

# Analysis of Subtraction Methods in 3D MR DSA for Peripheral Vascular Disease

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## Introduction

3D contrast enhanced MR angiography is one of the most promising modalities for treatment planning of peripheral vascular disease. To cover the large FOV required, there are generally two approaches: either use a moving table with a single injection of contrast agent, or use the standard stable table and multiple injections (one for each volume of interest). We use a multi-injection protocol to emphasize image quality of the lower leg<sup>1</sup>. Due to the time delay between multiple injections, the contrast from the prior injection flows into the veins, and will be visible during the scan of the next station. Thus the arteries and veins may overlap in the MIP images of the 3D data sets. Subtraction of a mask image from the overlapped image is a common way to separate arteries from veins. Several methods of doing the subtraction and MIP are possible. The purpose of this study is to compare the different methods and analyze the observed behavior through mathematical modeling.

## Method

Five patients with suspected peripheral vascular disease were scanned on a 1.5T MR system (GE Signa Advantage 5.7) using a two station, two injection protocol. At the first station we injected 20cc each of Magnevist (Berlex) and saline at a flow rate of 1.5ml/s. After a timed delay, we scanned one lower leg in the arterial phase with centric ordered 3D SPGR, FOV=40×20×6cm, TR/TE=9.5/1.5ms, flip angle=20°, 512×256×64 matrix. Prior to the second injection, we scanned the upper legs as the mask data set (FOV=40×40×6cm, 256×256×64 matrix). During this scan, the Magnevist from the first injection had become uniformly distributed, so both arterial and venous signals were increased. After the mask scan, we started the second contrast injection, and performed a scan of the upper legs when the new contrast was in the arterial phase. We assumed the contrast concentration level in veins did not change much between these two scans, so subtraction will reduce venous signal to near zero.

For processing the data of the upper legs, we can use either complex subtraction or magnitude subtraction, then create the MIP image, or we can simply subtract the two MIP images of the two 3D magnitude data sets (we call this MIP subtraction here). Complex subtraction has been found to be preferred over magnitude subtraction to reduce the partial volume effect<sup>2</sup>. However, different from the 2D thick slab protocol used in that paper, in our 3D study, the image pixel size is about 1.5×1.5×1.0mm, less than the diameter of main arteries. Thus, the partial volume effect is not a big issue here. As a result, the main question focuses on which subtraction-MIP method gives the best SDNR (signal difference to noise ratio) to separate arteries from veins and background tissues.

## Results

One set of clinical MR DSA MIP images produced with different subtraction methods is shown in Figure 1. The relative background noise distribution is shown in Table 1. After MIP subtraction, the mean of the background noise is dramatically decreased, while complex subtraction has the biggest noise mean and standard deviation. Figure 2 illustrated the mathematical reason of these changes.

## Simulation

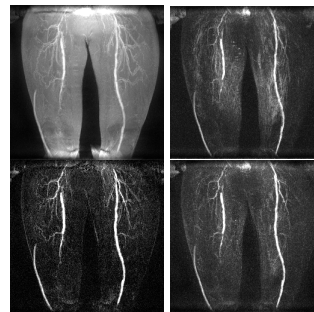
A computer simulation was run to verify the different noise distributions after subtraction-MIP operations. The result in figure 3 is in general agreement with what we expected. The noise mean and standard deviation normalized to those for complex subtraction are 0.51 and 0.77 for magnitude subtraction and 0.10, 0.61 for MIP subtraction respectively. In all cases, experimental measures are slightly higher. This may be due to the fact that noise in the original images has more structure than expected from standard statistics.

## Discussion

The purpose of subtraction is to improve arterial conspicuity by suppressing veins and background tissues. In arterial regions where there is significant signal both in the mask and new data sets, signal variability is similar in all post-processing methods described here<sup>3</sup>.

Specifically, all yield similar vessel intensities, demonstrating the lack of partial volume effects at high resolution. Generally, arterial SNR is degraded by subtraction since signal is removed while noise variance increased. The signals of background tissues are nearly completely subtracted; therefore, the noise distribution in the background tissue areas behaves similarly to the background noise areas. With the decrease of noise mean and variance in Magnitude and MIP subtraction, some small arteries in particular can be more clearly seen in these images. Complex subtraction not only increases background signal due to noise statistics, but can also introduce artifacts due to phase instability between the mask and new data sets.

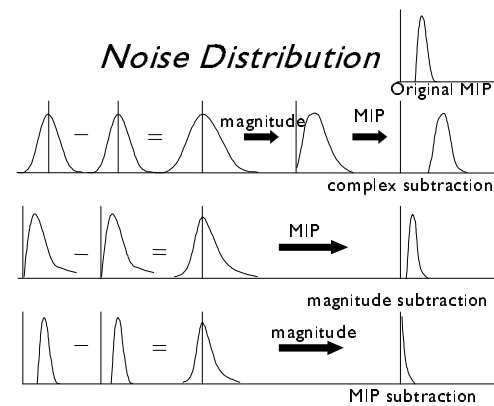
Therefore, where subtraction is considered necessary to remove background clutter for improving arterial conspicuity, MIP subtraction yields best background suppression. Alternative approaches, such as segmentation, may yield better arterial images if these can achieve background and venous suppression without the SNR loss in the arteries and without losing small arteries.



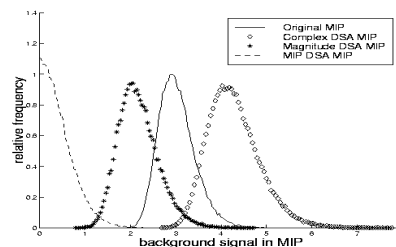
**Figure 1.** Subtraction of clinical images. Clockwise from the upper-left: original un-subtracted MIP image; Complex subtracted MIP image; Magnitude subtracted MIP image; MIP subtracted image. In MIP subtracted image, we can see more small vessels because its noise mean and standard deviation are both the smallest.

**Table 1.** Relative background noise distribution after subtraction-MIP

	Complex subtraction	Magnitude subtraction	MIP subtraction
Noise mean	1	0.63±0.06	0.14±0.01
noise std deviation	1	0.95±0.05	0.77±0.05



**Figure 2.** Illustration of noise distribution through subtraction-MIP. The distribution of complex data is Gaussian; their magnitude is Rayleigh distributed. After doing the MIP projection, the mean of the distribution gets bigger, while the deviation gets smaller<sup>4</sup>.



**Figure 3.** Simulation of noise distribution after subtraction-MIPs. The original complex data of a 256×256×60 matrix is Gaussian distributed with zero mean and standard deviation 1.

## References

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