Whole-heart coronary magnetic resonance angiography with patient-adapted respiratory motion compensation at 3 Tesla.

M. G. Kaul[1], P. M. Bansmann[1], A. Stork[1], C. Nolte-Ernsting[1], K. Nehrke[2], G. Adam[1]

[1]Department of Diagnostic and Interventional Radiology, University Hospital Hamburg-Eppendorf, Hamburg, Germany, [2]Philips Research Laboratory Hamburg, Hamburg, Germany

Introduction

Coronary magnetic resonance angiography (cMRA) in free-breathing is limited by motion artifacts as well as by the long and complex examination procedure. To overcome these limitations the effect of a patient-specific respiratory motion compensation method in combination with the whole-heart MR angiography (whMRA) was tested in a volunteer study.

Material & Methods

Ten healthy volunteers (mean 28 years; 25-33 years, 4 female and 6 male) were investigated on a 3T whole-body scanner (3T Intera, Philips Medical Systems, Best, Netherlands). A vector-ECG and a six-element phased-array cardiac coil were used. A transverse high temporal resolution cine scan at the level of the descending right coronary artery (RCA) was applied to define the trigger delay and acquisition window for the MRA scans. Navigator driven prospective motion compensation was used for all MRA sequences. Navigator pencil beams were placed on the dome of the right hemi-diaphragm.

To specify the individual respiratory induced heart motion a calibration scan was performed (2D dynamic single shot gradient echo: TR=3.6ms, TE=1.7ms, α=22°, SENSE AP2, FOV=370x278mm^2, matrix 128x64, slice thickness 10mm, 30 dynamics) and parameters were adapted to an affine transformation model (rotation, shearing, scaling and translation) [1]. Those parameters were applied to a transverse whole-heart MRA scan [2] (3D segmented gradient echo: TR=5.2ms, TE=1.7ms, α=21°, 217Hz/pixel, SENSE AP2, FOV=270x270mm^2, matrix 272x272, slice thickness 2mm, 55 slices, effective resolution 0.5x 0.5x 1mm^3) with a 20mm gating window (GW). The transverse whMRA images served as a localizer for the conventional double oblique scans (3D segmented gradient echo: TR=5.4ms, TE=1.6ms, α=21°, 217Hz/pixel, FOV=270x270mm^2, matrix 384x267, slice thickness 3mm, 10 slices, effective resolution 0.5x 0.5x 1.5mm^3) were planed targeted to the RCA. The scans were performed with a gating window of 5mm and a correlation factor of 0.6 between diaphragm and heart [3] for slice tracking. Furthermore, in a control group of five volunteers a whMRA scan with fixed correlation factor of 0.6 and 20mm gating window was performed.

The images were evaluated independently by two experienced radiologists according to an established segmentation scheme [4]. After segmentation the visibility of each coronary segment was graded qualitatively in five grades (0=not visualized, 1=non-sufficient, 2=sufficient, 3=good, 4=excellent). The quantitative analysis of the images was performed with an interactive tool [5] whereas vessel length, diameter and sharpness were calculated. The signal strengths (S) and standard deviations (σ) for blood and muscle were obtained by setting regions-of-interest in the proximal part of the coronary and surrounded tissue. CNR was calculated by $2*(S_{coronary} - S_{muscle}) / (\sigma_{coronary} + \sigma_{muscle})$. Continuous data were compared by a t-test.

Results

An overview of the results of the three sequences is given in table 1. An example of the standard double oblique cMRA and the whMRA with patient-adapted compensation using 20mm gating window is shown in figure 1.

Orientation	Compensation model	GW / mm	volun-teers	visible RCA segments with grade (0…4) proximal	middle	distal	CNR	vessel length / mm	diameter* / mm	vessel sharpness* / %	scan efficiency / %	total scan time
double oblique	factor 0.6	5	10	10 / 2.6	9 / 2.1	7 / 1.0	$7.6 \pm 2.3^{\#}$	89 ± 35	2.5 ± 0.3	59 ± 5	53 ± 12	6:27
transverse	patient-adapted	20	10	10 / 2.4	10 / 2.1	8 / 1.0	$10.1 \pm 1.6^{\#}$	101 ± 27	2.7 ± 0.3	60 ± 6	98 ± 2	10:02
			5	5 / 2.1	5 / 1.8	3 / 0.6	9.7 ± 1.8	85 ± 27	2.7 ± 0.3	60 ± 2	98 ± 2	9:21
Transverse	factor 0.6	20	5	5 / 2.1	4 / 1.3	2 / 0.4	8.6 ± 2.7	68 ± 21	2.8 ± 0.3	60 ± 7	98 ± 2	9:06

Table 1. Overview of results of cMRA scans (GW gating window; * in the first 4cm of the vessel; # significant $p < 0.05$)

The whMRA sequence results in an improved CNR ($p<0.05$). The benefit of the affine compensation by the whMRA is demonstrated by more visible segments, higher grades and a longer visualized RCA. The effect of the size of the gating window on the vessel diameter has to be examined in further studies. Blurring may be expected with a bigger gating window but the vessel sharpness was nearly the same for all sequences. Since the whMRA scan also covers the left coronary arteries examination time can be saved.

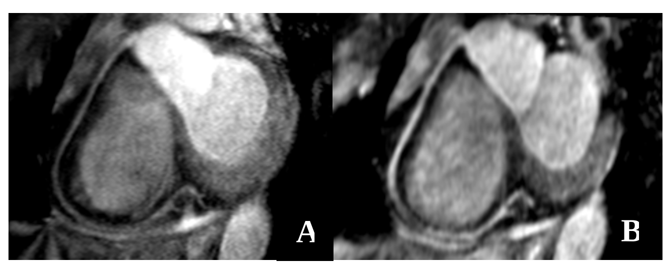

Figure1. RCA acquired with
(A) the standard double oblique technique with 5mm gating window (GW)
(B) the whole-heart approach with affine compensation and 20 mm GW.

Conclusion

The whole-heart approach in combination with the affine patient-adapted respiratory compensation shows to be a promising way to reduce respiratory motion artifacts, scan time and simplifies the examination handling.

References

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