A simple method to optimize partial Fourier acquisition schemes for glomerular imaging

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TARGET AUDIENCE

Scientists and clinicians involved in the imaging of the glomeruli in the kidney and/or using partial Fourier (PF) techniques to reduce scanning times

PURPOSE

In this work we present a simple method to create a custom PF acquisition strategy. The method was applied to the imaging of glomeruli in the kidney and compared to two commonly used PF acquisition strategies. The imaging of glomeruli is a recently introduced research area in MRI that could help the early diagnose of kidney diseases [1].

A spatial frequency of interest from one full k-space acquired image could be obtained and used it to find the maximum frequency harmonic required to resolve a certain spatial frequency. From the maximum frequency harmonic, a range of harmonic frequencies required in k-space can be selected. Thus, a custom PF acquisition strategy can be created.

Scanning times are proportional to the number of phase encoding (PE) lines. The number and position of the PE sampled in k-space modify the resolution of (and within) an image depending on the spatial frequencies that it contains. However, the selection of the PE lines to be acquired is not completely obvious. Elegant algorithms have been proposed to guide the selection of the PE lines based on image features but are not straightforward to implement [2-4].

METHODS

Imaging - One mouse kidney was labelled with cationized-ferritin (Sigma-Aldrich, St. Louis, MO), perfused and dissected as presented in [1]. The mouse kidney was embedded in agarose gel and scanned ex vivo using a linear full k-space acquisition. A 9.4 T Bruker BioSpec 94/20USR preclinical MR system and a two-channel Bruker CryoProbe™ (Bruker BioSpin GmbH, Ettlingen, Germany) were used for the imaging. The scanning protocol used a 2D FLASH sequence with the parameters: TE / TR = 10 / 100 ms, flip angle = 50 °, Averages = 30, FOV = 8 x 8 mm², slice thickness = 100 µm, in-plane spatial resolution = 50 x 50 µm², total scanning time = 8 minutes.

PF scheme creation - Image reconstruction and post-processing were performed with MATLAB (The Mathworks, Natick, USA). The kidney image was reconstructed initially from the full k-space. One glomerulus i.e. an object with high spatial frequency of interest was selected manually (Fig. 1A). Given the specific interest in frequency components of k-space, the signal intensity of the glomerulus was approximated and used to create a periodic function to evaluate the maximum frequency needed to resolve the given glomerulus (Fig. 1B). A discrete Fourier transform (DFT) was applied to the periodic function. The DFT was applied to obtain a set of determinant frequency components for the particular spatial frequency of the object in the image space. The next maximum value after the first harmonic (centre of k-space) was selected as the highest frequency harmonic that needed to be acquired. The mirror side was not used in an effort to further reduce the number of PE lines needed and thereby the scanning time. The lower spatial frequencies were necessary for the imaging of the kidney itself to locate the glomeruli and also to image bigger glomeruli and additional structures. The final number of PE lines was then selected to be from the centre of k-space to the next maximum to the right (Fig. 1C). The same number of lines were then used in a symmetric PF acquisition i.e. k-space was low pass filtered. Another main PF sampling strategy is to sample part of the k-space centred symmetrically. This strategy was also applied for comparison i.e. the PF fraction was shifted ~10 % to include more data in the k-space centre, leaving out the highest frequency harmonic found with the method presented here.

RESULTS

The specific location and chosen object is shown in Fig. 1A. The created periodic function based in the approximate values obtained from the selected glomerulus is displayed in Fig. 1B. The discrete Fourier transform of the periodic function showed the highest frequency harmonic resolving the selected glomerulus. This frequency was found 53 lines after the centre of k-space (Fig. 1C). The range of PE lines could be acquired in only 2 minutes and 42 seconds. The compared PF acquisition schemes are shown in Fig. 2-1. The images yielded by each scheme are shown in Fig. 2-2. The selected glomerulus and its surroundings are compared to the same region in the full k-space sampled image in Fig. 2-3.

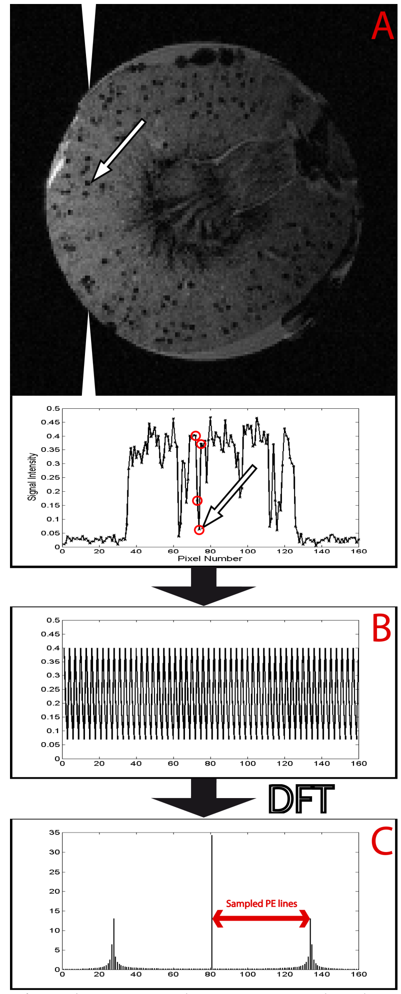

Figure 1 *Diagram of the steps performed to obtain the maximum frequency harmonic for a selected spatial frequency. The selected spatial frequency was selected manually (A) to create a periodic function (B). Fast Fourier transform shows the relevant frequency harmonic (C)*

DISCUSSION

The proposed method resolved the object better than the schemes used for comparisson, this can be observed in Fig. 2-3A by noticing a closer depth and shape of the glomerulus to the one yielded by the full k-space. However, the image quality was compromised, mostly in terms of shading. This was expected because the k-space centre was truncated. The glomeruli are still visible despite the reduced image quality and a ~66 % scan time reduction was achieved. An additional advantage in obtaining the highest frequency harmonic is that it could be used as a threshold in both halves of the k-space for zero-filling. Moreover, there are reconstruction PF techniques which aim to recover the missing data that have been extensively tested and reviewed [5]. These techniques could also be applied to this sampling strategy to improve imaging quality. The selection of the highest frequency object could be made an automated process and it could be applied to different objects. This is in the scope of our future work.

CONCLUSION

A simple method to create custom PF acquisition schemes with minimum resolution compromise for objects of interest was presented.

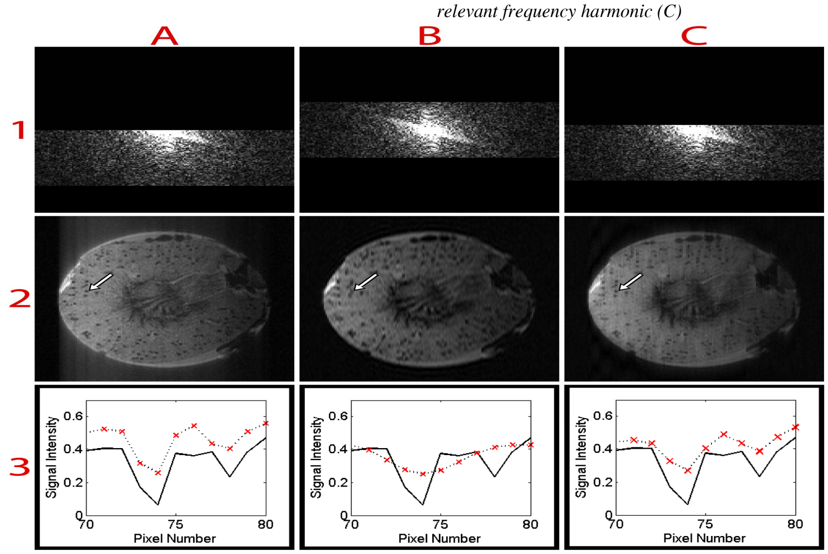

Figure 2 *K-space sampling schemes evaluated (1), resulting image (2), and evaluation of the selected glomerulus after the PF is plotted with a dotted line for comparison to the full k-space acquisition plotted with the solid line (3). 1) Proposed method, 2) symmetric acquisition, 3) a commonly used strategy to include more data from the k-space centre.*

REFERENCES

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