Improved perfusion imaging of the human brain using dynamic T1-weighted contrast enhanced MRI at 3 tesla.

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Introduction: Perfusion imaging of brain tissue is commonly obtained by dynamic susceptibility contrast enhanced MRI using T2* weighted imaging. The principal advantage is a high contrast to noise ratio, but it suffers from important disadvantages, especially difficulties in obtaining an arterial input function and the unequal susceptibility effect between tissue and artery. When attempting quantified perfusion estimates based on T2*-weighted perfusion imaging these disadvantages may typically cause a 6 - 10 times overestimation of brain perfusion.

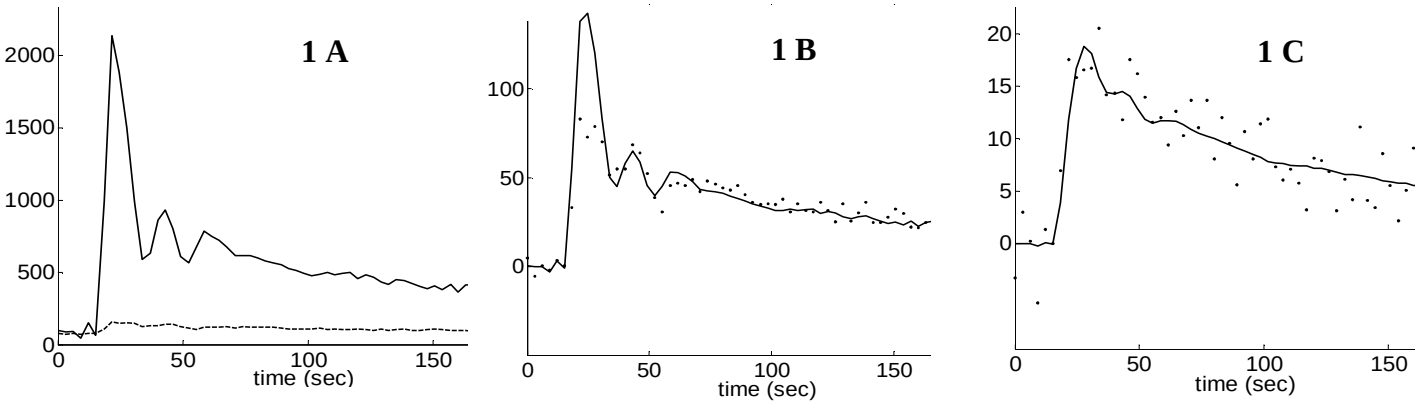
T1-weighted dynamic contrast enhanced perfusion estimation of the brain is possible at 1.5 tesla (1). The advantage is a consistent relationship, in both tissue and blood, between signal change and the corresponding contrast agent concentration. But at 1.5 tesla the disadvantage is a poor contrast to noise ratio of the tissue, especially in white matter, where the effect of the contrast agent hardly is seen (1).

The main aim of the present study was to see to what extent T1-weighted perfusion imaging of the human brain and quantification of brain perfusion would benefit from the improved signal to noise ratio (SNR) at the higher field strength of 3 tesla.

Methods: Five healthy volunteers were studied in a 3 tesla Philips Intera scanner, using a circular polarized head coil (the SENSE technique was not used). Through a superficial vein a bolus of 0.1 mmol/kg body weight of gadodiamide inj. (OmniscanR, Amersham inc.) was injected lasting 3 seconds. Imaging was started 10 seconds prior to the bolus injection, and the total duration of dynamic imaging was 180 seconds. The imaging sequence was a 3D inversion recovery Turbo-FLASH sequence, obtaining a 128 (read) x 100 (phase) x 6 (slice) data set every 3 seconds. The non-selective 180 degree prepulse was repeated before stepping in kz direction each time, keeping the inversion time short (app. 190 ms to center of k-space in each slice) in order to reduce water exchange problems (1). Time between each alfa pulse was 4.7 ms (TR), TE was 2.7 ms, nominal flip angle was 12 degrees. The signal was linear in R1 for the expected concentration range for both tissue and blood. Due to this linearity, we assumed that the signal was proportional to concentration in both tissue and blood, and that the proportionality was equal for tissue and blood.

Region of interest (ROI) for the arterial input function was placed in either right of left middle cerebral artery or the basilar artery. In all cases the arteries were highly delineated and identifiable. Brain tissue ROI's were placed in cortical gray matter, in subcortical white matter and in the brain stem (pons).
After having subtracted the baseline signal for the tissue and the input function, the perfusion and the vascular blood volume was quantified by direct deconvolution of the tissue curve with the input function, assuming a monoexponential impulse response function. No other manipulation of data was performed.

Results: The input function from the arterial ROI's had a very high SNR and 2 or 3 peaks corresponding to recirculation of the bolus could always be identified (figure 1A). Gray matter also showed a distinct tissue enhancement and recirculation could also be identified (figure 1B). In white matter the tissue enhancement was also clearly seen (figure 1C), but the SNR was considerably lower. However, at 3 tesla the tissue enhancement was higher than that of gray matter at 1.5 tesla in the previous study (1). The estimated perfusion in the gray matter ROI's (n=10) was mean 90 ml/100g/min (range 80 - 160), in the white matter ROI's (n=10) mean 10 ml/100g/min (range 4 - 20) and in the brain stem ROI's (n=10) mean 70 ml/100g/min (range 50 - 120).



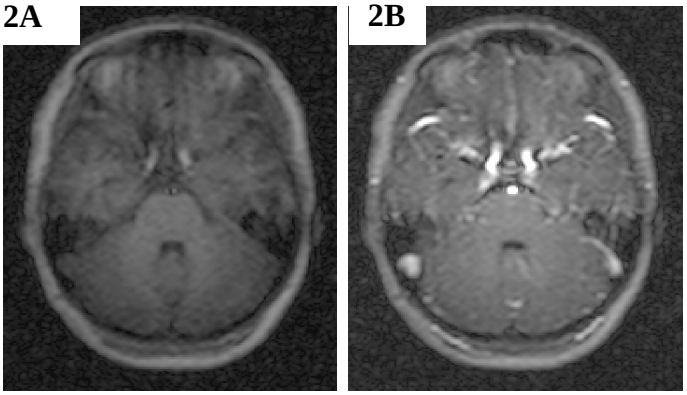


Figure 1
(A) Arterial input function (solid line) and tissue enhancement curve in gray matter (broken line).
(B) Tissue enhancement curve in a cortical gray matter ROI (from temporal lobe)
(C) Tissue enhancement curve in a subcortical white matter ROI
Note the difference in scaling on the y-scale between the figures. The y-scale values are signal intensity in the images in arbitrary units and after subtraction of the baseline signal intensity.

Figure 2
(A) Image acquired before arrival of the contrast agent in the brain (baseline).
(B) Image acquired 6 seconds after arrival of the contrast agent in brain arteries. Enhancement is observed in arteries, tissue and veins.

Conclusion: T1-weighted perfusion imaging of brain is greatly improved by increasing field strength from 1.5 to 3 T. Noise of the input function is highly diminished improving the stability of the deconvolution, and even perfusion of the white matter is possible to estimate. Possibly, the gain in contrast to noise at higher field strength, may facilitate the combined estimation of perfusion, vascular blood volume and the PS product of the blood brain barrier (BBB) in case of a deficient BBB.

References : (1). Larsson HB, Rosenbaum S, Fritz-Hansen T. Quantification of the effect of water exchange in dynamic contrast MRI perfusion measurements in the brain and heart. Magn Reson Med. 2001;46(2):272-281.