ECG Gated 3D Single Shot Fast Spin Echo with Variable TR for Non-Contrast Peripheral MR Angiography at 3T

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Purpose: ECG gated 3D single shot fast spin echo (SSFSE) sequence with partial Fourier can be used to acquire two sets of images of the same volume at systolic and diastolic phases and the subtracted image gives the arterial blood signal. This technique, also called Fresh Blood Imaging (FBI), has been applied to image the peripheral artery without contrast infusion [1-2], in which each slice encoding (SE) and the followed echo train are played in a fixed TR (TR=n*RR). The lower limit of TR depends on the length and timing of data acquisition, and it is also limited by SAR, which is mostly affected by refocusing flip angle, echo train length, and echo spacing, but can be regulated by TR (change the number of RR). Ideally, TR should be sufficiently long for the recovery of the longitudinal magnetization of blood and background tissue. Consequently, since the total scan time is proportional to TR, the 3T scan usually takes longer because of the increased blood and tissue T1 as compared to that at 1.5T. Longer scan time increases the uncomfortableness of the patient, and may introduce more motion artifacts. To reduce the scan time while still maintaining the blood signal with sufficient background suppression, a new variable TR (vTR) method is proposed in this work.

Methods: The study was approved by our institutional review board and informed consent was obtained. Five volunteers (29-60 years; 2 female) were enrolled and scanned by a Vantage Titan™ 3T scanner (Toshiba Medical Systems Corporation, Otawara, Japan) equipped with Atlas SPEEDER™ Spine coil and Atlas SPEEDER™ Body coil. Followed by the localizer, pelvic, thigh and calf stations were imaged using FBI with ECG gating. The FBI sequence is modified to incorporate the vTR function, i.e., the slice encoding steps at the k-space center have longer TR (increased number of RR intervals) and the number of the slice encoding steps with longer TR can be adjusted (Figure 1). FBI parameters: 3D coronal SSFSE with half Fourier in PE direction, TR=2-4RR with fixed TR, TR=2RR with vTR (2 extra RRs for the middle 20% SE steps), TE=60ms, 80-100 slices for each station, slice thickness=3mm, matrix 256X256; FOV 37cmX37cm, parallel imaging factor = 2, refocusing flip angle=140°, the acquisition delay times (TD_{sys} and TD_{dias}) were determined by DelayTracker, which is a build-in software with a GUI to automatically calculate delay times from the heart rate; Resolution 1.4mmX1.4mm. Refine in RO, PE and SE directions. Overall image quality was blindly scored by 2 experienced clinical scientists (0: low, 4: high). Student t-test was performed to compare the image quality.

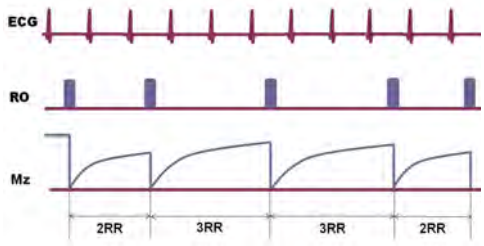

Figure 1. Demonstration of vTR FBI. Note the TRs for the slice encoding at the k-space center are 3RRs while the rest TRs are spaced by 2RRs.

Results: For fixed TR FBI, TR=2RR gives less arterial signal than longer TR (Figure 2, A vs. C). For TR=4RR and TR=2RR+20%4RR, the FBI coronal MIP images at the 3 stations showed comparable arterial image quality across all volunteers and the scored MIP image quality has no significant difference (2.42±0.69 vs. 2.58±0.69, p=0.26). In terms of arterial signal intensity, the mixture feature of short and long TRs in vTR function offers a signal level between fixed long TR and short TR images, as expected. In the volunteer with narrower lumen on iliac arteries, FBI MIP images with and without vTR function can both clearly delineate the narrower lumen at different sites (Figure 3).

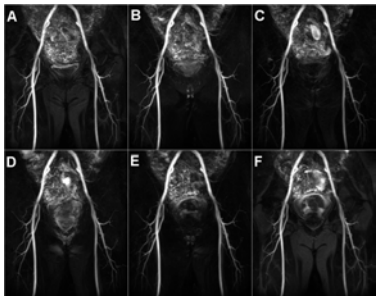

Figure 2. FBI MIP images without (A-C) and with (D-F) vTR function. The TRs are A:4RR, B:3RR, C:2RR, D:2RR+20%3RR, E:2RR+20%4RR, F:2RR+20%5RR;the scan times are 6:35, 4:56, 3:17, 3:36, 3:54, and 4:12 minutes, respectively. The arteries in image C have lower signal than others due to less recovered longitudinal magnetization, and the smaller vessels are not well delineated.

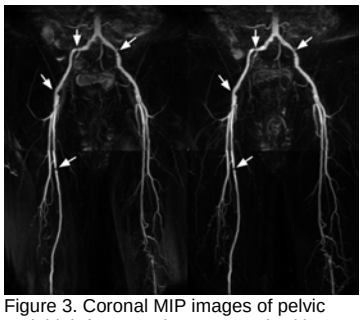

Figure 3. Coronal MIP images of pelvic and thigh from a volunteer acquired by FBI without vTR (TR=4RR, left) and with vTR (TR=2RR+20%4RR, right). Note the stenosis-like narrower lumen (arrows) on the external iliac arteries and right femoral artery can be identified in both images. The total scan times are 11:42 and 6:55 for each 2-station scan.

Discussion: The proposed vTR method offers significantly reduced scan time for the FBI because the TRs for the slice encoding away from the k-space center are shortened compare to fixed long TR scan. Compared to fixed short TR FBI, the arterial signal can be lifted because the center k-Space SE steps have higher longitudinal magnetization recovery with longer TR. Conventional FBI uses a fixed TR of 3-4RR, and vTR FBI can shorten the total scan time by 20-40%, which may significantly reduce motion artifacts. With vTR, the SAR can also be flexibly regulated if user wants to use minimal scan time without SAR violation. More advanced vTR patterns can be added to FBI with the purpose of reducing scan time while maintaining the arterial blood signal. To further reduce scan time, parallel imaging and partial Fourier can be applied in the SE direction. One need to note that systolic and diastolic acquisition of FBI should have the same vTR setting to minimize the background tissue difference. More volunteer and patient data will be collected to further evaluate the performance of vTR FBI at 3T.

References:

1. Miyazaki M. et.al, JMRI 12(5):776-783, 2000
2. Miyazaki M. et.al, Radiology 227:890-896, 2003