Effects of Corrupted Signals on Orientation Distribution Function in Q-ball Imaging: A Simulation Study

Yen-Wei Cheng[1], Ming-Chung Chou[2], Wen-Yih Isaac Tseng[3], and Hsiao-Wen Chung[4]

[1]*Department of Electrical Engineering, National Ilan University, IIran, Taiwan,* [2]*Department of Medical Imaging and Radiological Sciences, Kaohsiung Medical University, Kaohsiung, Taiwan,* [3]*Center for Optoelectronic Biomedicine, National Taiwan University, Taipei, Taiwan,* [4]*Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan*

Introduction

Q-ball imaging (QBI) is a diffusion imaging technique capable of resolving intra-voxel fiber crossings. However, inevitable signal loss in diffusion-weighted images (DWIs) due to hardware instability and physiological-related fluctuations has been observed in QBI data, which were unpredictable and could largely impact the derivation of orientation distribution function (ODF) [1]. Therefore, the purpose of this study was to simulate the randomly corrupted signals and evaluate the resultant ODF errors as well as error reduction rates by using a previously proposed correcting method [2].

Material and Methods

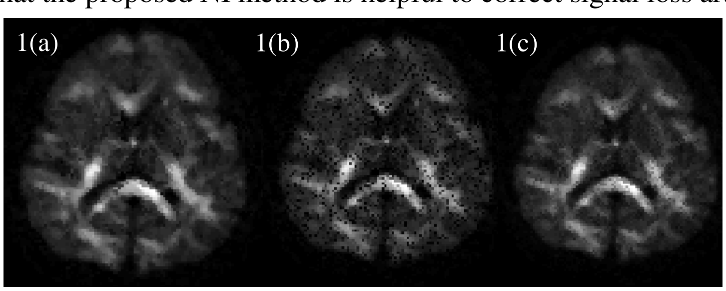
QBI data were collected from a 40 y/o healthy subject at a 3T MR scanner (Philips Achieva, Nederland) using 252-direction resolution with repeated scan for each direction. Other experiment parameters were: 128 x 128 matrix size, 25 slices, TR/TE=6300/120 ms, EPI factor = 39, b = 2000, 3000, 4000s/mm^2, slice thickness = 5mm, scan time = 70min40sec. The gold standard QBI datasets were obtained by replacing the damaged signals with those of undamaged signals in the repeated dataset. Subsequently, the simulation was performed by generating corrupted signals in the gold standard QBI with random loss of signal intensity as well as random occurrence of pixel location. As a result, 14.84%, 20.7% and 22.48% pixels with random signal loss were corrupted in b = 2000, 3000, 4000 s/mm2 QBI datasets, respectively. Finally, the neighboring interpolation (NI) method [2] which relied on the assumption that diffusion signals vary smoothly in q-sphere was used to correct those corrupted signals by averaging their neighbor-direction signals weighted by the inverse angular distances from the target signal.

Results

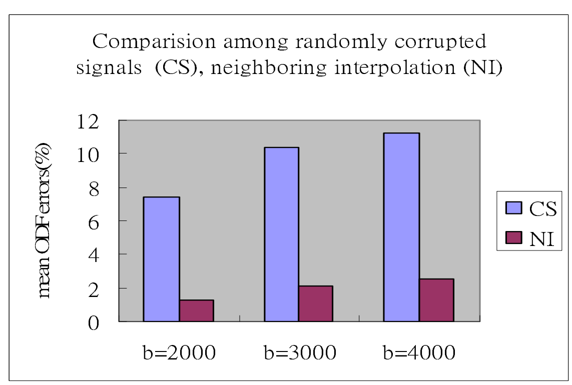
Figure 1(a) shows one gold standard DWI acquired with b = 4000 s/mm^2. By randomly adding the corrupted signals, the image exhibits unpredictable signal loss in intensities and in locations, as shown in figure 1(b). After correction with NI method, the DWI appears to be very similar to the gold standard DWI, as shown in figure 1(c). The ODF differences between the un-corrected QBI and gold standard QBI data are shown in figure 2(a), where there are on average about 11.24% ODF errors in b=4000 s/mm^2 QBI data. With NI correction for signal loss, the mean ODF errors in b=4000 s/mm^2 QBI data were reduced to 2.51%, as shown in figure 2(b). Figure 3 plots the mean ODF errors caused by simulated corrupted signals before and after NI correction in b = 2000, 3000, 4000 s/mm^2 QBI datasets.

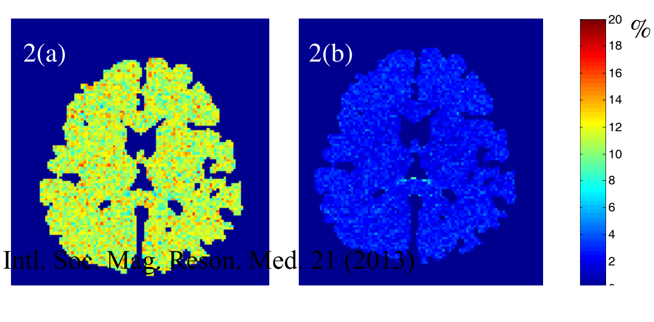
Discussion

In this simulation study, we found that the reduction rates of ODF errors by NI method were 82.62%, 79.32%, 77.67% for b = 2000, 3000, 4000 s/mm^2 QBI datasets, respectively, and the error reduction rates were found to decrease with b-value, which is due to the fact that higher b-value DWI exhibits lower SNR and hence reduces the correcting efficacy. With NI correction, the ODF errors were reduced to less than 3% in three commonly used b-values, suggesting that the proposed NI method is helpful to correct signal loss artifacts in QBI.



3





References
[1] Sharman M.A., et al, *JMRI* 2011; 33: 1491- 1502.
[2] Cheng Y.W., et al, *ISMRM* 2011, Montreal.