Smart Combination: A Technique for Reducing Cardiac Motion Induced Signal Loss in Diffusion-Weighted Liver Imaging

ZHIQIANG LI[1], *Zhenghui Zhang*[1], *Gaohong Wu*[1], *Xiaoli Zhao*[1]
[1]MR Engineering, GE Healthcare, Waukesha, WI, United States

Single-shot diffusion-weighted Echo-Planar imaging (DW-EPI) has gained popularity in detecting liver diseases. However, signal loss in areas proximal to the heart due to cardiac motion has jeopardized the diagnosis. Various techniques have been proposed to mitigate this issue. Different data acquisition strategies were proposed, including the use of respiratory/cardiac gating, navigator, or their combinations (1). Post-processing technique was also presented by combining images acquired at different cardiac phases (2). In this work, we present a new post-processing algorithm that help reduce the signal loss by utilizing data acquired with different diffusion gradient directions.

Theory and Methods It has been observed that the signal loss is dependent on the location and diffusion direction (3). The signal loss is more pronounced when diffusion gradient aligns with the direction of the cardiac motion. If the data are acquired along multiple diffusion gradient directions, one or more of these images may be less impacted by the cardiac motion, while others may be subject to more signal loss at certain location.

The conventional method to synthesize the combined diffusion-weighted image is to calculate the geometric mean of all diffusion-weighted images. The signal loss in the impacted image(s) is propagated into the combined image. However, given that the diffusion of liver is nearly isotropic (4), the combined image can be generated by placing different weights on the individual images. Several weighting mechanisms are possible, including Maximum Intensity Projection (MIP), weighted average, weighted multiplication, etc. Because of its good performance in SNR, Presented here is the weighted multiplication, $S_{comb} = \prod_{i=1}^{N} s(i)^{w(i)}$, where *s(i)* is the signal in the i^{th} diffusion direction, *w(i)* is the weight. There are various choices for the weights. In this work we choose $w(i) = s(i) / \sum_{j=1}^{N} s(j)$. The result regresses to the geometric mean if equal weighting is applied. Diffusion-weighted breath-hold data were acquired using clinically relevant parameters, with multiple diffusion directions (3 in this work). To avoid the influence of geometric distortion in EPI images, dual Spin Echo diffusion gradient was used.

Results and Discussion

The images were processed using the weighted multiplication and compared with the conventional result. Shown in the top row of Figure 1 are the individual images acquired with diffusion direction along S/I, R/L, and A/P. One can see significant signal loss in Figs. a) and c), while b) shows less impact. The combined image obtained with conventional algorithm is shown in d). As expected, the signal loss in a) and c) is propagated into d). Fig. e) shows the combined image obtained using the proposed weighted multiplication. The difference image between d) and e) is shown in f). One can observe that weighted multiplication generates good signal in areas affected by the cardiac motion. Also, in areas not affected by cardiac motion, the difference between the two combined images is minimal, supported by the assumption that liver diffusion is nearly isotropic.

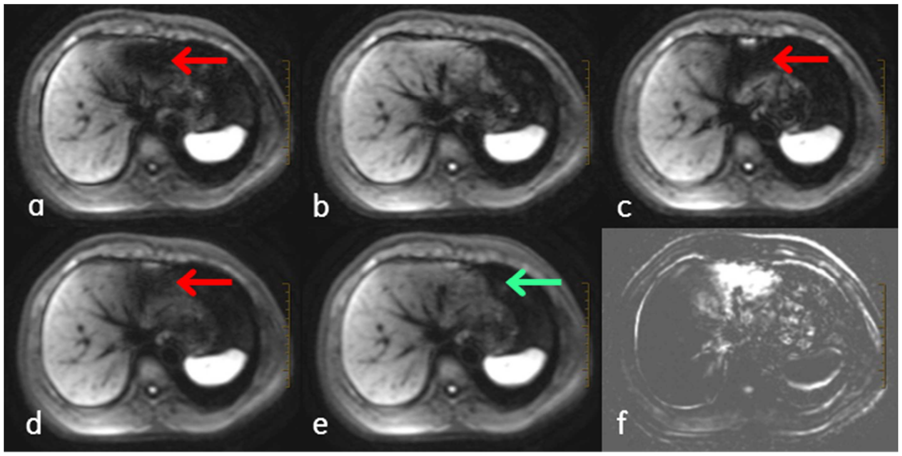

Fig. 1 Individual diffusion-weighted images with diffusion gradient along a) S/I, b) R/L, and c) A/P direction. d) and e) are the combined images obtained with the conventional and the proposed algorithms, respectively. f) is the difference image between d) and e).

In summary, a post-processing strategy to mitigate signal loss in liver DW-EPI images by combining the individual images with different weighting has proven to be feasible.

References

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