Continuously Moving Table Peripheral CE-MRA with a Radial-Elliptical Centric View Order and 2D Homodyne

A. J. Madhuranthakam[1], H. H. Hu[1], C. R. Haider[1], D. G. Kruger[1], A. V. Barger[1], J. F. Glockner[1], S. J. Riederer[1]

[1]Department of Radiology, Mayo Clinic College of Medicine, Rochester, Minnesota, United States

Introduction: Contrast-enhanced MR angiography (CE-MRA) of the extended peripheral vasculature is usually performed either using a multiple station (1) or continuously moving table (CMT) (2) technique. The demand for high spatial resolution in these studies increases as the vessel diameter becomes smaller, especially in the lower legs. In general, the spatial resolution in CE-MRA of a single station is intrinsically limited by the time window during which the contrast agent passes through the arteries of interest. This becomes critical for peripheral vasculature studies as the arteries of interest span an extended region. When compared to a multiple station approach, the k-space is more efficiently sampled in the CMT technique by eliminating the extra time in moving the table between stations and redundant data sampling in overlapping regions.

Several means are being investigated for improving the lateral spatial resolution in CMT by expanding the axial k-space coverage during the time that a given position is within the actively sampled FOV. These methods include parallel imaging (3) and undersampled projection reconstruction (PR) (4). However, for a non-time-resolved high quality angiogram without venous contamination, PR is limited as every view passes through the center of k-space. Previously, a hybrid radial-elliptical centric (EC) acquisition scheme utilizing 2D homodyne has been shown to provide improved spatial resolution when compared to a standard acquisition for a fixed FOV (5). In this work, we study the implications of combining this hybrid radial-EC view order with the CMT technique and present the results from peripheral CE-MRA studies.

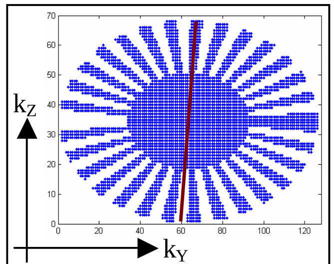
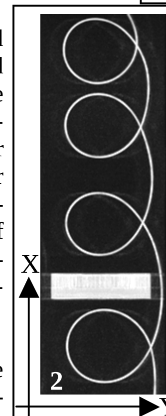


Fig 1. k-space sampling pattern of hybrid radial-EC

Methods: *k-space Sampling:* The k-space sampling was performed by modifying the standard 3DFT EC view order. As with standard EC, the desired phase encoding views were ordered based upon their Euclidean distance from the origin of the k_Y-k_Z plane. The views in the periphery were apportioned into different radial sectors or vanes of about 6° wide (Figure 1). During data acquisition, the sampling started from the center of the k-space as in a conventional EC sequence. After acquiring the central 1500 phase encodes, views that fell in every other radial sector in the upper hemisphere of the k_Y-k_Z plane were sampled. In the lower hemisphere the views that were anti-symmetrically oriented to the sampled views in the upper hemisphere were collected. As a result of this sampling pattern, for every non-sampled ($+k_Y$,$+k_Z$) view in the periphery, the conjugate symmetric ($-k_Y$,$-k_Z$) view was sampled. This allowed the 2D homodyne process to account for the non-sampled views by using the phase information from the fully sampled central k-space.



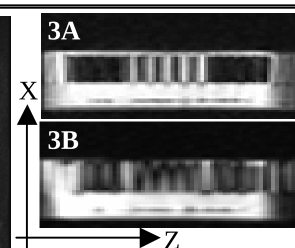


Fig 2. Coronal MIP using radial-EC sampling.
Fig 3. Sagittal reformats from radial- EC (A) and standard Cartesian sampling (B).

CMT Reconstruction: The above mentioned k-space sampling pattern was integrated with the CMT technique as described in Ref. 2. After each view was Fourier transformed (FT) along the X-direction, it was placed into the hybrid X-k_Y-k_Z space. At this point two separate reconstructions were performed. In the first reconstruction, only the central views that were fully sampled were further FT along Y and Z and corrected for gradient non-linearity (6). In the second reconstruction, homodyne detection was performed by weighting the outer k-space views by two. The final image was created by taking the real part of the second reconstruction after its phase was corrected using the first reconstruction. This process was repeated for each X value along the extended FOV.

Results: Fig. 1 shows the k_Y-k_Z plane of the radial-EC sampling pattern corresponding to 128 (N_Y) × 70 (N_Z) phase encoding views (N_{total} = 4100). A conventional, rectilinear k-space acquisition with a 128 (N_Y) × 32 (N_Z) matrix (N_{total} = 4096) was utilized for comparison. A tube filled with gadolinium doped water along with a resolution phantom was scanned with these two sampling patterns. Fig. 2 shows the maximum intensity projection (MIP) along the coronal orientation acquired with radial-EC sampling and Fig. 3 shows the sagittal reformats from both samplings in a slice containing the resolution bars. Fig. 2 shows good quality for the entire longitudinal extent and Fig. 3A shows superior resolving power along the slice direction when compared to Fig. 3B (both acquired with same scan time and table velocity). Fig. 4 shows coronal and sagittal MIPs of a peripheral CE-MRA study acquired with a 128 (N_Y) × 40 (N_Z) radial-EC sampling (N_{total} = 2671, FOV_s = 36 cm and v_t = 2.41 cm/sec).

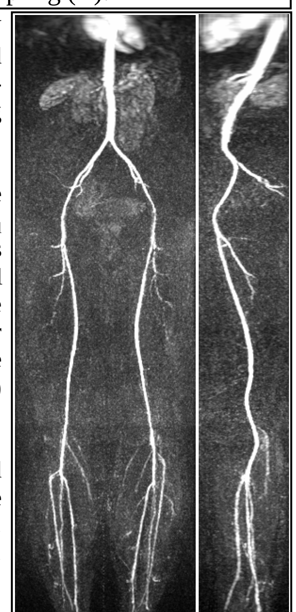


Fig 4. Coronal and Sagittal MIPs of a CE-MRA study using radial-EC sampling.

Discussion: We have integrated a hybrid radial-EC sampling scheme with a continuously moving table technique and demonstrated improved spatial resolution, in this case a doubling of the number of slice partitions. The 2D homodyne process permits sampling of higher spatial frequencies, and the EC view order allows capture of the arterial phase. The body coil was used for this preliminary study; future studies using surface coils are expected to improve the SNR. This sampling pattern can be readily implemented with parallel imaging techniques for additional benefits.

References: [1] Meaney JF, Radiology 211:59 (1999). [2] Kruger DG, MRM 47:224 (2002). [3] Hu HH, Proc. ISMRM p.325 (2004). [4] Fain SB, MRM 52:1093 (2004). [5] Madhuranthakam AJ, Proc. ISMRM p.8 (2004). [6] Polzin JA, MRM 52:181 (2004).