Visualization of subthalamic nucleus using Three-dimentional Phase Sensitive Fast Inversion Recovery: Preoperative identification of deep brain stimulator position

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Abstract

The feasibility of three-dimensional phase sensitive fast IR images for preoperative determination of deep brain stimulator position was studied. Geometric distortion measured with a grid phantom was less than 0.1%. The imaging parameters which provided high T1 contrast in the area of basal ganglia were optimized. In all volunteer and patient studies, subthalamic nucleus was clearly depicted in 3D real IR images. The measured coordinates of subthalamic nucleus were well agreed with conventional estimation method calculated from midpoint of AC and PC. This method was considered to be useful in visualization of subthalamic nucleus for effective deep brain stimulation.

Introduction

Deep brain stimulation has been widely recognized as an effective treatment of Parkinson's disease in recent years. In this method, preoperative identification of electrode implantation position is important in ensuring the efficacy of treatment and patient safety. Three-dimentional phase sensitive real inversion recovery (IR) provides high signal to noise ratio and contrast to noise ratio even with thin slice images and considered to be a useful method in assessing the position of subthalamic nucleus prior to the operation. The purpose of this study is to confirm usefulness of three-dimentional real IR in visualization of subthalamic nucleus and to optimize the imaging parameters.

Methods

All the studies were performed on a 1.5T MRI system (VISART/EX Ver.5.30 Toshiba Medical Systems, Japan). Three-dimensional Fast Spin Echo sequence with ETL of 12 was used. Images were reconstructed in a phase sensitive format. The following experiments were carried out. First, degree of geometric distortion in real IR image was measured using a phantom with grid structure. Secondly, optimization of acquisition parameters was performed using a phantom which has T1 and T2 relaxation time similar to those of cerebral white matter and basal ganglia. Finally, visualization of subthalamic nucleus by three-dimentional real IR was investigated with images of three healthy volunteers and two patients who were scheduled to undergo placement of deep brain stimulators in subthalamic nucleus.

Results

Geometric distortion was evaluated by measuring errors in distance between the grid both at the center of the magnet and 10 cm off-center in z-direction, which were less than 0.1%. The degree of distortion was not considered to be a major obstacle for accurate assessment of electrode placement. In phantom and volunteer studies, longer TR resulted in better signal to noise ratio, however TR of 4000 msec and 5000 msec did not make a significant difference. Figure 1 shows volunteer images with different TI varied from 100 msec to 400 msec. The optimum TI which provided high contrast between red nucleus and thalami was found to be 200 msec. In all volunteer and patients images, both right and left subthalamic nucleuses were clearly visualized using three-dimentional real IR.

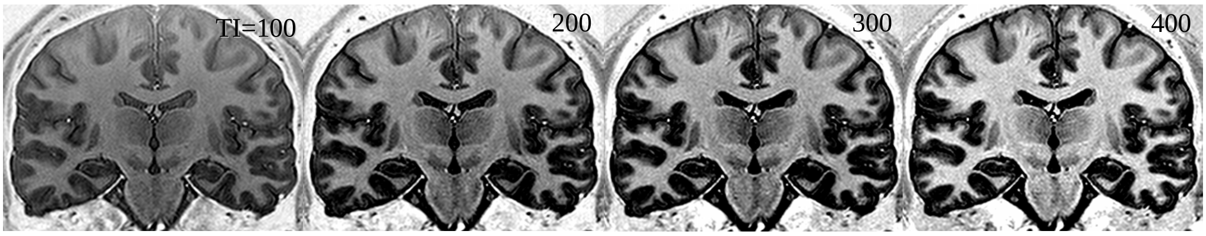

Figure 1 Three-dimensional Real IR images with different TI

Figure 2 shows an example of patient image. In the real IR image, the X, Y and Z coordinates of left subthalamic nucleus in a stereotactic frame were directly measured as 114, 91 and 106 respectively. The coordinates calculated from the midpoint of anterior commissure (AC) and posterior commissure (PC) using conventional estimation method were x=111-112, y=90-91 and z=104-106. The measured coordinates of two method showed consistent results. The burst of spontaneous discharge was observed when the implantation aimed at the target position was performed. This indicates that the electrode was successfully placed within the subthalamic nucleus. The patient showed a palliation of tremor and improvement in walking speed.

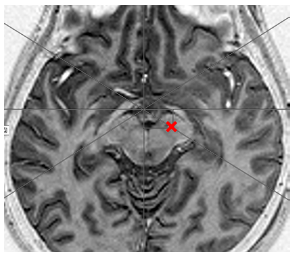

Figure 2 Subthalamic nucleus of a patient

Discussion

Three-dimentional real IR provides sufficient T1 contrast images with thin slice, which is considered to be a useful pulse sequence in the preoperative depiction of subthalamic nucleus for the deep brain stimulation. As the result of optimization for acquisition parameters, TR, TE and TI of 4000msec, 10msec and 200msec were obtained for superior contrast to noise ratio. This sequence is more useful compared with STIR due to the higher freedom in the selection of inversion time.

Conclusion

Three-dimensional real IR is confirmed to provide distortion free images, which enables determination of positioning of electrode in deep brain stimulation. This pulse sequence gives high contrast to noise ratio in the area of basal ganglia with thin slice images, which provides less partial volume effect and useful in visualization of subthalamic nucleus for an effective deep brain stimulation.