SNR increase in modified VD-AUTO-SMASH imaging

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Introduction

Parallel imaging techniques based on SENSE and SMASH are becoming very powerful MR tools because of their ability to shorten imaging time by several folds. However, there is usually a SNR loss associated with parallel imaging. For SENSE imaging, $\text{SNR} \propto 1/(g * \sqrt{R})$ where g is the geometry factor and R is the acceleration factor [1]. SNR performance of SMASH imaging has also been studied [2,3]. By using a variable sampling density, VD-AUTO-SMASH technique reduces image artifacts [4], but there is no report of its SNR performance. A modified VD-AUTO-SMASH (MVAS) technique was recently developed that further reduces image artifacts [5] and allows more accurate random noise measurement. It is the purpose of this study to investigate the SNR performance in MVAS imaging.

Methods

The MVAS technique used in this study has a k-space sampling density shown in figure 1 and uses a modified coil coefficient calculation method that improves coil fitting [5]. Coil-by-coil [6] and sum-of-square methods are used for image reconstruction. An overall acceleration factor of 2 was used, reducing the acquired phase encoding steps from 256 to 128. Computer simulation was performed in which MVAS and conventional sum-of-square images of a uniform object were generated using a simulated linear 4-element RF coil sensitivity profile. Phantom and human volunteer studies were conducted on a GE Signa 1.5T scanner. A uniform gelatin phantom was imaged using a 4-element phased array coil specially designed for knee imaging. For both computer simulation and phantom studies, 20 independent image sets were obtained to get the noise standard deviation for each image pixel. In the human study, knee images were obtained using the above knee phased array coil, and liver images were obtained with a standard torso 4-element phased array coil. The imaging sequences were modified to repeat each phase encoding step successively to form two image sets that were then subtracted from one another to give noise measurement. The MVAS images were compared with the conventional sum-of-square images with regard to SNR and image artifacts. For computer simulation and phantom imaging, average SNR values were obtained from the whole signal region while for in vivo images, average SNR values were obtained from 5 different signal locations.

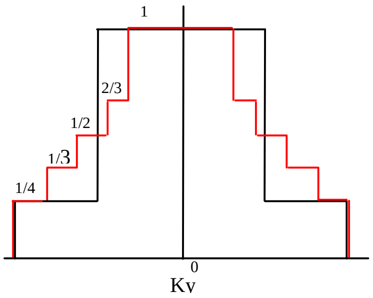

Figure 1. k-space sampling density of regular VD-AUTO-SMASH (black) and MVAS (orange).

Results

The computer simulation and uniform phantom studies show that the signals in MVAS were similar to that of conventional imaging (Fig 2b), but the noise in MVAS imaging varies spatially (Fig 2c). On the average, SNR of MVAS is about 20% higher than that of non-parallel sum-of-square imaging (Figs. 2d and 3). The knee and liver parallel images closely resemble the conventional images but also increase in average SNR (Fig. 4). The average SNR increases in the various parallel imaging experiments are summarized in Table 1.

Discussions and Conclusions

We have demonstrated that there can be simultaneous increases in both average SNR and scan speed in the MVAS over conventional imaging. The average SNR increase of about 20% is attributed to the reduction of noise in the MVAS reconstruction. The simulated study has a higher SNR increase than the experimental studies since it does not consider noise correlations among coil elements. The use of the MVAS technique is important for this study as it reduces image artifacts allowing more accurate measurement of random noise [5]. Its improved coil fitting and image reconstruction methods also contribute to the SNR increase. Besides SNR advantage, MVAS also has relatively short image reconstruction time and does not require an additional reference scan. Though SENSE has been shown to provide better image quality than the original SMASH [3], the MVAS technique significantly improves SMASH image quality by reducing image artifacts. Our future work includes analytical study of the noise distribution pattern and its relation to k-space sampling profile and RF coil configuration.

References

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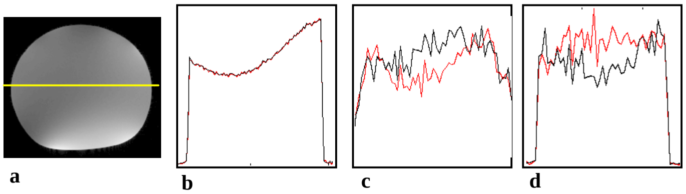

Figure 2. Conventional image of the phantom (a), and the signal (b), noise (c) and SNR (d) profiles of the conventional sum-of-square (black) and MVAS images (red). The yellow line in (a) indicates the location of the profiles.

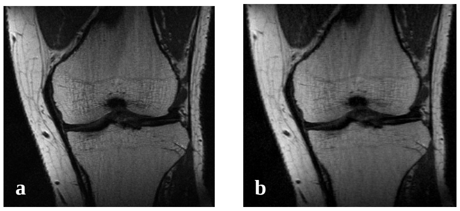

Figure 4. Conventional sum-of-square (a) and MVAS (b) images of the knee.

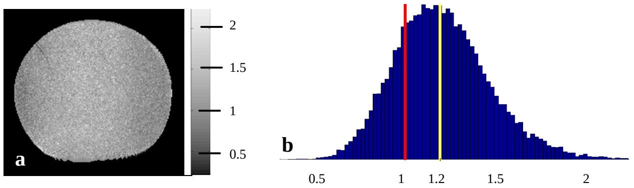

Figure 3. SNR gain map (a) and SNR gain histogram (b) of the phantom image. The SNR gain map is obtained by dividing the SNR of the MVAS image by that of the conventional sum-of-square image. The red line in the histogram indicates the SNR of the conventional sum-of-square image and the yellow line indicates the average gain of the MVAS image.

Table 1. Average SNR increases over conventional sum-of-square images

	Average SNR Increase
Simulation	0.27
Phantom	0.20
Knee	0.21
Liver	0.18