Perfusion imaging

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Perfusion means the delivery of oxygen and other nutrients to parts of the body, like organs and tissue, to assure the proper function. Furthermore, perfusion also drains waste product (like CO_2 and other metabolites) not needed in the cells anymore. Thus, perfusion provides important diagnostic information on status and functionality of tissue and organs, e.g. whether an ischemic organ is viable or not.

Human vasculature provides a well-balanced supply of nutrients to the cells. It is regulated by complex control mechanisms, which quickly respond to local and global changes of energy demands. Therefore, reliable measurement techniques are necessary to understand the complex nature of haemodynamic and utilize such information in clinical diagnosis and therapy monitoring.

Several techniques exist to assess perfusion including positron emission tomography (PET), single photon emission computed tomography (SPECT), Xenon-enhanced computed tomography (XeCT), dynamic perfusion computed tomography (PCT), MRI and Doppler ultrasound. All techniques have in common that a contrast agent is used and the distribution of this tracer is measured by the above mentioned imaging modality. However, except for one (see below), all techniques are based on the administration of an exogenous contrast agent. An excellent overview on perfusion measurement approaches including a comparison was published by Wintermark et al. (1). This publication not only covers MR-related approaches but spans the whole range of perfusion estimation based on medical imaging. This overview makes it apparent that there are two basic approaches of perfusion estimation based on medical imaging: bolus tracking and the steady state technique. Nowadays, bolus tracking is most often used for perfusion estimation especially in MRI but also in CT. Here, a certain amount of contrast agent is injected into a vein and the passage of this contrast agent bolus through tissue is observed. Depending on the imaging modality, appropriate contrast media have to be used, but the basic idea remains the same. In MRI, the bolus tracking approach is often called dynamic susceptibility contrast (DSC) imaging. A nice overview on the methodology of DSC imaging for perfusion measurement is presented in (2).

Steady state techniques are often used, when the imaging modality is not fast enough to capture the bolus passage with sufficiently high temporal resolution or if other parameters beyond perfusion are to be assessed (e.g. transfer rates between vasculature and surrounding tissue). In MRI, this technique is called dynamic contrast enhanced (DCE) imaging.

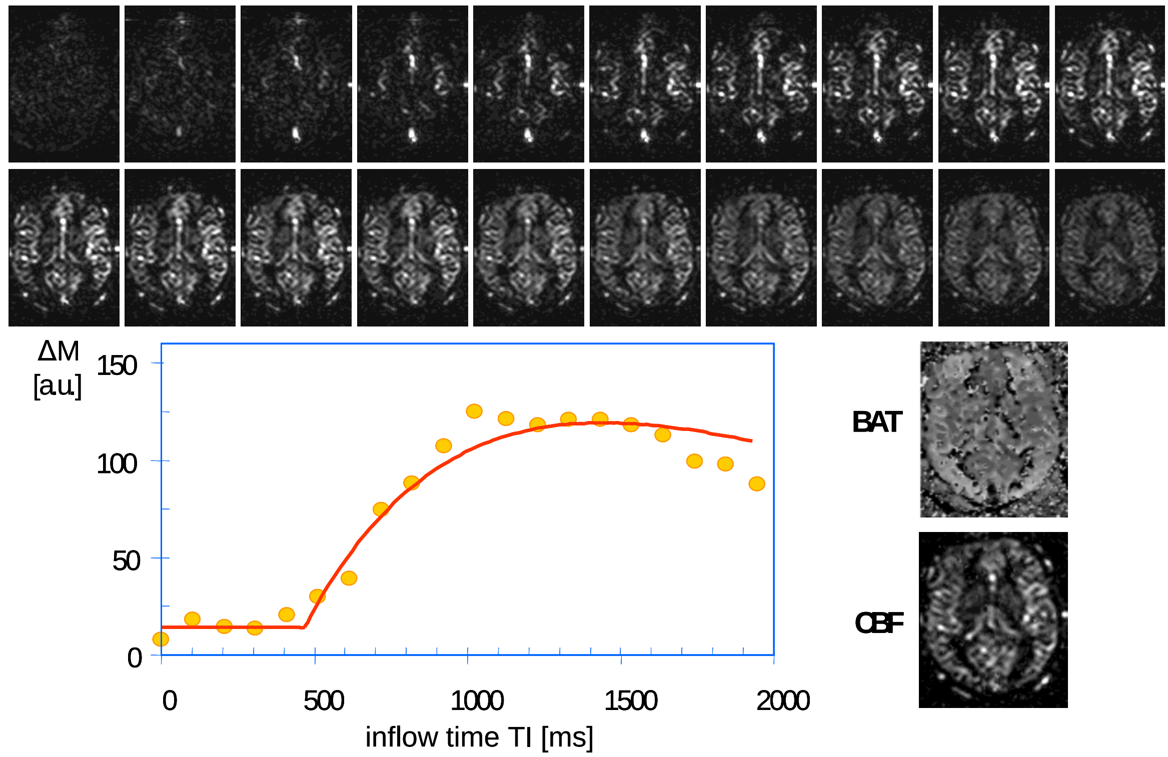

Fig 1: Perfusion measurement by arterial spin labeling (ASL): Signal dependence of difference image for varying inflow times (time between preparation and image acquisition) after ASL preparation. The time curve shows the inflow of the labeled blood over a period of 2 seconds. Applying an appropriate model function (red curve) to the data allows to extract parameter maps like bolus arrival time (BAT) and cerebral blood flow (CBF) (bottom left).

MRI offers a second method to measure perfusion, which is becoming more and more popular. The technique is called arterial spin labeling (ASL) and is – in contrast to the bolus tracking approach – truly non-invasive, since no exogenous contrast media injection is needed. Instead, inflowing blood water spins are tagged magnetically in one region and measured downstream in another region. This allows the estimation of perfusion (and more). ASL is a very flexible and powerful tool, which is just now making its way into clinics. The inflow of labeled blood water spins into the imaging slice is depicted in Figure 1. A lot of different approaches have been developed in ASL. The overview by Petersen (3) provides an excellent entry point for this class of techniques.

References

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