Susceptibility blooming effect: Quantifying spatial resolution dependence

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Target Audience: MR physicists, research scientists, and physicians who are interested in susceptibility contrast imaging and its applications in detecting small lesions/structures with iron component.

Purpose: Susceptibility blooming effect (or dark glow) in MRI refers to signal loss due to local field inhomogeneity and spin dephasing that extends outside the true object size with enhanced visibility. It has been reported that such blooming effect increases at higher field strength and TEs using gradient-echo type sequences[1, 2], however, its dependent relationship with spatial resolution is not well known. The purpose of this study is to explore and quantify the spatial resolution dependence of blooming factor (i.e. size expansion change) at different TEs and iron concentrations at 7T MR using a multicomponent phantom.

Methods: A phantom was fabricated using plastic cylinders (diameter of 3mm) filled with different iron concentrations made of varied solutions of Ferumoxytol, an Ultrasmall SuperParamagnetic Iron Oxide (USPIO) particle, and one cylindrical well contained only normal saline. The plastic cylinders were immersed in agarose gel to reduce susceptibility effects near the phantom edges. All images were collected on a 7T MR scanner using a multi-echo 3D gradient echo imaging parameters were as follows: TR=40, Flip Angle 20◦, FOV=384mm, TEs=[3.36 - 6.16 - 8.96 - 11.76 - 14.56 - 17.36 - 20.16 - 22.96 - 25.76 - 28.56 - 31.36], BW=390Hz/px, with slice thickness 1 mm and matrix size of 448x448, 256x256, 192x192, 128x128 with resultant spatial resolution of 0.86, 1.5, 2, 3mm respectively. Mathematical phantom simulations were also involved the modulation of object size/shape, susceptibility values, and resolution in order to characterize the algorithm performance across a variety of conditions. The blooming factor (BF) was computed as: BF = detected area / true cylinder area.

Results: In consistent with the simulated results, the blooming effect is more pronounced at lower spatial resolution (or larger pixel size) in our phantom experiment (**Figure 1**). The blooming factor is increasing with TE increases (**Figure 2**). For example, for 3mm-diameter cylinder at 3mm isotropic resolution and TE of 31.36ms, iron concentration of 3.55mmol/l, the BF is 7.0 compared to 4.5 at TE of 14.56ms. At TE=31.36 and 3mm spatial resolution, the BF was 125%, 116% and 104% higher than the one measured on the images with higher resolutions of 0.86, 1.5 and 2mm; respectively.

Conclusion: Our data suggest that the spatial resolution has an impact on blooming factor (i.e. size enlargement). The simulation had proved that the blooming factor can be increased by playing on the ratio of the voxel size to the object size. In a clinical perspective, the blooming factor could be helpful to measure the micro lesions that are not seen on conventional imaging, given 3-7 times bigger blooming effect with optimized imaging parameters at ultra-high-field MR.

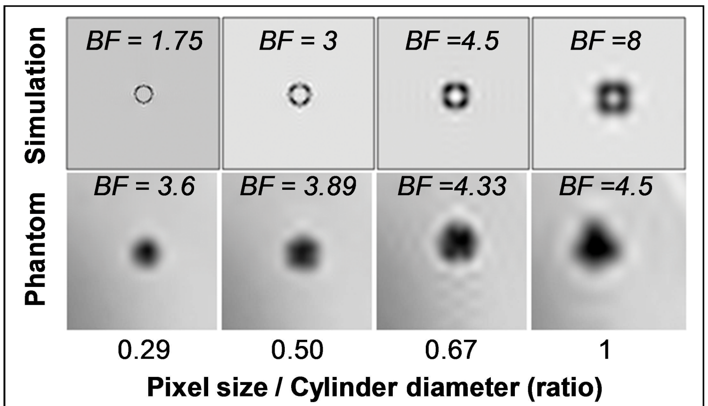

Fig 1. Simulation and 3mm phantom acquisition of a USPIO tube at [Fe] = 3.55mmol/l, TE=14.56ms. BF= Blooming Factor

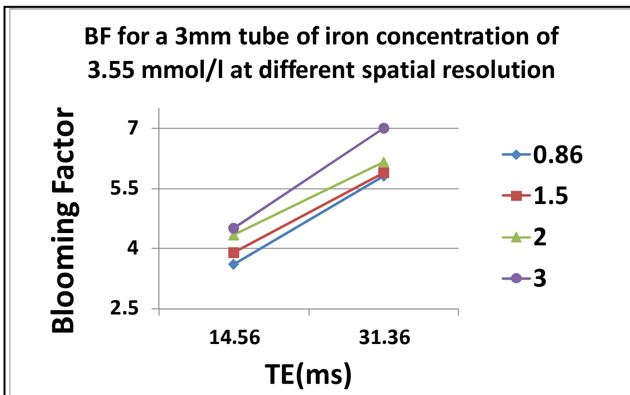

Fig 2. Measurement of the blooming factor at twoTEs for spatial resolution 0.86, 1.5, 2 and 3 mm isotropic.

References: 1. Haacke EM, Susceptibility weighted imaging in MRI: basic concepts and clinical applications: Wiley. com; 2011. 2. Haacke EM,. Magnetic resonance imaging: physical principles and sequence design: Wiley-Liss New York; 1999.
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