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Original Research Article

PRESENCE OF ACCESSORY RENAL ARTERY IN SUDANESE PEOPLE

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ABSTRACT

Background: Renal artery variations including their number, source, and course are very common congenital abnormalities. The renal artery variations in Sudanese population are not fully studied. Comprehensive studies on the incidence and types of renal artery anomalies are limited. This study, aimed at study renal artery variations in population living in Sudan in the period from May 2010 - May 2011.

Methodology: The sample size of this study was 301 individuals, (549 kidneys), from which 60 were cadavers (111 kidneys), 191 donors (339 kidneys), and 50 angiographs, (99 kidneys) from patients with renal and many other problems from both sexes in Gezira and Khartoum state. The study used three different methods for renal artery identification. These are the intra operative surgical way, dissection and postmortem, and the imaging (angiography) method. Cadavers were carefully dissected and the kidney and renal artery length and width were measured by using ruler. The mean age of the individuals was 36±0.806 years.

Result: The result revealed that single renal artery occurred in 439(79.96%) out of 549 kidneys. 110(20.04%) kidneys analyzed presented multiple renal arteries. 78(14.21%) had double renal artery, 26(4.74%) had triple renal arteries, and 6(1.09%) kidneys had four renal arteries.

Conclusion: The study concluded that the renal arteries present a broad spectrum of variability in Sudanese in their morphological expression.

KEY WORDS: Renal artery, Postmortem, Angiographs.

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INTRODUCTION

Kidneys usually get their blood supply by the renal artery arising from the aorta and terminating in the kidney. There are cases though when more than one renal artery can be found. The first systematic attempt to study the frequency of occurrence of renal vascular variations was that undertaken by the Anatomical Society of Great Britain and Ireland as far back as 1890. The term «additional renal artery» was first established by Satyapal [1], and by replacing terms like accessory, aberrant, anomalous, supernumerary, supplementary and multiple, it was used as a more comprehensive expression in describing renal arteries, other than the main one [2].

Additional renal arteries are not uncommon; they appear in about 25 to 30% of the general

Additional renal arteries are not uncommon; they appear in about 25 to 30% of the general population, and represent persistence of the embryonic pattern [3].

It is not only unwise but dangerous to suggest that each kidney receives only a single artery. This is commonly stated and shown in illustrations in textbooks of anatomy used by professional students of medicine and the allied health sciences. This could be easily rectified in a single sentence such as, "The kidneys may receive a single artery although each organ may equally be supplied by as many as six end arteries. When there are two or more renal vessels the vessels do not anastomose within the substance of the kidney, hence none of the multiple renal arteries can be regarded as accessory. Obstruction of any renal branch leads to cessation of function and death of that part of the kidney supplied by it; hence the term accessory is misleading [4].

It is important to remember that, the renal arteries are end arteries and do not intrarenally anastomose, each one feeds only a segment of the kidney's parenchyma. Because of that the occlusion or obstruction of the blood flow in one of them may cause segmental ischaemia with subsequent hypertension [2].

Additional arteries may be equally [5], Or differently [1], distributed between the two kidneys. The incidence of additional renal arteries, vary according to the ethnic origin of the individual. Indians show an incidence of 17.4%, Coloured 18.5%, Caucasians 35.3%, and the Africans as high as 37.1% [1].

The renal vascular segmentation was discovered by John Hunter in 1794, but a detailed account was given in 1950's by corrosion cast studies. There are five defined arterial segments: apical, superior, middle, inferior and the posterior. The anatomical knowledge of these segments is important while performing nephrectomies [6].

Renal artery variations are not uncommon either and give rise to several problems that are encountered by clinicians. Kidneys with a large number of renal arteries are reported to have a higher rate of transplantation failure than those with a single renal artery. The risk represented by these vascular variations is not, however, limited to renal transplantations and to the surgical treatment of renovascular hypertension. Digital subtraction angiography (DSA) is regarded as the gold standard in the evaluation of vascular structures, although its invasive nature significantly limits its role. In recent years, the introduction of multidetector CT (MDCT) and its ability to image vascular structures of small diameter have led to a significant reduction in the utility of invasive DSA examinations [7].

The abdominal aorta begins and descends after aortic hiatus at the level of the twelfth thoracic vertebrae, courses downward with the inferior vena cava and terminates at its bifurcation at the level of the fourth lumbar vertebra. Branches of abdominal aorta may be described as ventral, lateral, dorsal and terminal, corresponding to their origins. The ventral braches are the celiac trunk, superior and inferior mesenteric arteries; the dorsal branches are the lumbar and median sacral arteries; the lateral branches are the inferior phrenic, middle suprarenal, renal, ovarian or testicular arteries and the terminal branches are the common iliac arteries [8].

The primitive aorta appears firstly in the embryo and gives segmental branches to the digestive tube (ventral splanchnic arteries), to the mesonephric ridge (lateral splanchnic arteries) and to the body wall (somatic arteries); many intersegmental branches supply the somites and their derivatives during the development. Inferior phrenic arteries may arise separately from the aorta, just above celiac trunk and help to supply the diaphragm. Classically, each kidney is supplied by a single renal artery; however, anatomic variations are common as two or more renal arteries can supply a kidney. The testicular arteries usually arise from the anterior aspect of the abdominal aorta just inferior to the renal arteries at the level of the second lumbar vertebra; however, they may also originate from the renal artery, middle suprarenal artery, one of the lumbar arteries, common or internal iliac artery. Each passes obliquely downward and laterally on the psoas major muscle [9].

As the kidneys ascend from the pelvis during the embryological development they receive

their blood supply from the vascular structures close to them. Initially renal arteries are the branches of common iliac arteries. Later, while the kidneys ascend they receive new branches from the aorta, and the inferior branches disappear. In the ninth week of the intrauterine life the kidneys come in to contact with the suprarenal glands and the ascent stops. The kidneys receive their most cranial branches from the aorta. These are the permanent renal arteries. The permanent mesonephric arteries other than renal arteries are the middle supra renal, gonadal, and inferior phrenic arteries [9].

This continuously changing blood supply of the kidneys as they ascend explains the high incidence of the variations in the blood supply to the kidneys.

The frequency of multiple renal arteries ranges from 9% to 76%, but generally changes between 28 and 30% [10].

The diagnosis of renal vein anomalies is important in retroperitoneal surgery. Unawareness of this situation during retroperitoneal surgery can result in bleeding, nephrectomy, and even death.

Fig. 1: Dissection showing early division in the main right renal artery.

MATERIALS AND METHODS

This is observational analytical case study was performed in Sudanese (15-70 years old) to study renal artery variations in central Sudan in Khartoum and Gezira state. In Gezira the records from the donors for renal transplantation were taken from Gezira teaching hospital for renal surgery. In Khartoum state they were taken from Ahmed Gasim hospital for cardiac and renal surgery.

Fifty cadavers were selected from the dissection rooms of different faculties of medicine in Khartoum and Gezira state including Khartoum and Gezira, Elribat, Elzaeim Elazhary, Omdurman, Aali Elneel, Elrazi, Eltigana, Elsudan universities, and the National College.

CT Angiography images were taken from wadmedani center for diagnostic rays, in Gezira state and modern medical center and Sudan diagnostic center in Khartoum state.

The sample size of this study was 301 individuals, (549 kidneys), from which 60 (111 kidneys) were cadavers of both sexes from Gezira university and different universities in Khartoum state. 191 (339 kidneys) were studied as donors for renal transplantation in Gezira and Khartoum state. Finally 50 (99 kidneys) angiographs were taken from patients with renal and with many other problems.

Data were collected by a carefully designed questionnaire.

The first part consisted of participants biographical data which were the name, gender, age, recent residence, health history, and the second part was designed to answer the questions of the study which included the method of renal artery identification, state of the kidney, number of ureters, number, length, and width of the renal artery, type of extrarenal artery and presence of extra renal veins.

Cadavers were carefully dissected and the kidney and renal artery length and width were measured by using ruler, then the state of the kidney was noticed for the shape, size, and outlines.

The angiogram device was used for CTA and MRA. The CT angiographic examination was performed by multi-detector CT (Somatom Sensation 64, Siemens, Germany).

The following parameters were evaluated:

-The length of the main renal artery (from the ostium to branching).

-The diameter of the main renal artery at emergence from the aorta;

-The number of accessory arteries, if any;

-The presence of early branching;

-Kidney length and width.

The data was analyzed using the soft ware program

(social package for scientific statistic) SPSS. Results were tabulated and presented in percentage forms.

Ethical clearance was obtained from University of Gezira Ethical Committee and permissions from hospital authority. Verbal consent was obtained from all donors.

RESULTS

Kidney length and width:

Table 1: Average measures (Length, diameters) of the kidney and renal artery according to the presentation side.

Variable	Right side	Left side	P.value
Length of kidney	9.91±0.09	10.16±0.09	0
Width of kidney	4.46±0.11	4.71±0.10	0
Length of Renal Artery	3.92±0.18	3.72±0.17	0.41
Width of Renal Artery	0.46±0.49	0.42±0.48	0.06

The mean length for the right kidney was 9.91 ± 0.092 cm and the width was 4.46 ± .107 cm, and the mean length of the left kidney was 10.16 ± 0.085 cm and the width was 4.71 ± o.102 cm.

A comparison of left and right kidney length and width showed that the length and width of the left kidney were greater than of the right, and these differences were highly significant (p = 0.00 and p = 0.00, respectively).(Table 1).

Table 2: Average measures (Length, diameters) of the left and right kidneys in relation to gender.

Variable	Male	Female	P.value
Length of right kidney	9.88±0.15	9.89±0.10	0.974
Length of left kidney	10.24±0.13	10.02±0.09	0.194
Width of right kidney	4.81±0.13	3.86±0.13	0
Width of left kidney	4.96±0.14	4.27±0.13	0

A comparison between the right kidney in males and females showed that the length in females is greater than that of males although this difference was not significant (p=.974).

The width of the male right kidney is greater than that of the females and the difference is highly significant (p=.000).

No significance difference between the length of the left kidney in males and females (p=o.194) although the width of the left kidney showed highly significant difference (p= 0.000).

Renal artery length and width: The mean diameter of the right renal artery was 0.464 ± 0.049 cm, and the length was 3.92 ± .181 cm. And the mean diameter of the left renal artery was o.416 ± 0.048cm and the length was 3.71 ± .169cm.

There was no significant difference between the diameters of the right and left arteries or in the length. (p=0.41) and (p=0.06) respectively (Table 1).

Table 3: Average measures (Length, diameters) of the main renal artery in relation to gender.

Variable	Male	Female	P.value
Length of right renal artery:	4.18±0.24	3.38±0.32	0.08
Length of left renal artery:	3.86±0.18	2.95±0.26	0.01
Width of right renal artery:	0.67±0.02	0.53±0.07	0
Width of left renal artery:	0.75±0.16	0.48±0.08	0.41

Table 3 showed that a comparison between males and females showed that the diameters of the right renal arteries in males to be significantly higher than those in females, and no significant difference between males and females regarding the length of the right renal artery, (p=0.08).

The left renal artery showed significant difference between males and females in length (p= 0.01) and no significant difference in width between males and females (p=0.41).

Renal artery variations:

Single and multiple renal arteries:

Table 4: Numbers (%) of renal arteries.

Number of renal arteries	Frequency	Valid Percent
1	439	79.96%
2	78	14.21%
3	26	4.74%
4	6	1.09%
Total	549	100%

Single renal artery occurred in 439 (79.96%) out of 549 kidneys. One hundred and ten (20.04%) out of the 549 kidneys analyzed presented multiple renal arteries; 78 (14.21%) had double renal artery, 26 (4.74%) had triple renal arteries, and 6 (1.09%) had four renal arteries (Table.4).

There was 17.56% frequency of additional arteries on the right side and 22.30% on the left.

The greatest frequency (58.97%) in kidneys having double renal arteries corresponded to the left side compared to 41.03% on the right side (Table 6). A statistically significant difference between these rates was not determined (Chi-Square test, p= 0.550).

Table 5: Numbers (%) of renal arteries according to contra lateral kidney anatomy.

Right kidney	Left kidney				
	1	2	3	4	Total
1	177(71.37%)	23(9.27%)	4(1.61%)	1(0.40%)	205(82.66%)
2	13(5.24%)	12(4.84%)	5(2.02%)	0	30(12.10%)
3	3(1.21%)	3(1.21%)	4(1.61%)	0	10(4.03%)
4	1(0.40%)	0	0	2(0.81%)	3(1.21%)
Total	194(78.23%)	38(15.32%)	13(5.24%)	3(1.21%)	248(100%)

P.value <0.000

The same number of arteries was presented in 195 cases, 177 (58.80%) cases had a single bilateral renal artery, 12(3.99%) had double bilateral renal artery, 4(1.33%) cases had triple bilateral, and 2 cases (0.66%) had four renal arteries (Table 5).

There was a single artery on one side and two arteries on the other in 36(11.96%) specimens; 8 (2.66%) had two on one side and three on the other and 6(1.99%) cases presented a single artery on one side and three on the other. The probability of a kidney having a single artery on one side and the other having more than one was 5.10% for the left side and 2.37% for the right (p = 0.029),(Table 5).

Table 6: Additional renal arteries according to the presentation side.

Side	Number of renal arteries				
	1	2	3	4	Total
Right Kidney	216(39.34%)	32(5.83%)	11(2.00%)	3(0.55%)	262(47.72%)
Left Kidney	223(40.62%)	46(8.38%)	15(2.73%)	3(0.55%)	287(52.28%)
Total	439(79.96%)	78(14.21%)	26(4.74%)	6(1.09%)	549(100%)

P.value = 0.550

In the right side 32(5.83%) kidneys presented double renal arteries ,while 46(8.38%) in the left side .11(2.00%) presented three renal arteries in the right side while 15(2.73%) in the left side .only 3(0.55%) of the kidneys appeared with four renal arteries in the right side and also 3(0.55%) in the left side . , a statistically significant difference between these rates was not determined (P = 0.550), (Table.6).

Table 7: Distribution of renal arteries according to gender.

Sex	Number of renal arteries				Total
	1	2	3	4	
Male	252(45.90%)	45(8.20%)	17(3.10%)	3(0.55%)	317(57.74%)
Female	187(34.06%)	33(6.01%)	9(1.64%)	3(0.55%)	232(42.26%)
Total	439(79.96%)	78(14.21%)	26(4.74%)	6(1.09%)	549(100%)
	P.value = 0.852				

The total number of kidneys noticed with double arteries was 78 (14.21%), of which 45(8.20%) were males and 33(6.01%) were females. 26(4.74%) kidneys appeared with three renal arteries, 17(3.10%) in males and 9(1.64%) in females. 6 (1.09%), had four renal arteries 3(0.55%) in males and also 3(0.55%) in females. There was no statistically significant difference between these rates. (Chi square test, p=0.852), (Table 7).

Table 8: Distribution of renal arteries on the right and left sides according to gender.

No. of arteries	Right Side			Left Side		
	Male %	Female%	Total	Male%	Female%	Total
1	126(48.09%)	90(34.35%)	216	126(43.90%)	97(33.80%)	223
2	19(7.25%)	13(4.96%)	32	26(9.06%)	20(6.97%)	46
3	7(2.67%)	4(1.53%)	11	10(3.48%)	5(1.74%)	15
4	2(0.76%)	1(0.38%)	3	1(0.35%)	2(0.70%)	3
Total	154(58.78%)	108(41.22%)	262	163(56.79%)	124(43.21%)	287
	P.value = 0.977			P.value = 0.734		

Fig. 2: Renal vein variations

Fig. 3: Double renal artery

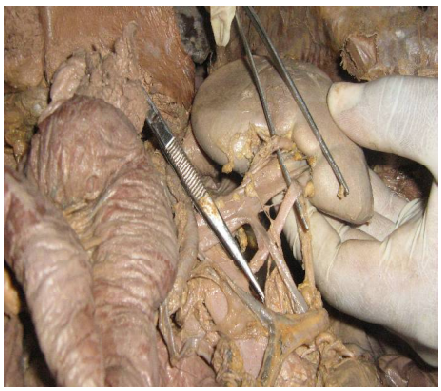

Fig. 4: Early branching left renal artery

Fig. 5: Multiple renal arteries.

Pre-hilar segmental branching (Early division):

Table 9: Showing the type variation of renal artery according to the presentation side.

Type of variation in renal artery	Right kidney	Left kidney	Total
Early division	(71.93%)41	(68.75%)55	(70.07%)96
Extra renal artery	(21.05%)12	(21.25%)17	(21.17%)29
Early division and extra renal artery	(7.02%)4	(10.00%)8	(8.76%)12
Total	57	80	137

P.value = 0.827

There were early divisions in 96(17.49%) kidneys (fig. 4.8), 41(7.47%) of which occurred on the right side, and 55(10.02%) on the left. Extrarenal artery of a separate origin were noticed in 29(5.28 %) kidneys, 12(2.19%) of which occurred on the right side, and17 (3.10%) on the left. 12(2.19%) cases of the sample studied presented early division and extra renal artery (fig 4.9), of which 4(0.73%) in the right kidney and 8(1.46%) in the left .A statistically significant difference in early division and ERA between the right and left side was not determined, p=0.827.

Table 10: Showing the type of variation of renal artery according to gender.

Type of renal artery	Male	Female	Total
Early division	(70.11%)61	(70.00%)35	(70.07%)96
Extra renal artery	(18.39%)16	(26.00%)13	(21.17%)29
Early division and extra renal artery	(11.49%)10	(4.00%)2	(8.76%)12
Total	87	50	137

P.value = 0.234

Early division occurred in 61 (11.11%) males and 35 (6.38%) females kidneys out of 549 kidneys. No statistically significant difference between males and females, p= 0.234 (Table.11).

Fig. 6: Early division

Fig. 7: Early division and extra renal artery

Hilar and polar renal arteries:

Table 11: Route of entrance of additional renal arteries to the parenchyma of the kidney.

Type of extra renal artery	Frequency	Percent
Hilar	111	53.62%
Upper Polar	68	32.85%
Lower Polar	28	13.53%
Total	207	100.00%

There were 111 (20.22%) of the specimen presented additional hilar, 47(42.34%) of which were in the right side and 64(57.66%) in the left side.

Table 12: Distribution of the Hilar and polar arteries according to side.

Type of extra renal artery	Right	Left	Total
Hilar	47(22.71%)	64(30.92%)	111(53.62%)
Upper Polar	24(11.59%)	44(21.26%)	68(32.85%)
Lower Polar	14(6.76%)	14(6.76%)	28(13.53%)
Total	85(41.06%)	122(58.94%)	207(100.00%)

P.value = 0.380

Upper polar arteries (fig 4.18) appeared in 24(35.29%) in the right side and in 44(64.70%) in the left side for a total of 68(12.39%).

Lower polar arteries appeared in 14(50%) in the right side and 14(50%) in the left side for a total of 28(5.10%). There were no significance difference appeared between these rates in the right and left side. (Chi square test, p=0.380, (Table 14).

Table 13: Distribution of the Hilar and polar arteries according to gender.

Type of extra renal artery	Male	Female	Total
Hilar	63(30.43%)	48(23.19%)	111(53.62%)
Upper Polar	39(18.84%)	29(14.01%)	68(32.85%)
Lower Polar	14(6.76%)	14(6.76%)	28(83.57%)
Total	116(56.04%)	91(43.96%)	207(100%)

P.value = 0.785

Regarding the gender 63 (11.48%) of the specimen with additional hilar were males and 48(8.74%) were females. 39 (7.10%) males and 29(5.28%) females had upper polar arteries .And 14(2.55%) males and 14(2.55%) females presented lower polar arteries . there were no significance difference between males and females p=0.785,(Table 15).

Fig. 8: Accessory Renal artery entering the anterior surface of the kidney.

Extra renal veins:

Table 14: Distribution of extra renal veins, between the left and right kidneys.

Presence of extra renal veins	Right Kidney	Left Kidney	Total
Yes	22 (4.01)	29(5.28)	51(9.29)
No	240(43.72)	258(46.99%)	498(90.71%)
Total	262(47.72%)	287(52.28%)	549(100%)

P.value = 0.491

There were 51 (9.3%) of the specimen studied presented additional renal vein, 22(8.4%) of which occurred on the right side, and 29(10.1%) on the left. no significance difference between the left and right side. (Chi square test, P=o.491).

Table 15: Distribution of extra renal veins in relation to gender.

Presence of extra renal veins	Sex		
	Male	Female	Total
Yes	(8.52)27	(10.34)24	(9.29) 51
No	(91.48)290	(89.66)208	(90.71) 498
Total	317	232	549

P.value = 0.466

Regarding the gender 27(8.5%) males and 24 (10.3%) females had additional renal veins. A statistically significant difference between these rates was not determined (Chi square test, p=.466).

DISCUSSION

Renal irrigation is assumed to be provided by a single renal artery in descriptions given by texts dealing with anatomy, (8); however, considerable variations on this pattern have been reported in the literature specializing in the topic [11,12].

This result was consistent to the finding of Aragoa, et al., [13] who stated that out of the 60 kidneys investigated, 78.33% had a single renal artery. This is higher than what was found by Shruthi and Shubha [14] and Saldarriaga, et al; [15] who reported that single renal artery was noticed in 75% and 74.9% of the specimen studied.

In this study bilaterally single renal artery had been noticed in 177 patients (58.80%). This was greatly lower than what was reported by Cicekcibasi, et al [12] and Ozkan, et al [7] who stated that there was only one renal artery

feeding both of the kidneys in 75% and 76% of the patients respectively.

A discrepancy was found regarding the most frequent side for the presence of a single renal artery. In this study single renal artery was noticed in 39.34% kidneys in the right side and 40.62% kidneys in the left side. Greater predominance of the left-hand side was found in this study, agreeing with Satyapal, et al. [16] and Bordei [11] who described a higher incidence of additional renal arteries on the left side. Contrary, other work had pointed out that this anatomical expression is more frequent on the right-hand. Khamana-rong et al. [2] suggested a higher frequency on the right side. Such differences could be explained by the number of renal specimens evaluated and by the techniques or study methods used.

In this study there were 20.04% of the kidneys analyzed presented multiple renal arteries (Table 4). The result was consistent to the finding of Rosa, et al. [17] who reported 18-30% prevalence rates of multiple renal arteries, with 15% being bilateral [17]. It was slightly lower than Saldarriaga et al. [18] who reported ninety seven (24.9%) out of 390 kidneys having additional arteries. The differences in additional artery frequency may have been due to ethnic factors, the type of study or the evaluated sample's size.

In the present study there was a single artery on one side and two arteries on the other in 36 (11.96%) specimens; 8 (2.66%) had two on one side and three on the other and 6 (1.99%) cases presented a single artery on one side and three on the other. This was lower than Saldarriaga et al. [18] who reported that there was a single artery on one side and two arteries on the other in 47 (24.2%) specimens. 9 (4.7%) had two on one side and three on the other and only one case presented a single artery on the left side and three on the right. Additional arteries were present in 89 (26.7%) male and 8 (14%) female kidneys. Kidneys having two additional arteries were only observed in men [18]**.** Although there were large differences in additional artery frequency between men and women in this study (Table 4), these differences were not statistically significant (p = 0.852), due to the low number of female specimens. There was discrepancy regarding the side the additional arteries were presented; some authors have reported a higher frequency on the left side. Other work has reported this variation to be more frequent on the right side, and it has also been reported that there is no significant difference regarding additional arteries' presentation side [19].

A higher left side frequency of additional renal arteries was observed in this study (Table 6); however, such difference was not statistically significant (p = 0.550). This result was consistent with Saldarriaga et al. [18] who stated that there was 22.2% frequency of additional arteries on the right side and 27.3% on the left [18]. Khamana-rong et al [2] suggested a higher frequency on the right side.

In this study the frequency of the double renal artery was found to be 14.2%. This result was slightly higher than what was reported by Bergman, et al. [20] Who stated that double renal arteries occur in about 10% of cases. This percentage was lower than the finding of Bordei, et al [11] and Khama-narong et al [2] who found higher rates for the incidence of double renal arteries (20% and 17.43% respectively).

The incidence of triple renal artery in this study was found to be 4.9% kidneys. The result was consistent with Satyapal et al [16] who reported that triple renal arteries were noticed in 4.5% of the specimen. Lower than that was found by Bergman et al (20) who found lower percentage (1-2%).

In this study In the right side 32 (10.63 %%) cases presented double renal arteries In the right side, while 46 (15.28%) in the left side. 11 (3.65%) presented three renal arteries in the right side while 15 (4.98%) in the left side. This result was higher but the right double renal artery was lower than Ozkan, et al [21] who stated that there were two right renal artery in 126 (15%) patients, and 3 renal arteries in 9 (1%) patients. On the left side two were observed in 105 (12%) patients, in 6 (0.7%) patients, 3 were seen [21].

Bilateral additional renal arteries were noticed in 8.6% of the individual studied. Cicekcibasi, et al., [12] stated that the presence of bilateral additional arteries has been reported, ranging from 4.3% to 10.2% [12]. The same frequency range of bilateral additional artery was observed

in this study.

Kadir, (22) stated that the rate of early division in the general population is 15%, that aberrant renal arteries are observed twice as often as accessory renal arteries [22]. Early ramification of the main renal artery as observed in this study was (17.48%) this was slightly greater than that reported by Kadir [22] and by Holden et al. [23], and Raom et al. [24] who stated that bilateral prehilar multiple branching of the renal arteries appeared in 11.66% cases. In this study 96 kidneys had an early division 42.70% of which occurred on the right side and 57.29% on the left side. This percentages were slightly high than what was reported by Ozkan, et al. [21] who stated that there were early divisions in 67 (8%) patients, 32% of which occurred on the right side, 25% on the left, and 22% on the both sides [21].

Additional arteries mainly entered the renal parenchyma through the renal hilum according to 13% of the reports; other authors have reported lower frequencies [25].

In this study the frequency of additional renal artery which enters through the hilum was higher (20.22%). This finding may represent a particular feature of the Sudanese population. The incidence of renal superior polar artery in the present study (12.39%) was greater than that reported by Saldarriga [18]. These authors reported 16.6% frequency for this artery in Caucasians (whites) and 11.9% in Negros. There were no marked differences between the findings observed in different racial groups.

The inferior polar renal artery was found less frequently than the superior polar renal artery. The findings of this study (5.10%) had an intermediate range between the percentages reported by Sampaio & Passos [26], and Longia et al. [27]. The frequency of inferior polar arteries in this study was lower when compared to the Colombian population (10.8%), [2]. This is much higher than that reported in previous work [25]. The presence of these arteries was observed as a characteristic of early ramification of the renal artery; such morphological expression is clinically important, especially when emergency surgery is involved.

In this study the frequency of renal vein variation is very low. 9.3% kidneys appeared with additional renal vein. (8.4% in the right side and 10.1% in the left) (Table 16). On the other hand, Bergman *et al*., pointed that, the renal veins show less variation than do the renal arteries and this finding was agreed with this study, and multiple renal veins to be rare on the left side (1%) and common on the right side (28%) [28]. Variations of renal veins are rare compared to the renal arteries. Variations of right renal veins are more common (23%) than left renal veins (6.7%) [29].

The lengths of the right- and left-hand renal arteries (39.2 and 3.72 mm) observed in the present work agreed with that reported by Bergman, et al [28] who stated that the right renal artery, from aortic origin to its division point, can measure 0.5 - 8 cm long; the length of the left can vary from 0.5 - 6 cm. Greater length right renal arteries (44 to 111 mm) were described by Janschek *et al*., [29]; such discordance could have been due to the greater number of specimen having late ramification of the right renal artery observed in the reference works.

CONCLUSION

This study, carried out on Sudanese population, showed that seven out of each ten individuals present single bilateral renal arteries. The renal arteries present a broad spectrum of variability in their morphological expression regarding their length, level of ramification, diameter and entrance to the kidney parenchyma. The incidence of additional arteries in our study was considerably higher than that reported in other population groups.

Conflicts of Interests: **None**

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