Automatic Motion Correction of FSE Wrist Exams: Towards Full Clinical Implementation

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Introduction

Automatic retrospective correction of rigid-body motion in MRI by optimization of an image quality measure [1] has been demonstrated on many types of MR acquisitions, and its effectiveness proven by detailed comparisons with navigator echo results on clinical images twice: on 144 rotator cuff images [2] and on 26 high resolution 3D wrist exams [3]. However, clinical implementation of this technique has been hindered by the computational times required (reported times for the studies above ranged from 20 minutes [2] to hours [3]).

Our goal is the full integration of automatic motion correction into the clinical environment for selected MR exams, with the correction being available on demand, fully automatic, and with corrected images appearing on the original scanner (as a separate series from the original images) within 5 minutes. The infrastructure for such a system is in place, and the initial target application has been identified as FSE wrist exams on a 3T scanner. Prior to testing this system in the clinical environment, we wanted to verify the proper functioning of the correction system, test its speed, and estimate the image quality improvements achieved. For this purpose, we implemented an automated system that daily (1) saved the raw (complex) data for all exams with selected pulse sequences from the specific scanner, (2) downloaded these data sets to our computer after clinical hours, and (3) automatically corrected all the data sets. We then evaluated the quality of the original and corrected images and the correction time required.

Materials and Methods

Clinical oblique-axial fast spin echo wrist images were acquired at 3T (Signa HDx, GE Healthcare) using a BC-10 T/R wrist coil (Mayo Clinic Medical Devices). The standard clinical protocol included the following parameters: 1) T1-weighted: 10x7.5 cm field of view (FOV), 384x256 acquisition matrix, 24 - 2.0mm skip 1.0 slices, 800ms/11ms/2/±32kHz (TR/TE/NEX/BW), 4 ETL, 2:54 scan time and 2) fat-suppressed T2-weighted: 10x7.5 cm FOV, 320x256 acquisition matrix, 24 – 2.0 mm skip 1.0 slices, 3500ms/45msec/2/±32kHz, 12 ETL, 2:09 scan time. However, patient specific scan prescription from a pool of 34 technologists resulted in variations in FOV, scan resolution, number of slices, TR and ETL. All such changes to the protocol were interpreted correctly and automatically by the software.

The data sets were corrected for 2D translational rigid body motions. The image quality measure used was the entropy of the image gradient [4]. The correction process was analogous to [2] in that the acquisition time was initially broken up into four blocks of time, with motions estimated for each block in turn with simplex optimization, and then the block size was halved and the process repeated, down to individual echo trains. The determination of which lines of k-space were acquired at each echo was performed automatically by the software. Corrections were implemented on both a standard PC and a 16-processor cluster. To save time, only alternate slices of the images were corrected, and the motions determined were interpolated to correct the intervening slices.

Results

160 series of data sets from 44 patients were collected over a 3 month period. This represented all such exams performed on this scanner, except for 4 patients that did not sign consent forms allowing the use of their data for research purposes. Of the 160 series, 90 were deemed to have no visible signs of motion. Of the remaining 70 series, 6 were judged to be unimproved by the automatic correction, 34 were judged to be slightly improved, and 30 were judged to be significantly improved, with at least incremental improvement in the diagnostic value of the images. All images that were already excellent were essentially unchanged, and no images were degraded. Fig. 1 shows examples of two significant corrections. Correction times averaged 1 min 51 sec per series on a 3.0 GHz Linux PC. Correction times on a 16 processor cluster were ~10X faster.

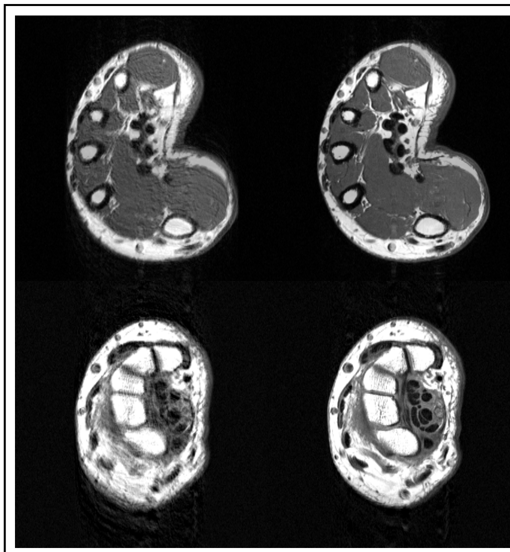

Fig. 1. Images before (left) and after (right) two significant corrections.

Discussion

Fully automatic translational motion correction of FSE wrist exams can be successfully performed in times consistent with return of the data to the clinical scanner within 5 minutes. 44% of the series acquired were judged to have some sign of motion, and 91% of these were improved to some degree. With this validation, a separate study in which the corrected exams are returned to the scanner and evaluated by radiologists is now under way. Preliminary tests similar to that described here are also under way for FSE knee and lumbar spine exams.

References

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