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TRAUMATIC DAMAGE PATHOMECHANISM OF CEREBRAL VESSELS CAUSED BY GERIATRIC CHANGES

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The knowledge of mechanical properties of the brain blood vessels enables an assessment of pathological changes caused by human aging. As it results from our investigations, a greater elasticity of blood vessels in the occipital region accounts for the rare occurrence of subdural space blood clots in this region of the brain. Also, a map can be derived based on our results, of the most severe head trauma directions causing damages of blood vessels in the subdural space.

Key words: Biomechanics, cerebral vessels, mechanical strength, geriatric changes

1. Introduction

The knowledge of mechanical properties of the brain blood vessels enables one to assess the changes evoked by human aging. In the literature these problems were considered by Fung [8], Berg [3], Dali and collaborators [5], Learoyd [17] and Yates [25], as well as Sobin [21]. Principally, the mentioned authors were concerned with extracerebral arteries and veins in the human and in the animal. However, no results have been reported on determining the mechanical strength of cerebral veins. Taking into account an important role played by the cerebral vessel system in the subdural haematoma pathomechanism, we have addressed these problems in this paper.

Many existing contributions dealing with subdural haematomas (Aronson [2], Greenfield [9], Krauland [15], Sthebens [22], Wolf [24], Lindenberg [18], Jagodziński [12], Kawiak [13]) do not provide any data on the pathological changes in blood vessels caused by human aging. In the case of patients advanced in years, subdural haematomas elicit considerable diagnostic problems. The senile age period is characterized by a decrease of brain mass, an extension of ventricles and of the subarachnoid space (DYMECKI and OSTROWSKA [6], [7], LUERS and SPATZ [19], MOREL and WIDI [20], HALLERVORDEN [10], ALBERT [1], BRAUNMÜHL [4], HASSLER [11], TARNOWSKA-DZIDUSZKO [23]).

A large individual variability of cerebral blood vessels should be stressed (KĘDZIA [14], KRAYENBUHL [16]), whose understanding will allow us to comprehend the pathological processes completely.

It should be expected that an examination of mechanical strength of cerebral veins on the basis of a static tensile test cannot be accomplished on the typical tensile strength machines. The reason is that the minimum value of tension force measured by the machine exceeds considerably the maximum feasible tension force applicable to cerebral veins. An adaptation to this purpose of the usual machinery exploited for tensile steel test pieces or for resembling cerebral veins elastomeric test pieces, so far has not brought in any positive results. Also, it has been observed that ordinary, plane, self-locking jaws may crush the cerebral vein with a part of their mount. An apparent sign that a destruction caused by tightening the mount jaws begins is a decrease of the tensile force accompanied by an increase in the measured sample extension.

In these circumstances we needed to design a specialized research instrumentation presented in Figs. 1–2, as well as to assemble appropriate electronic devices able to register the measurement results.

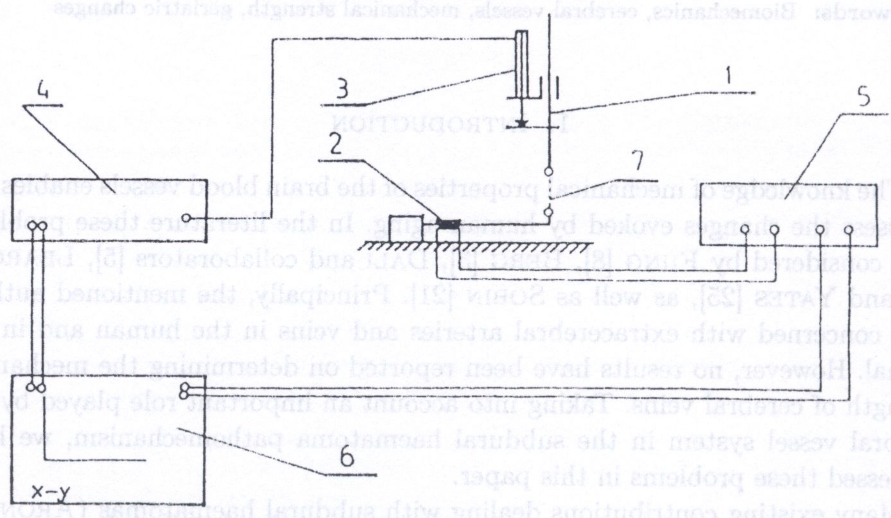

FIG. 1. Block diagram of the research stand: 1 – microscarifier, 2 – force sensor, 3 – linear extension sensor, 4 – mechanical quantities gauge, 5 – stabilized electric feeder, 6 – XY recorder, 7 – test sample.

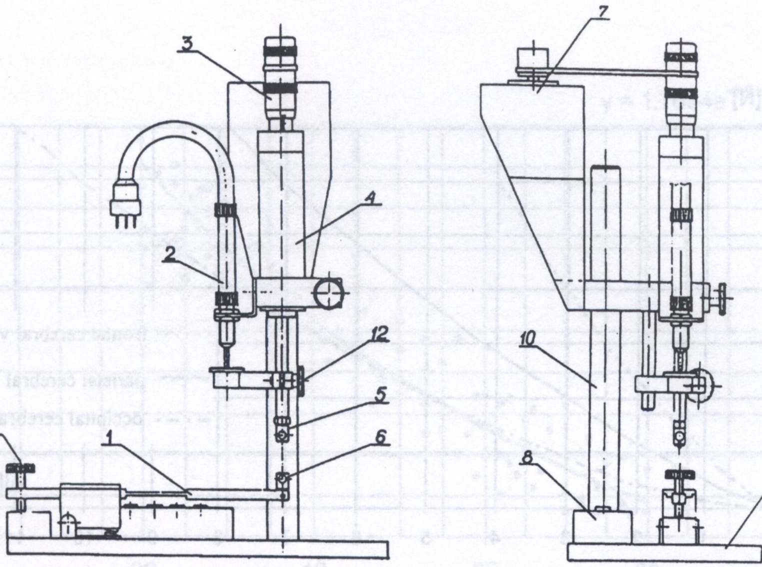

FIG. 2. Microscarifier: 1 – force gauge beam, 2 – linear extension sensor, 3 – analog displacement indicator, 4 – tightener unit, 5 – upper mount seat, 6 – lower mount seat, 7 – actuator, 8 – force gauge electrical unit, 9 – base of microscarifier, 10 – column, 11 – preliminary tension correction screw, 12 – preliminary tension control knob.

The microscarifier has been equipped with a system allowing for a precise control of the applied tension force. The measurement of physical quantities, such as extension and tension force, has been accomplished, respectively, by a displacement and a force sensor. The measuring and registering system consists of a stabilized electric feeder, a measuring instrument of mechanical quantities, and an XY recorder.

Along with human aging, the value of breaking force decreases, a suitable dependence $F(t)$ for frontal veins is presented in Fig. 5, for parietal veins – in Fig. 6, while for occipital veins – in Fig. 7. Even these preliminary results reveal a strict dependence between the vessels strength and the human age and the cerebral region from which the vessels were taken out. The results inform also of changes in time of the properties of collagen and elastin, and allow to assess the pathomechanism of subdural haematoma. In reference [15] KRAULAND points out that a hit in the head from the front-lateral side or from behind causes a brain displacement followed by breaking the bridge veins, particularly in persons suffering from a certain atrophy of the brain mass. According to ZULCH [26], a predilective region for subdural haematomata is the frontoparietal area. An occipital trauma yields a damage of frontal veins according with the d'Alembert principle. A parietal trauma causes a disruption of the opposite parietal veins.

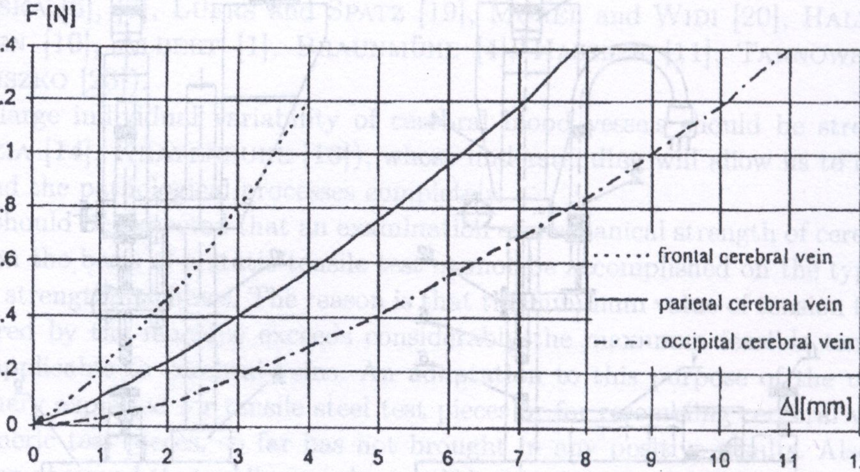

FIG. 3. Tensile force F vs. extension Δl plot for cerebral veins (a man of age 20).

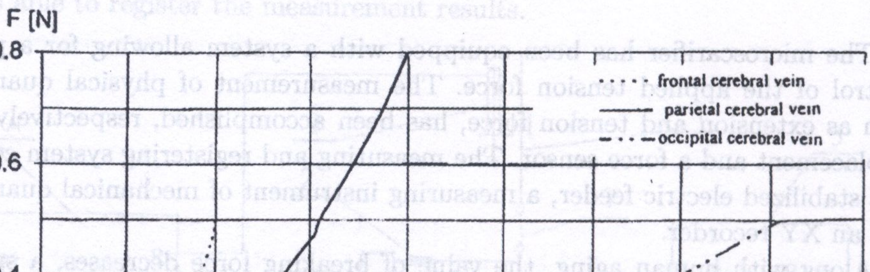

FIG. 4. Tensile force F vs. extension Δl plot for cerebral veins (a man of age 70).

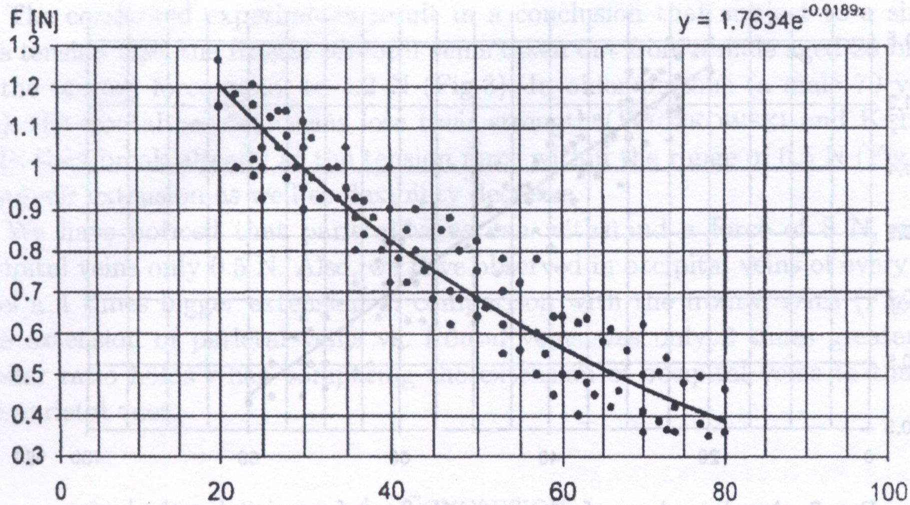

FIG. 5. Age dependence of average tensile forces for frontal cerebral veins.

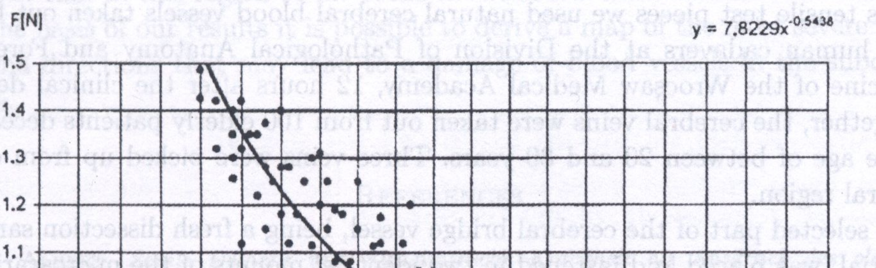

FIG. 6. Age dependence of average tensile forces for parietal cerebral veins.

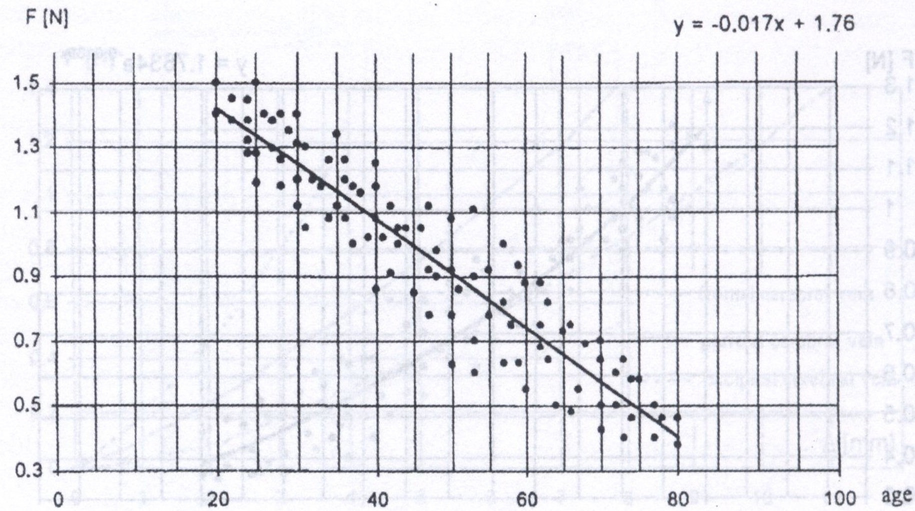

FIG. 7. Age dependence of average tensile forces for occipital cerebral veins.

2. Experimental setting

As tensile test pieces we used natural cerebral blood vessels taken out from fresh human cadavers at the Division of Pathological Anatomy and Forensic Medicine of the Wrocşaw Medical Academy, 12 hours after the clinical death. Altogether, the cerebral veins were taken out from 100 elderly patients deceased at the age of between 20 and 80 years. Three veins were picked up from each cerebral region.

A selected part of the cerebral bridge vessel, being a fresh dissection sample material, was placed and fastened in two identical mounts of the microscarifier, suitably matched to the diameter of the tested object (Fig. 3). The mounts were adjusted in such a way that they produced a pure tension, with no torsion effect. One end of the vein was seated in the measuring beam (Fig. 2, item 6), while the other was inserted in a mount on the slide block of the tension unit (Fig. 2 item 5). The force and extension were registered using an XY self-registering recorder as a function plot $F(\Delta l)$, applying a constant load velocity up to the breaking point.

In the course of this experiment we have observed both shape changes of the examined object as well as the narrowing point as a spot of a likely break. The sample lengths were 9 times greater than the vessel diameter. All the experiments were performed at the same tension velocity, equal to 1 mm/min.

3. Results

The conducted experiments result in a conclusion that subject to a single axis tension test, the frontal cerebral veins taken out from a male aged 20 break at the tension force equal to 1.2 N (Fig.3). In older persons (a male 70 years old), the frontal cerebral veins lose their strength (Wiczkowski and Kędzia [27]); they break already at the tension force within the range of 0.5 N (Fig. 4), also their extension as well as flexibility decrease.

We have noticed that parietal veins can withstand a force of 8 N, while occipital veins only 0.5 N. Also, we have observed in occipital veins of every age level a 4 times bigger extension in comparison with the frontal veins (Fig. 4). The extension of parietal veins vs. frontal veins was only 2 times greater. A similar ratio holds when comparing the extension of occipital veins to that of the parietal ones.

4. Conclusion

The mechanical strength of cerebral blood vessels depends on many factors, but it is most affected by the aging process. The presented functional characteristics $F(t)$ for cerebral veins (Figs. 5, 6, 7) confirm this conclusion completely. A larger flexibility of occipital veins, as follows from our experiments, confirms the fact that in this region of the brain the subdural haematomata occur rarely. On the basis of our results it is possible to derive a map of the most severe head trauma directions that may lead to a damage of blood vessels in the subdural space.

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