Correlation between Corpus Callosum Shape and Craniometric Measurements According to MRI Data

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Abstract: *The correlation between the cranial height and the height of the corpus callosum trunk bulge, and the relationship between the corpus callosum shape and the cranial shape have not been studied. The purpose of the article was to determine the individual variability of the corpus callosum height and shape of adults, and their dependence on the cranial height and shape. The material was two samples from a series of MR scans of the head of men and women of the second period of adulthood (19 variations in each group) without the central nervous system pathology. Magnetic resonance tomographic scanner Magnetom C was used for obtaining MRI images. Morphometric study was conducted using RadiAnt Dicom Viewer software on MR scans performed in the sagittal area in T1- and T2-weighted images modes. According to the findings, the height of the corpus callosum trunk bulge of men is on average – 26.1 ± 2.8 mm, women – 25.2 ± 2.6 mm, and the neurocranium height – 150.4 ± 6.9 mm and 140.2 ± 4.2 mm, respectively. Wherein the aspect ratio of the neurocranium height to the corpus callosum trunk bulge height in men is 5.8 ± 0.7, in women – 5.6 ± 0.5. The aspect ratio of the corpus callosum longitudinal size along the constricting chord to its trunk bulge height in men is on average 2.8 ± 0.3, in women – 2.7 ± 0.3. The absence of correlation between the cranial height and the corpus callosum trunk bulge height, and the absence of correlation between the corpus callosum shape and cranial shape in people of the second period of adulthood have been concluded.*

Keywords: *brain, corpus callosum shape, corpus callosum trunk bulge height, morphometry, individual variability, neurocranium.*

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Introduction

The corpus callosum has been comprehensively studied for centuries (Sigirl et al., 2012; Van Der Knaap & Van Der Ham, 2011; Westerhausen et al., 2018), whereby it is now known that its function includes interhemispheric information exchange, integration of background information that reaches one or both hemispheres, as well as the facilitation of certain types of cortical activity and its suppression (Aboitiz & Montiel, 2003; Bloom & Hynd, 2005; Buklina, 2005; Roland et al., 2017). Meanwhile, attempts were made to find the representation of the psychophysiological differences between men and women in the corpus callosum size, whereby ambiguous data were obtained (Garel et al., 2011; Roy et al., 2014; Sullivan et al., 2001).

For the achievement of this goal, it is necessary to have data on reliable quantitative criteria regarding its size and shape, which can be obtained by conducting familiar morphometric study, the essence of which is to choose conditional markings on the material, which are typically differently remote points and straight-line distances between them (Farag et al., 2010; Krause et al., 2019; Miguelote et al., 2011). Thus, in the patent for the invention No. 2396907 "Method of lifetime determination of the corpus callosum size", all measurements were made on brain median images obtained by magnetic resonance imaging. They include: 1) corpus callosum genu thickness – the distance between the anterior and posterior points of genu of corpus callosum; 2) the thickness of the anterior department of the corpus callosum – the distance between the upper and lower points of the anterior third of its trunk; 3) middle part thickness – the distance between the upper and lower points of the middle third of the corpus callosum trunk; 4) corpus callosum posterior part thickness – the distance between the upper and lower points of the posterior third of its trunk; 5) corpus callosum splenium thickness – the distance between the anterior and posterior points of its splenium; 6) corpus callosum length – the distance between the anterior and posterior points of the corpus callosum; 7) corpus callosum height – the distance between the line connecting the lower points of genu and splenium, and the upper point of the corpus callosum. Other distances proposed by the author are used to determine the depth of location of the corpus callosum in the cerebrum.

In the literature there are other attempts to conduct a corpus callosum morphometric study. Hence, for quantitive evaluation of corpus callosum F. Tomaiuolo et al. (2014) used a rectangular contour that encircles its boundaries on median MR images of the cerebral hemispheres and allows

to determine the angle of curvature of the corpus callosum by calculating the angle value at the apex of the isosceles triangle that has the same side and altitude as the rectangle circumscribed around the corpus callosum contour. Based on such calculations, the authors were able to find out that the angle of curvature of the corpus callosum in blind people is more convex than in sighted people.

Some authors have used a multifactor mathematical apparatus which helps to simulate the corpus callosum shape by configuring conditional labels, which include: the center of the genu, the center of the splenium and 50 half-labels equally spaced in circles of double contour of the corpus callosum, starting from the posterior border of the genu (Bruner et al., 2012) These configurations are recorded through a Procrustes overlap, shifting the coordinate system to a single centroid by scaling them according to a single centroid size, as well as rotation in order to minimize the remainders of least squares between the corresponding labels. Herewith the centroid size is calculated as the square root of the sum of the squares of the distance of all labels from their centroid. This geometric analysis method of the corpus callosum, in our opinion, is too labour-intensive. The results obtained therewith are not substantially different from those obtained by other researchers using simpler methods of morphometric study.

Therefore, despite repeated attempts by researchers to obtain and analyze statistically significant data on individual variability of the corpus callosum dimensional features, modern science has not yet completely solved this problem.

In our previous work, a correlation was found between the neurocranium length and the corpus callosum longitudinal size along the constricting chord in men and women of the second period of adulthood (Boyagina et al., 2017). But the correlation between cranial height and the corpus callosum trunk bulge height, and the relationship between the corpus callosum shape and cranial shape have not been studied.

The purpose of the article was to determine the individual variability of the height and shape of the corpus callosum of adults and their dependence on the cranial height and shape.

Conducting of the morphometric study

The material was two samples from a series of MR scans of the head of men and women of the second period of adulthood (19 variations in each group) without the central nervous system pathology, which were made on the basis of the European Radiological Center Gemo Medika Kharkiv, LLC.

The age-dependent periodization adopted at the VII All-Union Conference on Age Morphology, Physiology and Biochemistry of the Academy of Pedagogical Sciences of the USSR was used to classify the material.

Magnetic resonance tomographic scanner Magnetom C was used for obtaining MRI images. Morphometric study was conducted using RadiAnt Dicom Viewer software on MR scans performed in the sagittal area in T1- and T2-weighted images modes. When performing morphometric studies, three points of the corpus callosum were used: the most protrusive point of the genu, the most protrusive posterior point of the splenium, and the most protrusive upward point of the corpus callosum trunk bulge. After drawing straight lines through the mentioned points, we inscribe the corpus callosum contour profile within a scalene rectangle, the long sides of which are equal to its longitudinal size, which we call the corpus callosum constricting chord, and its short side are equal to its trunk bulge maximum height. The neurocranium length was determined between the points of the glabella and opisthocranion, and the neurocranium height – between the points of the basion and bregma.

Variational statistical and correlation analyses were used in the study.

Correlation between the corpus callosum shape and cranial shape

According to the obtained quantitative data, the corpus callosum trunk bulge height in men falls within 20.4 to 31.3 mm (on average 26.1 ± 2.8 mm) (Table 1), and the neurocranium height varies from 134.8 up to 166.1 mm (on average 150.4 ± 6.9 mm) (Table 2). Herewith the aspect ratio of the neurocranium height to the corpus callous, trunk bulge height falls within 4.7 to 7.4 (on average 5.8 ± 0.7).

Table 1. *Corpus callosum morphometric study results in men and women pf the second period of adulthood (M±m)*
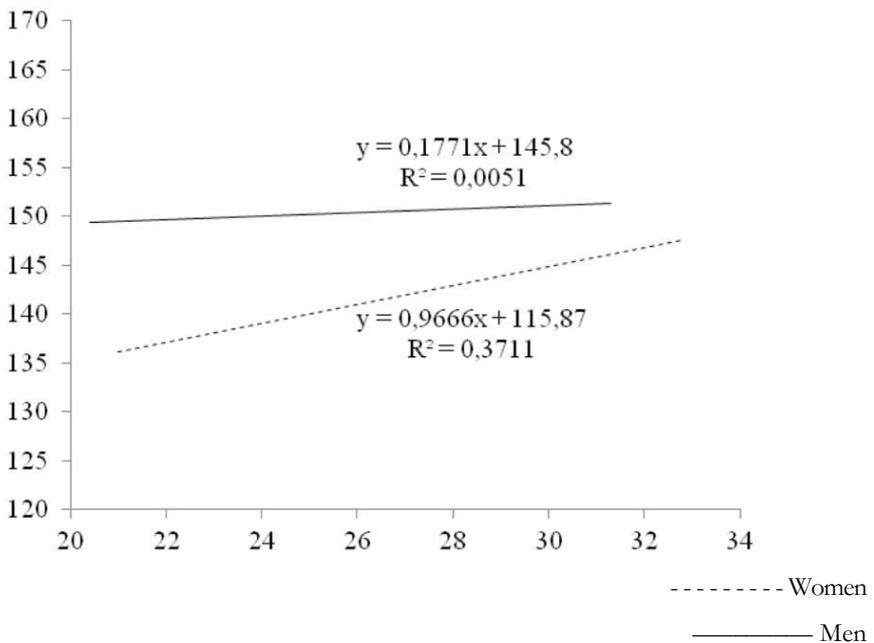Source: Authors' own conception

Sex	Longitudinal size along the constricting chord (mm)	trunk bulge height (mm)	Aspect ratio of the longitudinal size along the constricting chord to the trunk bulge height
Men	72.9±4.5	26.1±2.8	2.8±0.3
Women	68.3±3.0	25.2±2.6	2.7±0.3

Table 2. *Neurocranium morphometric study results in men and women pf the second period of adulthood (M±m)*
Source: Authors' own conception

| Sex	Cranial height (mm)	Neurocranium length (mm)	Correlation between the cranial length and height
Men	150.4±6.9	188.9±5.7	1.3±0.1
Women	140.2±4.2	177.8±7.2	1.3±0.1

The corpus callosum trunk bulge measurements in women have almost no difference from that in men and are distributed in the range from 21.0 to 32.8 mm (on average 25.2 ± 2.6 mm). Neurocranium height measurements in women are slightly less, they fall within 133.7 to 151.0 mm (on average 140.2 ± 4.2 mm). The ratio of the neurocranium height to the corpus callosum trunk bulge height falls within 4.6 to 6.4 (on average 5.6 ± 0.5), not being significantly different from the same measurement in men. The correlation between the cranial height and the corpus callosum height is slight and statistically insignificant in both men and women (Fig. 1).


$y = 0.1771x + 145.8$
$R^2 = 0.0051$

$y = 0.9666x + 115.87$
$R^2 = 0.3711$

- - - - - - - - Women
————— Men

Fig.1. *Correlation between the cranial height (indicated on the ordinate axis, mm) and corpus callosum height (reflected on the the abscissa axis, mm)*
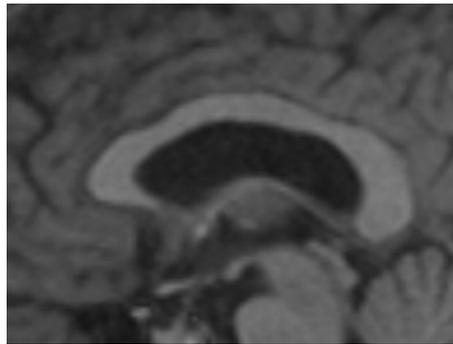Source: Authors' own conception

As shown by the Table 1, individual variability is attributable to the corpus callosum length and height. We calculated the aspect ratio of the aspect ratio of the corpus callosum longitudinal size along the constricting chord to its trunk bulge height. According to the obtained data (Table 1), this aspect ratio in men varies from 2.3 to 3.5 (on average 2.8 ± 0.3). In women, this measurement falls within 2.1 to 3.2 (on average 2.7 ± 0.3). Based on the found aspect ratio and the corpus callosum trunk bulge shape, it was proposed to divide the latter into low-bulged, medium-bulged and highly-bulged shapes (Fig. 2) (Boyagina, 2015). Low-bulged shapes correspond to the ratio x > 2.8, medium-bulged – to the ratio 2.8 ≥ x ≥ 2.7, highly-bulged – to the ratio x < 2.7. It is noteworthy that the quantitative distribution of the above corpus callosum shapes is approximately the same in both men and women.
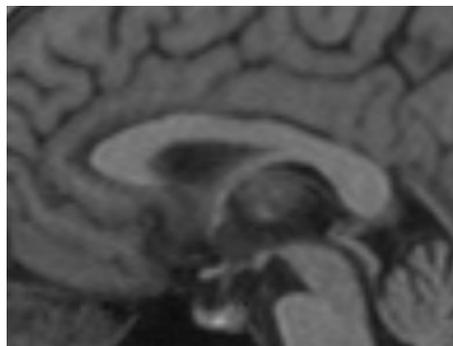
Low-bulged shape
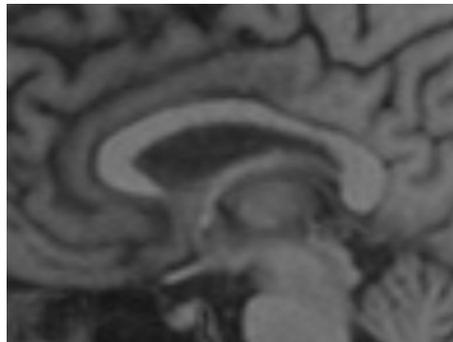
Medium-bulged shape

Highly-bulged shape

Fig. 2. *MR scans of corpus callosum shapes of diverse bulge*
Source: Authors' own conception

It is well known about the high correlation between the brain development and neurocranium development, as well as the full correspondence of their shapes with each other. In the fetal period, it is the brain, developing first, is dominant in the formation of the chondrocranium, and then the osteocranium, which is entirely driven by the genetic programme. Hereditary factor certainly becomes decisive for the further synchronous brain and cranium development, but after birth, during the period of active growth, their formation also depends on a whole range of external factors, including purely mechanical actions that impact the cranial shape and cause cerebral conformal changes.

As is clear from the data shown in the Table 2, the cranial linear size is variable (Vovk & Sukhonosov, 2016), and thus there is a variability in the length and height ratio, and, therefore, the variability of the cranial shape. The correlation between the corpus callosum shape and the cranial shape, which is determined by the ratio of its length and height, is shown in Figure 3. According to these data, the corpus callosum shape does not depend on the cranial shape neither in men nor in women.
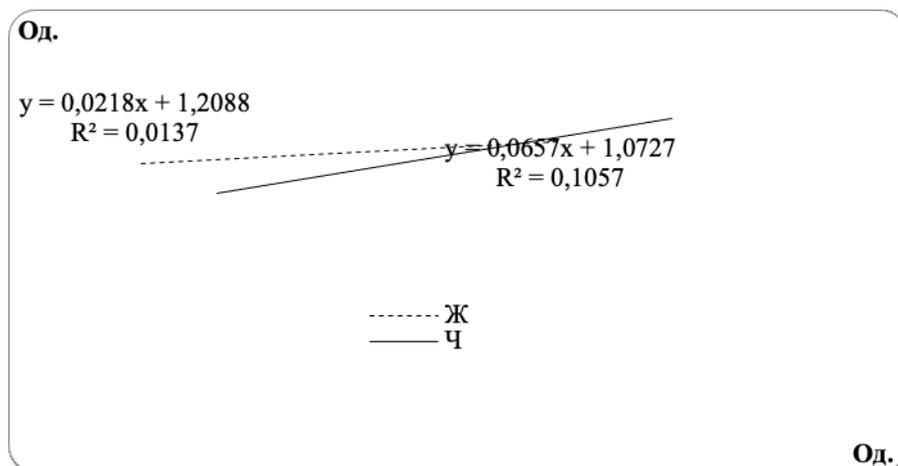
Fig. 3. *Correlation between the corpus callosum shape and cranial shape*
Source: Authors' own conception

Conclusions

1. Corpus callosum trunk bulge height in men falls within 20.4 to 31.3 mm (on average 26.1 ± 2.8 mm), in women – 21.0 to 32.8 mm (on average 25.2 ± 2.6 mm). Aspect ratio of the neurocranium height to the corpus callosum trunk bulge height in men falls within 4.7 to 7.4 (on average 5.8 ± 0.7), in women – 4.6 to 6.4 (on average 5.6 ± 0.5). On evidence, the absence of correlation between the cranial height and the corpus callosum trunk bulge height, and the absence of correlation between the corpus callosum shape and cranial shape in people of the second period of adulthood have been concluded.

2. The aspect ratio of the corpus callosum longitudinal size along the constricting chord to its trunk bulge height in men falls within 2.3 to 3.5 (on average 2.8 ± 0.3), in women – 2.1 to 3.2 (on average – 2.7 ± 0.3). Based on the found aspect ratio, it was proposed to divide the corpus callosum shapes into low-bulged, medium-bulged and highly-bulged shapes. The absence of correlation between the corpus callosum shape and cranial shape in men and women of the second period of adulthood have been concluded.

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