Black-Blood Contrast-Enhanced MRI: Validation of a Novel Technique for the Diagnosis of Myocardial Infarction

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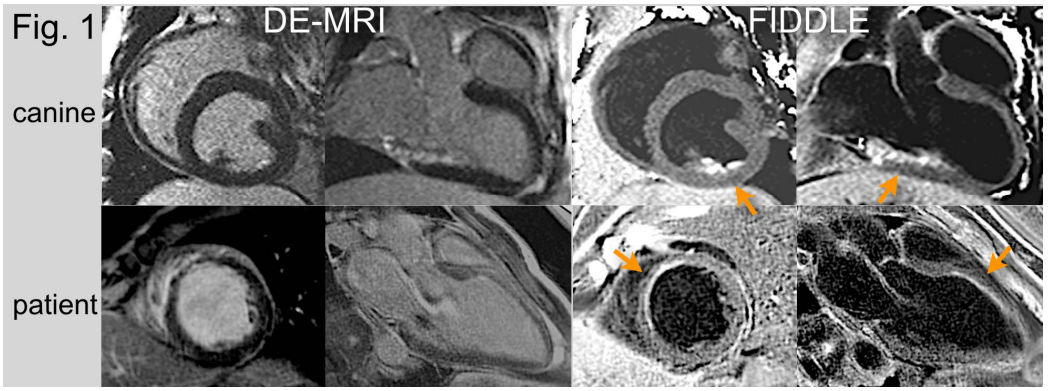
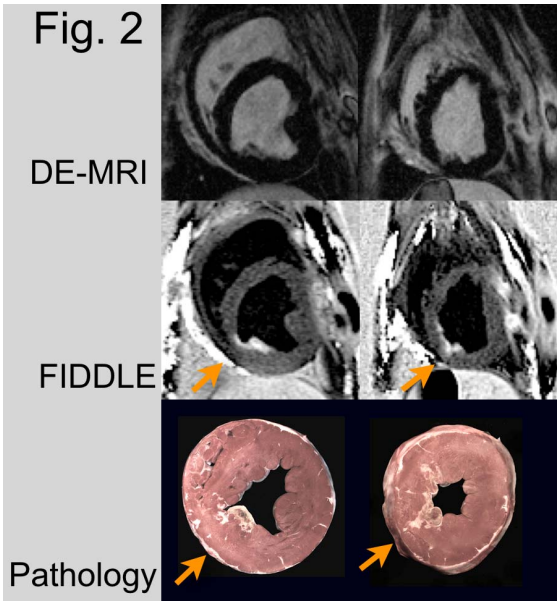
Target Audience. Scientists/clinicians interested in new techniques or cardiac imaging.

Purpose. A fundamental component of the MRI exam is contrast media enhanced imaging, which is often crucial for delineating diseased from normal tissue. Unfortunately, diseased tissue adjacent to vasculature often remains hidden since there is poor contrast between hyperenhanced tissue and bright blood-pool. Conventional 'black-blood' double-IR techniques are not a solution; these were not designed to function after contrast administration since they rely on the long native T1 of blood (~2 sec at 3T) and sufficient blood flow within this time period.[1] We introduce a novel **F**low-**I**ndependent **D**ark-blood **DeL**ayed **E**nhancement technique (FIDDLE) that allows visualization of tissue contrast-enhancement while simultaneously suppressing blood-pool signal. We validate FIDDLE in an animal model of myocardial infarction (MI) and demonstrate feasibility in patients with MI.



Methods. The study was in accordance with all IACUC (animal) and IRB (patient) guidelines. A canine model with variable coronary occlusion times was employed to create a range of infarct sizes and infarct transmurality. Following MRI, hearts were excised and stained with triphenyltetrazolium chloride to provide a gold standard histopathology reference. In brief, the primary components of FIDDLE are, (1) a prep pulse that differentially saturates tissue compared with blood (eg. MT-prep); (2) phase-sensitive inversion recovery (PSIR); and (3) inversion time (TI) selection under condition: blood M_Z < tissue M_Z.[2] MRI was performed either acutely (<3-weeks post-MI) or chronically (>2-months) at 3T (Verio). FIDDLE and standard delayed-enhancement images (DE-MRI) were acquired using matched parameters (eg. slice thickness, 7 mm; inplane resolution, 1.2x1.0 mm; etc) 10-20 minutes after gadolinium administration (0.2 mmol/kg). Patients had enyzmatically confirmed MI and x-ray coronary angiography confirmed the infarct-related-artery (IRA). The patient MRI protocol was similar to that in canines. FIDDLE and DE-MRI analysis was performed separately and blinded to subject identity and pathology (canines) or angiography results (patients).



Results. In all canines (n=22) and patients (n=21), black-blood images were successfully acquired using FIDDLE (**Fig.1**). Slow-flow artifacts (non-suppressed blood signal adjacent to endocardium) were not observed on any short or long-axis images. **Table 1** shows the performance of FIDDLE in comparison with DE-MRI for the diagnosis of MI in canines (reported on per slice basis). FIDDLE provided improved sensitivity (and accuracy) for the detection of MI, particularly in the setting of small, subendocardial infarcts. Example of subendocardial infarction detected by FIDDLE but missed by DE-MRI is shown in **Fig.2** with pathology as reference. The diagnostic performance of FIDDLE was similar in acute and chronic MI. Patient findings were similar in that FIDDLE provided higher accuracy in detecting MI in the correct IRA territory (100% vs 86% for DE-MRI, on per patient basis).

Table 1. Diagnostic Performance in Canines

	Sensitivity	Specificity	Accuracy
Overall			
FIDDLE	97% (95/98)	92% (35/38)	96% (130/136)
DE-MRI	81% (79/98)	95% (36/38)	85% (115/136)
p-value	<0.001	0.65	0.001
Subendocardial MI (transmurality <25%)			
FIDDLE	98% (44/45)	92% (35/38)	95% (79/83)
DE-MRI	71% (32/45)	95% (36/38)	82% (68/83)
p-value	<0.001	0.65	0.008

Discussion. We demonstrate that FIDDLE is more sensitive and accurate than standard delayed-enhancement imaging for the diagnosis of MI. In patients with coronary disease, even the smallest amount of myocardial necrosis represents an important jump in risk for adverse outcome. Unfortunately, the smallest infarcts are subendocardial and even DE-MRI, which is considered the gold standard in imaging infarction, is known to miss up to 25% of subendocardial infarcts,[3] because of poor contrast between bright infarction and bright LV cavity blood-pool. Detection of MI has the potential to change patient management.

Conclusion. We introduce a novel technique that allows visualization of tissue contrast-enhancement simultaneous with blood-pool suppression. Validation and feasibility is demonstrated for diagnosis of MI, however, the technique is easily transferable beyond cardiac imaging and additional applications are expected in other clinical settings (such as vascular wall imaging) where there is need to distinguish abnormal tissue enhancement from blood-pool.

References. (1) Simonetti OP et al. *Radiology* 1996;199:49-57. (2) Kim RJ et al. US Patent 20110275928 A1 May 3, 2011. (3) Kim RJ et al Circulation 2008;117:629-637.