Reducing motion sensitivity in free breathing DWI of the heart with localized Principal Component Analysis

S. Rapacchi[1], P. croisille[1,2], V. Pai[3], D. Grenier[1], M. Viallon[4], P. Kellman[3], N. Mewton[1,2], and H. Wen[3]
[1]CREATIS, Université Lyon 1, INSA Lyon, Villeurbanne, France, [2]Hopital Cardiologique et Pneumologique L. Pradel, Lyon, France, France,
[3]LCE/NHLBI/NIH, United States, [4]Hopital Cantonal Universitaire de Genève, Switzerland

Introduction: Free breathing in vivo cardiac Diffusion Weighted Imaging (DWI) is highly sensitive to physiologic motion. Double spin-echo bipolar sequences (1) significantly reduce DWI motion sensitivity and eddy current artifacts. However they still rely on the diastatic phase which is variable or even absent in the case of fast heart rates or arrhythmia. To cope with this issue, we designed a DWI protocol which repeats image acquisition multiple times with incremental trigger delays to cover a large time window in diastole. After co-registration (2), temporal Maximal Intensity Projection (tMIP) (3) is used to find the diffusion weighted intensity for each pixel. Nevertheless resulting tMIP-DWI image can be as noisy as individual repetitions at high b values. Averaging over the repetitions improves the SNR but does not correct for motion-induced signal loss.

Method: To take advantage of the multiple repetitions to improve the SNR of the tMIP image, we performed a localized Principle Component Analysis (PCA) prior to tMIP. A box of 5x5 pixels was placed on images of all repetitions, and PCA was performed in the box to isolate the leading two temporal eigenvectors. These were used to project the PCA-filtered pixel intensities within the box. This operation was repeated while the box scanned over the entire FOV to cover all pixels. Since each pixel was covered by multiple boxes, weighted sums biased towards the center of the box were used to obtain the final pixel intensity. tMIP was then performed to reduce the repetitions to a single true diffusion weighted image.

Patients and Volunteers' scans: We compared simple tMIP, PCA-tMIP and simple averaging in 3 healthy volunteers. 6 patients were also examined under an IRB approved protocol 6 months after Acute Myocardial Infarction (AMI). We performed 10 incremental repetitions each of b=0, 50 and 100s/mm² in 3 orthogonal directions in a short axis slice, while letting subjects breath freely. Whole acquisition takes about 5min. A non-rigid registration algorithm (2) was applied first before processing.

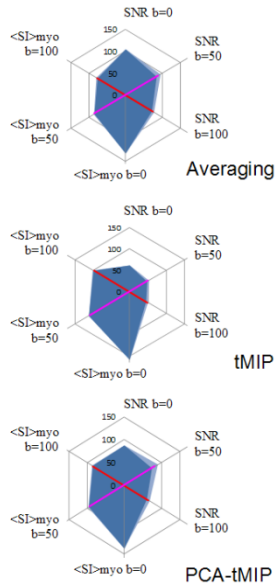

Figure 1: scoring of DWI combination methods

Results: Scoring of these methods is shown (fig.1) based on image SNR and mean myocardial signal intensity (SI). As averaging is a good compromise of SNR and signal attenuation, tMIP shows a clear improvement of the signal attenuation at the cost of a lower SNR. PCA-tMIP combines both a high signal intensity and good SNR for diffusion weighted images (pink and red bars). The Mean Diffusivity (MD) values of one volunteer are reported in the table here. Diffusivity values are high since they include both molecular diffusion and capillary circulation at these low b values (4). The tMIP measurements were consistent with a previous in vivo animal study (4). Moreover PCA-tMIP achieved comparable SNR to simple averaging. But simple averaging over estimated diffusivity due to motion induced signal losses, while this was corrected by the tMIP procedure.

	mean MD(10^{-3} mm²/s)
Averaging-DWI	13.79 ± 3.97
tMIP-DWI	4.46 ± 2.01
PCA-tMIP-DWI	6.59 ± 2.68

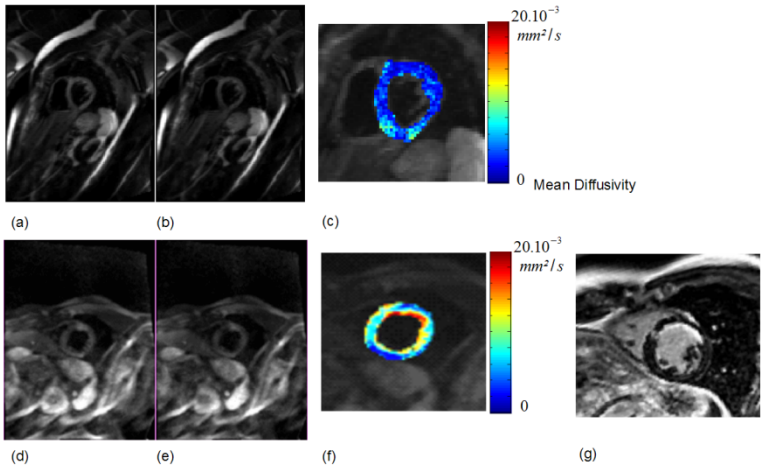

Figure 2 : PCA-tMIP DWI results on a healthy volunteer(a-c) and a patient with anterior non transmural scar(d-g)

Discussions: Preliminary results showed reproducible quality and coherent mean diffusivity (MD) maps. Figure 2 (a,b,c) show diffusion trace-weighted PCA-tMIP images of a healthy volunteer at b=50 and 100s/mm² and mean diffusivity with fairly homogeneous diffusion map. These are compared to fig. 2 (d,e,f) from a post-conditioned patient 6 months after AMI with a non transmural scar in the LAD territory. The MD values (identical scale as fig. 2 c) appear elevated in the scar region and match the post gadolinium T1-weighted IR-TFL images (fig 2.g). These early results show promise and warrant further trials in a larger patient population.

References

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