Isotropic Diffusion Weighted MR Imaging with Tetrahedral Gradients in the Upper Abdomen

M. Hori[1], T. Murakami[1], T. Kim[1], H. Onishi[1], M. Kuwabara[1], K. Tomoda[1], H. Nakamura[1], M. Hirano[2], A. Nozaki[2]
[1]Department of Radiology, Osaka University Graduate School of Medicine, Suita, Osaka, Japan, [2]GE Yokogawa Medical, Hino, Tokyo, Japan

INTRODUCTION:

Diffusion weighted MR imaging can be possible by analyzing the spin dephasing and signal loss caused by random motion along magnetic field gradients [1]. The clinical application of the technique has been expanding in the last decade, and is currently used as a routine imaging technique in many hospitals. However, one of the problems with diffusion weighted MR imaging is its relatively lower signal to noise ratio of the images especially when using higher b-values. One of solutions for the problem is to use shorter echo time (TE) of the sequence. By using motion probing gradient (MPG) pulses with simultaneous application of all three orthogonal gradients instead of a single orthogonal one, TE could be shortened without reducing the strength of MPG pulses [2]. In this method, four different gradient vectors can be generated (Fig 1), thus it is called tetrahedral technique. It can be used to obtain both isotropic and anisotropic diffusion weighted images. We have implemented an isotropic diffusion weighted single-shot SE echo planar MR sequences by using the tetrahedral technique for the body. The purpose of this study was to determine efficacy of the isotropic diffusion weighted MR sequence using tetrahedral technique in the upper abdomen by comparison with conventional sequence using orthogonal gradients.

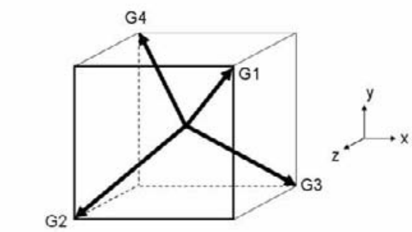


Figure 1. Spatial Configuration of tetrahedral gradient vectors

METHODS:

The isotropic diffusion weighted single-shot SE echo planar MR sequence using the tetrahedral technique was implemented for a 1.5-T clinical imaging MR scanner (Signa Excite-HD 1.5T, GE Healthcare, Milwaukee, WI). The system provides a maximum gradient strength of 33 mT/m with a peak slew rate of 120 mT/m/msec. Using the newly developed tetrahedral sequence, diffusion weighted images (b-factor, 800 s/mm^2) of the upper abdomen were able to be obtained with a TE of 53ms, while it was 62ms when using commercially available conventional diffusion weighted sequence with orthogonal gradients.

Twenty patients (11 men, 9 women) who ranged in age from 29 to 84 years (mean 63 years) with suspected liver tumors were enrolled in this study. Single-shot SE echo planar isotropic diffusion weighted transverse images of the upper abdomen during a single breathhold were obtained both with (a) conventional sequence using orthogonal gradients (TE 62 ms) and (b) new sequence using tetrahedral gradients (TE 53 ms). A b-factor of 800 s/mm^2 was used. Other parameters were the same as follows: a TR of 4000ms, 128 x 128 matrixes, 8-mm thickness, 2-mm gap, 1 NEX, and 36 x 36-cm FOV. Spectrally selected fat saturation pulses were applied for both techniques. An 8-channel body phased array coil was used for signal reception, and a parallel imaging technique (ASSET) was employed.

An experienced abdominal radiologist subjectively graded diffusion weighted images obtained with both techniques in terms of (a) signal homogeneity in the liver, (b) image distortion, and (c) overall image quality using a 4-point scale (0=poor, 1=fair, 2=good, 3=excellent). Wilcoxon signed-rank sum test was used for statistical analysis. Apparent diffusion coefficient (ADC) values were also calculated for the liver and the spleen, and compared between the values obtained with the two techniques.

Table. Distribution of Score for Overall Image Quality

	0	1	2	3	
Orthogonal	0	19	1	0	P = **0.001** Wilcoxon signed rank sum test
Tetrahedral	0	8	12	0	

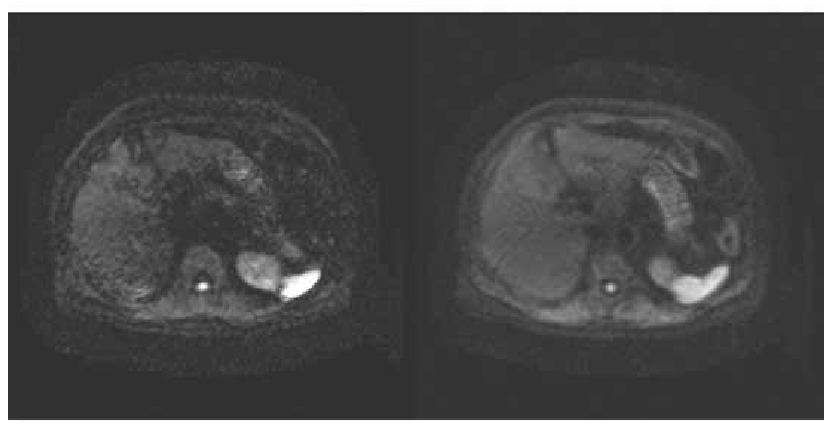
Note. 0 = poor, 1 = fair, 2 = good, 3 = excellent

RESULTS:

Image quality was significantly superior with the tetrahedral technique to the orthogonal technique in terms of signal homogeneity in the liver (P=0.001) and overall image quality (P=0.001). However, there was no significant difference in the degree of image distortion (P=0.32) between the techniques (Table, Fig 2). The ADC value calculated by the tetrahedral technique was significantly correlated with the value by the orthogonal technique in the liver (r=0.62, P=0.003) and the spleen (r=0.49, P=0.03).

DISCUSSION:

A tetrahedral gradient diffusion sequence for body imaging was successfully implemented for a clinical MR imaging machine. The tetrahedral technique showed significantly better image quality than the conventional orthogonal technique, probably due to higher signal strength achieved by the technique. Therefore, it would improve the value of diffusion weighted body imaging in clinical use. Moreover, it has a capability for making higher b-value diffusion weighted imaging fit for practical use.



(a) Orthogononal (b) Tetrahedral

Figure 2. Diffusion weighted images (b=800) obtained with each technique

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