Fast & Furious: The New Era of Rapid Imaging
Fast cardiovascular imaging - Emerging Techniques

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Applications in cardiovascular MRI ranges from global and regional assessment of myocardial function, flow quantitation, perfusion imaging, to angiography. Across the diverse applications, imaging speed is of primary interest due to their dynamic nature.

In the last decade or so, imaging speed has increased dramatically, partly due to faster pulse sequences and hardward that can handle the higher duty cycle and larger bandwidth, as well as to sparse sampling and reconstruction techniques that reduce the acquisition process to a minimum. This lecture reviews the emerging techniques in these exciting applications.

Global function assessment
Conventionally, the gold standard technique in MRI for assessing global systolic function has been breathheld cine 2D imaging. Increasingly, with the use of parallel imaging, *k-t* acceleration, and/or radial sampling, it becomes feasible to perform real-time imaging of ventricular function in a free-breathing manner, without the need for ECG triggering [1 – 5]. Such real-time images are then amenable to post-processing steps such as registration and warping that retrospectively produce images that approach the quality of those from a breath-held cine acquisition [6].

Regional function assessment
Regional function of the myocardium can be assessed by MRI with a tagging experiment. Through the development of HARP [7] and DENSE [8], it was recognized that the displacement information is contained without a relatively small region of *k*-space, beyond which only limited information can be recovered due to SNR constraints. As a result, it is only necessary to acquire the small *k*-space region, thereby enabling regional function assessment in real-time with an extremely rapid readout [9-10].

Perfusion imaging
The performance of perfusion imaging has been determined for some time by the raw bandwidth of data acquisition. As a result, EPI and more recently bSSFP have been the techniques of choice. The advent of parallel imaging and massively parallel arrays have enabled the demonstration of real-time 3D perfusion imaging, which achieves whole ventricular coverage, albeit at the expense of resolution [11]. More recently, the development of *k-t* techniques have led to further acceleration in perfusion imaging, resulting in significant improvements in spatial coverage, acceptable heart rate range, and/or spatial resolution [12-15].

Flow quantitation
Flow measurements by phase contrast techniques have been accelerated primarily by parallel imaging [16]. Acceleration using *k-t* approaches has been demonstrated, although fidelity can be affected at high acceleration for cine acquisition due to temporal blurring [17-18]. Undersampled radial trajectories have also been applied to flow quantitation [19]. Flow imaging is now fast enough to enable 7D acquisitions (3 spatial, 1 temporal and 3 velocity dimensions) on a practical basis [20].

Angiography

Angiography holds considerable opportunity for acceleration due to the sparsity of the blood vessels. This opportunity has been recognized for some time, and has enabled advances in dynamic contrast enhanced angiography through view sharing techniques such as TRICKS [21]. More recently, HYPR has been developed that utilizes the temporal relationship of the imaging signals, and allows significant acceleration beyond an order of magnitude [22]. There is a trade-off between acceleration and the fidelity of the images, but the trade-off appears acceptable in this application. The rise of compressed sensing has also found numerous applications in MRI. Angiography is a clear application of this technique due to the inherent sparsity [23-24].

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