4D flow MRI

Traditionally, magnetic resonance imaging (MRI) of flow using phase contrast (PC) methods is accomplished using methods that resolve single-directional flow in two spatial dimensions (2D) of an individual slice. More recently, three-dimensional (3D) spatial encoding combined with three-directional velocity-encoded Phase contrast magnetic resonance imaging (here termed 4D flow MRI) has drawn increased attention. 4D flow MRI offers the ability to measure and visualize the temporal evolution of complex blood flow patterns within an acquired 3D volume. Various methodological improvements permit the acquisition of 4D flow MRI data encompassing individual vascular structures and entire vascular territories such as the heart, the adjacent aorta, the carotid arteries, and abdominal, or peripheral vessels within reasonable scan times. To subsequently analyze the flow data by quantitative means and visualization of complex, three-directional blood flow patterns, various tools have been proposed. [1].

Schnell S, Wu C, Ansari SA. Four-dimensional MRI flow examinations in cerebral and extracerebral vessels - ready for clinical routine? Curr Opin Neurol. 2016 Aug;29(4):419-28. doi: 10.1097/WCO.0000000000000341. PMID: 27262148; PMCID: PMC4939804.

4D-Flow MRI has emerged as a powerful tool to non-invasively image blood velocity profiles in the human cardiovascular system. However, it is plagued by issues such as velocity aliasing, phase offsets, acquisition noise, and low spatial and temporal resolution. In imaging small blood vessel malformations such as intracranial aneurysms, the spatial resolution of 4D-Flow is often inadequate to resolve fine flow features.

Fathi et al. address the problem of low spatial resolution and noise by combining 4D-Flow MRI and patient-specific computational fluid dynamics using Least Absolute Shrinkage and Selection Operator. Extensive experiments using numerical phantoms of two actual intra-cranial aneurysms geometries show the applicability of the proposed method in recovering the flow profile. Comparisons with the state-of-the-art denoising methods for 4D-Flow show lower error metrics. This method can enable more accurate computation of flow-derived pathophysiological parameters such as wall shear stresses, pressure gradients, and viscous dissipation [2].

4D flow MRI for Moyamoya disease diagnosis

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2)
Fathi MF, Bakhshinejad A, Baghaie A, Saloner D, Sacho RH, Rayz VL, D'Souza RM. Denoising and spatial resolution enhancement of 4D flow MRI using proper orthogonal decomposition and lasso regularization. Comput Med Imaging Graph. 2018 Aug 7;70:165-172. doi: 10.1016/j.compmedimag.2018.07.003. [Epub ahead of print] PubMed PMID: 30423501.