Dual-Injection Contrast-Enhanced (DICE) Peripheral MRA at 1.5T and 3.0T

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Synopsis: Venous enhancement is a problem with typical multi-station Single-Injection Contrast-Enhanced (SICE) bolus-chase peripheral MRA. We propose a solution to this problem using a Dual-Injection Contrast-Enhanced (DICE) MRA technique. SICE and DICE MRA were compared to catheter angiography in patients with symptomatic peripheral arterial disease (PAD) using 1.5T and 3.0T MRI scanners. We found that the DICE MRA significantly increases the diagnostic accuracy for calf arteries compared to SICE technique ($p<0.001$), yielding a practical and reliable exam of the lower extremities at 1.5T. The DICE technique can be adapted for use at 3.0T.

Introduction: Adequate visualization of the distal run-off vessels is a prerequisite for accurate treatment planning. Moving table, 3D gradient-echo, SICE MRA is a promising technique for evaluating patients with PAD [1-5]. Images are typically acquired in three or four consecutive stations following a single contrast bolus injection. The method allows for an optimal timing of data acquisition with synchronization of bolus arrival in the first station (pelvis) and an acceptable timing in the second station (thigh). However, the timing of data acquisition for the third and fourth stations is not optimal, causing frequent venous contamination in the calf and foot [1]. To address this problem, a Multi-Injection Contrast-Enhanced (MICE) technique has been described where multiple, typically three or four, injections are used to image individual arterial stations [4]. MICE MRA, however, requires large volumes of contrast agent and suffers from remnant venous signal due to the multiple injections. We hypothesized that dividing the arterial tree into two segments **only** and collecting images using a dual-injection (DICE) MRA technique with injection and data acquisition synchronized for each segment can potentially remedy the venous contamination problem.

Methods: Thirty male patients (mean age 65.8 years, range 48-80) with symptomatic PAD were examined on a 1.5T MRI (Philips) prior to catheter angiography. The MRA exam included two parts: a single station dedicated 3D contrast-enhanced calf MRA and a three-station (pelvis/thigh/calf) bolus-chase SICE MRA, separated by approximately 15 minutes. To examine the effect of image acquisition order patients were assigned to two groups. In the first group of patients the dedicated calf MRA preceded the three-station SICE MRA and in the second group the order was reversed. 20cc of Gd-DTPA were used for the dedicated calf MRA and 40cc for the bolus chase MRA. Mask images were acquired prior to contrast injection and later subtracted from the enhanced images for MIP reconstruction. 3D field-echo (T1-FFE) pulse sequence parameters included: TE/TR/flip 5ms/1.5ms/30, FOV 45cm-53cm in coronal plane, 70-100 slices, 0.75mm-1.5mm thick, resolution 256x512, breath hold for pelvic station.
Two radiologists blinded to the catheter angiography evaluated the MRA exams independently. The catheter angiography exams were evaluated in a consensus reading by two angiographers. The arteries of the calf were divided into eight segments and the arteries of pelvis and thigh into seven. Segments were graded using a four point scale: 1 = normal, 2=stenosis $\leq$50%, 3 = stenosis > 50%, 4 = occlusion. Statistical analysis was performed using Chi-Square tests (McNemar and Pearson) and Cohen's Kappa.
In addition, the DICE technique has been adapted to image volunteers and symptomatic PAD patients using a short bore 3.0T scanner (Philips). Four stations (FOV 34cm) were used to adequately cover the arterial tree from the abdominal aorta to pedal arteries [6]. The four stations were divided into two segments (upper and lower) consisting of two stations each. The upper segment included pelvis and thigh arteries and the lower segment included calves and pedal arteries. Each segment was imaged following a separate contrast bolus injection.

Results: 472 calf segments and 420 pelvis and thigh segments were analyzed. Eight calf segments were excluded because of non-diagnostic catheter angiography. Of the 472 calf segments, 0.6% (reader 1)/1.5% (reader 2) were non-diagnostic using the dedicated calf MRA and 15.9%/19.3% using-the bolus chase MRA. Diagnostic accuracy for the calf arteries was 81.4%/ 79% for the dedicated sequence and 68.2%/ 63.6% for bolus chase. The difference of non-diagnostic calf segments and diagnostic accuracy of the calf arteries was statistically significant between the two MRA techniques ($p<0.001$). There was no statistically significant difference between the diagnostic accuracy of the pelvis/thigh MRA whether performed before or after the dedicated calf MRA using a 1.5T MRI scanner.

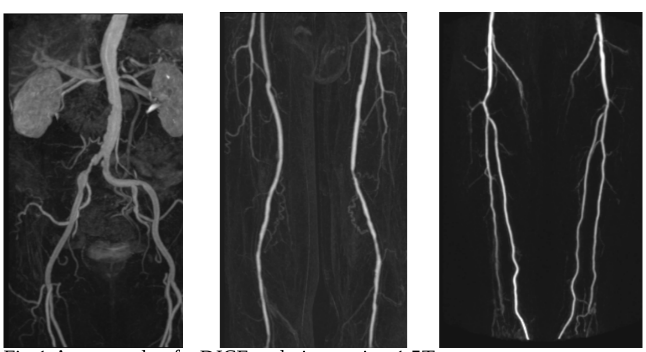

Fig.1 An example of a DICE technique using 1.5T scanner

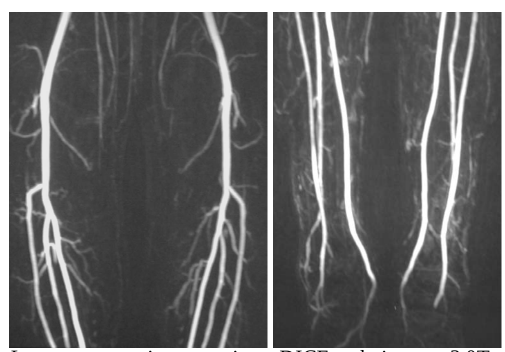

Fig2. Lower segment images using a DICE technique on 3.0T scanner. Note lack of venous signal and increased SNR at 3.0T.

Conclusions: At 1.5T DICE MRA significantly increased the diagnostic accuracy for calf arteries compared to standard bolus chase MRA and did not jeopardize the diagnostic accuracy of the pelvis and thigh arteries. Early experience suggests that DICE MRA can be successfully used at 3.0T.

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