Redefining MRI:
From Image to Insight

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Researcher's View Point of 4D Flow MRI

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Time-resolved three-dimensional phase-contrast MRI (4D flow MRI) has emerged as a uniquely powerful modality for cardiovascular hemodynamic research, offering volumetric velocity information that supports both intuitive flow visualization and advanced quantitative analysis. From a researcher's viewpoint, the greatest strength of 4D flow MRI is that it allows qualitative insight from flow visualization to be systematically converted into quantitative biomarkers that are directly meaningful to clinicians.

Our translational studies rely heavily on close, early-stage collaboration with clinical partners. Before any quantitative analysis, we identify distinctive intravascular flow features using basic flow visualization and clarify the clinical question that motivates the study. Based on these visualization-driven observations, acquisition parameters — including velocity encoding (VENC), spatial and temporal resolution, coverage volume, and respiratory/cardiac gating strategy — are jointly optimized so that the hemodynamic features driving the downstream analysis are preserved. This loop between visualization and quantification ensures that the result is both scientifically robust and clinically interpretable.

This presentation highlights three representative applications where such a visualization-first, collaboration-based workflow produced translational value. First, in myocardial infarction, altered intracardiac vortex structures observed on 4D flow visualization were quantified through vorticity and kinetic energy indices, reflecting impaired ventricular function and remodeling. Second, in patients with an arteriovenous fistula (AVF), quantitative analysis of the descending aorta revealed reduced retrograde (regurgitant) flow, providing hemodynamic evidence of the systemic circulation changes associated with the fistula. Third, in the portal vein, helical flow characteristics detected by streamline visualization were quantified as helicity-based indices, offering non-invasive insight into hepatic circulation under normal and diseased conditions.

Collectively, these cases demonstrate that 4D flow MRI is not merely an imaging tool but also a communication platform between engineers, physicists, and clinicians. Pairing early visualization with jointly optimized acquisition and rigorous quantification broadens the translational scope of 4D flow MRI and reinforces its role as shared research infrastructure across cardiovascular and hepatic domains.

Keywords: *Hemodynamics, 4D flow MRI, Fluid mechanics, Flow visualization*