Unreliability of Cortical Volumetry in Regions near The Skull Base on 3D T1-weighted Imaging: Comparison study with 3D Double Inversion-recovery Imaging

E. Yoo[1], D-H. Kim[2], H-J. Park[1], and E-Y. Kim[1]

[1]Department of Radiology and Research Institute of Radiological Science, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea, Republic of, [2]School of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea, Republic of

Introduction

Most volumetric studies have used an automatic technique such as voxel-based morphometry by using three-dimensional T1-weighted imaging. Although 3D T1-weighted imaging provides good contrast between the cortex and white matter, this imaging is based on gradient-recalled echo sequence. Therefore, susceptibility artifact due to air-bone interface may happen and consequently give rise to hyperintensity within the cortex, which may be a problem for accurate and reliable measurement of the cortical volume. This may be true in the cortical regions in close proximity to the paranasal sinus and mastoid air cells, including orbitofrontal, inferior temporal, and fusiform gyri. It has been reported that volumes of these gyri are decreased variously in patients with schizophrenia, Alzheimer's disease, bipolar disorder, frontotemporal dementia, obsessive-compulsive disorder, and major depressive disorder (1, 2). All of the previous studies did not mention this potential pitfall in measurement of cortical volume in these regions, nor perform manual volumetric measurement for reliability test. This pitfall can be solved if imaging is obtained with fast-spin echo sequence such as 3D double inversion-recovery imaging (DIR). We hypothesized that 3D T1-weighted imaging may underestimate cortical volume in the orbitofrontal, inferior temporal, and fusiform gyri due to hyperintensity caused by susceptibility artifact, and 3D DIR may measure more accurately and reliably than 3D T1-weighted imaging. The purpose of this study is to investigate whether 3D T1-weighted imaging may underestimate cortical volume in these specific regions and verify underestimation by using 3D DIR.

Methods

Eight healthy volunteers (each of 4 male and female; mean age, 29.4 years) underwent MRI at 3.0 T (Tim Trio, Siemens Medical Systems). MR imaging consisted of 3D T1-weighted (MP-RAGE) and 3D DIR imaging. Whole brain coronal imaging perpendicular to the anterior commissure-posterior commissure line was obtained with the same geometrical parameters in both 3D MP-RAGE and 3D DIR. The scan parameters of 3D DIR are as follows: field of view, 280 mm; slice thickness, 1.3 mm; TR/TE = 10000/312 ms; long inversion time, 3100 ms; short inversion time, 550 ms; matrix, 256x256 (in-plane resolution, 1.1x1.1x1.3); parallel imaging factor, 2. Three-dimensional MP-RAGE images were obtained with the vendor-provided conventional protocol. A neuroradiologist visually assessed side by side both 3D MP-RAGE and 3D DIR imaging in regard to the presence of susceptibility artifact causing underestimation of cortical volume near the skull base. Underestimation of cortical volume was determined when at least three slices showing hyperintensity within the presumed cortex were found. If the regions of underestimation of cortical volume are found, signal intensity profile was analyzed in the underestimated cortical region by using ImageJ (http://rsb.info.nih.gov, v1.38).

Results

On 3D T1-weighted imaging, one or more regions in the bilateral orbitofrontal, inferior temporal, and fusiform cortices showed susceptibility artifacts causing underestimation of cortical volume. However, 3D DIR did not show underestimation in the corresponding regions. In these regions, signal intensity profiles of 3D MP-RAGE confirmed underestimation of cortical thickness compared to the thickness estimated by the 3D DIR (Fig 1, 2). In other regions where susceptibility artifact was not present, the thickness did not differ for the two methods.

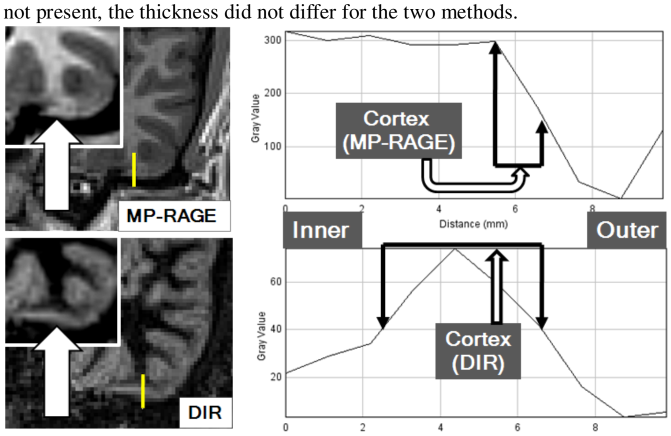

Fig. 1. The left fusiform cortex shows artifactual signal loss on 3D MP-RAGE, but not on 3D DIR (arrows on inset images). Signal intensity profile curves show thinner cortex on 3D MP-RAGE than on 3D DIR.

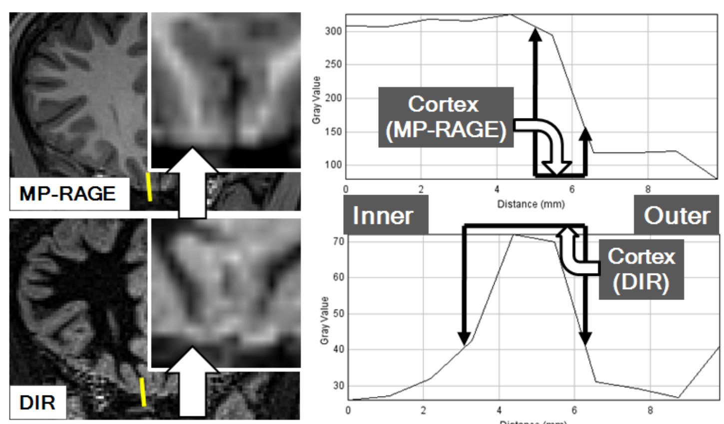

Fig. 2.The right straight cortex shows artifactual signal loss on 3D MP-RAGE, but not on 3D DIR (arrows on inset images). Signal intensity profile curves show thinner cortex on 3D MP-RAGE than on 3D DIR.

Discussion and Conclusion

Double inversion-recovery imaging suppresses the signals from both white matter and cerebrospinal fluid, selectively depicting cortex with bright signal intensity. It is based on fast-spin echo sequence unlike 3D MP-RAGE. Therefore, DIR is relatively free from susceptibility artifact caused by air-bone interface compared with 3D MP-RAGE. In addition, 3D DIR can be used for cortical volumetry because of its excellent contrast between the cortex and white matter. We demonstrated that 3D MP-RAGE is not a reliable technique for cortical volume measurement in the regions near the air-bone interface. The previous studies did not validate cortical volumetric technique in these regions. Therefore, it may be suggested that the results of previous studies underestimates the thickness and validation study using 3D DIR is needed. We are developing a new algorithm for cortical volumetry by using 3D DIR, which may show different results compared with those of the previous studies. In conclusion, 3D MP-RAGE underestimates cortical volumes in multiple regions near the skull base including the orbitofrontal, inferior temporal, and fusiform gyri. Accurate and reliable measurement of the cortex in these particular regions may be acquired by using 3D DIR.

References

1. Kuperberg GR, Broome MR, McGuire PK et al. Regionally localized thinning of the cerebral cortex in schizophrenia Arch Gen Psychiatry 2003;60:878-888
2. Du A, Schuff N, Kramer JH, et al. Different regional patterns of cortical thinning in Alzheimer's disease and frontotemporal dementia Brain 2007;130:1159-1166