# B1 inhomogeneity in the thigh at 3T and implications for peripheral vascular imaging

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**Introduction:** Some degree of artifactual signal loss has been reported in the proximal right femoral artery in contrast-enhanced MRA images acquired at 3T [1]. We have observed much greater signal loss in the same region on non-contrast MRA images acquired using a variable flip angle 3D turbo spin echo sequence [2]. The fact that the signal from this sequence depends strongly on flip angle suggests that the origin of the signal loss is B1 inhomogeneity. We test this hypothesis using B1 mapping and B1 simulations, and investigate the use of dielectric pads and a passive off-resonance surface coil [3] to couple RF power into the region of reduced B1.

**Methods:** Imaging studies were performed on 9 healthy volunteers. All subjects provided informed consent under an approved IRB protocol. Studies were conducted on a 3T Siemens TIM Trio system using a peripheral phased array coil over the legs, a body phased array over the pelvis, and the appropriate spine coils in the patient table. Subjects were positioned in the scanner feet-first supine. Non-contrast MRA was performed over the thigh in all subjects, using an ECG-gated variable flip angle turbo spin echo technique [2]. Briefly, a 3D image set is acquired during systole, when arterial flow is fast, and a second set during diastole, when arterial flow is slow. The arteries appear dark on the systolic images due to flow-related dephasing, but brighter on the diastolic images. Subtraction of the systolic images from the diastolic images produces a 3D angiogram of the arteries [4]. We used a proton-density weighted 3D variable flip angle turbo spin echo sequence with non-selective excitation and refocusing pulses, and the following parameters: FOV 450mm, BW 977Hz/px, echo spacing 2.38ms, partition thickness 2mm, repetition time 2 R-R intervals, GRAPPA3, partial Fourier 4/8 (phase) and 6/8 (slice), base resolution 320, phase/slice resolution 86%/75%, and either 1 or 2 echo trains per slice.

In four subjects comparisons were made with and without dielectric pads placed over the upper thighs. In two subjects, comparisons were made with and without a passive rectangular surface coil [3], 18cm x 30cm, and tuned to 129MHz (5.8MHz above the resonant frequency). This is designed to modify the field distribution locally by coupling weakly to the transmit body coil. The coupling coil had been tested on a phantom and found to produce a small local enhancement in B1 while only slightly increasing local SAR. It was placed on the pelvis, with one side of the coil positioned directly over the location of the right femoral pulse.

B1 mapping was performed in four subjects using a 3D low flip angle phase-based method proposed by Mugler [5]. The magnetization is excited using a composite pulse, either $\alpha(x)\ \alpha(y)\ \alpha(-x)\ \alpha(-y)\ \alpha(x)\ \alpha(y)$, or $\alpha(y)\ \alpha(x)\ \alpha(-y)\ \alpha(-x)\ \alpha(y)\ \alpha(x)$, which rotate the magnetization by 1.5 turns in opposite directions. Since rotations do not commute, the effect of the pulses differs by a phase, which varies quadratically with $\alpha$. By measuring the phase difference, the magnitude of $\alpha$ can be determined. The technique was implemented using a gradient echo sequence, with the composite pulse substituted for the excitation, and played out with no slice-selection gradient. The pulses were interleaved during alternate TR periods to avoid spurious phase differences due to frequency drift of the scanner. The nominal flip angle ($\sqrt{2}$ times the nominal value of $\alpha$) was chosen between 18 – 20 degrees. Other parameters were TR 50ms, base resolution 128, FOV 450mm, partition thickness 4mm.

Results of the B1 mapping were compared with field simulations (courtesy of Juergen Nistler). The simulations were performed in CST Microwave Studio by modeling the whole body transmit coil of a 3T system (a 16 rung highpass birdcage) and calculating the resulting field distribution in the presence of a human voxel model.

**Results:** In all subjects the non-contrast MRA images exhibited signal loss in the proximal right femoral artery. A maximum intensity projection from a typical case is shown in Fig 1. The field of view extends from just above the femoral heads to just above the knees. Note the absence of signal from the right femoral artery, while the left is well depicted. Gradient echo images acquired at three levels are provided in Fig 2 as an anatomical reference to demonstrate the location of the arteries within the leg. Fig 2a is taken at the level of the femoral heads, while Figs 2b and 2c are acquired at mid-thigh and just above the knee respectively. Note that at the more superior level (Fig 2a) the arteries lie close to the anterior surface of the body, and the right artery has reduced signal compared to the left. Further distally (Figs 2b and 2c) the arteries lie more posterior. Fig 3 shows B1 maps obtained from the same subject. Note the rotational symmetry of the B1 profile, which decreases at the anterior medial side of the right leg and, to a lesser extent, on the posterior medial side of the left leg. The B1 maps in the other subjects were similar. The reduction in B1 on the right anterior side just above the groin would explain the absence of signal from the proximal right femoral artery, which is located relatively superficially (cf. Figs 2a and 3a). The more distal femoral and popliteal arteries are not affected to the same degree since their anatomic location does not coincide so closely with the B1 minima (compare Fig 2b with 3b and Fig 2c with 3c). Fig 4 shows simulated B1 profiles calculated in CST Microwave Studio. Although the dimensions of the human model (height 186 cm, weight 114kg) do not match that of our volunteer (height 188cm, weight 75kg), the simulated profiles agree qualitatively with the measured B1 maps.

Use of dielectric pads gave inconsistent results, with one subject showing a marginal increase in signal, and three subjects showing no improvement. The coupling coil produced some improvement in one subject (Fig 5), but not in a second subject.

**Discussion:** B1 maps acquired in the thigh agreed qualitatively with simulation, and exhibited a rotational symmetry, with B1 minima on the anterior medial side of the right leg and the posterior medial side of the left leg. The agreement with simulation and the symmetry of the profile indicate that this phenomenon is an inherent feature of the interaction between the circularly polarized RF field and the human form. The superficial location of the proximal right femoral artery coincides with a B1 minimum. This explains its lack of signal on many sequences, especially the variable flip angle turbo spin echo technique, which is sensitive to variations in B1. Our attempts to solve the problem using dielectric pads and a novel coupling coil met with mixed success. The coupling coil was modeled directly on the one used in reference [3] but appears overly large for our application. A smaller coupling coil and adjustment of the frequency offset could provide significantly better B1 enhancement, but the potential for increased local SAR would require additional safety tests.

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**References:** [1] Nael, Eur Radiol [2] Xu, ISMRM 2008, 730 [3] Schmitt, ISMRM 2005, 331 [4] Miyazaki, Radiol 2003; 227:890 [5] Mugler, ISMRM 2007, 351

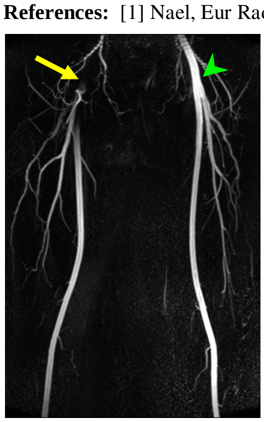

Fig 1. Non-contrast MRA of the thigh in a healthy subject. Signal is lost from the proximal right femoral artery (arrow) although the left is well depicted (arrowhead).

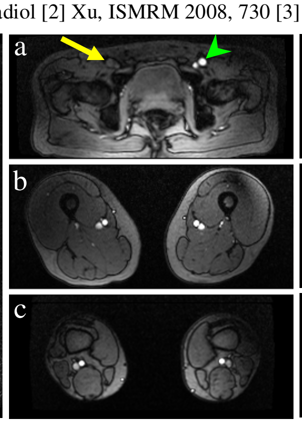


Fig 2. GRE images from the same subject as Fig 1. Note the superficial location of the proximal femoral arteries in the topmost slice.

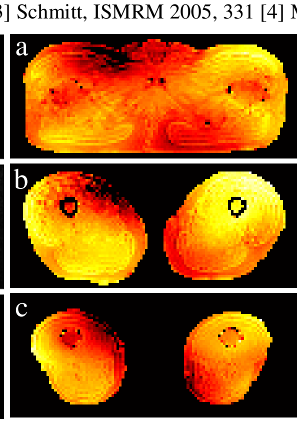


Fig 3. B1 maps from the same subject. The color indicates the value of the effective FA divided by the nominal FA, using the scale on the right.

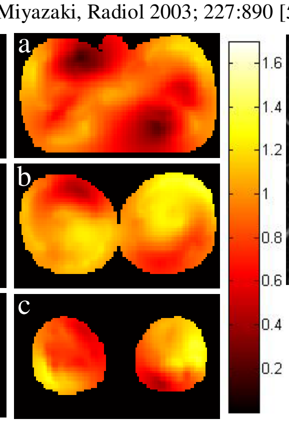


Fig 4. Simulated B1 profiles. The scale is identical to that used in Fig 3.

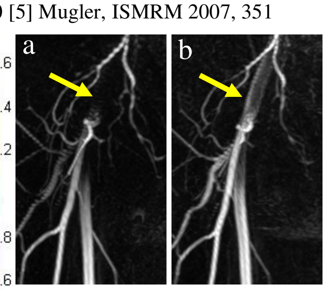


Fig 5. Enlarged view of the proximal right femoral artery (arrow) without (a) and with (b) the coupling coil.