Fast high resolution whole brain T2* weighted imaging using echo planar imaging at 7T

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Introduction: The applicability of high resolution susceptibility (T_2*) weighted imaging is hampered by long scan times, even for a limited number of slices [1], due to the low signal-to-noise ratio (SNR) efficiency of the conventional spoiled gradient echo sequence (GRE). This work shows that high resolution (0.5 mm isotropic) and high SNR T_2* weighted images of the whole brain can be obtained in less than 6 minutes by utilizing the high SNR efficiency of EPI.

Table 1. Imaging parameters.	2D EPI	2D GRE	3D EPI	3D GRE
FOV (mm^2)	240 x 190	240 x 190	240 x 192	240 x 192
Matrix (AP x RL)	300 x 234	300 x 237	480 x 381	480 x 384
Resolution (mm^2)	0.8 x 0.8	0.8 x 0.8	0.5 x 0.5	0.5 x 0.5
Slice thickness (mm)	2	2	0.5	0.5
Nr slices	1	1	300	66
Flip angle (°) / TR/TE (ms)	15/70/27	15/70/27	19/70/27	13/32/27
BW (Hz/pixel)	997	1080	677	203
EPI factor	13	-	13	-
Repetitions[1]	26	2	-	-
k-space shutter (sampled fraction of *k*-space)	1.0	1.0	1.0	0.78
SENSE (LR)	1.0	1.0	2.3	2.3
Fat suppression	SPIR	SPIR	SPIR	none
Scan time (s)	33.3	33.9	350	354

[1]*Last repetition performed without RF or gradient pulses in order to sample noise.*

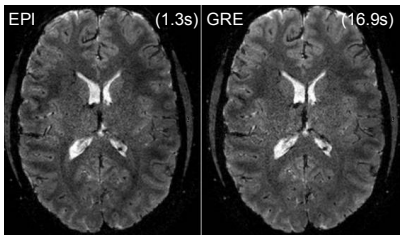

Fig 1. *Example of the high SNR efficiency obtained with EPI as compared to standard GRE imaging. The same imaging parameters are used (Table 1), but the 2D EPI protocol is 13 times (EPI factor) faster than the 2D GRE protocol without degrading the SNR.*

Methods and Materials:
Imaging was performed on 8 healthy subjects (4 male, age 27 ± 4 years) who gave written informed consent, in accordance to our Institutional Review Board. Images were acquired at a 7 Tesla MRI system (Philips Healthcare) with 16 channel receive coil and volume transmit coil (Nova Medical). The SNR efficiency of EPI versus GRE imaging was quantified for a single slice (Table 1, Fig. 1).
A 3D T_2* weighted protocol was constructed with 0.5 mm isotropic resolution (125 nl voxel volume) and whole brain coverage. The EPI factor was set to 13, yielding an EPI train length of 23 ms, below the T_2* for gray matter (GM) and white matter (WM) [2]. As a reference, a 3D GRE imaging protocol was constructed with the same resolution, TE and scan duration (Table 1). The contrast between GM and WM in the two 3D sequences was compared for three different regions. Contrast in the magnitude images was defined as the signal ratio GM/WM, because the conventional measure of contrast, $SNR_{GM} - SNR_{WM}$, is directly affected by the overall difference in SNR.

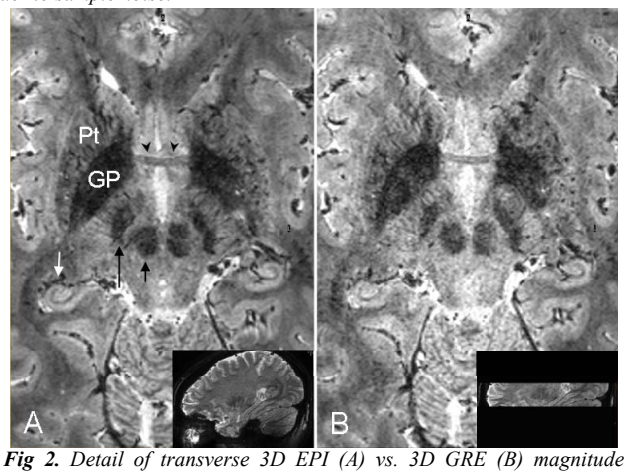

Fig 2. *Detail of transverse 3D EPI (A) vs. 3D GRE (B) magnitude images, showing considerably enhanced SNR with 3D EPI. The insets show the gain in coverage. The scan time was equal for both sequences. Visible structural details include: putamen (Pt), globus pallidus (GP), anterior commissure (black arrow heads), substantia nigra (long black arrow), nucleus ruber (short black arrow), hippocampus (white arrow), and cerebellum.*

Results: The 2D EPI images (Fig. 1) had similar SNR (15.8 ± 0.6) as the 2D GRE images (14.9 ± 0.5) (mean ± SD across subjects), despite the fact that they were acquired 13 times faster. Spatial coverage in 3D EPI was increased by a factor of 5 compared to 3D GRE, and the SNR was considerably higher (Fig 2). Image contrast for both magnitude and phase between GM and WM was similar for both sequences (Table 2), with better conspicuity of anatomic details in the 3D EPI images due to the increased SNR (Fig 2).

Discussion and Conclusion: Image blurring and distortion is negligible if the EPI train length remains short (not longer than the T_2* of the imaged tissue) [3]. 3D EPI provides steps (speed, whole brain coverage, improved SNR, and high isotropic resolution) that are necessary to utilize the benefits of high field MRI in research that employs T_2* weighted imaging.

Table 2. Contrast comparison.		3D EPI	3D GRE
CG vs. CC	(magnitude)	1.7 ± 0.2	1.7 ± 0.2
Pt vs. IC	(magnitude)	0.8 ± 0.1	0.8 ± 0.1
GM_{vc} vs. WM_{vc}	(magnitude)	1.2 ± 0.2	1.1 ± 0.1
CG vs. CC	(phase (Hz))	-0.3 ± 0.7	-0.2 ± 0.5
Pt vs. IC	(phase (Hz))	-2.6 ± 0.4	-2.4 ± 0.5
GM_{vc} vs. WM_{vc}	(phase (Hz))	-3.4 ± 1.0	-3.5 ± 1.2

CG: cingulated gyrus, CC: corpus callosum, Pt: putamen, IC: internal capsule, GM_{vc} / WM_{vc}: GM/WM visual cortex.

References:
1. Duyn JH, et al., PNAS, 2007(104), 11796-801. 2. Peters, AM et al., MRI, 2007(25), 748-53. 3. Haacke EM, MRM, 1987(4), 407-21.