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Hypothesis

Arachnoid granulations may control heat exchange between intracranial dural sinuses and cerebrospinal fluid

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Selective brain cooling;
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Abstract
Selective brain cooling is a system in a human that protects the brain from hyperthermia. Cool venous blood from head skin and upper respiratory tract drains into intracranial dural sinuses. In that region, cool blood in the dural sinuses decreases the temperature of the cerebrospinal fluid. Cerebrospinal fluid provides brain cooling. All cortical arteries to the brain pass the cerebrospinal fluid compartment. Also cerebrospinal fluid washes cortical nervous tissue.
To provide optimal temperature for the brain cortex, heat exchange between cerebrospinal fluid and venous blood in dural sinuses should be well controlled. Head skin is in direct contact with the outside, and significant heat exchanges may occur within dural sinuses. A barrier made of dura mater and arachnoid mater has been proposed to transmit heat from dural sinuses to the cerebrospinal fluid. However, this barrier is a mechanical barrier and can't optimize the temperature of cerebrospinal fluid. Also it has two laminas (dura mater and arachnoid mater) and dura mater has a high vascularization. Therefore, this barrier may obstruct heat exchange.
In this hypothetical paper, I offer arachnoid granulations as a functional barrier for heat exchange between blood in dural sinuses and cerebrospinal fluid. Arachnoid granulations are invaginations of arachnoid mater to the dural sinuses. Cerebrospinal fluid passes to the dural sinuses via arachnoid granulations. An arachnoid granulation provides a very thin wall between two compartments and may transmit heat effectively. Also arachnoid granulations may control cerebrospinal fluid flow to the dural sinuses according to temperature differences between two compartments. It is worth researching whether there are any functional or histological differences of the arachnoid granulations between people living in cold and hot places. There may also be an association between pathologies such as migraine and pseudotumor cerebri and this possible control mechanism.

SELECTIVE BRAIN COOLING

Cells and tissues need optimal heat for best enzymatic activity. Body temperature is well controlled by hypothalamic nuclei. However, there is an extra control mechanism for brain temperature identified in a number of animal species called "carotid rete" [1]. Arterial blood supply to the brain is being cooled by venous blood within carotid rete. This mechanism is referred to as "selective brain cooling".

Humans have no carotid rete. However, there are some anatomic features that are supposed to correspond to selective brain cooling [2-4]. Cool venous blood from head skin drains to intracranial dural sinuses [Fig.1]. Venous blood of nasal mucosa and paranasal sinus mucosas are cooled by evaporation. This blood drains to intracranial dural sinuses, as well. Cerebrospinal fluid fills subarachnoid space and the surrounding region with intracranial dural sinuses. The temperature of cerebrospinal fluid is reduced by cool venous blood within dural sinuses. Cooling cerebrospinal fluid is very important for brain cooling, because all cortical arteries to the brain pass the cerebrospinal fluid compartment. Also cerebrospinal fluid washes cortical nervous tissue. Cortical arteries and cortical tissues increase the temperature of cerebrospinal fluid. Cooling cerebrospinal fluid provide brain cooling. Sphenoid and ethmoid sinuses are suggested to contribute to selective brain cooling by cooling inferior segments of the brain and internal carotid artery across very thin bone layers [5].

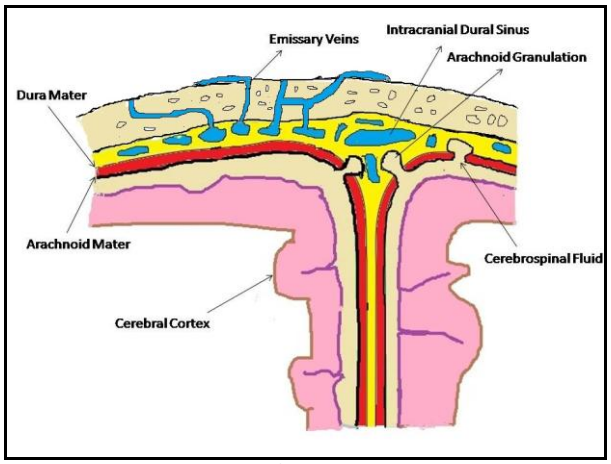

Figure 1. Cool venous blood from head skin drains to intracranial dural sinuses via emissary veins. Heat exchange occurs between venous blood and cerebrospinal fluid.

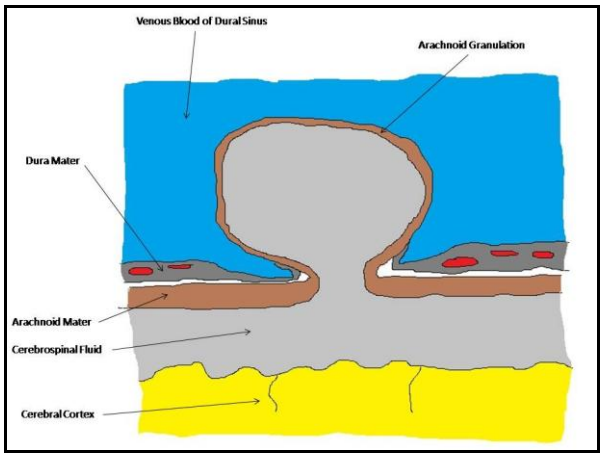

Figure 2. There is a barrier between venous blood and cerebrospinal fluid made of dura mater and arachnoid mater. Being formed from two laminas (dura and arachnoid mater) and because of extraordinarily high vascularization of dura mater, this structure may isolate two compartments from heat exchange. Arachnoid granulations may be the only points at which heat exchange occurs.

The brain has significant metabolic activity and blood supply. Also it is isolated from the outside by cranial bones. Selective brain cooling is very important for optimal brain function. However, there should be a control mechanism for selective brain cooling. Venous blood of the head skin drains to dural sinuses via emissary veins [Fig.1]. Emissary veins are valveless, and blood may flow in both directions [6]. Head skin is directly connected to the outside. So it can cause great temperature exchanges in dural sinuses during hyperthermia or hypothermia.

A possible mechanism for control of selective brain cooling has been previously described [7]. It hypothesized that to keep the brain warm, cooling activity of paranasal sinuses may be obstructed during hypothermia. It suggested that sinus ostiums may close and mucus may accumulate to reduce air within sinuses. Moreover, this hypothesis proposed to explain why a person gets a sinus headache during cold weather. In the present paper, I propose another mechanism for control of selective brain cooling:

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There is a barrier made of dura mater and arachnoid mater between venous blood in dural sinuses and cerebrospinal fluid. However, this barrier is a mechanical barrier and can not control excessive heat exchanges. Furthermore, being formed from two laminas (dura and arachnoid mater) and possessing extraordinarily high vascularization of dura mater, this structure may isolate two compartments from heat exchange. There needs to be a thin and functional barrier. I offer arachnoid granulations as a functional barrier for heat exchange between blood in dural sinuses and cerebrospinal fluid. Arachnoid granulations are invaginations of arachnoid mater to the dural sinuses [8]. Cerebrospinal fluid passes to the dural sinuses via arachnoid granulations [Fig.2]. Arachnoid granulations provide a very thin wall between two compartments and may transmit heat effectively. Also arachnoid granulations may control cerebrospinal fluid flow to the dural sinuses according to temperature differences between the two compartments.

It seems to be worthwhile to search if there are any functional or histological differences of the arachnoid granulations between people living in cold and hot places. There may also be a link between pathologies such as migraine and pseudotumor cerebri and this possible control mechanism.

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