Quantifying the Effect of Posture on Cerebral Vascular Mechanical Compliance using Cerebral Blood Flow Measurements: Possible Implications for fMRI BOLD Response

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Introduction:

The mechanical compliance of the cerebral vasculature compartment is affected by body posture. In the supine posture a larger volume of blood resides in the cerebral vasculature compared with the upright position where blood volume is preferentially redistributed in the lower part of the body due to gravitation. The change in the volume of blood residing in the cerebral vasculature is affecting the overall mechanical compliance. Dynamic MRI measurements of arterial inflow and venous outflow were used to estimate cerebral vascular compliance in an upright and supine postures of the same subjects in order to quantify the effect of posture on compliance. We further tested the hypothesis that subjects with reduced cerebral vascular compliance will exhibit reduced BOLD response in a simple motor fMRI activation study due to reduced hemodynamic response.

Method:

Ten healthy volunteers (7 females, 3 males, mean age 29+/- 7) were studied at upright and supine positions in a SP 0.5T MRI scanner (GE Medical system, Milwaukee). Upright imaging is accomplished with the patient seated and held in place by a combination of foam and inflatable pads attached to rails anterior and posterior to the patient's head (Figure 1). A 8"X10" flex coil was used in a transmit/receive mode for the upright position and receive mode for the supine. Retrospectively gated cine phase contrast scans were used to measure arterial inflow and venous outflow with the flowing scanning parameters; velocity encoding (VENC=70cm/s), TR=19ms, FA=25deg, and FOV=16cm. Total cerebral blood flow was dereived by summation of the mean volumetric flow rates through each of the 4 vessels feeding blood to the brain and the cerebral vascular compliance was estimated from the venous outflow pulsatility (the peak to peak amplitude) relative to the arterial inflow pulsatility, i.e., pulsatility index (PI) [2]. Venous outflow is more pulsatile (less low pass filtering of the arterial inflow) for lower compliances. Three subjects further underwent a brain activation study in the supine posture on a 3T MRI scanner (GE Medical system, Milwaukee) using a simple finger movement paradigm. The BOLD response was estimated by quantifying the area of active pixels in the primary motor area. BOLD response was then compared with measure of cerebral compliance.

Results:

A statistically significant 2-fold decrease in the pulsatility ratio index (corresponds to increase in cerebral vascular compliance) was found in the upright position. The mean PI in the supine posture was 0.61 +/- 0.15 and in the upright position 0.35 +/- 0.11 (single tailed T-test, $P < 0.0005$). The amplitude of the arterial flow was similar in both postures. A lower total cerebral blood flow (mean of 12%) was also measured in the upright position. One of the 3 subjects studied with fMRI had a 40% higher PI compared with the other 2 subjects. A much-reduced BOLD response (47 vs. 389 voxels) was measured. Figure 2 shows the BOLD repose in a subject with normal compliance (low PI) and with reduced compliance (high PI).

Discussion:

Cerebral vascular compliance can be estimated from the relationship between the input (arterial inflow) and the output (venous outflow) of the cerebral vascular compartment. The methodology applied to estimate the compliance was validated using measurements in upright and supine postures in healthy subjects. Lower compliances were consistently measured in the upright posture compared with the supine posture as expected. The influence of cerebral vascular compliance on the hemodynamic response and the resulting BOLD signal is evident by the reduced activation associated with low cerebrovascular compliance.

Reference: [1] Alperin N et al, Intl. Soc. Mag. Reson. Med. (2002) Vol. 2:1281.

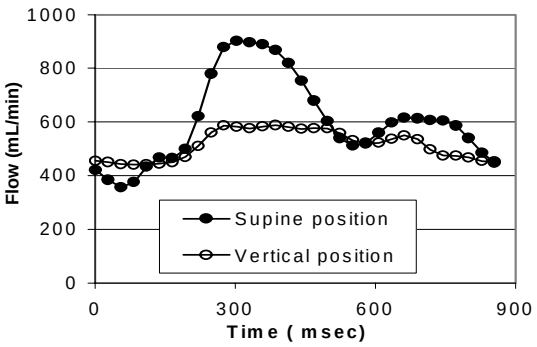

Figure. 1: Venous flow waveforms demonstrating the less pulsatile flow (open) in the upright position.

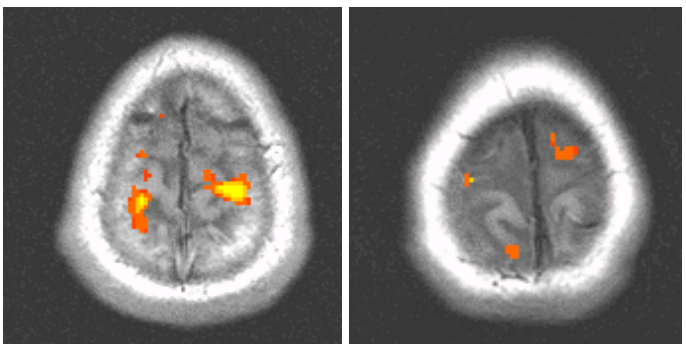

Figure 2. BOLD response during finger movement in a subject with high (left) and low (righ) cerebral complaince.