

High Temporal and Spatial Resolution Time-Resolved 3D CE-MRA of the Hands and Feet

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Introduction. MRA of the hands and feet is technically demanding because of the high spatial resolution required to image small vessels of interest and high temporal resolution required to capture first pass bolus dynamics. Because of this, conventional intra-arterial angiography continues to be the imaging modality of choice for presurgical planning in peripheral vascular bypass planning despite failing in up to 70% of cases to identify all possible distal graft sites [1]. MRA on the other hand is known to be able to image radiographically occult vessels [2], and the use of gadolinium contrast-enhancement (CE) improves depiction of tortuous or in-plane vessels [3-6]. The purpose of this work was to investigate methods for improving the quality of MRA of the extremities. It is hypothesized that: (i) time-resolved 3D CE-MRA can be used without compression to provide high diagnostic quality and better than 1 mm³ resolution for bilateral imaging of the hands and feet, (ii) dedicated peripheral vascular arrays can allow for order of magnitude (>10x) acceleration with negligible loss of image quality.

Methods. All acquisitions were performed using a fast GRE sequence at 3T (GE, V14.0) using the CAPR acquisition technique [7]. The imaging parameters were modified to account for either the pedal or hand anatomy. *Bilateral Pedal Imaging:* 3D CE-MRA of both feet was done with a net acceleration, $R_{net} = 15.1$, from the combination of R=8 2D SENSE and 1.9 partial Fourier over a FOV of 30x24x19.8 cm³ with acquired 0.75x0.75x0.9 mm³ spatial resolution. The image update time and temporal footprint were 6.8 sec and 27.2 sec respectively. *Bilateral Hand Imaging:* 3D CE-MRA of both hands was done with a net acceleration, $R_{net} = 12.7$, from the combination of R=8 2D SENSE and 1.6 partial Fourier over a FOV of 30x22.5x10.8 cm³ with acquired 0.75x0.75x1.8 mm³ spatial resolution. The image update time and temporal footprint were 3.1 sec and 12.4 sec respectively. Custom eight-channel and twelve-channel peripheral arrays that align elements circumferentially around the anatomy of interest were used.

Results. Fig. 1 shows MIP images of the feet from one volunteer acquired using an 8-element coil. Note the crisp leading edges of the contrast bolus owing to the high spatial resolution and temporal sharpness. Fig. 2 shows individual MIPs of the two feet in a bilateral study of another volunteer using a 12-element coil. In both volunteers the dorsalis pedis, plantar arch, and tarsal arch are all well seen. Furthermore, the SNR and spatial resolution are sufficiently high to clearly see the small digital arteries perfusing the toes. The short image update time and temporal footprint allow many clear arterial frames to be seen prior to venous enhancement.

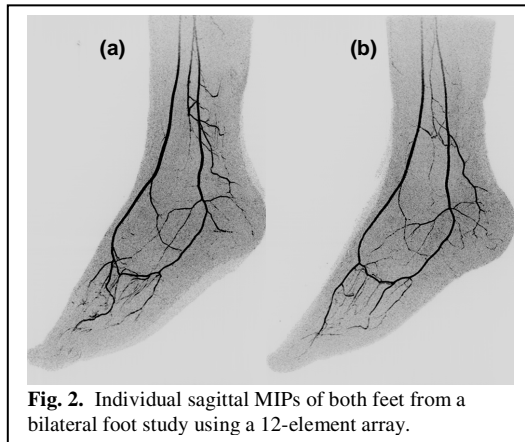


Fig. 2. Individual sagittal MIPs of both feet from a bilateral foot study using a 12-element array.

Fig. 3 shows an A/P MIP of the hands of a volunteer using the same eight-element array used for pedal vessel imaging (Fig. 1). Fig. 4 shows results using a dedicated twelve-channel hand array. For both studies a sense of the high image quality and SNR can be appreciated from the clarity with which the small digital arteries are seen. The temporal time series shows many clear arterial frames prior to pronounced venous return.

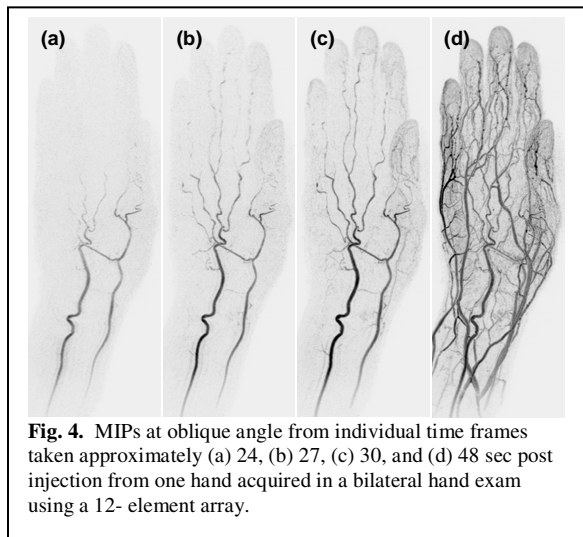


Fig. 4. MIPs at oblique angle from individual time frames taken approximately (a) 24, (b) 27, (c) 30, and (d) 48 sec post injection from one hand acquired in a bilateral hand exam using a 12-element array.

Conclusion. The feasibility of high diagnostic quality, high spatial resolution, time-resolved 3D CE-MRA of the pedal and hand vasculature has been demonstrated. Critical to the performance has been the development of peripheral vascular arrays that allow net accelerations of 10 or higher.

References. [1] Velázquez O Surg.Clinic North Amer 1998; [2] Owen RS NEJM 1992; [3] Wentz KU Lancet 2003; [4] Brauck K Eur Radiol 2007; [5] Ruhl KM AJR 2008; [6] Winterer JT Eur Radiol 2008. [7] Haider CR MRM 2008.

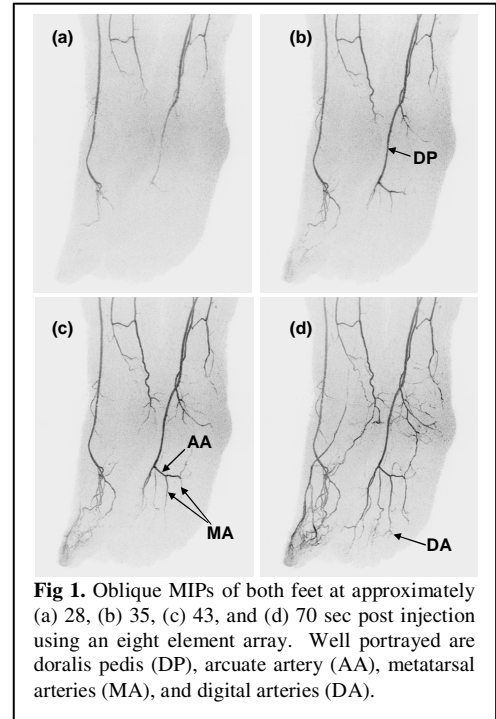


Fig 1. Oblique MIPs of both feet at approximately (a) 28, (b) 35, (c) 43, and (d) 70 sec post injection using an eight element array. Well portrayed are dorsalis pedis (DP), arcuate artery (AA), metatarsal arteries (MA), and digital arteries (DA).

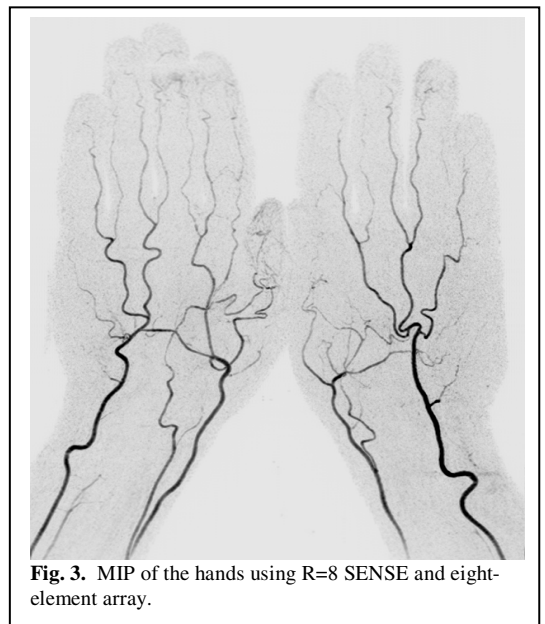


Fig. 3. MIP of the hands using R=8 SENSE and eight-element array.