Efficient CSF Flow Imaging with a Multiple Flexible Labeling Band Sequence at 3.0T

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Introduction

The movement imaging of cerebrospinal fluid (CSF) has been used for many years to diagnose hydrocephalus, particularly to distinguish hydrocephalus from ventricular enlargement caused by other diseases, such as Alzheimer disease. In clinical practice, cardiac-gated phase-contrast (PC) magnetic resonance imaging is the only noninvasive technique to visualize CSF flow [1]. Recently, a time-spatial labeling inversion pulse (SLIP) prepared single-shot sequence [2] was developed to visualize the movement of CSF and overcome some advantages in PC, such as turbulent flow and bulk flow.

Derived from the concept of the time-SLIP technique, we developed a flexible multiple-band labeling sequence to image the CSF flow in this study, which could display the CSF flow of the aqueduct and foramen magnum simultaneously to improve the scan efficiency.

Methods

Previously, we implemented a preparation of spatial labeling with multiple inversion pulses (SLEEK) [3]. In this study, the SLEEK preparation was modified and applied to a two-dimensional cardiac-gated (CG) single-shot fast-spin-echo (SSFSE) readout to generate a dynamic CSF flow imaging, Fig. 1. The SLEEK preparation here contained three adiabatic inversion recovery (IR) pulses to have the capability of generating two labeling bands. The sequence of the IR pulses was optimized to balance the labeling performance of the two labeling bands. TI increased at intervals of 200ms from 1300ms to 5300ms from shot to shot. The number of R-R intervals contained a total 10-second-length pulse sequence.

Phantom study and human study were performed on a 3.0T MR scanner (EXCITE HD, GE Healthcare, Milwaukee, WI, USA) with an eight channel phased array brain coil under the whole gradient mode in order to guarantee the gradient linearity in a large area. Scan parameters were as follows: Eff. TE = 80ms, slice thickness = 8mm, FOV = 24cm x 24cm, matrix = 256 x 256, NEX = 1, ASSET factor = 2, ETL = 78, receiver bandwidth = ±83.3kHz, ESP = 5.4ms. From 1300ms to 5300ms, 21 different TI images of one sagittal slice were acquired within a total scan time around 240s.

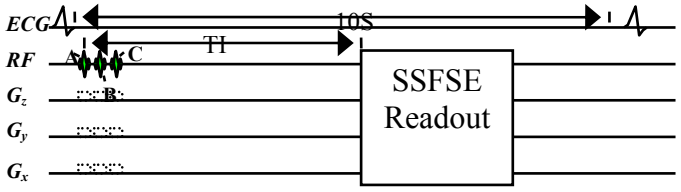

Fig 1: Diagram of the CSF flow imaging sequence. Dashed gradients indicated that the amplitude of the gradients would be adjusted based on the freehand description. Pulse B inverted the entire brain; Pulse A and C only inverted the labeling areas. A and B contributed to the first labeling band; B and C contributed to the second labeling band. TI changed from shot to shot.

Results

A home made pure water phantom was used in the phantom study. An 80-beat-per-minute emulator was taken as CG. The description of one or two labeling bands was shown in Fig 2a or Fig 2g, respectively. Different TI images of one-band method (Fig 2b-2f) and two-band method (Fig 2h-2l) were collocated corresponding to TI 1500ms, 2300ms, 3100ms, 3900ms and 4700ms. For both kinds of labeling methods, the signal in the labeling area(s) did not change significantly along with the TI change due to the double inversion recover effect; the background signal changed with TI because of T1 relaxation. The labeling bands were bended somewhat by the field inhomogeneity induced by the shape of the phantom.

Two volunteers participated in the human feasibility study. Two pairs of TI images (Left: TI=1700ms, Right: TI=2100ms) of one band (Fig 3a, 3b) and two bands (Fig 3c, 3d) were compared here. The two scans presented the same capability of displaying the CSF flow of the aqueduct. But the scan with two bands could display the CSF flow of the foramen magnum simultaneously. Red arrows pointed the upward and downward CSF flow in the labeling band superior to the aqueduct. Green arrows indicated the CSF flow in the second band superior to the foramen magnum with two-band method.

References

[1] Wagshul ME, et al. J Neurosurg. 2006; 104(5): 810-9; [2] Yamada S, et al. Radiology. 2008; 249(2): 644-52; [3] Shen H, et al. ISMRM 2010, #1251.

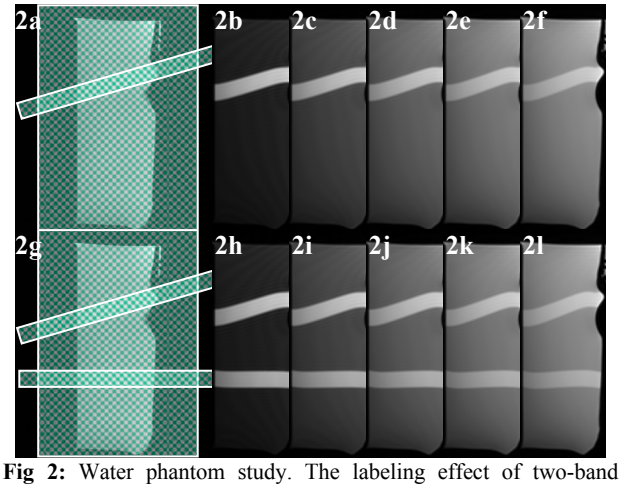

Fig 2: Water phantom study. The labeling effect of two-band method (bottom row) was similar to one-band method (top row), but doubled the scan efficiency.

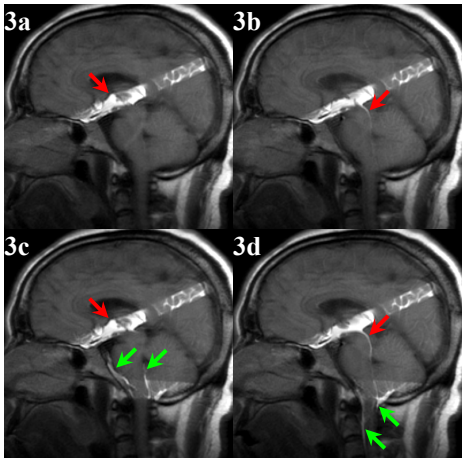

Fig 3: Volunteer study. Both one-band method (top row) and two-band method (bottom row) could display the CSF of the aqueduct. Two-band method could display the CSF flow of the foramen magnum simultaneously.