Water Fat Separation with BLADE Based on Two Points Dixon Technique

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Introduction

Chemical shift based methods are often used to achieve uniform water fat separation that is insensitive to magnetic field inhomogeneity. Many spin echo (SE) [1], gradient echo (GRE) and turbo spin echo (TSE) [2] approaches sample data in a Cartesian trajectory. Previous work demonstrated that Cartesian sampling was sensitive to motions such as pulsation, flow which caused artifacts that degraded image quality. We proposed a non Cartesian sampling method, BLADE based on three points Dixon technique to address this problem [4], This technique acquires one in-phase and two out-of-phase images with two BLADE sequences respectively; the phase map caused by magnetic field inhomogeneity is solved by phase unwrapping slice by slice, while phase unwrapping is prone to error by adding multiple of 2π to the unwrapped phase map which causes inconsistent in water and fat image series. Eddy current correction is needed if bi-polar readout mode is selected and it is sensitive to motion due to the fact that in-phase and out-of-phase images are acquired in different shot. To address these problems, BLADE based on two points Dixon is proposed, two echoes are acquired to create time dependent phase shifts caused by water fat chemical shift, they are called in-phase and out-of-phase images. The in-phase image is reconstructed with method proposed in reference [3], while the out-of-phase image is reconstructed by using all blades from in-phase image for phase correction. Sign detection based on region growing [5] is used to correct the out-of-phase image before the calculation of water and fat images, making this method insensitive to inconsistent error or eddy current.

Methods

Sequence: BLADE sequence is modified to acquire double echoes (Fig. 1); they are out-of-phase and in-phase images. This design ensures that out-of-phase and in-phase images are acquired with same shot, therefore, motion problem in three points BLADE is avoided, while all blades from in-phase image can be used to do phase correction for the out-of-phase image during re-regridding. Reconstruction consists of a 2D re-gridding operations for in-phase and out-of-phase images, followed by a sorting of all slices of in-phase and out-of-phase miages into a 3D data set according to their spatial location. Region growing is used to detect the sign of each pixel by using the 3D out-of-phase image, the sign is set to 1 if the absolute phase error between the pixel and the mean value of its 7×7×7 neighborhoods is smaller than 90°, which means content of water is larger than that of fat in one pixel, and -1 if the absolute phase error is larger than 90°, which means content of water is less than that of fat. The water and fat images are calculated with formula 1.

$$w = |S_{in}| + sign \cdot |S_{out}|,\ f = |S_{in}| - sign \cdot |S_{out}| \qquad (1)$$

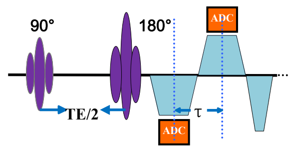

Figure 1. In-phase and out-of-phase sequence diagram

Where w and f represent water and fat images, respectively, S_{in} and S_{out} represent in-phase and out-of-phase images respectively, $sign$ is the result of region growing sign detection.

Human Study at 1.5T: Volunteers were scanned on Siemens MAGNETOM ESSENZA 1.5T scanner. Three points BLADE Dixon acquisition parameters were, orbit, transversal plane, FOV=300mm × 300mm, matrix size=256 × 256, TE=214ms, TR=6000ms, slice thickness=5.0mm, turbo factor=35; knee, transversal plan FOV=165mm×165mm, matrix size=256×256, TE=116ms, TR=5000ms, slice thickness=4.0mm, turbo factor=15. The parameters for two points BLADE Dixon are the same as three points BLADE Dixon, except that the total scan time is half of the three points method.

Evaluation: Water and fat images of head from two points and three points BLADE Dixon are compared, respectively.

Result

A comparison between images acquired with two points and three points BLADE Dixon are shown in Fig 2, all images are displayed with same windowing. Fat and water images of orbit obtained by two points and three points BLADE Dixon method are shown in Fig 2.A and B, Fig 2.E and F, respectively. The result shows that water and fat images have been separated correctly with two points BLADE Dixon by comparing the result from three points BLADE Dixon method. Fat and water images of knee from two points and three points BLADE Dixon method are shown in Fig 2.C and D, Fig 2.G and H, respectively, there is no obvious different between these two methods.

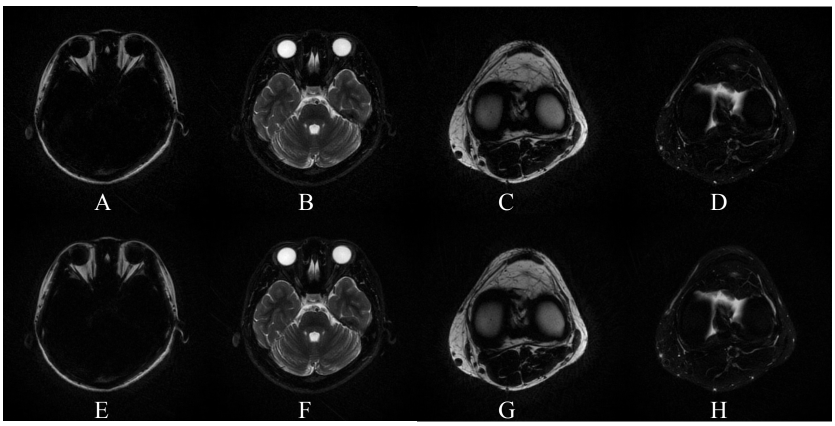

Figure 2 Water and Fat images from two points and three points BLADE Dixon

Discussion & Conclusion

A two points Dixon method based on BLADE has shown to separate water and fat images correctly. It is time saving, not eddy current correction needed and insensitive to bulk motion between in-phase and out-of-phase images scanning, which is problem for three points BLADE Dixon. In addition, it is not vulnerable to artifacts caused by rigid motion, pulsation, flow, and has high signal to noise due to BLADE trajectory etc. Important to note is that bipolar readout mode is possible without any further phase correction for eddy current, although mono-polar readout is possible. However, there is one small area near sinus, where water and fat is swapped (images are not shown here) from two points and three points BLADE Dixon, the error area from two points BLADE Dixon is larger than that from three points BLADE Dixon, the performance of two points method maybe worse than three points method in the area with severe magnetic field inhomogeneity.

References

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