ASSESSMENT OF SPATIAL RESOLUTION EFFECTS IN MR-CAT SCAN

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INTRODUCTION: Recently a modular concept for MR hybrid imaging, CAT (Combined Acquisition Technique) was presented (1-3). The CAT concept essentially integrates different imaging modules wherein the echo generation mechanisms and the echo contrast characteristics of the different applied imaging modules can be quite distinct. This feature is rather unusual, since one might first imagine that the image quality would be degraded by this individual relaxation behavior. However, there is in fact no conflict when well designed CAT scans are created. The following simulations were designed (i) to verify the interplay between the distinct imaging modules involved and (ii) to evaluate the theoretical resolution associated with the CAT-strategy.

SIMULATIONS: The following simulations were performed for one specific member of the CAT family, the FLASH/EPI-CAT. This approach integrates FLASH and EPI modules in a sequential fashion. First the upper periphery of k-space is sampled with an EPI-type oscillating readout gradient collecting N(1-λ)/2 echoes, where N is the total number of echoes and λ the fraction of k-space covered by the FLASH module. Then Nλ central views of k-space are sampled with a FLASH-type imaging module, and finally a second EPI-type readout gradient follows to cover the lower periphery of k-space with N(1-λ)/2 echoes. Both EPI trajectories start at the inner part of k-space and work outward with a blipped phase-encoding trajectory.

The computer simulations were performed for conventional FLASH which corresponds to λ=1, for a two shot center-out EPI which corresponds to λ=0, and for FLASH/EPI-CAT imaging techniques with varying factors 0<λ<1. For these simulations attenuation curves were calculated assuming N=256 echoes, the absence of noise and T1 relaxation effects, and simple T2* based relaxation. The experimental input parameters for the underlying imaging modules were as follows:

• FLASH module: TE = 1.9 msec, TR = 4.4 msec
• EPI module: TR<echo=1.9 msec, TENTER=1.5 msec

After calculation of attenuation curves for each imaging technique, (shown in Fig. 1), point-spread functions (PSFs) were calculated by Fourier transformation of the attenuation curves.

RESULTS: Figure 2 depicts the observed pixel size as a function of T2* relaxation rate over the entire range of T2* values from 10-90 msec and as a function of the CAT parameter λ for the FLASH/EPI-CAT hybrid. In this figure, a FWHM of 1 corresponds to a 256-point reconstruction with λ=1 (i.e., no T2* relaxation effects). In this simulation, λ=1 corresponds to the slow “pure” FLASH-type module with the highest spatial resolution and λ=0 corresponds to the fast “pure” EPI-type module with the lowest spatial resolution. This simulation reveals that it is possible through the appropriate choice of a particular CAT factor λ to find a compromise between imaging time and spatial resolution.

CONCLUSION: One issue particular to the modular nature of CAT is the difference in the relaxation behavior of the distinct modules. This could create discontinuities in the k-space matrix, which could result in increased ghosting and ringing in the images. As demonstrated by our simulations, there are in fact no additional resolution losses or artifacts in these “married” modules.

These simulated results can be used as an model for the definition of an optimal CAT sequence for a particular imaging situation. However, several uninvestigated factors in this study serve to complicate the definition of the optimal CAT sequence in a real world application. These factors include the off-resonance behavior and flow/motion sensitivity. In the future, all contributions must be considered for each possible CAT combination to achieve truly optimal CAT implementations.

References:
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