Postprocessing and Cross Validation

Modeling and Quantification

Measurement of plasma input functions using MRI

Klaas Nicolay
Department of Biomedical Engineering, Eindhoven University of Technology, Eindhoven, Netherlands

Learning Objectives:

- Describe the basic MRI sequences with which arterial input function can be measured
- Describe the most used procedures for converting MRI contrast or parameter changes to arterial input function Describe the strengths and weaknesses of MRI-based arterial input function measurement
- Describe a number of key examples of the use of arterial input function measurements for the quantification of tissue perfusion in brain, heart and tumors

This presentation addresses the use of MRI for measuring the arterial (or plasma) input function (AIF). Quantitative measurements of the AIF are needed when using first-pass dynamic contrast enhanced (DCE) MRI for measuring the perfusion status of tissues in vivo. DCE-MRI refers to a very broad category of MRI acquisition techniques that dynamically monitor changes in MRI signal or MRI indices serially over time following injection of MRI contrast agent. In the specific case of quantifying the perfusion of biological tissues, the DCE-MRI recordings involve ultra-fast MRI scanning to monitor the first passage of a bolus of MRI contrast agent through the tissue of interest. The dynamic scans are converted to tissue concentration-time curves and these should subsequently be subjected to mathematical modeling to yield quantified perfusion values in units of ml/g tissue/min. To arrive at such quantified tissue perfusion values, the tissue response needs to be calibrated via deconvolution with the AIF. Willats and Calamante recently prepared a very insightful review on the use of dynamic MRI scanning for measuring tissue perfusion (1) and the different steps that are needed to conduct a meaningful study. The measurement of the AIF, i.e., the measurement of the arterial contrast agent concentration time course, presents several challenges and therefore accurate AIF quantification is an active area of research. In most cases, Gd-based MRI contrast agents are used as these are clinically approved and rapidly eliminated by renal excretion. During the presentation, examples of the use of AIF quantification for measuring perfusion of brain (2), heart (3,4) and tumors (5) will be given. It should be noted that there are also alternative MRI methods for quantifying tissue perfusion, such as Arterial Spin Labeling (ASL) (6,7). The advantage of ASL is that it makes use of an endogenous “tracer” (i.e., arterial water protons), which has certain distinct advantages. However, the relatively low signal-to-noise ratio of ASL-based perfusion mapping is a main limitation of its routine use. Nevertheless, recent advances in hardware as well as pulse sequence functionalities increasingly present ASL as an alternative for DCE-MRI-based perfusion quantification.

Relevant Publications:

1. Willats L, Calamante F. The 39 steps: evading error and deciphering the secrets for accurate dynamic susceptibility contrast MRI. NMR Biomed 2012.
2. Bleeker EJ, Webb AG, van Walderveen MA, van Buchem MA, van Osch MJ. Evaluation of signal formation in local arterial input function measurements of dynamic susceptibility contrast MRI. Magn Reson Med 2012;67(5):1324-1331.

3. Coolen BF, Moonen RP, Paulis LE, Geelen T, Nicolay K, Strijkers GJ. Mouse myocardial first-pass perfusion MR imaging. Magn Reson Med 2010;64(6):1658-1663.
4. van Nierop BJ, Coolen BF, Dijk WJ, Hendriks AD, de Graaf L, Nicolay K, Strijkers GJ. Quantitative first-pass perfusion MRI of the mouse myocardium. Magn Reson Med 2013;69(6):1735-1744.
5. Huang W, Tudorica LA, Li X, Thakur SB, Chen Y, Morris EA, Tagge IJ, Korenblit ME, Rooney WD, Koutcher JA, Springer CS, Jr. Discrimination of benign and malignant breast lesions by using shutter-speed dynamic contrast-enhanced MR imaging. Radiology 2011;261(2):394-403.
6. Detre JA, Zhang W, Roberts DA, Silva AC, Williams DS, Grandis DJ, Koretsky AP, Leigh JS. Tissue specific perfusion imaging using arterial spin labeling. NMR Biomed 1994;7(1-2):75-82.
7. Wu WC, St Lawrence KS, Licht DJ, Wang DJ. Quantification issues in arterial spin labeling perfusion magnetic resonance imaging. Top Magn Reson Imaging 2010;21(2):65-73.

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