# USPIOs quantification in brain mice 2D MR images by default field deconvolution

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## Introduction

UltraSmall SuperParamagnetic Iron Oxide (USPIO) particles are used in MRI contrast agents for diagnosing different pathologies such as stroke and cancer. Determining the concentration of USPIO in MRI is of great interest. Here we present a non invasive quantification process of the USPIOs' concentration from MR images based on the physical effect of these nanoparticles induced by the difference of magnetic susceptibility.

## Materials

120,000 cells, labeled with Sinerem®, have been injected in brain mice (the iron concentration is theoretically equal to 0.32mM [Fe]). Two gradient echo images were performed in the coronal view with TE=5.4 and 10 ms (see Fig. 1). The other acquisition parameters are: TR=468 ms, flip angle=20°, $B_0$=7T and BW=50-kHz.

## Methods

To perform the concentration estimation of USPIOs, we use the SYMDEF method [1] defined by:

$$\chi = TF^{-1}\left( \frac{\hat{\Delta B}_0}{\hat{H}} \frac{\left|\hat{H}\right|^2}{\left|\hat{H}\right|^2 + k_{cls}\left|\hat{P}\right|^2} \right) \qquad \textit{(Eq. 1)}$$

where $\hat{.}$ stands for the Fourier variable, H our deconvolution filter described in [1], P the Laplacian operator, $k_{cls}$ a tuning parameter to reduce noise effect, and $\hat{\Delta B}_0$ is the estimated default field computed from the unwrapped [2] difference of phase obtained from two gradient echo images [3]. Finally, we estimate the concentration $C_{uspio}$ as described by (Eq. 2).

$$C_{USPIO} = \frac{\chi B_0}{\mu_0 \chi_m (1+\chi)} \qquad \textit{(Eq. 2)}$$

with $\chi_m$ is the USPIOs magnetic moment ($\chi_m$=4.7 µA/m²/µmol[Fe]).

## Results

Fig. 2 presents the estimated default field map and fig. 3 the magnetic susceptibility map obtained with the SYMDEF method. The noise standard deviation is measured to 0.02 and the tuning parameter is chosen equal to $8e^{-4}$. In order to asses the quality of our approach we have defined a mask from this map (fig. 3) to measure the mean value of magnetic susceptibility of the USPIOs and of the brain. Table 1 gives the mean susceptibility measure. The brain susceptibility is supposed to be equal to -9.06 ppm and our method finds a mean susceptibility of -9.16 ppm. The susceptibility of USPIOs is evaluated to -6.35 ppm. It is compared to -6.32 ppm calculated by inversing (Eq. 2) and considering the label 1 equally composed of cells and USPIOs. Based on the same assumption and according to (Eq. 2) that corresponds to an iron concentration of 0.35 mM [Fe] compared to 0.32 mM expected.

## Conclusion

The proposed USPIOs quantification process based on the SYMDEF deconvolution approach only requires two classical gradient echo MR images and performs a coherent estimation of the iron concentration. Indeed, the error is below 10% (0.35 mM instead of 0.32 mM). Such a process is defined in 3D and can also directly be applied on multi-slice or 3D MR acquisitions.

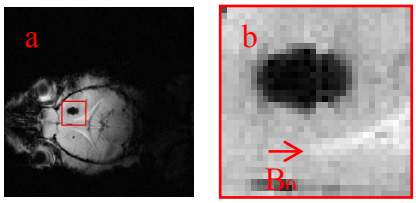


Figure 1: MR gradient echo images of brain (a) 256x256 pixels, TE/TR=10/468ms – (b) ROI of 32x32 pixels around USPIOs.

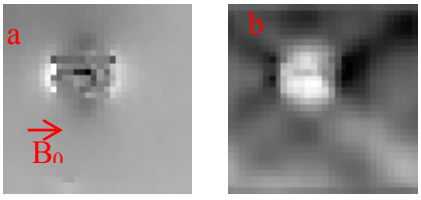


Figure 2: (a) Default field estimation – (b) Magnetic susceptibility estimation from SYMDEF method.

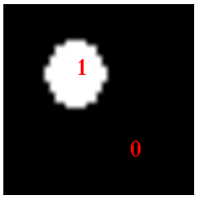


Figure 3: Mask used to estimate the mean susceptibility of the brain (0) and of the USPIOs' labeled-cells (1).

| | Brain (0) | UPSIOs (1) |
|---|---|---|
| Susceptibility (ppm) | -9.16 +/- 0.3 | -6.35 +/- 0.9 |
| Theoretical susceptibility (ppm) | -9.06 | -6.32 |

Table 1: Mean susceptibility values calculated from the mask of fig. 3.

**References:** [1] Charpigny D. *et al* ICASSP, p.485, 2010– [2] Goldstein *et al* Radio science, vol. 23(4), pages 713–720, 1988– [3] Kanayama *et al* Magnetic Resonance in Medicine, vol. 36, pages 637–642, 1996.