Multi-station multi-sequence approach for whole-body diffusion-weighted imaging

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INTRODUCTION

Acquisition of diffusion-weighted images in body allows fast screening of disseminated tumors, lymph nodes or abscesses. Currently, the clinical evaluation of diffusion-weighted whole-body imaging with background body signal suppression (DWIBS) [1] focused on tumor detection, lymph node imaging, and imaging of bone metastases is being performed. In the meantime, technical improvements of the acquisition methods are also necessary regarding the reduction of acquisition time because almost 30 minutes is required for whole-body (wb) DW MRI [2]. Recent report on wbDWI shows images acquired with body coils because surface coils cause significant respiratory artifact and the patients have to suffer from the weights of the surface coils. However, surface coils can generate better images for certain regions. Thus, we propose a method to employ the advantages of both the body and the surface coils to effectively obtain wbDWI.

METHODS

All experiments were performed on a 1.5T Siemens Avanto system with parameters as follows: b=0, 500s/mm^2, slice thk=6mm, TR/TE = 4600/91 ms (surface coils, GRAPPA, factor=2) 7000/142 ms (body coil), matrix size=192x192 and a FOV of 400x400 mm^2, 30 slices/station with 5 stations. With time required for extra preparations such as RF calibration and shimming, the acquisition time for each station is 70 seconds without breath-holding. Although images with surface coils show better qualities especially for areas with less respiratory motion, signals are severely degraded where most respiratory motions occur. Thus, a built-in body coil was used for areas with high respiratory motions. Since a long acquisition time with body coil also results in image degradation, a compensation method to reduce the acquisition time is proposed as follows: EPI data is acquired with half of the phase encoding lines in order to reduce the TE and the total data acquisition time. Any additional data for EPI correction such as a fieldmap or navigator data are not acquired so that the acquisition time can be minimized. In order to correct for the N/2 ghosts and geometric distortions in EPI, the correlation coefficient between the neighboring even and odd phase encoding (PE) lines are calculated for 20 central PE lines to find the shifts s between lines. By using the average shift s_{ave} of 20 lines, every odd line is shifted by s_{ave} for the whole k-space data. Fig.1 shows uncorrected (left) and corrected (right) k-space data of a phantom image. In order to show the feasibility of the proposed method, another set of data was acquired using the same parameter as above. The number of slices in each station was adjusted to 38 so that the suspected region of heavy respiratory motion can be fully covered by one station. The data was acquired using a built-in body coil for 2nd station and surface coils for 1st, 3rd, 4th, and 5th stations.

RESULTS

Fig.2 shows images acquired with a body coil and surface coils. These images show that surface coils can generate better images when respiratory motions are subtle. The data acquired by surface coils for the GRAPPA reconstruction method produced a wbDWI as shown in Fig.3 (left) with maximal intensity projection (MIP) in inverted intensity. As highlighted by the arrow, regions with high respiratory motion are severely degraded. This problem could be overcome by acquiring the data of this region using a body coil and reconstructing the images using the proposed method. Fig.4 shows the image reconstruction technique used for the 2nd station (the area with more motions). In order to demonstrate the advantage of the reconstruction method, low diffusion data with b=100 s/mm^2 was acquired with 92 phase encoding lines as shown in Fig.4 (top). The motion that occurs during data acquisition could result in artifacts as shown by the arrow. As a comparison, data was acquired with 96 phase encodings, which is half of the full encoding numbers to reduce the influence of breathing motion on the images. The images in the middle and at the bottom of Fig. 4 show uncorrected and corrected images, respectively. Due to the shortened acquisition time, image shows less motion-related artifacts and the N/2 ghosts are successfully corrected using the proposed correction method. Since the SNR of k-space data are not as high in high b-value data as in low b-value data, the average shift s_{ave} is calculated once from low b-value data and is used also for high b-value images. This is efficient in many clinical cases because more than 2 b-value data are usually acquired. Fig.3 (right) shows a reconstructed wbDWI data set acquired with a body coil and corrected with the proposed method (marked with a square) and surface coils (rest of the body). As shown in the image, signal degradation due to the respiratory motion was reduced. For acquisition of one low b-value and one higher b-value data, the total acquisition time was about 15 minutes.

DISCUSSION

In order to employ the advantages of both the surface and body coils, different acquisition methods were used for different body parts (different imaging stations) for acquisition of whole-body diffusion weighted images. As the images were acquired with SE-DWEPI sequences, insufficient fat suppression was observed as mentioned in other literatures [1]. The insufficient fat suppression (marked with an arrow in Fig.3 (right)) can be overcome by the short time inversion recovery (STIR) DWEPI technique. The proposed method together with STIR-DWEPI sequence should produce good quality images with sufficiently suppressed fat signals. A careful clinical evaluation should be followed to prove the efficiency of the proposed method.

REFERENCES

(1)Takahara T, et al. Radiation Medicine 22:4:275-282 (2004). (2)Li S, et al. JMRI 26:1139-1114 (2007).

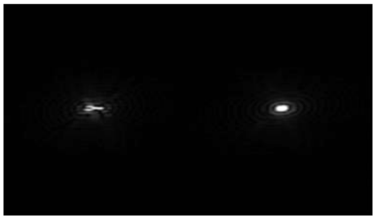
Fig.1. K-space data acquired with SE-DWI sequence (left) and corrected data by shifting odd phase encoding lines by a factor calculated with correlation coefficient (right).

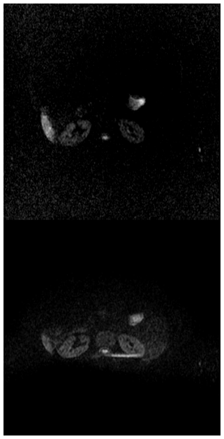
Fig.2. DWI acquired with a built-in body coil (up) and surface coils (down).

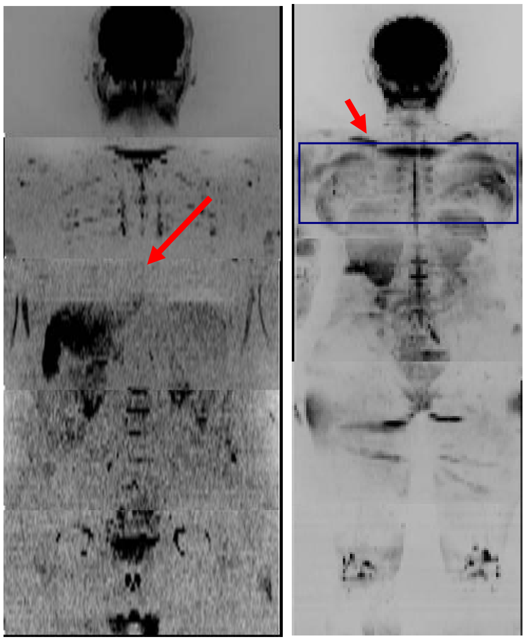
Fig.3 MIP of DWI. The image on the left is acquired by the GRAPPA method and the image on the right is acquired with a mixture of the body coil (in square) and surface coils (rest).

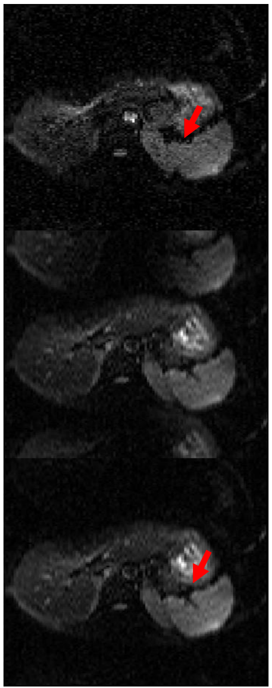
Fig.4. Images acquired with 192 PE lines (top), uncorrected 96 PE lines (middle) and corrected 96 PE lines (bottom).