Selective TOF MRA using Beam Saturation pulse

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Introduction

Three dimensional TOF MRA is used widely to visualize whole brain arteries. If 3D TOF MRA pulse sequence is combined with an artery selective saturation pulse, it may show additional information about blood flow in the brain, such as cross flow in carotid stenosis patients. In order to realize such selective TOF MRA, we investigated use of a 2D beam excitation [1] pre-pulse (hereafter Beam Sat pulse) to saturate a carotid artery.

Materials and Methods

1. Beam shape stability was evaluated for B0 inhomogeneity which causes a radiofrequency difference between the excitation RF pulse and local magnetic resonance signal which should be saturated. Computer simulation was performed using the small-tip-angle approximation [2]. The radiofrequency difference (hereafter dF) is the same as a linear increase of phase of the RF excitation pulse (Fig. 1). Therefore the B0 inhomogeneity (0-150Hz) was modeled as a linear increase of RF phase in the simulation. Beam Sat pulse parameters were: duration 8ms; spiral trajectory turns 10, maximum gradient 9.8 mT/m; RF waveform was Gaussian. We measured FWHM and FA of the simulated excitation profiles.
2. The position and direction of the Beam Sat pulse were evaluated for selective saturation of the internal carotid artery (ICA) with 8 healthy volunteers. We set a beam in the following positions and identified the overlapping neighboring main blood vessels and petrous part of the ICA for the beam:
   SAG: the upper border of the cylinder touches nasal root and sella turcica (Fig. 2a).
   AX: the side border of the cylinder touches clivi and petrous bone (Fig. 2b).
3. The effective saturation of signal intensity in the artery was evaluated by studying the saturated range and saturation rate of the blood. The Beam Sat pulse was applied to 3D TOF MRA. Typical scan parameters: TR/TE = 46.2ms / 6.9ms, imaging matrix 512 / 224. A 1.5T MRI unit (Hitachi Medical Corporation, Tokyo, Japan) and 8ch head coil were used for volunteer imaging. The number of volunteers was 8. We explained the purpose and significance of this study to healthy volunteers and obtained written consent. The artery from ICA to MCA-M4 was evaluated by measuring blood signal and calculating the signal ratio of one with and without saturation on original images. We evaluated the visibility of each blood vessel by making MIP images.

Results and Discussion

1. The excitation profile became broader with increasing dF. When beam diameter was 30mm and B0 inhomogeneity was less than 50Hz, the expansion of FWHM from specification was less than 10%, and the reduction of FA was less than 10% (Fig. 3). As a result of prior evaluation, we found that dF of the head was less than 50Hz, so we believed that Beam Sat is applicable to the upper part of head, including ICA.
2. For all volunteers, the Beam Sat pulse overlapped with the ICA petrous part, and did not overlap with other main blood vessels. We concluded that one side ICA could be saturated selectively.
3. For 7 volunteers (No.1~No.7), the signal intensity from ICA to MCA-M4 was saturated almost equal to white matter of ~100, and was invisible in the MIP image (Fig. 4). But for one volunteer (No.8), the signal intensity of the MCA-M4 was higher than white matter (Table 1; MCA-M4 is 114), and was visualized in the MIP image.
   We assume that the increase of signal ratio (Table 1) is related to T1 relaxation time and to distance from the saturated position. When the blood velocity is slow, transit time becomes longer and signal ratio becomes worse because of T1 relaxation. In our initial results, the blood signal in MCA-M3 can be saturated by Beam Sat pulse when it is set in the petrous part of the ICA.

Conclusion

The Beam Sat pulse is able to saturate the carotid artery selectively. When combined with 3D TOF MRA, the Beam Sat pulse seems to visualize additional information about internal brain blood flow.

References

[1] J. Pauly et al.; IEEE. Trans. Med. Imaging, ***10****; 53-65 (1991)*
[2] J. Pauly et al.; J. Magn. Reson. ***81****; 43-56 (1989)*

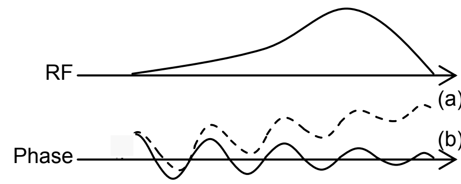

Figure 1 Beam Sat pulse sequence in simulation.
(a) dF = 50Hz, (b) dF = 0Hz

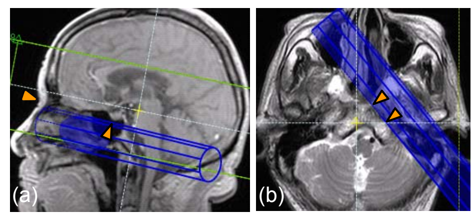

Figure 2 Position of Beam Sat pulse
(a) SAG, (b) AX

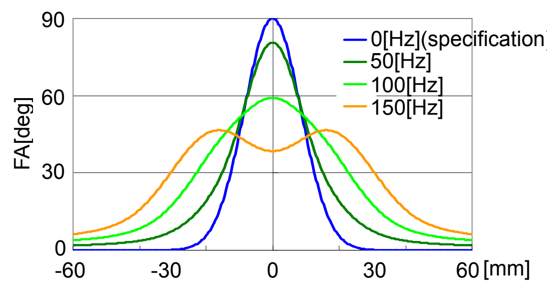

Figure 3 The simulated excitation profile
(the range of dF : 0Hz ~ 150Hz)

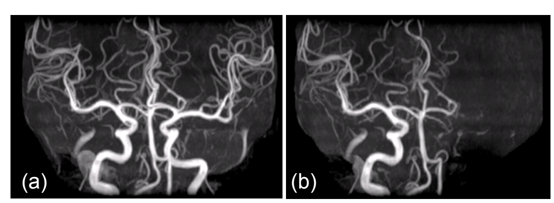

Figure 4 MIP images (Volunteer No.1)
(a) without Beam Sat, (b) with Beam Sat

Table 1 The signal intensity from ICA to MCA-M4
(Volunteer No.8)

		signal intensity		signal ratio
		without B.S	with B.S	with / without
Brain(white matter)		100	**99**	0.99
ICA		341	24	0.07
MCA	M1	382	22	0.06
	M2	272	36	0.13
	M3	234	76	0.32
	M4	175	**114**	0.65