Preliminary study of hypoxic exposure effect on cerebral blood perfusion of pilots using 3D ASL

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Target audience: Radiologist and MR researchers, who interested in cerebral hemodynamics under conditions, e.g. low pressure environment.

Purpose: To investigate how the cerebral blood perfusion changed in pilots with hypoxic exposure through the measurement of resting cerebral blood flow (CBF) using a 3D pseudo-continuous arterial spin-labeling (pcASL) technique.

Introduction: Pilots often need to face and overcome all kinds of extreme situations during a flight, especially at upper atmosphere, where hypoxia is common due to low oxygen concentration and low pressure which cannot be fully avoided no matter how good of equipment sealing in modern aviation. At moment, few reports have been found in peer-reviewed publications on investigation of CBF variation with hypoxia in human, with only a few relevant animal experimental trials showed that hypoxia could cause a decrease of CBF. For the first time, in this study we mimicked hypoxic environment equal to 3000m altitude and obtained the CBF of the subjects before and after hypoxic exposure using 3D pcASL, and then fixed the corresponding brain areas.

Methods: 35 healthy male pilots (mean age 30 years, mean total flight time 1328 h) were included in this study. In order to investigate the change of CBF of the brain in the condition of hypoxic exposure, the low oxygen mixed gas inhaled by participants through a breathing mask was approximate to the air composition at the altitude of 3000 m with the oxygen concentration of 14.5%. Pulse oximetry was applied to monitor in real-time the immediate pulse and oxygenation saturation of each subject pre- and post-hypoxic exposure. Then, 3D pcASL images were acquired at both pre- (pre-OI) and post-low oxygen mixed gas inhalation (post-OI) using 3D-FSPGR BRAVO sequence on a 3.0T scanner (GE MR750, WI, US) with the scanning parameters: TR/TE= 4632ms/10.5ms; FOV=24cm^2; slice thickness = 4.0mm; bandwidth=62.5KHz; flip angle=111°. Thereafter, CBF maps could be calculated from the acquired 3D pcASL images using an automatic software in the AW workstation of GE. To enhance the spatial normalization, T1 axial plane anatomical image were also acquired. CBF maps were preprocessed and analyzed by FSL and SPM8.

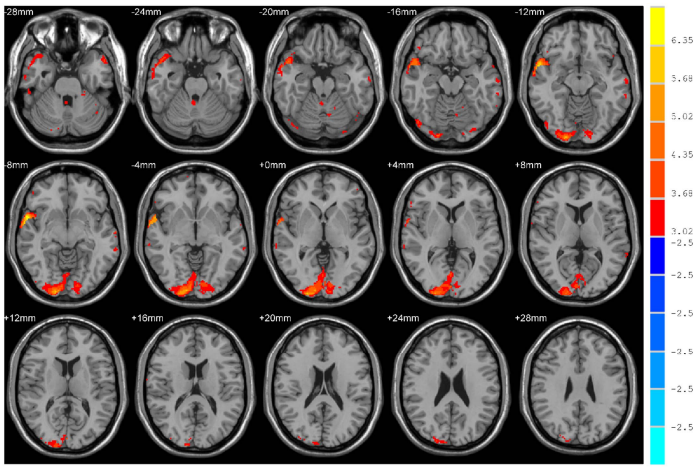

Fig.1. Statistical differences of CBF between pre- and post-low oxygen gas inhalation. Results were shown by REST Slice Viewer, color bars represented T values using paired t test. The red area means the cerebral blood perfusion was reduced after hypoxic exposure. The left side of the picture represented the right hemisphere.

Tab. 1. Brain areas of significant CBF variation (before-after)

Brain area	Hemi-sphere	Brodmann's area	MNI			t value
			x	y	z	
STG	L	38/42	-28	10	-46	3.7062
	R	21/22/38/42	56	10	-14	5.6683
MTG	L	21/22/38	-34	10	-42	3.6627
	R	21/22/38	60	2	-10	6.0069
ITG	L	20/21	-64	-12	-22	3.4508
	R	-	-	-	-	-
MOG	L	-	-	-	-	-
	R	18/19/37	24	-102	-2	5.0800
IOG	L	-	-	-	-	-
	R	17/18/19	30	-98	-10	3.7196
Lingual Gyrus	L	17	-14	-94	-4	3.5905
	R	17/18/19	20	-102	-12	5.2258
Cuneus	L	-	-	-	-	-
	R	17/18/19	24	-102	-6	5.4953
Fusiform Gyrus	L	-	-	-	-	-
	R	20	60	-8	-32	3.7440
Cerebellar Lingual	L	-	-	-	-	-
	R	-	4	-48	-22	3.1630
Culmen	L	-	-	-	-	-
	R	-	4	-46	-26	2.9887
Declive	L	-	-28	-74	-54	3.0559
	R	-	-	-	-	-

Note: The threshold was set at P<0.05(uncorrected).

Results: After hypoxic exposure, the pulse was (63.97±10.43) beats/min, the oxygen saturation was (92.46±3.64) %, it's significant lower than initiate examination ((71.46±10.63) beats/ min, (96.31±1.23) %). 3D pcASL scan for pilots after hypoxic exposure showed lower CBF values in various regions, including bilateral superior temporal gyrus (STG), middle temporal gyrus (MTG), lingual gyrus, left inferior temporal gyrus (ITG), right middle occipital gyrus (MOG), inferior occipital gyrus (IOG), fusiform gyrus, cuneus and cerebellum (P<0.05), as shown in Tab.1 and Fig. 1.

Discussion: After hypoxic exposure, the oxygen saturation was kept around 92%, which was in the state of acute mild hypoxia[1]. At this point, the oxygen partial pressure of inhaled gas decreased, so the alveolar air and the arterial blood oxygen partial pressure decreased as well, then peripheral chemoreceptor and nerve regulation made breathing exercises deepen and fast to increase pulmonary ventilation, which caused CO_2 partial pressure drop, leading to low carbonic acid hematic disease, the PH around cerebrovascular increased, the small vessel of brain is very sensitive to PH change, so the cerebrovascular contraction leading to cerebral blood flow and cerebral blood volume reduced. Cahill et al.[2-3] showed CBF values of rats under hypoxic experiment was decreased comparing with the normal control. Using 3D pcASL technique, lower CBF values were observed in pilots after hypoxic exposure in various regions, including bilateral superior temporal gyrus, middle temporal gyrus, lingual gyrus, left inferior temporal gyrus, right middle occipital gyrus, inferior occipital gyrus, fusiform gyrus, cuneus and cerebellum (P<0.05). In addition, the right hemisphere was sensitive to hypoxia, which may be related to the pilots' professional characteristics[4-5]. The left hemisphere of right-handed people is priority to language function while the right one is more involved in visual-space. Pilots have higher space cognitive ability to perceive things around and make modification and reconstruction of visual experience accurately. Usually, pilots have more inherent advantage in spatial cognition through spatial cognitive ability test, the function of the right hemisphere is relatively active and is more sensitive to hypoxia.

Conclusion: 3D pseudo-continuous arterial spin-labeling technique could monitor CBF changes in pilots with hypoxic exposure, and the cerebral blood perfusion after hypoxic exposure was decreased mainly in the temporal and right occipital lobes.

References:

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