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ANATOMICAL FEATURES OF RENAL ARTERY IN A BLACK KENYAN POPULATION: CORRELATION WITH MARKERS OF ATHEROSCLEROSIS

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ABSTRACT

Knowledge of anatomical features of the renal artery is important in prediction, management and control of atherosclerotic renal artery stenosis. These features show population variations but data from black African populations are scarce. The aim of this study was therefore to describe the anatomical features of the renal artery in a black Kenyan population. Six hundred and ten (610) single renal arteries from 305 adult black Kenyans [206 males, 99 females; age range 22 – 79 years] were studied by dissection at Department of Human Anatomy, University of Nairobi, Kenya. Specimens with macroscopic features of stenosis and dilatation were excluded. The implantation angle, length and branching pattern were studied. These features were correlated with intima-media thickness and luminal diameter. The latter were determined by micrometry on Eosin/hematoxylin stained 5 micron sections obtained from the proximal segment of the renal artery. Data was analysed by SPSS version 16.0. Student's t-test, was used to test for statistical significance at 95% confidence interval where P value of < 0.05 was taken as significant. The results are presented in a bar graph, tables and macrographs. The mean implantation angle was $94^0 \pm 15^0$ (range 58^0-125^0). In 26.7% cases, the angle was more than 100^0. Mean length was 34±1.4 mm with 21.6 % of arteries measuring ≤ 20 mm. Variant branching pattern was present in 40.5 % of cases. It comprised trifurcation (33 %), quadrifurcation (6.6 %) and pentafurcation (0.8 %). Higher implantation angle, short arteries and variant branching were associated with statistically significant higher intima - media thickness and luminal diameter. These results suggest that higher implantation angle, shorter length and variant branching pattern constitute geometric risk factors for renal artery atherosclerosis. Ultrasound screening for individuals with suboptimal geometric features for renal artery atherosclerosis is recommended.

Keywords: anatomical risk factors, atherosclerosis, renal artery

INTRODUCTION

Geometric features of arteries, namely arterial lengths, branching angles and variant branching patterns have been shown to constitute risk factors for atherosclerosis in coronary (Gazetopoulous et al., 1976 a, b; Friedman et al., 1983; Candir et al., 2010) and carotid (Ogeng'o et al., 2013) arteries. In the renal artery, these factors show population variations (Rubin et al., 1995; Satyapal et al., 2001), but data from the Kenyan population are lacking and their relationship with atherosclerosis are seldom reported. We recently reported variant anatomy of the renal arteries in the Kenyan population (Ogeng'o et al., 2010) but with no reference to

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their relationship with atherosclerosis. Renal artery atherosclerosis is an important cause of kidney disease among Kenyans (Ogeng'o et al., 2011). Data on the anatomical risk factors are important in prediction and management of atherosclerosis in a population. This study, therefore, investigated the implantation angle, length, variant branching, mean diameter and intima - media thickness (IMT) of the renal artery in a black Kenyan population.

MATERIALS AND METHODS

The study was done on 610 renal arteries from 305 adult black Kenyans [206 males, 99 females; age range 22 – 79 years] obtained during autopsy at the Department of Human Anatomy, University of Nairobi, Kenya.

The peritoneal cavity was opened via an extended midline abdominal incision. Gastrocolic ligament was incised, stomach and pancreas reflected superiorly and inferiorly respectively. Retroperitoneal connective tissue was removed to expose the aorta, renal artery and kidneys. Renal arteries were defined as those which supplied the kidneys. Only renal arteries which were single bilaterally, arose from the aorta and showed no gross abnormalities were included. Implantation angle, defined as that angle between the lateral border of the infra- renal aorta and the lower border of the initial portion of renal artery was measured with a protractor and recorded to the nearest degree. Care was taken to ensure the kidneys and renal arteries were not mobilized before implantation angle was measured.

The length of the renal artery from the aorta to the point of first division was measured in millimeters. Measurements were taken on both the left and right renal arteries.
Morphometric parameters were determined on proximal segments of fourty two randomly selected specimens. Two millimeter specimens obtained from the proximal renal artery were processed routinely for paraffin embedding and sectioning. Five micron sections were stained with Haematoxylin and Eosin to demonstrate the general organization of the arterial wall. The slides were examined at x35 magnification and photographed. Photographs of 10 serial sections from each specimen were then scanned using a hp scanner and analyzed using Scion Image ™ Multiscan software. The region around the lumen was traced and the circumference measured. The diameter of the lumen was computed using the mathematical formula:

Diameter = circumference/π (π = 22/7). The average of the 10 was taken as the diameter of that artery. The intimal and medial thickness was measured. The extent of the intima was defined as between the lumen and the internal elastic lamina. Four random points (ISa, ISb, ISc, ISd) were selected and the average size computed based on the protocol by Nakashima et al., [Nakashima et al., 2002].

The media was defined as the area between the internal elastic lamina and the external elastic lamina. Four random points (Msa, Msb, Msc, Msd) were selected and the average size computed based on the protocol by Zhdanov [Zhdanov et al., 1993] [Figure 1].

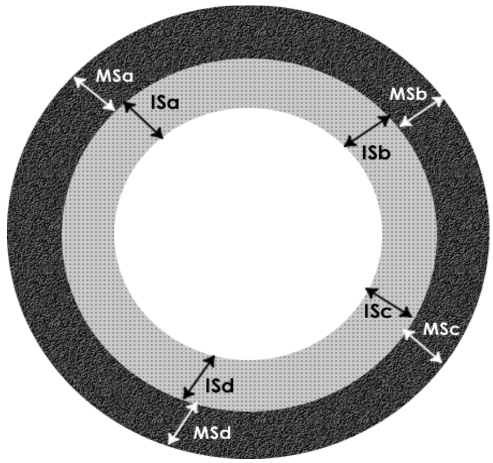

Figure 1: Measurement of intimal and medial Size: IS = intimal size; MS = medial size

RESULTS

All the renal arteries studied were single branches of the abdominal aorta and branched before entering the kidney. The features reported here were implantation angle, length, branching pattern, intima – media thickness and luminal diameter.

Implantation angle: The mean implantation angle was $94{\pm}15^0$ (range $58 – 125^0$). Majority (53.7%) of the renal arteries branched off the aorta at an angle between $81 – 100^0$. Twenty-six point seven percent (26.7 %) branched off at more than 100^0 (Figure 2). The mean angle on the left was 96± 2.5 (range 58 – 25) and on the right 94± 2.0 (range $65 – 120^0$). Side differences were not statistically significant.

Wider implantation angles were associated with higher IMT and diameter (Table 1)

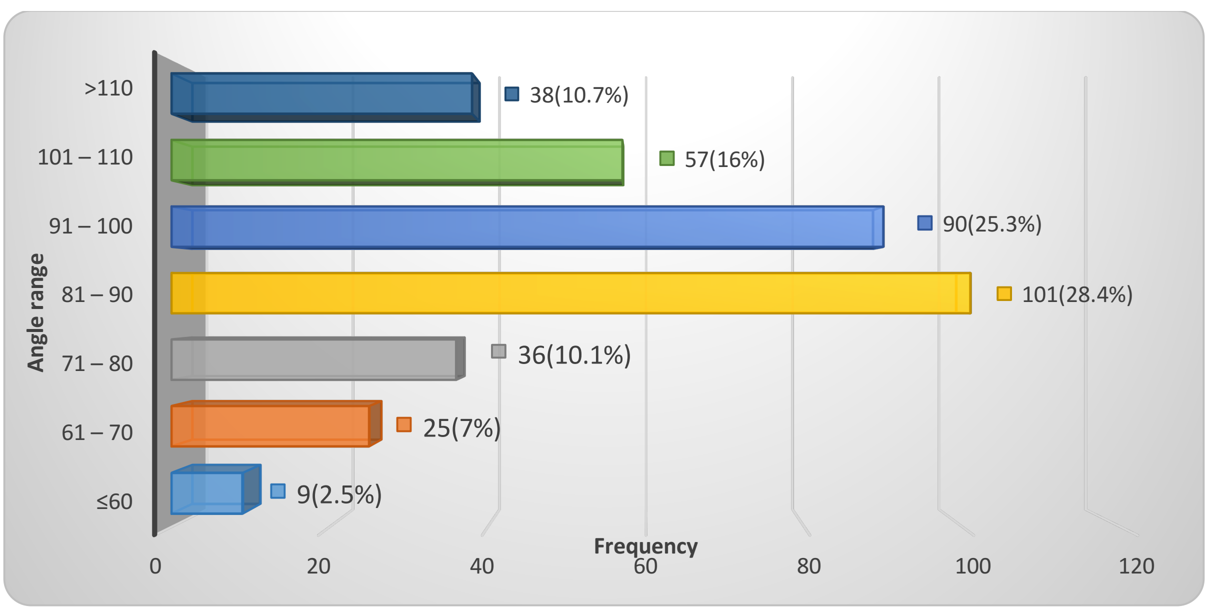

Figure 2: Distribution of renal artery implantation angle in a black Kenyan population

Table 1: Variation of IMT with implantation angle of renal artery in a black Kenyan population

Angle Range	IMT Mean± SE	Diameter Mean± SE
<60	0.39±0.015	3.5±0.15
61 – 70	0.42±0.035	3.52±0.13
71 – 80	0.42±0.023	3.53±0.17
81 – 90	0.45±0.018	3.61±0.13
91 – 100	0.51±0.016	3.7±0.11
101 – 110	0.54±0.031	3.8±0.15
>110	0.59±0.026	3.8±0.13

The mean for those with >100^0 was 0.57 ± 0.018 mm, while that for those with angle <100^0 was 0.46 ± 0.017 mm. The difference was statistically significant [p = 0.025].

There was variation in diameter with implantation angle. Those with ≥100^0 had a mean luminal diameter of 3.8 ± 0.12 mm, while those with angle ≤ 100 had a mean diameter of 3.57 ± 0.18mm. The difference was not statistically significant (p = 0.074).

Length: Mean length of the renal artery was 34± 1.4mm (range 12 – 67 mm). [Left artery 27±1.0 mm; Right, 34±1.3 mm]. Side differences in length were statistically significant (P<0.001). Shorter arteries had higher IMT and diameter. Early branching ≤ 20 mm occurred in 21.6% of cases. The mean IMT for early branching arteries was 0.52 ± 0.016 mm compared to those with hilar branching (0.35 ± 0.017 mm). The difference was statistically significant (p = 0.013). The mean luminal diameter was 3.6 ± 0.09 mm. It was inversely related with length, being higher in prehilar than in hilar ones (Table 2). The mean for pre hilar branching arteries was 3.75 ± 0.25 mm, while that for hilar branching arteries was 3.32 ± 0.017mm. The difference was not statistically significant (p = 0.067).

Table 2: Variations of IMT and diameter of renal artery with its length in a black Kenyan population

Length (mm)	IMT Mean± SE	Diameter Mean± SE
0 – 10	0.58±0.031	3.9±0.12
11 – 20	0.49±0.019	3.7±0.009
21 – 30	0.39±0.021	3.5±0.11
31 – 40	0.37±0.014	3.5±0.13
41 – 50	0.36±0.021	3.4±0.15
51 – 60	0.33±0.019	3.3±0.12
>60	0.32±0.011	3.2±0.08

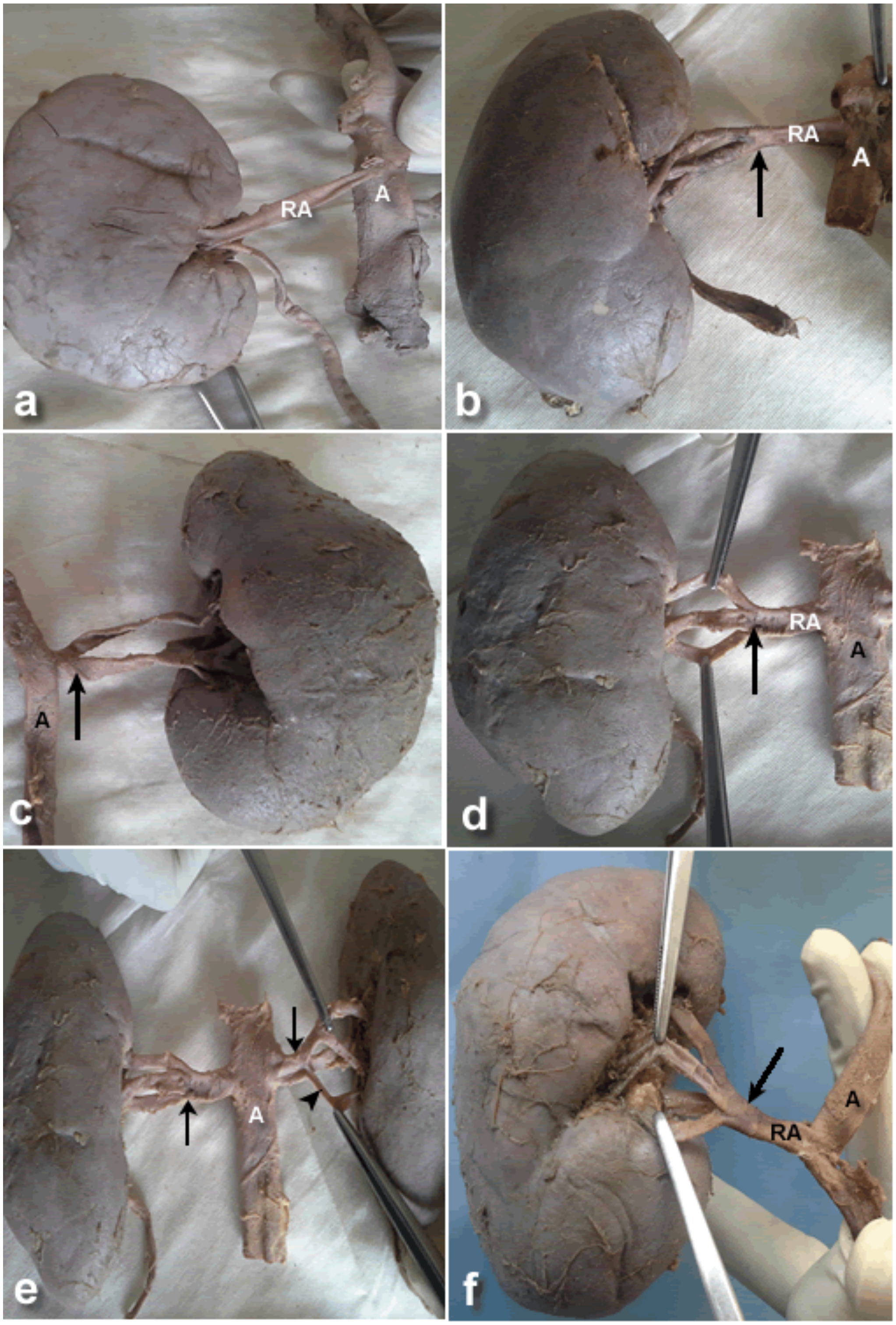

Figure 3: A: Intraparenchymal branching. **B**: Bifurcation (arrow) of renal artery (RA) midway between aorta (A) and kidney. **C**: Prehilar branching of renal artery. Note the very short stem (arrow), dividing shortly after leaving the aorta (A). **D**: Trifurcation (arrow) of renal artery (RA) arising from the aorta (A). **E**: Bilateral trifurcation (arrows) of renal artery. Note also the short stems, arising from the aorta (A). **F**: Quadrifurcation (arrow) of renal artery (RA) arising from the aorta (A).

Branching Pattern: Of all the renal arteries, 76.4 % showed hilar, 21.6 % prehilar and 2% parenchymal branching (Fig 3A). The most common branching pattern was bifurcation (59.6 %). The bifurcation was either hilar (Fig 3B) or prehilar. Some of the latter had stems shorter than 10 mm (Fig 3C). Trifurcation occurred in 33 % of cases. The trifurcations were unilateral (Fig 3D) in 25.5 % and bilateral (Fig 3E) in 7.6 % cases. Quadrifurcation (Fig 3F) occurred in 6.6 % of cases.

IMT was higher in cases of quadrifurcation (0.61 ± 0.035 mm) than those of bifurcation (0.42 ± 0.018 mm) [Table 3]. The difference was statistically significant (p = 0.002).

Table 3: Variations of IMT and diameter of renal artery with its branching pattern

Branching Patttern	**IMT** **Mean± SE**	**Diameter** **Mean± SE**
Bifurcation	0.42±0.018	3.4±0.09
Trifurcation	0.53±0.014	3.8±0.12
Quadrifurcation	0.61±0.035	4.3±0.14
	[p = 0.002]	[p > 0.05]

DISCUSSION

Implantation angle of the renal artery may impact its length and histomorphometric measures. A relationship has been demonstrated between these features, suggesting that the geometric factors in this artery influence the predisposition of its proximal segment to atherosclerosis.

Implantation angle

Implantation angle is important in predicting renal artery morphometry and when interpreting variability in renal vascular anatomy (Ardalan et al., 2008). Bifurcation angle plays an important biophysical role in determining susceptibility to atherosclerosis (Hademenos and Massoud, 1997; Rodriguez – Granillo et al., 2007) and plaque growth (Tadjfar, 2006). Large bifurcation angles favour eccentric thickening which predisposes to lipid accumulation and atherosclerosis (Friedman et al., 1996; Ding et al., 1997; Balu et al., 2004). This is because the wider angles cause higher turbulence and low shear stress which induce atherogenesis (Rodriguez – Granillo et al., 2007; Moore et al., 2010; Sun and Cao, 2011). The mean implantation angle was 94±15^0 with 26.7 % being higher than 100^0. The current study reveals that those arteries with implantation angle > 100^0 have a higher IMT. This suggests that over 26 % of the Kenyan population are, on this account, predisposed to atherosclerosis. Ultrasound screening for those who are at risk is recommended.

Length

Mean length of the renal artery was 34±1.4 mm comparable to 34.37±10.68 mm and 34.6 m reported by Ardalan et al., and Saldarriaga et al respectively. It is within the range in prevailing literature [Table 4].

Table 4: Mean length of Renal Artery in various populations

Reference	Population	Method	Length (mm)	
			Left	Right
Talenfeld et al., 2007	American	MDCT	38.7±12.6	48±16.2
Saldarriaga et al., 2008	Colombian	Anatomic	28.6	34.6
Palmieri et al., 20**11**	Brazilian	MSCTA	34.1	39.6
Thatipelli et al., 2007	American	CTA	39.9±6.7	44.9±7.4
Dhar&Lal, 2005	Indian	Anatomic	25±9.5	31±12
Tarzamni et al., 2008	Iranian	MDCT	32.4±12	35.6±17.7
Current study, 2015	Kenyan	Anatomic	27±1.0	34±1.4

A remarkable observation of the current study is that 21.6 % of the renal arteries were shorter than 20 mm and can be described as displaying early branching. Short stem arteries are geometric risk factors for atherosclerosis (Gazetopoulos et al., 1976a,b). This implies that over 20 % of the population studied would, on this basis, be more prone to atherosclerosis of renal artery. A corroborating observation of the current study is that early branching is associated with high intima media thickness. The 21.6 % incidence of early branching is higher than most of the reported cases (Ogeng'o et al., 2010). This may suggest higher vulnerability to atherosclerosis.

Luminal diameter

Luminal diameter, like IMT and atherosclerotic plaque is considered an indicator of atherosclerosis (Kiechl and Welleit, 1999; Schott et al., 2009). Observations of the present study reveal that the diameter of renal artery is 3.6 mm, lower than those reported for Asian and European populations (Aytac et al., 2003; Saldarriaga et al., 2008; Ramadan et al., 2010; Vaghela et al., 2013).

A remarkable finding of the current study, however, is that the diameter was higher in arteries which branched early; and those with higher implantation angle which have also been found to have higher IMT. This suggests that the higher diameter is related to IMT, which is a surrogate marker of atherosclerosis (Coll and Feinstein, 2008). This suggests that the renal artery in this population is prone to atherosclerosis. Indeed 3.5% of cases of hypertensive kidney diseases were due to atherosclerosis (Ogeng'o et al., 2011)

Branching Pattern

The renal artery usually divides into anterior and posterior divisions (Dyson, 1999). Observations of the current study reveal that bifurcation occurred in only 59.6%. The rest trifurcate (33%); quadrifurcate (6.6%) or pentafurcate (0.8%). This frequency of variation is within the range reported in prevailing literature (Table 5).

Table 5: Pattern of renal artery branching in various populations

Reference	Population			
		Bifurcation	Trifurcation	Quadrification
Shoja et al., 2008	Iranian	80.2	12.4	
Daescu et al., 2012	Romanian	70	23.3	6.67
Tarzamni et al., 2008	Iranian	45.3	40.5	12.0
Budhiraja et al., 2012	Indian	88.34	11.66	
Current study, 2009	**Kenyan**	**59.6**	**33.1**	**6.6**

Near ostia of arterial bifurcations and multiple branches, complex geometries cause disturbed or oscillatory flows characterized by turbulence and boundary separation which affect velocity profiles and shear stresses (Lee et al., 2001; Liu et al., 2002; Weydahl and Moore, 2002). Since unusual branching patterns cause disturbed flow patterns and alter hemodynamics (Furuichi et al., 2007; Rubinstein et al., 2012), high frequency of variant branching pattern observed in the current study implies that the renal artery in the Kenyan population is more prone to atherosclerosis. Pertinent to this suggestion is the observation that higher number of branches was positively associated with increasing intima media thickness, similar to that for the common carotid artery (Ogeng'o et al., 2013)

In conclusion, implantation angle, length and branching pattern of renal arteries influence their intima media thickness and diameter, suggesting that they constitute geometric risk factors for renal artery atherosclerosis. Ultrasound screening individuals with suboptimal geometric features for atherosclerosis is recommended.

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