VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 67, No. 2, pp. 129–134

ISSN 0015–5659
www.fm.viamedica.pl

A direct anatomical study of additional renal arteries in a Colombian mestizo population

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[Received 12 October 2007; Revised 18 January 2008; Accepted 24 January 2008]

Traditional anatomy describes each kidney as receiving irrigation from a single renal artery. However, current literature reports great variability in renal blood supply, the number of renal arteries mentioned being the most frequently found variation. Such variation has great implications when surgery is indicated, such as in renal transplants, uroradiological procedures, renovascular hypertension, renal trauma and hydronephrosis. This article pretends to determine the frequency of additional renal arteries and their morphological expression in Colombian population in a cross-sectional study. A total of 196 of renal blocks were analysed from autopsies carried out in the Bucaramanga Institute of Forensic Medicine, Colombia; these renal blocks were processed by the injection-corrosion technique. The average age of the people being studied was 33.8 ± 15.6 years; 85.4% of them were male and the rest female. An additional renal artery was found in 22.3% of the whole population and two additional ones were found in 2.6% of the same sample. The additional renal artery was most frequently found on the left side. The additional artery arose from the aorta's lateral aspect (52.4%); these additional arteries usually entered the renal parenchyma through the hilum. No difference was established according to gender. Nearly a third of the Colombian population presents one additional renal artery and about 3% of the same population presents two additional renal arteries. Most of them reached the kidney through its hilar region. (Folia Morphol 2008; 67: 129–134)

Key words: additional renal artery, variation, kidney, polar arteries, arterial calliper

INTRODUCTION

Traditional anatomy describes each kidney as being irrigated by a single renal artery. However, current literature reports great variability in the pattern of renal irrigation. It should be emphasised that the number of renal arteries is the most frequently occurring variation; some people have presented from 2 to 4 additional renal arteries [2, 7, 20]. Such findings refer to accessory, additional, multiple or supernumerary renal arteries [16, 17]. Moreover, additional arteries are called hilar, superior and inferior polar, according to the point where they enter the renal parenchyma [17]. The ostium of renal arteries is usually located in the lateral and front lateral aorta; posterolateral origin is less common [10]. Renal arteries also display other variations in origin, diameter, length and segmental distribution. All these variations can be attributed to embryological

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Table 1. Numbers (%) of renal arteries according to contralateral kidney anatomy

Arteries, right kidney (%)	Arteries, left kidney (%)			Total
	Single	One additional	Two additional	
Single	122 (62.9%)	28 (14.4%)	1 (0.5%)	151 (77.8%)
One additional	19 (9.8%)	15 (7.7%)	5 (2.6%)	39 (20.1%)
Two additional	0	4 (2.1%)	0	4 (2.1%)
Total	141 (72.7%)	47 (24.2%)	6 (3.1%)	194 (100%)

development [18]. Additional renal arteries have been reported in different population groups, incidence varying from 10% to 50% [5, 7, 9, 11, 15, 17]. A single additional left renal artery has been most commonly reported [2, 5, 17].

A thorough knowledge of morphological variations of the renal arteries is important and relevant for renal transplant surgery, uroradiological procedures, renovascular hypertension, renal trauma and hydronephrosis [2, 3, 8]. This research was aimed at establishing the frequency and morphological expression of additional renal arteries found in a Colombian population.

MATERIAL AND METHODS

This was a descriptive study of 196 renal blocks which were extracted from individuals on whom autopsy had been performed in the Bucaramanga Institute of Forensic Medicine (Colombia) between 2004 and 2006.

The extraction of organs for research purposes was done according to the regulations of the Institute of Legal Medicine and Forensic Sciences of Colombia (resolution No. 00485 of 2002) and the Health Ministry (resolution No. 008430 of 1993). The research project was approved by the Institutional Ethics Committee of the medicine schools of the Universidad Industrial de Santander and Universidad Autónoma de Bucaramanga.

A renal block is considered to be a single anatomical piece including the right and left kidneys, renal pedicles, abdominal aorta artery and inferior vena cava. This research included 390 kidneys from a mixed racial phenotype group (we considered "Colombian mestizo" individuals having a Caucasian, mongoloid and Negroid racial group phenotype mixture) having no evident signs of pathology or retroperitoneal trauma; 338 (84.5%) of them were extracted from males.

The renal arteries were injected with synthetic resin (80% palatal GP41L and 20% styrene) at 120 mm mercury pressure. After leaving them for 24-hours, perfused renal blocks were processed by a 20% KOH corrosion technique for 8 hours.

The variables considered in this investigation were the number of additional renal arteries, which side they were presented, their length, diameter, the place where they originated from in the aorta and the distance between the superior mesenteric and renal arteries. It was considered that the main renal artery presented the greatest diameter, vascular territory and hilar position. Each piece evaluated was photographed.

A descriptive analysis was done; frequency and percentage were calculated for categorical variables and the average and standard deviation (±) for continuous variables. Bivariate analysis was used for comparing right and left additional renal arteries, a χ^2 test for nominal variables and t-Student test for continuous variables. Statistically significant differences were lower than 5%. STATA 9.0 was used for all statistical analysis.

RESULTS

The average age of the people from whom the renal blocks were extracted was 33.83 ± 15.59 years, ages ranging from 12 to 86. The age range was similar for both men and women (34.1 ± 15.2; 30.9 ± ± 17.0 years, p = 0.122). 194 specimens were analysed bilaterally (Table 1), one in just the right kidney and another in the left one.

Ninety-seven (24.9%) out of the 390 kidneys analysed presented additional arteries; 87 (22.3%) had one additional artery (Fig. 1) and 10 (2.6%) had two additional arteries (Fig. 2). There was 22.2% frequency of additional arteries on the right side and 27.3% on the left. The greatest frequency (56.3%) in kidneys having one additional artery corresponded to the left side compared to 43.7% on the right side (Table 2).

Tables 1 and 2 show the correlation for the number of renal arteries, according to side. The same

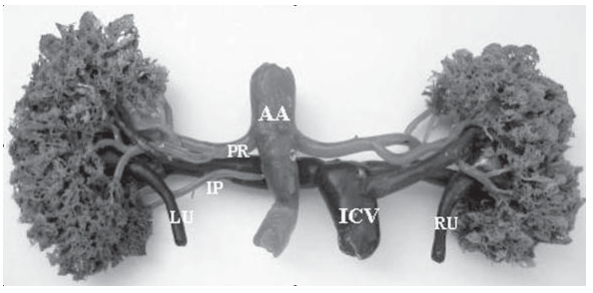

Figure 1. Unilateral additional renal arteries (Inferior polar); AA — abdominal aorta; LU — left ureter; RU — right ureter; IP— inferior polar; PR — main renal artery; ICV — inferior cava vein.

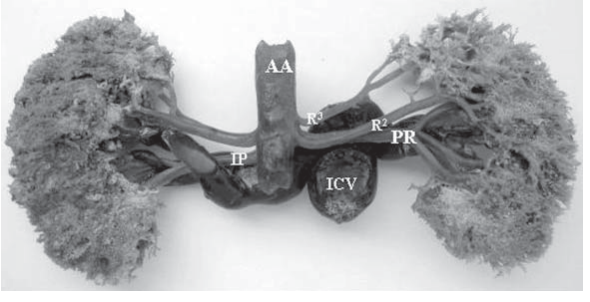

Figure 2. Bilateral additional renal arteries (Inferior polars) with parallel traject; AA — abdominal aorta; IP — inferior polar; ICV — inferior cava vein; PR — main renal artery; R^2 — first additional renal artery, R^3 — second additional renal artery.

Table 2. Additional renal arteries according to the presentation side

Arteries	Right	Left	Total
Single	151 (51.5%)	142 (48.5%)	293 (100%)
One additional	38 (43.7%)	49 (56.3%)	87 (100%)
Two additional	4 (40%)	6 (60%)	10 (100%)
Total	193	197	390

number of arteries was presented in 137 cases (70.6% agreement), 122 (62.9%) cases had a single bilateral renal artery and 15 (7.7%) had one additional bilateral renal artery (Fig. 3–5). There was a single artery on one side and two arteries on the other in 47 (24.2%) specimens (Fig. 1); 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. The probability of a kidney having a single artery on one side and the other having more than one was 13.5% for the left side and 19.2% for the right ($p = 0.187$).

Greater length of right renal artery was observed, compared to the left ($p < 0.001$). No significant differences regarding length and diameter according to side were found in the additional arteries; additional arteries had greater length (on average) than main arteries. Regarding distance to the origin of the superior mesenteric artery, the right main renal artery emerged more cranially than the left side one ($p < 0.003$). There was no difference in this distance in the additional arteries (Table 3).

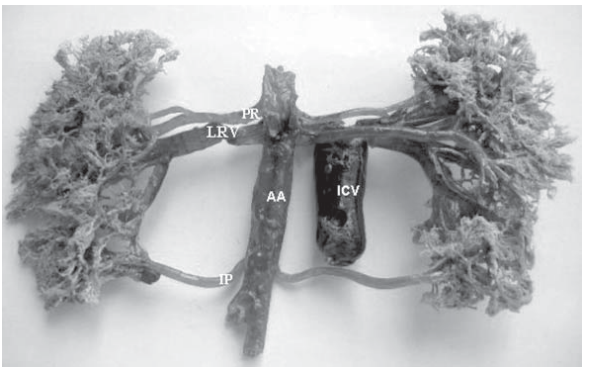

Figure 3. Bilateral additional renal arteries; AA — abdominal aorta; ICV — inferior cava vein; LRV — left renal vein; IP — inferior polar; PR — main renal artery.

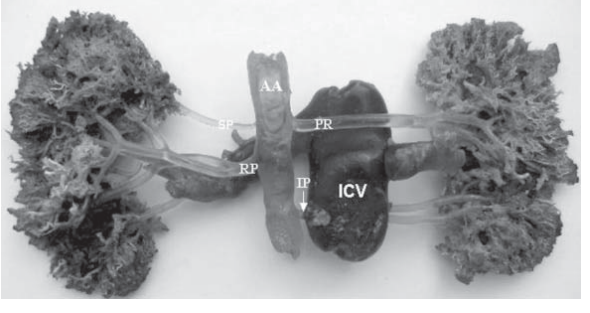

Figure 4. Bilateral additional renal arteries. The course of the left inferior polar artery is anterior to the left renal vein; AA — abdominal aorta; IP — inferior polar; PR — main renal artery; ICV — inferior cava vein; RP — renal polar, SP — superior polar.

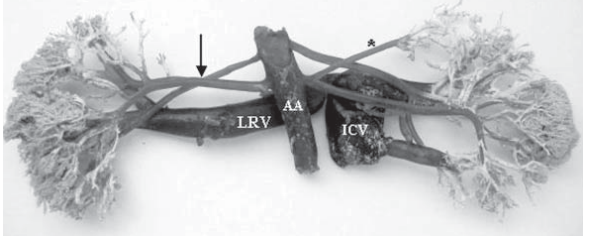

Figure 5. Bilateral additional renal arteries: the trajectory in horizontal parallel (right side) and traject crossed (↓) (left side); AA — abdominal aorta; ICV — inferior cava vein; LRV — left renal vein; *superior polar of the additional renal artery.

Table 3. Length, diameter and distance to the superior mesenteric artery (SM) from the main renal artery and the first additional artery

	Right main artery	Left main artery	First additional right artery	First additional left artery
Length	34.5 ± 11.4	28.4 ± 0.96	42.1 ± 10.32	41.3 ± 7.2
Diameter	4.78 ± 0.86	4.92 ± 0.92	2.85 ± 0.42	2.8 ± 0.41
Distance to SM	10.2 ± 6.0	11.2 ± 5.7	18.8 ± 12.5	18.0 ± 4.82

Additional arteries were present in 89 (26.7%) male and 8 (14%) female kidneys. Kidneys having two additional arteries were only observed in men; no significant differences were found in additional artery frequency related to gender ($p = 0.317$).

Additional arteries originating from the surface of the aorta were observed with greater frequency on lateral (52.4%) (Fig. 2, 3) and front lateral sides (38.1%) (Fig. 1), much lower frequency being observed on front (7.6%) and posterior sides (1.9%) (Fig. 4). A higher frequency was observed regarding the origin of the lateral side in left renal arteries; however, these differences were not statistically significant ($p = 0.192$).

Compared to additional arteries, the main renal arteries' ostium was mostly located on the aorta's anterolateral surface on both right (86.3%) and left sides (87.8%); the ostium was found to be located on the lateral and posterolateral side to a much lesser extent. No significant differences were found for each side in relation to gender ($p = 0.28$ for the right side and $p = 0.392$ for the left side).

12.1% of the specimens presented additional hilar (Fig. 2, 5), 10.8% lower polar (Fig. 1, 3, 4) and 4.3% superior polar arteries (Fig. 2, 4).

Additional arteries' horizontal parallel trajectory in relation to the main renal artery was observed with 50.5% frequency (Fig. 3, 4), followed by divergent arteries (24.3%) (Table 4).

There was a 7.5 ± 10.5 mm average distance from the first additional artery to where the main renal artery originated; differences in relation to side were not significant (8.5 mm from the right side and 6.7 mm from the left).

The main renal artery's early ramification (branches originated at a distance less than 20 mm from the place where they emerged from the aorta) was observed in 9.4% of right side specimens having a single renal artery and 16.5% of the same on the contralateral side; 3.1% of the cases had additional renal arteries on the right side as well as the left.

Table 4. Trajectory of the first and second additional arteries with respect to the main artery; the trajectory of 4 arteries was not obtained

Trajectory	First and second additional renal artery
Horizontal parallel	52 (50.5%)
Descendent parallel	2 (1.9%)
Convergent	6 (5.8%)
Divergent	25 (24.3%)
Proximal crossed	3 (2.9%)
Medial crossed	3 (2.9%)
Distal crossed	12 (11.7%)
Total	103 (100%)

DISCUSSION

Additional arteries are frequently found in renal vascular irrigation studies [9]. The frequency observed in this study of the Colombian population (24.9%) was higher than that reported for the Indian population (13.5%), mestizo population (18.5%) [17], the Thailandese (17%) [7] and black populations (18%). Studies on Caucasian and black populations have reported frequencies raging from 30% to 40% [9, 12, 19]. Our findings were similar to those reported for the Turkish population [3, 11]. The differences in additional artery frequency may have been due to ethnic factors, the type of study or the evaluated sample's size.

Although there were large differences in additional artery frequency between men and women, these differences were not statistically significant ($p = 0.317$), due to the low number of female specimens. Several earlier studies did not take this variable into account; a higher significant frequency of additional arteries

found in men than women were reported amongst those which did [17]. De Beer [5], Sampaio and Passos [15], Ozkan et al. [11], and Merklin and Michels [9] found no gender difference. The obvious predominance of male subjects (84.5%) in the sample being studied was determined by the high available number of male cadavers used for forensic necropsy; this is quite common in direct anatomical studies, thereby limiting a suitable statistically-supported comparison of anatomical gender differences.

There was discrepancy regarding the side the additional arteries were presented; some authors have reported a higher frequency on the left side [2, 17, 19], other work has reported this variation to be more frequent on the right side [3, 7, 11] and it has also been reported that there is no significant difference regarding additional arteries' presentation side [9, 14]. A higher left side frequency was observed in our study; however, such difference was not statistically significant ($p = 0.187$). The scant presentation of 2 or more additional arteries should be stressed; the presence of 2 or more additional arteries in this work was slightly higher (2.6%) than that reported in other studies [7, 11, 14].

The presence of bilateral additional arteries has been reported, ranging from 4.3% to 10.2% [3, 4, 11, 12, 17]. Greater bilateral additional artery frequency was observed outside this range in this study; 7.7% of the specimens studied here presented a bilateral additional artery and 4.7% presented one additional artery on one side and two on the other.

Additional arteries mainly entered the renal parenchyma through the renal hilum (12%) according to 13% of the reports [1]; other authors have reported lower frequencies [5, 13]. The higher frequency of inferior polar arteries should be stressed in this study (10.8%), this being much higher than that reported in previous work [4, 5, 13]. This finding may represent a particular feature of the Colombian population; however, this should be confirmed with further studies. By contrast, a lower percentage of superior polar arteries were found when compared to other studies [5, 9].

Few anatomical studies focus on establishing additional arteries' trajectories regarding the main renal artery as they only report the site of entry into the renal parenchyma (hilar and polar); wide variability in the path of additional arteries was found in this work, horizontal parallel and divergent trajectories clearly predominating and thereby agreeing with Bordei et al. [2]. Crossed trajectory frequency was considerably higher in this study. Great variability in additional artery trajectory and their distance from the origin of the main renal artery are aspects which should be taken into account during surgical procedures involving the kidneys and the retroperitoneum. Suitable regard being paid to such anatomical considerations will certainly be reflected in a reduced amount of complications.

The presence of additional renal arteries is a frequent finding in anatomical and radiological studies; the wide differences found in the reported frequencies are determined by ethnic factors, type of study and sample size.

Early ramification of the main renal artery as observed in our study was slightly greater than that reported by Holden et al. [6]. Such morphological expression is important due to these branches being erroneously interpreted as being additional arteries in diagnostic imaging studies and determines surgical complications in renal transplants, since the first 15 mm of the renal artery can be used for anastomosis with the recipient's iliac artery. It should also be emphasised that early ramification of the main renal artery and the presence of additional arteries represent exclusion criteria in laparoscopic renal surgery.

The features mentioned above mean that these studies should be extended to other population groups, especially in Latin America. Our results contribute towards basic knowledge regarding renal irrigation, having great potential in the clinical field, general medical training and the specialised fields of urology and diagnostic imaging.

CONCLUSION

The incidence of additional arteries in our study was considerably higher than that reported in other population groups; high inferior polar frequency and low superior polar frequency were both remarkable. Additional arteries' trajectories presented great variability, horizontal parallel predominating. Additional arteries' morphological expression was higher in men than women (without being statistically significant). These represent morphological aspects which are relevant to the basic study of renal irrigation and those applications deriving from it.

ACKNOWLEDGEMENTS

This work was supported by COLCIENCIAS Colombia, Universidad Autónoma de Bucaramanga, Universidad Industrial de Santander and the Bucaramanga Institute of Forensic Medicine, Colombia.

We thank Luis Alfonso Diaz and Maria Eugenia Niño, Associate Professors of Medicine, Universidad Autonoma de Bucaramanga, for statistical analysis of study.

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