Coronary Artery Diameter Determination from Contrast Enhanced MR Angiography; Comparison with Selective X-ray Contrast Angiography

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Introduction

The use of a blood pool agent allows the performance of high resolution 3D MR coronary angiography with enhanced image contrast to non-vascular tissues [1]. This improved visualization of the coronary arteries facilitates image postprocessing. More objective and automated vessel diameter determination is of importance as a first step towards stenosis quantification. In this study we compared automated coronary vessel diameter determination from 3D MR datasets to diameter values obtained by X-ray contrast angiography.

Methods

The proximal coronary trees of four farm pigs (weight of 36 ± 4 kg) were imaged both with contrast enhanced MR imaging and selective X-ray contrast angiography. The animals were sedated and ventilated.

MR imaging was performed on a 1.5 Tesla whole body system (*Gyroscan S15 ACS-NT, Philips Medical Systems, The Netherlands*) using a 20 cm diameter RF surface coil. Before MR angiography BSA-$(Gd\text{-}DTPA)_n$ at a dose of 0.2 mmol/kg [Gd] was injected, resulting in a constant blood T1 value of 33 ± 5 ms for more than an hour [1,2]. 3D MR coronary angiography was obtained using an ECG triggered fast gradient echo technique with flow compensation (TR 14 ms, TE 4 ms, α 31-54°) [1]. Eight phase encoding steps were performed each heart cycle, acquired in mid-diastole. MR signal of fat and myocardium were suppressed by a fat frequency selective RF pulse and an inversion pulse prior to the imaging pulses, respectively. The acquisition was respiratory gated using a navigator image from the diaphragm. The image resolution was set to 1x1x1 mm^3 with a field of view of 256x160x60 mm^3, covering the proximal coronary arteries in an acquisition time of about 40 min.

Selective X-ray contrast coronary angiography was performed immediately after the MR protocol using a digital catheterization laboratory (*Hicor, Siemens, Erlangen, Germany*). At least 4 different projection views were obtained for each artery. The vessel diameter was determined at different proximal segments in all views applying the commercial algorithm on the Hicor system using the catheter tip (6 French) for calibration.

From the 3D MR dataset the diameter of multiple segments in the proximal RCA, LAD, and LCX were determined. First, the MR dataset was reformatted with the slice orientation equal to the view orientation of the X-ray data. Subsequently, the image slice within this reformatted slab was chosen with the segment for evaluation in-plane. Only in-plane segments were evaluated. For each animal multiple reformats were performed, according the different views obtained with the X-ray protocol. At the position for diameter evaluation a line of 2 pixels wide was drawn perpendicular to the vessel. This line-plot was interpolated by a factor of 4. Two slightly different algorithms were used for the diameter determination from this line-plot: 1) the full width at half maximum (FWHM), 2) the full width at half between maximum and baseline signal next to the artery (FWHMB). These algorithms were implemented on an image analysis workstation (*EasyVision, Philips Medical Systems, The Netherlands*).

Results

In total 97 diameter measurements were performed both with MR and X-ray. Figure 1 shows the result of this diameter determination with both algorithms.

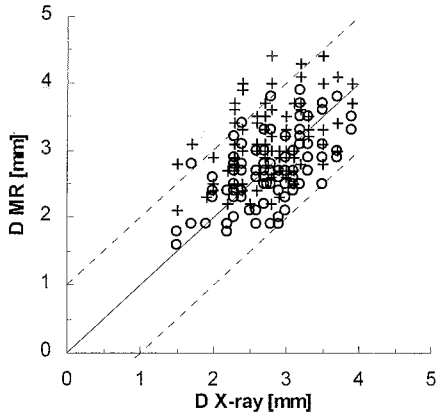

Figure 1. *Coronary vessel diameter determined with MR (+ FWHM, O FWHMB) versus diameter determined with X-ray. The lines show the line of identity plus or minus 1 mm.*

The mean difference in diameter between MR and X-ray was -0.06 mm with a standard deviation of 0.5 mm for the FWHMB, and was -0.36 ± 0.6 mm for the FWHM. The variation observed in the diameter comparison was similar in magnitude for the different coronary arteries studied.

Discussion

In this study we tested a simple algorithm for coronary diameter detection in contrast enhanced MR angiography. The performance of the FWHMB showed a good agreement in diameter determination compared to the X-ray measurement, but a large variation with a standard deviation of about half the MR resolution was found.

A number of potential sources of error can be considered. The accuracy of the X-ray diameter determination is approximately 10% [3]. Remaining respiratory and cardiac motion during the MR acquisition would induce blurring of the MR data, resulting in a systematic overestimation with some variance. There can be some variation in animal positioning between the MR and X-ray imaging studies. However, a large part of the variance could possibly be accounted for by variation in animal hemodynamics and physiology during the MR and X-ray protocol. The dose of contrast agent in combination with the long duration of anesthesia can result in variation of arterial pressure, as observed in one animal in this study. Alteration of vascular tone can also play a role as evidenced in this study by a one mm variation in vessel diameter found in the same animal in different views of the same projection. Blood pressure measurements were not systematically recorded in this study, and should be included in future studies.

In summary, a simple algorithm for diameter detection was tested and good correlation with X-ray data was observed. However, it is possible to devise more sophisticated algorithms such as "snake" algorithms by taking signal gradients and edge continuity into consideration. Additional studies on the detection of the reduction of cross-sectional area at a stenosis will permit further evaluation of this approach.

References

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3. Dodge, J.T., et al., *Circulation* 86, 232, 1992.