Perfusion: Finding Flow

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Cerebral perfusion (or cerebral blood flow, CBF) refers to the rate of blood delivery to brain tissue; it is the blood flow at the capillary level, where exchange of oxygen and nutrients take place. Therefore, perfusion plays an important role both in tissue viability and in brain function. It is therefore not surprising that numerous disease process involve in one way or another disturbances to blood flow supply, and that the development of robust methods to measure perfusion has been a major area of research in neuroimaging

Bolus tracking MRI, also known as dynamic susceptibility contrast MRI (DSC-MRI), is currently the most commonly used perfusion MRI technique for clinical investigations (1). One of the main reasons for its widespread use is that bolus tracking MRI data can be acquired very fast (in approximately 1 min acquisition time), using MRI sequences in widespread use (e.g. gradient-echo echo-planar imaging) while still retaining very good contrast-to-noise ratio compared with other perfusion imaging methods, such as arterial spin labeling (ASL) or perfusion computer tomography (CT).

One of the most important clinical applications of perfusion MRI is in acute stroke, where perfusion MRI is often combined with diffusion MRI to define the so-called ischemic penumbra (2,3). Due to the need for an urgent decision with regards to patient management (4), there has been considerable interest in the development of automatic methods to analyze perfusion MRI data (e.g. (5-7)). These automatic methods also facilitate the widespread use of these advanced imaging methods by hospitals with limited local specialist expertise. However, one of the drawbacks of these 'black-box' types of tools is the lack of user quality control at the various steps involved during the analysis. Several practical issues during the analysis pipeline can have major consequences in the outcome of the analysis, which the user needs to be aware in order to minimize the inappropriate use and interpretation of the perfusion MRI results.

A bolus tracking MRI study involves an intravenous injection of a bolus of paramagnetic contrast agent, and the rapid measure of the associated signal changes during its passage through the brain. The bolus of contrast agent induces a transient signal drop on T_2^*-weighted images, which can be used to infer the time-dependent contrast-agent concentration. Quantification of perfusion involves measurement of the so-called arterial input function (AIF, which describes the contrast agent input to the tissue of interest), and a deconvolution analysis to remove, from the shape of the tissue concentration time-course, the temporal spread contribution associated with the AIF (8). There are however many issues regarding the potential of DSC-MRI to accurately quantify perfusion (e.g. see (9-14)); these include partial volume effect, bolus delay and dispersion effects, extravasation of the contrast agent due to
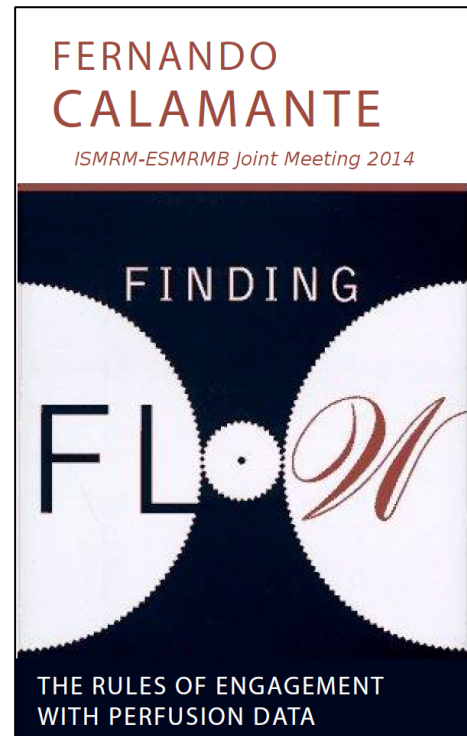
blood-brain barrier leakage, deconvolution errors, and difficulties in estimating the contrast agent concentration.

A typical perfusion MRI study involves the following analysis steps:
1. Motion correction
2. Estimation of the (time-dependent) contrast agent concentration
3. AIF measurement
4. Deconvolution analysis to remove the AIF contribution
5. Quantification of the hemodynamic parameters of interest
6. Scaling of these measurements to absolute units, if required

This lecture will discuss the most common pitfalls that can occur in these steps, as well as describe some practical recommendations to eliminate or minimize their occurrence. For further details, the reader is referred to recent review articles on this topic (9-13).

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