Anatomic Variability of the Morphometric Parameters of the Fourth Ventricle of the Brain

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J Neurol Surg B 2018;79:200–204.

Abstract

Objectives The defining of the normal parameters of spacious relations and symmetry of the ventricular system of the brain depending on the gender and age is currently one of the topical research problems of clinical anatomy. The present research aims to identify the correlation between the morphometric parameters of the fourth ventricle of the brain and the shape of the skull in middle aged people.

Design This is a prospective cohort study.

Setting This study was set at the Trinity School of Medicine.

Participants A total of 118 normal computed tomography scans of the head of people aged from 21 to 86 years (mean age—48.6 years $\pm$ 17.57) were selected for the study.

Main Outcome Measures The anteroposterior, transverse diameters, and height of the fourth ventricle were measured and compared in dolichocranial, mesocranial, and brachycranial individuals.

Keywords

- fourth ventricle
- anatomic variability
- morphometry
- computed tomography

Results The study has shown the presence of a statistically significant difference between morphometric parameters of the fourth ventricle of the brain in dolichocranial, mesocranial, and brachycranial individuals.

Conclusion The morphometric parameters of the fourth ventricle of the brain, such as height, anteroposterior, and transverse diameters, depend on the individual anatomic variability of the skull shape and gender.

Introduction

The defining of the normal parameters of spacious relations and symmetry of the ventricular system of the brain depending on the gender and age is currently one of the topical research problems of clinical anatomy.^{1,2} This scientific issue was addressed by many researchers recently.³ Although the variability of the parameters of the ventricular system is extremely important, especially in the neurosurgery field, there is still a lack of the sources providing precise, unambiguous, or bias data on the subject matter.

The fourth ventricle of the brain is an important part of the ventricular system, which is connected to the third ventricle

by the cerebral aqueduct and to the central medullary canal. The obstructive pathology of the liquor system of the brain is common. Many cases are caused by the tumors originating in the fourth ventricle, or from the substance of the brain around the ventricular cavity. Most of the cases require operative treatment.^{4–6} These tumors change the configuration of the ventricle and liquor passage through the system. There is a lot of data in the literature about changes of capacity of ventricular system and alterations of the shape and symmetry of the ventricles in patients with mental health diseases, particularly patients with schizophrenia. It was reported that thalamic shrinkage, especially of medial nuclei and the adjacent striatum and insular cortex in patient

received

January 23, 2017

accepted after revision

July 25, 2017

published online

September 11, 2017

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Stuttgart · New York

DOI <https://doi.org/10.1055/s-0037-1606331>.
ISSN 2193-6331.

with schizophrenia, appears to be an important contributors to ventricular enlargement. It was widely agreed that schizophrenia must be considered as an organic brain disorder.^{7,8}

Previous research mainly focused on the distribution of the data in relation to the age and the gender of the subjects. Some of the previous studies showed positive correlation between age and fourth ventricle dimensions and prevalence of the studied parameters in males.⁹ Modern neuroimaging techniques provide an excellent opportunity to investigate and research the deep brain structures and ventricular system parameters. These had led to better understanding of anatomy of different intracranial lesions.

The purpose of our study is to identify the correlation between the morphometric parameters of the fourth ventricle of the brain and the shape of the skull in middle aged people. The theory of the individual anatomic variability states that the population can be classified by the shape of the skull into three major groups: brachycranial, mesocranial, and dolichocranial. It is thought that the morphometric parameters of the intracranial structures vary in accordance with the shape of the skull and some of the parameters of the skull correlate with parameters of the intracranial structures (e.g., dural sinuses).¹⁰ The knowledge of these data will enable us to identify minor pathological deviations from the normal anatomical parameters. This will make the early diagnostic of brain diseases easier and faster, and will create more detailed data available for the planning of the stereotactic operations in neurosurgery. This will allow to diagnose and treat the ventricular system and other brain pathologies on early stages.

Materials and Methods

A collection of 340 computed tomography (CT) scans of patients who underwent a routine CT of the head in the radiology department of the private "mother and child" clinic of Lugansk city (Ukraine) during 2013 to 2014 was reviewed for the study. The scans were made on the Asteion Super 4 multislice Helicat CT scanner. A total of 118 scans of the head were selected. The inclusion criteria were the subjects of both genders without the history of congenital posterior fossa anomalies, cerebral infarction, trauma, local mass lesions, previous intracranial surgery, and known vascular pathology. The rest of scans were excluded because of the diagnosed pathological changes in the brain. Among the studied subjects were 49 males and 69 females. The age of participants ranged from 21 to 86 years (mean age—48.6 years $\pm$ 17.57). The study was approved by the Institutional Review Board and Ethics Committee of the Trinity School of Medicine.

Craniological parameters were measured first. The length of the skull was measured between the glabella (gl) and opisthocranium (op), skull height was measured between bregma (br) and basion (ba), and the width (transverse diameter) was measured between eurion (eu) of the right and left sides (**—Figs. 1–3**). The cranial index (CI) was calculated as a ratio of the length of the skull to the transverse diameter percentagewise according to standard anatomical descriptions:^{11,12} $CI = \text{skull length} / \text{skull height} \times 100$. The studied

Fig. 1 Craniological measurement of the length of the skull performed on the sagittal computed tomography image of the head. Gl, glabella; Op, opisthocranium.

subjects were subdivided into the subgroups: dolichocranial (CI < 74.9%), mesocranial (CI: 75–79.9%), and brachycranial (CI > 80%).¹³

After the craniological measurements, the diameters of the fourth ventricle of the brain were investigated. The height of the ventricle was assessed between the point of entry on the level of the lower opening of the cerebral aqueduct and the point of the upper end of the central medullary canal (**—Fig. 4**). The anteroposterior diameter was measured in the widest portion of the ventricle between the posterior surface of the pons and cerebellum, on the level between the superior and inferior medullary vela (**—Fig. 5**). The transverse diameter was assessed on the level of the middle cerebellar peduncles (**—Fig. 6**).

Statistical analysis of the data was performed using the SPSS 15.0 package. The data were checked for the normality of the distribution. Standard statistical parameters were estimated (e.g., mean, standard deviation, minimum, maximum, etc.)

Fig. 2 Craniological measurement of the height of the skull performed on the sagittal computed tomography image of the head. Br, bregma; Ba, basion.

Fig. 3 Craniological measurement of the transverse diameter (width) of the skull performed on the transverse computed tomography image of the head. Eu, euron.

were calculated in each group and compared. The correlation analysis with the Student's paired *t*-test was performed to investigate the interdependence of the ventricular parameters, CI, and particular craniological parameters (skull length, height, and transverse diameter). A *p*-value ≤ 0.05 was considered as statistically significant. We have also looked at the dependence between the investigated parameters of the fourth ventricle and the gender of studied individuals.

Results

Analysis of the differences among dolichocranial, mesocranial, and brachycranial individuals has shown that the mean value of the skull length (gl-op) of the brachycranial individuals was the smallest— 17.60 ± 0.84 cm; for the mesocranial individuals, it was 17.99 ± 0.95 cm; and in the dolichocranial individuals, it was the largest— 18.63 ± 0.72 cm. The mean value of the skull width (transverse diameter) was the largest

Fig. 4 Morphometry of the height of the fourth ventricle on the sagittal computed tomography image.

Fig. 5 Morphometry of the anteroposterior diameter of the fourth ventricle on the transverse computed tomography image.

for the brachycranial individuals— 15.12 ± 0.62 cm. It was a little less for the mesocranial individuals— 14.48 ± 0.67 cm, and the least mean value of the transverse diameter was identified in the dolichocranial individuals— 14.06 ± 0.61 cm (**> Table 1**).

Assessing the results of morphometric study of the fourth ventricles, it was established that the largest anteroposterior diameter was detected in the dolichocranial individuals— 1.11 ± 0.22 cm; for the mesocranial individuals, it was 1.08 ± 0.27 cm; and the brachycranial individuals had the smallest anteroposterior diameter of 1.07 ± 0.21 cm. The transverse diameter assessment had

Fig. 6 Morphometry of the transverse diameter of the fourth ventricle on the transverse computed tomography image.

Table 1 Craniometric parameters of the skull^a

	Skull length (gl-op)	Skull width (eu-eu)	Skull height (br-ba)
Dolichocranial CI	18.63 ± 0.72 ^b	14.06 ± 0.61 ^c	13.90 ± 0.54 ^c
Mesocranial CI	17.99 ± 0.95 ^b	14.48 ± 0.67 ^b	13.41 ± 0.71 ^c
Brachycranial CI	17.60 ± 0.84 ^c	15.12 ± 0.62 ^b	13.31 ± 0.72 ^c

Abbreviations: ba, basion; br, bregma; CI, cranial index; eu, eurion; gl, glabella; op, opisthocranion.

^aDepending on the craniotype, mean values and ranges of their distribution (standard deviation), cm.

^b $p < 0.01$.

^c $p < 0.05$.

shown opposite. The largest width of the fourth ventricle belonged to the brachycranial individuals— 1.32 ± 0.19 cm, and the smallest transverse diameter was indicated in dolichocranial individuals— 1.28 ± 0.18 cm. The height of the fourth ventricle was the biggest in the dolichocranial individuals— 2.92 ± 0.28 cm, and the least was identified in the brachycranial individuals— 2.80 ± 0.31 cm (►Table 2).

Analysis of the data between males and females groups has shown a slight prevalence of the diameters of the skull as well as of the diameters of the fourth ventricle in males. According to our study, the mean skull length (gl-op) in males was 18.57 ± 0.77 cm, and in females, it was 17.34 ± 0.65 cm. Skull height was identified being 13.87 ± 0.73 and 13.11 ± 0.53 cm for males and females, respectively. Skull width (transverse diameter) was 15.21 ± 0.65 cm for males and 14.50 ± 0.66 cm for females (►Table 3).

The anteroposterior diameter of the fourth ventricle for the males was 1.08 ± 0.22 cm, and for females, it was 1.06 ± 0.23 cm. The transverse diameter and height were 1.36 ± 0.19 and 2.88 ± 0.44 cm in males, and 1.25 ± 0.18 and 2.72 ± 0.40 cm in females, respectively (►Table 4).

We have also looked at the correlation between the diameters of the skull and of the fourth ventricle. It was established that a weak positive correlation is present between the skull length (gl-op) and anteroposterior diameter of the fourth ventricle: 0.271 ($p < 0.01$). Weak positive correlation was also found between skull height (br-ba) and fourth ventricle height 0.354 ($p < 0.01$). Between the skull width (transverse diameter, eu-eu) and the transverse dia-

Table 2 Morphometric parameters of the fourth ventricle of the brain^a

	Anteroposterior diameter	Transverse diameter	Height
Dolichocranial CI	1.11 ± 0.22 ^b	1.28 ± 0.18 ^c	2.92 ± 0.28 ^d
Mesocranial CI	1.08 ± 0.27 ^c	1.30 ± 0.19 ^d	2.87 ± 0.38 (NS)
Brachycranial CI	1.07 ± 0.21 ^c	1.32 ± 0.19 ^c	2.80 ± 0.31 ^d

Abbreviations: CI, cranial index; NS, not significant.

^aDepending on the craniotype, mean values and ranges of their distribution (standard deviation), cm.

^b $p < 0.001$.

^c $p < 0.01$.

^d $p < 0.05$.

Table 3 Craniometric parameters of the skull^a

	Skull length (gl-op)	Skull width (eu-eu)	Skull height (br-ba)
Males	18.57 ± 0.77 ^b	15.21 ± 0.65 ^c	13.87 ± 0.73 ^c
Females	17.34 ± 0.65 ^c	14.50 ± 0.66 ^c	13.11 ± 0.53 ^c

Abbreviations: ba, basion; br, bregma; CI, cranial index; eu, eurion; gl, glabella; op, opisthocranion.

^aDepending on the gender, mean values and ranges of their distribution (standard deviation), cm.

^b $p < 0.001$.

^c $p < 0.01$.

meter of the fourth ventricle, a moderate positive correlation was found 0.573 ($p < 0.001$).

Discussion

The fourth ventricle of the brain is a part of the liquor system which develops within the third brain vesicle and represents the cavity of the rhombencephalon (hindbrain). Its floor is formed by the pons and medulla oblongata, and its roof is formed by the medullary vela and cerebellar peduncles. Its communication with the third ventricle via the cerebral aqueduct, central canal, and subarachnoid space via foramen of Luschka and Magendie are important for proper circulation of the cerebrospinal fluid. Inflammatory or organic obstruction of the ventricle outflow with a tumor growing inside or any other posterior cranial fossa mass will lead to dilation or compression of its cavity.^{14,15}

Recent literature shows increased amount of the reports describing primary congenital and acquired pathology of the fourth ventricle or of the other parts of the liquor system and brain structures in general, secondarily affecting it. This is in part due to advances in the neuroimaging techniques.¹⁶

To correctly assess what we see when we look at the different imaging studies of the brain and ventricular system in particular (e.g., CT, magnetic resonance imaging), we have to have well-defined criteria telling us that we are looking at normal or pathologically changed structures, which will promote early diagnostics of brain pathology. On the contrary, knowledge of the variations depending on the craniotype, gender, and age will prevent hyperdiagnostics

Table 4 Morphometric parameters of the fourth ventricle of the brain^a

	Anteroposterior diameter	Transverse diameter	Height
Males	1.08 ± 0.22 ^b	1.36 ± 0.19 ^c	2.88 ± 0.44 ^b
Females	1.06 ± 0.23 ^c	1.25 ± 0.18 ^b	2.72 ± 0.40 ^b

^aDepending on the gender, mean values and ranges of their distribution (standard deviation), cm.

^b $p < 0.05$.

^c $p < 0.01$.

cases, when a different from average data just representing an anatomic variation rather than pathologic changes.

The received data will help neurosurgeons to assess the diameters of the fourth ventricle in dynamics during the recovery of their patients after the operative treatment of the hydrocephalus, preventing severe complications of the shunt obstruction (e.g., cerebellar tonsillar herniation) on early stages.^{17,18}

In accordance with our findings, the diameters of the fourth ventricle correlate with the diameters of the skull, showing weak (skull length—anteroposterior diameter of the fourth ventricle and skull height—fourth ventricle height) and mild (skull width—fourth ventricle transverse diameter) positive correlation between these parameters.

There is a statistically significant difference in the parameters of the fourth ventricle in relation to the craniotype. Brachycephalic individuals possess the largest transverse diameter of the ventricle, while dolichocephalic individuals possess the largest anteroposterior diameter and height of the fourth ventricle. This supports the theory of individual anatomic variability, which states that brachymorphic type of body constitution is related to larger transverse dimensions of the body structures, while dolichomorphic type is related to prevalence of the longitudinal diameter over the transverse diameters of the body structures.¹⁹

The gender differences that we have found in our studies support previous works, which show the evidence of the fact that the dimensions of the fourth ventricle in males are slightly greater than in females.^{20,21}

Conclusion

The morphometric parameters of the fourth ventricle of the brain, such as height, anteroposterior, and transverse diameters, depend on the individual anatomic variability of the skull shape and gender. These factors should be taken into account during the processes of diagnostics and treatment of pathologies of the brain in general and of the fourth ventricle in particular.

Conflict of Interest

None.

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