Introduction: Concerns about nephrogenic systemic fibrosis (NSF) have spurred a search for alternatives to first-pass gadolinium-enhanced MRA in patients with renal insufficiency. Among the proposed alternatives for peripheral MRA are non-contrast ECG-gated techniques [1-3] that exploit differences in flow velocity between diastole and systole. Due to flow-related dephasing, arteries appear dark in systole when the flow is fast, but brighter in diastole, when the flow is slow. Bright-blood images of the arteries can therefore be obtained by subtraction. These techniques are capable of providing highly detailed angiograms in healthy subjects. The goal of this work was to examine the performance of ECG-gated 3D FSE [1,2] in patients with vascular disease, who may have atypical flow patterns. It has earlier been shown that the flow sensitivity of FSE increases as the flip angle of the refocusing pulses decreases [4]. This provides some ability to adapt to individual flow patterns. However, it is not yet known whether it provides sufficient control to obtain accurate depiction of vascular pathology over a wide range of disease states.

Methods: Imaging was performed on a Siemens 1.5T Avanto system using a peripheral phased array coil. 26 patients and 9 healthy subjects were included in the study, of whom 15 patients were enrolled prospectively (8 men, 7 women, ages 68.5±17.5 years, range 22–88). A second patient (54-year old man) had reduced pulsatility and high diastolic flow (‘tardus parvus’ waveform) distal to an occlusion of the superficial femoral artery (Fig 2). The flow pattern in the profunda femoris, which supplied the collateral vessels, was also affected. Both the profunda femoris and the arteries distal to the occlusion were poorly visualized on FSE-based MRA. As predicted, the SSFP-based sequence was necessary to determine whether this phenomenon in any of the much older patients, despite the presence of severe disease. Further studies will be necessary to determine whether better arterial depiction in the presence of altered flow patterns can be obtained with the existing FSE-based sequence by more judicious parameter choices.

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Figure 1. Visualization of arteries in 15 patients with non-contrast 3D FSE-based MRA as compared to first-pass contrast-enhanced MRA in the calf and thigh stations.

Results: In the healthy subjects, peak systolic flow in the popliteal arteries was 43.8±7.8 cm/s. Mean diastolic flow was 1.8±2.9 cm/s (including negative values). The highest diastolic flow measured in any of the healthy subjects was 6.5±3.1 cm/s; for this subject, optimal arterial conspicuity over both large and small vessels in the calves was achieved with FA=120°. Results from the prospective patient study are shown in Fig. 1. Non-contrast FSE-based MRA performed better or the same as contrast-enhanced MRA in 73% and 52% of named arterial segments in the calves and thighs respectively. Reasons for poor vessel visualization included patient motion and vessel orientation perpendicular to the frequency-encoding direction. Signal loss in the right groin, probably due to B1 inhomogeneity [5], contributed to the inferior overall performance in the thigh compared to the calf station. However, faster flow in the thigh may also warrant flip angles higher than 120°.

Two patients in the prospective study were notable in having particularly high diastolic flow due to their pathology. One was a 22-year-old man with a non-healing wound. Diastolic flow velocity measured in the tibioperoneal trunk in this patient was 14.8 cm/s. Vessel visualization on the non-contrast FSE-based MRA was poor despite a high FA (120°). A second patient (54-year-old man) had reduced pulsatility and high diastolic flow (‘tardus parvus’ waveform) distal to an occlusion of the superficial femoral artery (Fig 2). The flow pattern in the profunda femoris, which supplied the collateral vessels, was also affected. Both the profunda femoris and the arteries distal to the occlusion were poorly visualized on the non-contrast FSE-based MRA despite a high FA (120°). Hypothesizing that the diffusion-prepared SSFP-based sequence [3] might be better adapted to this flow pattern, since it is flow-sensitive only in systole, we retrospectively analyzed data from a study that compared FSE- and SSFP-based non-contrast MRA. One patient (a 59-year old man) from that study also exhibited reduced pulsatility and increased diastolic flow distal to a severe stenosis, which correlated with poor visualization of the distal segments on FSE-based MRA. As predicted, the SSFP-based sequence provided improved visualization of these segments, although the images exhibited venous contamination.

Discussion: While we have highlighted flow patterns that resulted in poor performance of the FSE-based MRA sequence, there were many cases in which it accurately depicted pathology. The patients in whom we observed the tardus parvus waveform were both relatively young, and presumably had fairly compliant vessels. We did not observe this phenomenon in any of the much older patients, despite the presence of severe disease. Further studies will be necessary to determine whether better arterial depiction in the presence of altered flow patterns can be obtained with the existing FSE-based sequence by more judicious parameter choices.