

Title Session: Evaluation of Flow

Presentation Title: Technical Foundations: How Is It Done?

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Take-Home Messages:

- With velocity-encoded MRI or phase-contrast MRI, two acquisitions are performed to encode the phase angle of spins which move into a specific direction. After subtraction of both acquisitions, a linear relation exists between the phase angle difference of the subtracted signal and the velocity magnitude of the moving spins. Stationary spins present with no phase angle difference.
- With velocity mapping, the flow rate (eg. through a blood vessel or over a heart valve) is quantified, by voxelwise integration of all velocity values over a cross-sectional area. By using ECG synchronization, the stroke volume during one cardiac cycle can be calculated.
- Velocity mapping is used in clinical practice for calculating cardiac output, quantifying valve regurgitation, or estimating trans-stenotic pressure gradients and the fractional flow reserve.
- Velocity encoding can be performed in any arbitrary direction, and by combining multiple directions (i.e., multi-directional velocity-encoding), accurate three-dimensional information of a blood flow field can be obtained. Visualization techniques may contribute to 4DFlow applications by providing insight in pathologically altered flow features in the cardiac chambers and the great vessels. For trans-valvular flow assessment, 4DFlow with retrospective valve tracking is more accurate than conventional single-slice through-plane velocity-encoding.

Velocity-encoded MRI or phase-contrast MRI is an accurate method that is used for quantification of motion (1). For spins moving into a direction along a magnetic field gradient, the precession frequency will change accordingly with the field strength, resulting in an accumulated phase difference compared to stationary spins which do not experience a change in field strength. The phase difference is linearly related to the local field strength and therefore, proportional with the velocity of the spins. This principle is used to encode the velocity of moving structures and enables blood flow quantification. Two techniques are used for synchronizing MRI data with the cardiac cycle: prospective gating, in which acquisition starts at a trigger (i.e., the R-peak in the ECG-signal), or retrospective gating, in which continuous data collection is performed and retrospectively during image reconstruction, data is assigned to the consecutive phases in the cardiac cycle. Using cardiac synchronization, a time-resolved evaluation of the blood flow can be performed with phase-contrast MRI.

In this presentation, the physics of velocity-encoded MRI will be briefly explained and the main pitfalls and potential sources of error will be discussed (2). Velocity mapping will be illustrated by the most common application of quantitative flow in cardiovascular MRI, i.e., the assessment of the stroke volume into a blood vessel during one cardiac cycle (3). By voxelwise integration of velocity and area over the lumen of interest, the flow rate per phase in the cardiac cycle can be determined, and by integrating this over the cardiac cycle, the stroke volume is obtained.

Two applications of trans-valvular flow assessment (i.e., for evaluating cardiac output, or valve patency) will be discussed: conventional one-directional velocity-encoded MRI assessment (4) and a more sophisticated and a 4DFlow approach with retrospective

valve tracking (5, 6). Conventional, single-slice one-directional through-plane velocity-encoding of trans-valvular flow velocity overestimates inflow volumes and underestimates valve regurgitation. As it will be shown in this presentation, 4DFlow with retrospective valve tracking is more accurate in quantifying volumes and valve regurgitation. Especially when evaluation of multiple valves is required, 4DFlow may improve clinical practice.

References

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