Technical Foundations: Physics of Bright Blood Imaging

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Topics

- Current clinical standards of 2D cardiac cine imaging
- Gradient echo and balanced SSFP cardiac cine imaging, choice of imaging parameters
- Cardiac cine imaging at 3T, near devices, artifacts reduction

2D Breath-held, Segmented, Retrospective Cardiac Cine Imaging

Cardiac cine imaging is clinically performed for assessment of cardiac structure and function and is challenged by both cardiac and respiratory motion. The respiratory motion is reduced by acquiring during a breath-hold and is enabled by k-space segmentation (1).

Cardiac cine imaging can be acquired with prospective ECG triggering or retrospective ECG gating. In prospective ECG triggering the k-space segments are acquired from the R trigger for a fixed duration that is less than the average R-R interval. Hence, the last 10% of the diastole may not be acquired with prospective ECG triggering (2). This is overcome using retrospective ECG gating where the k-space segments are acquired continuously and are retrospectively binned into different cardiac phases (3,4).

Gradient Echo Imaging

Spoiled Gradient Echo (SPGR/GRE/T_1-TFE) imaging is a T_1 weighted pulse sequence. With similar blood and myocardium T_1, the contrast between these tissues in cardiac cine imaging is due to the through-plane blood flow. Hence when the imaging plane is perpendicular to direction of blood-flow (short-axis plane), the blood-myocardium contrast is higher compared to four-chamber imaging plane with predominant in-plane flow. Moreover, in patients with poor cardiac function, the blood-myocardium contrast is poor is all the imaging planes.

Balanced Steady State Free Precession (bSSFP) Imaging

The image contrast in bSSFP imaging is predominantly due to the T_2/T_1 ratio that results in dark myocardium signal and bright blood signal (5,6). Hence bSSFP imaging provides excellent blood-myocardium contrast in all the imaging planes even in patients with poor cardiac function. The blood bSSFP signal also depends on the flow (7), choice of TR and TE which determine the optimal FA for cardiac cine imaging (8).

Cardiac Cine Imaging at 3T

Cardiac cine imaging at 3T is benefitted by increase in SNR that can be traded for higher spatial or temporal resolution (9). However, at higher field strengths, B_0 and B_1 inhomogeneity also increase which results in pronounced off-resonance induced banding and flow artifacts in bSSFP cardiac cine imaging. Specific absorption rate (SAR)/RF-induced heating due to the use of higher flipangle also increases by a factor of four compared to 1.5T. The off-resonance artifacts at 3T can be reduced by appropriately choosing the RF synthesizer frequency that produces the least banding artifacts within the heart (10).

Cardiac Cine Imaging near Devices

Cardiac imaging in patients with pacemakers or implantable cardioverter defibrillator (ICD) may have poor image quality due to the susceptibility artifacts caused by the device. Hence bSSFP cardiac cine imaging results in increased banding artifacts, and GRE results in signal drop-out adjacent to the device. MRI in these patients is performed at 1.5T with lower flip angles to reduce SAR (< 2W/kg) (11). When the bSSFP cardiac cine imaging results in poor image quality affecting the cardiac anatomy, GRE imaging is preferred (12,13).

Contrast Enhanced Cardiac Cine Imaging

Contrast enhanced GRE cardiac cine imaging is preferred to bSSFP imaging especially at 3T or imaging near devices. Blood pool contrast agents such as gadofosveset trisodium are retained in the blood for a longer time and results in prolonged reduction in blood T_1. GRE cardiac cine imaging with blood pool agents provide good blood myocardium contrast at 3T without the banding artifacts (14). When myocardial scar imaging is performed (15), contrast agents such as gadopentetate dimeglumine are used to improve the blood-myocardium contrast in GRE cardiac cine imaging (16).

Summary

2D cardiac cine imaging is performed using retrospectively ECG gated, k-space segmented acquisition during a breath-hold. Excellent blood-myocardium contrast can be obtained at 1.5T with bSSFP cardiac cine imaging. At 3T, with proper selection of RF synthesizer frequency, the banding artifacts may be moved away from the region of interest, with excellent image quality. However, in some patients at 3T and patients with pacemaker/ICD, with poor bSSFP image quality, GRE or contrast enhanced GRE may be used for cardiac cine imaging.

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