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Morphometric Examinations of Internal Carotid Arteries of Patients with Hypertension and Patients with Type 2 Diabetes Mellitus: A Radio Anatomic Study Based on Computed Tomography Angiography Findings

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ABSTRACT

AIM: To examine the relationship between the morphologic features of the internal carotid artery (ICA) and symptoms affecting cerebral blood circulation including type 2 diabetes mellitus (T2DM) and hypertension (HT).

MATERIAL and METHODS: In this study, retrospective morphometric analysis of ICA measurements from 100 patients (aged 45-60 years) was performed using computed tomographic angiography (CTA) images. The images were divided into four groups: patients with HT (group 1), patients with T2DM (group 2), patients with HT and T2DM (group 3), and a healthy control group (group 4). Length and diameter measurements of the cervical, petrous, cavernous, and terminal segments of the ICA were made using 3D CTA images and recorded. The measurements of the male and female patients were compared using the Mann-Whitney U test and the groups were compared using the Kruskal-Wallis H test.

RESULTS: It was found that there were statistically significant differences between male and female patients in terms of the right and left petrous, cavernous, and terminal segments of the ICA in group 1, right and left cervical left cavernous in group 3, left cervical, right and left petrous, cavernous, and right cavernous in group 4 ($p<0.05$). According to the Kruskal-Wallis H test analysis results, it was determined that there were no statistically significant differences between the patients in the four groups for all segment measurements ($p>0.05$).

CONCLUSION: It was determined that ICA was more affected by HT than diabetes. In addition, we think that being knowledgeable of morphometric measurements of ICA will guide radio-anatomic evaluations and increase the level of microanatomic knowledge in surgical treatment.

KEYWORDS: Internal carotid artery, Computed tomographic angiography, Type 2 diabetes mellitus, Hypertension

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INTRODUCTION

The internal carotid artery (ICA) supplies most of the ipsilateral cerebral hemisphere, the eye and its accessory structures, the frontal region, and part of the nasal cavity. At its origin, it is located on the outer side of the external carotid artery (2). Occlusion of the ICA causes ischemic stroke in 20% of young adults and is usually seen between the ages of 40-45 years. The rate of arterial pathology is similar in people (5).

In the literature, the ICA has been examined under four segments including cervical, petrous, cavernous, and terminal segments, and it has been reported that atherosclerosis is most frequently seen in the cervical segment (10,13). Morphometric differences of the carotid system have received more attention from researchers because any obstruction that may occur in the carotid system causes cerebral ischemia, which often results in mortality (16). Being knowledgeable about the anatomic formations and their relationship with the surrounding tissues, and considering the possible anomalies of these structures is very important to prevent unpredictable complications (3,5).

The anatomy of ICA is very important for surgeons and radiologists, as well as anatomists. To increase the success of interventions in the cavernous sinus and to treat lesions of the cranial nerves passing through the area, knowledge of the course and variations of the arteries feeding these nerves is also very important (11).

Hypertension (HT), which is a major risk factor for stroke, is defined as arterial blood pressure higher than 140 mmHg systolic or 90 mmHg diastolic pressure. The cerebrovascular changes associated with HT include arterial wall thickening and endothelial damage. These changes trigger or accelerate the formation of atherosclerosis, which will change cerebral blood flow and eventually cause pathologies such as stroke (20).

Type 2 diabetes mellitus (T2DM) is a heterogeneous metabolic disorder characterized as hyperglycemia, which develops due to insufficient insulin secretion. It is a common disease associated with chronic complications including nephropathy, angiopathy, retinopathy, and peripheral neuropathy. T2DM frequently leads to a variety of brain disorders in the long term. Neurochemical, electrophysiologic, structural, and cognitive changes caused by diabetic cerebral disorders have been defined in the literature. The effects of T2DM on the brain are seen as changes in cerebral blood supply and metabolic disturbances. The brain is also affected by recurrent episodes of hypoglycemia and poor metabolic control (7).

Pathologies such as T2DM can lead to changes in the structure of vessel walls that may result in an important clinical picture such as stroke (6). In healthy people, vessel wall tension is low; however, it increases due to reasons such as HT and diabetes (14).

To the best of our knowledge, there is no study measuring and comparing the diameters of different segments of the ICA in male and female patients with HT and T2DM. This study aimed to compare the morphologic features of the four segments of the ICA in male and female patients with HT and T2DM and a control group on computed tomographic angiography (CTA) images.

MATERIAL and METHODS

Patient Population

Morphometric analyses were performed retrospectively on 100 brain CTA images of patients aged 40-65 years who were admitted to Malatya Inonu University Faculty of Medicine, Department of Radiology between 2012 and 2020. Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Malatya Inonu University (2021/1629).

Patients with cerebral aneurysm, acute ischemic stroke, those with a history of embolism, previous endovascular treatment, those with a history of chronic hyperlipidemia, and CT images with artifacts were excluded from the study. Patients with significant proximal ICA stenosis in CTA were excluded from the study because it affected the diameter of the ICA segments.

The individuals included in the study were divided into four groups:

Group 1: Patients who were diagnosed as having HT, aged 40-65 years

Group 2: Patients who were diagnosed as having T2DM, aged 40-65 years

Group 3: Patients who were diagnosed as having both T2DM and HT, aged 40-65 years

Group 4: Patients without T2DM or HT, aged 40-65 years (control group)

Imaging Method

The CTA images of the patients included in the study were obtained using double-source spiral CTA (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany), located in the Radiology Department of Inonu University. The device was a 256-slice multislice CT with a dose of 120 kv 35 mA and section thickness of 0.6 mm, and the amount of contrast material was 100 mL.

According to the scanning protocol, the patients were placed on the table in the supine position with the head forward and the arms at the sides; the scanning area was adjusted from vertex to mentum. Using the 'bolus tracking' method, a single section from the 'region of interest' (ROI) pattern to the aorta was placed on the reference image, and the threshold contrast value was set to 100 HU to start scanning. A low-osmolarity non-ionic iodinated contrast material of 80-100 mL was injected into the median cubital vein using an automatic pump with an injection rate of 4-5 mL/sec, and 40 mL of saline solution was injected after the contrast agent for homogeneous distribution.

The examined segments of the ICA:

Cervical segment (Cer-R, Cer-L): Lumen diameter was measured 1 cm ahead of the proximal ICA (Figure 1A).

Petrous segment (Pet-R, Pet-L): Lumen diameter was measured distal to the petrous segment of the ICA to avoid petrous bone artifacts (Figure 1B).

Cavernous segment (Cav-R, Cav-L): Lumen diameter was measured proximal to the cavernous segment of the ICA (Figure 1C).

Terminal segment (Term-R, Term-L): The ICA's a. cerebri anterior (ACA) and lumen diameter was measured from the distal segment without giving two terminal branches as the a. cerebri media (ACM) (9) (Figure 2).

Statistical Analysis

The data are given as median, minimum (min), and maximum (max) values. Normality of distribution was examined using the Kolmogorov-Smirnov test and it was found that the data did not show normal distribution. The parameters of male and female patients were compared using the Mann-Whitney U test. Intergroup comparisons were performed using the Kruskal-Wallis H test. P-values of <0.05 were considered statistically significant. Statistical analyses were performed using the IBM SPSS Statistics 22.0 for Windows package program.

RESULTS

Group 1 included 13 female patients with a median age of 60 years and 12 male patients with a median age of 61.5 years. The median (min-max) values of the variables of patients with HT and Mann-Whitney U analysis results are given in Table I. It was found that there were statistically significant differences between the male and female patients in group 1 in terms of Pet-R, Pet-L, Cav-R, Cav-L, Term-R, and Term-L parameters ($p<0.05$) (Table I).

Group 2 consisted of 10 female patients with a median age of 50 years and 15 male patients with a median age of 58 years. The median (min-max) values of the variables of patients with T2DM and Mann-Whitney U analysis results are given in Table 2. According to the results of the analysis, it was determined that there were no statistically significant differences between the male and female patients in group 2 in terms of the measured parameters ($p>0.05$) (Table II).

Group 3 consisted of 12 female patients with a median age of 62 years and 15 male patients with a median age of 63 years. The median (min-max) values of the measured parameters of patients with HT and T2DM and Mann-Whitney U analysis results are given in Table III. According to the results of the analysis, it was determined that there were statistically significant differences between the male and female patients in group 3 in terms of Cer-R, Cer-L, and Cav-L parameters ($p>0.05$) (Table III).

Group 4 consisted of 12 female patients with a median age of 50 years and 13 male patients with a median value of 50 years. The median (min-max) values of the measured parameters of patients in the control group and Mann-Whitney U analysis results are given in Table IV. According to the results, it was determined that there were significant differences between

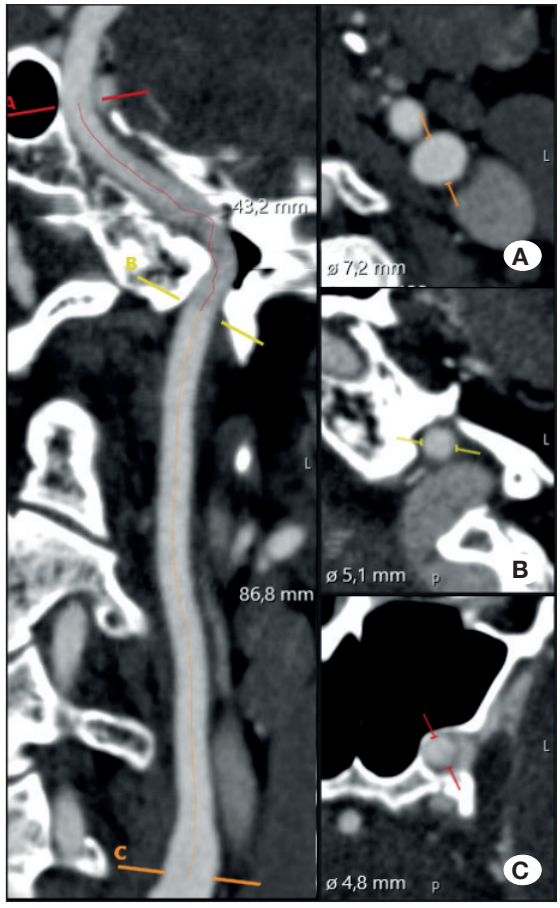

Figure 1: Computerized tomography angiography (CTA) diameter measurement in the cervical (A), petrous (B) and cavernous (C) segments of the ICA after 3D vascular analysis on sagittal reformat images.

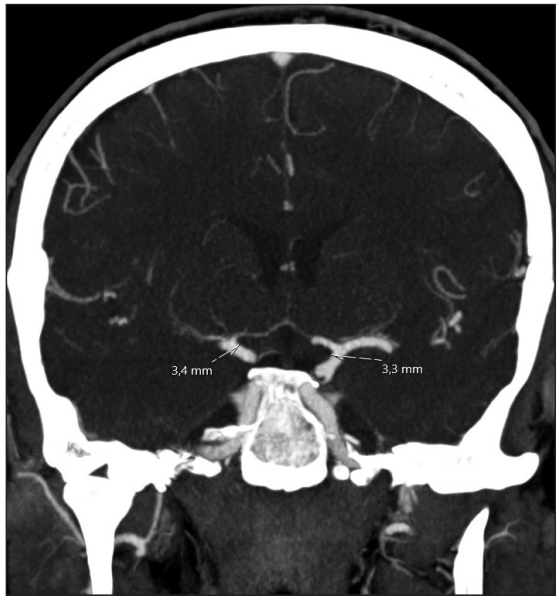

Figure 2: Computerized tomography angiography (CTA) diameter measurement in bilateral ICA terminal segment after vascular analysis on coronal reformat images.

Table I: Median (min-max) Values of ICA Diameters of Male and Female Patients with HT and Analysis Results

Group	Variable	Female	Male	p
		Median (min-max)	Median (min-max)	
Group1	Age (years)	60 (24-65)	61.5 (59-65)	0.387
	Cer-R	6.3 (5.2-8.1)	6.7 (6-8.5)	0.190
	Cer-L	6.3 (4.8-7.7)	6.9 (5.8-9.2)	0.182
	Pet-R	3.8 (3-4.9)	4.2 (3.5-4.5)	**0.020**
	Pet-L	3.8 (3.1-5.1)	4.2 (3.7-5.4)	**0.026**
	Cav-R	4.1 (2.7-5.5)	4.5 (3.8-5.5)	**0.033**
	Cav-L	4.1 (2.8-5.6)	4.6 (4-5.4)	**0.035**
	Term-R	3 (2.5-4)	3.3 (2.9-3.7)	**0.033**
	Term-L	3 (2.6-4.2)	3.3 (2.8-3.9)	**0.015**

Cer-R: *Right cervical segment,* ***Cer-L:*** *Left cervical segment,* ***Pet-R:*** *Right petrous segment,* ***Pet-L:*** *Left petrous segment,* ***Cav-R:*** *Right cavernous segment,* ***Cav-L:*** *Left cavernous segment,* ***Term-R:*** *Right terminal segment,* ***Term-L:*** *Left terminal segment.*

Table II: Median (min-max) Values of ICA Diameters of Male and Female Patients with T2DM and Analysis Results

Group	Variable	Female	Male	p
		Median (min-max)	Median (min-max)	
Group 2	Age	50 (47-65)	58 (46-65)	0.271
	Cer-R	6.3 (4.5-8.2)	7 (5.7-7.5)	0.181
	Cer-L	7.1 (5.1-7.7)	6.9 (5.5-8.8)	0.995
	Pet-R	3.9 (3.1-4.5)	4.1 (3.8-4.6)	0.208
	Pet-L	4 (3.3-4.6)	4.2 (3.6-4.8)	0.521
	Cav-R	3.8 (3.2-4.5)	4.1 (3.7-5)	0.177
	Cav-L	3.9 (3-4.4)	4.1 (3.2-5.3)	0.285
	Term-R	3.1 (2.7-3.3)	3.2 (2.8-3.5)	0.288
	Term-L	3 (2.5-3.2)	3.1 (2.6-3.7)	0.092

Table III: Median (min-max) Values of ICA Diameters of Male and Female Patients with HT and T2DM and Analysis Results

Group	Variable	Female	Male	p
		Median (min-max)	Median (min-max)	
Group 3	Age	62 (42-65)	63 (44-65)	0.717
	Cer-R	5.5 (4.9-7)	6.4 (5.6-8.3)	**0.029**
	Cer-L	5.6 (4.7-7.3)	6.3 (5.2-7.8)	**0.029**
	Pet-R	4 (3.2-4.7)	4.3 (3.5-5.1)	0.095
	Pet-L	4 (3.2-4.8)	4.4 (3.8-5.2)	0.091
	Cav-R	4.2 (3.5-4.8)	4.5 (3.3-6.1)	0.126
	Cav-L	4.1 (3.6-5.3)	4.6 (3.6-5.4)	**0.027**
	Term-R	3 (2.6-3.6)	3.3 (2.7-4)	0.274
	Term-L	3.1 (2.8-3.8)	3.2 (3-4)	0.411

Table IV: Median (min-max) Values of ICA Diameters of Male and Female Patients in the Control Group and Analysis Results

Group	Variable	Female	Male	p
		Median (min-max)	Median (min-max)	
Group 4	Age	55 (26-67)	50 (26-67)	0.978
	Cer-R	6.7 (4.9-8)	7 (5-9)	0.165
	Cer-L	6.7 (4.8-9.1)	7.3 (6-8.5)	**0.036**
	Pet-R	3.6 (3.1-4.4)	4 (3.5-4.5)	**0.003**
	Pet-L	3.7 (3.1-4.2)	4 (3.7-4.6)	**0.001**
	Cav-R	3.9 (3.4-5.5)	4.5 (4-5.4)	**0.002**
	Cav-L	4.1 (3.9-4.6)	4.5 (4.1-4.9)	**0.002**
	Term-R	2.9 (2.5-4)	3.2 (2.7-3.8)	**0.043**
	Term-L	2.9 (2.5-4.1)	3.1 (2.5-3.8)	0.100

Table V: The Comparison of the Parameters of All Male and Female Patients in Group 1, Group 2, Group 3, and Group 4

Variable	Female	Male
Age	0.618	0.090
Cer-R	0.158	0.134
Cer-L	0.210	0.111
Pet-R	0.113	0.377
Pet-L	0.145	0.503
Cav-R	0.495	0.119
Cav-L	0.745	0.062
Term-R	0.482	0.420
Term-L	0.200	0.084

the male and female patients in group 4 in terms of Cer-L, Pet-R, Pet-L, Cav-R, Cav-L, and Term-R parameters ($p<0.05$ for all) (Table IV).

The measured parameters of all female and male patients in the four groups were compared using the Kruskal-Wallis H test. According to the results, it was determined that there were no statistically significant differences between the measured parameters of the male and female patients in the groups ($p>0.05$) (Table V).

DISCUSSION

The aim of this radio-anatomic study was to compare the diameter measurements taken from the four segments of the ICA in patients with T2DM and HT. When the measurements were compared according to the sexes, it was found that the differences between the diameters of Pet-R, Pet-L, Cav-R, Cav-L, Term-R, and Term-L in group 1, which consisted of patients with HT, Cer-R, Cer-L, and Cav-L group 3, which comprised patients with HT and T2DM, and Cer-L, Pet-R, Pet-L, Cav-R, Cav-L, and Term-R in group 4, which constituted healthy individuals, were statistically significant ($p<0.05$ for all).

The morphology of the ICA has been investigated in cadaver studies since the 20th century and is still being investigated in angiographic studies (9,12). The number of studies conducted in the last two decades, aiming at more detailed examinations using newer imaging technologies such as Doppler, CTA, and MRI, show the interest in the anatomy of this artery (12,21). However, in these studies, it is seen that there is no consensus on the ROIs or measurement methods due to the differences in the technologies used (9,12,21).

CTA is a frequently used technology, which is a sensitive, specific, and highly accurate method for imaging both internal and external vascular structures. It is superior to carotid Doppler in distinguishing carotid occlusions from very high-grade occlusions (15,19).

In this study, considering the frequency of vascular pathology in the carotid system, we hypothesized that it would be beneficial to have an accurate and complete knowledge of the anatomy of this system. We measured and compared the diameters of four segments of the ICA in individuals with diseases known to cause vascular changes including HT and T2DM and healthy individuals. Baz et al. reported that they found significant differences between the sexes for almost all segments of the ICA and that the diameter of the ICA was smaller in both the cervical segment and the intracranial part of the female population included in the study (4). Similar findings were also reported by Gabrielsen and Greitz, who found a correlation between the dimensions of the ICA, sex, and skull width, and they reported that the differences might be due to height and craniometric parameters (9). In our study, it was determined that the diameter of all segments of ICA was lower in females compared with males in the four groups examined.

Although HT is a common disease known to cause hypertrophic formation in cerebral vessels, we found no studies in the literature comparing the diameters of different segments of the ICA in hypertensive and normotensive individuals. The lack of studies to compare with our study was a limitation for the discussion section of our study. However, we hope our study will provide a basis for future studies in this field. In our study, we found that there were no statistically significant differences between the measured parameters of the patients with HT and the other groups.

T2DM is known to reduce the regenerative capacity and accelerate the degeneration of the vascular system (1). In the literature (17), although studies are investigating the morphology of the ICA in individuals with T2DM, we found no study that evaluated the diameter of the segments of the ICA. In the same study reported that combined effects of T2DM and HT were associated with cortical thinning and impaired cerebrovascular reactivity compared with HT alone in older adults. In our study, it was observed that the measured parameters of the patients with HT and T2DM in group 3 were lower compared with the other groups. We suggest that this difference may indicate that individuals with both HT and T2DM are more predisposed to cerebrovascular events such as atherosclerosis. It is thought that inadequate hypertensive control accompanying T2DM exacerbates macro and microvascular complications and worsens vascular and structural abnormalities (8,18).

CONCLUSION

The dimensions of vascular structures are important in neurovascular procedures. The ICA is the main vascular structure for intracranial access in the treatment of aneurysms, cerebral hemorrhage, vascular malformation, cerebrovascular disease, and tumors. Knowing the variation of ICA diameters according to sexes and common chronic diseases such as HT and T2DM may help in determining the size of invasive devices such as catheters and stents. before starting the treatment of patients. Our study aimed to contribute to the literature at this point.

Morphometric studies related to ICA parameters focus on evaluating atherosclerosis, geometric variations, and the location and types of bifurcation using imaging modalities, but there is a lack of studies investigating the diameters of different segments of the ICA in patients with HT and T2DM. In our study, it was concluded that the parameters measured in different ICA segments did not differ statistically significantly between the male and female groups.

AUTHORSHIP CONTRIBUTION

Study conception and design: RC

Data collection: RC

Analysis and interpretation of results: HEU, IOY

Draft manuscript preparation: RC, DS, ST

Critical revision of the article: RC, DS, SY, HEU, IOY

Other (study supervision, fundings, materials, etc...): IOY

All authors (RC, HEU, DS, ST, IOY) reviewed the results and approved the final version of the manuscript.

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