

Reduced FOV velocity mapping by complex subtraction unfolding

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PURPOSE

Velocity and acceleration mapping sequences require a long acquisition time due to the bipolar or tripolar encoding gradient application¹ that multiply acquisition time by the number of motion-encoded steps. To limit respiratory motion artifacts, cardiac-triggered cine images are usually acquired using breath-holds which can reach the upper limit of ~30 seconds and can be difficult to achieve for some patients. Fast imaging techniques have been proposed to reduce breath-hold duration. However, these techniques may require a priori knowledge or complicated reconstruction schemes². Here, a technique based on field of view (FOV) reduction is proposed for faster phase contrast velocity mapping. A full image without encoding gradients is acquired, while the motion encoded image is acquired with a reduced FOV, decreasing significantly the acquisition time. Velocity image is then reconstructed using complex differences. Proof-of-concept is demonstrated on a volunteer providing stimulating preliminary results in order to achieve multi-dimensional velocity and acceleration mapping in a single breath-hold.

METHODS

This unfold technique aims at extracting useful information from a folded phase-contrast encoded image, where the fold-over region is assumed to be static and is thus not affected by the encoding gradients. Phase contrast (PC) blood flow velocity is determined by the phase difference between two images with different velocity encoding steps in one flow direction. Here, we consider that the first step has no encoding gradient and that the second has one.

Experiments were carried out on a 1.5T MRI system (Philips, Best, the Netherlands) on a young male volunteer. An in-house modified PC velocity mapping sequence was used to measure blood flow in the aorta on a through-plane section. Acquisition parameters were as follows: 1.1x1.1x8 mm³, TE/TR=3.0/5.1 ms, FOV= 224x224, V_{enc}=180 cm/s. 40 cardiac frames with retrospective ECG triggering. We acquired full k-space (full FOV) on the first non-encoded step (full) and an undersampled k-space (reduced FOV) on the encoded one (fold-coded). In post-processing, the non-coded image was undersampled by the same ratio and will be referred to as the 'fold-non-coded' image. Hence, the 3 obtained images can be expressed as:

$$I_{full}(\vec{r}) = I_0(\vec{r}) \cdot e^{i\phi_b(\vec{r})} \quad (1)$$

$$I_{fold-non-coded}(\vec{r}) = I_0(\vec{r}) \cdot e^{i\phi_b(\vec{r})} + I_f(\vec{r}) \cdot e^{i\phi_f(\vec{r})} \quad (2)$$

$$I_{fold-coded}(\vec{r}) = I_0(\vec{r}) \cdot e^{i\phi_b(\vec{r})} \cdot e^{i\phi_v(\vec{r})} + I_f(\vec{r}) \cdot e^{i\phi_f(\vec{r})} \quad (3)$$

where $I_0(\vec{r})$ is the image amplitude, $\phi_b(\vec{r})$ the first step background phase and $\phi_v(\vec{r})$ the encoded velocity phase

(equal to $\frac{v \cdot \pi}{V_{enc}}$). $I_f(\vec{r})$ and $\phi_f(\vec{r})$ are respectively the amplitude and the phase of the fold-over region of the image.

By subtracting the complex images, the encoded velocity phase can be directly extracted (figure 1):

$$\phi_v(\vec{r}) = \arg \left(\frac{I_{fold-coded}(\vec{r}) - I_{fold-non-coded}(\vec{r})}{I_{full-non-coded}(\vec{r})} + 1 \right)$$

It was converted to velocity and used to estimate flow rate in the ascending aorta with respect to time which was compared to a full FOV acquisition.

RESULTS

The acquisition time of the reduced FOV dataset with velocity encoding gradient was reduced by 50%, and the total acceleration factor obtained considering the 2 encoding steps was 25%. The flow curves computed in the ascending aorta on the full FOV, fold-over and unfolded images are depicted in figure 2. The curves from full FOV and unfolded images are in good agreement whereas the one from the fold-over image is slightly underestimated. The root mean square error (RMSE) is 3.48% between the unfolded image and the full FOV and 6.73% between the fold-over and the full FOV. Differences may be due to physiological variation, measurement or reconstruction errors.

DISCUSSION

The method presented here is easily implemented: it only needs few modifications in the sequence to enable the undersampling of k-space. We have shown the results obtained with a FOV reduction of 50%. However, greater FOV reduction could be achieved in order to reach shorter breath-hold duration. Indeed, static tissues are removed using this technique, enabling theoretically to reduce the FOV down to only flowing regions. The acceleration obtained could also be used to encode additional motion-encoding directions or increase resolution. More acquisitions have to be done to fully evaluate the efficiency and reproducibility of the technique to measure flow rate, and may be extended to acceleration mapping.

CONCLUSION

We have shown a simple and efficient unfolding technique that reduces breath-hold duration during velocity mapping. A time reduction of 25% was obtained for a half-FOV with a limited influence on blood flow quantification in the ascending aorta as compared to a full FOV image. These results provide stimulating preliminary data indicating the possibility to achieve multi-dimensional velocity and acceleration mapping in a single breath-hold.

REFERENCES

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- [2] B. Madore, Syllabus contribution, Weekend Educational Program of the ISMRM annual meeting, Seattle, WA, USA. Generalized spatial and temporal interpolation, and limited data reconstruction, 2006.

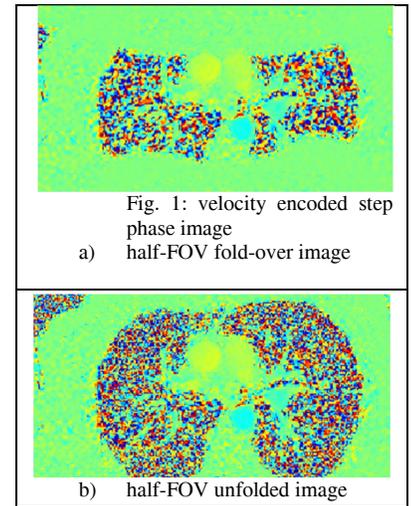


Fig. 1: velocity encoded step phase image

a) half-FOV fold-over image

b) half-FOV unfolded image

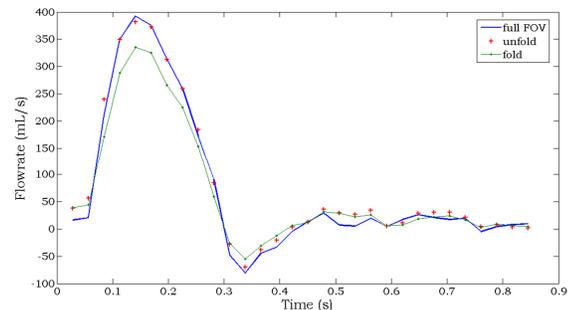


Fig.2: Flow curves measured in the ascending aorta from a full-FOV, a half-FOV fold-over and a half-FOV unfolded images.