Biplane X-Ray Magnetic Resonance Image Fusion Prototype for 3D Enhanced Guidance in Cardiac Catheterization Procedures

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Introduction: The complex anatomy of patients with congenital heart disease is often imaged by magnetic resonance imaging (MRI), prior to the catheterization procedure. To date, the images are generally only viewed before the procedure. Using X-ray magnetic resonance fusion (XMRF), we can now enhance live X-ray images with 3D information. We present a new method for biplane XMRF involving an augmented fluoroscopy prototype (Siemens, Forchheim, Germany). With this software it is possible to easily register multiple 3D data inputs to biplane X-ray projections with sufficient clinical accuracy. Visualization techniques such as contour or solid rendering and surface carving are supported to facilitate a clear presentation of complex 3D structures.

Materials and Methods: We reviewed data rendered with different visualization methods on 20 patients that underwent clinical XMRF procedures. Surface models were generated by threshold-based segmentation from high resolution MRA data using Mimics (Materialise, Belgium). Initial registration was performed manually by visual matching of the 3D data to biplane X-ray projections in the anterior-posterior (AP) and lateral view directions. Multiple visualization techniques and tools were compared, see Figure 1. In addition, the registration accuracy of the prototype was assessed using a phantom.

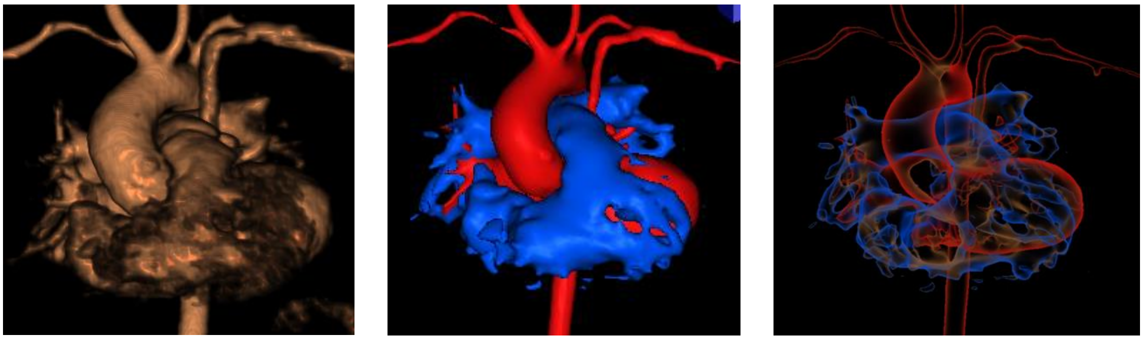

Figure 1: Comparison of visualization options. A) Volume-rendered. B) Solid rendering, C) contour rendering of two surface models, right heart (blue) and left heart (red).

Results: The max segmentation time was 10 min (range 2 - 10 min) and registration took at most 30 sec (range 10 - 30 sec). Registration was based on internal markers, e.g., heart outline, without the need for contrast injection or additional radiation exposure. In phantom experiments the registration accuracy was measured at 0.6 ± 0.3 mm in the AP projection and 0.3 ± 0.2 mm in the lateral projection.

Discussion: Compared to volume rendering, solid rendered surfaces were preferred, because they provided a better view onto internal structures, such as vessel ostia, thanks to the carving feature, compare Figure 2 A) and B). Contour rendering alone was not suitable for complex overlapping structures due to lack of 3D depth information. It was found to be helpful in combination with solid rendered structures, where it provided a see-through 3D relation between adjacent structures, see Figure 2 C).

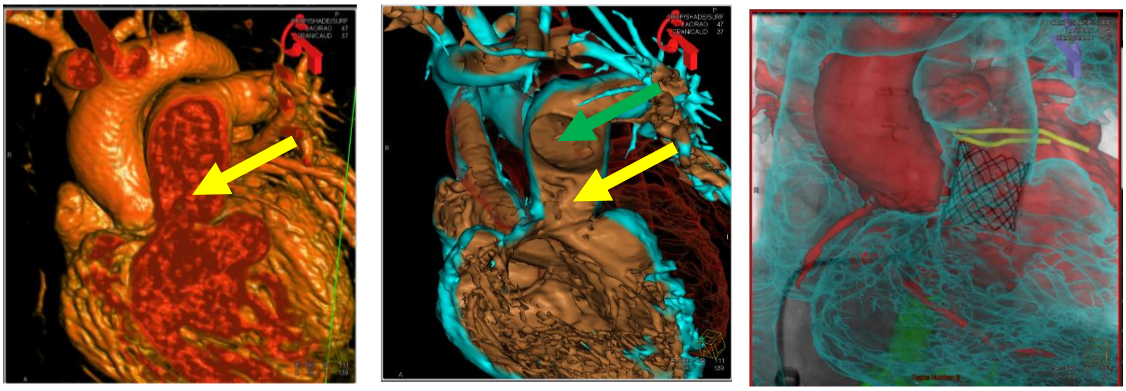

Figure 2: A) Volume rendered image with clip plane, showing the area of the stenosis (arrow). B) Solid rendered surface model cut open using the "carving" technique to better visualize the relationship between the stenosis (yellow arrow) and the right pulmonary artery ostium (green arrow). C) Contour rendered overlay of the right side of the heart in a cranial projection showing the spatial relation between the pulmonary valve stent and the left coronary arteries (marked yellow).

Conclusion: The prototype facilitates quick and accurate registration of 3D data to biplane 2D X-ray images. We found solid rendering of surface models in combination with carving techniques to be most useful. This new biplane XMRF technique has the potential to improve safety and efficiency of fluoroscopically guided procedures, in particular for complicated cases.

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The concepts and information presented in this paper are based on research and are not commercially available