XMR image displayed the landmark vessel and heart chamber of interest overlaid on the X-ray images.

To assess registration accuracy, a phantom was constructed with embedded pieces of insulated copper wire visible on both MR and X-ray. After co-registration, *FluoroFusion* was used to identify the wire endpoints on both MR and X-ray and calculate their 3D coordinates (Fig. 1). *Volume Viewer* was used to measure the 3D error between the corresponding landmarks (wire endpoints) derived from MR and X-ray (Fig. 2). The accuracy of patient image co-registration was evaluated visually from cardiac anatomy (Fig. 3). An additional study was performed in which phantom images were co-registered using only a single X-ray image and MR dataset. For this study, after the co-registration was completed, an orthogonal X-ray image was used to define points and measure 3D errors.

Results: Phantom images were successfully fused with 3D error of 1.7 ± 0.7 mm and range 0.1-3.7 mm, from 14 trials utilizing two X-ray views each. In the second study of 10 trials utilizing only a single X-ray view for co-registration, the errors were 19.7 ± 11.0 mm, with range 4.8-39.9 mm. Finally, in the third study with patient data, utilizing two X-ray views for co-registration, the accuracy was within a few millimeters based on qualitative visual assessment.

Discussion: The semi-automatic segmentation of the blood vessel and heart chamber can be efficiently performed by a technologist prior to the intervention. The blood vessel to be used for co-registration should be in close proximity to the chamber of interest for best results. *FluoroFusion* calculates an approximate co-registration from gantry angulation for the X-ray image, but the user was required to manually refine the position of the MRI projection on the X-ray images. Automation of this step is a work-in-progress and will include angular parameters. The phantom study performed with a single X-ray image could only be adjusted in 2D and had large errors, thus co-registration with more than one X-ray image of sufficient (>30 deg) separation is necessary for good (1.7 mm) accuracy. Integrating *FluoroFusion* into the clinical routine appears to require minimal workflow adjustment or operator time. While the best results are obtained by using the motorized patient transfer bed, images from any stand-alone MRI and X-ray systems could be used with *Fluorofusion*, provided the patient orientation is similar. The future work will be focused on quantifying the accuracy of cardiac and respiratory motion compensation and its influence on the accuracy of the image fusion process.

References: 1. Circulation 2005; 112: 3763-3768. 2. Heart Rhythm 2005; 2: 55-63.

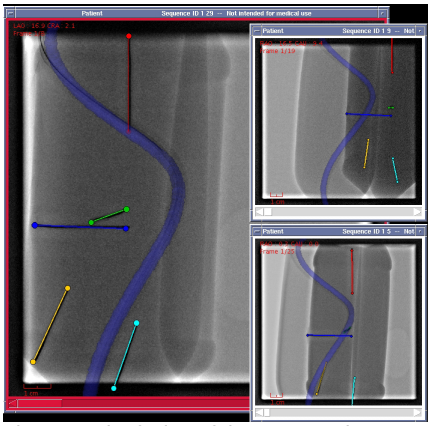

Figure 1: The fusion of the X-ray and MR images of a phantom in FluoroFusion. Points represent landmarks (wire endpoints) identified on X-ray images.

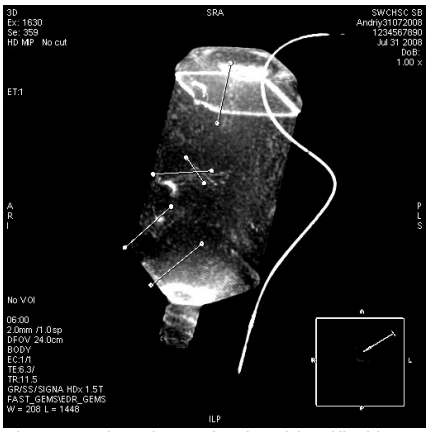

Figure 2: The wire end points identified in *FluoroFusion* are displayed with the segmented phantom for 3D error measurement.

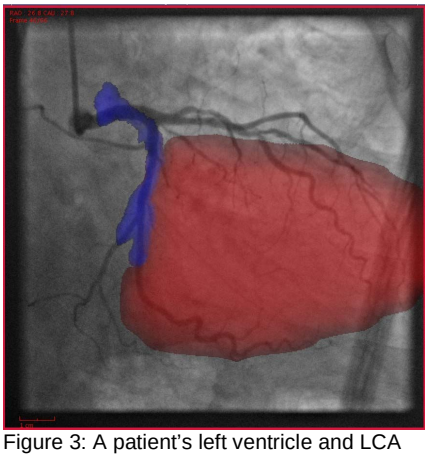

Figure 3: A patient's left ventricle and LCA vessel are shown fused with X-ray angiography.