3T MR Research Program

Center for MR Research

University of Illinois at Chicago

TECH 2000 3T MRI RESEARCH FACILITY

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3T MRI Facility Updates

By Mike Flannery.

MRI Facility Operations

Thankfully, the COVID-19 infection rates have dramatically been reduced on campus at UIC and throughout the Chicagoland area. However, the 3T MR Research Program would like to take this opportunity to remind everyone to continue to observe the COVID-19 policies still in place at the MR Research Center.
First, the "No-Visitor" policy remains in effect within the entire Advanced Imaging Center complex. We will continue to ask that each user group only allow 1 Research Assistant and 1 subject for each scheduled exam. The only exceptions to this policy would be in either the case of onsite training of a new RA and / or coupled family studies.
Second, please make sure to submit all COVID-19 screening forms <u>BEFORE</u> arrival at the MR Center. Please make sure to email all forms for both RA and the subject being scanned to both research technologists within 24 hours of the scheduled scan.
Finally, any subject who has tested positive for COVID-19 may be rescheduled under the following guidelines / criteria:

1. COVID-19 positive <u>WITHOUT</u> Hospitalization:
   a. After 10 days
   b. Symptom free
2. COVID-19 positive <u>WITH</u> Hospitalization:
   a. After 20 days
   b. Symptom free

The 8-channel head coil has reached its "end of life" service status and will no longer be supported by GE for any future replacement or repairs. The 8-channel head coil is in good working order and remains in use for a few research projects. The 3T MR Research Program would like to encourage any user groups starting new projects to strongly consider using the 32-channel head coil being utilized with many of the current multiband ABCD fMRI projects.

MRI Safety Updates

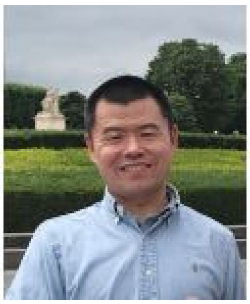
We would like to send a friendly reminder to the research community regarding a few safety concerns. From time to time, your subject(s) may present a medical history that includes some sort of medical implant. When this occurs, please contact the imaging center technologists with the following information:

- Make / Manufacturer
- Model / Device name
- Date device was implanted

In some cases, the subject may have an implant card that contains all the necessary MR safety information. If the subject does not have an implant card, we would need a post-operative report that contains this information. The MR research technologists would also request that this information be provided **<u>48-hours</u>** prior to the subject's scheduled scan to allow sufficient time to investigate the device(s) for MR safety at 3T.
Lastly, we would like to remind the RAs that every subject will need to remove all jewelry prior to their scan regardless

of its composition. This includes all metal jewelry as well as any plastic, nylon, acrylic, wooden, etc. jewelry. There is always the potential that these other materials could contain trace metal within them as well as creating a potential hazard for physical injury to the subject by getting caught on the head coil or other ancillary equipment used during each scan.

Research at UIC



Dr. Qingfei Luo received his Ph.D. in Medical Physics at the University of Chicago. Dr. Luo's research focus at the Center for MR Research includes the following: 1) Development and application of fast functional MRI pulse sequences, 2) Sparse MRI reconstruction algorithms and 3) Simultaneous EEG and fMRI acquisition techniques. This issue highlights one of his recent publications on SPEEDI, an advanced MR imaging capable of sub-millisecond temporal resolution. Any investigators who are interested in collaborating with Dr. Luo are encouraged to contact him at qluo@uic.edu.

"Accelerated Ultrahigh Temporal-Resolution MRI with Random k-Space Undersampling"

Introduction: MRI techniques capable of sub-millisecond temporal resolution began to emerge recently, and one of these promising techniques is SPEEDI. Despite its capability of ultrahigh temporal resolution, SPEEDI scans are relatively long due to the reliance on phase-encoding, even with a more efficient implementation – epi-SPEEDI. This study aims at accelerating epi-SPEEDI acquisition by randomly undersampling k-space time series (termed epi-SPEEDI-kt), followed by image reconstruction based on joint spatiotemporal partial separability and sparsity constraints (PS-Sparse). We demonstrate the performance of epi-SPEEDI-kt technique through an example of visualizing the dynamic process of aortic valve opening/closing in humans with a temporal resolution of 0.6 ms.

Methods

epi-SPEEDI-kt pulse sequence: The epi-SPEEDI-kt sequence is built upon epi-SPEEDI[3] (Fig. 1) which utilizes an echo-train for readout without inter-echoblipped phase-encoding (PE) gradients. Each echo generates one separate k-space matrix corresponding to a distinct time delay relative to a trigger from a periodic event such as an ECG. Assuming echo-train length (ETL) = L and image matrix in PE direction = N_p, L k-space matrices are filled after repeating the event and the echo-train acquisition N_p times, and then these k-space matrices form a time block (TB) with the temporal resolution = echo spacing (esp). Typically, multiple TBs are acquired to cover the entire periodic event. The epi-SPEEDI-kt pulse sequence differs from epi-SPEEDI in the PE scheme (Fig. 2A). Linear PEs are utilized in epi-SPEEDI and the PE step is the same across all the TBs during one event cycle, while epi-SPEEDI-kt employs random PE steps, which are different between TBs and event cycles. Furthermore, the acquisition is accelerated in epi-SPEEDI-kt by reducing the number of PEs to N_s ($< N_p$), i.e., acceleration factor = N_p/N_s. A fixed number (N_{nav}) of phase lines are sampled in the central k-space (k_c) ((N_p-N_{nav})/2+1 to (N +N $_{av}$)/2) in all the TBs, and the other (N_s-N_{nav}) acquired phase lines are randomly and sparsely distributed in the outer k-space regions (k_o) (Fig. 2B).

Image Acquisition: Images of the aortic valve were acquired from healthy subjects on a 3T GE MR750 scanner (General Electric Healthcare, Waukesha, WI) with a 32-channel phased-array cardiac coil. The scans were performed with epi-SPEEDI and epi-SPEEDI-kt using the following parameters: TR/TE = 20/8.8 ms, flip angle = 10º, FOV = 24 cm × 24 cm, slice thickness = 8 mm, ETL = 16, esp = 0.6 ms, matrix size = 80 × 118 (N_p = 80) for epi-SPEEDI and N_s/N_{nav} = 40/6 in epi-SPEEDI-kt. To fill in the time gaps between TBs, an "interleaved multi-phase" acquisition scheme was adopted with two ECG trigger delays (12 and 22 ms) and 36 cardiac phases per delay (Fig. 3). The epi-SPEEDI/epi-SPEEDI-kt scans were completed with 160/80 heart beats and 8/4 breath-holds. The total scan time was ~6/3 minutes including the preparation time between breath-holds, which represented a two-fold scan time reduction with epi-SPEEDI-kt.

Image Reconstruction: A total of 1152 k-space matrices (72 TBs x ETL) were acquired from each scan and reconstructed offline using customized MATLAB programs (MathWorks, Inc., Natick, MA). The epi-SPEEDI data were reconstructed from each coil channel with FFT followed by a sum-of-squares combination. To reconstruct the epi-SPEEDI-kt images, the k-space matrices at the same echo index were extracted from all the TBs to form 16 echo k- space time series, each of which included 72 time points. The PS-Sparse algorithm[4] was then applied to reconstruct individual echo k-space time series. Finally, the reconstructed images were aligned in the time order relative to the ECG trigger.

Results

As shown in Fig. 4, the rapid opening and closing process of aortic valve was observed in both the epi-SPEEDI (Fig. 4A) and epi-SPEEDI-kt (Fig. 4B) scans with a temporal resolution of 0.6 ms. Compared to epi-SPEEDI, epi-SPEEDI-kt provided comparable image quality for visualizing the aortic valve opening and closing, despite a two-fold scan time reduction. Furthermore, slight artifacts were observed in lower regions of some images (outside the heart) in the epi-SPEEDI time series (Fig. 4A), but not in epi-SPEEDI-kt. These artifacts could be caused by inconsistent respiration positions across multiple breath- holds. This observation implies that the reduced times of breath-holds afforded by epi-SPEEDI-kt likely decreased the susceptibility to breath-holding inconsistency and thus improved the image quality.

Conclusion and Discussion

Our study demonstrated that the epi-SPEEDI-kt technique was able to reduce the scan time of epi-SPEEDI by approximately 50% and offered comparable image quality in imaging the dynamics of aortic valve opening/closing. Further, epi-SPEEDI-kt required fewer breath-holds, which improves not only the reliability of SPEEDI imaging, but also patient comfort and compliance. In this study, although the feasibility of epi-SPEEDI-kt was illustrated with a cardiac imaging study, the technique is expandable to other applications for capturing ultrafast dynamic events. In addition, The PS-Sparse reconstruction method would achieve better performance with a larger number of time points[4], enabling higher accelerations beyond what was investigated in this study. In summary, epi-SPEEDI-kt is a viable way to implement SPEEDI techniques. By reducing the scan time, epi-SPEEDI-kt has provided an enhanced tool for studying ultrafast, periodic physiological and physical processes with a sub-millisecond temporal resolution.

Acknowledgements

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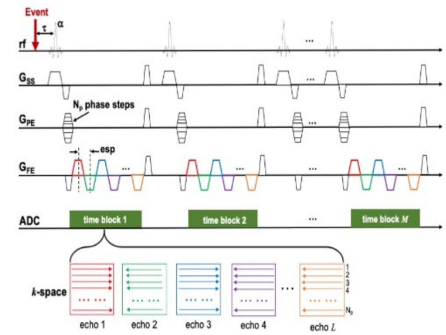

Figure 1: Pulse sequence design of epi-SPEEDI. The rf excitation, slice-selection gradient, phase-encoding gradient, frequency-encoding gradient, and readout are indicated by rf, G_{SS}, G_{PE}, G_{FE}, and ADC, respectively. τ is the time delay between the event and the first rf excitation.

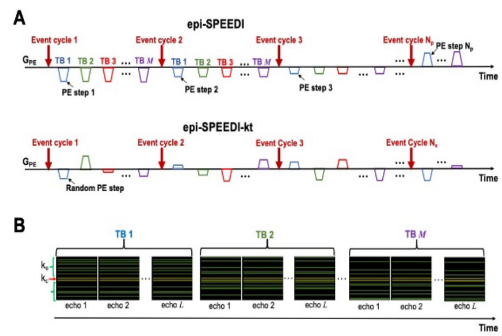

Figure 2: Comparison of phase-encoding schemes used in epi-SPEEDI and epi-SPEEDI-kt sequences (A) and the k-space sampling pattern in epi-SPEEDI-kt (B). Nnav phase lines (yellow lines) in the central k-space (k_c) region are sampled in all the time blocks (TBs) while the outer k-space (k_o) regions are randomly and sparsely sampled (green lines). The k-space sampling patterns are the same at the echoes in one TB but different between TBs.

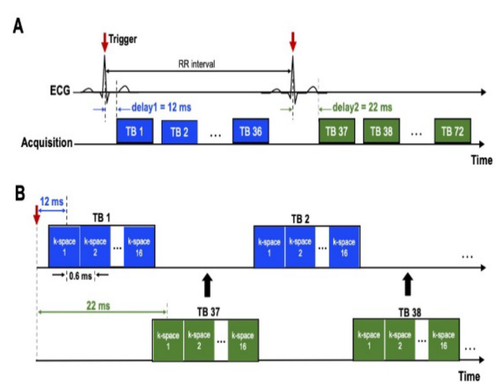

Figure 3: Interleaved multi-phase acquisition with two trigger delays of 12 ms and 22 ms as shown in (A) and the temporal alignment of TBs (B).

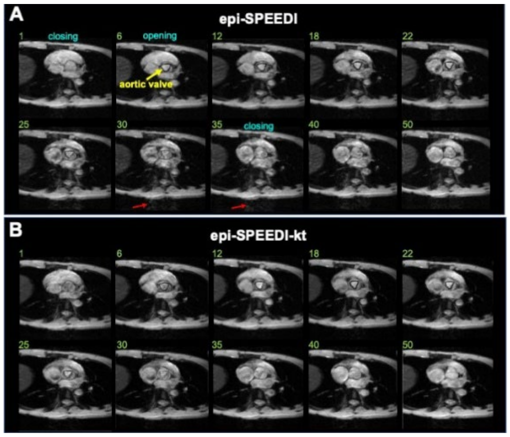

Figure 4: Fig. 4. Dynamic cardiac valve images acquired using epi-SPEEDI (A) and epi-SPEEDI-kt (B). Each image corresponds to a specific time point during the aortic valve movement process. The temporal resolution was 0.6 ms. Images 6-30 show the opening status of cardiac valve (annotated by the yellow arrow), and the cardiac valve is closed in the other images. The red arrows indicate artifacts.