Morphological Expression of the Renal Artery. A Direct Anatomical Study in a Colombian Half-caste Population

Expresión Morfológica de la Arteria Renal. Un Estudio Anatómico Directo en Población Mestiza Colombiana

Bladimir Saldarriaga*; Sergio A. Pinto** & Luis E. Ballesteros***


SUMMARY: Irrigation of the kidneys is usually provided by a single renal artery; however, variations on this pattern have frequently been reported. This study was aimed at establishing the renal arteries’ frequency and morphological characteristics in cadaverous material taken from a half-caste population from Bucaramanga (Colombia). The sample included 195 renal blocks corresponding to 57 (14.6%) kidneys from females and 333 (85.4%) from males. The renal arteries were injected with synthetic resin (palatal GP41L); following the resin’s polymerization, the renal blocks were placed in KOH solution for corrosion the renal parenchyma. The individuals from whom the renal blocks, 74.9% of the kidneys presented renal arteries single and 25.1% had additional renal arteries. Average right and left renal artery length was 34.6 mm and 28.6 respectively (p<0.001). Renal artery diameter was 4.87 mm. Main renal artery diameter in kidneys presenting additional renal arteries was less than that of those having a single renal artery, this being a significant difference (p= 0.0000). The renal arteries more frequently (85%) originated from the anterolateral part of the aorta. The right renal artery emerged rostrally in 49.2%, whilst both arteries were located at the same level in 34.4%. The renal poles received a greater contribution from frontal division branches, the upper pole 46.4% and the lower pole 55.9%. No significant differences were presented in the characteristics studied here regarding gender. The renal arteries presented great variability in morphological expression regarding their emergence and ramification level.

KEY WORDS: Renal artery; Anatomical variations; Kidney.

INTRODUCTION

Great technological advances due to modern diagnostic imaging techniques, particularly in the field of urology, in non-interventionist radiological procedures and in the area of surgery, have emphasized having better morphological referents for the renal vascularization pattern. Even though imaging techniques have good resolution, direct anatomical studies lead to recognizing anatomical vascularization patterns in greater detail, offering a referent having great usefulness for interpreting, managing, surgical approaches and diagnosing functional alterations (Longia et al., 1984).

Renal irrigation is characterized by presenting great variability, the presence of a single bilateral or unilateral renal artery significantly predominating in most studies. Such variability is influenced by ethnic factors, and less so by gender (Ajmani & Ajmani 1983). The renal artery emerges from the lateral surface of the aorta in most cases (Garcier et al., 2001; Ozan et al., 1997) It emerges from the posterolateral, anterolateral and posterior surfaces with less frequency. Other sites of origin have been described, such as the celiac trunk, common iliac and inferior phrenic artery (Garti et al., 1986).

The distance from the renal arteries origin to the superior mesenteric (Garcier et al.,) and celiac trunk (Ajmani & Ajmani) have been taken as reference in determining the level of emergence. The renal arteries may emerge at the same level, or at different levels, the right renal artery may be found proximal or caudal to the left (Odman & Ranniger, 1968).

The renal arteries present a diameter of around 5mm. The right renal artery is longer than the left due to the aorta’s location to the left of the middle plane of the abdominal cavity.
Based on the level of the renal artery ramification, it is known as the hiliar renal artery when it divides at renal hilium level and extrahiliar when the artery emits a segmentary branch entering the kidney’s upper or lower poles before entering the hilium (Sampaio & Passos 1992).

This study was aimed at establishing the frequency of renal arteries and their morphological expression in cadaverous material taken from a half-caste population from Bucaramanga (Colombia), to enrich knowledge concerning renal vascularization, thereby serving as referent in teaching and clinical practice.

**MATERIAL AND METHOD**

One hundred and ninety-five renal blocks were studied in this non-probabilistic, cross-sectional, descriptive study; they were extracted from individuals, who had necropsy performed on them at the Instituto de Medicina Legal, Bucaramanga (Colombia).

The sample included 57 (14.6%) kidneys from females and 333 (85.4%) from males.

A convenience sample was obtained complying with the following inclusion criteria: kidneys from half-caste male and female subjects (half-castes were considered to be individuals presenting a phenotypical mixture of Caucasoid, Negro and Mongoloid racial groups), having no signs of retroperitoneal pathology or trauma. The renal arteries were injected with synthetic resin (80% palatal GP41L and 20% styrene) at 120 mm mercury pressure. Perfused renal blocks were subjected to polymerization (24 hours) and corrosion (8 hours) with 20% KOH.

An electronic calibrator was used for taking measurements. The different findings from patterns of renal irrigation were reported considering the specimens’ gender, number of renal arteries, side on which presented, length, diameter, emergent surface from the aorta, ramification level and distance to the superior mesenteric. Photographic records were made of each piece evaluated.

The continuous variables were described with their means and standard deviations while nominal variables were described in terms of percentages; Chi($\chi^2$) square and Student T-test statistical tests were made, accepting an alpha error of up to 5%. Epinfo 2002 was used for creating the database and STATA 8.0 for making the statistical analysis.

**RESULTS**

The individuals from whom the renal blocks were extracted had an mean age of 33.8 (15.6 SD), ages ranging from 12 to 86. mean male and female age (34.1±15.2 and 30.9±17.0 years old, respectively) was similar (p = 0.122).

Two hundred and ninety-two kidneys (74.9%) presented single renal arteries and 98 (25.1%) additional renal. Single renal artery presentation frequency was great on the right-hand side (151, 77.8%) than the left-hand side (141, 72.7%), no significant differences being presented regarding the number of renal arteries according to side (p = 0.140).

The length of the right-hand renal artery (34.6 mm) was significantly greater (p<0.001) than the left-hand one (28.6 mm). Most specimens presented renal artery lengths ranging from 31 to 45 mm on the right-hand side and 16 to 30 mm on the left-hand side (Table I; Figs. 1 and 2). Short-length arteries, determined by early ramification of the main renal artery (arteries having a length less than 15 mm), were observed on the right-hand side in 7.3% of cases and in 9.4% on the contralateral side (Table II; Figs. 3 and 4).

Left-hand side renal artery diameter in cases of single renal artery had an average 4.93 mm diameter and 4.8mm on the right-hand side. No significant differences were found regarding gender (Table I). The main renal artery presented a 3.98 mm diameter (0.86 SD) in kidneys presenting additional renal arteries on the right-hand side and 4.28 mm (0.92 SD) on the left-hand side. These diameters were significantly less than those for kidneys presenting a single renal artery (p= 0.0000).

Regarding renal arterie’s diameter, this was greater in taller individuals, correlation not being significant between these two parameters (Spearman’s rho= 0.1641 and 0.1876 for the right- and left-hand sides, respectively). Taking the distance from the renal arterie’s emergence to the origin of the superior mesenteric artery as reference, it was observed that the right renal artery was proximal related to the left-hand one, this difference not being significant in relation to gender (Table III). The right-hand renal artery emerged proximally in 60 (49.2%) of the 122 renal blocks having a single bilateral artery; the left was proximal in 20 of them (16.4%) and both arteries emerged at the same level in the remaining 42 speci-mens (34.4%). The distance in the aorta vertical axis separating the origin of the right renal artery from the left-hand one was 2.9 mm on average.
The renal artery emerged with greater frequency (84.8% of the pieces evaluated) from the anterolateral part of the aorta on both the right- and left-hand sides, no significant differences being presented between males and females ($p = 0.28$ on the right-hand side and $p = 0.392$ on the left). The renal artery emerged from the posterolateral surface of the aorta in very few cases (Table IV).

The renal pole’s blood supply was presented with greater frequency from the anterior division’s branches, 46.4% corresponding to the superior pole and 55.9% to the inferior one. Irrigation provided by a branch originating directly from the renal artery (superior renal polar branch) was observed on the right-hand side in 26 kidneys (17.2%) and in 19 on the left-hand side.

### Table 1. Average measures (length, diameter, distance) between the superior mesenteric artery and the singles renal arteries.

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the right-hand renal artery</td>
<td>34.38 ± 11.58</td>
<td>35.98 ± 9.51</td>
<td>0.2566</td>
</tr>
<tr>
<td>Length of the left-hand renal artery</td>
<td>28.68 ± 10.30</td>
<td>28.20 ± 6.56</td>
<td>0.8141</td>
</tr>
<tr>
<td>Diameter of the right-hand renal artery</td>
<td>4.84 ± 0.90</td>
<td>4.57 ± 0.63</td>
<td>0.1550</td>
</tr>
<tr>
<td>Diameter of the left-hand renal artery</td>
<td>4.97 ± 0.73</td>
<td>4.71 ± 0.96</td>
<td>0.1841</td>
</tr>
<tr>
<td>DSMR</td>
<td>10.36 ± 6.29</td>
<td>9.36 ± 4.78</td>
<td>0.52</td>
</tr>
<tr>
<td>DSML</td>
<td>11.23 ± 5.95</td>
<td>11.07 ± 4.62</td>
<td>0.91</td>
</tr>
</tbody>
</table>

DSMR = Distance of the right renal artery to the superior mesenteric artery. DSML = Distance of the left renal artery to the superior mesenteric artery.

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Fig. 1. Kidney arteries with symmetrical emergence (Posterior view). AA. Abdominal Aorta; IC. Inferior vena cava; L. Left renal artery; R. Right renal artery; U. Ureter.

Fig. 2. Kidney arteries with asymmetrical emergence (Posterior view). AA. Abdominal aorta; IC. Inferior vena cava; L. Left renal artery R. Right renal artery; U. Ureter.
The superior renal polar artery was observed on the right-hand side with greater frequency in females, such difference not being statistically significant (p = 0.053); presentation of this branch being very similar on the left-hand side (p= 0.575).

The right-hand inferior renal polar branch was observed in 5 specimens (3.3%) and 5 on the left-hand side (3.5%), no significant differences being presented regarding gender (p= 0.505 for the right-hand side and p= 0.909 for the left).

**DISCUSSION**

Renal irrigation is assumed to be provided by a single renal artery in descriptions given by texts dealing with anatomy (Testut & Jacob 1979; Williams et al., 2001); however, considerable variations on this pattern have been reported in the literature specializing in the topic (Anson et al., 1936; Bordei et al., 2004; Cicekcibasi et al., 2005; Harrison et al., 1978; Ronstrom, 1947). Renal irrigation provided by a single renal artery had 75.1% frequency in the present study, agreeing with that reported by Cicekcibasi et al.; Merklin & Michels, 1958 and Harrison et al. Other authors have reported high frequency ranging from 82% to 87% (Reis & Esenlher, 1959; Ronstrom; Wozniak et al.; 1972; Engelbrecht et al., 1969). Differing from the previously-mentioned results, Coen & Raftery (1992) reported remarkably lower single renal artery incidence (50.9%) in the population being studied.
The presence of bilateral single renal arteries had 62.9% frequency, similar to that reported by Odman & Ranniger; other studies have reported 69% (Coen & Raftery), 75.1% (Geyer & Poutasse, 1962) and 35% (Anson et al.).

A discrepancy was presented regarding the most frequent side for presenting a single renal artery; greater predominance of the right-hand side was found in our study, agreeing with Bordei et al.; Satyapal et al., 2001; Vilhova et al., 2001. Other work has pointed out that this anatomical expression is more frequent on the left-hand side (Khamanarong et al., 2004; Cicekcibasi et al.). Such differences could be explained by the number of renal specimens evaluated and by the techniques or study methods used.

The lengths of the right- and left-hand renal arteries (34.6 and 28.6 mm) observed in the present work agreed with that reported by Dhar & Lal (2005). Greater length right renal arteries (44 to 111 mm) were described by Janschek et al., 2004; such discordance could have been due to the greater number of specimen having late ramification of the right renal artery observed in the reference work.

The short-length renal artery frequency (early ramification) observed in our study (8.3%) was less than that reported by Holden et al., 2005 (12%); Patil et al., 2001, Sasaki et al., 2000 (10%); Kapoor et al., 2004 (11.8%). Kawamoto et al., 2003 reported a considerably greater frequency to the foregoing (19%). The low frequency (2.6%) reported by Sampaio & Passos can be highlighted. It is important that this characteristic be born in mind, as these branches may be erroneously interpreted as being additional arteries in diagnostic imaging studies. Surgical complications may also be determined in renal transplants since the first 15 mm of the renal artery may be used for anastomosis with the receptor iliac artery. Early ramification of the main renal artery in renal laparoscopic surgery is considered to be exclusion criteria. In surgical terms, early or precocious division of the renal artery is considered to be equivalent to arterial supply by multiple arteries, such morphological characteristic being important to consider when performing a transplant (Sampaio & Passos).

There is little information about these arteries’ diameter in current morphometric studies of renal arteries.

Table III. Distance between the superior mesenteric artery and the right and left renal arteries.

<table>
<thead>
<tr>
<th>Distance SMA (mm)</th>
<th>Right renal artery</th>
<th>Left renal artery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>0 - 5</td>
<td>19</td>
<td>18.1</td>
</tr>
<tr>
<td>5.1 - 10</td>
<td>33</td>
<td>31.4</td>
</tr>
<tr>
<td>10.1 - 15</td>
<td>35</td>
<td>33.3</td>
</tr>
<tr>
<td>15.1 - 20</td>
<td>12</td>
<td>11.4</td>
</tr>
<tr>
<td>&gt; 20.1</td>
<td>6</td>
<td>5.7</td>
</tr>
</tbody>
</table>

SMA: Superior mesenteric artery.

Table IV. Emergence of the renal artery from the surface of the aorta in relation to gender.

<table>
<thead>
<tr>
<th>Emergence</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (%)</td>
<td>Female (%)</td>
</tr>
<tr>
<td>Lateral</td>
<td>19 (15.5)</td>
<td>2 (7.4)</td>
</tr>
<tr>
<td>Anterolateral</td>
<td>102 (83.6)</td>
<td>24 (88.9)</td>
</tr>
<tr>
<td>Posterolateral</td>
<td>1 (0.9)</td>
<td>1 (3.7)</td>
</tr>
<tr>
<td>p value</td>
<td>0.28</td>
<td>0.392</td>
</tr>
</tbody>
</table>

The presence of bilateral single renal arteries had 62.9% frequency, similar to that reported by Odman & Ranniger; other studies have reported 69% (Coen & Raftery), 75.1% (Geyer & Poutasse, 1962) and 35% (Anson et al.).

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focused on managing pathological cases, especially those characterized by renovascular hypertension-associated stenosis. Data from diagnostic imaging studies varies, depending on the technique used. Renal artery diameter found in our study (4.87 mm) was slightly less than the 5.9 mm reported in angiographic studies (Aytac et al., 2003; Behar et al., 2002) and that reported by Testut & Jacob.

The difference in single renal artery diameter (4.87 mm) was evident in relation to that of the main renal artery when additional arteries were presented (4.15 mm). This characteristic is very important for predicting the presence of accessory renal arteries. The presence of additional renal arteries is very probable (98.8% specificity) when the main renal artery has a diameter of less than 4.15 mm. Kidneys presenting a main renal artery greater than 5.5 mm very probably do not present additional renal arteries (Aytac et al.).

The emergence of single renal arteries from the anterolateral surface of the aorta (84.8%) agreed with reports by Beregi et al., 1999 and Verschuy et al., 1997. This percentage was greater than that reported by Ozan et al. and Kosinski, 1994. This finding was less than that reported for the right-hand renal artery (95%) by Garcia et al. Contrasting with the foregoing results, Ciceckibasi et al. described remarkable lesser frequency (26.9%) of the ostium on the anterolateral surface of the aortic wall. An occasional finding related to the presence of the ostium of the renal artery in the posterolateral part of the aorta (1%), agreeing with that reported by Ozan et al.

Discrepancies in results regarding the location of the ostium of the renal arteries arose from the criteria used for demarking the surface of the aorta; this meant that the differences could have been just a few millimeters in defining the site of emergence. The advanced age of the individuals providing most cadavers hampered determining the ostium by direct dissection (the aorta was sinuous). Such situation can be avoided in diagnostic imaging studies and corrosion injection, since it allows suitable visualization and demarcation of the aortic surface.

The right-hand renal artery had a cranial origin in relation to the left in a greater number of specimens (49.1%), agreeing with that reported by Ozan et al.; Keen, 1981; Kosinski; Merklin & Michels; Ciceckibasi et al.; Pick & Anson, 1940. A greater frequency (65%) of cranial origin of the right-hand renal artery has been reported by Garcia et al. The symmetrical emergence of the renal arteries observed in the present study (34.4%) agreed with that observed by Merklin & Michels; Ciceckibasi et al. and Pick & Anson, and was considerably greater than that found by Ozan et al.; Keen, who reported such morphological expression ranging from 10% to 16%. Beregi et al. have described a higher frequency for the symmetrical emergence of the renal arteries (50%). This parameter is relevant in angiographic studies Behar et al. and in invasive management of atherosclerotic stenosis of the renal arteries.

The incidence of renal superior polar artery in the present study (15.4%) agreed with that reported by Sampaio & Passos, and other studies referred to by Eisendrath (1920) and Ronstrom. 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. Our findings (3.4%) had an intermediate range between the percentages reported by Sampaio & Passos, Eisendrath and Longia et al. 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.

This study, carried out on a half-caste Colombian population, showed that six out of each ten individuals present single bilateral renal arteries, rostral emergence from the surface of the right renal artery’s aorta predominating. The renal artery’s diameter is a factor which should be considered as predicting the presence of additional renal arteries. The renal arteries present a broad spectrum of variability in their morphological expression respecting their length, level of ramification, diameter and emergence. Such aspects are important when considering a surgical approach, trauma, interpreting diagnostic images and teaching renal vascularization.

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We would also like to thank Carlos Bermúdez Barajas, Lab Technician, María Eugenia Niño Associate Professor, School of Medicine, Universidad Autónoma de Bucaramanga for statistical analysis and Jason Garry for translating the manuscript.

**RESUMEN:** La irrigación de los riñones es proporcionada usualmente por una arteriarenal única; sin embargo, variaciones en este patrón han sido frecuentemente reportadas. El objetivo de este estudio fue establecer las características morfológicas y frecuencia de las arterias renales en material cadavérico de una población mestiza de Bucaramanga (Colombia). La muestra incluyó 195 riñones, correspondiendo 57 (14.6%) y 333 (85.4%) a cadáveres femeninos y masculinos respectivamente. Las arterias renales fueron inyectadas con resina sintética (palatal GP41L), luego de la polimerización de la resina, fueron sumergidos en solución de KOH, para la corrosión del parénquima renal. Los bloques renales presentaron una arteria renal única en un 74.9%, y arterias renales adicionales en un 25.1%. El largo promedio de las arterias renales derechas e izquierdas fue 34.6 mm y 28.6 mm respectivamente (p < 0.001). El diámetro renal fue de 4.87 mm. El diámetro mayor de las arterias renales adicionales fue menor que el de la arteria renal única, con una diferencia significativa (p = 0.0000). Las arterias renales se originaron con mayor frecuencia (85%) de la parte anterolateral de la aorta. La arteria renal emergió por anterior en un 49.2%, aunque ambas arterias estaban localizadas al mismo nivel en un 34.4%. Los polos renales recibieron su irrigación de las ramas de la división anterior en un 46.4% y 55.9%, en el polo superior e inferior respectivamente. No existieron diferencias significativas en las características con respecto al sexo. Las arterias renales presentan gran variabilidad en su expresión morfológica con respecto a su emergencia y nivel de ramificación.

**PALABRAS CLAVE:** Arteria renal; Variación anatómica; Riñón.

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