Coronary Sinus Extraction for Multimodality Registration to guide Transseptal Puncture

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Objective

Atrial fibrillation (Afib) is the most common heart arrhythmia and a leading cause of stroke. The treatment option is radio-frequency catheter ablation (RFCA). RFCA is performed in electrophysiology (EP) labs using C-Arm X-ray systems for navigation and guidance. The goal is to electrically isolate the pulmonary vein-left atrial junction thereby rendering myocardial fibers responsible for induction and maintenance of AF inactive [1]. The use of overlay images for fluoroscopic guidance may improve the quality of the ablation, and it can reduce procedure time [2,3]. Overlay images, acquired using CT, MRI, or C-arm CT, can add soft-tissue information otherwise not visible under X-ray. MRI can be used to image a wide variety of anatomical details without ionizing radiation. In this paper, we show how to register 3-D MRI volumes to 2-D X-ray images based on the coronary sinus.

Materials and Methods

The MR images were obtained on a Siemens Avanto MR system (Siemens, Erlangen, Germany). For intra-procedural imaging, a biplane C-Arm system (AXIOM Artis dBC, Siemens, Forchheim, Germany) was used. Such a system consists of two C-Arms that allow simultaneous fluoroscopic imaging under different viewing directions. In our case, the system had two small detectors, each with size 20 cm x 20 cm. Images were acquired during the ablation at 2 p/s, and during contrast agent administration at 7.5 p/s.

A standard software (*syngo* InSpace EP, Siemens, Forchheim, Germany) was used to segment the left atrium in the MR images and to generate a 3-D mesh. This mesh (or shell) is then used as overlay during the ablation procedure. To outline the coronary sinus (CS) in the MRI data sets, an X-ray navigation prototype (Siemens, Forchheim, Germany) was used. The same prototype facilitates the overlay of the outlined CS as well as the 3-D mesh of the LA onto live fluoroscopic images.

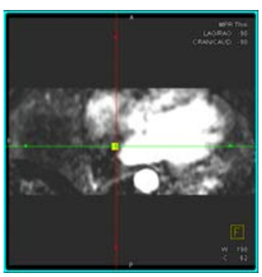

Figure 1. Step 1: We locate the coronary sinus in the triangle of tricuspide valve, interatrial septum and inferior vena cava.

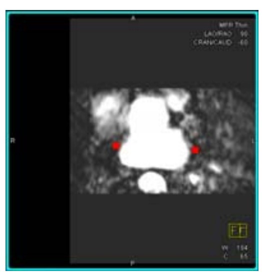

Figure 2. Step 2: The transition of the CS to the Great Cardiac Vein is found caudal to the left pulmonary veins. Afterwards, the MPR slices are adjusted to show both set points.

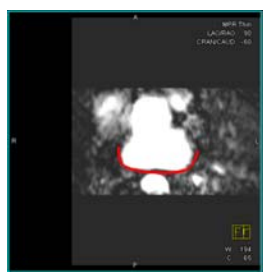

Figure 3. Step 3: We extract the remaining parts of the coronary sinus. The CS is represented as a curve.

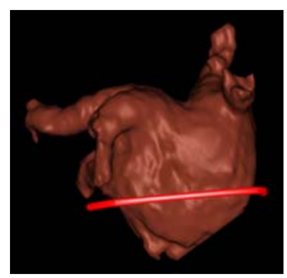

Figure 4. Step 4: The extracted CS is visualized in 3-D together with the segmented left atrium obtained from the MRI.

Our registration workflow has three main steps. In the first step, the coronary sinus is extracted from the MRI. The CS is the main venous vessel of the heart, located in the sulcus between left atrium and left ventricle. On the frontal slices, this sulcus can be located as a hypo-dense structure at the transition of the left atrium to the left ventricle. On the axial slices the coronary sinus is located at the lower right atrium in the triangle of tricuspide valve, inter-atrial septum and inferior vena cava and the transition of the coronary sinus to the great cardiac vein is located caudal to the left pulmonary veins. The steps to extract the CS are shown in Figures 1 – 4. The coronary sinus was usually extracted in less than five minutes. This step can be performed during preparation of the patient or as soon as the MR images are available.

The second step of our method is the registration of the coronary sinus together with the MRI and the extracted mesh to the fluoroscopic images. At the beginning of each ablation procedure, a catheter is put into the coronary sinus. As soon as this catheter is in place, the coronary sinus extracted from 3-D is manually registered to the live fluoroscopic images. It is advantageous to perform registration during a breath-hold maneuver, to obtain stable conditions. Registration is performed by manually moving the 3-D overlay in both imaging planes such that the extracted CS overlaps with the catheter in the coronary sinus. If we restrict registration to translational registration only, then it is usually performed in less than a minute.
After this registration step, fluoro overlay guidance can already be provided, e .g., to provide additional help for the transeptal puncture. Afterwards, contrast agent can be directly administered into the left atrium to perform re-registration. The required 3-D offset for re-registration is measured. Note, however, that this does not provide the accuracy of our method, as the left atrium might be moved during the puncture. Moreover, it can not be guaranteed that the patient holds his breath in the exact same position. This is another source of errors potentially compromising the registration result. To rule out misregistration, contrast can be injected. The administration of contrast agent is shown in Figures 5 and 6.

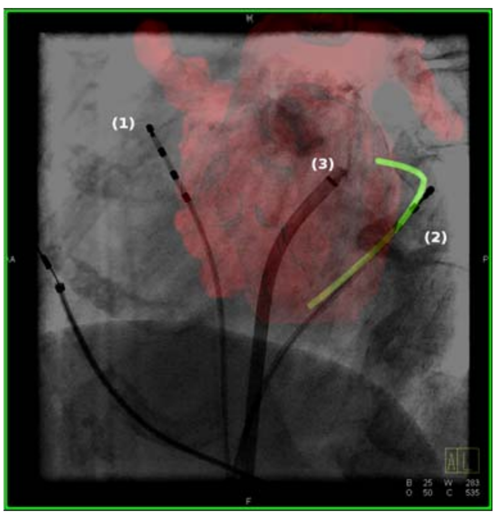

Figure 5. Fluoroscopy 60° left anterior oblique view, displaying electophysiological catheters. EP-catheters in the high right atrium (1) and the coronary sinus (2), transseptal sheath within the left atrium (3). Re-registration is performed when contrast agent is administered into the left atrium. The image shows the 3-D overlay and the extracted CS.

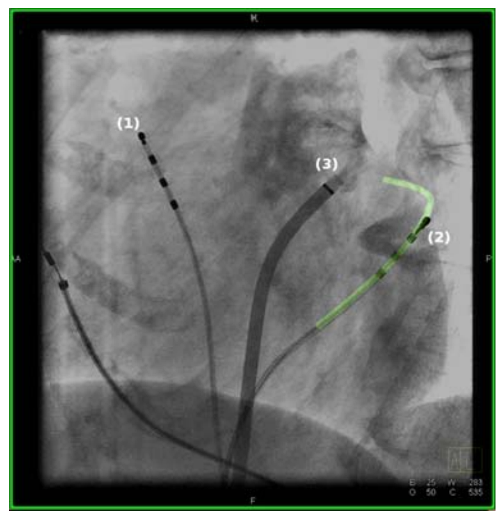

Figure 6. Fluoroscopy 60° left anterior oblique view, displaying electophysiological catheters. EP-catheters in the high right atrium (1) and the coronary sinus (2), transseptal sheath within the left atrium (3). This image shows the administration of contrast agent and the manually extracted CS. The 3-D overlay is not shown as comparison to Figure 5.

Results

Our proposed method was evaluated during clinical trial on 13 patients. The required offset for re-registration was measured for all procedures and was below 2 cm in all cases. The results are presented in Figure 7. On average, a re-registration of 10.6 mm was required, with a minimum of 2.6 mm for one case, and a maximum of 18.9 mm for another patient.

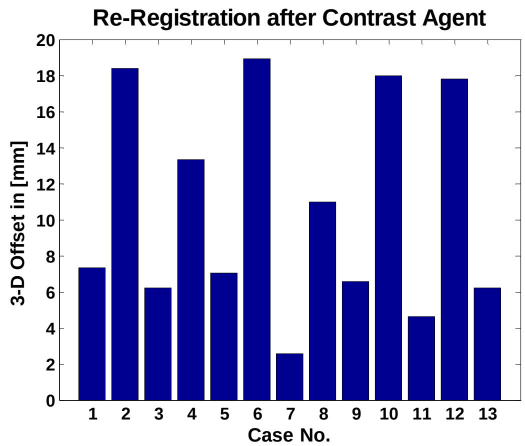

Figure 7. The 3-D offset required for re-registration is calculated using the Euclidean distance. Registration considered only translation. The average 3-D re-registration required 10.6 mm with a minimum of 2.6 mm and a maximum of 18.9 mm.

Conclusion

Our technique provides an early registration method at the beginning of an RFCA procedure for Afib. This can be especially interesting for the transseptal puncture. The use of MR overlay images reduces significantly the radiation exposure for the patient as compared to CT imaging or rotational angiography. Keeping a good registration during the procedure can be facilitated by motion compensation, as shown in [4]. Extending this method might open the possibility to further reduce the use of contrast agent during the procedure.

References

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