# Interactive Real-time Large Field-of-View Peripheral MR Digital Subtraction Angiography

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## Introduction

Extended anatomic coverage is required in the diagnosis of peripheral vascular disease. In continuously moving-table peripheral contrast-enhanced MR angiography (CE-MRA), a large field-of-view (LFOV) image is built up from hybrid ($x$, $k_y$, $k_z$)-space data as a smaller local $FOV_x$ is translated along the patient in the $x$-direction.[1,2] To achieve optimal image quality, the translation of the table and the data acquisition need to be synchronized with the arterial passage of the contrast agent.[3,4] Previously, we proposed a 3D LFOV imaging technique to allow one to follow the passage of the contrast material in conjunction with real-time reconstruction of the hybrid-space data. [2] We proposed undersampled phase-encoding acquisition strategies [4] that are necessary because of the restricted acquisition time in contrast imaging and we addressed the implementation challenges.[5] Due to the signal of background tissue, however, robust visualization and tracking of the contrast bolus in real-time is challenging. In this work, we present a real-time MR digital subtraction angiography (DSA) method for interactive LFOV peripheral CE-MRA. The technique was tested on a vascular phantom and two normal volunteers. The results showed improved background suppression and enabled consistent visualization of the contrast agent in the legs during the scan. This allowed effective table motion in tracking the contrast agent producing LFOV 3D angiograms with a *single* bolus injection.

## Methods

A 3D fast spoiled gradient-recalled echo pulse sequence was modified to work in real-time mode with undersampled phase-encoding acquisition patterns.[4] Custom software extracted the MR data directly from scanner memory, filled the hybrid-space and reconstructed the images continuously. For accurate filling of hybrid-space, the patient table position was determined precisely and integrated with the sampled readouts after every TR.[5] Overlapped acquired data – produced due to the potentially stochastic acquisition patterns and arbitrary table motion – were efficiently combined to minimize gradient-induced geometric distortion in the real-time and LFOV images.[6] A large vascular phantom and two humans were scanned on a 3.0 T MR scanner (Signa; GE Healthcare, Waukesha, WI) using a body coil. A high-resolution LFOV mask volume was first acquired with slow table motion and was then used for real-time magnitude subtraction during the LFOV CE acquisition. A floating table was moved manually and independently for the mask and CE scans according to the real-time information (contrast flow in CE). Typical scanning parameters were: undersampled EC-TRICKS acquisition [7] of 12% to 30% hybrid-space coverage, TR/TE 6.8 ms/1.8 ms, $FOV_x$ 40 cm, acquisition matrix 160-256 $\times$ 160-256 $\times$ 16-36, slice thickness of 2-4 mm, LFOV matrix 768-896 $\times$ 160-256 $\times$ 16-36, scan time of 60 s to 90 s. Real-time subtracted projection images (from the 3D data) were provided to the operator at about 5 frames per second. CE MR data were acquired during automatic injection of 0.15 mmol $kg^{-1}$ of MR contrast (Magnevist; Berlex, Berlin, Germany) at 1.5 mL $s^{-1}$.

## Results

The contrast agent was clearly seen and successfully tracked in real-time in the phantom and humans during the CE acquisitions. Fig. 1a illustrates the coronal maximum-intensity-projection (MIP) of a LFOV mask volume obtained from one volunteer. Figs. 1b-1c show the coronal MIP's of the LFOV CE and subtracted images, respectively. Fig. 1c represents an initial large, continuous, contrast-enhanced peripheral angiogram of the subject after off-line construction. The major peripheral arteries are visualized without venous contamination. The use of the real-time gradient field non-linearities correction method greatly reduced the geometric warping effects in the real-time subtracted $FOV_x$-sized monitoring and LFOV images. It also led to a reconstruction time of 25 s to 32 s. The total table time for each examination was less than 5 min.

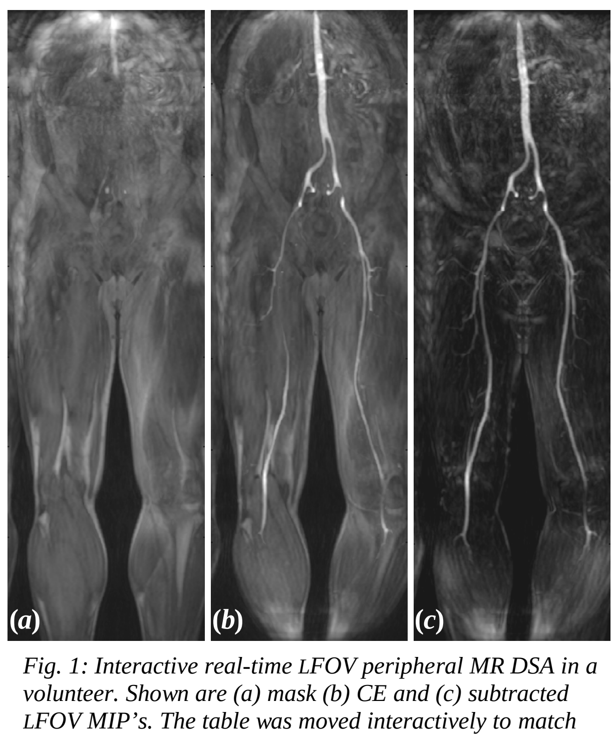


*Fig. 1: Interactive real-time LFOV peripheral MR DSA in a volunteer. Shown are (a) mask (b) CE and (c) subtracted LFOV MIP's. The table was moved interactively to match the on-line visualized contrast flow. The mask and CE were acquired during different table motion scenarios.*

## Discussion and Conclusions

In interactive LFOV MR imaging, the table motion does not have to be constant and, ideally, matches the specific contrast dynamics in regions of pathology. We implemented an MR DSA approach for this technique and have shown its ability to follow the contrast in real-time in the peripheral arteries. The current implementation allows individual acquisitions to be interactively customized to the anatomic requirements. We accomplished this by accurately registering the data in mask and CE hybrid-spaces and by implementing a real-time subtraction method. We have shown the feasibility of a robust real-time monitoring of the contrast and optimal matching of the table translation to the passage of the contrast agent in the legs. This improved image quality would enable a rapid and patient-friendly examination of the peripheral vasculature in clinical use.

## References

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