The following discussion regarding the use of 3T MR scanner for clinical cardiac MR examination for the evaluation of patients with congenital heart disease is based upon 4 years of clinical experience of using the Philips Achieva 3T scanner with multi-transmit radiofrequency (TX) technology.

In the 3T environment, when compare to 1.5T, there is greater B_1 and B_0 field inhomogeneity and greater sensitivity to motion. The ECG triggering system is more sensitive to electromagnetic noise. These are the main challenges in performing clinical cardiovascular (CV) examinations on 3T. On the other hand, 3T environment provides greater signal-to-noise (SNR) and longer T1 that can be advantageous for CV imaging.

The B_1 field inhomogeneity will cause large variation in flip angle across the imaging volume and so-called SAR hot spots. Simplistically, this variation in flip angle will result in loss of signal in spin echo based sequences as in double inversion recovery black blood sequence and loss of tissue contrast in gradient echo sequence as in cine balanced steady-state free precession (SSFP) sequence. With the advent of the TX technology, the B_1 field can be calibrated to the particular imaging volume of the patient achieving a much more homogeneous B_1 field. The variation of flip angle and SAR hot spot significantly diminished. Besides improvement in image quality with recovery of loss signal in spin echo sequences and better tissue contrast in gradient echo sequence, the more consistent flip angle across the imaging volume allows for using a slightly lower flip angle on balanced SSFP sequences which has the secondary effect of lowering the TR. Moreover, the TR also will be lower by having less SAR hot spots. This secondary effect of lowering of the TR can improve the banding artifact that is related to field B_0 inhomogeneity.

The B_0 field inhomogeneity, in my experience, is the most problematic issue on 3T CV imaging with balanced SSFP based imaging as this technique is very sensitive to homogeneity of B_0. For the gold standard cine balanced SSFP sequence, there can be dark bands across the imaging volume. These bands exists on 1.5T acquisitions also but they are typically so far apart that they do not affect the image quality. However, with the increased B_0 field inhomogeneity, these bands on 3T can occur across the heart. These bands occurs in areas where the accumulated phase shift from each TR sums to 180 degrees. Therefore, by making the field as homogeneous as possible by shimming and decreasing the value of TR, these areas of dark bands will be spatially further apart. Shimming over the heart and the descending thoracic aorta posterior to the heart prior to scanning with cine balanced SSFP sequence is a must. Even then, some times, depending on the geometry of the imaging volume, this may not adequately to prevent the dark bands from appearing over the heart and the shim volume will need to be adjusted. Typically, depending on the particular MR scanner system, if TR is kept below 3 msec (by keeping flip angle around 40-45 degrees and an acceptable spatial resolution of 1.7 mm in-plane resolution with 6 mm thick slices), the majority of the cine balanced SSFP will have acceptable diagnostic quality. For coronary MRA, there is less artifacts by using the non-balanced fast gradient echo sequences.

Increase sensitivity of ECG triggering system to the 3T electromagnetic noise requires meticulous preparation of placement of the electrode and connections of the clips to the electrodes. Cleaning of the skin surface and ensuring proper connections is mandatory. Use of vectocardiogram triggering system is the method of choice.

The increase in SNR afforded by 3T can allow for high spatial resolution imaging. Alternatively one can trade off the higher SNR for faster imaging using higher acceleration factor in parallel imaging as higher acceleration factor incur more noise in the image. Additionally, the longer T1 in 3T environment translates to higher tissue contrast in contrast-enhanced MRA images. There are also reported improvement in higher SNR and CNR in perfusion imaging and longer lasting saturation tags in myocardial tagging studies.

In summary, performing CV imaging on 3T MR scanner for patients with congenital heart disease is clinically feasible. All state-of-the-art 3T MR scanners are equipped with TX technology which is required to reduce the B_1 field inhomogeneity. Presence of MR safe and compatible sternal wires, surgical clips, stents, and embolization coils should be avoided if there is a 1.5T option but not considered contraindication as the available state-of-the-art gradients allow for very short TR and TE and can minimize artifacts. The B_0 shimming may need to be adjusted to minimize the banding artifacts with inhomogeneity introduced by the devices. With the availability of TX technology and couple with careful B_0 shimming, using low TR/TE on cine balanced SSFP (less than TR = 3 msec) can yield diagnostic examinations routinely. When manufacturers can introduce improvement in higher order B_0 shimming, CV 3T clinically examination should be even more robust.

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