

Evaluation of Vessel Area using Time-of-Flight MR Angiography, Contrast-Enhanced MR Angiography and CT Angiography in a Rabbit Peripheral Arterial Disease Model

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Introduction: Vascular regenerative therapy using stem cells is a new treatment for patients suffering from peripheral arterial disease (PAD). Computed tomography angiography (CTA) is often used as a gold standard method for evaluating vessel diameters in ischemic tissue after therapy. Our purpose was to compare vessel area measurements by Time-of-Flight (TOF) MR angiography (MRA), contrast-enhanced MRA (ce-MRA) and CTA after transplantation of mesenchymal stem cells (MSCs) in an animal PAD model.

Methods: Thirteen female New Zealand White rabbits were randomized to receive either intramuscular MSCs or sham injection in the left medial thigh 24h after endovascular occlusion of the left superficial femoral artery (SFA). Three-dimensional (3D) TOF-MRA (3T Trio Siemens, TR/TE 30ms/3.69ms; 0.6x0.4x0.6mm³ voxel size) acquired in the axial plane, 3D ce-MRA (3T Trio Siemens, TR/TE 4.27ms/1.73ms; 0.4x0.4x0.8mm³ voxel size; 15ml gadobenate dimeglumine 185mg/mL with flow rate 0.1mL/s) acquired in the coronal plane and a dynamic C-arm CTA (Axiom Artis dFA, Siemens, 0.37x0.37x0.37mm³ voxel size; 16 ml Iohexol at 4ml/s IV) were acquired in random order to include distal aorta and superficial femoral arteries prior to SFA occlusion and 14 days after occlusion. Vessel areas in distal aorta and proximal deep femoral artery (DFA) were measured (Figure 1, A-D) in the axial plane using custom software (VesselMass, The Netherlands). Intra-observer and inter-observer reproducibility was estimated for CTA, TOF-MRA and ce-MRA methods by intra-class correlation coefficients. Contrast-noise-ratio (CNR) between vessel lumen and normal muscle were estimated on 8 rabbits at baseline in the three imaging techniques. Data are presented as mean \pm standard deviation.

Results: Vessel areas in the distal aorta was $0.116 \pm 0.02\text{cm}^2$ and decreased to on average $0.012 \pm 0.003\text{cm}^2$ in the proximal DFA. TOF-MRA showed slightly better agreement than ce-MRA with CTA ($r^2=0.86$ vs. $r^2=0.79$, Figure 1, E-F). Intra-observer agreement for vessel detection was excellent by CTA ($r^2=0.98$), TOF-MRA ($r^2=0.99$) and ce-MRA ($r^2=0.98$, respectively). Mean CNR for CTA was 49.4 and was higher than CNR for TOF-MRA or ce-MRA ($p<0.0001$). There was no difference between TOF-MRA and ce-MRA in CNR (33.5 vs. 23.4, $p=0.068$, Figure 1, G).

Conclusions: Mean vessel area measured by CTA agreed more strongly with TOF-MRA than with ce-MRA in our rabbit PAD model. This could be explained by the reduce in-plane resolution of the ce-MRA image reformatted in the axial plane for measurement. Given strong inter-observer agreement, each measurement technique was reproducible and not operator dependent. Therefore, both MRA techniques could provide an acceptable precision to measure small vessel diameters without ionizing radiation for the assessment of an arteriogenesis therapy efficacy.

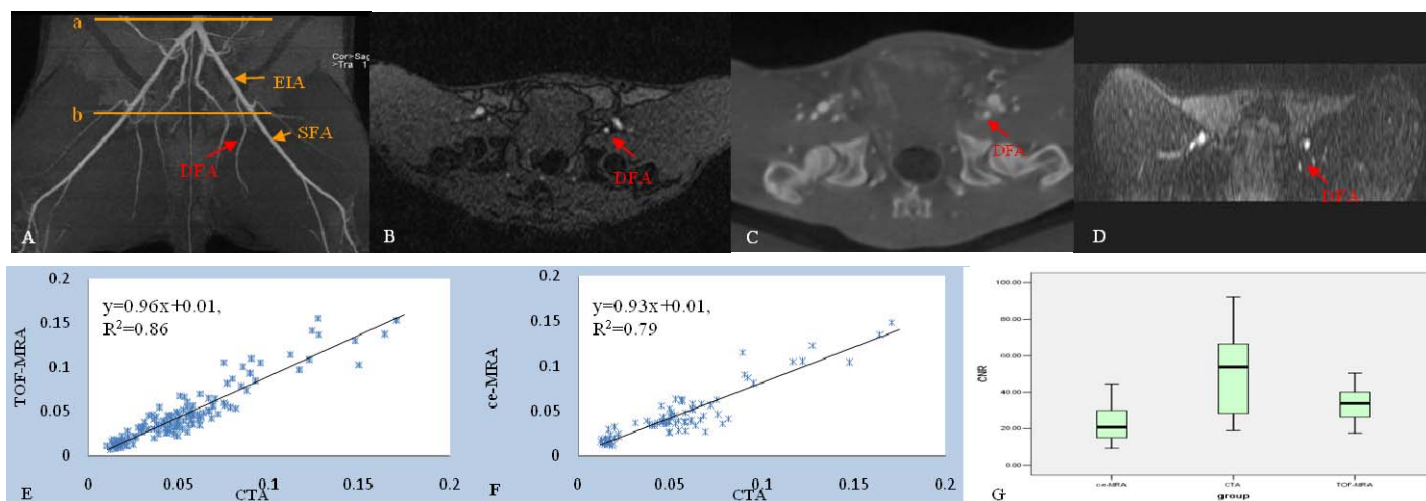


Figure 1 A maximum intensity projection TOF image (A) shows the vessel areas measurement at different level. The two orange lines (a-b) denote the position located at distal aorta (a) and the proximal deep femoral artery (DFA) (b), respectively. The left DFA (red arrow) is demonstrated at an axial image on TOF-MRA, CTA and ce-MRA (B, C and D). EIA=external iliac artery. SFA=superficial femoral artery. The correlation of vessel area measurement between TOF-MRA and CTA (E, $r^2=0.86$) showed a higher agreement than between ce-MRA and CTA (F, $r^2=0.79$). Boxplots of contrast-noise-ratio (CNR) between vessel lumen and normal muscle of 8 rabbits in three imaging techniques. Mean CNR of CTA is statistically higher than TOF-MRA and ce-MRA (G).