Optimized free-breathing inner-volume black-blood (FB-IV-BB) cine FSE of the descending aorta

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Target Audience: Investigators interested in studying aortic wall displacements

Purpose

The motions of aortic wall can be utilized to monitor the abdominal aortic aneurysms. Cine fast-spin-echo (FSE) has been used to visualize dynamic vessel wall motion in the carotid arteries [1]. Application of cine FSE to the aorta, however, is hampered by artifacts from respiratory motions as well as flow turbulence. Although respiratory triggering could be used to synchronize the scan, prolongation of the total acquisition duration is inevitable. In this study, we proposed a novel technique named the free-breathing inner-volume black-blood (FB-IV-BB) cine FSE to overcome these limitations. In our method, respiratory motion is minimized using the inner volume (IV) excitation [2] for reduce FOV (rFOV) acquisition. In addition, flow suppression is achieved using the DANTE (delay alternating with nutation for tailored excitation) pulse [3]. The cine data allow a temporal display of the aortic wall motion similar to M-mode ultrasound.

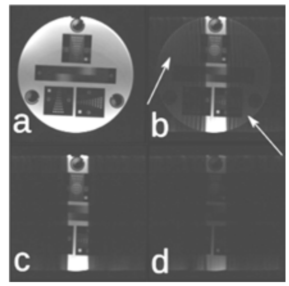

Figure 1. Static phantom study comparing the methods. (**a**) 2D cine FSE (**b**) FB-IV-BB cine FSE without crusher gradient, (**c**) FB-IV-BB cine FSE with crusher gradient removes residual signals (arrows), (**d**) DANTE cine FSE with RF spoiler was suboptimal quality due to signal dropout.

Methods

Phantom scan and three healthy volunteers (one male and two females, age 26±5y/o) were included in the ethically approved preliminary study. Cine FSE and FB-IV-BB cine FSE were acquired on a 1.5T system (MR450, GE Healthcare, Waukesha, WI, USA) using an 8-channel cardiac array. For FB-IV-BB cine FSE, a Shinnar-Le Roux pulse was designed with a short duration of 3.2ms. The widths of phase FOV (pFOV) were adjusted to 10%, 15%, and 50% of the full FOV for comparison. TR/TE/ETL = 2500/53/12, with total acquisition time of 3 min 40 s. A total number of 1056 phase encodings were randomly arranged in 88 echoes as the time of each encoding bin was recorded. Reconstruction of cine FSE images follows the method as established for carotid imaging [1], which intends to minimize the following cost function: $\boldsymbol{G}=\| \boldsymbol{W}(k_x,k_y,t)\, \boldsymbol{F}_{xy}[s_n(x,y)\, \boldsymbol{m}(x,y,t)] - \boldsymbol{d}_n(k_x,k_y,t) \|_2^2 + \|\lambda(x,y)\nabla_t [\boldsymbol{m}(x,y,t)]\|_2^2$, where **W** is the acquisition bins, **F** is the 2D FFT operator, **d** is the data, **m** is the current estimated images, and ∇_t is the temporal gradient of the images, respectively. In other words, temporal and spatial constraints were applied for reconstruction, using the conjugated gradient method. Effects of gradient crusher following the DANTE pulse train as well as RF spoiler were also compared in terms of removal of residual signals from outside the rFOV.

Results

Signals from outside of the rFOV arising from the use of DANTE and IV were successfully removed with the crusher gradients (Fig.1). pFOV at 10% compared favorably over 15% and 50% in terms of respiratory motion artifacts (Fig.2). FB-IV-BB cine FSE with 10% pFOV (Figs.2b and 3b) removed 43% of intraluminal signals as compared with 2D cine FSE with flow suppression at full FOV (Figs.2a and 3a), whereas the DANTE pulse eliminated 84% of the flow signals within the descending aorta as compared with no flow suppression (Figs.2d and 3d). Measurements from the M-mode display (Fig.3b) yielded the mean diameter of 15±1.3mm for the aorta, and the displacements of 2.2±1.2mm and 0.68±0.28mm for anterior and posterior aortic walls, respectively (anterior to posterior displacement ratio: 3.84±2.8), in close consistency with literature values [4].

Discussions

In this study we demonstrate the effectiveness of FB-IV-BB cine FSE, which successfully renders the temporal dynamics of black-blood images of abdominal aorta. The use of crusher gradients removes the unwanted signals, whereas the choice of 10% pFOV yields satisfactory M-mode display. This novel FB-IV-BB cine FSE has three advantages which suggest its potential utility in future clinical studies. First, the FSE readout inherently exhibits high SNRs and tissue contrasts, both of which are beneficial for the depiction of pathology. Second, neither breath-holding nor triggering is necessary in FB-IV-BB, thus the scanning procedure can be simplified. Third, FB-IV-BB cine FSE allows multi-slice acquisition which is clinically essential. Possible directions for future studies include a comparison of the performance of FB-IV-BB cine FSE with other free-breathing techniques such as the use of self-gating and navigator echoes.

Conclusion

The combined use of DANTE and IV with gradient crushers allows black-blood cine FSE to be used for rFOV to investigate aortic wall motion with free-breathing at prominently reduced artifacts.

References

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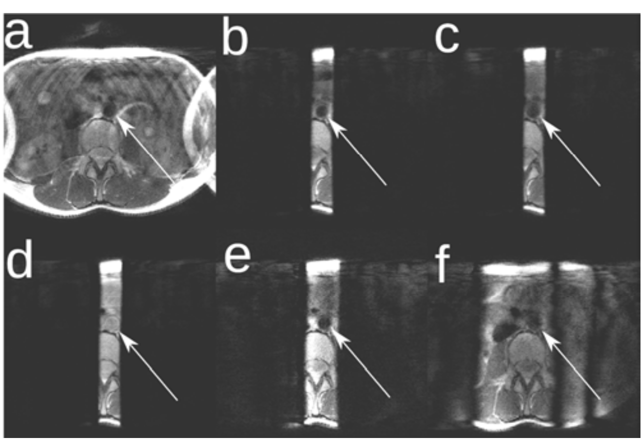

Figure 2. Transverse sections of the descending aorta (white arrows) using (**a**) 2D cine FSE with flow suppression (**b**) FB-IV-BB cine FSE with crusher, pFOV=10% (**c**) FB-IV-BB cine FSE without crusher, pFOV=10% (**d**) FB-IV-BB cine FSE without flow suppression, pFOV=10% (**e**) FB-IV-BB cine FSE with crusher, pFOV=15% (**f**) FB-IV-BB cine FSE with crusher, pFOV=50%. Only (b) achieved successful acquisition without artifacts.

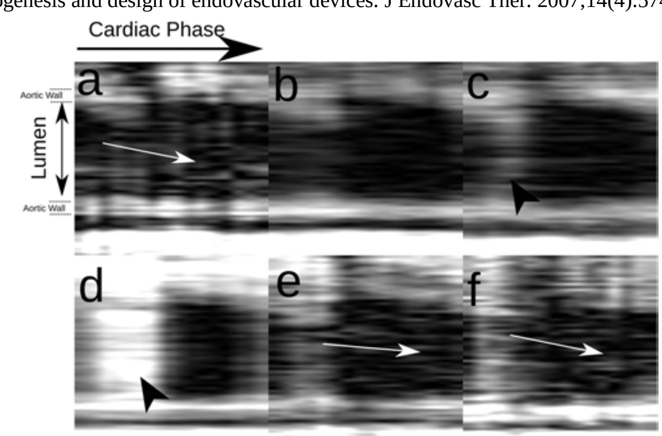

Figure 3. M-mode display of the descending aorta using images obtained in Fig.2: (**a**) 2D cine FSE with flow suppression (**b**) FB-IV-BB cine FSE with crusher, pFOV=10% (**c**) FB-IV-BB cine FSE without crusher, pFOV=10% (**d**) FB-IV-BB cine FSE without flow suppression, pFOV=10% (**e**) FB-IV-BB cine FSE with crusher, pFOV=15% (**f**) FB-IV-BB cine FSE with crusher, pFOV=50%. White arrows demonstrate respiratory ghosts from adjacent tissues. Black arrow heads indicate residual flow signals. Results from (**b**) again show the best visualization for the displacements of aortic walls without respiratory artifacts and residual flow signals.