Whole Heart Cardiac MRI with High Temporal and Spatial Resolution Using a 128-Element Cardiac Array at 3 Tesla

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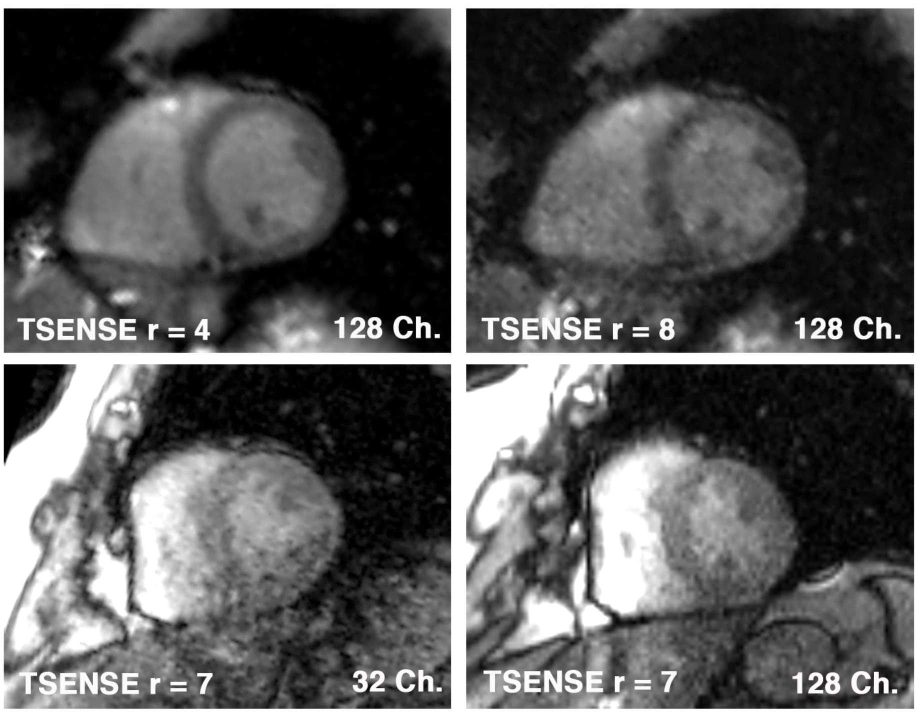
Background and Aims: Cardiac MRI requires images with both high temporal and spatial resolution to be acquired in the limited duration of a breathold. The use of 32-element arrays and parallel reception at 1.5 T has proven highly valuable, but still does not allow high-resolution whole heart imaging to be performed in a breathold. We have recently reported the construction of a 128-channel receive only coil for cardiac MRI at 3 Tesla.[1] We have shown that the g-factors produced by this 128-channel coil at 3 T are significantly lower than those produced by a prototype 32-element array.[1] The aim of the present study was thus to perform whole heart cine MRI in a single breathold at 3 Telsa with both a 128-channel and a 32-element array. We aimed to demonstrate the feasibily of cardiac imaging with the 128-channel array and to compare its performance with that of a 32-element array.

Methods: Construction of the coil has been previously described.[1] Imaging with both the 128 and 32-element (In Vivo Medical, Florida) arrays was performed on a prototype 3T scanner (Trio, Siemens Medical, Erlangen) with 128 independent receive channels. The RAM on the image reconstruction computer (MRIR) on the system was upgraded from 16-32 gigabytes to process data from the 128-channel array. 9 healthy volunteers (7 male) were imaged with the 128-channel array and 4 with the 32-element array. Three acceleration protocols, all designed to acquire short axis cine images over a contiguous 100 mm area in a single breathold, were studied: Acceleration rates (R) in a single direction of 4-7 were used with GRAPPA, rates of 4-8 with TSENSE, and a rate of 4 with TGRAPPA. Image parameters were as follows: Tru-fisp cine, FOV 360 mm, matrix 192 x 101, flip angle 35, TE 1.4 ms. The in-plane resolution(1.9 x 2.9 mm) of the three protocols was kept constant. The number of slices, slice thickness and temporal resolution of each protocol were optimized on an individual basis. Heart rate in the volunteers imaged ranged from 55 to 80 beats per minute.



Results: The TSENSE protocol allowed cines at 12 slice locations (slice thickness = 8mm) to be imaged in a single breathold, lasting approximately 20 seconds (2 RR intervals per cine). The temporal resolution of these TSENSE cines averaged 20 frames per RR interval at rate 8 acceleration, 18 frames at rate 7, 14 frames at rate 6 and 11 frames at rate 4. Online reconstruction of all 12 slices took < 20 seconds with both the 32 and 128-array datasets at all acceleration rates.

TGRAPPA imaging could be performed with the 32-element array using the identical parameters and with similar reconstruction times to those of the TSENSE acquisition. However, reconstruction times using TGRAPPA with the 128-channel array were dramatically longer than those required with TSENSE. Approximately 12 minutes were required for the rate 4 TGRAPPA reconstruction, and acceleration rates higher than this with TGRAPPA could not be reconstructed online.

Whole heart coverage with GRAPPA required significant compromises to be made in order to maintain high spatial resolution: Slice number was reduced from 12 to 10, slice thickness was increased from 8 to 10 mm and 16 frames per RR interval were acquired. Despite this, breathold duration increased from 20 to > 35 seconds.

Images from 2 volunteers are shown in the Figure. Diagnostic image quality could be obtained with the 128-channel array in all cases, even at high acceleration rates. Image quality was consistently better with the 128-element array than with the 32-element array, regardless of the acceleration protocol used. The improvement in image quality with the 128-element array was most marked at acceleration rates of 6, 7 and 8 (see Figure).

Conclusion: Whole heart cine imaging with both high spatial and temporal resolution can be robustly performed at 3 Tesla using TSENSE, 1D acceleration factors of 7 or greater, and a 128-element cardiac array. The long reconstruction times required with the current implementation of TGRAPPA, however, do not support the routine use of this technique with 128-channel arrays.

Improvements in hardware and pulse sequence design on this highly experimental system have the potential to improve image quality even further. These include improved shim algorithms, the ability to use retrospective gating and optimization of SAR measurements/flip angles with the 128-element array in place. Reducing the number of dummy pulses during the transient state of the tru-fisp (balanced SSFP) sequence also has the potential to half the duration of the required breathold to approximately 10 seconds (1 RR interval per slice). While 3D whole heart cardiac imaging remains the ultimate goal, the 2D technique described here is of significant value and provides additional proof-of-principle for the use of multi-element arrays and high acceleration factors in cardiac MRI.

1. Schmitt M, Potthast A, Sosnovik DE, Polimeni JR, Wiggins GC, Triantafyllou C, Wald LL. A 128-channel receive-only cardiac coil for highly accelerated cardiac MRI at 3 Tesla. *Magn Reson Med.* 2008;59:1431-1439.