Cardiac CINE MRI at 7 T using a transmit array

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Introduction

With its need for high SNR and short acquisition times, Cardiac MRI (CMR) is an intriguing target application for ultrahigh field MRI. Due to the sheer size of the upper torso, however, the known RF issues of 7T MRI are also most prominent in CMR. Recent years brought substantial progress [1-4] but the full potential of the ultrahigh field for CMR is yet to be exploited. Parallel transmission (pTx) is a promising approach in this context and several groups have already reported B_1 shimming for 7T CMR [1-3]. In such a *static* pTx application amplitudes and phases of all Tx channels are adjusted individually but otherwise imaging techniques established in current clinical practice 1.5 T and 3 T are applied. More advanced forms of pTx as spatially selective excitation (SSE) using Transmit SENSE [5-7] promise additional benefits like faster imaging with reduced fields of view or improved SAR control. SSE requires the full dynamic capabilities of pTx, however, and for the majority of today's implemented pTx hardware the internal synchronization of the Tx array does not easily permit external triggering as needed for CMR. Here we report a software solution to this problem and demonstrate the feasibility of CINE CMR at 7 T using a Tx array.

Materials and Methods

Experiments were performed on three healthy volunteers using a 7T scanner (Siemens AG, Erlangen, Germany) equipped with an 8-channel Tx array and a 4-channel Tx/Rx cardiac coil [1]. The Tx array is controlled by eight independent CPUs synchronized only at sequence start. As the simultaneous input of eight external trigger pulses is not possible with the given system hardware, a FLASH sequence was written where the array is halted and restarted –and thus resynchronized– after each heart cycle. The restart is initiated by one master CPU which itself is conventionally triggered by an acoustic gating device (MRI.TOOLS GmbH, Berlin, Germany) [8]. The approach proved successful and is now implemented into the base level of the system software. It can be used by many pulse sequences requiring only minor modifications. CINE FLASH images (24 cardiac phases over 18 heart cycles, FOV= 270mm×360mm, matrix 154×256, TR/TE = 2.6/47.8ms) were acquired in a single breath hold, prospectively triggered or retrospectively gated using a modified cardiovascular product sequence. Basic B_1 shimming tests were performed starting from arbitrary settings and optimizing the Tx phases on the fly. For one volunteer the measurements were repeated using the scanner in its (normal) single channel Tx mode, using power splitters and delay cables to drive the four elements of the same RF coil.

Results and Discussion

Fig. 1 shows that short axis (SAX) views of the heart of clinical quality (A) can be achieved with the pTx array once the transmit RF phases are properly adjusted. Panels (B – D) show SAX views using various sets of non-optimal phase adjustments. Two four-chamber views (E, F) were acquired with identical phase settings but different RF coil positions: the signal void in the lateral wall only in (F) demonstrates the interrelation of these two parameters. No significant differences in signal quality were found when the scanner was run in single-channel (G) or pTx (H) mode, proving that the synchronization within the Tx array is not interfering with the internal timing of the CMR sequence. In summary, the feasibility of CINE CMR at 7T using pTx has been demonstrated. The triggering solution is purely software based and the concept is applicable to any Tx array architecture with independent CPUs. In this proof-of-principle study we restricted ourselves to basic B_1 shimming; the next steps will be to extend this work to more advanced dynamic applications like transmit SENSE which are also permitted by this concept.

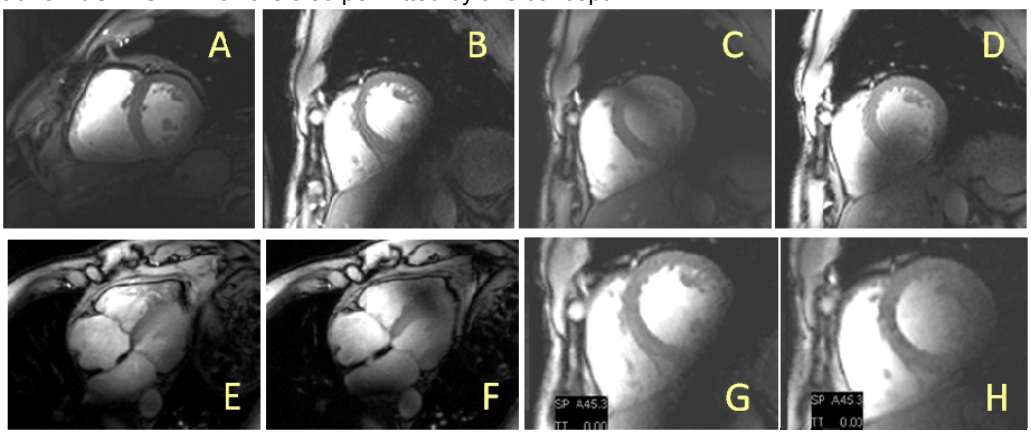

Fig 1. Single frames derived from CINE FLASH imaging at 7 T. Top row: short axis views with different Tx phase settings. A) optimized B_1 shim, B) – D) signal voids due to suboptimal phase settings. E)+F): four-chamber views with identical phase settings, but differently positioned RF coils. G)+H): short axis views acquired in single-channel (G) and pTx (H) mode.

References: [1] Niendorf T *et al.*, Eur Radiol 2010, 20:2806. [2] Dieringer MA *et al.*, JMRI 2011, 33:736. [3] Suttie JJ *et al.*, NMR Biomed 2011, doi: 10.1002/nbm.1708. [4] Maderwald S *et al.*, Proc ISMRM 2011, 1322. [5] Ullmann P *et al.*, MRM 2005, 54:994. [6] Grissom W *et al.*, MRM 2006, 56:620. [7] Lindel TD *et al.*, Proc ISMRM 2011, 2901. [8] Frauenrath T *et al.*, Invest Radiol 2009; 44:539