Using physiological MRI to estimate dynamic cerebral autoregulation metrics: functional MRI feasibility study

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Abstract

Cerebral autoregulation is the homeostatic mechanism that maintains sufficient cerebral circulation despite changes in the perfusion pressure. Dynamic CA refers to the changes that occur in CBF within the first few seconds after an acute MAP change. Assessment of the CA impairment plays important role in the prognosis of many cerebrovascular diseases such as stroke, sub-arachnoid haemorrhage, as well as traumatic brain injury and neurodegenerative disorders.

This thesis investigates the feasibility of using physiological MRI to estimate dynamic cerebral autoregulation (dCA) metrics. In particular, this thesis has an emphasis on measuring beat-to-beat arterial blood pressure inside the scanner to provide better understanding of the physiological aspects of dCA. Further, continuous blood pressure (BP) measures in response to different non invasive BP fluctuating methods are acquired to evaluate the reliability of these methods to induce response changes.

Blood Oxygen Level Dependent (BOLD) fMRI method was used to estimate the expected variations of tissue oxygenation during induced dCA changes in healthy volunteers. The non invasive arterial blood pressure measurements were acquired using MR compatible arterial blood pressure monitoring device (NIBP-MRI/Caretaker; Biopac®). Further, sudden release of inflated thigh-cuffs (TCR) and inspiratory breath-hold (iBH) methods were used in the scanner to induce dynamic autoregulatory changes. These two methods were investigated in a pilot study, to evaluate the reliability prior to the MR study by comparing BP measurements obtained outside the scanner using non invasive methods. This pilot study included monitoring BP changes in response to four types of non invasive BP fluctuating methods. The reliability of NIBP/MRI Caretaker device was examined by comparing the BP response changes with the simultaneously acquired BP data from Finometer plethysmographic device. The cerebral autoregulation metrics were estimated by calculating the rate of regulation (RoR) following dynamic BP fluctuating events. Rate of regulation defines the rate at which the BOLD signal changes depending on MAP changes at a particular time. Further, the tissue specific regulation parameters were obtained for grey matter (GM), white matter (WM) and water shed areas (WS). The effect of iBH method on cerebral blood flow (CBF) and velocity (CBFV) was explored in a preliminary study by quantitative measures using time resolved 4D PC MRI angiography in two subjects.

The mean arterial blood pressure (MAP) changes in response to TCR and iBH method were comparable. The fMRI data demonstrated BOLD signal amplitude change in response to the induced fast MAP changes. The GM and WS areas showed similar rates of regulation, and these were nominally higher than WM RoR in both TCR and iBH methods. Further, the 4D PC MRI data suggested 29% CBF-increase in response to 33% iBH in four minutes acquisition time.

The acquired non invasive arterial BP measures concurrent with the BOLD signal amplitude response, allowed deriving the rate of regulation as a metric of dCA. It is not known whether this information is clinically relevant to gauge the haemodynamic risk association to cerebrovascular disease. However, BOLD signal change and CBF changes after iBH are confounded by the extent to which the CO2 gradually accumulate in response to iBH and causes an overshoot in the CBF response-change.

In conclusion, the presented study indicates the feasibility of using physiological MRI to measure dCA in response to non-invasively induced MAP changes. Estimation of the dCA metrics could be improved by using advanced data fitting methods as well as controlling for physiological parameters such as PECO2.