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Anatomical Variations of The Circle of Willis in Egyptians: A Study Using Computed Tomography Angiography (CTA)

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ABSTRACT

Background: The Circle of Willis (CoW) is the primary structure that provides regular blood flow to the brain. It demonstrates a lot of anatomical variants, which have been thought to be affected by age and sex.

Objectives: This study aimed to determine the frequency of CoW anatomical variations in an Egyptian population using computerized tomography angiography (CTA).

Materials and methods: Retrospective computed tomography (CT) angiography (CTA) study of 100 patients, divided into < 40 and > 40 age groups. 3D images were analyzed after bone removal. CoW morphology was classified based on completeness and potential for collateral flow. Diameters of the vessels were also measured.

Results: Significant differences in posterior CoW variations (types "a," "b," "d") between age groups, with higher "a" type frequency in younger patients. Significant differences in anterior CoW variation (type "a") between age groups (p=0.001). Significant difference overall in configuration of the CoW between the two age groups. Significant differences in arterial diameters (RT ICA, Left ICA, Left A1, LT PCOM, RT PCA and LT PCA) were recorded between males and females. Significant differences in arterial diameters were recorded (RT PCOM, LT PCOM, RT PCA and LT PCA) between age groups.

Conclusion: In terms of the Egyptian population, there was a great variability of the anatomy of the CoW in asymptomatic subjects. Hence, such anatomic changes have to be considered throughout radiologic interpretation and have to be documented in anatomy text.

Keywords: CoW, Circular arrangement, Aplasia, Computed tomography angiography.

INTRODUCTION

The CoW is the primary structure that offers blood flow to the brain. It connects the left internal carotid artery (ICA), right ICA, and vertebrobasilar artery through communicating arteries [1]. It is made up of the anterior communicating artery (AcomA), the first segments (A1) of the anterior cerebral arteries (ACA), the posterior communicating artery (PcomA), the basilar artery (BA), and the first segments (P1) of the posterior cerebral arteries (PCA) [2]. It is an important pathway for the brain's collateral blood supply in the event of obstruction in either system. It allows for collateral blood flow and pressure equalisation [3].

As a result, CoW allows redundancy in the cerebral blood supply [4]. The main divisions arising from the CoW are the anterior inferior cerebellar arteries, the superior cerebellar arteries, the second segments of the PCAs, the middle cerebral arteries (MCAs), and the second segments of the ACAs [5].

The CoW may demonstrate many anatomic changes that aren't sporadic; hence, proper recognition of these variants is of great importance not only for surgical but also for radiologic interpretation [6]. Completeness of CoW was recorded to range from 12.2% to 45% [5]. A complete CW configuration is accompanied by diminished risk of intracerebral haemorrhage after intravenous (IV) thrombolysis among cases with ischaemic stroke [7].

Lazorthes *et al.* [8] classified the anatomical variants of the CoW according to similarity and diameter. This classification is applied globally to compare the distribution of anatomic changes of the CoW among populations [9].

Even though the anatomic variants don't affect cerebral perfusion in a direct manner, they could raise increase the risk of neurologic disorders [10], causing nearovascular surgical adverse events [11], cerebral infarcts [12], migraine [13] or even psychiatric disorders [14] or the imbalanced branching geometry present in particular variants could predispose to wall shear stress accompanied by the development and rupture of cerebral aneurysms [15].

For example, bilateral aplasia of the PcomA could affect collateral flow between the anterior and posterior circulations, whereas aplasia comprising the unilateral PCA and the AcomA could interfere with affect arterial back-up between the right and left ICA. Based on mathematical model, it has been demonstrated that asymmetrical vascular morphology within the CoW´s structure inclines to position the flow divider at points of

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bifurcation unfavorably, causing turbulence and the onset of endothelial disease. These might have a role in encouraging atherogenesis, worsening the gravidity of strokes and favoring the development of aneurysms. In addition, the incidence of cerebral atherosclerosis is apparently greater among black subjects compared to Caucasian ones [16].

Recent advances in CT and multidetector CTA and magnetic resonance angiography (MRA) make it simpler as preliminary diagnosis in the context of acute stroke [17]. In terms of CTA, it isn't influenced by the patients' movement compared with MRA. In addition, it is conducted in sec. Also, it provides precise images to be acquired from the cases for the evaluation of various arterial diameters, making anatomical research on different variants of cerebral circulations among Egyptian subjects essential in the proper recognition of brain disorders such as ischemic stroke [18]. Hence, we aimed to study the frequency of anatomic variants of CoW among Egyptian population sample using CT angiography, also the gender difference was elucidated.

PATIENTS AND METHODS

This retrospective study was conducted using multidetector CTA on one hundered patients, 51 males and 49 female. The patients were selected from the radiology department in Mansoura University Hospital. The study was performed between the period from Janurary 2020 to April 2022.

The patients were classified into two groups: The young age group (< 40 years) and the old age group (> 40 years). The study ruled out those over 60 because they may have atherosclerosis, which could be mistaken for hypoplasia. Data were collected from individuals with good and normal general condition. Patients with cerebrovascular diseases, brain tumors, and traumas were excluded.

Methods: This retrospective study was conducted at Mansoura University Hospitals using CT machines (Phillips 128 slice & GE 16 slice and Toshiba 260 sclice). The studies were done for medial causes. Pre-study investigation: Serum creatinine. We obtained source images with a thickness of 0.6 mm, reconstruct with a thickness of two milimeter and an increment of one milimeter after injection of 100-120 mL of IV non-ionic H_2O soluble contrast material, which is administered intravenously by injection pump, with an 18-20 gauge catheter for peripheral access, usually at a flow rate of 4-5 mL/s. The reaction of the patient to the usage of contrast is recorded. Early imaging using CT machine (During early arterial phase), which is evaluated by Contrast Tracker technique. Imaging field from aortic arch till the vertex. Post-examination imaging processing was done using computerized bone removal technique, then 3D images were obtained.

Data analysis:

Based on caliber, the CoW was classified as normal if its diameter was greater than or equal to 0.8 mm, hypoplastic if it was less than 0.8 mm, or aplasia if it was nonexistent or invisible. If there was no space between the pre-communicating segment junctions of the two anterior cerebral arteries (A1), the Acom-A was regarded as normal. The mean diameters were computed by measuring the artery diameters of the anterior and posterior circles with respect to side. The anterior and posterior portions are the two parts of the CoW. A1 and Acom-A were visualized for the anterior portion, while (P1) and Pcom-A were evaluated on either side for the posterior portion.

The CoW's anterior and two posterior sections were categorized as either complete (All vessels are normal) or incomplete (If any vessels are absent or hypoplastic). An arterial lumen that is divided into two distinct lumens with distal convergence was subjected to fenestration. When PcomA was evident with either missing PCA and P1 segment (Full type fetal PCA) or ipsilateral hypoplastic PCA and P1 segment (partial type fetal PCA), the PCA's fetal origin was used. The anterior and posterior circles were the two parts into which the circle components were separated. The ICA, the pre-communicating portion of the ACAs (A1), and the AcomA are all part of the anterior circulation. The pre-communicating portion of the PCAs (P1) and the Pcom-A are included in the posterior circle.

The studied cases were subjected to a classification system of CoW, according to the completeness of the anterior and posterior circulations based on the likelihood of collateral flow development. Because of their morphology, which permits collateral flow formation through continuity of the anterior channels, the anterior circle variant types (a) through (f) are categorized as complete types. Likewise, because of their propensity to establish collateral flow across the posterior circle, the posterior circle variant types (a) through (c) are categorized as complete types. To avoid the drawbacks and hazards of post-processing measurements, all vascular components of CoW were evaluated by measuring the caliber on the original slices rather than on 3D reconstructed pictures. The circle was categorized as whole, incomplete, or partially complete with regard to the entire CoW. All of the circle's anterior and posterior components were visible, continuous, and showed sizes of 0.8 mm or more in full type. A defieicnt vessel segment was visible in the front and posterior sections of incomplete type. The remaining circles were categorized as partially complete since they had a complete anterior or posterior morphology.

Ethical Consideration: The study design was approved by the IRB, Faculty of Medicine, Mansoura University and based on the Declaration of Helsinki. Confidentiality was respected. Informed consents were obtained from all patients.

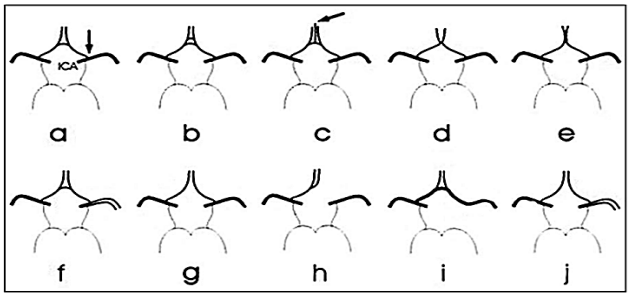

Figure 1. Schematic diagrams of anatomic variations in the anterior part of circle of Willis; **a.** A single anterior communicating artery (AcomA). The internal carotid artery (ICA) bifurcates into the precommunicating segment of the anterior cerebral artery (ACA) and the middle cerebral artery (MCA); **b.** Two or more AcomAs; **c.** Medial artery of the corpus callosum arises from the AcomA; **d.** Fusion of the ACAs occurs over a short distance; **e.** ACA forms a common trunk and split distally into two postcommunicating segments; **f.** MCA originates from the ICA as two separate trunks; **g.** Hypoplasia or aplasia of an AcomA; **h.** One precommunicating segment of an ACA is hypoplastic or absent, the other precommunicating segment gives rise to both post-communicating segments of the ACAs; **i.** Hypoplasia or absence of ICA on one side with the MCA and ACA supplied from the other side; **j.** Hypoplasia or absence of an AcomA. The MCA arises as two separate trunks [8].

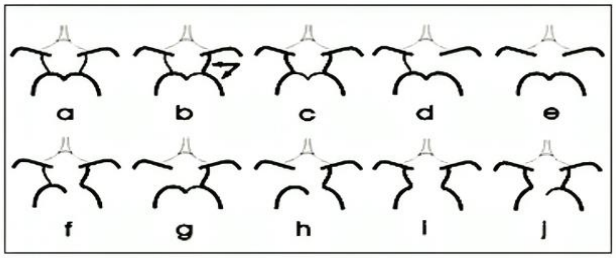

Figure 2. Schematic diagrams of the anatomical variations of the posterior part of circle of Willis; **a.** Bilateral posterior communicating arteries (PcomAs) are present; **b.** Posterior cerebral artery (PCA) originates predominantly from the internal carotid artery (ICA). This variant is known as a unilateral foetal type PCA; the PcomA on the other side is patent; **c.** Bilateral foetal type PCAs with both precommunicating segments of the PCAs patent; **d.** Unilateral PcomA present; **e.** Hypoplasia or absence of both PcomAs and isolation of the anterior and posterior parts of the circle at this level; **f.** Unilateral foetal type PCA and hypoplasia or absence of the precommunicating segment of the PCA; **g.** Unilateral foetal type PCA and hypoplasia or absence of the contralateral PcomA; **h.** Unilateral foetal type PCA and hypoplasia or absence of both precommunicating segments of the PCA and the PcomA; **i.** Bilateral foetal type PCAs with hypoplasia or absence of both precommunicating segments of the PCAs; **j.** Bilateral foetal type PCAs with hypoplasia or absence of the precommunicating segment of either PCA [8].

Statistical Analysis

Data were analyzed using IBM SPSS Corp, Version 22.0. Armonk, NY. Numbers and percentages were used to define qualitative data. The Kolmogorov-Smirnov test was used to check for normality. The median for non-normally distributed data and the mean ± SD for regularly distributed data were used to describe quantitative data. The significance of the differences between two independent research groups (parametric data) was evaluated using a Student t test. The significance of the difference between two independent study groups with non-parametric data was evaluated using the U test. When more than 25% of cells in tables (2*2) have a count of less than 5, we employed Fischer's exact test instead of the Chi-Square test for comparisons between at least 2 groups. The significance of the results was set at the (0.05) level.

RESULTS

This was a cross-sectional descriptive study that was conducted to assess the frequency of anatomical variations of CoW among the Egyptian population sample using CT angiography, and in addition, the gender difference was elucidated. A convenient sample of about 100 cases was included in the study. Table (1) displayed that the mean age of studied cases was 44.88 ± 14.50 years, ranging from 20 to 77 years, with 42% aged less than 40 years and 58% aged more than or equal to 40 years. Males represented 51% of the studied sample, and 49% were females.

Table (1): Demographic characters among studied cases

	N=100	**%**
Age / years		
• **<40 years**	42	42.0
• **≥40 years**	58	58.0
Mean ±SD (min-max)	44.88±14.50 (20-77)	
Sex		
• **Male**	51	51.0
• **Female**	49	49.0

As regards posterior circle variations among studied cases, seven circle variations were detected where the commonest type was type “a” with prevalence 59% followed by “b”, “d” variations with the following frequencies 9% & 8%, respectively (Fig. 1). Table **(2)** displayed that there was a significant difference of posterior circle variation at “a”, “ b” and “ d” types between cases aged less than 40 years and those aged 40 years and more. Higher frequency of type “a” was determined among younger age group, while type “b” and “d” among older age group (≥ 40 years). There was insignificant difference of posterior circle variation was determined between males and females at different types of variations.

Table (2): Relation between posterior circle variations and age and sex of studied sample

Age / years	**Posterior circle variations — Count (%)**									
	a	b	c	d	e	f	g	h	i	j
	N=59	N=9	N=0	N=8	N=0	N=2	N=3	N=2	N=1	N=0
<40 years	41(69.5)	1 (11.1)	0	0(0.0)	0	0(0)	0	0	0	0
≥40 years	18(30.5)	8(88.9)	0	8(100)	0	2(100)	3(100)	2(100)	1(100)	0
P value	*0.001**	*0.049**	..	*0.012**	..	*0.244*	*0.135*	*0.508*	*1.0*	..
Male	30(50.8)	4(44.4)	0	5(62.5)	0	1(50)	1(33.3)	1(50)	1(100)	0
Female	29(49.2)	5(55.6)	0	3(37.5)	0	1(50)	2(66.7)	1(50)	0(0.0)	0
P value	0.971	0.680		0.498		1.0	0.614	1.0	1.0	

Used test :Chi-Square test, Fisher exact test

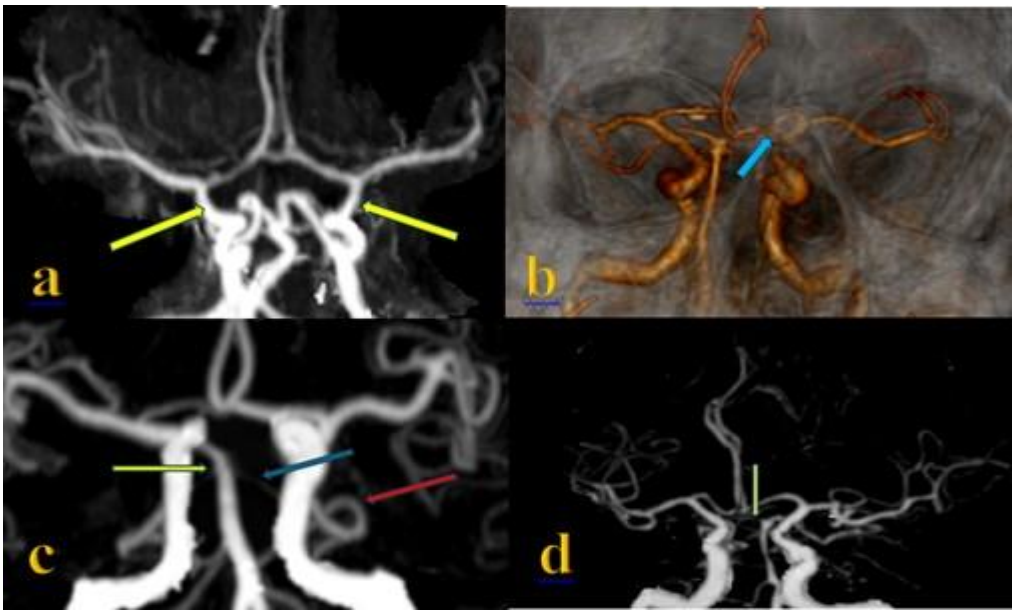

Figure (1): (a) Bilateral PcomAs. **(b)** Uni- lateral left PcomA. **(c)** Unilateral left sided foetal type PCA with hypoplasia precommunicating segment, yellow arrow: basilar artery , blue arrow: hypoplastic part of left PCA , red arrow: left PCA). **(d)** Hypoplastic right PCA.

As regards anterior circle variations among studied cases, six circle variations were detected where the most common type was type "a" with prevalence 59% followed by "b" and "g" variations with the same frequency 5% (Fig. 2). Table (3) showed a statistically significant difference of anterior circle variation at type "a" between cases aged < 40 years and those aged 40 years and more (p=0.001). Higher frequency of type "a" was determined among younger age group than older age group (69.5 % versus 30.5%). There was insignificant difference between males and females as regards anterior circle variation at different types of variations.

Table (3): Relation between anterior circle variations and age and sex of studied sample

Age / years	**Anterior circle variations — Count (%)**									
	a	b	c	d	e	f	g	h	i	j
	N=59	N=5	N=0	N=2	N=2	N=0	N=5	N=2	N=0	N=0
<40 years	41(69.5)	0	0	0	0	0	0	0	0	0
≥40 years	18(30.5)	5(100)	0	2(100)	2(100)	0	5(100)	2(100)	0	0
P value	*0.001**	*0.051*		*0.508*	*0.508*		*0.072*	*0.508*		
Male	30(50.8)	3(60)	0	1(50)	1(50)	0	2(40)	1(50)	0	0
Female	29(49.2)	2(40)	0	1(50)	1(50)	0	3(60)	1(50)	0	0
P value	0.971	1.0		1.0	1.0		0.675	1.0		

Used test: Chi-Square test, Fisher exact test, *statistically significant

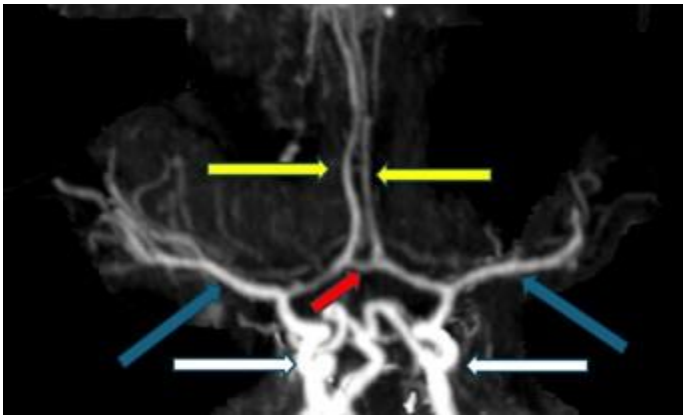

Figure (2): Normal: A single AcomA. The ICA bifurcates into the precommunicating segment of the ACA and the middle cerebral artery (MCA) (yellow arrows: ACAs, red arrow: ACOM, blue arrows: MCAs, White arrows: ICAs.

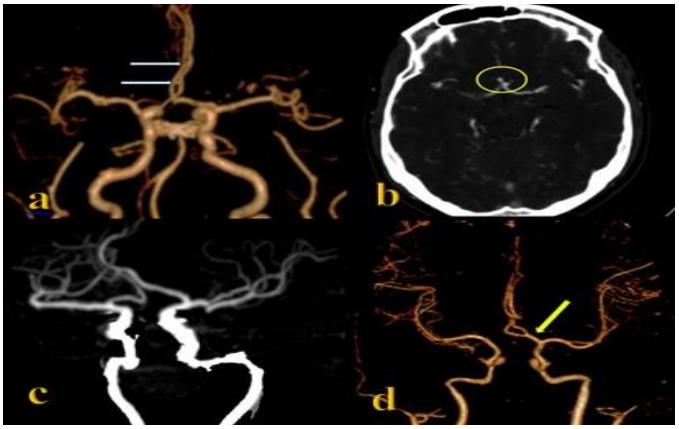

Figure (3): (a) Two Acom As **(b)** AcomA forms a common trunk and split distally into two post communicating segments **(c)** Hypoplasia or aplasia of an Acom A **(d)** Both post-communicating segments of the ACAS originate from the other precommunicating segment of the right AcomA, which is either absent or present. Arrow head points to left precommunicating segment of left AcomA giving both AcomAs.

Table **(4)** demonstrated insignificant difference between males versus females as regards CoW morphology. For anterior circle morphology, 25 were incomplete and 75 were complete. For 51 males, 13 cases had incomplete, and 38 cases were complete. For 49 females, 37 cases were complete, and 12 cases were incomplete. For posterior circle configuration, 16 were incomplete and 84 were complete. For 51 males, 8 cases had incomplete, and 43 cases were complete. For 49 females, 41 cases were complete, and 8 cases were incomplete. There was a statistically significant difference between cases aged < 40 years versus aged ≥ 40 as regards configuration of the CoW. For anterior circle configuration, 25 were incomplete and 75 were complete. For 42 cases aged < 40 years, one case had incomplete and 41 cases were complete. For 58 cases aged ≥ 40, 34 cases were complete and 24 cases were incomplete. For posterior circle configuration, 16 were incomplete and 84 were complete. For 42 cases aged less than 40 years, all were complete. For 58 cases aged ≥ 40 years, 41 cases were complete, and 16 cases were incomplete.

Table (4). Prevalence of the configuration of the CoW based on sex and age

	Configuration of the anterior circle			**Configuration of the posterior circle**		
	Incomplete	Complete	Total	Incomplete	Complete	Total
	N=25	N=75		N=16	N=84	
Sex						
Male	13(25.5%)	38(74.5%)	51	8(15.7%)	43(84.3%)	51
Female	12(24.5%)	37(75.5%)	49	8(16.3%)	41(83.7%)	49
P value	*0.908*			*0.930*		
Age						
<40	1(2.4%)	41(97.6%)	42	0	42(100%)	42
≥ 40	24(41.4%)	34(58.6%)	58	16(27.6%)	42(72.4%)	58
P value	*<0.001**		*<0.001**			

Used test: Chi-Square test, Fisher exact test, * statistically significant.

Table **(5)** demonstrated a significant difference between males and females as regards diameter of RT ICA, Left ICA and Left A1 (With higher mean diameter among males than females). No significant difference was determined between males and females as regards RT A1 diameter. There was a significant difference between group aged <40 versus those aged ≥ 40 as regards diameter of left ICA, right A1 and left A1 (With higher mean diameter among younger than older age group). No significant difference was determined between group aged < 40 versus those aged ≥ 40 as regards diameter RT ICA.

Table (5): Mean diameters of the arteries of the anterior circle according to sex and age of studied cases

		diameter RT ICA	**diameter LT ICA**	**RT A1**	**LT A1**
Sex					
Male	N	51	51	51	51
	Mean ±SD	4.21±1.07	4.37±1.19	2.27±0.60	2.46±0.73
	Min-Max	2.9-5.8	2.9-6.4	1.5-3.3	1.6-3.6
Female	N	49	49	49	49
	Mean ±SD	3.65±0.86	3.58±0.74	2.13±0.53	2.08±0.43
	Min-Max	2.9-5.4	2.9-5.4	1.5-3.0	1.6-2.8
P value		*0.005**	*0.001**	*0.227*	*0.002**
Age					
<40	N	42	42	42	42
	Mean ±SD	4.1±.11	4.32±1.26	2.64±0.56	2.73±0.67
	Min-Max	2.9-5.8	2.9-6.4	1.5-3.3	1.6-3.6
≥ 40	N	58	58	58	58
	Mean ±SD	3.82±0.91	3.74±0.83	1.88±0.29	1.94±0.33
	Min-Max	2.9-5.4	2.9-5.4	1.6-3.0	1.6-3.0
P value		*0.061*	*0.024**	*0.001**	*0.001**

Used test: Student t test, *statistically significant

Table **(6)** demonstrated statistically significant difference between males and females as regards diameter of LT PCOM, RT PCA and LT PCA (With higher mean diameter among males than females). No significant difference was determined between males and females as regards RT PCOM. There was statistically significant difference between group aged <40 versus those aged ≥ 40 as regards diameter of RT PCOM, LT PCOM, RT PCA and LT PCA (With higher mean diameter among males than females).

Table (6): Mean diameters of the arteries of the posterior circle according to sex and age of studied cases

		RT PCOM	**LT PCOM**	**RT PCA**	**LT PCA**
Sex					
Male	N	51	51	51	51
	Mean ±SD	1.4±0.39	1.41±0.25	2.16±0.73	2.16±0.86
	Min-Max	1.0-1.9	1.0-1.7	1.3-3.5	1.2-3.7
Female	N	49	49	49	49
	Mean ±SD	1.38±0.46	1.29±0.32	1.86±0.33	1.67±0.25
	Min-Max	*0.9-2.2*	*0.8-1.6*	*1.3-2.3*	*1.2-2.1*
P value		*0.430*	*0.046**	*0.012**	*0.001**
Age					
<40	N	42	42	42	42
	Mean ±SD	1.69±0.47	1.44±0.34	2.45±0.61	2.33±0.82
	Min-Max	0.9-2.2	0.8-1.7	1.9-3.5	1.6-3.7
≥ 40	N	58	58	58	58
	Mean ±SD	1.20±0.21	1.29±0.23	1.69±0.29	1.63±0.33
	Min-Max	*0.9-1.9*	*0.8-1.6*	*1.3-2.2*	*1.2-2.4*
P value		*0.001**	*0.001**	*0.001**	*0.001**

Used test: Student t test, * statistically significant

DISCUSSION

The pathophysiology of cerebrovascular diseases may be significantly influenced by anatomical differences in the CoW that are related to gender and age [19].

This was a cross-sectional descriptive study that was conducted on a total of 100 cases to assess the frequency of anatomic variants of CoW among Egyptian population sample using CTA. In addition, the gender difference was elucidated.

Regarding the demographic data, the present study displayed that mean age of studied cases was 44.88 ± 14.50 years ranging from 20 to 77 years with 42% aged less than 40 years and 58% aged ≥ 40 years. Males represented 51% of studied sample and 49% were females.

Also, **Diljohn *et al.*** [20] conducted their study on 152 subjects with male to female ratio was 28.3/71.7. The age of their studied cases ranged from 18 to 85 years. They are in agreement with the current study regarding ageing being within the age of 40, while they were against the present study concerning sex, in which male sex was predominant in their study, which may be due to ethnic variation between both studies.

Regarding the prevalence of the configuration of the CoW in all the studied cases, for anterior circle configuration, 25 were incomplete and 75 were complete and for posterior circle configuration, 16 were incomplete and 84 were complete, In agreement, **Hafez *et al.*** [21] displayed that the completeness of anterior circulation was 70% in males and 75% in females, while the completeness of posterior circulation was 44% in males and 58% in females. In contrast, another Egyptian study conducted by **Zaki *et al.*** [22] revealed that complete, partially complete and incomplete CoW were encountered in 28%, 38% and 34% in the studied cases respectively. The incomplete anterior circulation was demonstrated in 34% and the incomplete posterior circulation was demonstrated in 62%.

Concerning posterior circle variation among studied sample, the current study demonstrated that seven circle variations were detected. The commonest type was type "a" (Bilateral PcomAs) are present) with prevalence 59% followed by "b" PCA originates mainly from the ICA), "d" (Uni-lateral PcomA present) variations with the following frequencies 9% & 8% respectively. In the same line, **Zaki *et al.*** [22] reported 6 posterior circle variations, which were encountered in their study out of the 10 variations. In the same line, **Iqbal** [23] demonstrated that the embryonic origin of the PCA from the ICA persisted in ten percent of the circles (type b). An incomplete circle secondary to the absence of one or other PcomA was demonstrated in six percent of the specimens (type d).

As regard anterior circle variations among studied cases, six circle variations were detected where the commonest type was type "a" (A single AcomA). The ICA bifurcates into the precommunicating segment of the ACA and the MCA) with prevalence 59% followed by "b" (Two or more AcomAs) and "g" (Hypoplasia/aplasia of an AcomA) variations with the same frequency 5%. In agreement, **Zaki *et al.*** [22] detected seven anterior circle variants out of the ten recorded forms. The most frequent anterior circulation variant was type "a" representing fifty six percent of their studied cases, compared to forty seven percent in Polish cases and seventy six percent in Chinese cases [24, 25]. In the same line **Zaki *et al.*** [22] displayed that the 2nd common anterior circle variation and the commonest anomaly was type "g", which occurred in twenty four percent of their studied cases. Likewise, **Iqbal** [23] demonstrated that accessory vessels were common in anterior circulation (type b which was determined in 59% of the studied cases).

In terms of the prevalence of the configuration of the CoW based on sex, the current study revealed no significant difference between males versus females regarding configuration of the CoW. For 51 males, 13 cases had incomplete and 38 cases were complete and for 49 females, 37 cases were complete and 12 cases were incomplete. For 51 males, 8 cases had incomplete and 43 cases were complete and for 49 females, 41 cases were complete and 8 cases were incomplete. Likewise, **Diljohn *et al.*** [20] displayed that a complete CoW was recorded in 37 subjects (24.3%). In addition there was insignificant difference ($P = 0.12$) between their male and female populations. The majority of cases (55.2%) displayed a partial CoW. An incomplete CoW was determined in 20.4% of the studied cases only. Also, **Hafez *et al.*** [21] displayed that the completeness of anterior circulation was recorded in 70% and 75% of males and females respectively with non-significant difference (P>0.05).

Regarding the posterior circulation, the completeness was recorded in 44% and 58% of males and females, respectively. A totally complete circle was demonstrated in 45% of the studied cases, and it was greater in females compared to males. On the other hand, other research displayed that CoW completeness between sexes differs, with multiple research studies displaying a female predominance [26, 27] and some a male predominance [28, 29]. Also, **Zaninovich *et al.*** [19] revealed that completeness was higher in females compared to males (43.8% versus 31.2%) with a significant difference with the exception of the 18-39 years age group.

With regard to the prevalence of the configuration of the CoW based on age, more complete circles (97.6% in anterior and 100 in posterior) were detected in cases < 40 years than patients ≥ 40 years (41.4% in anterior and 72.4% in posterior) with significant difference (P <0.05). In the same line, **Diljohn *et al.*** [20] revealed that completeness was significantly increased among those under 46 years old (62.2%) compared to those over 46 years old (37.8%) (P<0.05). Also, **Zaninovich *et al.*** [19]

revealed that CoW completeness displayed a significant reduction among cases with advanced ages among males and females as well. In addition, **Amany & Ghobashy** [30] conducted their study on 100 cases (52% males and 48% females) and displayed that the mean arterial diameter was greater in the younger age group compared with the old age group (56% versus 44%, respectively). Similar results were documented, and all displayed a negative correlation between age and completeness [27, 31, 32].

The actual mechanism hasn't been confirmed till now, but has been recommended to happen due to both atherosclerosis and associated pathological conditions such as diabetes and hypertension, which cause vascular obstruction by time and radiologic absence, but not anatomic absence, a hypothesis reinforced by more complete CoWs in cadaveric researches [20]. Also, the main cause could be due to the drop of cerebral flow with advanced age. Additionally, the increase in vascular tortuosity with age could affect the flow pattern in the COW [33].

Regarding the average calibers of the arteries of the anterior circulation according to sex, our study displayed a significant difference between males and females regarding diameter of RT ICA, left ICA and left A1 (With higher mean diameter among males than females). No significant difference was determined between males and females concerning RT A1 diameter.

Regarding the average calibers of the arteries of the anterior circulation according to age, the current study displayed a significant difference between group aged < 40 versus those aged ≥ 40 as regards diameter of left ICA, right A1 and left A1 (With higher mean diameter among younger than older age group). No significant difference was determined between group aged < 40 versus those aged ≥ 40 as regards diameter RT ICA.

Regarding mean diameters of the arteries of the posterior circle according to sex the current study demonstrated a significant difference between males and females as regards diameter of LT PCOM, RT PCA and LT PCA (With higher mean diameter among males than females). Insignificant difference was determined between males and females as regards RT PCOM.

Regarding mean diameters of the arteries of the posterior circulation according to age, the current study demonstrated statistically significant difference group aged < 40 versus those aged ≥ 40 as regards diameter of RT PCOM, LT PCOM, RT PCA and LT PCA (with higher mean diameter among <40 cases than ≥ 40 cases). Similarly, **Afifi *et al.*** [34] displayed that the vessels of the CoW diameters were minor in females compared to males with the exception of the PcomA. They displayed the remarkable major variability of the CoW anatomy in the asymptomatic subjects. In the same line, **Horikoshi *et al.*** [26] displayed that females were associated with significant variations in the posterior circulation compared to matched-age males. In agreement, **Hafez *et al.*** [21] revealed that the average caliber significantly increased in males compared to matched-age females. On the other hand, the PcomA tended to be larger in the females, which was against the present study. In addition, **Stefani *et al.*** [35] illustrated that higher calibers were noticed in the vessels of the posterior circulation. On the other hand, **Hafez *et al.*** [21] displayed that no significant difference was recorded regarding the posterior circulation variants in both sexes.

CONCLUSION

In terms of the Egyptian population, the CoW's structure varied greatly across asymptomatic participants. Regarding the completeness of CoW, there were no significant differences between both sexes regarding the completeness of CoW. However, cases with an age less than 40 years old were associated with a greater diameter of vessels compared to cases with an age more than 40 years old. Males were associated with significant increases in the mean diameters of the arteries of the posterior circulation (except for the RT PCOM) as well as the anterior circle (except for the RT A1) compared to females. As a result, these anatomic variants have to be taken into consideration throughout radiological interpretation and have to be documented in anatomy text.

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