Technical Advances in Cardiovascular Imaging

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Highlights:

- Flow MR is problem solving in many clinical situations.
- Flow MR enables better understanding of cardiovascular pathophysiology.
- A breath held 4D sequence with high temporal and spatial resolution would be desirable.

Flow imaging: Clinical Needs

Flow imaging is both, a precious tool for clinical management of patients and a powerful research instrument for better understanding of cardiovascular pathophysiology.

Comprehensive assessment of valvular function includes measurement of peak velocity for stenosis grading. The modified Bernoulli Equation then allows for calculation of the pressure gradient through the cardiac valve. Clinical decisions, however, are not based on one single parameter. In a failing left ventricle, for example, the calculated gradient might be low although a significant aortic stenosis is present. Volume measurements are helpful for characterisation of valvular regurgitation. In a healthy valve, only a minimal portion of the ejected stroke volume regurgitates through the valve back into the chamber. In valvular insufficiency, however, a considerable portion of the stroke volume may regurgitate back into the ventricle and thus increase the volume load. In this condition, flow MR has the unique capability of quantifying the regurgitant fraction which is an important parameter for patient management. Another relevant application of flow volume quantification are left-to-right shunts. In a healthy individual, right and left ventricle have very similar stroke volumes, thus stroke volumes measured in the ascending Aorta and the pulmonary Trunc are very similar. In a left-to-right shunt such as in abnormal draining pulmonary veins oxygenated blood is directed towards the vena cava superior or the right heart resulting in volume overload and increased stroke volume of the right ventricle. Flow MR enables precise quantification of the shunt volume. In patients with restrictive cardiomyopathies such as amyloidosis, the restriction can be identified by measuring flow through the mitral valve. In postoperative situations such as after repair of Fallot Tetralogy, Flow MR may be helpful to quantify flow directed to the left and right lung respectively. Moreover, in complex congential heart disease Flow MR is useful to quantify flow through shunts and conduits. In rare cases of severe aortic stenosis in severly sick patients a ventriculo-aortic bypass may be established. Flow MR is a powerful tool to quantify blood volumes leaving the left ventricle through the bypass and through the native aortic valve, respectively.

Flow MR is also a powerful research tool for better understanding of pathophysiology of cardiovascular diseases. Four dimensional techniques enable precise analysis of shear forces and wall stress in aneurysms and fluid dynamics in aortic dissection. This may help to taylor therapeutic interventions to the specific clinical situation and to develop new treatment options. In cerebral aneuryms Flow MR has been used to simulate treatment by means of minimal invasive coiling in virtual models. Flow MR is also used to measure pulse wave velocity to monitor aging of the aorta. This is a relevant parameter to assess remodeling of the aorta in atherosclerosis which may result in systemic arterial hypertension and eventually in cerebral stroke. Flow measurements in the coronary sinus reflect the total blood volume perfusing the cardiac muscle. Research on this technique, however, was disappointing

because of the complex motion and the small size of the coronary sinus which makes it difficult to use such flow measurement for clinical or research purposes. Moreover, flow measurements in the coronary arteries may be useful to identify slow flow as an indicator of distal stenosis, but these measurements are difficult and usually not very reliable due to the small size and complex motion of the target vessels.

Flow MR can be a time consuming procedure. Four dimensional techniques would be desirable enabling multiplanar reconstructions when the patient has already left the MR suite. Moreover, short acquisition times enabling breath held acquisitions in 4 D would be desirable. In patients with left to right shunt a valsalva manoeurer might be helpful to provoque a shunt inversion. In some cases, however, breath holding may interfere with the circulation, particulary in the right heart. In such situations a free breathing technique would be helpful. Temporal resolution is another relevant issue. Ideally it should be close to 20 ms, particularly when peak velocity is probed. Moreover, spatial resolution is a critical issue. Ideally the in plane resolution should be close to 1x1 mm.