Wideband Parallel Imaging

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Abstract

Human lower limb images were successfully acquired with an acceleration rate of up to 8x by using wideband parallel imaging. The non-uniform multislice profile problem of this technique was successfully compensated to enhance the image quality of the outer slices. Also the signal-to-noise ratio (SNR) of this ultra fast imaging technique, wideband parallel imaging, was verified to be similar with that of gradient echo with GRAPPA.

Introduction

One of the most popular research topics in MRI is how to reduce the imaging time. SMA [1] and GRAPPA [4] are two of the fast MR imaging methods. SMA was first proposed by J.B Weaver [1] and SMA integrated with SENSE was first proposed in [2]. However there are problems of blur, low SNR and non-uniform multislice profile that result from SMA [1-2]. In this study we used the acceptable blurring index for the SMA + GRAPPA ultra fast imaging, compensate the non-uniform multislice profile for the outer slices. Also the SNR values of images obtained by using (4-slice SMA + GRAPPA), (2-slice SMA + GRAPPA) and GRAPPA only are verified. And the simultaneous excitation slice number of SMA in [2] was up to two for the human lower limb. In this study it was increased to four.

We call simultaneous multislice acquisition (SMA) [1-3] integrated with gradient echo imaging and GRAPPA [4] as wideband parallel imaging. Wideband parallel imaging is one of the series of wideband MRI techniques developed recently in our Lab. Other parts and the whole concept of our wideband MRI techniques will also be proposed in this conference.

Materials and Methods

Wideband parallel imaging includes simultaneous multislice acquisition (SMA) [1] integrated with parallel imaging method [4] when the k-space data was acquired. The total acceleration rate of wideband parallel imaging in this study is equal to the simultaneous excitation slice number of SMA multiplied by the acceleration factor R of parallel imaging method. For reducing the imaging time in this study we successfully used 4-slice SMA (4x) with gradient echo and GRAPPA (2x) to achieve the 8x acceleration rate imaging.

However, SMA images may have the disadvantages of blur, low SNR [1-2] and non-uniform multislice profile [1]. For compensating the non-uniform multislice profile in 4-slice SMA we designed the 4-slice SLR RF pulse with the same slice separation and slice thickness first. Then we simulated and measured its multislice profile. Next we added some weighting values to the multislice profile for the outer slices in the 4-slice SLR RF pulse, simulated and measured its the multislice profile again. This is repeated until the multislice profile became uniform. Then we used the compensated 4-slice SLR RF pulse for the imaging. The non-uniform multislice profile can be compensated by using the method mentioned above.

For verifying the SNR of the image obtained using wideband parallel imaging. We designed the 4-slice, 2-slice and single slice SLR RF pulses all with the same flip angle and slice thickness. And we made sure that every slice was excited and received with the same RF power. Note that for the 4-slice SMA + GRAPPA we adopted the 4-slice SLR RF pulse after compensation that mentioned above. For obtaining the better SNR of SMA image, the precise refocus gradient for the additional slice selection gradient when readout is also one of the important points. This was also confirmed in this study.

We used a 3T Bruker MR scanner for the experiment. The RF coil is a Rapid 4-channel receiving head coil. The multislice SLR RF pulse design, simulation, GRAPPA reconstruction algorithm and image analysis software were performed by using an in-house program written in MATLAB 6.5 (The Mathworks, USA).

Results and Discussion

The images and SNR values of GRAPPA (R=2) without SMA, GRAPPA (R=2) with 2-slice SMA and GRAPPA (R=2) with 4-slice SMA of the human lower limb are shown in Fig. 1(a), (b) and (c) respectively. It can be seen that the SNR values of (4-slice SMA + GRAPPA) and (2-slice SMA + GRAPPA) are close to the SNR of GRAPPA only.

The image resolutions of Fig. 1(a), (b) and (c) are 128x128, 256x128 and 512x128 respectively. The blurring index [1] of Fig. 1(a) and 1(c) are both 2.5 pixels. The imaging parameters of Fig. 1 are TR=1000 ms, TE = 7 ms, Flip angle = 30 degrees, FOV=15 cm x 15 cm, NEX = 1 and slice thickness = 2 mm. The slice separations are ±15 kHz, ±45 kHz for 4-slice SLR RF pulse and ±15 kHz for 2-slice SLR RF pulse.

It can also be observed from Fig. 1(c) that the non-uniform multislice profile was compensated to be more uniform for the outer two slices. This is down by 4-slice SLR RF pulse compensation mentioned above. The duration of the 4-slice SLR RF pulse is 4 ms. The reason for the SNR of the most-left hand side image in Fig. 1(c) is lower than others is because it has some points with lower signal in the selected area. Also it can be observed that the image quality and image contrast among Fig. 1(a), (b) and (c) are basically similar except for the slight blur, 2.5-pixel blur, in Fig. 1(b) and (c).

Further speeding up by integrating our another concept of wideband parallel imaging should be possible. And it is under developing in our Lab.
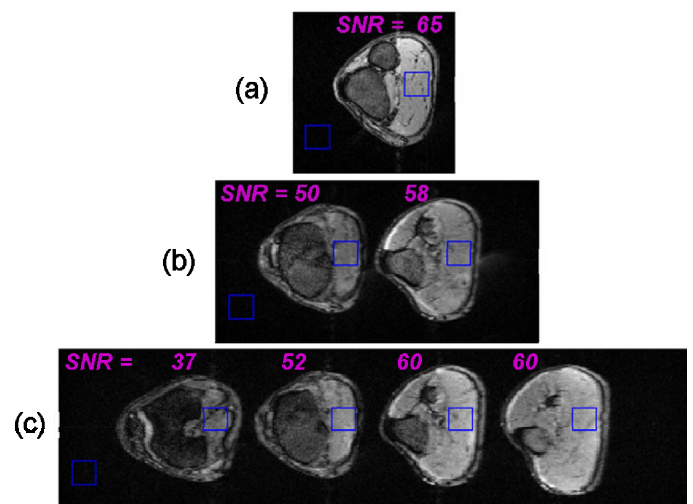

Fig. 1. (a) The image and SNR of GRAPPA (R=2) without SMA (b) The image and SNR of GRAPPA (R=2) with 2-slice SMA (c) The image and SNR of GRAPPA (R=2) with 4-slice SMA of the human lower limb

Conclusions

The wideband parallel imaging method was successfully adopted to achieve the high acceleration rate of up to 8x. In other words, it is 8x times faster than that of gradient echo imaging method. No additional gradient system is required for this. Also the non-uniform multislice profile in 4-slice SMA with GRAPPA was also compensated. The image quality, image contrast and SNR of (4-slice SMA + GRAPPA) and (2-slice SMA + GRAPPA) are designed and verified to be similar with that of GRAPPA only.

References

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