First-Pass Myocardial Perfusion Imaging using Interleaved Notched Saturation

Glenn S. Slavin, Steven D. Wolff*, Sandeep N. Gupta, and Thomas K.F. Foo
GE Medical Systems, Milwaukee, WI, USA and *Integrated Cardiovascular Therapeutics, Woodbury, NY, USA

Introduction
Successful T1-weighted, contrast-enhanced, first-pass, myocardial perfusion imaging requires several issues to be addressed. These include anatomic coverage of the heart from apex to base; adequate temporal resolution; and sufficient contrast and SNR to distinguish between perfused (enhancing) and ischemic (non-enhancing) myocardium. These requirements can be met by using echo-planar imaging (EPI) for rapid image acquisition (1,2) and magnetization preparation for image contrast. Although long-T1 preparations typically provide the best SNR and the strongest T1 weighting, the explicit delay time required to achieve the long T1 can substantially reduce the number of acquired slices (1).

The purpose of this work was to develop a more efficient magnetization preparation scheme that could provide the benefits of a long-T1 preparation without reducing slice coverage.

Methods
The new preparation sequence consisted of an RF pulse with a band-stop or “notched” frequency profile. Saturation bands are created on both sides of the notch, which is unaffected by the 90° saturation. The location of the notch coincides with the slice location that will be imaged by the subsequent acquisition. The presence of the notch causes each preparation pulse to affect the next (as opposed to the immediately following) slice. As a result, a longer recovery time is achieved without sacrificing spatial coverage or explicitly increasing the time between preparation and acquisition. By saturating the blood pool signal on both sides of the imaged slice immediately before acquisition, the notch can potentially reduce artifacts and help discriminate the myocardial wall from the ventricular space.

Each preparation sequence was followed by an interleaved GRE EPI acquisition (2) with parameters similar to those in (3), except: 90° preparation, 25° excitation, and 185 ms TI. Imaging was performed on a 1.5 T Signa CV/i scanner (GE Medical Systems, Milwaukee, WI) with 40 mT/m peak gradients and 150 T/m/s maximum slew rate. Seven interleaved short-axis slices were collected after a single ECG trigger, with data acquisition spanning two cardiac cycles.

Fig. 1. A) Pulse sequence timing diagram. B) Effect of the interleaved notched saturation. Gray boxes represent saturation bands.

Eighteen patients were studied using three contrast doses (two patients at 0.05 mmol/kg; fourteen at 0.10 mmol/kg; two at 0.15 mmol/kg). Patients underwent first-pass perfusion studies both at rest and under adenosine stress (3). Thirty images (phases) at each slice location were acquired over 60 heartbeats.

Results
Peak contrast enhancement (difference between peak and baseline signal divided by the baseline signal) was measured in a mid-ventricular slice for each patient. Results are shown in Fig. 2 and are compared with previous results acquired using a partial saturation protocol (3). In addition to significantly higher peak enhancement, the notched saturation results exhibit a linear relationship ($r^2=0.9989$) between peak enhancement and contrast dose that was not seen in the partial saturation results.

Figure 3 shows the time-intensity curves for normal and ischemic myocardium. The new technique exhibits greater dynamic range and desirable lower baseline signal than does partial saturation. Figure 4 shows a patient image from a stress perfusion study.

Fig. 2. Average peak contrast enhancement for notched saturation and partial saturation protocols. Error bars are ±2% for notched saturation at 0.15 mmol/kg.

Fig. 3. Typical signal intensity-versus-time curves for normal (*) and ischemic (O) myocardium using notched saturation (from Fig. 4). Normal myocardium using partial saturation from another patient is also shown (O).

Fig. 4. Image from a stress perfusion study of a patient with 80% RCA occlusion. Arrows indicate the region of perfusion deficit.

Conclusions
This work demonstrates a new implementation of saturation recovery for first-pass myocardial perfusion imaging. This technique provides image contrast and SNR equivalent to long-T1 preparations but without sacrificing slice coverage.

References