Optimization of gray-white matter contrast-to-noise in T1 weighted 3D FLASH imaging at 3T

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Introduction

The 3D FLASH sequence is frequently used in structural imaging of the brain. Depending on the imaging parameters, this sequence can generate contrast between gray and white matter derived from differences in proton density and T1. In this study an assessment was made of the contrast-to-noise ratio (CNR) between gray and white matter at 3T achievable within a constant imaging time.

Materials and Methods

Simulation: The contrast behaviour at 3T of the T1 weighted 3D FLASH (1) sequence was analyzed using a numerical simulation program based on the Bloch equations, as a function of TR [20-200 msec] and flip angle. In the first stage of the simulation, the flip angle was allowed to vary between 1°and 90° for each TR, while the other imaging parameters were kept constant (TE=5msec, BW=160 Hz/pixel, total imaging time=13:41min, matrix size = 128 x 128 x 32). The number of averages was adjusted for each TR to give a constant total scan time. The CNR was calculated as the signal difference between white and gray matter. The flip angle for optimum CNR was then determined for each TR. Two simulations were performed, the first one using the T1 values measured in a two-compartment phantom (see below) and the second one using the proton density, T1 and T2* for gray and white matter at 3T (T1 /T2* / ρ = 1331 msec / 42 msec / 75%, and 832 msec / 48 msec / 65% respectively) taken from the literature (2).

Experiments: Experiments were performed using a Siemens Allegra scanner operating at 3T. A two-compartment phantom with T1 relaxation constants close to those of cortical gray and white matter at 3T (T1(1) = 1360 msec, T1(2) = 1050 msec; see Figure 1) was imaged using a 3D FLASH sequence, with RF spoiling (3). The imaging parameters were: FOV = (128 mm)2, slab thickness = 32 mm, matrix size = 128 x 128 x 32, TE = 5 msec, BW = 160 Hz/pixel. TR and flip angle were varied according to Table 1. The flip angle was calculated using the simulation program to maximize CNR between the two compartments. The number of averages was adjusted to keep the imaging time constant (13:41 min). Sagittal images of the brain of a human volunteer were acquired using the same sequence, with the following imaging parameters: FOV = (256 mm)2, slab thickness = 64 mm, matrix size = 128 x 128 x 32, TE = 6.2 msec, BW = 110 Hz/pixel, TR=20 msec, flip angle = 23°, 5 averages (first scan) and TR=100 msec, flip angle = 47°, 1 average (second scan), scan time = 6:51 min.

Table 1. Imaging parameters used in phantom scans.

Scan	1	2	3	4	5	6	7	8
TR [msec]	20	25	33	40	50	67	100	200
Flip angle [degrees]	18	20	23	25	28	32	38	52
Averages	10	8	6	5	4	3	2	1

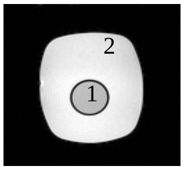
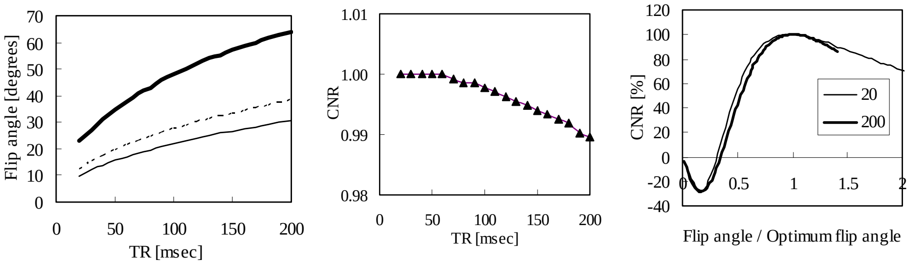


Figure 1. Two-compartment phantom filled with mixtures of copper sulphate doped water and agar gel.

Results and Discussion

The results of the simulation show that the flip angle for optimum gray-white matter CNR increases with TR (Figure 2a). At this optimum flip angle, the CNR for a constant imaging time is almost independent of TR, if the other imaging parameters remain constant (Figure 2b). The CNR is reduced in the presence of B1 inhomogeneity (Figure 2c); however this effect is slightly decreased for low TR. The CNR measured in the phantom images (see Figure 3) was found to agree with the results of the simulation. The CNR between the two compartments for a constant imaging time shows little variation with TR. The same result was obtained *in vivo*, where the CNR between gray and white matter for the two scans performed was: 35.97 (short TR) and 36.8 (long TR). The use of a long TR would allow a lower bandwidth to be used during acquisition, with a consequent increase in SNR. However, reducing the bandwidth would lengthen the echo time, which at high field strength should be kept as short as possible in order to minimize the susceptibility artefacts and dropouts. Therefore, the effects of changing the BW were not considered in this study.



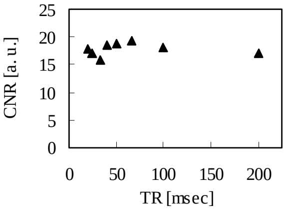


Figure 3: CNR in the phantom images, calculated as the difference of the SNR in the compartments.

(a) (b) (c)

Figure 2. Simulation results: (a) Flip angle for optimum gray-white CNR (bold line). Notice that it increases with TR and is higher than the Ernst angle calculated using T1 of gray (continuous line) and white (dashed line) matter. (b) CNR for a constant imaging time, as a function of TR. For each TR, the optimum flip angle has been chosen. (c) The CNR decreases when the flip angle is different from the optimum (shown here for TRs: 20 and 200).

Conclusions

The gray-white matter CNR with the T1 weighted 3D FLASH sequence is nearly independent of TR, when the optimum flip angle is chosen for each TR and the imaging time is kept constant by varying the number of averages. The use of a long TR and a reduced acquisition bandwidth would potentially increase the CNR, if the anatomical brain areas of interest are free from susceptibility artefacts.

Bibliography

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