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BIOMECHANICAL PROPERTIES OF CEREBRAL FALX AND TENTORIUM CEREBELLI OF HUMAN DURA MATER IN ADULT HUMAN

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The article gives data about research of such biomechanical properties of cerebral falx and falx cerebelli of human dura mater as elongation and ultimate strengtha. The research was made on 103 specimens of human dura mater, taken from cadavers in age from 19 to 95. Established, that specimens of cerebral falx possess higher extensibility then falx cerebelli specimens. But falx cerebelli specimens have 2,0–2,9 times higher ultimate strength.

Key words: cerebral falx, falx cerebelli, unit elongation, ultimate strength.

Introduction. Human dura mater of the brain is widely used in plenty of spheres of medicine. This fact proves the importance of this structure and grounds the scientific approach to study of this organ. As it is known that among these medical spheres are the vascular surgery [1, 6], traumatology [9] and other, it becomes obvious that it's essential to study not only the morphology of human dura mater [4,5], but also biomechanical testing should be carried out. Human dura mater of the spinal cord is a material for production of the surgical suture material, which is successfully exploited in practice [7, 11]. So it is very perspective direction to use human dura mater as a material for production of surgical thread in future due to its characteristics. It doesn't cause immune response. On the contrary, it acts like an immune correcting substance, what allows to use it like an immune corrector in ophthalmology and dentistry [2, 3, 8, 10].

Objectives. This study is aimed at general conclusion and review of biomechanical properties of such processes of human dura mater as falx cerebri and tentorium carebelli.

Materials and Methods. The research was made on 103 specimens of human dura mater, taken from cadavers in age from 19 to 95 during autopsy.

For conduction of biomechanical tests the specimens of cerebral falx and tentorium cerebelli were prepared in special way. For this purpose special instrument and algorithm were developed «The instrument for formation of transplants from dura mater» (patent of Ukraine № 45335 since 10.11.2009) and «The algorithm of preparation of adapted transplants from dura mater of the brain» (patent of Ukraine №44626 since 12.10.2009). The processes of dura mater of the brain were placed on the plane surface and pressed down with the instrument, along verges of which the specimens were excised with a scalpel.

After preparation an additional measurement of each specimen in the middle of its length and width was made, as it is to be the place of a rapture of specimen during tensile and strength tests. Each specimen received its marking and was inserted into special device: «The device for washing out of the dura mater of the brain specimens» (patent of Ukraine № 48625 since 25.03.2010). The washing out of each batch of specimens lasted for 2 hours. After that specimens were left on the open air to let them dry during 10–15 minutes.

He next step was to test the specimens on materials testing machine BZ 2,5 TN1S of German company Zwick Roell. Uniaxial tension of specimens was carried out. With the help of materials testing machine next data were established: unit elongation in % and breaking load at rapture moment in kg.

The ultimate strength of specimens of processes of dura mater of the brain (kg/mm^2) was defined by the ratio of the breaking load, required for the rapture of exact specimen (N, kg) to the area of its cross section in the rapture zone (F, mm^2): $\sigma_p = N/F$. The area of the cross section in the rapture zone was defined by the next formula: $F = L \times h$, where L – the length of the zone cross section, which is to be,

Table 1

Unit elongation of processes of dura mater

Age period	Process of dura	Statistical indicators		
		Mean value ($\bar{X}$)	Standard deviation (σ)	Error of mean (m)
I period of middle age	Falx cerebri	20,46	12,04	3,63
	Tentorium cerebelli	10,64	3,66	0,78
II period of middle age	Falx cerebri	19,31	10,49	1,77
	Tentorium cerebelli	9,53	4,37	0,52
Elderly age	Falx cerebri	16,31	7,91	1,55
	Tentorium cerebelli	8,56	2,72	0,42
Senility age	Falx cerebri	13,13	7,52	2,66
	Tentorium cerebelli	6,63	2,42	0,61

ruptured h – the thickness of specimen in the rupture zone. The speed of movement of mobile terminal of materials testing machine is 100 mm per minute.

Results and discussion. During the study of unit elongation of the specimens of processes of dura mater it was established that this parameter strongly depends on the age. The unit elongation of falx cerebri specimens in I period of middle age dwells in the range from 9 to 45 % ($\bar{X}$ = 20,46 %), and this measure for tentorium cerebelli ranges from 5 to 22 % ($\bar{X}$ = 10,64 %) (table. 1).

The elongation ability of dural processes in people of the II period of the middle age is next: the value of measure for cerebral falx is in the range from 9 to 51 % ($\bar{X}$ = 19,31 %), and for tentorium cerebelli – from 2 to 28 % ($\bar{X}$ = 9,53 %).

In individuals of elderly age the value of unit elongation of cerebral falx specimens ranges from 5 to 37 % ($\bar{X}$ = 16,31 %), of tentorium cerebelli spesimens – from 4 to 15 % ($\bar{X}$ = 8,56 %). In senility age the range of measure for falx cerebri is from 5 to 30 % ($\bar{X}$ = 13,13 %), and for tentorium cerebelli – from 4 to 12 % ($\bar{X}$ = 6,63 %).

As a result of study of ultimate strength measure it was established that it is also strongly depends on the age. Ascertained, that individuals of the I period of middle age have the range of ultimate strength of cerebral falx from 0,09 to 0,74 kg/mm^2 ($\bar{X}$ = 0,34 kg/mm^2), для намету мозочка межа міцності варіює в діапазоні від 0,31 до 2,74 kg/mm^2 ($\bar{X}$ = 0,75 kg/mm^2) (table 2).

In people of II period of the middle age the measures of ultimate strength for cerebral falx are in the range from 0,10 to 1,29 kg/mm^2 ($\bar{X}$ = 0,31 kg/mm^2). Tentorium cerebelli possesses higher ultimate strength, which in people of this age ranges from 0,21 to 2,48 kg/mm^2 ($\bar{X}$ = 0,72 kg/mm^2).

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In people of II period of the middle age the measures of ultimate strength for cerebral falx are in the range from 0,10 to 1,29 kg/mm^2 ($\bar{X}$ = 0,31 kg/mm^2). Tentorium cerebelli possesses higher ultimate strength, which in people of this age ranges from 0,21 to 2,48 kg/mm^2 ($\bar{X}$ = 0,72 kg/mm^2).

The ultimate strength of dural processes in elderly aged individuals distributes this way: the measure for falx cerebri ranges from 0,02 to 1,14 kg/mm^2 ($\bar{X}$ = 0,27 kg/mm^2), and for tentorium cerebelli – from 0,14 to 1,67 kg/mm^2 ($\bar{X}$ = 0,59 kg/mm^2). And in senility aged people this measure ranges from 0,06 to 0,53 kg/mm^2 for cerebral falx ($\bar{X}$ = 0,26 kg/mm^2) and from 0,20 to 1,27 kg/mm^2 for tentorium cerebella ($\bar{X}$ = 0,49 kg/mm^2).

Correspondingly to achieved results and becomes clear, that decreasing of extensibility with age is typical for both studied processes (fig. 1).

Each next period of age is featured by respective decrease of unit elongation of specimens of studied processes relatively to the previous period. Tentorium cerebelli is more rigid structure of dura mater than cerebral falx.

The ultimate strength of cerebral falx and cerebellar tentorium also decreases with age (fig. 2) and the difference in the resistance of these processes is quite significant. Tentorium cerebelly always 1,89–2,32 times more resistant than falx cerebri, that reflects its functional loading directed to the defense of cerebellar lobes from the pressure of the occipital lobes of the brain. Cerebral falx is quite a week part of dura mater of the. Its strength is 2,0–2,9 times less than of tentorium cerebelli. It is not surprising, as its function is not related to resist any pressure, it's just delimits hemispheres of the brain and serves as a base for dural sinuses and veins.

The biomechanical features of cerebral falx on the assumption of the typical for this dural process diagram of extension are relatively week (fig. 3). We can see high extensibility of this process, but its strength is very low. Except that the angle between curve and horizontal axis is very small that reflects its low measures of elasticity.

Tentorium cerebelli possesses higher measures of strength than falx cerebri (fig.. 4). Although having lower measures of extensibility it resists higher load and is more resilient than cerebral falx.

Thereby analyzing biomechanical features of processes of dura mater and their dependence on age we can conclude next that when choosing the proper dural transplant the age of donor should be less or the same as of recipient's. Universal donors of dura mater of the brain are individuals of the I period of middle age as they possess the highest measures of strength of cerebral falx

Table 2

Ultimate strength of processes of dura mater

Age period	Process of dura	Statistical indicators		
		Mean value ($\bar{X}$)	Standard deviation (σ)	Error of mean (m)
I period of middle age	Falx cerebri	0,34	0,17	0,05
	Tentorium cerebella	0,75	0,48	0,10
II period of middle age	Falx cerebri	0,31	0,23	0,04
	Tentorium cerebella	0,72	0,41	0,05
Elderly age	Falx cerebri	0,27	0,23	0,01
	Tentorium cerebella	0,59	0,41	0,06
Senility age	Falx cerebri	0,26	0,15	0,05
	Tentorium cerebella	0,49	0,28	0,07

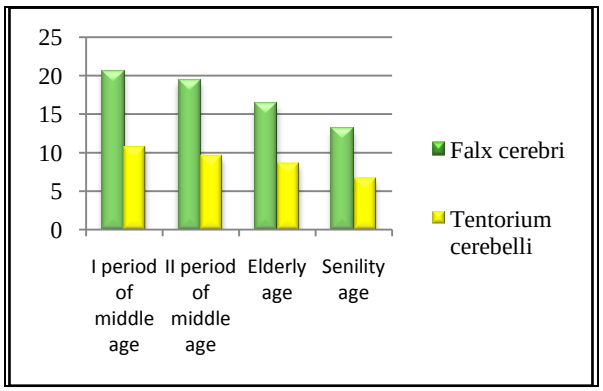

Fig.1. Age-related features of extensibility of studied processes, %.

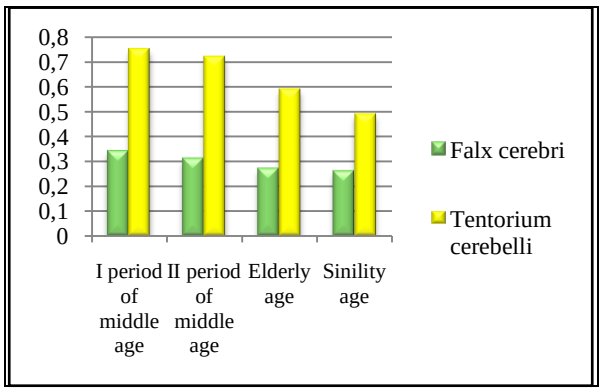

Fig.2. Age-related features of ultimate strength of studied processes, kg/mm^2.

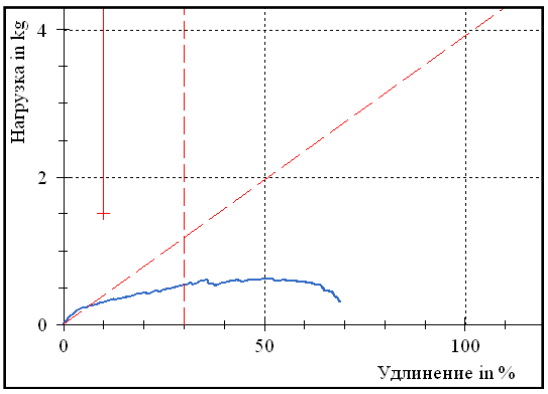

Fig.3. Falx cerebri extension diagram. Sample №11, female, 85 years.

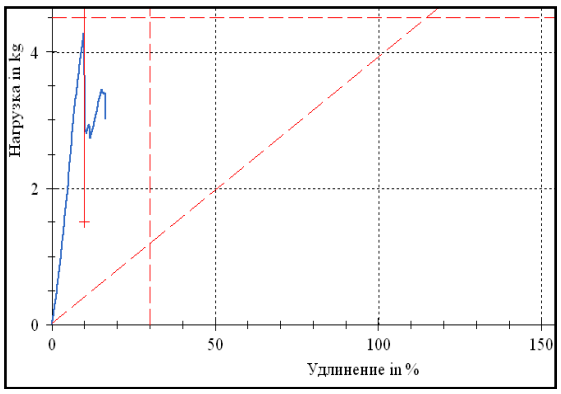

Fig.4. Tentorium cerebelli extension diagram. Sample №15,female, 60 years.

and tentorium cerebelli.

Conlusion. 1. Falx cerebri posesse higher extensibility than tentorium cerebelli.

2. The ultimate strength of tentorium cerebella is 2,0–2,9 times higher than of cerebral falx.

3. The choice of dural transplants should be depending on the donors age. The donor should always be younger than the recipient or f the same age. The individuals of the I period of middle age are the universal donors of dural processes.

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БИОМЕХАНИЧЕСКИЕ СВОЙСТВА ОТРОСТКОВ ТВЕРДОЙ ОБОЛОЧКИ ГОЛОВНОГО МОЗГА ВЗРОСЛЫХ ЛЮДЕЙ

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Резюме. В статье приведены данные исследования таких биомеханических параметров серпа большого мозга и намёта мозжечка человека, как относительное удлинение и предел прочности. Исследование было проведено на 103 препаратах твердой оболочки головного мозга человека, взятых у трупов людей в возрасте от 19 до 95 лет. Установлено, что серп большого мозга имеет большую, чем намёт мозжечка, растяжимость, а намёт мозжечка имеет высшие, чем серп большого мозга, показатели предела прочности в 2,0–2,9 раза.

Ключевые слова: серп большого мозга, намёт мозжечка, относительное удлинение, предел прочности.

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БІОМЕХАНІЧНІ ВЛАСТИВОСТІ ВІДРОСТКІВ ТВЕРДОЇ ОБОЛОНКИ ГОЛОВНОГО МОЗКУ ДОРОСЛИХ ЛЮДЕЙ

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Резюме. У статті наведені дані дослідження таких біомеханічних параметрів серпа великого мозку та намету мозочка людини, як відносне подовження та межа міцності. Дослідження було проведено на 103 препаратах твердої оболонки головного мозку людини, узятих у трупів людей у віці від 19 до 95 років. Встановлено, що серп великого мозку має більшу за намет мозочка розтяжність, а намет мозочка має вищі за серп великого мозку показники межі міцності в 2,0–2,9 рази.

Ключові слова: серп великого мозку, намет мозочка, відносне подовження, межа міцності.