# Quality Assurance for Diffusion Tensor Imaging Using ACR Phantom: Comparative Analysis with 6, 15 and 32 Directions at 1.5T and 3.0T MRI Systems

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## INTRODUCTION

Diffusion tensor imaging (DTI) has been widely used for quantitative analysis of white matter integrity of brain in clinical and research settings. Echo planar imaging (EPI) sequence, however, has many drawbacks such as Nyquist ghosting, signal dropout, geometric distortions, and low signal-to-noise ratio (SNR). At present, the American College of Radiology (ACR) MRI phantom is the most widely used. This standardized phantom evaluates 7 major items based on T1 and T2 axial spine echo (SE) images, which provide important information for system performance testing and QA of the equipment. In the present study, we report the QA for DTI in 6, 15 and 32 directions using the ACR MRI head phantom. We evaluated geometric accuracy, slice position accuracy, image intensity uniformity, percent-signal ghosting, low-contrast object detectability, image distortion, fractional anisotropy (FA) and apparent diffusion coefficient (ADC) on DTI images. Also, these values were compared with 1.5T and 3.0T MRI scanners.

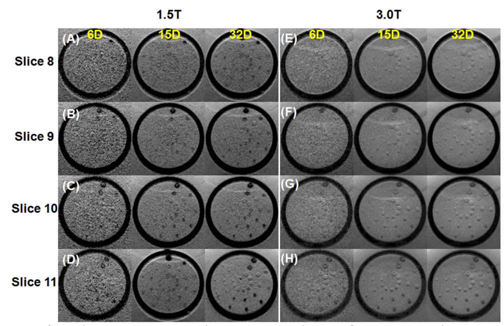


**Fig. 1.** Trace map images derived from DTI in 6, 15, 32 directions of slices 8-11. (A)-(D): The images from 1.5T scanner shows more spokes in slice 11 images than in slice 8 images, and more spokes in 32 direction images than in 6 direction images. (E)-(H): Additionally, the images from 3.0T scanner reveals better contrast in slice 11 and in 32 direction images. (6 direction; 6D, 15 direction; 15D, 32 direction; 32D)

## MATERIALS AND METHODS

All experiments were performed using 1.5T and 3.0T scanners (Intera Achiva 1.5T and Achiva Tx 3.0T; Philips Medical Systems, Netherlands) equipped with an 8-channel SENSE head coil. The ACR MRI phantom was filled with a solution containing 10 mM $NiCl_2$ and 75 mM NaCl. The standard axial SE T1-weighted MR images with 6, 15 and 32 directions of DTI were obtained using the standard scanning protocol "Phantom Test Guidance for the ACR MRI Accreditation Program". Slice thickness and slice gap were set at 5 mm for standard axial SE T1 images and echo planar images, and then both images were compared. Reproducibility was tested with 7 repeat scans in 1.5T scanner and 10 repeat scans in 3.0T scanner. Between the scanning, the ACR MRI phantom was completely removed from coil and was repositioned for each new trial. Parameters for the QA protocol are shown in Table 1. The ACR MRI phantom was stored in the scanner room for at least 24 hours before an experiment, and the room temperature was measured before scanning for DTI.

## RESULTS

Geometric accuracy was significantly different through the Mann-Whitney U test ($p=0.002$, $p=0.028$ for left-to-right and Rt-diagonal scans, respectively). Image intensity uniformity tests were significant in 6, 15, and 32 directions at 1.5T and 3.0T comparative analysis. Additionally, percent-signal ghosting tests were significant in all directions such as 6, 15 and 32 directions in both 1.5T and 3.0T. In our study, the DTI images from 1.5T system showed 2.85 spokes in 6 direction, 14.00 spokes in 15 direction, and 26.14 spokes in 32 direction. The DTI images from 3.0T system had 7.80 spokes in 6 direction, 32.20 spokes in 15 direction, and 37.30 spokes in 32 direction. Image distortion in the 1.5T scanner was 6.93 mm for AP direction and 0.26 mm for RL direction, while the same for 3.0T system was 8.55 mm for AP direction and was 0.28 mm for RL direction. FA values were 0.23 and 0.24 for 32 direction in 1.5T and 6 direction in 3.0T, respectively. In ADC values of 6 direction images for 1.5T system, the 5th and 6th values were 2.149 and 2.350 respectively, which were the biggest variations.

## DISCUSSION AND CONCLUSION

In this work, we evaluated geometric accuracy, slice position accuracy, image intensity uniformity, percent-signal ghosting and, low-contrast object detectability provided by ACR Guidance as well as image distortion, ADC and FA values measured with 6, 15, and 32 directions at 1.5T and 3.0T MR systems. This is the first trial using the ACR MRI phantom that are easily accessible in most of clinical MR centers. We propose a new method of DTI quality assurance that addresses conventional issues and methods.

## ACKNOWLEDGEMENT

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**Table 1.** Mean FA and ADC values for Broca's and Wernicke's areas in controls and patients with PD.
(All data are expressed as mean ± standard deviation. FA, fractional anisotropy; ADC, apparent diffusion coefficient)

| | | 1.5T | 3.0T | P-value |
|---|---|---|---|---|
| FA | 6 direction | 0.46 ± 0.01 | 0.24 ± 0.01 | < 0.001 |
| | 15 direction | 0.31 ± 0.02 | 0.13 ± 0.01 | < 0.001 |
| | 32 direction | 0.23 ± 0.02 | 0.09 ± 0.00 | < 0.001 ( 0.001 a ) |
| ADC | 6 direction | 2.22 ± 0.06 | 2.16 ± 0.03 | 0.033 |
| | 15 direction | 2.28 ± 0.04 | 2.15 ± 0.02 | < 0.001 |
| | 32 direction | 2.28 ± 0.03 | 2.15 ± 0.03 | < 0.001 |

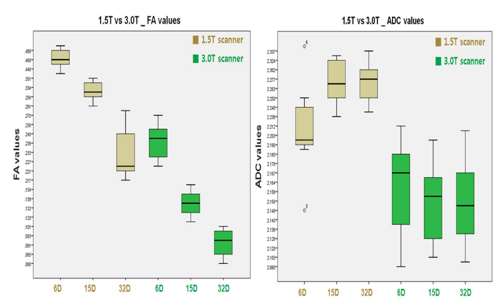


**Fig. 2.** FA values are relatively lower for 3.0T than for 1.5T, and 32 direction in 3.0T scanner had the lowest FA. ADC values of 3.0T system were lower than those of 1.5T, and 15 and 32 directions provided lower values.