ANGULARIS OCULI VEIN TEMPERATURE VARIATIONS RELATED TO MAN'S MENTAL ACTIVITY – *PRELIMINARY STUDIES*

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Summary : This preliminary study describes a noninvasive, inexpensive approach to the study of lateralization as related to mental activity. It supports the concept of a thermoregulatory role of blood in cerebral temperature control. Right and left angularis oculi vein temperatures were measured during periods of mental activity and mental rest and both temperature changes were asymmetrical. There was a consistent temperature drop during thinking, with a consistent rise after thinking ceased. Heat loss from superficial vessels of the buccal region and nasal mucosa to the ambient air was evident which caused lowering of the venous blood temperature flowing towards the cavernous sinus. This drop in blood temperature of angularis oculi veins coincided with increased brain metabolism and heat production occasioned by an increase in the level of mental activity and oxygen utilization.

Key words : brain temperature; carotid rete; countercurrent; heat exchange; cavernous sinus; thermal regulation

INTRODUCTION

The objectives of this study were to determine (a) whether the temperature of blood in the angularis oculi vein decreased with mental activity, and (b) whether the temperature decreases were asymmetrical.

Cognitive activity results in increased flow of blood to the cerebral hemispheres (12, 16) supporting the hypothesis of a thermoregulatory role of blood relative to brain metabolic activity. Sex differences in cognitive functioning have been extensively documented (20). Handedness also seems to have an effect on cognitive functioning (14).

Oxygen utilization is a function of cognitive activity and, thereby, increases brain metabolism and heat production (10). There is evidence that the mode by which temperature changes are produced in the brain is through circulating blood since the blood conveys thermal information about the body core to the brain (27), and this theory has further been substantiated in the anesthetized cat (1).

Current literature provides considerable evidence that the venous blood in the lakes of the alar fold region of the nasal vestibule, the ambient air passing over it, the core temperature blood in the carotid rete, and the venous blood in the cavernous sinus influence thermal regulation of the mammalian brain (21.). Further, it has been experimentally demonstrated that relatively cooled venous blood from the nasal and facial areas drains into the cavernous sinus, located at the base of the brain, in which the carotid rete, containing the core temperature blood, is bathed (3,4,18). The carotid rete – cavernous sinus vascular complex has been attributed to be the site for countercurrent heat exchange moderating the brain temperature in domestic mammals (9, 13, 19, 21, 29).

The angularis oculi vein is a component of a venous pathway from the nasal and facial areas to the cavernous sinus (dorsal and/or lateral nasal veins – angularis oculi vein – ophthalmic plexus – cavernous sinus) in many experimental animals and in man (2, 18, 21, 22, 23, 26). The presumption held heretofore that the blood was flowing caudally through the angularis oculi vein to the cavernous sinus has been proven to be true under normothermic and hyperthermic conditions in man (8) and sheep (18, 19).

In hyperthermia blood flowed rapidly towards the cavernous sinus via the angularis oculi vein collecting cool facial blood. During mild hypothermia in man, however, the blood flowed in the opposite direction in the angularis oculi vein (7). Therefore, selective cooling of the human brain is possible. Jessen and Pongratz (17) stated that during cold stress the hypothalamic temperature in the goat was uncoupled from the temperature of the upper respiratory surfaces and presented an undistorted body core temperature.

To be components of a physiologic temperature regulation system for the brain, there is evidence that heat transfer in the nasal area is modulated in accordance with changes in cerebral activity in animals (1, 3, 4, 19), but this has not been demonstrated in man. Evidence is strong, however, that the same holds true for man. Cabanac and Caputa (6) observed a significant lowering of skin temperature over the thermally insulated angularis oculi vein during facial fanning. These results suggest a selective cerebral cooling due to venous blood returning from the facial skin via the angularis oculi and ophthalmic veins to the cavernous sinus, where a cooling of the arterial blood ascending to the brain can take place.

The intrinsic myogenic tone of the rabbit facial vein, which is responsible for influencing the direction of venous return from the nose, responds to very small changes in ambient temperature (28). According to these authors, the tone of this temperature sensitive sphincter changes significantly with the temperature of the blood draining from the nasal turbinates (conchae). With slight rise in the ambient or nasal blood temperature the level of sphincter tone increases, shunting a great proportion of nasal venous blood towards the large central sinuses.

If the venous pathway from the nasal and facial regions to the cavernous sinus and heat transfer from the venous blood in the lakes of the alar fold region to the ambient air and from arterial to venous blood in the cavernous sinus are components of a physiologic system for brain temperature regulation in man, one would expect the temperature of the angularis oculi vein to decrease with mental activity as the blood in the angularis oculi vein is acting as the coolant for arterial blood ascending to the brain. Also, one would expect changes in the temperatures of the right and left angularis oculi veins to reflect the level of activity that was occurring in the homolateral side of the brain. The reason being that, under normal physiologic conditions, the cerebral arterial circle does not permit an intermingling of the bloodstreams in its main contributing vessels of the contralateral side (5, 25). If this is true under normal conditions, then the right and left venous pathways are separate physiologic systems. Therefore, the level of activity that each cortex attains during various types of mental tasks would be reflected asymmetrically in the temperature of the right and left angularis oculi veins. The only means of accomplishing this at present are brain lesion studies, commissurotomy, inactivation of a hemisphere by surgical removal, or anesthetization of one side of the brain.

MATERIAL AND METHOD

The experimental group consisted of eight first-year students and one Assistant Professor form the College of Veterinary Medicine. There were six males and three females in the group, all of them were right-handed.

The temperature recordings were taken either with thermistor needle probes[1] placed between the angularis oculi veins and the nasal bones near the medial canthus of the eye or with thermistor beads[2] placed on the skin overlying the angularis oculi veins in the same region and covered with Band-Aids®. Two methods of temperature recordings were employed for evaluating their relative merits as well as for minimizing physiologic reactants involving a system devoid of any surgical intervention. The recordings of the median antebrachial vein in three subjects were taken with thermistor needle probes inserted through the skin of the forearm and positioned alongside the vein. See Table I.

Noise was minimized as much as possible in the room where the trials were conducted. The attendant to the subject did not move during the trials except for giving hand signals. The subjects were maintained in a comfortable and relaxed sitting position.

1. Model HTBI-HN-075. High Temperature Instruments Corp., Philadelphia, PA.
2. Type 44030. Yellow Springs Instrument Co., Yellow Springs, OH.

The subjects were briefed before the beginning of the trials They were instructed to relax as much as possible and to attempt to go to sleep after the thermistors were positioned in the desired locations and then the room was darkened. These conditions were maintained until the recorded temperature of the angularis oculi veins stabilized and, therefore, each individual served as one's own control. Then they received a light touch on the back of the hand. At this time, the subjects were to begin subtracting from the number 10,000 by sevens, starting with a new number after each subtraction. They were to continue the subtraction as fast and accurately as possible until they again felt a light touch on the back of the hand. At this time, other stimuli were introduced. Finally, the subjects were signalled to revert back to the mental resting state to allow the recorded temperatures to again stabilize. The nature of the mental exercises and the temperature signals were recorded on a Grass Polygraph[3] located in an adjoining room.

RESULTS

In three subjects (Table I : 1, 2 and 8), the net change in temperature levels of both angularis oculi veins between before and after thinking ceased was zero. Of the remaining six, the net change was less after thinking ceased than it was before in subjects 3, 4, and 6 and was greater after thinking ceased than before in subjects 5, 7, and 9. However, there was a consistent temperature drop during thinking, with a consistent rise when thinking ceased. The comparative maximum changes in vein temperatures between the right and left sides during thinking ranged from no difference (Subject 6) to a difference of 0.9°C (Subject 9). Where a difference in the temperature of the right and left veins was observed during thinking, the vein which showed the greatest change was equally distributed between right and left sides among the eight subjects. Seemingly, right handedness of the subjects did not have any bearing on the temperature changes of the right and left veins.

There appeared to be no marked difference between the two methods of thermistor placement in regard to the temperature recordings of the vein during the initial mental rest period (i.e., thermistor placement for subjects 1–7 as compared to the placement for subjects 8 and 9).

With thermistor needle probes, the temperature recordings of the right and left angularis oculi and the left median antebrachial veins for Subjects 6 are shown in Fig. 1. The maximum changes in angularis oculi temperatures during thinking were the same for both sides (–1.0°C) for a net decrease of 2.0°C. The temperature of the median antebrachial vein decreased by 0.8°C. The maximum change in the temperature of the angularis oculi veins after the cessation of thinking was an increase of 0.8°C for the right vein and 0.6°C for the left for a net increase of 1.4°C of the pre-thinking levels.

3. Grass Instruments Co., Quincy, MA.

TABLE I : Temperature data for the angularis oculi and median antebrachial veins.

			°C						
Subject number[a]	*Sex*	*Vein*[b]	*Before thinking*	*Maximum change during thinking*	*Net change for both sides*	*Maximum change after thinking ceased*	*Net change for both sides*	*Difference between before and after thinking ceased*	*Net change for both sides*
1	F	L	34.8	− .3	− .5	+ .4	+ .5	+.1	0
*		R	34.6	− .2		+ .1		− .1	
2	M	L	36.7	− .6	− .7	+ .2	+ .7	− .4	0
*		R	36.3	− .1		+ .5		+ .4	
3	M	L	35.3	− .5	−1.1	+ .5	+ .7	+ 0	− .4
*		R	34.7	− .6		+ .2		− .4	
4	M	L	36.6	− .2	−1 1	+ .2	+ .9	0	− .2
*		R	35.4	− .9		+ .7		− .2	
5	F	L	30.7	− .9	−1.4	+1.1	+1.7	+ .2	+.3
*		R	33.5	− .5		+ .6		+ .1	
		A	32.3	− .3	—	0	—	− .3	
6	M	L	36.2	−1.0	−2.0	+ .8	+1.4	− .2	− .6
*		R	35.4	−1.0		+ .6		− .4	
		A	35.3	− .8	—	0	—	− .8	
7	F	L	35.0	− .6	− .8	+ .9	+ 1.2	+ .3	+.4
*		R	34.3	− .2		+ .3		+ .1	
		A	32.8	0	—	+ .2		+ .2	
8	M	L	34.8	0	− .2	0	+ .2	0	0
**		R	34.7	− .2		+ .2		0	
9	M	L	34.7	− .3	−1.5	+ .6	+1.9	+ .3	+.4
**		R	33.4	−1.2		+1.3		+ .1	

a*thermistors placed between the angularis oculi vein and nasal bone near the medial canthus of the eye

**thermistors placed on the skin surface overlying the angularis oculi vein near the medial canthus of the eye

b L = left angularis oculi vein

R = right angularis oculi vein

A = median antebrachial vein

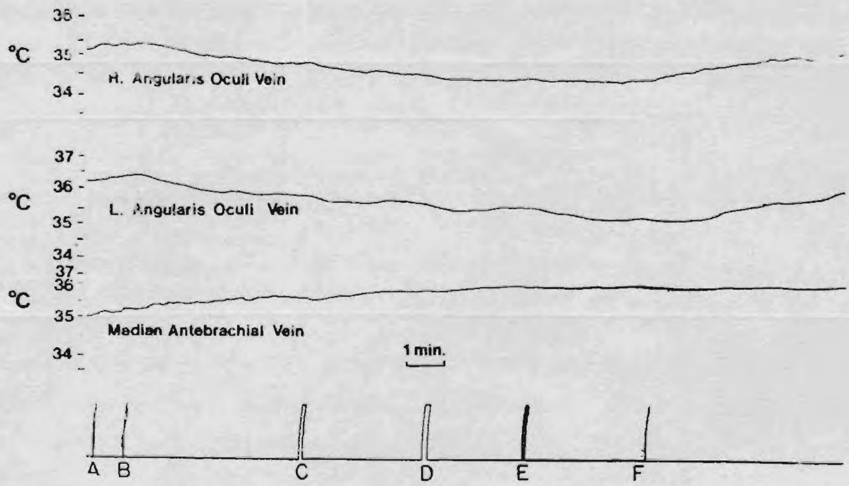

Fig. 1 : Continuous temperature recordings for subject 6. A to B : mental rest, eyes closed, room darkened; B to C : arithmetic, eyes closed, room darkened; C to D : reading non-cognitive material, lights on ; D to E: reading cognitive material, lights on ; E to F : reading cognitive material with music, lights on; F to end: mental rest, eyes closed, room darkened.

The temperature of the median antebrachial vein remained at 0.8°C, the same as pre-thinking levels after all stimuli !were discontinued. The subject began performing the mental exercises at B. The temperatures of both veins decreased about the same during the interval B to C. Using thermistor beads, the temperature recordings of the right and left angularis oculi veins for Subject 9 are shown in Fig. 2. The maximum decrease in the temperature of the right vein quadrupled that of the left, i.e., –1.2°C and –0.3°C, respectively, and this was attained in four minutes and forty seconds (B to C).

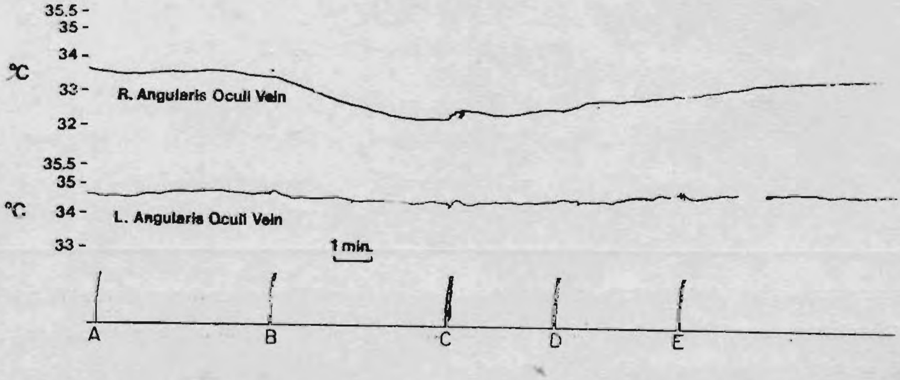

Fig. 2 : Continuous temperature recordings for subject 9. A to B : mental rest, eyes clcsed, room darkened; B to C: arithmetic. eyes closed. room darkened; C to D: arithmetic, eyes open, lights on ; D to E: artthmeic, eiyes open, lights on, news report on radio; E to end: mental rest, eyes closed, room darkened.

There was no apparent relationship between the temperature profiles of the median anterbrachial vein and the right and left angularis oculi veins (Subjects 5, 6, and 7 - Table I). However, temperature changes occurring at all over time in the absence of any thinking in this experimental group have not been monitored in this preliminary study.

DISCUSSION

Bear in mind that a) on the basis of oxygen utilization, mental arithmetic causes an increase in brain temperature, b) under normal physiologic conditions, the cerebral arterial circle does not permit an intermingling of the bloodstreams in its contributing vessels of the contralateral side, and c) during normothermia and hyperthermia, blood is flowing from the facial and nasal regions, possibly due to relative increase of the sphincter tone of the facial vein, towards the cavernous sinus where it bathes the internal carotid artery which is conducting blood ascending to the brain. Further, deviation of cool blood to deeper venous sinuses has been shown to be an important thermoregulatory mechanism (28). The evidence presented here supports the concept that the rate of heat transfer from the superficial vessels in the face and nasal mucosa to the ambient air is regulated in responses to mental activity. Consequently, the temperature of the venous blood flowing towards the cavernous sinus via the angularis oculi vein is decreased during periods of increased heat production in the brain occasioned by an increase in the level of mental activity. For obvious reasons brain temperature could not be measured directly in these experiments. Although temperature changes did occur in the median antebrachial vein, which is not a component of the venous pathway from the facial and nasal areas to the cavernous sinus, the changes were not synchronized with mental activity as were the angularis oculi veins (Subjects 5, 6 and 7 – Table I). There was no relationship between temperature changes in both angularis oculi veins and handedness as they relate to mental function.

Other investigators have demonstrated that the blood in the cerebral arterial circle does not cross the midline under normal physiologic conditions. Therefore, one could postulate in the case of Subject 6 where the maximum decrease in both veins was the same, that the two cerebral hemispheres show lesser degree of specialization, i.e., bilaterally organized with respect to the mental arithmetic that was being performed. In the case of Subject 9 where the maximum decrease in the temperature of the right angularis oculi vein was four times that of the left vein, one could speculate that there was lateralization of function of the right hemisphere which was organized for performing the arithmetic, although mental arithmetic and reading are believed to involve relatively more left than right hemisphere processing. Otherwise it may be possible that tasks concerning mental arithmetic are not optimal for differentiating lateralized activities between hemispheres as observed temperature changes were equally distributed between the right and left hemispheres with one subject showing no difference.

However, differences in the distribution of gray and white matter in human cerebral hemispheres, especially in the frontal and precentral regions (11) and a sexual dimorphism in the functional asymmetry of human brain (15) may tend to influence the temperature changes in the angularis oculi veins. In addition, cyclic alternation of airflow pattern through both nostrils due to engorgement of venous plexuses in the conchae and nasal septum of the rat and rabbit (24) and in sheep (25) might reflect in the relative changes in the angularis oculi vein temperatures.

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