

# The Performance of NODDI Estimation Using a Common 2-Shell Protocol

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### Purpose:

The neurite orientation dispersion and density imaging (NODDI) is a new model proposed recently to detecting microstructure changes of the brain [1]. It acquires a two-shell acquisition protocol to accurately calculate its indices. Optimized protocols were evaluated to shorten its acquisition time. The optimized protocols sample the higher b-value at twice the angular resolution of the lower b-value because of higher signal variation at high b-value. Although the optimized protocol achieved a good balance of acquisition time and image quality, its special gradient table setting cannot be directly configured on a commercial scanner, and required specific experience. In contrast, another multi-b-value diffusion model, diffusion kurtosis imaging (DKI) [2], normally adopts a common 2-shell protocol [3] with the same gradient direction setting in each shell and is available on most commercial scanners. Because of this simplicity, DKI has been widely applied in a large number of clinical studies so far. Thus, in this paper, we evaluate the feasibility to do NODDI estimation using a common 2-shell protocol, which may greatly facilitate the application of the NODDI model.

### Methods:

Brain diffusion datasets were collected from one healthy volunteer using a 3.0T system (Magnetom Verio, Siemens AG, Erlangen, Germany). Two different 2-shell diffusion protocols were adopted: an optimized NODDI protocol with 21 and 42 gradient directions at  $b = 700$  and  $2000 \text{ s/mm}^2$ , respectively; a 2-shell protocol with 30 gradient directions at both  $b = 1000$  and  $2000 \text{ s/mm}^2$ . The NODDI toolbox [2] was used to estimate NODDI indices: intra-cellular volume fraction (ICVF), isotropic volume fraction (IVF) and orientation dispersion index (ODI). Two regions of interest (ROI) were drawn in gray matter and white matter, respectively, and mean indices values from two protocols were compared. In addition, the joint histogram of the indices from 2 protocols were created, and correlation of the indices were also evaluated using a linear fitting with the formula " $Y = K \cdot X$ ", where X, Y are indices of 2 protocols, and K is the rate of two indices.

### Results:

The result showed that two protocols generated comparable NODDI indices maps (Figure 1). The IVF and ODI maps of two protocols look very similar, and have closed mean value in both white matter and gray matter, with differences less than 3% (Figure 2). Although the visual appearance of the ICVF map using an optimized protocol looks smoother than the common one in the white-matter region, the ROI mean did not showed any significant difference. Furthermore, the correlation of the indices from 2 protocols was very high (Figure 2). In the linear fitting, the rate and root mean square error were at 0.9926, 0.08116 for ICVF, 0.9974, 0.08929 for IVF, 0.9969, 0.1022 for ODI.

### Discussion:

The common 2-shell protocol was shown to be a good replacement of the optimized protocol with equivalent image quality and more convenience. On one side, the common protocol is easy to implement, thus can be widely adopted. On the other side, many other diffusion methods, such as DKI, bi-exponential model, uses common multi-shell protocols, and were widely applied in studies of brain development or neural disease. Thus the value of NODDI in other multi-b-value diffusion studies can be preliminarily evaluated without reacquiring clinical data, but using acquired data of other multi-b-value models. Moreover, NODDI, as a new and powerful diffusion model, provides unique and specific structural information of neurite. Thus, the comparison between NODDI and other multi-b-value diffusion models is also an interesting topic, and can also be easily conducted in the future.

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**References:** [1] Zhang H et al. Neuroimage. 2012. [2]Jensen et al., MRM. 2005. 61(4):1000-16. [3] Jensen et al. ISMRM 2009.

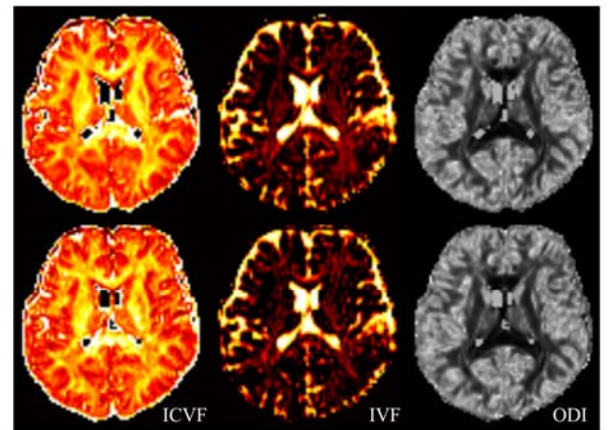


Figure 1. The indices of NODDI estimated using an optimized NODDI protocol and a common 2-shell protocol.

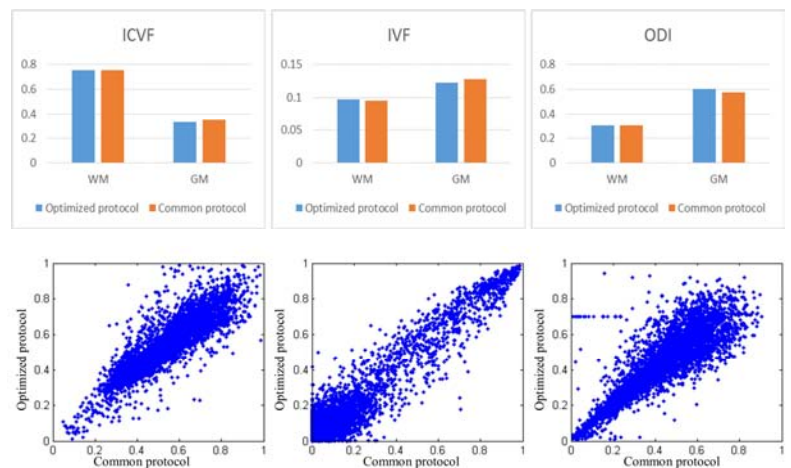


Figure 2. Comparison of NODDI indices using optimized and common protocols. In upper row, two ROIs in white matter and gray matter were drawn, and no significant differences were found between two protocols. In lower row, joint histogram was drawn, the indices of two protocols showed high linear correlation.