Atrial Thickness Mapping for EP Ablation using Black-Blood Restricted Field of View MRI

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Introduction

The treatment of cardiac arrhythmias by RF ablation has grown rapidly in recent years, both in patients with atrial fibrillation (AF) and atrial flutter. MR has the potential to deliver valuable anatomic information of the right and left atrium prior to the ablation procedure [1]. Knowledge of atrial wall thickness can provide information for more accurate RF ablation power settings, which may result in better transmural lesions while reducing the risk of perforation in areas of a thin atrial wall. Current MR imaging techniques use anisotropic resolution, i.e. a higher in-plane resolution, but a relatively large voxel size along the slice direction. Since the left atrium has a complex curved geometry, the use of such an imaging slab cannot resolve the atrial wall without partial volume effects. Isotropic high-resolution 3D spiral MRI was recently proposed to address this problem [2]. In this work, we propose the use of a set of small, localized scans ("beams") with high resolution along the direction perpendicular to the atrial wall to provide accurate thickness information at separate locations on the atrial wall. A segmented 3D surface of the left atrium is used to plan the perpendicular beams. Depending on the heart rate, up to 10 beam scans can be performed during a single breath-hold. An interpolation algorithm is used to calculate a thickness map for the whole left atrium, which is then displayed by a color coded overlay on the 3D surface.

Methods

The recently developed MR-EP Navigator was extended by a new planning functionality [3,4], used together with a 1.5T clinical scanner (Achieva, Philips Healthcare, Best, Netherlands). The whole mapping procedure consists of five work steps: **1.)** A conventional 3D balanced SSFP whole heart scan with navigator gating (end expiration) is performed, scan duration approx. 5 min for a 50% gating efficiency. ECG gating is applied and data are acquired during mid diastole. **2.)** The image data are transferred to the MR-EP Navigator, and a model-based, automatic segmentation of the different heart chambers is performed [5]. **3.)** The surface is displayed, and the operator can interactively place several planning points on the left atrium. Every point defines the center of a beam slice to be imaged, while the normal on the surface at that position forms the corresponding readout direction. **4.)** All planned scan geometries are transferred back to the scanner, and imaging is performed at these positions during several breath-holds. Each beam is acquired in a 2D single shot, black-blood, fat suppressed turbo spin echo (TSE) zoom image with perpendicular slice selection and refocusing gradients [6], which restrict the FOV in two dimensions. The parameters were as follows: FOV=300×60×3mm³, voxel size = 0.75×3×3mm³, 98ms acquisition window and TE_{eff} = 4.9 ms. Data were acquired with a 5-channel cardiac coil and ECG triggering at the same mid diastolic time point as the 3D whole heart data. Imaging was performed during every 2nd heart-beat to maintain efficient blood suppression in patients with irregular heart rates. Up to ten beam slices can be acquired during a single breath-hold. **5.)** Once all beams are acquired, the image data is transferred to the MR-EP Navigator. A gray-value-profile based algorithm is used to find the most central maximal value and the corresponding full width half maximum, which is taken as the wall thickness at the corresponding planning point. The operator can visually review the beam images and measure the thickness of the atrial wall manually to replace the value which was calculated by the automatic procedure. The discrete thickness values are now used as an input for a radial basis function (RBF) based scattered data interpolation algorithm. The same algorithm is already used in the MR-EP Navigator framework for electro-anatomical mapping [7]. The result can be visualized as an overlay on the 3D surface rendering (Figure 1c).

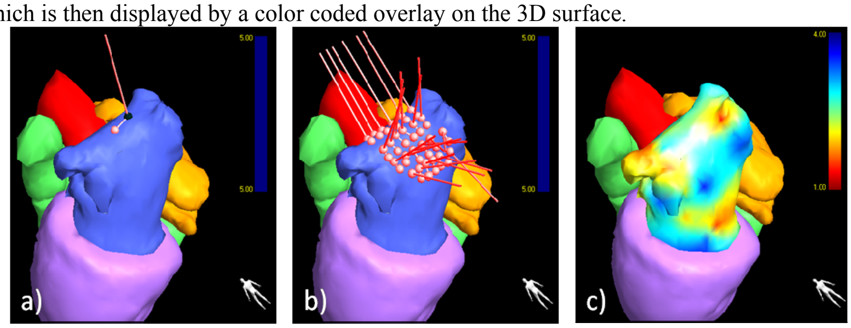

Figure 1: 3D surface rendering of the heart of one volunteer showing the planning and mapping functionality of the MR-EP Navigator for the left atrium. **a):** One beam scan is planned. The long tube depicts the normal on the surface of the atrium, defining the readout direction of the scanning slice. The smaller tube defines the corresponding phase encoding direction. **b)**: A set of 18 beam scans is planned in the same manner. **c)**: With the interpolation algorithm, the thickness is calculated for the whole atrium and displayed color coded on the 3D surface.

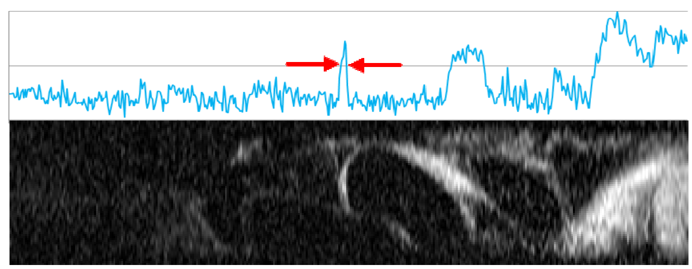

Figure 2: Selected atrial wall zoom image in a volunteer and corresponding central profile, which yields as input for the thickness calculation.

Results

The whole procedure was successfully tested in healthy volunteers. Selected in vivo results obtained in one volunteer are shown in Figure 2. The resulting thickness map is shown in Figure 1c. Fifty beam scans were planned on the surface and subsequently, data was acquired within nine breath holds, each 13 seconds long. The automatic measurement of the wall thickness from the beam scan image data was feasible for large parts of the atrium, but it has to be supported by manual interaction in areas, where different structures are very close to the atrium, e.g. the posterior wall, where the esophagus is located. Visual inspection of the beam scan image data showed good alignment with the 3D whole heart data.

Discussion and Conclusion

The proposed mapping approach achieves accurate thickness information for the left atrium. The single shot, single heart-beat beam scans, with high resolution only in one direction and a small acquisition window, may be advantageous in patients with AF, which often have irregular or very high heart rates. In patients, a contrast enhanced first pass bolus scan, which is acquired in one breath-hold, could replace the whole heart scan as input for the surface generation. The integration in the MR-EP Navigator allows visualization of the color-coded thickness map during the ablation procedure.

References

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