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Short communication

Age dependence of critical pressure in the segments and branches of the circle of Willis

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ABSTRACT

Spontaneous intracranial haemorrhage is one of the most dramatic neurological disasters. The source of haemorrhage is linked to the pathology of the arterial wall or is unknown. Because the risk of haemorrhagic stroke increases with age, we tried to investigate the relationship between age and rupture pressure of cerebral arteries. In the presented study, 51 segments of large cerebral arteries (at the level of the circle of Willis and its incoming and outgoing branches) were obtained from 33 cadaver brains aged 12–86 years. The segments were pressurized up to the rupture. The rupture pressure was noted. The highest observed pressure was 4.3 atm in specimen aged 24 years. The lowest pressure 1.19 atm was observed in specimen aged 80 years. The mean value of rupture pressure of all investigated segments was 2.28 atm.

Statistical analysis showed a nonlinear exponential decrease of the rupture pressure of the large cerebral arteries with age. The main conclusion from our study is that drop of cerebral arteries strength is observed to the age of 40. Later this lowering is visible but not so evident.

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1. Introduction

Spontaneous intracranial haemorrhage is one of the most dramatic neurological disasters that can result in devastating mental, motor and sensory disabilities. Usually, it coincides with elevated blood pressure. The highest value of systolic blood pressure during submaximal effort does not exceed 220 mm of mercury [1], whereas the highest value of systolic pressure in ambulating patients with hypertension does not

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Table 1 – Rupture pressures of all investigated groups of segments along with the standard deviations and the minimal and the maximal values.

Segment	Number	Mean rupture pressure [atm]	SD	Minimal rupture pressure (age) [atm]	Maximal rupture pressure (age) [atm]
BA + VA	12	2.24	0.45	1.71 (64)	3.05 (48)
ICA	5	2.15	0.56	1.38 (50)	2.65 (60)
M1	23	2.38	0.86	1.19 (80)	4.30 (24)
P1P2	7	2.22	0.29	1.81 (40)	2.50 (55)
ACoA	3	2.27	0.87	1.27 (80)	2.90 (29)
A1/A2	1	1.25	–	1.25 (39)	1.25 (39)
All	51	2.28	0.68	1.19 (80)	4.30 (24)

exceed 240 mm of mercury [2]. In patients hospitalised due to the hypertensive crisis, similar values are observed [3] that is, much less than 0.5 atm. Many persons tolerate such levels of pressure without intracranial haemorrhage from the moment of its detection to the moment of pharmacological lowering, which takes usually several minutes. Greater pressures are applied during intravascular procedures like balloon angioplasty and others [4]. Because of the frequency of haemorrhagic stroke as well as intravascular procedures increases with age [5–7] we tried to investigate the relationship between age and rupture pressure of large cerebral arteries. Results of the presented investigation show changes of the mechanical resistance of large cerebral arteries to transmural pressure with age.

2. Materials and method

The segments of cerebral arteries were obtained from 33 cadaver brains (27 men, 6 women) referred for an autopsy to the Department of Forensic Medicine of Warsaw Medical University. The donor age ranged from 12 to 86 (Mean 51 ± 17) years at the time of death. The death was from non-neurological pathology. All examined arterial segments were extracted at the level of the circle of Willis and its incoming and outgoing branches under a surgical microscope using a micro-neurosurgical technique. The samples had typical length of 1–2 cm with as small as possible number of perforators, which were ligated very close to the main trunk with 6.0 silk. Each of chosen segments was rinsed in normal saline and its inlet end was inserted on the Luer needle with flared tip and secured with 4.0 silk sutures. The outlet was closed with an aneurysm clip. Such prepared segment was mounted in a special container filled with normal saline. The Luer needle was connected via a T-joint to the computer controlled pump and the pressure transducer. The pressure was elevated under continuous visual and computer monitoring up to the rupture of the investigated segment.

3. Results

The highest observed pressure was 4.3 atm in a segment of the middle cerebral artery aged 24 years. The lowest pressure 1.19 atm was observed also in the segment of the middle cerebral artery while aged 80 years. The mean value of rupture pressure of all investigated segments was 2.28 atm. The mean rupture pressures of specific segments were above 2 atm.

Table 1 shows rupture pressures of all investigated groups of segments along with the standard deviations and the minimal and the maximal values.

51 segments in total were evaluated. The results of critical pressure of all investigated arterial segments as a function of donor's age are presented in Fig. 1 and indicates decreasing trend between both values. Nonlinear regression line were approximated by function $Y = 4.42\exp(-0.0482X) + 1.75$ with coefficient of determination $R^2 = 0.45$.

The morphology of rupture presents a variety of patterns, which was identified and evaluated under magnification. Ruptures occurred mainly at the main vessel trunk and their pattern was spiral, longitudinal or transversal in relation to the main axis.

4. Discussion

Preliminary results of our group, as well as the Lithuanian group showed that value of rupture pressure for cerebral arteries is much higher than highest observed values of systolic pressure, which are not greater than 250 mm of mercury that is, less than 0.5 atm [8,9].

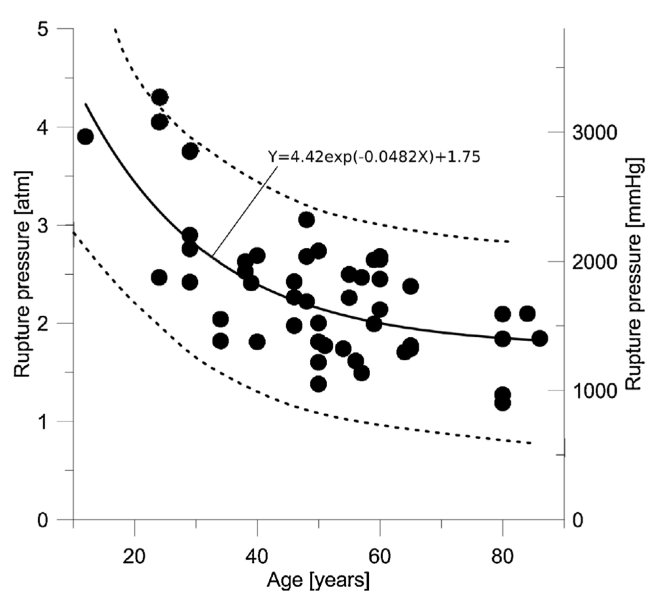

Fig. 1 – Rupture pressure during 53 experiments on 51 investigated cerebral vessels segments. Nonlinear regression trend and 95% confidence bands are marked by the solid and dashed lines, respectively.

We also showed that value of the rupture pressure lowers with age according to the exponential regression. It probably reflects the ageing of collagen fibres which play the main role in the strength of the vessel wall. It is supported by our investigations on adventitia resistance [10]. However, a small number of specimens limits the possibility of better evaluation of this relationship [8]. In present study greater number of specimens and experimental data gives more precise age related characteristic.

The main conclusion from our study is that drop of cerebral arteries strength is observed to the age of 40. Later this lowering is visible but not so evident.

Even after 40, the strength of health cerebral arteries is sufficient to protect the brain from haemorrhage due to the elevation of the blood pressure [1–3]. The study shows the range of structural and biomechanical disaster in the arterial wall of the cerebral arteries which is necessary to the rupture. The fall of rupture pressure from mean 2.28 atm (1733 mmHg) to the 0.328 atm (249 mmHg) indicates 7 times lost of arterial strength. Even in oldest cases, observed rupture pressure is three times greater than pressures observed during intracranial bleeding.

Many intravascular interventions like balloon angioplasty use high pressures to restore blood flow through cerebral arteries. During this procedure, a significant and unknown strain is generated which in some cases may damage the vessel wall and cause sudden intracranial haemorrhage similar to spontaneous intracranial haemorrhage [4].

Therefore, we have to remember about lower strength and greater stiffness of the cerebral arteries in older people which may be a source of important complications during the intravascular treatment.

5. Conclusions

We have experimentally identified values of ultimate pressures of intracerebral arteries. Significant negative age correlation of rupture pressure was shown. Dependence flattens after the age of 40. However, in all cases, it is well beyond the highest possible systolic blood pressures at the level of the circle of Willis.

Conflict of interest

None declared.

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Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

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