Perfusion MRI of the Human Brain with Dynamic Susceptibility Contrast: Gradient Echo versus Spin Echo Techniques

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Background: In computer models and animal studies, spin-echo (SE) based perfusion MRI techniques are less sensitive for the detection of macro-vasculature than gradient echo (GE) based techniques. Therefore SE-based measurements yield a better estimate of capillary tissue perfusion (1-3). However, the majority of perfusion MRI studies are performed with GE-based methods, primarily due to their higher contrast to noise ratio (CNR) compared to the SE-technique (4).

Objective: A systematic comparison of GE and SE techniques for rCBF measurements in the human brain.

Methods: Measurements were performed on a 1.5 T whole body scanner (GE SIGNA 5.8) with a fast gradient set (SR 120). Two perfusion scans were performed consecutively in each of six healthy subjects during the same session using the GE and the SE technique in random order. 39 repetitive scans of 13 axial slices were acquired with echo planar imaging (EPI) (TR = 2500 ms, FOV 20 cm, slice thickness 7 mm, TE = 30 ms for GE TE = 100 ms for SE). After 10 baseline scans, 18 mL of contrast agent (Gd-DTPA, Prohance, Squibb) were injected into the antecubital vein of one arm using a power injector (Medrad Spectris) over 3s followed by a saline flush of 6 mL. An axial fast inversion recovery (IR) sequence (TE/TI/TR = 32/120/4500ms, 3.5 mm slice thickness; no gap; 24-cm FOV) was acquired for co-registration.
To determine rCBF, a gamma-variate function was fitted directly to the signal-time-course of each pixel (5). The rCBF maps were coregistered to the high-resolution MRI scans and corrected for geometric distortions and inter-scan motion using a surface matching coregistration (6-7).

Results: rCBF maps calculated from the GE and SE source images are shown in the Figure. While large arteries and veins show very high rCBF values in the GE map, none of the draining veins on the cortical surface or between the hemispheres are visible in the SE maps.
In comparison to the SE method, the CNR of the GE method is 55% larger in the white and 135% larger in the gray matter. The regression coefficient between the rCBF from the GE and the SE method (all subjects) was -0.35, demonstrating a relatively lower SE rCBF in voxels with high GE rCBF value. The GE method yields higher gray-to-white matter ratios than the SE method (2.1 vs. 1.7).
One of the important parameters for clinical applications of perfusion MRI is the inter-subject standard deviation in rCBF. Both methods have small, and similar, standard deviations (5-8%) for the large cortical gray matter regions, despite the lower CNR of the SE method. For the smaller deep dray matter regions, such as the thalamus, which may include or be close to large arteries, the SE method in fact yields more reproducible rCBF values (4-10% stdev) across subjects than the GE method (7-16% stdev).

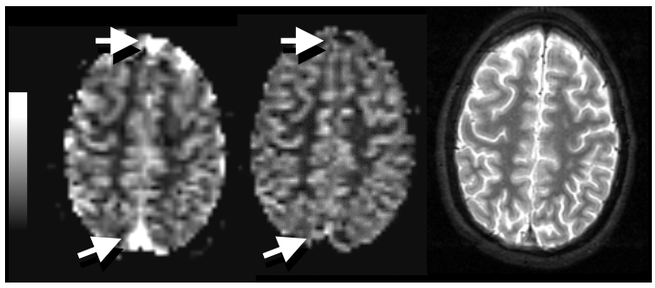

Figure: rCBF maps calculated from the GE (left), the SE (middle) technique, and the corresponding anatomical image.

Discussion: Our study provides evidence in humans for the theoretical predictions that GE methods measure rCBF in both larger vessels and capillaries, whereas SE methods are sensitive primarily to the latter.
For research and clinical applications of perfusion MRI, the sensitivity of each method for detecting pathologic changes in rCBF is ultimately defined by the inter-subject variability, which in turn is dependent on methodological and biological factors. For typical acquisition parameters, the SNR as well as the CNR of the GE method are considerably higher than those of the SE method. However, the two techniques are comparable with regards to the relevant parameter for *in vivo* studies, i.e. the inter-subject variability. The SE method shows smaller standard deviations than the GE method for small regions that are adjacent to or contain large vessels, such as the thalamus. This disparity between the methodological sensitivities (CNR) and the *in vivo* reproducibilities is mostly due to anatomical variations in the larger vessels.
The gray-to-white matter ratio with the SE method (1.7), is very close to that of capillary perfusion measurements from PET and SPECT measurements (1.6 to 1.8). The GE method overestimates the gray-to-white matter ratio by approximately 20%. The same gray-to-white ratios are observed despite methodological differences between perfusion MRI and nuclear medicine techniques. PET and SPECT employ diffusible tracers that penetrate the blood brain barrier, while perfusion MRI uses tracers that remain intravascular in the brain.

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