3D Phase Contrast MRA of the Thoracic Aorta at 3T: Feasibility and Effect of Standard and Blood-Pool Contrast Agents

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Introduction: Time resolved (CINE) phase contrast (PC) MRI (flow sensitive 4D MRI) permits the measurement of three directional velocities within entire vascular systems of interests [1]. These data can not only be used for analysis of blood flow but also to derive additional information on vascular geometry by PC angiography (PC-MRA). As PC-MRA is sensitive to available SNR, novel blood pool contrast agents may help to enhance PC-MRA image quality. It was the purpose of this study to determine the influence of different contrast agents on PC-MRA. Detailed evaluation of PC-MRA image quality in the thoracic aorta compared to the reference standard CE-MRA was performed in a study with 31 volunteers.

Methods: All examinations were performed on a 3T system (Magnetom Trio, Siemens AG, Germany, standard 8-chanel phased-array surface coil) on 31 healthy volunteers (mean age 23.7 years, 8 female). For 11 volunteers data were acquired without injection of contrast agent. The remaining 20 volunteers received either intravenous injection of extravascular contrast agent (Gd-BOPTA, Multihance®, Bracco, 10 volunteers, single dose = 0.1 mmol/kg body weight) or blood pool contrast agent (MS 325, Vasovist®, Schering AG, 10 volunteers, single dose = 0.03 mmol/kg body weight). For those 20 volunteers time-resolved contrast enhanced 3D MR-angiography (CE-MRA, injection rate 3.5 ml/s) was executed during free breathing (spatial resolution 2.22-2.24 x 1.25 x 1.5-1.7 mm^3) [1]. For all 31 volunteers flow sensitive 4D MRI measurements covering the entire thoracic aorta were performed using a respiration controlled and ECG-gated rf-spoiled gradient echo sequence (spatial resolution 3.62-4.57 x 1.58-1.69 x 2.60-3.50 mm^3, temporal resolution 48.8 ms, venc=150cm/s)[2]. The study was approved by the local ethics committee and review board and written informed consent was obtained from all subjects.

Data analysis: For all 31 cases PC-MRA were derived from velocity encoded data by calculation of time-averaged absolute flow velocities and additional magnitude weighting to reduce noise according to equation (1) [3]. All MRA data were converted into maximum intensity projections (MIP) and were evaluated by two independent experienced radiologists, who were blinded to the volunteer group (without contrast agent, Multihance® or Vasovist®). Evaluation concerning the image quality and the level of artifacts was performed on a 0-3 scale (see tab.1&2). Inter-observer variability was calculated for visualization quality and artifact level (tab.3). Furthermore, quantitative data evaluation was performed by comparing the diameters of the aorta in PC-MRA with conventional MRA as reference standard. Diameters were measured by two independent readers at ascending aorta (AAo) and descending aorta (DAo) at the height of the pulmonary artery and at the aortic arch (AA) at 12 o'clock position (s Fig 1).

$$I^{PCMRA}\left(\vec{r}\right) = \frac{1}{N}\sum_{i=1}^{N}\left(I_i^{Mag}\left(\vec{r}\right)^2 \sum_{j=x,y,z} V_{i,j}^2\left(\vec{r}\right)\right) \quad (1)$$

j: velocity encoding direction
i: measured time frame
N: total number of time frames

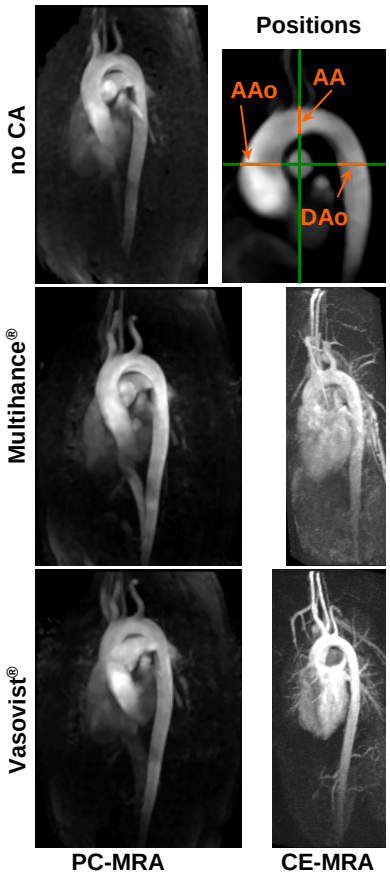

Fig. 1 *Upper row: MIP from PC-MRA derived from data acquired without contrast agent & illustration of positions where diameters were measured; Middle row: MIPs generated from PC-MRA & CE-MRA data acquired after injection of Multihance®; Bottom row: MIPs generated from PC-MRA & CE-MRA data acquired after injection of Vasovist®*

Results: Grading of image quality and artifacts level is summarized in tables 1 and 2. All results are given as mean ± standard deviation. In total, visualization quality was rated as excellent in PC-MRA derived from contrast agent data and as good without contrast agent. In the group with the blood pool contrast agent differentiation of non-arterial structures was slightly improved compared to the other groups. Supra-aortic branches could be better visualized in volunteers group with contrast agent injections. Only minor influence of artifacts on diagnostic image quality was observed (tab 2). An agreement between both readers was achieved with identical scale in 57.7% of all evaluations (52.7% in visualization quality and 67.8% in artifact level grading). The measurements of aorta diameters in PC-MRA data demonstrated excellent agreement with reference standard CE-MRA for both Vasovist ® data (Fig. 2a, r = 0.96) and for Multihance® data (Fig. 2b, r = 0.95).

Discussion: Our results show that PC-MRA can provide a reliable angiography for thoracic aorta of good quality compared to the reference standard CE-MRA, while PC-MRA offers the advantage of additional information on blood flow. Our findings demonstrate that PC-MRA of the thoracic aorta of good quality can even be achieved without additional SNR from contrast agents. However, contrast agent administration clearly improved PC-MRA quality with slight better results for the blood pool agent. Future work includes evaluation of the influence of the contrast agent on the 3D flow visualization (stream lines, particle traces) as well as the influence on quality in 2D data. Additionally further data evaluation such as SNR/CNR analysis is needed for a more detailed quantitative evaluation of image quality.

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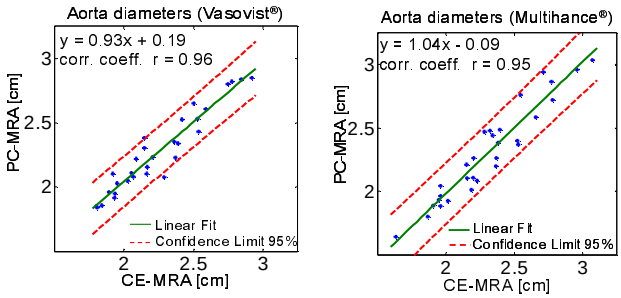

Fig. 2 *Aorta diameters measured in PC-MRA data compared to the reference standard CE-MRA (left Vasovist, right Multihance)*

References :

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Grading differed by	Visualization	Artifact level
0	52.7% (98)	67.8% (63)
1	37.1% (69)	29.0% (27)
2	10.2% (19)	3.2% (3)

Tab. 3 *Agreement of image quality grading*

Visualization	Segment 1 AAo	Segment 2 Arch	Segment 3 DAo	Segment 4 Ao abd	Supraaortic branches	Differentiation of non-arterial structures	**MEAN**
no CA	1.86 ± 0.97	2.50 ± 0.84	2.23 ± 0.79	2.09 ± 1.00	0.64 ± 0.64	0.91 ± 0.67	1.70 ± 0.69
Multihance	2.15 ± 0.85	2.95 ± 0.22	2.70 ± 0.46	2.92 ± 0.22	1.50 ± 0.97	1.05 ± 0.92	2.22 ± 0.73
Vasovist	2.35 ± 0.79	3.00 ± 0.00	2.80 ± 0.51	2.90 ± 0.30	1.35 ± 0.85	1.60 ± 1.02	2.33 ± 0.64

Tab. 1 *Visualization quality of MIP generated from PC-MRA data with following grading scale*
0 = poor diagnostic quality, 1 = moderate diagnostic quality,
2 = good diagnostic quality, 3 = excellent diagnostic quality

Artifacts	Ghosting	Blurring	Noise	**MEAN**
no CA	3.00 ± 0.00	2.05 ± 0.37	1.32 ± 0.70	2.12 ± 0.69
Multihance	2.95 ± 0.22	2.05 ± 0.50	2.20 ± 0.60	2.40 ± 0.39
Vasovist	3.00 ± 0.00	2.20 ± 0.51	2.25 ± 0.62	2.48 ± 0.37

Tab. 2 *Influence of artifacts on image quality with following grading scale*
0 = severe artifacts, 1 = moderate artifacts,
2 = minor artifacts, 3 = no artifacts