

High Temporal and Spatial Resolution 3D CE-MRA of the Peripheral Vasculature using 12-fold 2D SENSE

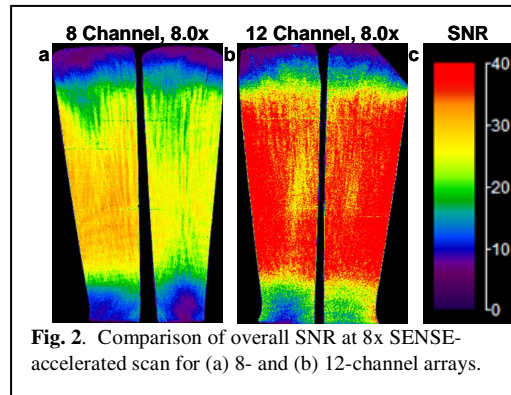
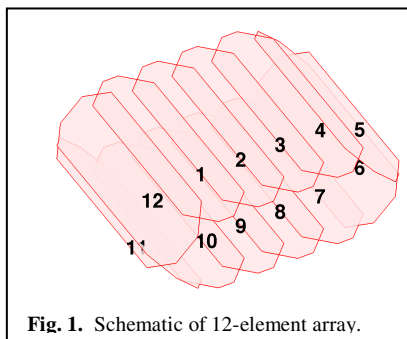
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Introduction. Imaging the peripheral vasculature requires high spatial resolution to allow accurate depiction of the origins of the major arteries. When the acquisition time is sufficiently small, spatial resolution in the range of 1 mm isotropic can be obtained with negligible venous contamination, even in patients with rapid venous return. Short acquisition times also allow the generation of time-resolved sequences which can address limitations due to timing errors and portray asymmetric left vs. right filling. The purpose of this work was to show the feasibility that 1 mm isotropic time-resolved 3D contrast-enhanced MR angiograms of the lower legs can be generated with frame times less than 4 seconds and overall scan times of less than 16 seconds.

Methods. The principal elements of the imaging technique were the development of a peripheral coil array and adaptation of a k-space sampling strategy for performing accelerated acquisition.

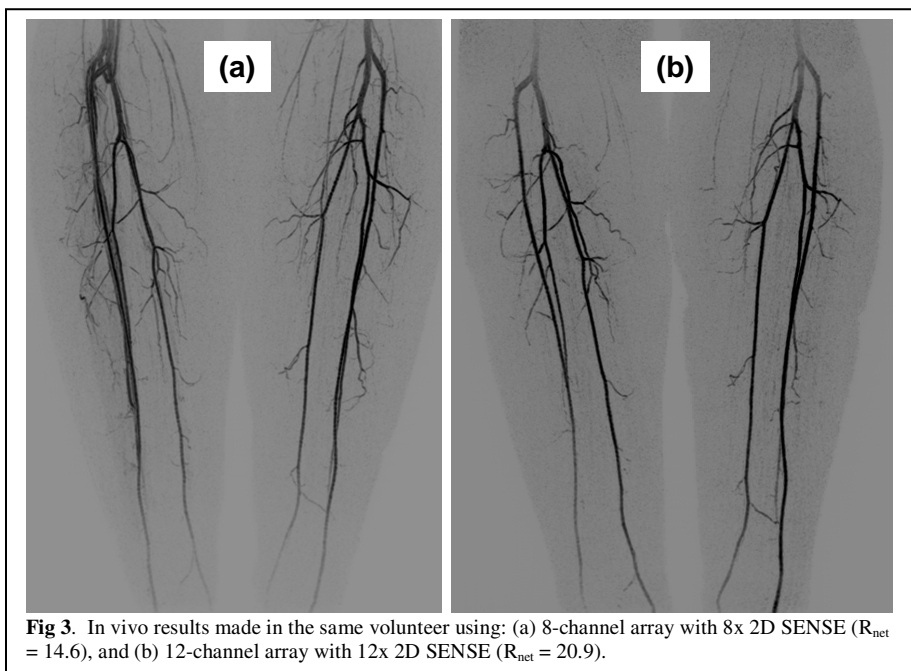
Peripheral Vascular Array: A previously developed [1] 8-element array provided a performance reference for this work. That array permitted 2D SENSE with $R=8$ ($R_z=2$ A/P, $R_y=4$ L/R) with g-factors no larger than 1.4 for 75% of all voxels in the 3D volume encompassing the lower legs. For this current work a 12-element peripheral vascular array was developed with the target of providing improved performance at $R=8$ and possible use at $R=12$ SENSE acceleration. The array consisted of equally sized elements placed circumferentially about the calves (Fig. 1). Each element had a width of 7.2 cm and length of 27.7 cm, adequate for imaging a 40 cm FOV in the SI direction.



Acquisition Technique: The acquisition was based on the CAPR method [2], a time-resolved 3DFT technique with phase encoding performed in the k_y - k_z plane. The k-space sampling consists of a fully sampled center surrounded by an outer annulus composed of four radially-oriented sets of vanes with unsampled gaps between individual vanes. Data in the gaps between the unsampled vanes are estimated by 2D homodyne reconstruction. Each image is formed from data from the full sampling of the k-space center and all four vane sets. From one image to the next in the time series the k-space center and one vane set are updated. For all acquisitions the central k-space region was chosen to contain 400 samples, a value selected to provide accurate homodyne reconstruction. 2D SENSE acceleration was done using either an acceleration of $R=8$ or $R=12$ ($R_y=4$, $R_z=3$). With the just-under two-fold undersampling permitted by 2D homodyne, the net undersampling factor was either 14.6 or 20.9.

Experiments: Experiments were performed using a fast GRE sequence on a 3T MR imager (GE Signa, V14.0). The field of view of $40 \times 32 \times 13.2$ cm³ and sampling matrix of $400 \times 320 \times 132$ yielded 1 mm isotropic spatial resolution. Additional imaging parameters included: BW of ± 62.5 kHz, flip angle of 30° , and TR/TE = 5.85/2.7 ms. Accelerated scans of a homogeneous phantom having similar shape and volume to the calves were performed using each array to compare the SNR for an acquisition with SENSE $R=8$ ($R_{net} = 14.6$). Additionally, to evaluate the new 12-element coil at the highest possible SENSE acceleration ($R=12$), a single volunteer was imaged once with the 8-element array ($R_{net}=14.6$) and once with the 12-element array ($R_{net}=20.9$). These exams were done on different days to allow contrast clearance. Contrast administration was injection of 20 mL of Multihance@ contrast at 3 mL/s followed by 20 mL of saline at 3 mL/s.

Results. Fig. 2 shows coronal SNR maps obtained using the phantom for the 8- (a) and 12-element (b) arrays at the same acceleration (SENSE $R=8$, $R_{net}=14.6$). Fig. 2c shows the SNR scale. Fig. 3 compares similar arterial frames from the same volunteer using the 8-channel array (a, $R_{net}=14.6$) and 12-channel array (b, $R_{net}=20.9$). In both studies the origins of the major vessels are well seen, as well as small muscular arteries, and secondary and tertiary branches of the major vessels.



Discussion and Conclusions. We have demonstrated that the 12-element array provides typically 30% higher SNR compared to the 8-element array at fixed acceleration (SENSE $R=8$; $R_{net}=14.6$). This improvement has in turn been exploited to maintain high image quality at even higher accelerations ($R=12$; $R_{net}=20.9$). High quality 1 mm isotropic time-resolved imaging of the lower legs is feasible with acquisition times under 16 sec and image update times under 4 sec.

References.

[1] Johnson Proc ISMRM 1079 (2008); [2] Haider MRM 60:749 (2008)