Volumetric Coronary MRA: Visualization of Coronary Arteries and Veins Using Ray Casting and the Bubble Wave Algorithm

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Synopsis

A 3D FIESTA cardiac acquisition covering a 6cm slab in a single breath hold was volume rendered by casting rays onto a surface shell and projecting both the coronary arteries and veins. The blood pool was selectively removed using the bubble wave algorithm. Surfaces of the proximal RCA and LAD with coronary veins are well contrasted by the maximum intensity projection through a 5mm thick region of the surface.

Introduction

Coronary magnetic resonance angiography has been proven to be of clinical value for the detection of coronary artery disease and for the identification of congenital coronary artery anomalies (1,2). Early implementations compromised spatial coverage by using single slice 2D techniques. (3,4). Robust 3D volume acquisitions present an alternative to accomplish adequate spatial resolution in a single breath-hold period or under free breathing conditions. The use of a thick slab volume offers the potential for an easier localization. Furthermore the reformatting versatility of a 3D sequence supports the visualization of long contiguous segments of the coronary arteries. This study examines the application of the ray-casting algorithm for the visualization of the coronary artery morphology.

Method

CMRA was performed in healthy volunteers. Informed written consent was obtained from each volunteer prior to the study, in compliance with the local IRB guidelines. All experiments were conducted on a 1.5 T EXCITE whole body scanner (GE Medical Systems, Waukesha, WI, USA) using an 8-element cardiac phased array coil (GE Medical Systems, Waukesha, WI, USA). Three-dimensional images of the heart were acquired using a fat saturated, ECG-gated 3D FIESTA technique, which was accelerated by exploiting sensitivity encoded parallel imaging. 32 straight axial slices (slice thickness=2.0 mm, interpolated to 1.0 mm) were acquired in a single breath hold resulting in a slab thickness of 64 mm. A data matrix of 256x256 and a FOV of 32 cm was leading to an in-plane spatial resolution of 1.2 mm x1.2 mm (interpolated to 0.6 mm x0.6 mm). Alternatively high spatial resolution images of the right coronary artery were acquired using a targeted slab (slab thickness = 3cm, slice thickness 1mm) and a 384x256 data matrix. For the ray casting a set of parallel rays was projected through the volume until they intersected voxels above a pre-selected intensity. An image of the surface vessels was reconstructed with a maximum intensity in a selected surface depth. In the second data set the blood pool was selectively removed using the bubble wave algorithm (1).

Results

Fig 1 A illustrates a ray casting of a left oblique view of the cardiac surface contrasting both arteries and veins. The arteries (red arrows) were more intense than the veins (blue arrows), Fig 1. Proximal RCA images were ray cast to show the surface morphology and the origin of the right coronary artery as demonstrated in Fig. 1B. The RCA was segmented using the second data set by selectively removing the blood pool indicated by a green arrow (Fig.1C). Both arteries and veins are clearly visualized (see Figure 1A) using the differences in intensity of a maximum intensity projection of a user selected surface shell (5 mm in this case). It is possible to track segments of the veins and arteries in order to assess their morphology (see Figure 1A), origins are very well depicted in order to check for anatomical anomalies (see Figure 1B), and the bubble algorithm supports the separation of the coronary artery from the blood pool (see Figure 1C).

Discussion

It has been demonstrated that the proposed ray-casting algorithm can yield reformatted high quality coronary artery images. Ray casting of an accelerated volume acquisition provides the morphology of both coronary arteries and veins. The blood pool can be selectively removed with the bubble wave algorithm to provide a clear coronary artery projection. In summary, the initial results indicate that the ray-casting algorithm can provide benefits for demonstrating the coronary arteries and thus may facilitate clinical coronary artery interpretations.

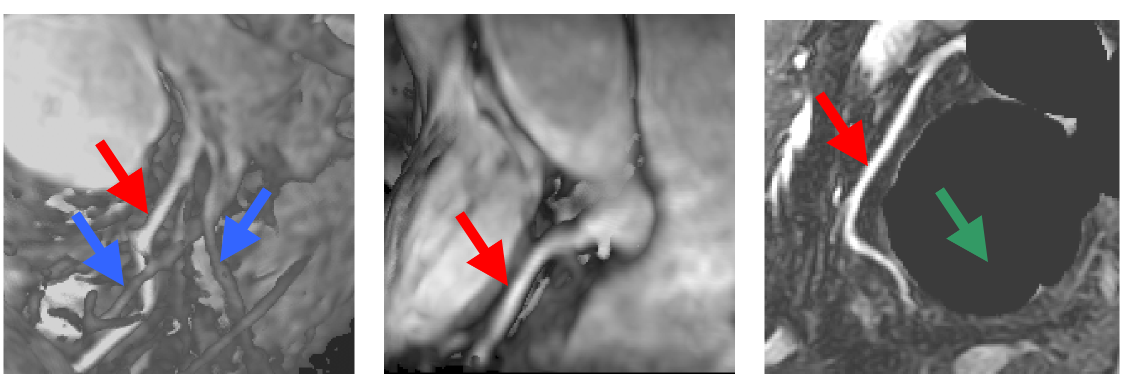

Figure 1. A) Ray cast anterior left oblique view of the left anterior descending artery LAD. **B)** View of the proximal right coronary artery (RCA). **C)** The blood pool was deleted using the Bubble wave algorithm to reveal the RCA

1) Manning WJ et . al, Curr Probl Cardiol. 2002;27:275-333.
2) Bunce NH et. al Radiology 2003; 227:201-208.
3) Edelmann RR et. Al, Radiology 1991; 18:641:643
4) Mayer CH et. Al, Magn. Reson. Med 1992;28:202-213
5) Cline HE et. al, Proc Intl. Soc. Magn Res 10, 2476 2002