Session: Emerging Cardiovascular Imaging Techniques

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Quantitative Cardiac Imaging: Perfusion, PC-MRI, regional wall motion

Quantitative cardiac imaging in clinical routine nowadays encompasses the determination of global functional myocardial parameters such as left ventricular ejection fraction, volumes and myocardial mass. However, different strategies have been proposed within the last decades to acquire and quantify data in terms of myocardial perfusion, blood flow in the heart and the great vessels as well as regional myocardial wall motion

Myocardial perfusion

Myocardial perfusion studies are performed with rapid T1 weighted MRI during the first pass of an injected contrast agent. The myocardial signal intensity is sensitive to the level of blood flow, i.e. the perfusion – the labeled blood passing through a volume of tissue per time. Commonly, in clinical routine data acquired during rest and stress (inducing vasodilation) are inspected visually without any further evaluation.

However, the signal time curve in myocardial segments can be used to determine semi-quantitative perfusion parameters such as the upslope of the first pass, the peak signal, the time to peak, and the mean transit time; the upslope is the most common parameter to semi-quantitatively evaluate myocardial perfusion.

Absolute myocardial blood flow can be determined by a constrained deconvolution of the measured signal curve, or the tissue impulse response, with the arterial input function obtained from the center of the left ventricle. Different models have been proposed to constrain the deconvolution such as the Fermi model or a model-independent analysis.

The myocardial perfusion reserve (MPR) quantifies the response to vasodilation and is crucial to determine the functional significance of coronary artery stenosis. The MPR can be approximated from the ratio of the myocardial blood flow measured at rest and measured during vasodilatation. For this purpose, the upslope of the signal time curve – normalized by the upslope of the arterial input function – is determined for rest and vasodilation.

Phase contrast MRI

Phase contrast MRI, based on a bipolar gradient to encode velocity directly into the phase of the signal, is a widely used technique to measure blood flow velocities. In clinical routine time-resolved (tr) 2D flow is used e.g. for determining the grade of retrograde flow in valve insufficiency.

The acquisition of tr-3D (4D) flow data is much more comprehensive and allows the quantification of velocities, flow rates etc. in any arbitrary plane. However, to visualize the huge amount of data as well to perform data quantification dedicated software is required which is not yet widely available and for which no standard procedure is defined yet. On the other hand, a variety of additional parameters such as wall shear stress, pulse wave velocities, pressure differences, etc. can be extracted from 4D flow data.

Regional wall motion

Regional wall motion can be measured by several techniques. Tissue tagging and phase contrast velocity mapping (also called tissue phase mapping, TPM) were already introduced in the 80ies,

more recently displacement encoding with stimulated echoes (DENSE) and strain encoding (SENC) have been proposed.

Tagging uses a preparation module where a grid of magnetic saturation bands (tags) is superimposed on the myocardium at the early systole followed by an imaging period showing the tag deformation throughout the cardiac cycle. An advantage of tagging is given by the quick visual inspection it allows for. The quantitative analysis of the tag deformation is rather complicated and can require time-consuming postprocessing, although the recently proposed harmonic phase (HARP) analysis techniques has significantly speeded up this process.

The TPM method directly measures the myocardial velocities using the phase contrast technique. The sequence is widely available, but even the postprocessing is rather quick straightforward dedicated software is necessary which is not widely available.

The DENSE technique encodes in-plane or through-plane tissue displacement directly in the signal phase. Because of the T1 relaxation, like tagging, the signal carrying the displacement encoding decays over the cardiac cycle. On the other hand, the postprocessing has the advantage of being very simple and quick. DENSE is not yet widely available on clinical scanners.

In SENC – the most recent technique – tag planes oriented parallel to the imaging plane (unlike tagging) are used. Therefore, through-plane strain is directly related to the pixel intensity, and only little postprocessing is needed. As in tagging, the tags still fade over the cardiac cycle due to T1 relaxation. Longitudinal strain can be determined from short-axis views, circumferential strain from a long-axis plane, radial strain cannot be measured.

Both quantities that are measured by the different methods, i.e. tissue velocities and displacement, can be transformed into each other; however, both ways lead to error propagation.

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