The effects of voxel size and image smoothing on R2* measurements of the human brain

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Introduction: Gradient echo imaging is gaining importance due to its high sensitivity to changes in tissue magnetic susceptibility, its fast data acquisition, with the growing number of ultra high field scanners and its low specific absorption rate. Quantitative imaging of the R2* relaxation rate employing multiple echoes can be used to assess blood oxygenation [1], for instance, or brain iron content [2,3]. However, R2* is not a strictly intrinsic tissue property, but it also depends on the spatial relationship between voxel geometry and background field inhomogeneities. These background field inhomogeneities cause an additional signal decay. Using low spatial resolution allows for faster data acquisition. However, signal to noise ratio (SNR), is only improved in areas with low background field inhomogeneities. High resolution data are less sensitive to background inhomogeneities, but smoothing of the images may be necessary to improve SNR. However, smoothing across tissue boundaries also influences R2* values, in particular if small regions of interest are analyzed. To investigate the influence of spatial resolution and smoothing on R2* values. We acquired images with high spatial resolution and applied spatial smoothing to the complex data (which simulates acquisition at lower spatial resolution) and to the magnitude data.

Material & Methods: 3D multi echo gradient echo data were acquired in 12 healthy volunteers (range from 20 – 53 years, average 34 years) on a 3T system (Philips Achieva) using an 8 channel head coil. Imaging parameters: TE=13ms–41ms; echo interval = 7ms; TR/FA = 45/17°; FOV = 210 x 160 x 60mm^3; acquired spatial resolution=0.5 x 0.75 x 1.5 mm^3; reconstructed voxelsize=0.4 x 0.4 x 0.75 mm³; reconstruction matrix of 512 x 512 x 80 voxels; scan duration = 6.7 min. Maps of R2* relaxation rates were computed from the five magnitude images using a Levenberg-Marquardt least squares method for non-linear equations with correction for signal decay due to background field inhomogeneities [4,5] using field maps computed from the phase of the first two echoes. To simulate the effects of a lower acquisition matrix, 3D Gaussian smoothing of the complex data (labelled GC) was performed with a 3x3x2 (G3C), a 5x5x3 (G5C) and a 7x7x5 (G7C) filter. Gaussian smoothing (GS) and median filtering (M) was applied also to the magnitude data. Twenty two regions of interest (ROI) were drawn in the original R2* images in all volunteers and R2* was analyzed for all variations of smoothing.

Results: Complex smoothing (G3c, G5c and G7c) leads to signal loss due to intravoxel dephasing and therefore to higher R2* values in areas with strong background field inhomogeneities. Gaussian smoothing of the magnitude data leads to blurring of R2* maps. Blurring across tissue boundaries leads to large changes in R2* of small structures. In large structures, on the other hand, the blurred area is small compared to the size of the ROI and the change in R2* becomes therefore smaller with increasing ROI-size. Median filtering better preserves tissue boundaries than GS (compare G3/5/7 with M3/5/7 in Fig. 1). Figure 2 shows the R2* values of each ROI averaged over all volunteers for the different smoothing approaches. R2* values increase with complex smoothing filter size, independent of ROI volume. Gaussian smoothing decreases R2* more than median filtering. With increasing ROI-volume R2* value differences due to spatial smoothing could be neglected in spatial GS or MS. Complex smoothing, however, increased R2* values independent of ROI volume. The changes in R2* increase with increasing kernel size.
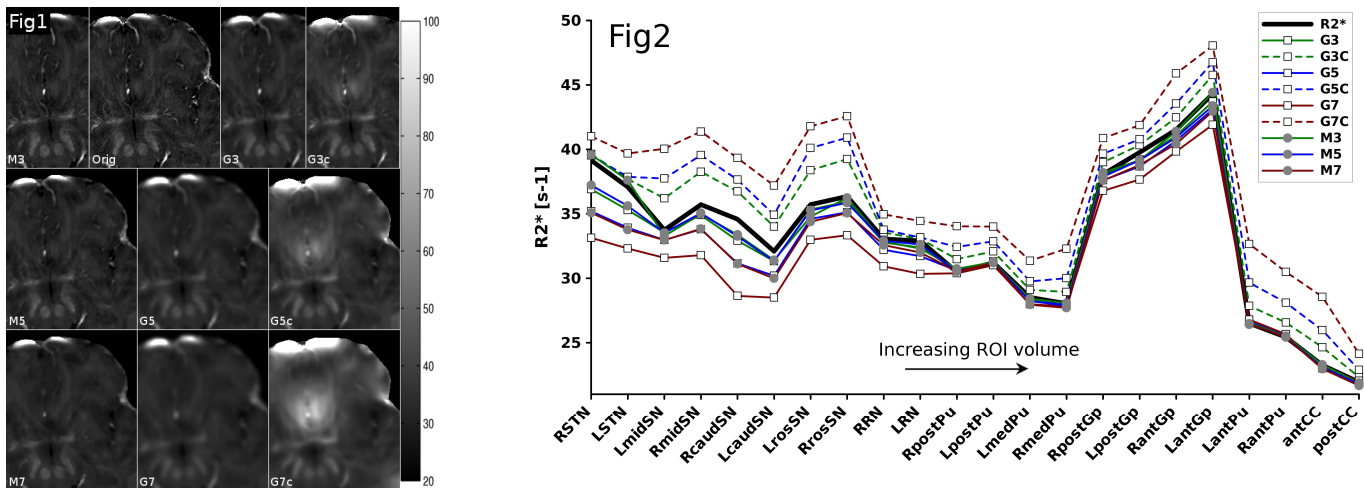
Discussion: Our results show that it is important to keep in mind that voxel size has an influence on the apparent R2* values. In general, the larger the voxel size the higher the contribution from background field inhomogeneities. This is also reflected in the fact that R2* is more sensitive to changes in spatial resolution in more caudal areas, such as the SN or the RN, where field inhomogeneities produced by the nasal sinus are present. These effects are well known and an increase in spatial result ion is often used as an effective way to reduce unwanted decay due to background field inhomogeneities. The effects of filtering the magnitude data are less dramatic, but in small structures, such as the STN or the SN, the R2* are changes can be relatively large. Our findings suggest that R2* values should interpreted in the light of voxel geometry and data processing.

References: [1] Sedlacik et al. Magn Reson Med 2007; 58(5):1035-44 **[2]** Haacke et al. Magn Reson Imaging. 2005;23(1):1-25 **[3]** Martin et al. Neurology. 2008;70(16 Pt 2):1411-7. **[4]** Fernández-Seara et al. Magn Reson Med 2000;44:358-366. **[5]** Dahnke et al. Magn Reson Med 2005;53:1202