Medical Hypotheses 104 (2017) 10–14

Contents lists available at ScienceDirect

Medical Hypotheses

journal homepage: www.elsevier.com/locate/mehy

Demyelinating diseases as a result of cerebral edema?

Helmut Barz [a,b,*], Almut Schreiber [c], Ulrich Barz [d]

[a] Holunderweg 17, D-18209 Bad Doberan, Germany
[b] Department of Neuropathology, Dietrich-Bonhoeffer Hospital, D-17022 Neubrandenburg, PF 400135 Mecklenburg-West-Pomerania, Germany
[c] Fit for work, Bautzener Landstraße 91, D-01324 Dresden, Saxony, Germany
[d] Helios-Klinikum Pirna, Struppener Straße 13, D-01796 Pirna, Saxony, Germany

ARTICLE INFO

Article history:
Received 6 November 2016
Accepted 1 May 2017

Keywords:
Tissue edema
Tissue pressure
Multiple sclerosis
Osmotic demyelination Syndrome
Migraine

ABSTRACT

Due to the elastic properties of the human organs, tissue edema causes an increased tissue pressure. This phenomenon leads to a reduction of blood circulation or ischemia, and thus leads to the hypothesis that tissue edema can be the cause of demyelinating lesions. Even though brain edema occurs in the whole brain, the authors assume that the characteristically focal appearance of demyelinated lesions, for instance of multiple sclerosis plaques, are attributable to anatomical and structural characteristics of the brain. In an experimental section, a balloon inserted into the brain and other organs removed during autopsies produces an increased tissue pressure. This model shows tissue pressure in the vicinity of the balloon up to 80 mmHg. The height of the produced pressure varies in different organs and special regions of the brain.

The verified pressures in the pons cerebri show that stretched myelinated fiber bundles in outer regions can induce strong pressures in enclosed edematous tissue, as seen in central pontine myelinolysis.

The presented experimental results support the hypothesis that demyelinated lesions, as seen in multiple sclerosis, may be caused by increased tissue pressure, or respectively, brain edema.

Introduction

Edema or other additional volume (bleedings, neoplasms) lead to an increased tissue pressure [1–4]. It is known that edema causes the increased intracranial pressure in cases of idiopathic intracranial hypertension and mountain sickness [5,6].

The main reason for the increase of tissue pressure in swollen organs is caused by the fact that cellular membranes and fibrous tissue structures have elastic properties. This especially involves the elastic and collagenous fibers, and in the brain in particular the neuronal and glial fibers. The myelin sheets of the axons; the vascular network, and the meninges show special elastic features.

For physical reasons, an increase in tissue pressure leads to a reduction in blood circulation. Hypothetically, we therefore assume that the consequence of edematous tissue swelling cause a hypoxic tissue damage, or even demyelinating brain lesions.

The numerous causes for the development of tissue edema cannot be taken into consideration in this paper.

However, it would be of considerable interest to see whether certain biochemical abnormalities of the white matter in MS patients promote the development of brain edema [7].

The rather complex structure of the central nervous system, which includes coating by the skull and the dura mater, cerebrospinal fluid filled spaces, and differences in elasticity of the white and gray matter [8,9], may explain that in cases of edematous brain swelling, the tissue pressure is not uniformly distributed, as it is in a fluid-filled cavity. Such pressure differences in the tissue initiate differences in the regional blood perfusion.

Hypothetically, it may be possible that the typical distribution patterns of the demyelinated lesions in multiple sclerosis (MS) are, in a certain sense, the most vulnerable regions of the brain under conditions of an increased tissue pressure.

MS plaques are often found in areas of close proximity to cerebral veins, encapsulated tissue areas, border-zones between the white matter and the brain ventricles, as well at border-zones between the white matter and the brain cortex.

The hypothesis that tissue edema, amongst other things, can cause demyelinating lesions, is based on the following argument: Multiple sclerosis (MS), migraines, and idiopathic intracranial hypertension affect women mainly during childbearing years.

* Corresponding author at: Holunderweg 17, D-18209 Bad Doberan, Germany.
E-mail addresses: helmutbarz@gmx.de (H. Barz), almut.schreiber@fit-for-work.eu (A. Schreiber), ulrichbarz@yahoo.de (U. Barz).

http://dx.doi.org/10.1016/j.mehy.2017.05.010
0306-9877/

The hormonal changes resultant from the menstrual cycle or pregnancies, are often accompanied by a considerable increase in edema formation throughout the entire body (premenstrual syndrome, pre-eclampsia) [10].

Pressure measurements on living organs pose numerous difficulties. Therefore, scientific publications on measurements of elasticity or pressure in the brain tissue are quite rare [11]. We only found one investigation of tissue pressure based on a thin elastic cylinder within the brain tissue [12].

Experimental arrangement for the measurement of an increased pressure in swollen tissues

In an experimental approach on human organs, removed during autopsies, measurements were carried out to quantify a local increase in tissue pressure.

A medical needle of Ø 0.9 mm sealed at the tip, was coated with an expandable thin-walled balloon of 1.7 cm in length and Ø 7 mm.

The balloon was connected to the inside of the needle by a hole in the needle wall. The needle with the coated balloon was penetrated into the brain tissue or other organs. Using hoses, the needle was connected to a commercial water-filled manometer and, parallel to this, to an insulin syringe (Fig. 1). The initially collapsed balloon was inflated using the syringe. The pressure in the balloon was continuously monitored by the manometer.

It should be noted that the pressure values on the manometer are composed of two pressure parts.

The first component represents the tissue pressure at the outer border of the balloon, which is caused by the elastic properties of the various expanded tissues. This tissue pressure decreases with increasing distance from the balloon, corresponding to the constantly decreasing stretch of the tissue.

The second part of the pressure is generated by the expansion of the balloon by filling it (a necessary pressure to inflate an air balloon). This second partial pressure can be seen as the volume-pressure curve of the balloon in Fig. 2. The pressure curves of the various organs in Fig. 2 are based only on the rising tissue pressure in the vicinity of the balloon.

Another feature of the measuring system should be considered. The volume of the balloon is not equal to the decreasing volume in the syringe. The manometer takes up about 30% of the injected water. The horizontal axis (x-axis) in Fig. 2 represents the real volume of the balloon (about 70% of the injected water of the syringe).

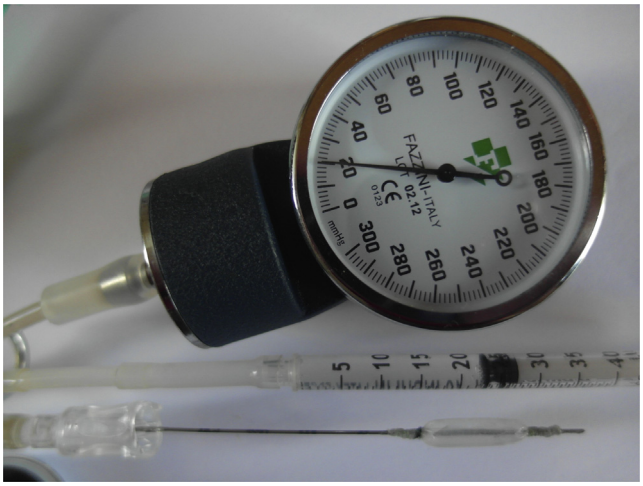

Fig. 1. Tools used for the measurement of pressure in expanded tissue (thin-walled rubber balloon, manometer, hypodermic syringe).

The axis of ordinates (y-axis) represents the hydrostatic pressure (mm Hg).

Measurement results

With the exception of the air-filled lung, all of the investigated organs show a similar, relatively high increase in tissue pressure even at a low filling stage of the balloon (Fig. 2).

However, as the volume of the balloon increases, the tissue pressure in the relatively soft brain tissue (examined at white matter (n = 4) and pons cerebri (n = 4)) increases to a lesser extent than in solid organ tissues (kidney n = 2, liver n = 2, myocardium n = 3, and even the lung n = 2).

With further expansion of the balloon, the pressure in the brain tissue no longer increases, but actually falls. The cause of this anomaly is likely tearing and dissection of the (dead) tissue at the vicinity of the balloon, resulting in the loss of elastic forces.

This relatively simple technique corresponds most closely to acute arterial bleeding. The authors assume that this experimental model also illustrates the increasing pressure of a swollen edematous tissue.

Discussion

Edema and blood perfusion pressure

The perfusion pressure of the blood vessels corresponds with the difference between the blood pressure and the tissue pressure. The blood flow and the volume of the blood vessels change with the increasing tissue pressure. When the tissue pressure rises, functional disturbances and ultimately irreversible tissue damages occur.

Tissue necroses caused by edema occur seldom. The cause of the moderate increase of the tissue pressure in most cases of brain edema is often based on the possibility that parts of tissue can escape into available adjacent spaces (brain herniation) [13].

Increased tissue pressure in regions of limited space

Necrosis of edematous swollen tissues or organs may occur if the tissues are restricted from further expansion by a more or less solid capsule.

Examples of such tissue necrosis include brain death following severe head trauma, atrophy of testis after blunt trauma, and necrosis of muscles in an acute compartment syndrome [1]. Furthermore, it is well known that an increased intraocular pressure (glaucoma) may lead to blindness in consequence of the ischemic atrophy of the retina. The sclera of the eye presents a continuation of the dura mater.

Coated by the dura mater, the optic nerve as well as the spinal cord (particularly the relatively wide intumescentia cervicalis) are common loci of demyelinated lesions in MS and neuromyelitis optica [14,15].

If expanded capsule-like myelinated fiber bundles enclose areas of edematous swollen gray matter (comparable with the inner space of a balloon), the pressure increases in these areas more than in edematous gray matter areas without such surrounding fiber bundles:

Capsular structures in central pontine myelinolysis (CPM)

Suggestions for our measurements have been found in the conclusion from Messert et al. (1979) that in cases of CPM an increased tissue pressure can be the cause of tissue necroses [16].