Balanced SSFP cisternography in the cerebellopontine (CP) angle: inconsistent vessel contrast and a possible remedy

P-H. Wu[1], C-Y. Lin[1], C-C. Cheng[2], H-W. Chung[1], W-C. Wu[3], B. A. Hargreaves[4], and N. J. Pelc[4]

[1]Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, [2]Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan, [3]Department of Clinical Medicine, National Taiwan University, Taipei, Taiwan, [4]Department of Radiology, Stanford University, Palo Alto, California, United States

Introduction

Cerebellopontine (CP) angle, which is a common site for the growth of acoustic neuromas, has been an important target for the evaluation of various pathologic processes. With very short TR and balanced gradients in all three directions, the balanced steady state free precession (bSSFP) technique provides high signal-to-noise ratio and is inherently flow compensated [1]. Moreover, images acquired with bSSFP are known to give strong T2/T1 contrast that highlights the CSF, hence ideally suited as an excellent screening tool to identify nerves and vessels in the cisterns at the CP angle [1,2]. However, inconsistent signal intensities of blood vessels have been observed, causing possible uncertainty in diagnosis. In this study, therefore, the bSSFP signal behavior in the presence of flow was investigated, with the influence of flip angles explored to aim at partial signal recovery for the arteries around the circle of Willis.

Methods

The main issue concerning bSSFP signal behavior in intracranial arteries is that flow along the phase encoding direction causes the SSFP angle to vary in a uniformly increasing manner for every TR, such that the steady state signal becomes a function of the flow velocity, and that it may take long time to reach steady state. Such a theoretical behavior was simulated from the initial thermal equilibrium magnetization with the scanning parameters as decribed for the imaging experiments. The phase accumulation is assumed to be $\varphi=2\pi\gamma\times n\times\Delta G\times v\times\tau^2$, where γ is gyromagnetic ratio, n is the order number for phase encoding, ΔG is the gradient stepping, v is the flow velovity along the phase direction, and τ is the duration of the phase-encoding gradient. The designated flip angle and blood flow velocity were varied from 30° to 70° and 0 to 100 cm/s, respectively.

Imaging was performed on a 3.0T Siemens Trio system using an 8-channel head coil. Two sets of images were acquired from 20 subjects for comparison. One was performed by 2D bSSFP sequence which is the common technique for MR cisternography in the CP angle. The image parameters were 220 mm FOV, 256 by 256 matrix size, 24 slices with 2 mm slice thickness, 48° flip angle and TR/TE = 4.88/2.44 ms. Three measurements were averaged to improve the image quality. The other one was time-of-flight (TOF) image, which was acquired to confirm the accurate locations of vessels. The parameters of TOF imaging were 288 by 384 matrix size, 96 slices with 0.8 mm slice thickness and the location of central slice is the same as that of 2D bSSFP imaging.

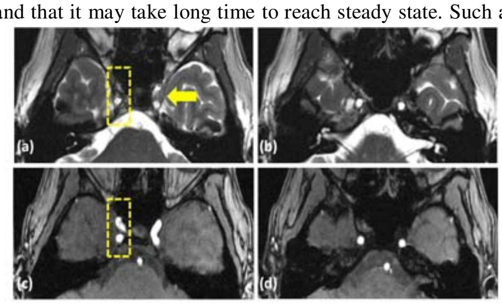

Fig.1 (a,b) bSSFP images with and without signal loss in the arteries, respectively. (c,d) the corresponding TOF images.

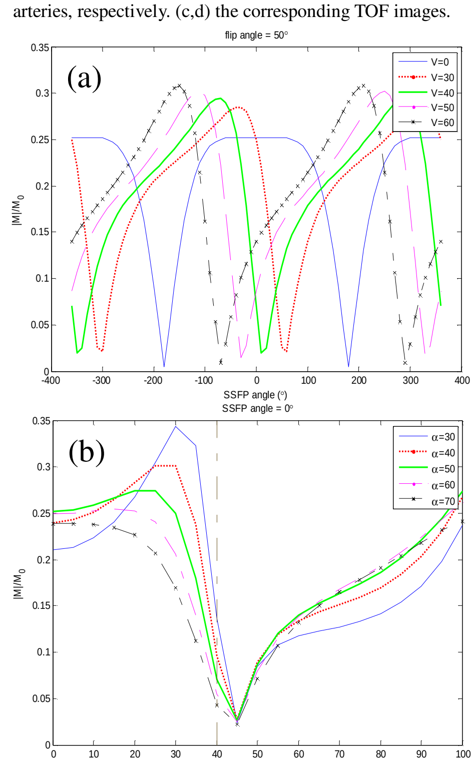

Fig.2 (a) bSSFP signal as a function of SSFP angle at different velocities. (b) On-resonance bSSFP signal intensity at different flip angles.

Results

Figs.1a and 1b show two slices from 2D bSSFP images. Figs.1c and 1d are the TOF slices at the same location. Inconsistent vessel signal intensity was found for 2D bSSFP, showing dark vessels in Fig.1a and bright ones in Fig.1b (arrow and dashed square). Simulations on the signal behavior as a function of SSFP angles from -360° to 360° show prominent intensity variations in the presence of flow (Fig.2a), in accordance with experimental observations. Fig.2b shows the intensity as a function of velocities from 0 to 100 cm/s with different flip angles when SSFP angle is zero (i.e., on-resonance condition). When the flow velocity is around the range of 30 to 40 cm/s as commonly encountered for intracranial arteries in the CP angle (red straight dashed line in Fig.2b) [3], the signal intensity for the blood vessels seems to be recoverable by using smaller flip angle such as 30° or 40°.

Discussion and Conclusion

A strong signal loss in the blood vessels in the CP angle could hamper clear distinction of the vessels from the nerve roots in bSSFP imaging. The results from our simulation suggest that flow along the phase encoding direction is likely a major cause for the change in magnitude profile at different SSFP angles, leading to signal loss in the blood vessels. Since the flow direction varies to a great extent around the circle of Willis for the intracranial arteries, inconsistent signal intensities in bSSFP cisternography commences. Moreover, our results suggest that different flip angles, one of the few parameters selectable by the operators, result in different magnitude profiles. It is therefore possible to adjust the flip angle in bSSFP imaging, to partially recover the vessel signals to allow clear distinction between CSF, nerve roots, and the blood vessels in the region of CP angle where the flow velocities is about 40 cm/s [3]. The outcomes indicate that the suitable contrast behavior could be achieved with the appropriate flip angle adjustment based on the flow velocity in the region of interest.

References

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