

Intra-individual assessment of the bolus properties of 0.5M gadopentetate dimeglumine and 1.0M gadobutrol in time-resolved contrast-enhanced 4D-MRA and dynamic CT in a minipig model

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Aim of the study

The study focuses on the intra-individual comparison of vessel signals in an animal model after the application of equimolar doses of 0.5 M gadopentetate dimeglumine and 1.0 M gadobutrol by using time resolved contrast-enhanced magnetic resonance angiography and dynamic CT imaging.

Introduction

Since limitations of temporal and spatial resolution are decreasing with technical progress, time resolved contrast-enhanced MRA (4D-MRA) is more and more applied in various clinical indications (1-4). Previous studies have shown that the choice of contrast-agent may have an impact on image quality parameters of vascular imaging and vessel-to-background contrast (5,6). Vascular bolus concentrations and magnetic properties of the contrast agents described by their r_1 - and r_2 -relaxivities are crucial factors that determine the vascular signal enhancement. 1.0M gadobutrol is the only gadolinium-based contrast agent approved for clinical use at a 1 molar concentration (7). This study was performed to systematically investigate the impact of the 1M concentration of GB in comparison to the standard 0.5M concentration of gadopentetate dimeglumine in regard to the vascular gadolinium concentration determined by dynamic CT and in regard to the MRI signal intensity determined by 4D-MRA in an animal model of minipigs.

Methods

7 Goettinger minipigs (2 female, age: 14.8±0.4 months) were examined on a 1.5 Tesla clinical whole body MRI and a clinical 64 slice CT. The animals were handled in compliance with the German animal welfare legislation and with the approval of the state animal welfare committee. With intervals of more than 2 days to allow for complete elimination of the prior contrast agent, all animals received dynamic CT and 4D-MRA with single doses of 0.1mmol/kgBW 0.5M gadopentetate dimeglumine (0.5GD) and 1.0M gadobutrol (1.0GB) and 10ml saline flushes each at flow rates of 1ml/s. Studies were carried out under full anesthesia with breath-holds for dynamic sequences. Contrast-enhanced 4D-MRA was performed using a TWIST (8-10) algorithm (TR, 2.45 ms; TE, 0.89 ms; FA, 25°; voxel size, [1.6 x 1.6 x 5.0] mm³; 70 dynamics, 16 slices each; 0.49s image update time; FOV: [400x200] mm²; partitions, 20%A, 25%B; partial Fourier 6/8; Grappa 2). Dynamic CT measurements (0-20s post injection) of the thoracic region were performed without table feed at 80 kV / 485 mAs_{eff} with a temporal resolution of 0.3 s.

Quantitative analysis of 4D-MRA included signal enhancement of regions of interest (ROI) placed in the pulmonary trunk, the ascending aorta and the descending aorta (fig.1). By quantifying the full width at half maximum, the temporal width of the bolus (signal time) curve was used to estimate bolus sharpness (MeanCurve, Syngo®, Siemens Healthcare, fit to gamma variate function [Matlab]) (11). Dynamic CT-signal enhancement was measured by ROI analysis, whereas the positions corresponded to the ROIs in 4D-MRA (DynEva, Syngo®, Siemens Healthcare). In CT, opacification levels were transformed to Gd-concentration on the basis of prior phantom measurements.

Results

In 4D-MRA, full width at half maximum calculations of the signal curves showed narrower bolus peaks for 1.0GB vs. 0.5GD with peak widths of 4.2±0.3s vs. 6.2±0.9s (pulmonary trunk, p=0.001), 5.6±0.3s vs. 6.7±0.9s (ascending aorta, p=0.008) and 5.9±0.4s vs. 7.0±0.9s (descending aorta, p=0.006). In 4D-MRA the peak signals were significantly higher for 1.0GB compared to 0.5GD in all investigated vessels (pulmonary trunk, 1013.4±94.2 vs. 845.0±80.6, p=0.001; ascending aorta, 705.0±91.3 vs. 583.1±122.2, p=0.001; descending aorta, 491.8±40.2 vs. 429.0±49.7, p=0.002).

In dynamic CT examinations, the bolus shape in examinations with 1.0GB compared to those with 0.5GD was also narrower and higher with significantly shorter time-to-peak intervals for 1.0GB vs. 0.5GD of 8.7±0.3s vs. 10.3±0.2s (pulmonary trunk, p<0.0001), 12.9±0.8s vs. 14.3±0.6s (ascending aorta, p=0.003) and 13.2±0.8s vs. 14.5±0.7s (descending aorta, p=0.005). Significantly higher peak signals were detected after injection of 1.0GB in dynamic CT. When compared to prior phantom measurements, the respective peak Gd-concentrations (in mgGd/mL) for 1.0GB vs. 0.5GD were 3.3±0.5 vs. 2.4±0.3 (pulmonary trunk, p=0.006) and 2.1±0.2 vs. 1.7±0.2 (ascending aorta [p=0.002] and descending aorta [p=0.004]).

Conclusion

Compared to standard 0.5M gadopentetate dimeglumine, 1.0M gadobutrol offers significantly higher vessel signal in 4D-MRA and optimized bolus kinetics. The latter is especially relevant for better arterio-venous separation and for perfusion analysis.

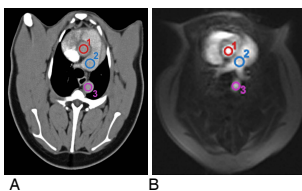


Fig. 1 Placement of regions-of-interest in the ascending aorta (1), pulmonary trunk (2), and descending aorta (3) in corresponding axial slices of dynamic CT (A) and 4D-MRA (B) for quantitative analysis.

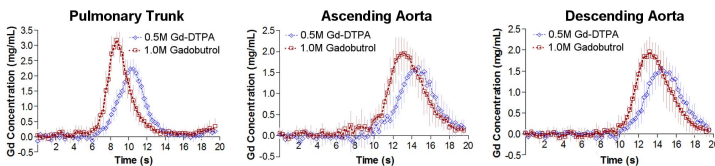


Fig. 2: Calculated Gd-concentration in dynamic CT in the pulmonary trunk, ascending aorta, and descending aorta after application of 1.0GB and 0.5GD at flow rates of 1ml/s.

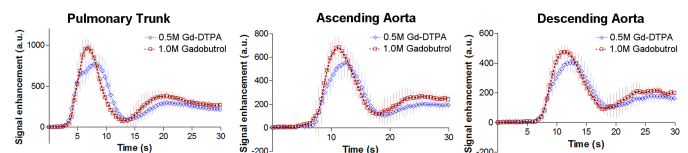


Fig.3: Vessel signal in 4D-MRA in the pulmonary trunk, ascending aorta, and descending aorta after application of 1.0GB and 0.5GD at flow rates of 1ml/s.

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