Improved dark blood cardiac morphology imaging using a navigated ECG-triggered BLADE sequence: scope of applications

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Introduction

T1 or T2 weighted TurboSpinEcho (TSE) and T1 Spin Echo (SE) dark blood (DB) MR imaging (eventually combined with fat saturation (FS) or inversion recovery(IR)) are involved to characterize pathologies like DAVD, tumours, sarcoïdosis, myocarditis, to determine the area-at-risk in acute myocardium infarction (MI) or to detail cardiac morphology in congenital disease [1]. Dark-blood TSE methods are subject to artifacts such as wall signal loss due to incoherent cardiac motion from RR length changes, resolution is restricted by the breathhold duration and it is sometime difficult to reach the necessary mandatory high resolution and high image quality to explore vessel wall and ventricular wall. In free breathing paediatric patients TSE DB techniques is dramatically hindered by the respiratory motion. Recently single-shot imaging with T2-prepared SSFP readout was proved to provide an alternative solution to dark-blood TSE in acute MI [2], but a robust clinical solution for the remaining aetiologies is still missing. PROPELLER then BLADE were new encoding strategies implemented to correct for intra and inter scan motion in brain morphological acquisition performed in uncooperative patients (Parkinson, stroke or Alzheimer diseases) [3,4]. We investigate here the capabilities of BLADE to overcome motion sensitivity in DB cardiac morphology imaging and improve image quality.

Methods

In BLADE acquisition scheme, k-space is covered by so-called blades consisting of the phase encoding lines (=turbofactor TF) of a conventional rectilinear TSE segment in k-space. During the acquisition process, the direction of the individual blades is rotated around the k-space center providing k-space oversampling, allowing further motion correction by comparing low resolution image reconstructed from undersampled k-space center common to each blades. Angular over-sampling (Blade coverage > 120%) can be used to prevent from image blurring and star artifacts resulting from local under-sampled k-space regions, where the Nyquist limit is violated. A proton density (PD) or T2 BLADE sequence was compared to the technique of reference (T2-prepared SSFP, TSE DB or TIRM DB sequence) in 20 subjects: 4 normal volunteers, 12 patients with acute MI (within 5 days), 5 paediatric patients with congenital disease (Ebstein, Tetralogy of Fallot of status post Contegra, CIV). Images were acquired on a Siemens Avanto scanner. In-plane resolution was typically 1.2x1.2 mm2 with 6mm slice-thickness. ECG triggering used 2 R-R intervals between readouts. All TSE and BLADE images used double triggering (ECG synchronization +an adaptative respiratory navigator), a double inversion-recovery dark-blood prep with 300% slice-thickness for selective inversion component, BW=500Hz/pixel, TF=25, TE=9-79 ms. All methods had similar surface coil intensity correction.

Results and Discussion

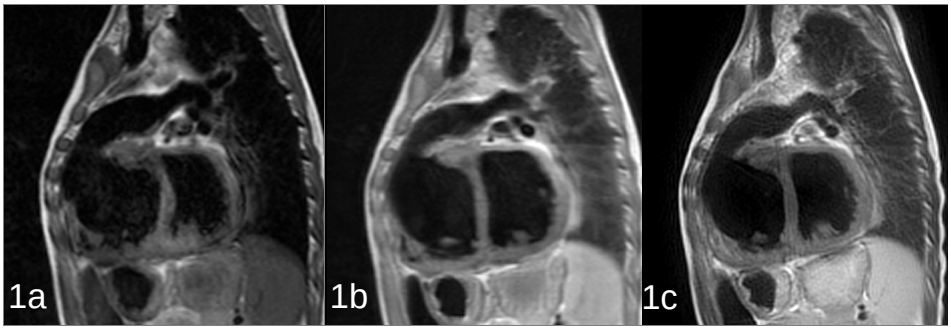

Fig1. Para-sagittal slice encompassing the contegra graft positioned in the pulmonary artery and imaged using T1 SE (1a), DP DB TSE navigated sequence(1b) and DP DB BLADE navigated sequence (1c). Note that the right ventricle wall is clearly visible on the BLADE images. Definition of the septum, papillary muscles and myocardium wall is increased by the BLADE motion correction and acquisition mode. The quality of the respiratory triggering (adaptative navigators) can be appreciated from definition reached in the PD lung image (Fig1c-3a-3b).

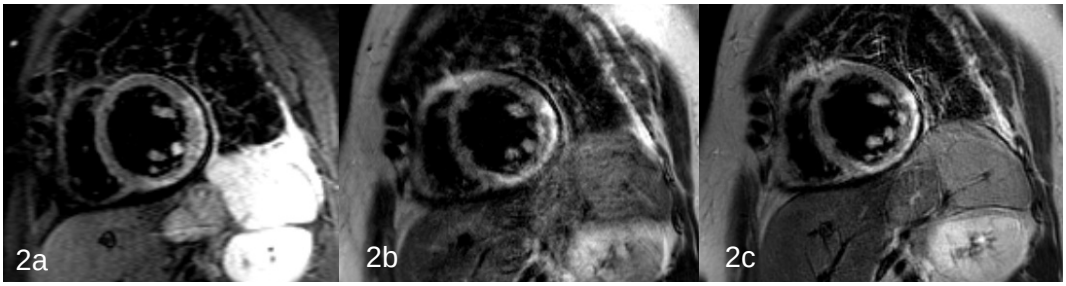

Fig2. Mid short-axis slice of acute MI patient with oedema of the infero-lateral wall imaged using T2 DB sequences: IR (TI =170ms) TSE breath-hold (2a), navigated TSE (2b) navigated BLADE (2c).

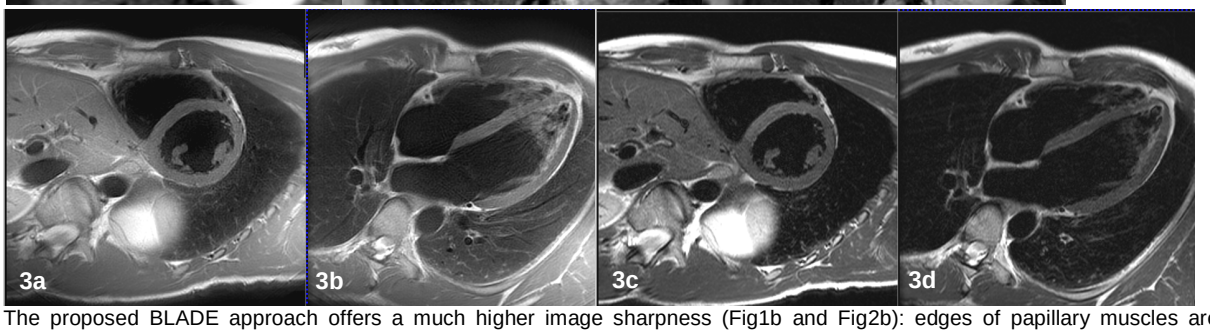

Fig 3. Short axis and 4 chamber view acquired on a volunteer using DP BLADE (3a-b) and T2 BLADE (3c-d).

The proposed BLADE approach offers a much higher image sharpness (Fig1b and Fig2b): edges of papillary muscles are more clearly depicted, ventricular wall (especially the right ventricle thin wall) are much better delineated (fig3b). Bright intra cavity signals due to stationary blood near the subendocardium (Fig3b) that are still shown in PD images are attenuated at longer TE (fig3d). Arythmia rejection was not implemented yet but could be included to further reduce sensitivity to RR variations. Image quality at high but stable heart rates like in pediatric patient was maintained (Fig1). Finally PD images provides a new anatomical contrast of interest for lung parenchyma and thorax MR imaging (fig 3b: note the resolution obtained on pulmonary vessels and tissues), that can be potentially combined to FS or IR to achieve more complex contrasts.

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