# GCFP – A New Non-Invasive Non-Contrast Cine Angiography Technique Using Selective Excitation and Global Coherent Free Precession

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**Introduction**

Conventional X-ray angiography allows visualization of both vascular morphology and blood flow. MR angiography (MRA) does not provide temporal information about flow. We developed a new MR method based on a fundamentally new physical principle that produces dynamic images directly analogous to those of x-ray angiography. However, the method requires neither ionizing radiation nor nephrotoxic contrast agents [1], and it is non-invasive.

**Methods**

The underlying concept of the new technique is that a condition of global coherent free precession (GCFP) can be created and maintained. In the GCFP state, excited protons continue to yield signal regardless of where they travel, even in the absence of additional radiofrequency (RF) excitation. To maintain the GCFP state the following fundamental conditions have to be met: a) radiofrequency excitation must remain in phase with previous excitations for moving protons (e.g. transmitter frequency on resonance with no phase increment); and b) the magnetic field gradients required for imaging must not cause the excited protons to lose phase coherence as they move through 3D space (e.g. zeroth and first moments are zero across TR[2]). Importantly, these GCFP conditions can be met while simultaneously achieving two additional goals. First, RF excitation pulses can be played every few milliseconds while the GCFP gradients play, effectively creating a continuous outward flow of excited protons. Second, projection images can be acquired using the same gradient waveforms used for RF excitation and GCFP. Thus the image data can be collected at the same time as a new physical state is created within the human body: spatially-selective RF pulses produce a continuous stream of coherently excited blood whose spins freely precess as it flows through regions of space unaffected by the ongoing excitation. A pulse sequence satisfying these conditions was implemented on a 1.5T clinical MRI scanner (Siemens Sonata) and tested in 15 dogs and 3 volunteers. All images employed ECG gating, segmented k-space, and breath holding.

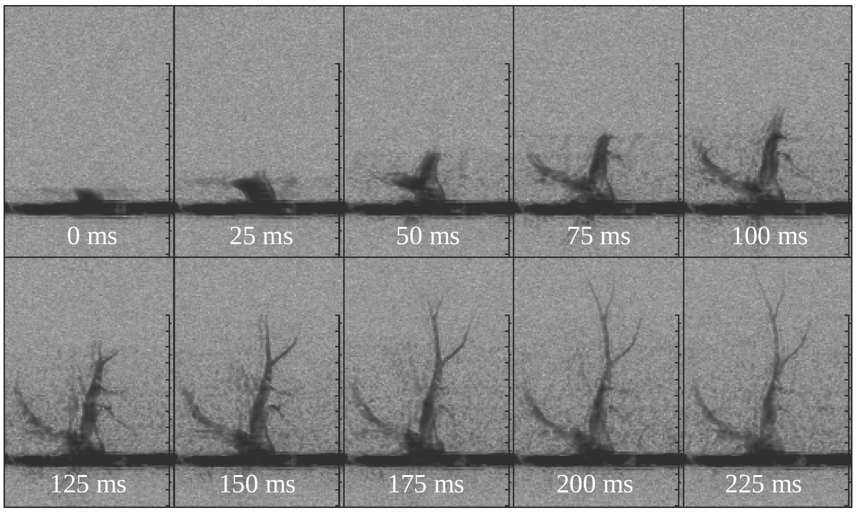


Figure 1: systolic frames of blood filling the pulmonary arteries

**Results**

Figure 1 shows frames of a representative movie depicting blood flow into the pulmonary arteries. Excited blood was seen to fill the pulmonary tree for a distance of approximately 11 cm (left-hand tick marks are 1 cm), and branch vessels as small as 1.5 mm in diameter were clearly visualized. Signal-to-noise ratios in major arteries were typically 80-100. Figure 2 summarizes in vivo filling distances in selected arteries.

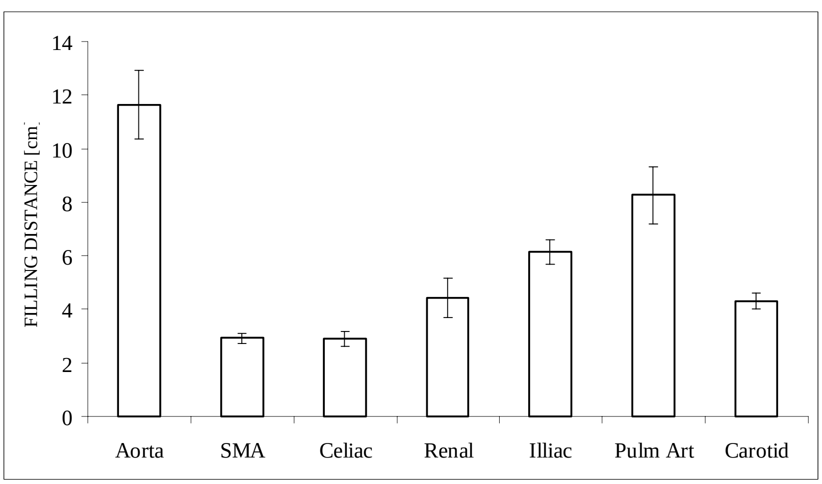


Figure 2: in vivo filling distance in selected arteries

**Conclusions**

Selective RF excitation combined with global coherent free precession results in a unique physical state within the human body that has not been previously described. By continuously maintaining this physical state magnetic resonance images can be acquired which are directly analogous to those of invasive catheterization non-invasively and without a contrast agent.

**References**

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