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Structure of the Upper and Lower Surfaces of Human Corpus Callosumg

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Abstract: *The corpus callosum in the interval between the cerebral hemispheres is a plate of white matter, uneven in thickness, in which two surfaces are distinguished - the upper and lower ones, bent according to its lateral profile. The objective of the study was to study the individual variability of location of the lateral and medial longitudinal strips on the upper surface of the corpus callosum, as well as structural features of its lower surface. The material was the brain of men and women (10 specimens each) of the second period of adulthood, who died for the causes not related to the pathology of the central nervous system. After two weeks of fixation in a 10% formalin solution, the brain was prepared by separating the cerebral hemispheres and other parts of the brain from the corpus callosum, resulting in exposure of its upper and lower surface, which was photographed using a digital camera. As evidenced by the obtained data, the width of the trunk of the corpus callosum in men varies from 9 to 16 mm, whereas in women the difference between the minimum (11.0 mm) and the maximum (20.0 mm) values is greater than in men, when in fact there is only small difference of the arithmetic mean value. Thus, we offer to consider the lateral longitudinal strips to be the boundaries of the corpus callosum hemispherical part and the distance between them determines the width of this formation, which in average is 13.0 ± 2.5 mm in men and 14.4 ± 2.7 mm in women. In the meantime, the nature of the individual variability of the width of the corpus callosum trunk in women is more diverse than in men.*

Keywords: *lateral and medial longitudinal strips, indusium griseum, surface of the corpus callosum, sagittal plane, plating in epoxy resin, dissection.*

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Introduction

According to the information contained in the manuals of human anatomy, published at different times, including recent years, the corpus callosum located between the cerebral hemispheres is an uneven (in terms of thickness) plate of white matter, comprised of two surfaces – the upper and lower ones, bent to its side profile (Salvolini et al., 2010; Ardekani et al., 2012; Raybaud, 2010). On the upper surface there are some transverse strips (striae transversalis) that are visible in some places through a thin layer of induseum griseum. They are the outer reflection of the bundles of interhemispheric (cortico-cortical) nerve fibers transiting through the corpus callosum. The induseum griseum, according to the literature, has been studied quite superficially.

In addition, the upper surface of the interhemispheric part of the corpus callosum attracts attention due to the presence of longitudinally stretched eminential strips, two of which are medially close (striae longitudinalis medialis) and there is a pair of lateral ones (striae longitudinalis lateralis) bordering the cingulate gyrus (gyrus cinguli). In the anterior part these strips, girdling the genu of corpus callosum, reach the subcallosal gyrus, and in the posterior part, they continue under the splenium of corpus callosum, reaching the hippocampal zone in the form of a dentate gyrus showing the annular arrangement in the limbic brain structures (Luders et al., 2010; Battal et al., 2010). According to the literature, these strips are represented by bundles of nerve fibers that provide associative interactions between distant ancient formations of the pallium.

The lower surface of the corpus callosum is remarkable because of the fact that, slightly posteriorly from the middle of corpus callosum trunk, it is coalesced with the body of the fornix, also belonging to the limbic brain. But the consideration of the morphological connections of the corpus callosum does not end at this point. It should be noted that the space between the anterior part of the trunk, the genu and rostrum of the corpus callosum, on the one hand, and the columns of the fornix, on the other, are tightened by two, medially located thin plates of brain matter, which are separated by a narrow space called the septum pellucidum (Prakash et al., 2010).

The above brief sketch of the outer structure of the corpus callosum aims to show how it is described in the literature.

The objective of the study was to study the individual variability of location of the lateral and medial longitudinal strips on the upper surface of the corpus callosum, as well as structural features of its lower surface.

Applying the Dissection of the Corpus Callosum

The material obtained at Kharkiv Regional Bureau of Forensic Medical Examination was the brain of men and women (10 specimens each) of the second period of adulthood, who died for the causes not related to the pathology of the central nervous system. After two weeks of fixation in a 10% formalin solution, the brain was prepared by separating the cerebral hemispheres and other parts of the brain from the corpus callosum, resulting in exposure of its upper and lower surface, which was photographed using a digital camera. Morphometric analysis of the upper surface of the corpus callosum was performed by means of Adobe Photoshop CS6 Extended software.

Some of the preparations were examined using routine histological methods with Van Gieson staining.

Some plates, about 0,5 mm thick, were cut from part of the corpus callosum preparations. Then they were subjected to epoxy resin lamination applying the well-known method (Kostilenko et al., 2008) according to the following scheme: 1 – substitution of alcohol in tissues with acetone; 2 – substitution of acetone in the tissues with epoxy resin and immersion of the preparations into pure, immediately prepared, epoxy resin. The next step was to remove the preparations from the still unpolymerized epoxy resin and place them on the pre-prepared plastic sheeting, which were covered with the same size sheetings. After that, each such layered block was individually placed between two evenly sized glasses that were tightly clamped. After complete polymerization, polished sections of different thickness were made from the obtained epoxy plates with the preparations of corpus callosum. Then they were painted with 1% solution of methylene blue on 1% borax solution.

The study of the obtained preparations, as well as their photographic documentation were carried out with the help of binocular magnifier MBS-9 and a light microscope "Konus, equipped with a digital photo set-top box.

The research methods described in the publication were applied in compliance with human rights in accordance with the legislation in force in Ukraine, meet international ethical requirements and do not violate ethical norms in science and standards of biomedical research.

Studying the Upper Surface of the Corpus Callosum

As a result of the study of the upper surface of the corpus callosum, we can say that the name "strips" can be applied with a bit of a stretch to the longitudinally oriented by the outer surface of the corpus callosum "strips", the pair of which in the contralateral position occupies a boundary position between the free part of the corpus callosum and the medial parts of the gyrus cinguli although in terms of appearance they have the shape of a rounded cord (about 1.5 mm thick) passing across a rough uneven outer surface. Therefore, by retaining this name (lateral longitudinal strips), we must refer it to the string-shaped conducting (i.e., comprised of nerve-fiber bundles) cords, which are separated from the corpus callosum, connecting the opposing distal centers of the limbic brain. It should be noted that in some cases there are individual variants in the form of small branches, which are immersed in the medial direction in the thickness of the corpus callosum. In other cases, the lateral longitudinal strips do not have the form of continuous strands, but resemble a suture line due to the wavy bending of their transverse rollers (Fig. 1, 2). However, these lateral strands (lateral longitudinal strips) can be considered as lateral boundary orientations of the latitudinal boundary of the free (interhemispheric) part of the corpus callosum, and therefore we have the opportunity to determine its width by simply measuring the transverse distance between them. These metrics are indicative only, since only 10 preparations of the corpus callosum of men and women were taken to obtain them. However, by the mean of the random sampling error, they are quite reliable.

It should be noted that these results are limited only to the trunk section of the corpus callosum. According to them, the width of the trunk section of the corpus callosum in men varies from 9 to 16 mm (arithmetic mean value is 13.0 $\pm$ 2.5 mm), whereas in women the variation between the minimum (11.0 mm) and the maximum (20, 0 mm) values is greater than in men, with a virtually small difference in the arithmetic mean of 14.4 $\pm$ 2.7 mm. In other words, the nature of the individual variability of the width of the corpus callosum trunk in women is more diverse compared to men.

In the intermediate position between these nerve fibers (longitudinal lateral strips) along the upper surface of the corpus callosum, according to the literature, there is a pair of similar formations called medial longitudinal strips. However, according to our observations, they are not in all cases different in terms of parity of location, that is, their shape varies individually. Often this formation looks like a single longitudinal strand corresponding to the median plane of the brain (Fig. 1, 2), in other cases it splits in some places. But along with this, in our small sample, there were also variants of its relatively wide split. In such cases, on the upper surface of the trunk section of the corpus callosum there were four strands, approximately equally spaced from each other, that is, two medial and two lateral ones (Fig. 2).

But in no case we came across such a formation in the classic version, that is, in the form of two parallel medial longitudinal strips. Of course, this does not mean that there are no such options. Probably, they did not get into our sample of preparations, which testifies to the possibility of the existence of many other individual forms of the outer contour of the obligate formations connected with the upper surface of the corpus callosum, which are closely soldered to subjacent part and therefore are inseparable. Additional individual evidence of this is the local immersion of longitudinal strips, which occur periodically along their length, into the thickness of the corpus callosum. This, as noted above, sometimes gives them the appearance of a suture. Besides, their shape depends largely on the relief of the surface where they are longitudinally laid; and this is already the case with another type of upper body surface formation, that is called transverse strips (i.e., at right angles to the longitudinal ones) in the literature.

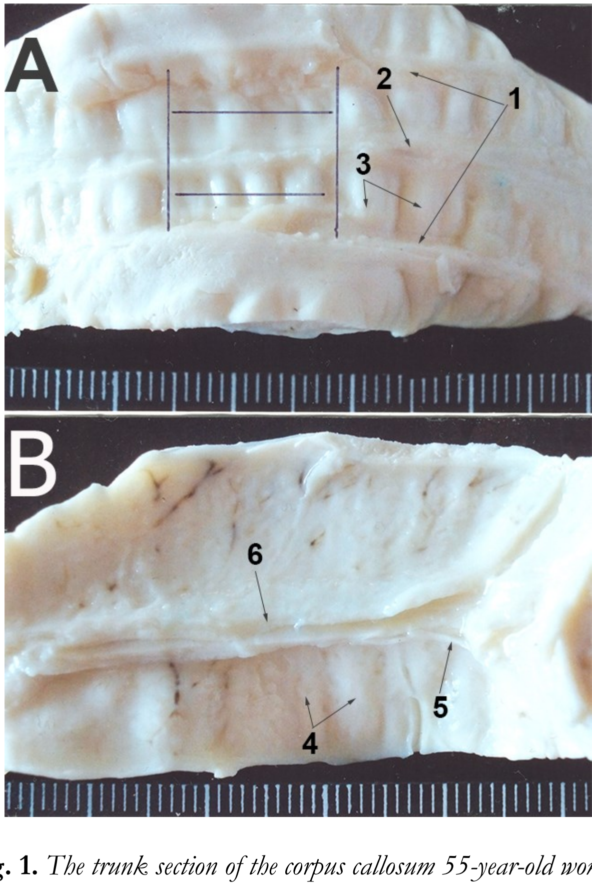

Fig. 1. *The trunk section of the corpus callosum 55-year-old woman.*

A – the upper surface, B – the lower surface. 1 – lateral longitudinal strips, 2 – medial longitudinal strip, 3 – transverse roller-shaped convexities (transverse strips), 4 – lower transverse roller-shaped convexities, 5 – remains of septum pellucidum, 6 – remains of the body of the fornix.

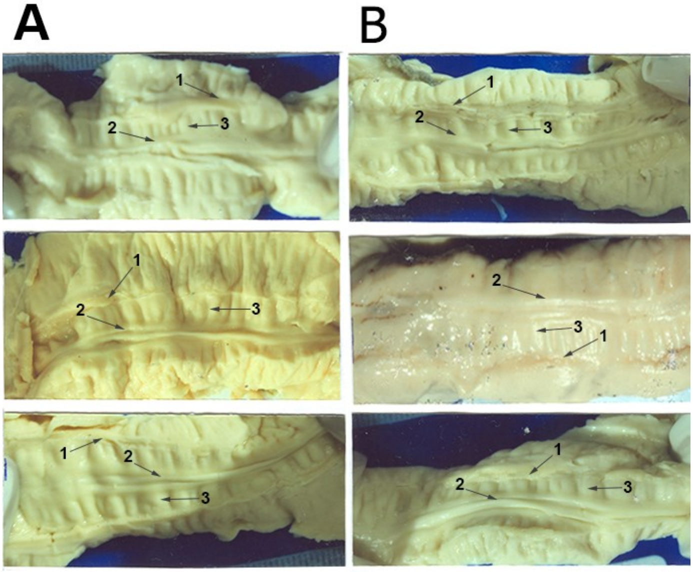

Fig. 2. *The upper surface of the trunk section of the mature adults corpus callosum.*

A – men, B – women. 1 – lateral longitudinal strips, 2 – medial longitudinal strip, 3 – transverse roller-shaped convexities (transverse strips).

In addition, the literature does not pay much attention to the study of the lower surface of the corpus callosum. It is only known that in its trunk part it is the upper wall of the central department of the lateral ventricles, separated from each other by the median plane, fused with the lower surface of the corpus callosum, a transparent septum supplemented at the back by the body of the fornix. It is pertinent to recall that the fornix begins with columns from the mammilary bodies (corpus mamillare), which then merge into the body, which fuses with the lower surface of the corpus callosum (at the border between the posterior department of the trunk and the splenium). From here they split up, heading for the anterior poles of the temporal lobes, where they continue into the right and left hippocampus. Given that fused part of fornix is adhered from below with the corpus callosum, its indirect role of switching interactions between the limbic brain and the neopallium through the corpus callosum collector system becomes apparent. Not to be overlooked is the fact that the space between the anterior part of the trunk, the genu and the rostrum of the corpus callosum, on the one hand, and the columns of the fornix, on the other, is tightened by two medially spaced thin plates of the brain matter, which are separated by a narrow space of approximately 1 mm. It is the so-called septum pellucidum.

It is easy to be convinced in all of the above during the process of corpus callosum preparation in order to gain access to its lower surface. Thus, when removing the septum pellucidum and fornix, the remnants of the described formations can be clearly seen on its lower surface. In this case, the septum pellucidum looks like a double medially located rim that splits up back to the location of the adhesion of the fornix (Fig. 1). Note that this double rim from the septum pellucidum exactly coincides with the projection of the medial longitudinal strip located on the upper surface of the corpus callosum. It may seem that the septum pellucidum, passing through the corpus callosum, protrudes on its upper surface. Further studies have shown that this is not the case.

In terms of our consideration of the outer structure of the corpus callosum itself, its lower surface is interesting because under the ependymus there are quite clearly visible transversely placed roller-like elevations, similar to the same elevations on its upper surface with the only difference being that they are more monotonously wide without any presence of dichotomous division. These elevations form orderly rows on either side of the mid-point attachment of the septum pellucidum (Fig. 1). It is in this order that they extend into the thickness of the white matter of the cerebral hemispheres.

Based on the above data, we can conclude that the corpus callosum itself, in the sense that it provides a predominantly commissural connection between the contralateral cortical centers of the neopallium, consists of a certain number of cord formations that are visualized at the macroscopic level (the naked eye). Due to the fact that they are not mentioned in the literature, we propose to call them commissural cords of the corpus callosum or its funicular components, which can be considered as first-order subcutaneous units.

The Surface of The Corpus Callosum

It is necessary to pay attention to the surface layer of the upper surface of the corpus callosum – the so-called indusium griseum (Fig. 3). To get clearer visualization of the microscopic structure of the surface, we made extremely thin epoxy resin plates of corpus callosum, the thickness of which did not exceed 0.5 mm. As a result, they could be viewed in a passing microscope at relatively high magnifications (with 10 and 20^x lenses).

Fig. 4 shows that this indusium griseum generally has a predominantly pileous structure, which is a close set of double-loop fibers extending from the thickness of the commissural cords at right angles to the upper surface of the corpus callosum. On their apical parts in the surface plane there are star-shaped (due to the numerous, radially directed apophyses) cells located in a regular order. Although they are very similar to dendrites of neurons, these nerve cells do not belong to nerve cells, which is confirmed by the literature devoted to the study of the structural organization of the outer surface of the brain. According to these sources, the central nervous system, as a whole, is completely covered with glial cells along the entire surface, both internal (from the ventricles) and outer ones (from the soft, vascular membrane). On the outer surface of the brain (the corpus callosum is no exception) there is a limiting glial membrane (membrana limitans gliae superficialis), represented by lamellar apophyses of astroglia, which overlap each other, and the bodies of astrocytes themselves. This membrane is separated from the superimposed soft, vascular membrane by the basal membrane only.

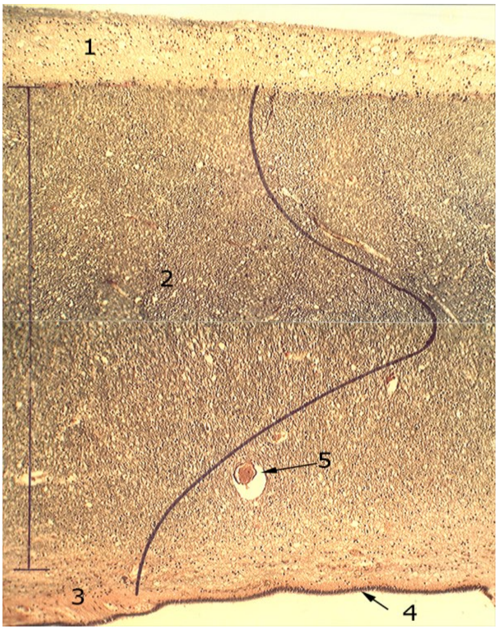

Fig. 3. *Histotopography of the corpus callosum of a mature man. Paraffin section in the transverse section of the corpus callosum. Van Gizon, 4ˣ lens.*

1 – outer limiting glial membrane (indusium griseum); 2 – corpus callosum proper (its thickness is indicated by a straight vertical line); 3 – inner limiting glial membrane; 4 – ependymal layer; 5 – venous vessels. The curved line shows the trajectory of the interfascicular connective tissue layer.

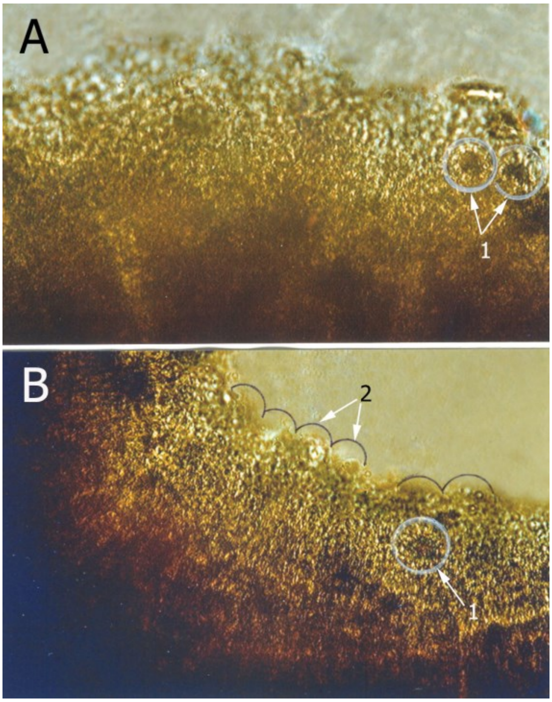

Fig. 4. *Indusium griseum of the corpus callosum.* Epoxy plate, 0.5 mm thick. Methylene blue, 20^x lens. A – at the top of the transverse roller-shaped elevation; B – on its slope.

1 – astroglia cells are circled in white; 2 – arcuate brackets indicate the columnar assemblages of double-loop fibrous structures of indusium griseum.

Therefore, our own data concerning the surface coverage of the corpus callosum are consistent with the ideas about the nature of the terminal limitation of the outer surface of the brain substance itself. So, like everywhere, the corpus callosum is covered with the thinnest layer of astroglia. But we still do not know exactly what the main thickness of the indusium griseum located below the corpus callosum is. Let's just mention that, as noted above, it consists of a close set of double-loop fibers coming out of the thickness of the commissural cords, are directed at right angles to the limiting glial membrane. Careful examination of the preparations reveals that in this continuous fibrous coating of the corpus callosum upper surface there are some assemblies having a columnar shape; in Figure 4, they are marked with arcuate brackets. It was found out that the width of these columnar assemblies is commensurate with the width of the fascicular portions, as subunits of commissural cords.

Conclusions

1. We propose to consider the lateral longitudinal strips that run along the corpus callosum upper surface to be the marginal boundaries of its free (interhemispheric) part. The distance between them determines the width of this formation, which in males varies from 9 to 16 mm individually (on average – 13, 0 ± 2.5 mm), whereas in women the difference between the minimum (11 mm) and the maximum (20 mm) values is slightly larger with a virtually small difference of the mean value that equals to 14.4 ± 2.7 mm. In other words, the nature of the individual variability of the width of corpus callosum trunk section in women is more diverse than in men.

2. Our research results are consistent with the literature and confirm the current knowledge concerning the nature of the terminal limitation of the corpus callosum outer surface, which is covered by a layer of astroglia.

Compliance with Ethics Requirements:

„The authors declare no conflict of interest regarding this article"

„The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients involved in the study"

„No funding for this study"

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