The merged images with different central frequencies can reduce banding artifact of 3D-SSFP MR cisternography

Koji Matsumoto[1,2], Hajime Yokota[3,4], Hiroki Mukai[4], Ken Motoori[4], Toshiaki Miyachi[2], Yoshitada Masuda[1], and Takashi Uno[4]

[1]*Department of Radiology, Chiba University Hospital, Chiba, Chiba, Japan,* [2]*Division of Health Sciences, Kanazawa University, Kanazawa, Ishikawa, Japan,*

[3]*Department of Radiology, Kyoto Prefectural University of Medicine, Kyoto, Japan,* [4]*Diagnostic Radiology and Radiation Oncology, Chiba University, Chiba, Japan*

INTRODUCTION

Magnetic resonance (MR) cisternography using three dimensions steady-state free precession (3D-SSFP) is widely used for visualizing the inner ear [1-5]. 3D-SSFP can achieve high signal to noise ratio in relatively short acquisition time to 3D spin-echo sequences. However, local magnetic field of the inner ear is easy to be heterogeneous due to surrounding air cells. The heterogeneity causes phase shift in pixels and banding artifact on 3D-SSFP [2-6]. Although addiction of changing phase cycling is used to reduce banding artifact, it is available only in advanced machines [6]. Varying central frequency can cause phase shift and change locations of banding artifact. We expected the merged images with difference central frequencies can reduce banding artifact.

	± 10Hz				± 20Hz				± 30Hz				± 40Hz				± 50Hz			
	Compared to the basic images				Compared to the basic images				Compared to the basic images				Compared to the basic images				Compared to the basic images			
Anatomic Structure	Better	Worse	Equal	*p*	Better	Worse	Equal	*p*	Better	Worse	Equal	*p*	Better	Worse	Equal	*p*	Better	Worse	Equal	*p*
Device A																				
Vestibule	0	0	20	1	0	0	20	1	0	0	20	1	3	0	17	0.25	4	0	16	0.125
Semicircular canals																				
Superior	5	0	15	0.063	11	0	9	<0.001	12	0	8	<0.001	14	0	6	<0.001	13	0	7	<0.001
Posterior	3	1	16	0.625	6	4	10	0.625	5	2	13	0.156	6	0	14	0.031	5	2	13	0.156
Horizontal	9	0	11	0.004	12	0	8	<0.001	11	0	9	<0.001	13	1	6	0.002	12	1	7	0.003
Device B																				
Vestibule	0	0	20	1	1	0	19	1	3	0	17	0.25	4	0	16	0.125	11	0	9	<0.001
Semicircular canals																				
Superior	2	3	15	0.813	8	1	11	0.039	9	1	10	0.014	9	2	9	0.024	8	0	12	0.004
Posterior	2	1	17	0.75	9	1	10	0.027	7	2	11	0.098	9	0	11	0.004	9	2	9	0.032
Horizontal	5	2	13	0.375	10	2	8	0.034	9	0	11	0.004	11	0	9	<0.001	11	1	8	0.003

Table . Grades of the structures in the IAC and membranous labyrinth | Device A and B, n=20

PURPOSE

To evaluate reducing banding artifact using the merged images of the inner ear with different central frequencies.

METHODS

Our institutional review board approved this study and written informed consent was obtained from all volunteers. ***Subject:*** Twenty ears of 10 healthy adults including 6 men and 4 women ranging in age from 23 to 34 years (mean, 26.7) were enrolled for this study. ***Data acquisition:*** All volunteers underwent MR imaging on two 1.5-tesla MR imaging units (device A: Signa HDxt; GE Healthcare, Milwaukee, Wisconsin, USA and device B: Intera achieva; Philips Medical Systems, Best, Netherlands) by using 8-channel head coils. 3D-SSFP of device A was obtained with the following parameters: TR = 5.6 ms, TE = 2.4 ms, flip angle = 60°, FOV 180*180*112 mm, resolution = 0.7*0.63*0.8 mm and scan time = 1 minute 55 seconds. The device B's was obtained with the following parameters: TR = 5.0 ms, TE = 2.0 ms, flip angle = 60°, FOV 180*180*112 mm, resolution = 0.63*0.58*0.8 mm and scan time = 1 minute 50 seconds. Additionally, the images with different central frequencies were also obtained on each MR unit. The Volume shim was set at the cerebellopontine angle to obtain resonant frequency of optimum water on every healthy volunteer. The images with basic central frequencies ±10, 20, 30, 40 and 50 Hz were obtained. The images with the positive and negative frequencies were merged respectively by Advantage Workstation VolumeShare5 (GE Healthcare). ***Evaluating method:*** Two neuroradiologists evaluated the anatomical structures including all 4 nerves within the internal auditory canal (the facial, cochlear, superior vestibular and inferior vestibular nerves), the cochlea turns, the modiolus, the spiral lamina of the cochlea and the semicircular canals (SCC; superior, posterior, and horizontal canals) [4]. Two neuroradiologists evaluated independently and visually graded the image quality of the anatomical structures as good, fair and poor. Final decision was made by consensus. Each merged image with different central frequencies was compared to the basic image with the grades. ***Statistics:*** Wilcoxon signed-rank test was performed on each merged image. P value of less than 0.05 was considered as statistically significant.

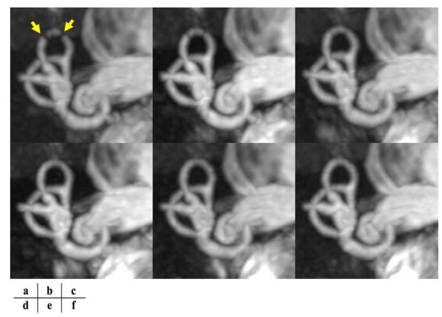

Figure 1. a: basic image, b:±10H, c: ±20Hz d:±30Hz, e:±40Hz, f: ±50Hz: Banding artifact of

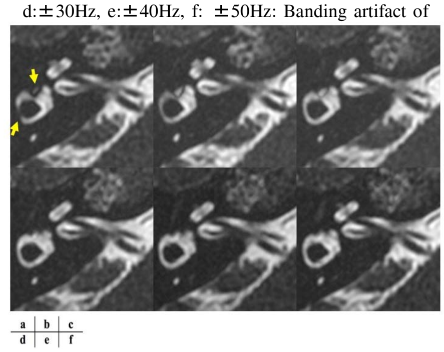

Figure 2. a: basic image, b:±10H, c: ±20Hz d:±30Hz, e:±40Hz, f: ±50Hz: Banding artifact on the horizontal SCC and vestibule (arrows).

RESULTS

Table shows comparison between the basic and merged images. Two devices demonstrated the same tendency. The image quality of the three SCCs was significantly better on more than the ±20 Hz images, especially in the superior and horizontal SCCs (Figure 1 and 2). The image quality of the vestibule has significantly better only on ±50 Hz image. The ±40 Hz images can improve the maximum cases on both the devices. The imaging quality of the nerves in the inner auditory canal and the cochlea was equal to the basic images.

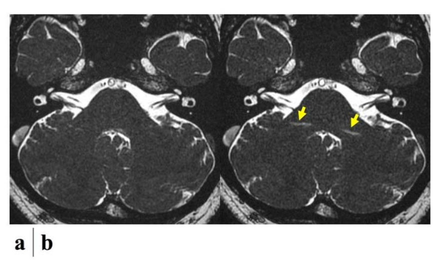

Figure 3. a: ±30Hz, b: ±50Hz: Wrapping artifacts have occurred at ±50Hz (arrows).

DISCUSSION

The merged images with small difference of central frequencies cannot improve the images quality, because locations of banding artifact do not shift sufficiently. Conversely on the merged images with large difference of central frequencies, signal-to-noise ratio is decreased and wrapping artifact toward slice direction likely appears (Figure 3). We think the ±40 Hz image can be optimal. This technique seems to be independent on MR imaging units. Extending repetition time (TR) can cause banding artifact on 3D-SSFP. However, this technique can reduce banding artifact and increase the number of matrices without worrying about the extending TR. High spatial resolution images can be therefore obtained by this technique.

CONCLUSION

To improve the image quality of the inner ear, the merged images with ±40 Hz difference of central frequencies is ideal for 3D-SSFP.

References

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