METHOD OF MORPHOMETRIC ANALYSIS OF THE CORPUS CALLOSUM FORM ON THE BASIS OF MR-IMAGES AND APPLICABLE TO ITS NATURAL PREPARATIONS

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Abstract

Further development of neurosurgery requires increased knowledge of the anatomy of the corpus callosum. That is why the current direction of modern morphological research is the study of the sexual dimorphism of the corpus callosum in the age aspect, taking into account individual variability. The purpose of the study was to develop an integrated approach to digital quantization of the corpus callosum, which will allow to solve the problem of defining the characteristics of the individual variation of the human corpus callosum sexual dimorphism in the age aspect in more detailed and comprehensive way. The material used were 40 MRI images of male and female heads of the II period of mature age without a pathology of the central nervous system and 44 brain preparations of men and women of the II period of mature age, who died for reasons not connected with the pathology of the central nervous system either. As a result of the study, the longitudinal-altitudinal index of the corpus callosum was calculated and its three main forms were distinguished: low convex, medium convex and high convex. By isolating the two thighs in the trunk of the corpus callosum (anterior and posterior), we obtained additional data specifying the true length of the corpus callosum. We also resorted to the topological transformation of a complicated configuration of the corpus callosum shape into a simple planimetric figure, which is a circle, by determining its radius according to the formula $R=L/2\pi$, where L is the total length of the corpus callosum perimeter. This provides an opportunity to express the nuances of its individual, sexual and age variability in more visual form in diagrams. Conclusions. To obtain an optimal morphometric characteristic of the planar projection of the sagittal profile of the corpus callosum, we offer a simple geometric analysis that is applicable not only for MRI images, but also for anatomical preparations on the basis of photographs of the medial surface of the cerebral hemispheres. Thus, we get the opportunity to find out how the corpus collosum differs in vivo from the postmortem state.

Key words: *corpus callosum, individual variability, sexual dimorphism, morphometry.*

Introduction

In order to study sexual dimorphism and age-related differences of the corpus callosum, it is necessary to have reliable quantitative criteria about its shape [1–6]. It can be achieved by conducting a well-known morphometric analysis based on conventional reference points, which are usually unequally distant points and straight-line distances between them [7-13]. An example of this approach is the content of the patent for an invention owned by A.N. Biryukov [14] named "Method of the corpus callosum size determination in vivo". All measurements were carried out by the author on the midline images of the brain obtained using magnetic resonance imaging, where the corpus callosum quantization is made on the basis of the measurements of the thickness of its individual parts (genu, trunk and splenium), as well as its length and height. It is quite obvious that this principle can also be applied to natural preparations of the cerebral hemispheres, where the medial surface demonstrates the desired formations.

It should be noted that this method is an example of a simplified approach to the analysis of such a complex geometric formation as the sagittal profile

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of the corpus callosum. Therefore, in the literature there are some other attempts to get closer to a more comprehensive coverage of its form. For example, to quantify it, F. Tomaiuolo, S. Campana and D. Collins [15] used a rectangular contour covering the corpus callosum on midline MRI scans of the cerebral hemispheres, making it possible to determine the angle of its bend by calculating the angle at the top of an isosceles triangle that has the same base and height as the rectangle outlined around the corpus callosum. Obviously, this method can be applied as an additional metric parameter to the previous method.

In the pursuit of a more comprehensive quantitative analysis of the shape and size of the corpus callosum, some authors [16] used multifactorial mathematical apparatus. For this purpose, its shape is modeled using a configuration of conditional marks, which include the center of the genu, the center of the splenium and 50 half-marks, evenly spaced on the circles of the dual contour of the corpus callosum. These configurations are registered by procrust overlay, shifting the coordinate system to a single centroid, by scaling them in accordance with a single centroid size, and also by their rotation in order to minimize the remaining parts of the smallest squares between the corresponding marks. In this case, the centroid size is calculated as the square root of the sum of the squares of all marks from their centroid. Due to the fact that the results obtained by the authors objectively do not differ a lot from those obtained by other authors using simpler methods of morphometric analysis, we consider this method to be excessively complicated.

Thus, the above methods of the morphometric analysis of the corpus callosum do not satisfy the intention to achieve the most optimal result of its quantitative assessment using relatively simple mathematical operations.

Purposes, subjects and methods:

2.1. The purpose of the work was to develop an integrated approach to the digital quantization of the corpus callosum, which will allow to solve the problem of defining the characteristics of the individual variation of the human corpus callosum sexual dimorphism in the age aspect in more detailed and comprehensive way.

2.2. Subjects and methods

The material used were 40 MRI images of the male and female heads of the II period of mature age without the central nervous system pathology, obtained from LLC "Hemo Medica Kharkov". The material obtained from Kharkiv Regional Office of the Chief Medical Examiner was presented by 44 brain preparations of men and women of the II period of mature age, who died for reasons not connected with the pathology of the central nervous system either.

In the the course of study of corpus callosum anatomical preparations, the brain was dissected in a longitudinal split of the cerebrum into two halves after washing and two-week fixation in 10% formalin solution. The medial surfaces of the halves were photographed using a digital camera at the same focal length using a vertically mounted tripod. The image of the corpus callosum sagittal profile obtained in this way corresponded to those ones of MP-tomograms. Morphometric analysis of the sagittal profile of the corpus callosum was performed using the RadiAnt Dicom Viewer and Adobe Photoshop CS6 Extended software.

Conflict of interests. There is no conflict of interests.

3. Results and discussion

Our approach is based on a preliminary geometric analysis of the longitudinal (sagittal) profile of the corpus callosum, which has complex outlines, bordered by two closed (in the region of the rostrum and splenium) arcuate circles, which are smooth curved conjugation of curved lines with different radii of the circles. First of all, its analysis requires the use of relatively conditional, compatible with the shape, coordinates. The most acceptable for this purpose are the rectangular coordinates, where the initial points (marks) used for measurements are determined by the distance between them along straight lines. To do this, we fit the contour profile of the corpus callosum into the limits of an unequal rectangle, the long sides of which are equal to its longitudinal size, and the short sides are equal to the maximum height of its upper trunk bulge (*Fig. 1*). In this case, we will consider the lower long side under the name of the tightening chord of its two arcuate circles (upper and lower), because it is shorter than the length of each of these arcs. We also restrict ourselves to only a few basic dimensional quantities, which include: 1 – the longitudinal dimension along the chord (the length of the corpus callosum as it is usually mentioned in the literature); 2 – the maximum height of its trunk bulge (the vertical distance between the most protruding point of the trunk and the chord); 3 – the thickness of the corpus callosum in the area of the genu, the trunk (in the area of maximum bulge) and the splenium [17, 18].

Using the metric values of length (L) on the constricting chord and the maximum height (H) of

Fig. 1. MRI-image of the male head of the II period of the mature age in the lateral projection; the principle of geometric analysis of the corpus callosum form:
1 – the longitudinal size of the corpus callosum on the constricting chord, 2 – the maximum height of the trunk convex of the corpus callosum, 3 – the length of the anterior trunk thigh, 4 – the length of the posterior trunk thigh, 5 – the largest anteroposterior diameter of the brain skull.
A scale metric bar is added below on the right

convexity of the corpus callosum, it is possible to calculate its longitudinal-altitudinal index in accordance with the common formula $I=H/L \cdot 100$. By its value one can determine the individual forms which supposedly will be distributed within the three main ones, which we mention under the name of low convex, medium convex, and high convex forms of the corpus callosum. This is the first supplement we introduce to the method of the morphometric analysis of the corpus callosum previously known in the literature. With these data, it is possible to relate its longitudinal-altitudinal index to the shape of the brain skull of a given individual.

But by determining the length of the lateral profile of the corpus callosum, as it is described in the literature, one ought not speak of its true length, since in its trunk section, approximately in the middle, it is "humped", forming an obtuse angle open downwards. Consequently, the vertex of its angular bend is in accordance with the well-known maximally elevated point of its convexity, which makes it possible to distinguish two thighs in the trunk of the corpus callosum - the anterior and the posterior. Their length can be separately determined by two straight lines connecting a given angular point with the anteriorly projecting point of the genu and posteriorly projecting point of the splenium (*Fig. 2*). It is quite obvious that their total length will be greater than that of the constricting chord, which in this case can be regarded as a hypotenuse with respect to the sides. Thus, we will receive additional data specifying the true length of the corpus callosum, which enables us to obtain

Fig. 2. The medial surface of the cerebral hemisphere of the men of the second period of the mature age.
1 – the longitudinal size of the corpus callosum on the pulling chord; 2 – maximum height of the stem convexity of the corpus callosum; 3 – length of the anterior stem hips; 4 – length of the posterior stem hips

more accurate information when studying its individual variability, sexual dimorphism, and age transformation [19]. By this we introduce the second supplement to the methodology of the corpus callosum morphometry.

But this data do not exhaust the opportunities to expand the metric base of the corpus callosum in its versatile study. For some reason researchers overlooked the opportunity to resort to a planimetric estimation of the area occupied by the corpus callosum in its sagittal section which is currently practically feasible with the help of "Inobitec DICOM Viewer" software [20]. Concurrently, it is possible to measure the length of the outer contour of the corpus callosum (*Fig. 3*).

Having these metric data, we can resort to a topological transformation of a complicated configuration of the corpus callosum shape into a simple planimetric figure, which is a circle, by determining its conditional (isometric) radius (CRCC) according to the formula $R=L/2\pi$, where

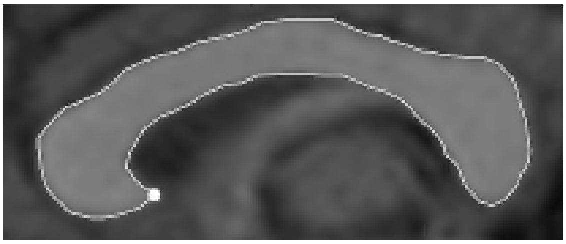
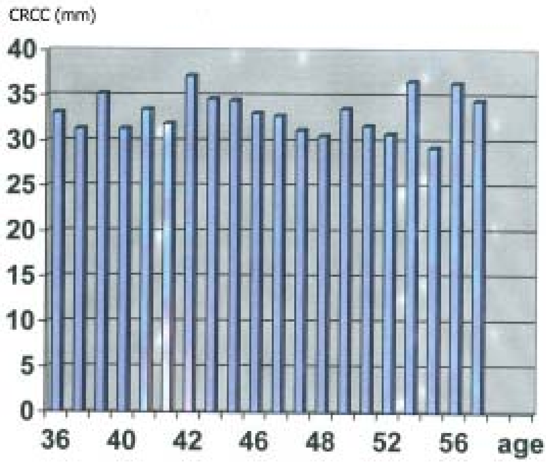


Fig. 3. MR-images of the human corpus callosum, outlined along the perimeter with a white line, interrupted in the terminal part of the beak by a reference point when measuring the length of its contour circumference

L is the total length of the corpus callosum perimeter; this provides an opportunity to express the nuances of its individual, sexual and age variability in more visual form in diagrams (*Fig. 4*). Such a planimetric method, which involves the topological transformation of a complicated configuration of the corpus callosum outline into a circle that makes it more understandable for the visual assessment. As our experience shows, this method is highly productive and has no analogues in the literature, as evidenced by the results of the patent-information retrieval.

Conclusions. Thus, to obtain an optimal morphometric characteristic of the planar projection of the lateral (sagittal) profile of the corpus callosum, we offer a simple geometric analysis that is applicable not only for MRI images, but also for anatomical specimens on the basis of photographs of the medial surface of the cerebral hemispheres. Thus, we get the opportunity to find out how the corpus collosum differs in vivo from the postmortem state according to the following metric parameters: 1 – the length of the corpus callosum along the constricting chord; 2 – the maximum height of its trunk bulge; 3 – the length of the anterior and posterior trunk thighs of the corpus callosum and their total value; 4 – the maximum thickness of the corpus callosum in the area of its genu, trunk and splenium; 5 – the total area of the sagittal profile of the corpus callosum; 6 – the total length of its outer circumference, whose value is used for the topological transformation of the actual form of the corpus callosum into an isometric circle. It should be noted that for this purpose other two-dimensional geometric shapes can be used, such as a square or an equilateral triangle. In these cases, it is necessary to divide the total length of the outer circumference into four or three parts, respectively. In our studies, we preferred the circle, since it is figuratively more similar to the shape of the corpus callosum.

1



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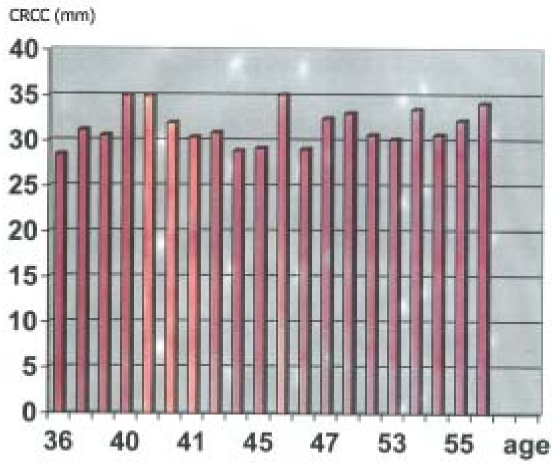

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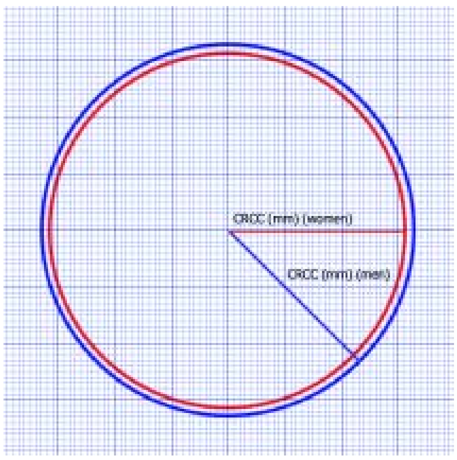

1 – men (on the abscissa is age (years), along the axis of the ordinate – CRCC (mm));

2 – women (on the abscissa is age (years), along the axis of the ordinate – CRCC (mm));

3 – the difference between the circular area of the corpus callosum of men (blue) and women (red).

Fig. 4. Individual variability and sexual dimorphism of the medial profile of the corpus callosum, formally expressed by the calculation of its conditional (isometric) radius

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