Simultaneous Image Refocusing (SIR): a New Approach to Multi-slice MRI

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Introduction

The new multi-slice imaging technique described herein, makes multiple images in a single echo train sequence. Simultaneous image refocusing (SIR) technique differs from conventional multi-slice in the timing of processes of excitation (Ex) and refocusing (R) of signals from different slices (s). Conventional multi-slice: [Ex of s1, R of s1, Ex of s2, R of s2], SIR: [Ex of s1, Ex of s2 , R of s1 and s2]. As proof of concept, SIR is incorporated here into an EPI sequence.

Theory and Methods

When signals from different slices have identical phase history, they are superimposed in time and inextricably combined. To overcome this problem, SIR uses specific linear combinations of dephasing pulses, causing the signals to occur adjacent to each other in each readout period. After data acquisition and echo time reversal, the k-spaces of different slices are located in adjacent regions on the k_r axis which can be divided into smaller matrices and independently processed by 2D FT to give the multiple image slices.

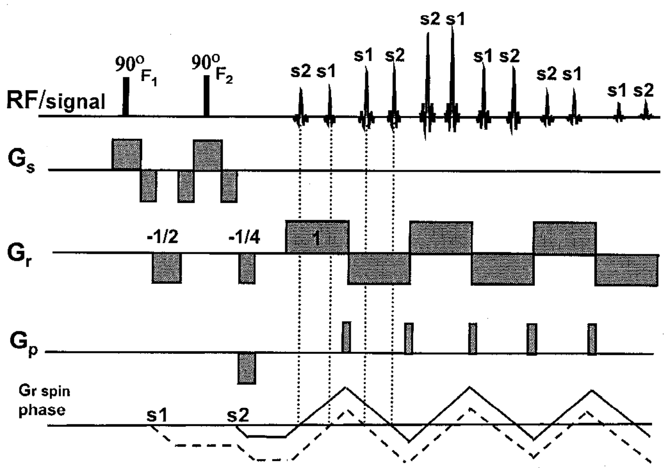

Fig. 1 Simultaneous refocusing of two images in a SIR EPI sequence. RF frequency offsets F_1 and F_2 determine locations of the image planes.

More specifically in Fig.1, two consecutive 90^0 RF excitations create magnetization in two slice planes. Referring to the spin phase graph, the first dephasing pulse on Gr axis encodes only the magnetization of the first slice (s1) since the second slice magnetization has not yet been created. The second dephasing pulse, after the two RF excitations, encodes both slices equally. If the Gr read gradient pulses are of unit area (amplitude G x width T = 1), and the preceding dephasing pulses are -.5 and -.25 area, respectively, they produce specific magnetization pathways for s1 and s2 that refocus echoes on opposite sides of the read period, alternating with each EPI gradient switching.

With equal signal bandwidth in EPI and SIR EPI, the echo trains are 30ms and 45ms, respectively, for 64 readout periods with linear phase encoding on a 1.5T scanner.

Results

Fig.2 shows SIR EPI k-space data and respective images, $2mm^2$ resolution and 4mm thickness. The phantom's rectangular and square plastic bars identify adjacent slice positions. The SIR image quality, SNR and Nyquist ghost intensity were the same as conventional EPI images, analyzed by image subtractions. Without spoiler pulses in this initial implementation, leakage between the SIR k-spaces of low energy high spatial frequency data gave an additional faint ghost, lower intensity than the Nyquist ghost, at edges only on the frequency axis.

Discussion

While there is faster single shot imaging with SIR EPI, this advantage becomes much greater in diffusion or BOLD weighted imaging with long preparatory periods simultaneously encoding two slices. Stimulation effects might also be lessened. The above must be optimized against disadvantages of either reduced SNR from higher bandwidth or increased artifact from longer T2* decay.

Conclusion

The novel SIR technique has been demonstrated by encoding two slices in an EPI pulse sequence which could be generalized for additional slices and combined with conventional multi-slice technique. Future application of SIR in RARE type sequences might use half the number of 180^0 RF pulses with weak selectivity, to reduce rf heating, a health risk that limits image acquisition rate.

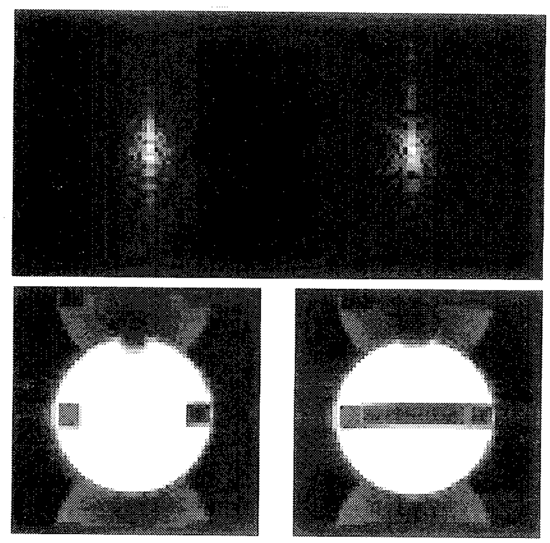

Fig.2 Acquired SIR k-space data and resulting EPI images.