Journal of Cardiovascular Magnetic Resonance

Oral presentation

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Clinical CMR at 3.0 Tesla using parallel RF transmission with patient-adaptive B1 shimming: initial experience

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from 13th Annual SCMR Scientific Sessions
Phoenix, AZ, USA. 21-24 January 2010

Published: 21 January 2010

Journal of Cardiovascular Magnetic Resonance 2010, **12**(Suppl 1):O72 doi:10.1186/1532-429X-12-S1-O72

This abstract is available from: http://jcmr-online.com/content/12/S1/O72

Introduction

The clinical implementation of high-field CMR systems has introduced new challenges for cardiac imaging due to B0 and B1 field inhomogeneities. TSE Black-Blood sequences (BB) are compromised by dielectric artifacts, whereas SSFP cine-sequences are known to suffer from dark-band artifacts. The flip-angle non-uniformity across the field of view affects image homogeneity of both sequences. The use of a multi-source RF transmission system may help reduce dielectric effects, improve flip-angle uniformity and avoid local SAR peaks, thus allowing a shorter minimum TR/TE in SSFP-sequences.

Purpose

In this study we investigated the benefit of a novel multi-source RF transmission system with patient-adaptive RF shimming for cardiac imaging at 3.0 Tesla.

Methods

A clinical 3.0 T MRI system (Philips Achieva TX, Healthcare, Best), equipped with flexible dual-source RF transmission, was used. With this setup it is possible to independently control phase, amplitude and shape of the RF waveforms. A standard 6 element cardiac phased-array coil was used for signal reception.

The effect of single-source (SingleTransmit) vs. multi-source (MultiTransmit) RF-transmission with B1-shimming on SSFP cine-sequences and Black-Blood (BB) sequences was evaluated. Images were analyzed independently by two readers for homogeneity and off-resonance artifacts. Both were rated on a 4-point grading-scale: (4) uniform signal/no off-resonance artifacts, (3) mild signal inhomogeneity/off-resonance artifacts, (2) moderate signal inhomogeneity/off-resonance artifacts, (1) strong signal inhomogeneity/off-resonance artifacts.

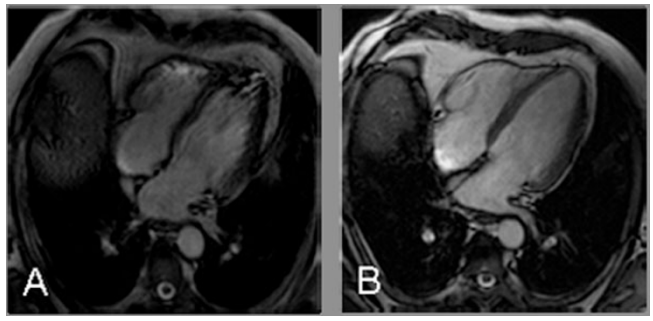

Figure 1
HLA view of s SSFP cine sequence with (A) Single Transmit and with (B) MultiTransmit of a 39 year old male patient with suspected coronary artery disease. Multi Transmit clearly eliminates the strong off-resonance artifacts seen at the apex of left and right ventricle and markedly improves image quality and interpretation.

Table 1: Mean ratings of both reviewers 2 for SSFP images.

	Image inhomogeneity		Off-Resonance artifacts		Diagnostic confidence	
Mode	**Single Transmit**	**Multi Transmit**	**Single Transmit**	**Multi Transmit**	**Single Transmit**	**Multi Transmit**
Left ventricle	2,1 ± 0,7*	3,4 ± 0,7 *	2,4 ± 1 *	3,8 ± 0,4 *	2,8 ± 0,8 *	3,6 ± 0,5 *
Right ventricle	2,0 ± 0,6*	3,2 ± 0,7*	1,9 ± 1 *	3,4 ± 0,5 *	2,4 ± 0,9 *	3,5 ± 0,5 *

* = $p < 0.0001$

In addition diagnostic confidence was rated on a 4-point grading-scale: (4) very high confidence in diagnostic content, (3) good confidence in diagnostic content, (2) reservations about diagnostic content, (1) non-diagnostic. P-values were calculated using the Wilcoxon signed-ranks test. Percentage of overall interobserver agreement (Po) was calculated.

Results

A total of 14 SSFP- and 7 BB-sequences were analyzed (patients = 7). For the SSFP-sequence the left and the right ventricle showed significant improvements with respect to homogeneity, off-resonance artifacts and diagnostic confidence (see Table 1 and Fig. 1).

In the BB-sequence homogeneity and diagnostic confidence significantly improved for the right ventricle (see Table 2 and Figure 2). Percentage of overall interobserver agreement for all ratings was good to excellent ($0.66 < Po < 0.95$).

Conclusion

Parallel multi RF-transmission with B1-shimming significantly improves the image homogeneity and contrast of cardiac SSFP and BB sequences and thus represents a major step forward in clinical CMR at 3.0 T.

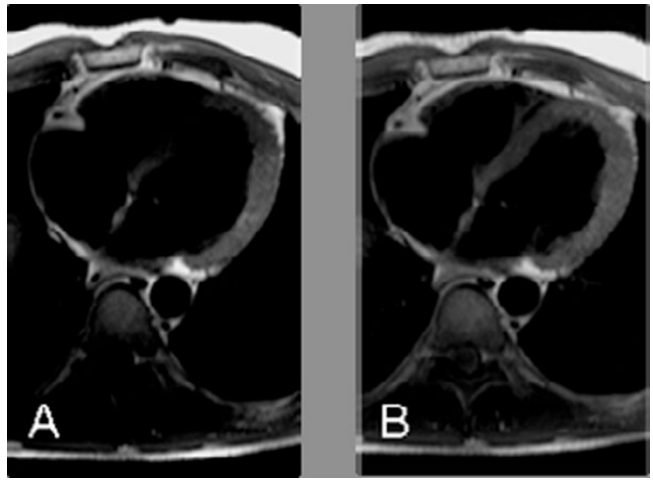

Figure 2
Axial BB sequence with (A) Single Transmit and with (B) MultiTransmit of a 39 year old male patient with suspected arrhytmogenic rightventricular dysplasia. Note the markedly improved signal homogeneity of the image acquired with MultiTransmit, which allows the clear delineation of the interventricular septeum and the anterior wall of the right ventricle.

Table 2: Mean ratings of both reviewers for BB images.

	Image inhomogeneity		Diagnostic confidence	
Mode	**Single Transmit**	**Multi Transmit**	**Single Transmit**	**Multi Transmit**
Left ventricle	2,3 ± 1 *	3,3 ± 0.7 *	2,417 ± 1,1 *	3,2 ± 0,7
Right ventricle	1,6 ± 0,8 *	3,0 ± 0,9 *	2,0 ± 1,1 *	2,8 ± 0,7 *

* = $p < 0.005$