Fusion of MRI and X-ray Angiography to Guide Clinical Revascularization of Chronic Total Occlusion

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Introduction Combined MRI and X-ray angiography (XA) systems (XMR) exploit the strengths of both modalities [1,2]. We have implemented a real-time image fusion technique for our XMR system to combine MRI with real-time XA in clinical applications. Here we describe our first experience of this approach to guide revascularization of chronic total occlusion (CTO) of the superficial femoral artery (SFA). CTO revascularization is challenging because XA contrast does not identify the vascular lumen, and the operator is effectively "blind" during navigation. We acquire pre-operative MR images to characterize the target vessel including the occluded segment. These images are then registered with conventional XA images using dual modality fiducial markers on the patient's skin surface. The borders of the occluded vessel are then overlaid with XA "live" to guide the revascularization procedure.

Methods A subject with limiting intermittent claudication due to a focal occlusion of the left SFA was studied in our XMR suite, which consists of a Siemens Sonata 1.5 T scanner and an Axiom Artis XA system connected by a Miyabi sliding table (Siemens, Erlangen, Germany). Ten fiducial markers (14 mm diameter hollow glass spheres, Wilmad LabGlass, Buena, NJ) filled with a mixture of 5 mM Gd-DTPA and 300 mM iodinated contrast agent were placed on the surface of the left thigh. The X-ray calibration and registration procedure have been described previously [3].

MR Imaging: A 3D contrast-enhanced MR angiogram of the lower extremities was performed. The occluded segment was also imaged with high-resolution T1-weighted 2D/3D gradient echo sequences before and after Gd-DTPA injection. MR images were gradient warp corrected before registration, and then used to identify the centerline and to segment the borders of the target vessel.

XA Imaging and Fusion: During catheterization we provide the MR information in the form of image overlays during live fluoro or cine acquisitions while the operator manipulates the intravascular devices. The registration is maintained during gantry changes and table motions. Three-dimensional MR images are displayed as registered maximum intensity projections (MIP), with the projections calculated along a fan beam corresponding to the current XA view. MIP images are used to confirm the registration during the procedure since it similarly fails to show total occlusion. Manually segmented contours from 2D MR images are displayed as vascular borders describing the safe path for the guidewire within the lesion. Limited patient motion during the procedure did not degrade the quality of the image fusion.

Results Fig. 1 shows an A/P XA image of the occlusion. Fig 2 shows a high-resolution 2D image of the occluded segment and the hand drawn contours of the vessel border. Fig. 3 displays an XA view of the occlusion with the vessel borders as determined from Fig. 2. Fig. 4 displays an XA view of the lesion after successful revascularization by balloon angioplasty with an overlay of the pre-operative 3D MRA in red.

Conclusions This study is the first demonstration of our fusion method of XA and MRI images to guide clinical peripheral artery intervention. We believe this fusion technique may be especially valuable for facilitating revascularization of more complex peripheral artery CTO's.

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