AGE-RELATED CHANGES IN KINETICS OF BRAIN PERFUSION MEAUSURED BY PULSED ASL MRI

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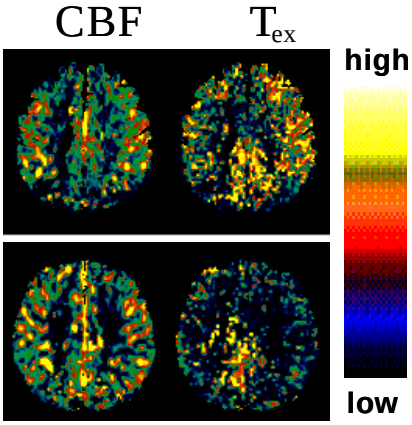
Introduction:

The overall goal of this study was to characterize age-related changes in brain perfusion and blood flow of normal subjects using arterial spin labeling (ASL) techniques. Based on recent reports of an age-related decline in arteriolar and capillary density [1], we hypothesized that the time for arterial water to flow into the capillary bed and eventually perfuse into brain tissue would increase with age, because of increased vascular resistance due to reduced volumes of arterioles and capillaries at older age. In addition, we expected that cerebral blood flow (CBF) would decrease with increasing age, inversely to increased vascular resistance.

Methods:

We developed a new kinetic model for pulsed ASL perfusion, accounting for a finite time of labeled water to flow into the capillary bed, termed exchange time (T_{ex}), in addition to variations in blood flow, transit time, bolus time, and relaxation. Furthermore, we considered for the exchange time an initial phase, during which the capillary bed fills with labeled blood and a stationary phase, during which labeled blood continues to flow into the capillary bed already filled with labeled blood. Eleven volunteers, between 29 and 88 years old (4 women, 7 men) were studied with pulsed ASL perfusion MR using the DIPLOMA sequence, described previously [2]. Subjects were asked to relax and close their eyes to obtain perfusion at "resting state". To measure dynamic perfusion, sixteen image frames of DIPLOMA were acquired by increasing the delay between the ASL pulses and image acquisition from 200ms to 2000ms. T1-weighted MPRAGE images were also acquired. Using Statistical Parametric Mapping (SPM2), each perfusion image was co-registered with the corresponding T1 image to minimize movement errors. Further, T1 data allowed tissue segmentation to mask perfusion of gray matter and white matter. The experimental perfusion data were fitted using a Downhill simplex algorithm and simultaneously estimating all variables of the kinetic model.

Fig 1: Parametric maps of CBF and T_{ex}



Results:

Fig 1 shows representative parametric maps of CBF and T_{ex} for gray matter perfusion from an 80-year-old (top) and a 33-year-old subject (bottom), demonstrating that overall CBF was decreased and T_{ex} increased in the older subject. Evaluating kinetic perfusion of gray matter from the 11 subjects showed that global T_{ex} increased with age ($r = 0.71$, $p<0.02$), as hypothesized, while global CBF of gray matter decreased with age ($r = -0.25$, $p > 0.1$), although this was not significant. The relationships of T_{ex} and CBF with age are shown in Figure 2a and 2b, respectively. Similar results for T_{ex} and CBF were obtained in white matter.

Fig 2a: T_{ex} of gray matter

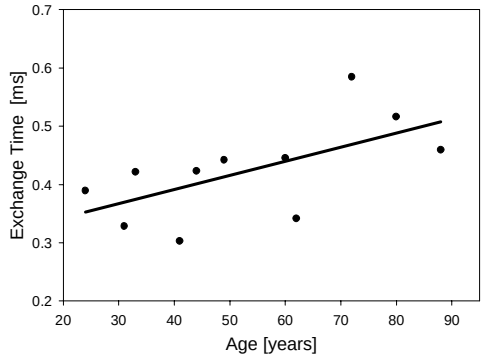
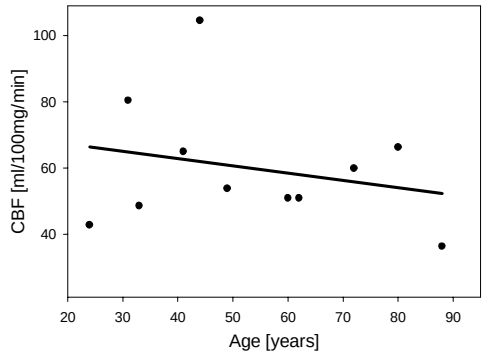


Fig 2b: CBF of gray matter



Conclusion:

In agreement with our hypothesis that reduced volumes of arterioles and capillaries with age cause increased vascular resistance, we measured an age-related increase in time of labeled blood to flow into the capillary bed and perfuse into brain tissue. Moreover, the increase of exchange time was stronger related to aging than the decrease of cerebral blood flow. This suggests that exchange time is a sensitive marker for age-related alterations in microvascular plasticity. However, age-related reduction of brain activity, could also explain the increase in exchange time, because less brain activity should be associated with decreased CBF and thus, reduced perfusion pressure. Nevertheless, the strong correlation of exchange time with age underscores the significance of considering exchange time in perfusion studies in age-related brain diseases, such as Alzheimer's disease and vascular dementia.

References:

[1] E. Farkas, et al. Prog. Neurobiol. 2001; 64; 575-611.
[2] Jahng et al., Magn Reson Med 2003; 49:307-314.