Quantitative Flow Imaging With “NoQuist” Reduced Field of View Acquisition

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Synopsis
High-resolution breathhold phase velocity encoded imaging is performed by conventional full-grid acquisition and by NoQuist rFOV reconstruction using 53% of the data. Comparison of calculated aortic blood flow shows excellent agreement between the two techniques. NoQuist may accelerate high-resolution flow imaging to within clinically feasible breathhold times.

Introduction
Acquiring dynamic cardiac MRI in breathhold mode avoids respiratory artifacts. Since breathheld positions are not very reproducible, data must be acquired in a single breathhold when geometric co-registration is required. Fast imaging with TrueFISP and parallel imaging with SMASH or SENSE are improving the success rate and quality of cine acquisitions and are redefining temporal and spatial resolution limits. “Reduced field of view” (rFOV) techniques, which trade S/N or temporal resolution for spatial resolution, promise to further this trend.

Breath-hold quantitative flow (QF) imaging remains a challenge. Phase velocity encoding at least doubles imaging time. Its combination with fast steady-state techniques has not been fully studied and is not yet generally available. Recent studies recommend 192 or more phase encoding views for reliable renal artery scans1. At this resolution, gradient echo QF techniques still require over 25 seconds on most current 1.5T machines.

Two years ago we introduced a rFOV technique called NoQuist2. Here we report experiments using it to speed up velocity-encoded acquisition without compromising spatial or temporal resolution.

Materials and Methods
A transverse 5 mm single-slice breathhold scan was acquired through the liver of a healthy volunteer. A gradient-echo technique was used with TR=18 ms, TE=9 ms, and a 35 degree flip on a Philips Gyroscan 1.5T Intera, using the standard body coil. Phase velocity encoding was performed at 200 cm/s maximum for measuring aortic blood flow, and 180 phase encoding views on a cartesian grid were used for reconstruction at a 320 mm square field of view. Raw data were exported to an image processing workstation.

Image reconstructions and velocity map calculations were executed using Matlab R6.1. Calculations were performed both by conventional FFT reconstruction from 180 phase encoding views in each phase of the cardiac cycle, and by the NoQuist technique using a subset of these data. For the same spatial and temporal resolution, NoQuist rFOV reconstruction used only 95 phase encoding views per phase, roughly 53 percent as much data.

In the flow analysis a semi-automatic thresholding technique was used to determine the aortic lumen boundary. Integrating the measured flux through the aortic cross-sections over each phase of the cardiac cycle gave stroke volume. Multiplication by heart rate gave the aortic flow rate.

Results
Figure 1(a) shows the modulus reconstruction. Figures 1(b-c) compare aortic flow maps at systole and diastole, generated by conventional FFT reconstruction (b,c) and, using only 53% of the data, by NoQuist (d,e). Flux values at the cardiac phases calculated from conventional and NoQuist reconstructions are highly correlated (R²=0.9995). Figure 2 compares the associated aortic flow curves. Total aortic flow rate estimations were 3657 ml/min from the conventional reconstruction, and 3844 ml/min by NoQuist, representing a 5% difference.

Discussion and Conclusions
The Noquist method appears sufficiently stable with respect to image phase to accommodate flow imaging. Flow curves from full-grid and reduced-data reconstructions agree closely. If slight differences in calculated flow are due to higher noise in NoQuist, array coils should help. Acquiring only data needed for NoQuist would have reduced scan time from 28 to 15 seconds, allowing routine clinical application.

References