MRI/X-ray fusion for overlay guidance during congenital heart disease catheterization procedures

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TARGET AUDIENCE – Radiologists, interventional cardiologists, and researchers interested in using MRI to guide interventional procedures.

PURPOSE – To study the accuracy and clinical feasibility of fusing 2D x-ray images and 3D MRI datasets (XMRF) in the cardiac catheterization suite. The complex anatomy of patients with congenital heart disease is often imaged by MRI prior to catheterization. To date, the images are generally only viewed before the procedure on a workstation outside of the cath lab. XMRF allows for *in situ* viewing of MRI sequences to inform navigation during the case. We present a new biplane method for XMRF using a prototype system (Siemens AG, Healthcare, Forchheim, Germany) and describe the accuracy of the resulting 2D overlay (roadmap) when rendered from an underlying, registered 3D MRI.

METHODS – *Accuracy of fused MRI overlay:* The accuracy of the XMRF prototype system was assessed using a cylindrical phantom containing dual-modality fiducial markers (Beekley Corporation, Bristol, CT). An MRI of the phantom was acquired (syngo Twist, TR 3 ms, TE 1 ms, flip angle 25°, FOV 250x250x250 mm, isotropic voxel size 1.0 mm) prior to its placement in isocenter of a biplane X-ray field. Registration was achieved by sequential alignment of the MRI-rendered fiducial markers, rendered in the biplane MRI overlay images, with their associated X-ray counterparts in the anterior-posterior and lateral views. The maximum distance between these fiducial marker boundaries defined by the respective modalities was measured using ImageJ (US National Institutes of Health, Bethesda, MD). *Clinical feasibility:* High resolution MRA (syngo Twist or Navigator gated 3D flash IR sequence) was performed on 20 patients using a 1.5T MRI system (Siemens AG, Healthcare, Erlangen, Germany). Parameters were: Twist: TR 3 ms, TE 1 ms, flip angle 25°, FOV 250-400 mm, isotropic voxel size 1.0 mm; Flash IR: navigator gated to end expiration, coronal, TR 300 ms, TE 1.5 ms, Flip angle: 20°, FOV: 250-400 mm, isotropic voxel size 1.0-1.3 mm. 3D surface models of the left and right heart anatomy were created from the MRA datasets by means of a threshold based segmentation of cardiac vessels and structures of interest using Mimics (Materialise, Leuven, Belgium). The MRI was manually registered to the patient using anterior-posterior and lateral view positions and matching anatomical landmarks, including bones, airway, and the heart and vessel borders. No contrast or fiducial markers were used for registration[1]. Visualization preferences for contour and solid rendering were investigated on various anatomic regions of interest.

RESULTS– Initial registration can be performed in less than 30 seconds. Figure 1 shows a volume rendering of the MRI overlaid on an x-ray image of the same phantom used for error calculation. The registration error calculated using the phantom measured a mean and a standard deviation of 0.6 ± 0.3 mm in the anterior-posterior projection and 0.3 ± 0.2 mm in the lateral projection. Figure 2 illustrates the solid and contour rendering options. Solid rendering provides visualization of the exterior surface while the "carving" feature, illustrated in figure 2B, reveals the interior, which users found helpful for visualizing the vessel ostia. We found contour rendering preferable for vessel-like structures that are smooth; wherein complex anatomy often showed a cluttered scene of image edges that obfuscated true anatomical boundaries. Figure 3 illustrates XMRF during the closure of a residual left hepatic vein to atrium connection in a patient with persistent cyanosis following a total cavopulmonary anastomosis (Fontan).

DISCUSSION and CONCLUSIONS – XMRF demonstrated a high level of accuracy for biplane overlay as shown in the phantom study. Manual registration, based on internal markers, can be performed quickly, with minimal radiation and without the need of contrast. The software prototype has the potential to provide 3D guidance and reduce radiation during complicated congenital heart disease catheterization procedures.

REFERENCES – [1] Dori et al. X-Ray Magnetic Resonance Fusion to Internal Markers and Utility in Congenital Heart Disease Catheterization. Circ Cardiovasc Imaging. 2011;4(4):415-424.

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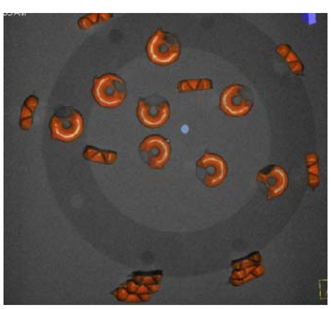

Fig. 1 – Volume-rendered MR image of the phantom in the AP projection fused to the fluoroscopic image illustrating the method used for error calculation. The error was calculated as the distance between the center of the blue marker to the edges of specific landmarks in the MR and the fluoroscopic image.

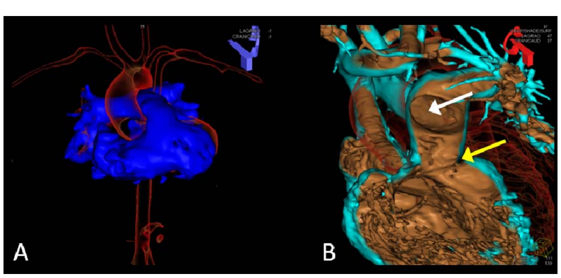

Fig. 2 – Visualization options for MRI-derived surface models. (A) Two surfaces loaded; the right side of the heart (blue) is solid rendered, the left side of the heart (red) is contour rendered. (B) Solid-rendered surface carved open to visualize the relationship between a stenosis (yellow arrow) and the right pulmonary artery ostium (white arrow).

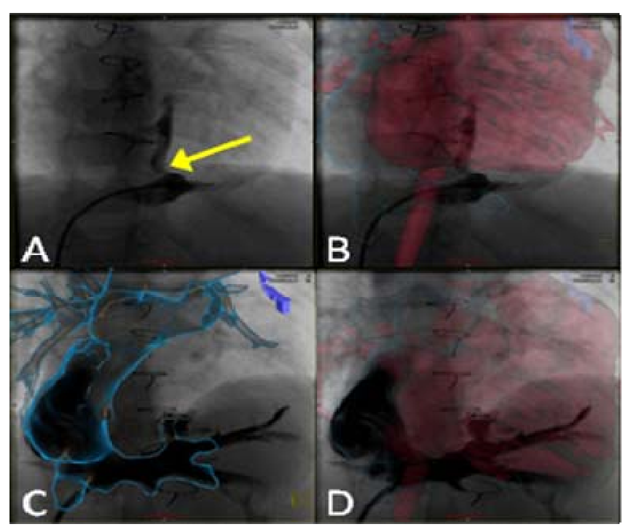

Fig. 3 – Clinical XMRF A) X-ray image of the residual left hepatic vein to atrium connection (yellow arrow). B) Addition of the MRI overlay of the right heart in blue and the left heart in red, showing the flow from the hepatic into the atrium. C,D) XMRF images acquired after an 8mm Amplatzer plug was seated in the connection, showing no residual flow into the atrium.