Influence of Respirations on Cerebrospinal Fluid (CSF) Movement Using bSSFP Time-Spatial Labeling Inversion Pulse (Time-SLIP)

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Target Audience: Researchers and clinicians interested in cerebrospinal fluid (CSF) physiology.

Introduction: MRI cardiac gated phase contrast (PC) cine techniques have non-invasively shown the effect of the cardiac pulse on cerebrospinal fluid (CSF) movement (1). Echo planar imaging (EPI) has shown CSF movement as influenced by both cardiac pulsation and respiration (2,3). Previously, the non-invasive visualization of CSF movement in response to respirations has not been possible. Spin labeling technique, time-spatial labeling inversion pulse (Time-SLIP) using SSFSE was reported to observe the CSF movement in various regions (4). In this study, the effect of respiration on CSF movement (5) was investigated using a non-contrast time-spatial labeling inversion pulse (Time-SLIP) with balanced steady-state free precession (bSSFP) cine readout.

Materials and Methods: Institutional Review Board approval and informed consent were obtained for this study. A non-contrast MRI spin labeling, Time-SLIP with bSSFP cine was applied to observe CSF movement in the intracranial compartment in response to respirations in 10 normal volunteers (8 males and 2 female; age range, 28-56 years; mean age, 39 years), who were each imaged in a supine position. To elucidate the respiration effect, the acquisition was triggered at the beginning of deep inspiration, deep expiration and breath-holding. Typical deep respiration (inspiration and expiration) and breath-holding acquisition parameters were repetition time (TR) = 4.2 ms, echo spacing = 2.1 ms, segmentation = 1, inversion time (TI) = 230 ms, matrix = 96 (phase encoded) x 192 (read out) (352 x 384 after interpolation), slice thickness =7 mm, FOV = 24 x 26 cm^2, parallel imaging factor = 3, and Time-SLIP tag pulse width = 10 – 30 mm. The acquired spatial resolution of 2.5 mm x 1.35 mm was interpolated to 0.68 mm x 0.68mm.

Results and Discussion: The cine acquisition using Time-SLIP with bSSFP cine (Fig. 1) allows observation of continuous CSF flow. Figure 2a and Figure 2b show CSF flow in sagittal views during deep inspiration and expiration, respectively. The breath-holding data are not shown. By employing a respiration-induced spin labeling bSSFP cine method, we were able to visualize CSF movement induced by respiratory excursions. CSF moved cephalic (16.4 ± 7.7 mm) during deep inspiration and caudal (11.6 ± 3.0 mm) during deep expiration in the prepontine cisternal area. Small but rapid cephalic (3.0± 0.4 mm) and caudal (3.0 ± 0.5 mm) movement was observed in the same region during breath-holding and is thought to reflect cardiac pulsations. Figure 3 summarized the average CSF movement distance of inspiration, expiration and breath-holding in 10 volunteers. Our results demonstrate that a substantial amount of CSF movement occurs with deep respiration. During the deep inspiration, significant cephalic CSF movement was observed; whereas, a corresponding caudal CSF movement was noted during deep expiration.

Conclusion: Time-SLIP bSSFP cine presents for non-invasive visualization of CSF movement associated with respiration to a degree not previously reported.

References: 1) McCormack EJ, et al, *MRI* 2007, 25:172-182. 2) Klose U, et al, *JMRI* 2000, 11:438-444. 3) Friese S, et al, *Invest Radiology* 2004, 39:120-130. 4) Yamada S, et al, *Radiology* 2008, 249:644-652. 5) Yamada S, et al, Fluids and Barriers of the CNS 2013, 10:36.

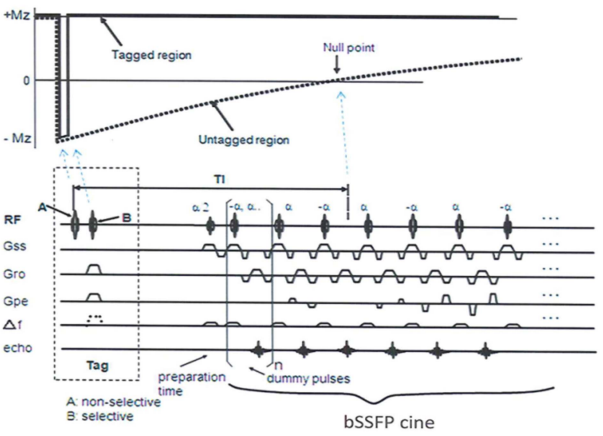

Fig 1 Spin magnetization (top) and sequence diagram (bottom).

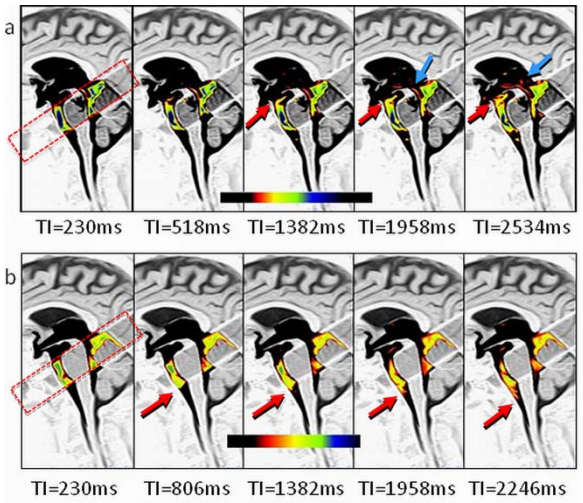

Fig 2 Time-SLIP bSSFP cine images during inspiration a) and expiration b).

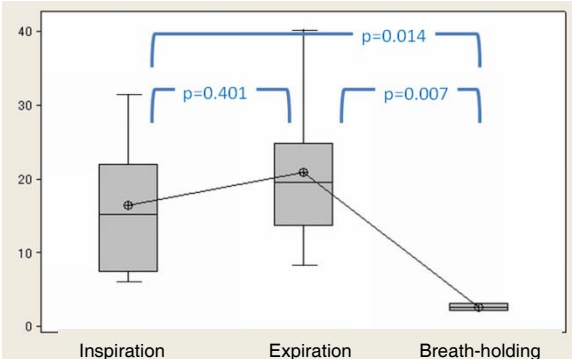

Fig 3 Average maximum distance (mm) of CSF movement during inspiration and expiration and breath-holding.