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Three-Dimensional Microsurgical Anatomy of the Choroid Plexus Using the Volume Rendering Technique

Hacim Oluşturma Tekniği ile Koroid Pleksusun Üç Boyutlu Mikrocerrahi Anatomisi

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ABSTRACT

AIM: The choroid plexus (CP) is a specific anatomical structure producing cerebrospinal fluid into the ventricular space. The three-dimensional anatomical structure of the choroid plexus located within the lateral ventricle may be evaluated by using the three dimensional volume rendering technique (3D-VRT) from acquired two-dimensional contrast enhanced computerized tomographic images.

MATERIAL and METHODS: The raw data of Three-dimensional Computerized Tomography Angiography (3D-CTA) were transferred into the computer and recorded in a software program. These images were evaluated in terms of anatomical shape, borders, extensions length and dimensions.

RESULTS: The patient group consisted of 57 (27 female and 30 male) patients. The mean age of the patients was 55±9 years. In male individuals, the distance of the superior tip from Frazier's point was 7.96±0.71 centimeters at the right side. In males, the distance of the inferior tip of the CP was estimated as 1.93±0.26 centimeters posterior-lateral from the anterior clinoid process, 1.64±0.23 centimeters posterior-lateral from the bifurcation of internal carotid artery, and 2.86±0.23 centimeters posterior-medial from the bifurcation of middle cerebral artery on the right side.

CONCLUSION: The results of this study showed us that this technique could be used in the three-dimensional evaluation of some anatomical structures such as the choroid plexus.

KEYWORDS: Choroid plexus, Volume rendering, Surgical anatomy, Three-dimensional images, Computerized tomography

ÖZ

AMAÇ: Koroid pleksus, ventriküler mesafeye beyin omurilik sıvısı üreten özel bir anatomik yapıdır. Lateral ventriküller içinde yerleşik koroid pleksusun üç boyutlu anatomik yapısı iki boyutlu kontrast verilerek elde edilen bilgisayarlı tomografi görüntülerinden üç boyutlu volüm kazandırma tekniği ile incelenebilir.

YÖNTEM ve GEREÇLER: Üç boyutlu bilgisayarlı tomografik anjiyografiden elde edilen ham görüntüler, bilgisayara transfer edilerek yazılım programına kaydedildi. Bu görüntülerle anatomik yapı sınırlar uzanımlar, uzunluklar ve çaplar yönünden incelendi.

BULGULAR: Hastaların toplam sayısı 57 (27 kadın ve 30 erkek) dir. Ortalama yaş 55±9 yıl olarak bulundu. Erkek bireylerde, sağ tarafta, Frazier noktasından superior uca kadar olan mesafe 7,96±0,71 cm olarak ölçüldü. Erkek bireylerde sağ tarafta koroid pleksusun inferior uç noktası anterior klinoid prosesin 1,93±0,26 cm posterior lateralinde, internal karotid arter bifurkasyonunun 1,64±0,23 cm posterior lateralinde ve orta serebral arter bifurkasyonun 2,86±0,23 cm posterior medialinde olarak bulundu.

SONUÇ: Çalışmanın sonuçları bize koroid pleksus gibi bazı anatomik yapıların bu teknik ile üç boyutlu olarak incelenebileceğini göstermektedir.

ANAHTAR SÖZCÜKLER: Koroid pleksus, Hacim oluşturma, Cerrahi anatomi, Üç boyutlu görüntüler, Bilgisayarlı tomografi

INTRODUCTION

The choroid plexus (CP) is an anatomical structure that produces cerebrospinal fluid inside the ventricles of the brain (2, 5). The origin of the choroid is the Greek term of "khorion" meaning the specific membrane enclosing the fetus during pregnancy. The other term of plexus is used to describe a wide network or system (2, 5). The CP consists of many capillaries separated from the ventricles by choroid epithelial cells (5). The epithelial cells of the CP actively transport sodium, chloride and bicarbonate ions into the ventricular space and water follows the resulting osmotic gradient (5). This structure may be able to produce about 500 milliliters of cerebrospinal fluid in a day (5).

Although the anatomical structure of the lateral ventricle, fornix, and choroideal fissure have been studied in detail, it is not possible to say the same things for the CP. The complete

evaluation of the CP with its three-dimensional anatomical details is difficult in cadaveric specimens. Because of this, the evaluation of this anatomical structure in living subjects with neuroradiological examination may give more accurate results. The volume rendering technique may be used in the three-dimensional evaluation of some anatomical structures such as the CP.

The volume rendering technique is a group of modalities in the conversion of two-dimensional images into the three-dimensional images (1, 3, 4). The two-dimensional images acquired by computerized tomography and magnetic resonance imaging are used to create the volume rendered images (1, 3, 4). In this study, we used the OsiriX software program for the volume rendering technique to create three-dimensional CP images. The results of this study and the feasibility of this technique are discussed under the light of published medical literature.

MATERIAL and METHODS

Patient Population

Any additional radiological examination and providing a drug were performed to the patients for this study. The patient population included the cases that were brought to our neurosurgery department because of subarachnoid hemorrhage, and where a further decision had been made to perform 3D-CTA for cerebral aneurysm evaluation. The purpose of performing 3D-CTA was only to examine the intracranial vascular pathology after the insult of subarachnoid hemorrhage.

Neuroradiological Evaluation

The images analyzed in this study were performed using an Aquilion ONE multidetector row computerized tomography scanner (Toshiba, Medical Systems, Tokyo, Japan). After obtaining a frontal and lateral scanogram, a conventional unenhanced computerized tomography was performed if necessary, depending on the clinical purpose (120 kV, 200 mAs). Computerized tomographic angiography images were acquired following intravenous timed injection of contrast agent (Visipaque [Iodixanol] 270 mg/100 ml, OPAKIM) using an auto-triggered mechanical injector.

Three-Dimensional Volume Rendering

Imaging data were stored in the digital imaging and communications in medicine format (DICOM) and subsequent analyzed with the OsiriX imaging software (OsiriX Foundation, Geneva, Switzerland). Three-dimensional reconstruction of the data was performed to permit viewing of the anatomical area of interest (three-dimensional anatomy of the choroid plexus using software program). The imaging cluster was unpacked to the front window. The 3D Volume Rendering option was selected to create three-dimensional volume rendered image after the opening of 2D/3D Reconstruction Tools from the dashboard. Following automatically opening of the next window including the volume rendered image graphics processing unit (GPU) engine was selected to render the image at the best resolution. The button of rotation around the focal point was selected among the Mouse button functions for rotating the images, viewing the region from a point perpendicular to the anatomic area of interest. Then, Window-Level section was selected to arrange the opacity of the image for maximal reconstruction of the vascular and/or bone structures. The Measurement button was selected to estimate the diameter, width and length of the structures as well as the measurement of the distance between two different points.

Segmentation of the CP

Using three-dimensional volume rendered images, the CP was divided into three segments as the body, the atrial part and the temporal part. The body part started from the most superior tip of the CP and ended at the superior level of the atrial extension. The atrial part began at the superior level of the atrial extension and ended at the imaginary straight line drawn from the superior border of the temporal part. The temporal part started with this imaginary line and ended at the temporal tip of the CP (Figure 1, 2). The segmentation of the CP is shown in Figure 1, 2. The length and the width of the CP segments were estimated using the measurement button of software. The distances between the right and left inferior tips, and the right and left superior tips were estimated using the same technique (Figure 3, 4).

Estimation of Distances

The distances of the inferior temporal tip of the CP from the anterior clinoid process, the bifurcation of the internal carotid artery, and the bifurcation of the middle cerebral artery was estimated on the right and left sides (Figure 5, 6). The dimension between Frazier's point (6 centimeters superior to the inion and 4 centimeters lateral to the midline) and the superior tip of the CP was also estimated (Figure 7).

RESULTS

Patients Population

The total number of patients was 57 (27 female and 30 male). The mean age was 55±9 years. When an aneurysm was detected, the optimal appropriate management, either surgical clipping or endovascular coiling, was chosen and offered to the patients and their families.

Segments of the CP

In male individuals, the length of the CP body from the superior tip to the level of the atrial extension was estimated as 3.82±0.2 centimeters on the right side and 3.83±0.41 centimeters on the left side. In female individuals, the measurements were estimated as 3.09±0.31 centimeters on the right side and 3.08±0.22 centimeters on the left side. In male individuals, the length of the atrial part of the CP was estimated as 1.42±0.11 centimeters on the right side and 1.78±0.27 centimeters on the left side. In female individuals, the values were estimated as 1.28±0.04 centimeters on the right side and 1.49±0.29 centimeters on the left side. In male individuals, the temporal

Figure 1: The segmentation of the CP is shown in this figure (**ST:** superior tip; **IT:** inferior tip; **AE:** atrial extension; **BP:** body part; **AP:** atrial part; **TP:** temporal part; **LCP:** left choroid plexus; **SV:** septal veins; **TSV:** thalamostriate veins; **ICV:** internal cerebral veins; **BV:** basal vein).

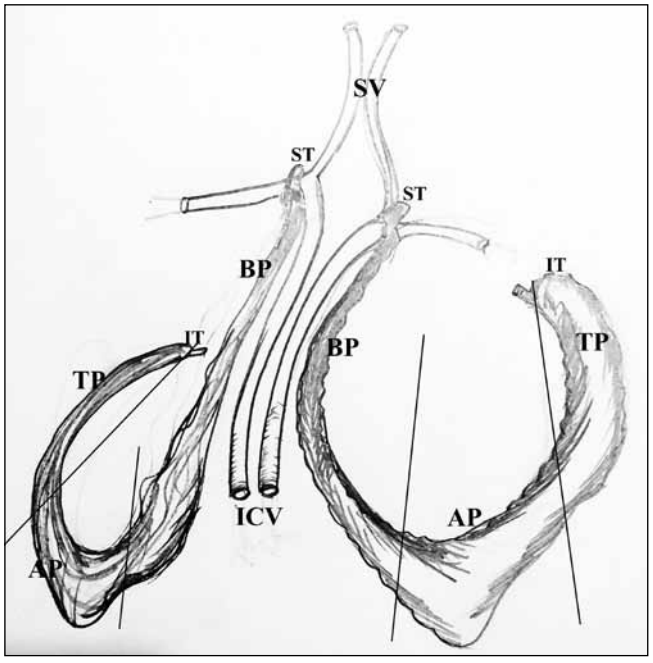

Figure 2: This schematic figure represents the segmentation of the CP (**ST:** superior tip; **IT:** inferior tip; **BP:** body part; **AP:** atrial part; **TP:** temporal part; **SV:** septal veins; **ICV:** internal cerebral veins).

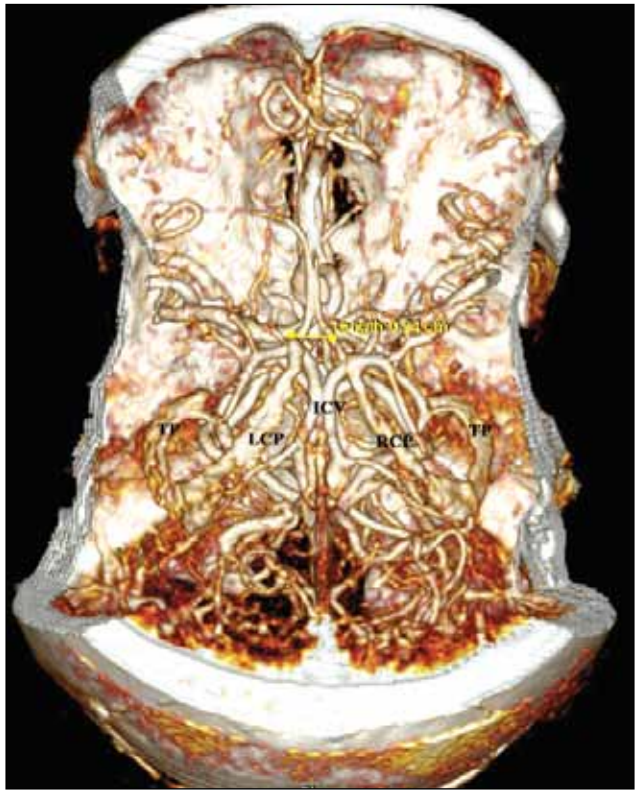

Figure 3: The measurement of the distances between the right and left superior tips (superior interchoroideal distance) was shown in this figure (**TP:** temporal part; **LCP:** left choroid plexus; **RCP:** right choroid plexus; **ICV:** internal cerebral veins).

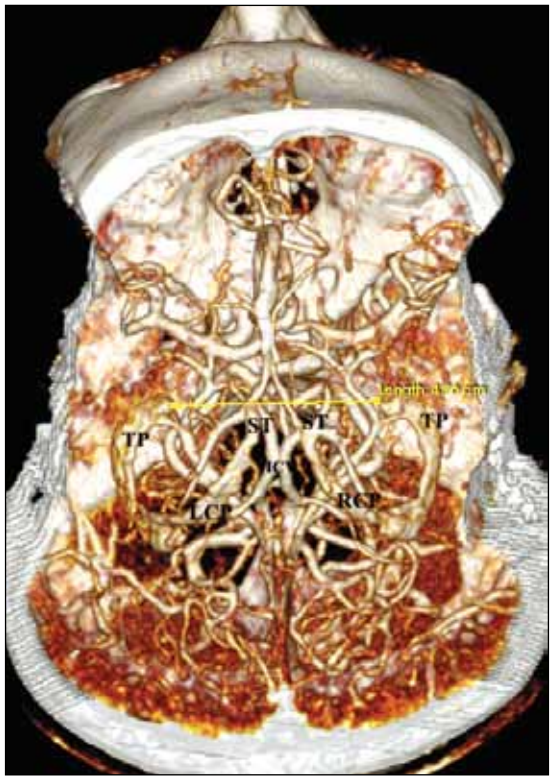

Figure 4: The using of measurement tool in the measurement of the distances between the right and left inferior tips (inferior interchoroideal distance) was shown in this figure (**TP:** temporal part; **ST:** superior tip; **LCP:** left choroid plexus; **RCP:** right choroid plexus; **ICV:** internal cerebral veins).

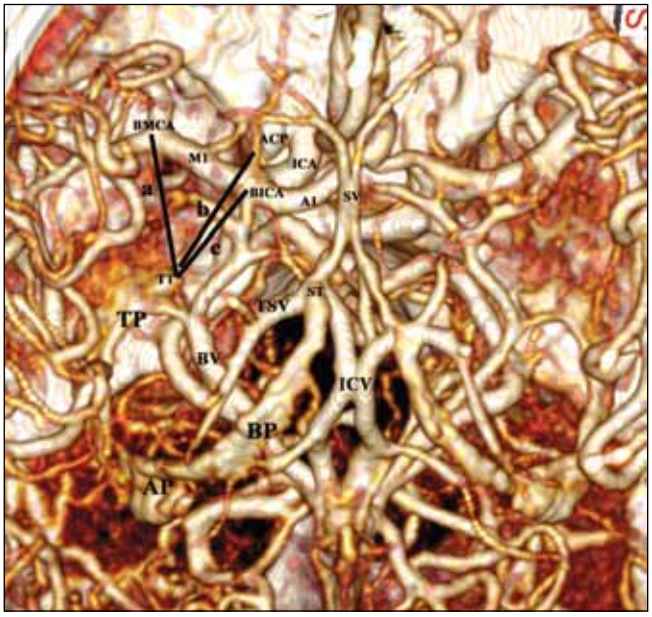

Figure 5: The estimation of the distances of the inferior temporal tip of the CP from the anterior clinoid process, the bifurcation of the internal carotid artery, and the bifurcation of the middle cerebral artery is shown in Figure d (BMCA: bifurcation of middle cerebral artery; **M1:** M1 segment of the middle cerebral artery; **BICA:** bifurcation of internal carotid artery; **ACP:** anterior clinoid process; **ICA:** internal carotid artery **A1:** anterior cerebral artery A1 segment; **SV:** septal veins; **TT:** temporal tip; **TP:** temporal part; **AP:** atrial part; **BP:** body part **BV:** basal vein **TSV:** thalamostriate vein **ST:** superior tip **ICV:** internal cerebral veins; **a:** the distance between the bifurcation of middle cerebral artery and temporal tip of choroid plexus; **b:** the distance between the anterior clinoid process and temporal tip of choroid plexus; **c:** the distance between the bifurcation of internal carotid artery and temporal tip of choroid plexus).

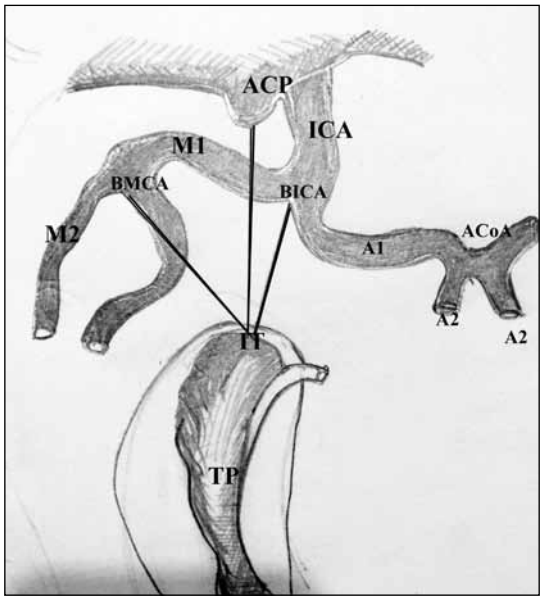

Figure 6: This schematic figure shows the estimation of the distances of the inferior temporal tip of the CP from the anterior clinoid process, the bifurcation of internal carotid artery, and the bifurcation of middle cerebral artery (BMCA: bifurcation of middle cerebral artery; **M1:** M1 segment of the middle cerebral artery; **BICA:** bifurcation of the internal carotid artery; **ACP:** anterior clinoid process; **ICA:** internal carotid artery **A1:** anterior cerebral artery A1 segment; **IT:** inferior tip; **TP:** temporal part; **A2:** anterior cerebral artery A2 segment; **ACoA:** Anterior communicating artery; **M2:** Middle cerebral artery M2 segment).

part of the CP was estimated as 2.37±0.14 centimeters on the right side and 2.7±0.27 centimeters on the left side. In female individuals, the values were estimated as 2.19±0.07 centimeters on the right side and 2.34±0.32 centimeters on the left side. Figure 8 and 9 shows the entire choroid plexus obtained from three-dimensional volume rendered images. Table I shows the length of the segments of the CP.

In male individuals, the width of the CP body was estimated as 0.35±0.09 centimeters on the right side and 0.44±0.08 centimeters on the left side. In female individuals, the measurements were estimated as 0.24±0.02 centimeters on the right side and 0.34±0.14 centimeters on the left side. In male individuals, the width of the atrial part of the CP was estimated as 1.07±0.22 centimeters on the right side and 1.17±0.14 centimeters on the left side. In female individuals, the values were estimated as 0.89±0.10 centimeters on the right side and 0.80±0.25 centimeters on the left side. In male individuals, the temporal part of the CP was estimated as 0.66±0.14 centimeters on the right side and 0.70±0.17 centimeters on the left side. In female individuals, the values were estimated as 0.71±0.03 centimeters on the right side

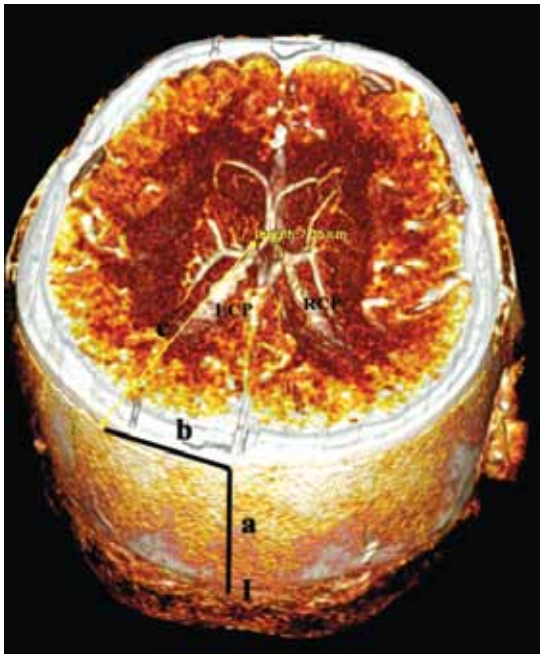

Figure 7: The estimation of the dimension between Frazier's point and the superior tip of the CP was shown in this figure (**l:** inion; **a:** 6 centimeters superior to the inion; **b:** 4 centimeters lateral to the midline **c:** the distance between the Frazier's point and the superior tip of the CP).

and 0.71±0.09 centimeters on the left side. Table II shows the width of the segments of the CP.

In male individuals, the distance between right and left CP was estimated as 0.69±0.31 centimeters at the level of the superior tips and 4.43±0.35 centimeters at the level of the inferior tips. In female individuals, the measurements were estimated as 0.64±0.21 centimeters at the level of the superior tips and 4.02±0.31 centimeters at the level of the inferior tips. The distances of the right and left choroid plexus at the level of the superior and inferior tips in male and female individuals are shown in Table III.

Estimation of Distances

In male individuals, the distance of the inferior tip (the tip of the temporal part of the CP) from the anterior clinoid process was estimated as 1.93±0.26 centimeters on the right side and 2.04±0.21 centimeters on the left side. In female individuals, the measurements were estimated as 2.13±0.21 centimeters on the right side and 2.21±0.10 centimeters on the left side. In male individuals, the distance from the bifurcation of the internal carotid artery was estimated as 1.64±0.23 centimeters on the right side and 1.71±0.24 centimeters on the left side. In female individuals, the measurements were estimated as 1.58±0.19 centimeters on the right side and 1.95±0.02 centimeters on the left side. In male individuals, the distance from the bifurcation of the middle cerebral artery was estimated as 2.86±0.23 centimeters on the right side and 2.2±0.31 centimeters on the left side. In female individuals,

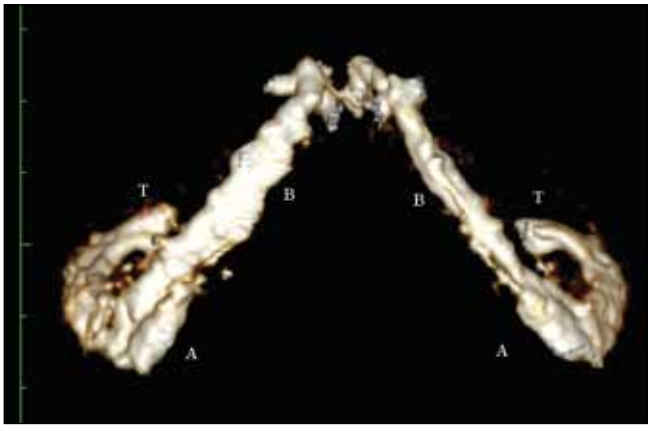

Figure 8: The three-dimensional volume rendered images of the choroid plexus in the posterior view. **T:** Temporal part, **A:** Atrial part, **B:** Body part.

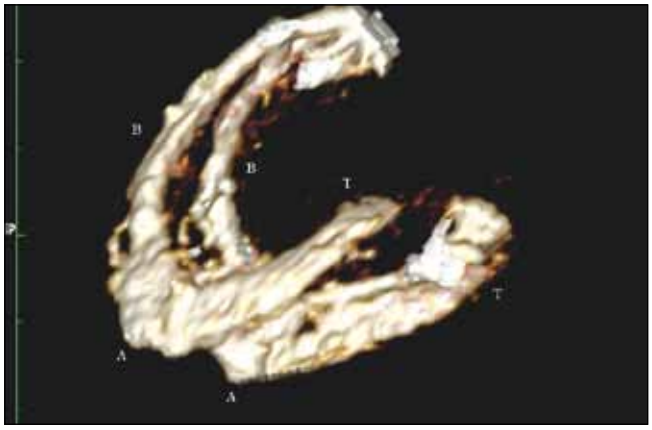

Figure 9: The three-dimensional volume rendered images of the choroid plexus in the lateral aspect. **T:** Temporal part, **A:** Atrial part, **B:** Body part.

Table I: The Lengths of the Segments of the CP

	n	Right			Left		
		Body Part	Atrial Part	Temporal Part	Body Part	Atrial Part	Temporal Part
Male	30	3.82±0.2	1.42±0.11	2.37±0.14	3.83±0.41	1.78±0.27	2.7±0.27
Female	27	3.09±0.31	1.28±0.04	2.19±0.07	3.08±0.22	1.49±0.29	2.34±0.32

Table II: The Widths of the Segments of the CP

	n	Right			Left		
		Body Part	Atrial Part	Temporal Part	Body Part	Atrial Part	Temporal Part
Male	30	0.35±0.09	1.07±0.22	0.66±0.14	0.44±0.08	1.17±0.14	0.70±0.17
Female	27	0.24±0.02	0.89±0.10	0.71±0.03	0.34±0.14	0.80±0.25	0.71±0.09

Table III. The Distance of the Right and Left Choroid Plexus at the Level of the Superior and Inferior Tip in Male and Female Individuals

	n	The distance between the superior tips (Superior interchoroideal distance)	The distance between the inferior tips (Inferior interchoroideal distance)
Male	30	0.69±0.31	4.43±0.35
Female	27	0.64±0.21	4.02±0.31

Table IV: The Distance of the Inferior Tip (Tip of Temporal Part) from the Anterior Clinoid Process, the Bifurcation of the Internal Carotid Artery, and the Bifurcation of the Middle Cerebral Artery on the Right Side

Right Side					
	n	Anterior Clinoid Process	Bifurcation of internal carotid artery	Bifurcation of middle cerebral artery	Frazier's point
Male	30	1.93±0.26	1.64±0.23	2.86±0.23	7.96±0.71
Female	27	2.13±0.21	1.58±0.19	2.54±0.32	7.39±0.81

Table V: The Distance of the Inferior Tip (Tip of Temporal Part) from the Anterior Clinoid Process, the Bifurcation of the Internal Carotid Artery, and the Bifurcation of the Middle Cerebral Artery on the Left Side

Left Side					
	n	Anterior Clinoid Process	Bifurcation of internal carotid artery	Bifurcation of middle cerebral artery	Frazier's point
Male	30	2.04±0.21	1.71±0.24	2.2±0.31	7.88±0.8
Female	27	2.21±0.10	1.95±0.02	2.13±0.08	7.32±0.68

the measurements were estimated as 2.54±0.32 centimeters on the right side and 2.13±0.08 centimeters on the left side.

In male individuals, the distance of the superior tip (the tip of the body part of the CP) from Frazier's point (6 centimeters superior to the inion and 4 centimeters lateral to the midline) was estimated as 7.96±0.71 centimeters on the right side and 7.88±0.8 centimeters on the left side. In female individuals, the measurements were estimated as 7.39±0.81 centimeters on the right side and 7.32±0.68 centimeters on the left side. The distances are summarized in Table IV and V.

DISCUSSION

Choroid plexus is a specialized membranous vascular plexus included within the lateral, the third, and the fourth ventricles of the brain and is responsible for generating and secreting cerebrospinal fluid (6, 7, 8). The lateral ventricle, fornix, thalamus, and choroid fissure should be taken into account in the evaluation of anatomical details of the CP (6, 7, 8). The choroid plexus is mainly located in the lateral ventricle attached to the choroid fissure between the thalamus and fornix (6, 7, 8). Rhoton et al. anatomically divided the choroid fissure into three parts as the body portion, the atrial part, and the temporal part (6). The segments of the choroid fissure were used in the segmentation of the CP. Three-dimensional anatomy of the CP, its details, shape and extensions can be imagined using the volume-rendering technique.

The choroid plexus is a C-shaped anatomical structure when viewed from the lateral aspect of three-dimensional volume rendered images. The superior tip of the C-shaped choroid plexus is located within the lateral ventricles. On the other hand, the inferior tip of the CP (the temporal tip) is localized inside the inferior horn of the lateral ventricle. When viewed from the posterior aspect, the C-shape is oblique as its upper end is very close to midline (medialized), and the lower end is in contrast far from the midline (lateralized). The distance between the right and left superior tips of the CP (superior interchoroideal distance) was found to be nearly equal in male and female individuals. In male individuals, the value was estimated as 0.69±0.31 centimeters. In female individuals, the measurement was 0.64±0.21 centimeters at the level of the superior tips. In males, the distance between the right and left inferior tips of the CP (inferior interchoroideal distance) was 9.25% higher than in females. In males, the mean value was measured as 4.43±0.35 centimeters at the level of the inferior tips. In female individuals, the measurement was estimated as 4.02±0.31 centimeters at the level of the inferior tips. The practical implementation of the superior interchoroideal distance measurement can be underlined the worth during the surgical intervention through the interhemispheric transventricular approach to the third ventricle and related structures. From another aspect, the inferior interchoroideal distance may be used as a reference point during surgical interventions in the unilateral mesial temporal regions including the amygdalohippocampal structures.

Using three-dimensional volume rendered images, the CP was divided into three segments as the body, the atrial and the temporal part. In male individuals, the length of the CP body from the superior tip to the level of the atrial extension was nearly equal on the right and left sides. The values were 3.82±0.2 centimeters on the right side and 3.83±0.41 centimeters on the left side. In female individuals, the length of the body part was 19.3% lower than those of males. The shortest segment of the CP was the atrial part. In male individuals, the length of the atrial part of the CP was estimated as 1.42±0.11 centimeters on the right side and 1.78±0.27 centimeters on the left side. In female individuals, the values were estimated as 1.28±0.04 centimeters on the right side and 1.49±0.29 centimeters on the left side. In males, the length of the left atrial CP was 20.22% longer than the right side. On the other hand, in females, the left atrial CP was found to be 14.09% longer than the right side. The

inferior segment of the CP located within the temporal horn (inferior horn) of the lateral ventricle was estimated in terms of its length. In male individuals, the temporal part of the CP was estimated as 2.37±0.14 centimeters on the right side and 2.7±0.27 centimeters on the left side. In female individuals, the values were estimated as 2.19±0.07 centimeters on the right side and 2.34±0.32 centimeters on the left side. In males, the length of the inferior part of the CP was 12.22% longer than the right side. On the other hand, in females, the left inferior part of the CP was 6.41% longer than the right side. The clinical intention to slice virtually the anatomical structure of the choroid plexus may be tackled as subsidiary sectional classification of the ongoing pathological process related with choroid plexus and neighboring structures.

Three-dimensional volume rendered images of the CP revealed that it is ribbon-like with non-uniform width from the superior to inferior tip. Although the choroid plexus resembles the letter C, it makes a 90-degree angle at the level of the inferior turning point in where it has the widest width. In contrast, the narrowest part of CP was found along the body part. In male individuals, the width of the CP body was estimated as 0.35±0.09 centimeters on the right side and 0.44±0.08 centimeters on the left side. In female individuals, the measurements were estimated as 0.24±0.02 centimeters on the right side and 0.34±0.14 centimeters on the left side. In males and females, the width of the left body part of the CP was estimated as 22.72% wider than the right side. In male individuals, the width of the atrial part of the CP was estimated as 1.07±0.22 centimeters on the right side and 1.17±0.14 centimeters on the left side. In female individuals, the values were estimated as 0.89±0.10 centimeters on the right side and 0.80±0.25 centimeters on the left side. In males, the width of the atrial part of the CP was estimated as 8.54% wider than the right side. On the other hand, in females, the left atrial part of the CP was found to be 10.11% wider than the right side. In male individuals, the temporal part of the CP was estimated as 0.66±0.14 centimeters on the right side and 0.70±0.17 centimeters on the left side. In female individuals, the values were estimated as 0.71±0.03 centimeters on the right side and 0.71±0.09 centimeters on the left side. In male and female individuals, the width of the inferior part of the CP was nearly equal on the right and left sides. Individual measurements of the width of the choroid plexus may be used during surgical intervention performed inside the lateral ventricle to measure the distance down to the choroideal fissure as well as the septal region.

In this study, four anatomical points were selected to estimate the distance between some important surgical points and the superior-inferior tips of the CP. The distance between the inferior tip of the CP and the anterior clinoid process, the bifurcation of the middle cerebral and the internal carotid artery was estimated. On the other hand, the distance of the superior tip of the CP and Frazier's point (6 centimeters superior to the inion and 4 centimeters lateral to the midline) was also evaluated. In male individuals, the distance of the inferior tip (the tip of the temporal part of the CP) from the anterior clinoid process was estimated as 1.93±0.26 centimeters posterior-lateral on the right side and 2.04±0.21 centimeters on the left side. In males, the distance was estimated as 5.39% more posterior-lateral than the right side. In female individuals, the measurements were estimated as 2.13±0.21 centimeters on the right side and 2.21±0.10 centimeters on the left side. In females, the distance was estimated as 3.61% more posterior-lateral than the right side. The bifurcation of the middle cerebral and the internal carotid artery are also important anatomical landmarks. In male and female individuals, the distance from the bifurcation of the internal carotid artery was found to be nearly equal on the right side. The left side distance was found as 18.97% in males and was higher than the distance in females. In male individuals, the distance from the bifurcation of the middle cerebral artery was estimated as 2.86±0.23 centimeters posterior-medial on the right side and 2.2±0.31 centimeters on the left side. In female individuals, the measurements were estimated as 2.54±0.32 centimeters on the right side and 2.13±0.08 centimeters on the left side. In male and female individuals, the distance from the bifurcation of the middle cerebral artery was found to be nearly equal on the left side. On the other hand, the right side male's distance was 11.18% more posterior-medial than the distance in females. In males, the distance of the inferior tip of the CP was estimated as 1.93±0.26 centimeters posterior-lateral from the anterior clinoid process, 1.64±0.23 centimeters posterior-lateral from the bifurcation of the internal carotid artery, and 2.86±0.23 centimeters posterior-medial from the bifurcation of the middle cerebral artery on the right side. These distances may be taken into account for cases needing selective amygdalohippocampectomy. The endeavor of the measurement the distance between the inferior tip of the CP and some anatomical points such as the bifurcation of the middle cerebral artery and the internal carotid artery, and anterior clinoid process may be appraised as an auxiliary ingredient reaching down to the temporal horn and hippocampal region. In the other words, following the finite microsurgical dissection of the bifurcation of the middle cerebral artery, the distance remaining from the bifurcational point to the inferior tip of the choroid plexus and amygdala may be estimated via the presented measurements in this study as a subsidiary reference structures.

In male individuals, the distance of the superior tip (the tip of the body part of the CP) from Frazier's point (6 centimeters superior to the inion and 4 centimeters lateral to the midline) was estimated as 7.96±0.71 centimeters anterior-medial on the right side and 7.88±0.8 centimeters on the left side. In female individuals, the measurements were estimated as 7.39±0.81 centimeters on the right side and 7.32±0.68 centimeters on the left side. In males, the right superior tip of CP was found to be 8.04% more anterior-medial than the distance in females. On the other hand, in males the left superior tip of the CP was estimated as 6.21% more anterior-medial than in females. These distances should be taken into account for cases needing ventricular shunt placement to avoid proximal catheter malfunction. The practical value of

the distance of the superior tip of the CP from the Frazier's point should be esteemed in the determination of the place, location and position of the proximal ventricular catheter in the cases with hydrocephalus.

Knowledge of the three-dimensional anatomical structure of the choroid plexus is important in the grouping of tumors originating from the choroid plexus, and planning of the surgical intervention to the lateral ventricles. Microsurgical and gross macroscopic anatomy of the choroid plexus may be evaluated using volume-rendering technique in living objects. The results of this study revealed that the gross macroscopic anatomy, attachments, extensions, and portions of the choroid plexus could be adequately imagined using the volume-rendering technique. Further evaluations are necessary to study in terms of vascular and neural relationships.

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