# Value of MRA Sequences and Contrast Agents For the Evaluation of High-Degree Stenosis: A Phantom Study.

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## Introduction

MRA has been greatly improved by the combined use of contrast agents that reduce the T1 of blood and fast three-dimensional (3D) gradient echo T1-weighted sequences. In order to better evaluate stenosis, 3D contrast-enhanced (CE) MRA must overcome opposite constraints: to provide a high temporal resolution that will avoid venous overlapping while maintaining excellent spatial resolution and sufficient contrast supplied by contrast agents (CA). Blood pool contrast agents (BPAs), characterized by a high r1 relaxivity and an intravascular distribution, which reduces extravasation and thus the background intensity, have been developed to improve contrast resolution [1]. Our purpose was to investigate the role of high resolution (i.e., spatial or temporal) of MRA sequence and the role of contrast agent (i.e, r1 relaxivity, r2 relaxivity, doses) in the evaluation of high degree stenosis.

## Methods

Phantom and MR protocol: A double centric elliptic stenotic phantom (50% and 95% diameter reduction with a reference diameter at 6 mm) manufactured as previously described [2], successively filled with four concentrations of two CA, was studied in a head coil of a 1.5T magnet (Vision, Siemens, Germany). Images were acquired in the sagittal plane of the phantom with two 3D FISP MRA sequences: 1) a booster MRA sequence, selected for its high temporal resolution (TR/TE = 3.2/1.1 msec; flip angle: 25°; voxel size: 3.82 mm3; acquisition time:6 sec) ; 2) a high resolution (HR) MRA sequence, selected for its high spatial resolution ( TR/TE = 4.4/1.4 msec; flip angle: 30°; voxel size : 1.39 mm3 ; acquisition time: 22 sec). Contrast media: Two CA were tested: a reference Gd chelate , i.e. Gd-DOTA (Guerbet, Aulnay-sous-bois, France; MW:557 Da; r1 relaxivity in water at 60 Mhz: 2.9 mM-1.s-1), and a high r1 efficiency Gd-compound with low extravascular diffusion rate, i.e. P760 (Guerbet, Aulnay-sous-bois, France; MW: 5290 Da; r1 relaxivity in water at 60 Mhz: 25 mM-1.s-1). Four equivalent concentrations, in terms of r1 efficiency, were defined according to experimental data obtained in rabbits by serial arterial sampling, as explained elsewhere [3]. Concentrations A and B corresponded to the arterial peak concentration after an IV bolus injection of respectively a double (0.2 mmol/kg) or a single dose (0.1 mmol/kg) of Gd-DOTA. C corresponded to the half-arterial peak after injection of a single dose of Gd DOTA and D to the arterial concentration one minute after IV injection of a single dose. Image Analysis: Qualitative analysis: both stenotic and reference diameters were ranked on a scale of 0-3, as follows: 0 = no signal; 1 = signal with sharp boundaries <50% of the length of the stenosis and/or reference diameter; 2 = with sharp boundaries >50% of the length; 3 = with sharp boundaries over the full length. Quantitative analysis: maximum of signal intensity (SI) and signal-to-noise ratio (SNR) were studied at concentration A-D of the two CA, in both stenosis and in the reference diameter of phantom, with the two 3D MRA sequences. Experimental SI was compared to theoretical SI [4]. Data analysis: Analysis of variance was performed (significance for $p<0.05$) and experimental SI was compared to theoretical SI using a regression analysis.

## Results

With the 3D HR sequence, both visual and quantitative analysis were significantly better compared to the 3D booster sequence, at each phantom diameter. Quantitative analysis was significantly improved by injection of a double versus a single dose of each CA (Gd-DOTA or P760), primarily in high degree stenosis. Theoretical data, well correlated to experimental data ($R2=0.91$), showed that T2* effects are negligible at the clinical dose tested, and that SI/Mo initially increased with increasing concentrations of CA, until a peak, before decreasing.

Fig 1a and 1b : Experimental SI (i.e. estimated marginal means) expressed in function of the concentration D to A of respectively Gd-DOTA and P760, with the 3D Booster ( solid line) and the 3D HR ( dotted line) MRA sequence. At any concentration of CA, SI was significantly higher with the 3D HR compared to the 3D booster sequence and significantly increased from D to C, from C to B and from B to A ( p< 0.005).

## Discussion

In the optimized conditions of a phantom study, we demonstrated that spatial resolution is the more accurate parameter to be optimized, to accurately analyze a high-degree stenosis. Most important, the injection of a double dose of both CAs provided a better quantitative analysis than a single dose, particularly in the analysis of the high-degree stenosis.

## References

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*Figures omitted at submission.*