Evaluation of Spatial Distortion in the 7.0T MRI for Clinical Use Using New 3D Mesh Phantom

Y-D. Son¹, H-K. Kim¹, S-T. Kim¹, N-B. Kim¹, Y-B. Kim¹, and Z-H. Cho¹
¹Gachon University of Medicine and Science, Neuroscience Research Institute, Incheon, Korea, Republic of

Introduction
The recently developed ultra-high field MRI having higher magnetic strength than 7.0T can produce fine structural images of the brain with high resolution and signal-to-noise ratio (SNR) not having observed in the past. In the recent studies, the clinically useful T2-weighted images with the high resolution have been acquired using 7.0T MRI, such as subthalamic nucleus, substantia nigra, hippocampus, and lenticulostriate arteries [1-3]. All of these areas are important in studying mechanism and treatment of major neurodiseases, such as Parkinson’s disease, Alzheimer’s disease, and stroke. These images can also be used directly in the neurosurgery or image-guided neurosurgery. The most critical issue, however, to be considered before applying 7.0T MR images for clinical use is the spatial accuracy. Unfortunately, spatial accuracy of the MRI becomes worse, as the strength of magnetic field increased. No study has been reported for the spatial distortion of the T2-weighted image in the 7.0T MRI yet. In this article, we will report the measurement of the spatial distortion in 7.0T MR image using in comparison with 1.5T MRI.

Method
In order to measure the spatial distortion, a new 3D mesh phantom was designed and manufactured for this study (Fig. 1(a)). The phantom contains 8x8x8 water-filled mesh having 512 crossing points in a cube. The cube was made of acrylic and each side had a dimension of 177mm. Diameter of a tube of mesh was 3mm and center to center between the tubes are 15.2mm in all direction. In order to obtain uniform intensity in the 7.0T MRI, filled water was mixed with 5g of NiSO4 and 20g of NaCl to shorten the T1 value. CT image was acquired as a reference image to calculate the spatial distortion from the MRI image. Using 1.5T and 7.0T MRI, gradient echo T2*-weighted image was taken. Commercial coil was used for 1.5T MRI and a house-made single channel Tx volume coil / eight channel parallel Rx coil for 7.0T MRI. The matrix size of 896x1024x70 with 0.25x0.25 mm of in-plane resolution and 2mm of slice thickness were used for 7.0T MRI. Two different pixel bandwidths, 200 Hz/pixel and 30 Hz/pixel, were used to compare degree of spatial distortion in the different susceptibility. The matrix size of 512x512x63 with 0.25x0.25 mm of in-plane resolution and 4mm of slice thickness were used for 1.5T MRI. Acquired MRI images were registered to the CT image with 6 parameters of linear transformation using the Vinci Software (Max-Planck Institute, Cologne, Germany). Volume of interest (VOI) with 60mmx60mmx60mm at the center of the phantom was selected to minimize the effect of distortion when the images were registered. Coordinates of each control points were obtained by using the local projection method from each slice of images. Distortion error was estimated by calculating the distance between the centers of MRI and CT.

Results
At 200Hz/pixel, measured distortion of the most areas within the whole phantom is less than 1mm and the average value of distortion is about 0.3mm, which corresponds to about one pixel of the MR image (Fig. 2(a) and (b)). 1.5T and 7.0T MR image were not significantly different each other. However, the image became more distorted, as pixel bandwidth of image decreased. Maximum distortion was about 3.5mm, which corresponds to 14 pixels, when pixel bandwidth is 30Hz/pixel. Average of the distortion was not varying with the pixel bandwidth, but the variance became increased when the pixel bandwidth decreased. However, for the central region around the isocenter of the MRI system, distortion is not a problem and almost same as 1.5T regardless of bandwidth (Fig. 2(c)). It should be noted that the spatial distortion is increased along the direction of frequency encoding as the sampling bandwidth decreased.

Discussion
Spatial distortion in the MR image is mainly due to the B0 field inhomogeneity, nonlinear gradient, and susceptibility effect. Among these factors, susceptibility effect is object-dependent components and the others are system-dependent components. It means that the distortion measured in this study could be more severe depending on the magnetic property of the object, such as the brain regions around nasal area. This distortion could be minimized by maximally increasing the pixel bandwidth with sacrificing SNR in the applications, which the spatial accuracy is more important than the image quality. Some distortion compensation pulse sequence, such as phase warping or gradient reversal methods, can be used to minimize the distortion. In conclusion, 7.0T image can be utilized in the image-guided surgery, such as accurate targeting of deep brain stimulation (DBS) needle to the subthalamus region using MR image, only if the imaging parameter or pulse sequence was carefully considered to avoid the distortion.

References