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ORIGINAL ARTICLE

Absolute and regional cerebral perfusion assessment feasibility in head-down position with arterial spin-labeling magnetic resonance. A preliminary report on healthy subjects

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Summary
Purpose: Head-down (HD)-positioning, used in some stroke centers during early ischemic stroke management, is empirical but supported by some physiological findings. It has been shown by nonmagnetic resonance methods that this position can increase cerebral perfusion. This study aimed to investigate magnetic resonance imaging (MRI) ability to measure the response to head-down tilt (HDT) challenge in healthy volunteers. Cerebral blood flow (CBF) was assessed with arterial spin labeling (ASL) in supine and HD (−15°) positions.
Methods: Cerebral perfusion was measured in supine and HD positions in seven healthy subjects at 1.5 T with a large magnet bore (70 cm) MRI device. 3D pseudocontinuous arterial spin-labeling (pCASL) sequences were acquired in both positions and cerebral blood flow (CBF) maps were reconstructed. Regions of interest were subcortical gray matter structures (accumbens nuclei, amygdala, caudate nucleus, hippocampus, pallidum, putamen and thalamus), whole cortical gray matter and whole white matter.
Results: White matter and subcortical gray matter structures' CBF, averaged over the volunteers' sample, remained stable from supine to HD position. Accumbens nuclei and cortical gray matter CBF decreased by 11.5% ($P = 0.013$) and 11.4% ($P = 0.018$) when head position was changed from flat to −15°.

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Conclusions: Regional CBF assessment, especially in HDT, is challenging with most perfusion techniques because of ionizing radiations, inherent limitations and logistical considerations. This preliminary report presents a noninvasive technique assessing regional and absolute cerebral blood flow changes in response to posture change. It can lead to further clinical investigations for a better understanding of cerebral perfusion.

Introduction

Cerebral blood flow (CBF) quantification is challenging. Different techniques have been used to assess cerebral perfusion directly or indirectly with the gold standard being ^{15}O-PET [1,2] (positron emission tomography). However, because of radiation exposure and its high cost, the availability of this modality is limited.

The most common noninvasive technique for CBF indirect assessment is transcranial Doppler [3,4] (TCD), which provides good temporal resolution. With TCD, blood flow velocity can be continuously monitored in the main supply arteries, usually the middle cerebral artery (MCA). The vessel' cross-sectional area is the proportionality coefficient between flow and velocity. However, TCD can only assess relative and hemispheric CBF changes. Moreover, velocity is measured only in the MCA trunk while microvascular blood flow in deep cerebral parenchyma is poorly assessed. Near infrared spectroscopy (NIRS) [5] and, more recently, diffuse correlation spectroscopy [6] are also noninvasive and allow continuous monitoring of deoxyhemoglobin and oxyhemoglobin cortical regions. Like TCD, NIRS and diffuse correlation spectroscopy can assess cerebral perfusion during position changes but, again, they only estimate relative changes. Imaging techniques like single photon-emission computed tomography (SPECT), PET [7] and perfusion computed tomography (CT) [8] can evaluate CBF, but continuous CBF measurement or repeated assessments within brief intervals (<24 h) are not possible, because of contrast-agent persistence or potential side effects.

Magnetic resonance (MR)-perfusion techniques visualize global or regional absolute CBF and correlate positively with TCD and ^{15}O-PET [1,9].

However, due to small bores, MRI was so far restricted to the supine position and did not allow position changes. Moreover, the first MR-perfusion assessment technique was done through dynamic susceptibility contrast (DSC) [10], requiring an intravenous contrast agent based on gadolinium chelates. Gadolinium persistence in vessels prevents repeated CBF assessments at brief intervals. Arterial spin-labeling (ASL) is an MR technique providing images of absolute regional CBF without contrast-agent injection, used in perfusion assessment [11,12].

Head down (HD)-positioning, used in some stroke centers during early ischemic stroke management, is empirical but supported by some physiological findings. In acute ischemic stroke patients, this position may be used to increase cerebral perfusion [6,13]. Most studies dealing with posture influence on cerebral perfusion usually investigate global effect on perfusion and assess relative cortical perfusion [6,13]. The aim of this preliminary study was to assess the feasibility of measurements of regional and global CBF changes with ASL MRI in the HD position.

Materials and methods

Subjects

Seven healthy subjects (2 women, 5 men) were enrolled. Mean age was 33.4 ± 7.7 (range 26—42) years. They underwent a physical examination and gave their informed consent. All were nonsmokers, normotensive, and without diabetes; none were on medication. No caffeine or alcohol intake was allowed the day of the MRI and, for women of procreation age, the test was performed soon after their menstrual periods. The protocol was approved by the local ethics committee and they received institutional review board agreement. Our procedures were in accordance with the Helsinki Declaration of 1975 (and as revised in 1983).

Head-down tilt protocol

Angles of 0° and −15° were sequentially evaluated. Measurements at 0° (supine) were considered as the baseline against which HD position (−15°) angle was compared. Supine position was carried out before HD position. To achieve the HD position, the subject was carefully positioned on a customized foam mattress (with 40° angulation over 20 cm at one end; Fig. 1), avoiding neck extension or compression of jugular veins or carotid arteries, with a mean −15° angle between the upper thorax and head. The head was approximately 20 cm below the heart, whereas the lower body remained flat. In each position, a 3D-ASL sequence was obtained after 4 min of equilibration.

Cerebral blood flow measurement

MRI measurements were obtained with a large bore (70 cm) 1.5-T MR magnet (MR450w, GE, Milwaukee, WI, USA). We used a standard head—neck—spine array (8-channel head coil).

Axial T1-weighted images were acquired using a 3D gradient echo (GRE) sequence for segmentation purpose. 3DT1 images were acquired in supine position. Acquisition parameters were set as following: repetition time (TR)/echo time (TE): 10.796 ms/4.4 ms; inversion time (TI): 500 ms; bandwidth: ±88.79 kHz; field of view (FOV): 240 mm × 240 mm; matrix size: 256 × 288; in plane resolution: 0.94 mm × 0.83 mm; slice thickness: 1.4 mm, for a total acquisition time of 2 min.