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Studies on renal arteries origin from the aorta in respect to superior mesenteric artery in Polish population

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Abstract

Background: The aim of the study was to determine the location of the branching of the renal arteries from the aorta in respect to superior mesenteric artery.

Materials and methods: 324 vasculo-renal samples were collected from corpses (180 male and 144 female), and subject to x-ray contrasting and preparation. The distance between the branching of selected arteries from the superior mesenteric artery (SMA) was measured. Results were subject to statistical analysis.

Results: Results were presented in group A (191/324;58.9%) considering subjects with bilateral, single renal arteries, as well as group B(133/324; 41.1%) considering patients with multiple renal arteries. The average distance between SMA and the renal artery in group A, male patients was 0.6 ± 0.57 cm, while in group B 1.3 ±2.03 cm (p=0.0001). In case of female A patients results amounted to 0.66 ± 0.58 cm and 1.12 ± 1.7 cm, respectively (p=0.006). The above mentioned left- sided distance in male group A was 0.89 ± 56 cm, while the right- sided distance 0.73 ± 0.94 cm(p=0.382). In case of female A patients 0.80 ± 0.50 cm and 0.71 ± 0.89 cm, respectively (p=0.615).In case of left- sided group B male patients the distance amounted to 0.87 ± 0.70cm, and the right–sided distance 0.71 ± 0.60cm (p=0.291). Considering female patients results were as follows: 0.82 ± 0.51 cm(left) and 71 ± 1.21cm (right), respectively (p=0.706).

Conclusions: Knowledge of the described topography of renal artery branching from the aorta should be considered in the preoperative planning of vascular kidney system radiology examinations, as well as retroperitoneal surgical and urological procedures, especially endoscopic kidney transplantations.

Key words: renal arteries, topography, superior mesenteric artery, Polish population
Introduction

Knowledge of the topography of renal artery branching from the aorta is important, considering diagnostics and therapy. Preoperative x-ray examinations, selective renal angiography, renal artery stenting, renal artery reconstructive procedures, as well as laparoscopic kidney transplantations require good knowledge of the topography of renal artery branching [3,5,7,9,10,25,28,32].

The branching off the renal arteries from the aorta is usually located between the lower 1/3 of L1 and upper 1/3 of L2, slightly below the SMA [3,16,32]. Both renal arteries in the adult population are located below those observed in the pediatric population, being localized at the level of 1/3 T12 and 1/3 L 1 [2,4].

Since the average renal arteries diameter is approximately 4-5 mm and accessory arteries are considered to be smaller, up to 15% of vessels can be missed by 1-4 detector row CTA [15]. CT-angiography images and surgical findings agreed in 93% by Kawamoto et al. [17].

Based on our own material we decided to determine the topography of the branching off the renal arteries, considering the Polish population.

Material and methods

The study group comprised 324 corpses, including 180 male (55.6%), aged between 0.1 – 88 years (\(\bar{x}=51.75 \pm 20.1\) years), as well as 144 female (44.4%), aged between 1.5 – 90 years (\(\bar{x}=49.78 \pm 23.5\) years) (p=0.79) (approval of the Bioethical Committee: Nr. 2/BOPD/2017 DIL).

The vasculorenal samples were collected from the corpses “en bloc” during routine diagnostic sections performed at the Department of Pathomorphology. The arteries were subject to x-ray contrasting and preparation (Fig. 1 – 4), according to previously described details [29]. The distance between the branching off each renal artery from the SMA were performed by means of a rigid ruler parallel to the aorta in centimeters. In case of numerous arteries the most distant vessel from the SMA was measured. There were 2.77% of cases in which the renal arteries (exclusively, multiple renal arteries) originated above the SMA (0.1 – 1.0 cm, \(\bar{x}= 0.33 \pm 0.25\) cm), so their distance could be considered as negative, being rounded to the level of the SMA, equaling 0. The obtained data were subject to statistical analysis (MS
Excel 2013 and Statistica 12 software: Student’s t test, Chi-square test, analysis of variance (ANOVA), nonparametric ANOVA-Kruskal Wallis test and Turkey’s test.

**Results**

Results were presented in two main groups, and both subgroups. Group A comprised cases of bilateral, single renal arteries (191/324) (58.9%) (Tabl.1), while in group B additional renal arteries were observed (133/324 (41.1%) (Tabl.2). Considering both groups, the main renal arteries branched off the aorta at the same level- isotopic, or at different levels- heterotopic. In men, the distance between the branching off the renal arteries from the SMA, considering group A, ranged between 0.0 and 5.5 cm ($\bar{x}=0.68 \pm 0.57$ cm), while in group B, between 0.0 and 12.0 cm ($\bar{x}=1.3 \pm 2.03$ cm) (p=0.0001). In women, the distance between the branching off the renal arteries from the SMA, considering group A, ranged between 0.0 and 4.5 cm ($\bar{x}=0.66 \pm 0.58$ cm), while in group B, between 0.0 and 12.0 cm ($\bar{x}=1.12 \pm 1.70$ cm) (p= 0.006). Considering group A females the distance was always statistically insignificantly lower, as compared to male samples (Tabl.1). In case of group B, considering the isotopic position, the above-mentioned average distance was significantly greater in men ($\bar{x}=0.65 \pm 0.38$cm), as compared to female samples ($\bar{x}=0.50 \pm 0.27$ cm) (p=0.012). Also, the average distance of the branching off additional renal arteries from SMA in men was statistically greater ($\bar{x}=3.05 \pm 2.86$cm), as compared to women ($\bar{x}=1.94 \pm 2.09$cm) (p=0.0374). Apart from specified cases, no other significant differences were observed, considering the average distance of renal artery branching from the aorta, as compared to SMA. It was demonstrated, however, regardless gender, considering both groups and subgroups, that the average distance of renal artery branching in relation to SMA was insignificantly greater on the left side, as compared to the right. In group A men, it amounted to 0.89±0.56 cm, and on the right side- 0.73±0.94cm (p=0.382). In women, the above-mentioned was 0.80±0.50cm and 0.71±0.89 cm, respectively (p=0.615). In case of group B men, the left-sided distance was 0.87±0.70cm, as compared to the right side -0.71±0.60cm (p=0.291). In women, the above-mentioned was 0.82±0.51cm, and 0.71±1.27 cm, respectively (p=0.706). The average distances of renal artery branching off to the SMA in relation to age, presented in tables 3 and 4, were stable. Only in group A, between the young (0-20 years) and the elderly patients (above 60 years), one observed a statistically significant difference (right side: p=0.034, and left side: p=0.05). The classic one – way ANOVA test showed no significant difference between age categories, considering group B (Tabl.4).
Considering the study material, accessory renal arteries branched off the lateral side of the aorta in 54.12% of cases, from the anterolateral side in 40.72%, and anterior side in 5.15%. The topography was insignificantly differentiated, depending on gender. Accessory renal arteries branched off the lateral side of the aorta in 57.02% of male and 49.32% of female cases; from the anterolateral surface in 37.16% of male and 46.58% of female cases; from the anterior surface in 5.79% of male and 4.11% of female cases (p=0.509); details are given in diagrams 1-4.

Discussion

The localization of renal artery branching off was determined on the basis of x-ray examinations in relation to the vertebral bodies [7,9,25,31,34], and anatomically in relation to SMA [1,2,4,22,25], as well as to the abdominal aortic bifurcation [14].

Considering our current studies, similar to other Authors [19] SMA was used as the reference point for the measurement of the distance of the branching off renal arteries from the aorta. The above mentioned artery is relatively thick, and easily visualized during clinical procedures, while in anatomical samples an ideal reference point for conducting such measurements.

In our studies, we showed that the average distance between renal arteries and SMA branching depends, on whether we are dealing with samples of one artery or multiple arteries. Both in men and women the average distance was significantly lower, considering the presence of one artery, as compared to samples with multiple renal arteries (p = 0.0001 and p=0.006).

In case of adult samples, renal arteries branched off the aorta at the L1/L2 level [1,3,25,33], and in children slightly higher (T 12/L1) [2,4].

According to Danek [7], only 30% of the renal arteries branched off at the above-mentioned level. Keen [18] showed that the branching off the renal arteries at the same level was observed in 32.7% of cases; according to Kosinski in 16% [19], Garcier at al [10] in 44.7%, Beregi et al. [3] in 50%, Danek in 80% [7], and finally in our own material in 58%. The location of the branching off the right renal artery was usually higher than that of the left artery [1-3,10,18,19,22,25,32]. Beregi et al. [3] showed that the right renal artery branched off the aorta on the average 14.5 mm, and the left- 18 mm below the SMA. In case of fetuses, the right artery branched off at a higher level than the left artery in 47.4% [2]. In our study, as mentioned by the cited authors, the left renal artery in both sexes, branched off the aorta insignificantly lower in relation to SMA, as compared to the right artery. Accessory renal
arteries branch off the aorta at, either a low or high level [32], usually between T 11 and L4 [33]. As compared to the diameter of the aorta, the branching off the renal arteries was in
different locations. The right artery usually originated anterolateral, while the left-
posterolateral of abdominal aorta wall [8,18,24]. Verschuyl et al [34] showed, that 93% of
right ostia and only 20% of left ostia were in anterolateral location. In case of fetuses, the
right renal artery branched off laterally in 73%, and anterolateral in 26.9% of cases, while the
lateral and anterolateral wall origin percentages of the left renal artery were 90,3% and 9,6%
respectively [4]. In our study, the branching off the accessory renal arteries differed,
depending on gender, although being statistically insignificant. It is worth noting, that in 2.7%
of cases, the accessory renal arteries branched off the aorta above the SMA (Fig.4). Ödman
and Ranniger [24] observed such a location in 4 of the 86 examined kidneys (4.7%).

The distribution and variation of the branching off the renal arteries from the aorta is
most easily explained by the complex development of the genitourinary system arteries
[5,14]. The 7mm mesonephros receives symmetrical numerous arteries from the aorta,
included in three groups. Cranial, whose branches lie on the dorsal surface of the adrenal
glands; central, whose arteries run through the adrenal glands, and caudal, whose branches
run anteriorly to the adrenal glands. The different groups supply blood to the diaphragm,
adrenal glands, kidneys, and reproductive system. These vessels form the “rete arteriosum
urogenitalne”. The process of formation and ascending of the mesonephros might lead to
various deviations in the development of the main renal artery. The consequence of the above-
mentioned, is the erroneous location of the ostium, as well as persistence of additional
(accessory) mesonephrotic arteries. Literature data has numerous descriptions of such
situations. We are well aware of the branching off the renal arteries from SMA [20], and as a
common trunk with the SMA [6]), originating of inferior mesenteric artery [12,13], and as a
common trunk with the inferior mesenteric artery [21], the high-branching off the renal
arteries from the aorta (T 11) [30], on the branching off the renal arteries from the celiac
trunk [11], from a common trunk of low aortic origin [23], gonadal arteries arising from renal
arteries [26,27], and finally a renal artery arising from the left testicular artery [16]. Shoja et
al. [26] observed a statistically significant dependency, between the occurrence of multiple
renal arteries, and branching off the testicular artery from some of the above-mentioned.

Knowledge of the described anatomy is a prerequisite in the proper use of correct
angioneurophrographic techniques, and assessment of obtained x-ray images, as well as
performance of surgical procedures on the vascular renal bundle [3,7,9,10,15,25,28].
Conclusions

The average distance between the branching off the renal arteries from the aorta, in relation to SMA is significantly greater in patients with multiple renal arteries, as compared to patients with bilateral, single, renal arteries. The branching off the left renal artery in relation to SMA, independently of gender, is insignificantly lower, as compared to the right artery. Topographically, considering both sexes, the branching off the renal arteries is insignificantly differentiated between the above-mentioned, being observed on the lateral and anterolateral, and least often on the anterior surface of the aorta. These moments should be considered before planned angionephrography, as well as during procedures on the vascular kidney bunch.

References

### Table 1. Distance of single (isotopic and heterotopic) renal artery (AA) to superior mesenteric artery (SMA)

<table>
<thead>
<tr>
<th>No.</th>
<th>Subject</th>
<th>Male</th>
<th>Female</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N.B</td>
<td>N.AA</td>
<td>Distance of AA to SMA in cm</td>
<td>t test</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>1</td>
<td>Isotopic AA</td>
<td>64</td>
<td>128</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>Right-side heterotopic AA</td>
<td>36</td>
<td>36</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Left side heterotopic AA</td>
<td>36</td>
<td>0.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3.</td>
<td>Total</td>
<td>100</td>
<td>200</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Explanations: N.B- number of bodies, N.AA.- number of arteries, min- minimal value, max. – maximal value, $\bar{x} \pm SD$- mean plus minus standard deviation
Table 2. Distance of the main (isotopic and heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA)

<table>
<thead>
<tr>
<th>No.</th>
<th>Subject</th>
<th>Male</th>
<th></th>
<th>t test</th>
<th>Female</th>
<th></th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N.B N.AA</td>
<td>Distance of AA to SMA in cm</td>
<td></td>
<td>N.B N.AA</td>
<td>Distance of AA to SMA in cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min Max</td>
<td>$\bar{x} \pm SD$</td>
<td>P</td>
<td>Min Max</td>
<td>$\bar{x} \pm SD$</td>
<td>N</td>
</tr>
<tr>
<td>1</td>
<td>main AA isotopic</td>
<td>41  82</td>
<td>0.0  1.5</td>
<td>0.65±0.3 8</td>
<td>0.012</td>
<td>28  56</td>
<td>0.0  1.0</td>
</tr>
<tr>
<td></td>
<td>accessory AA</td>
<td>60  0.0</td>
<td>12.0</td>
<td>15.0±2.5 3</td>
<td>0.699</td>
<td>33  0.0</td>
<td>12.0</td>
</tr>
<tr>
<td>2</td>
<td>main AA heterotopic right-side</td>
<td>39  39</td>
<td>0.0  2.2</td>
<td>0.71±0.6 0</td>
<td>0.997</td>
<td>25  25</td>
<td>0.0  6.5</td>
</tr>
<tr>
<td></td>
<td>main AA heterotopic left-side</td>
<td>39  39</td>
<td>0.0  2.5</td>
<td>0.87±0.7 0</td>
<td>0.744</td>
<td>25  25</td>
<td>0.1  2.0</td>
</tr>
<tr>
<td></td>
<td>accessory AA</td>
<td>61  0.0</td>
<td>10.5</td>
<td>3.05±2.8</td>
<td>0.0374</td>
<td>40  0.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Main artery</td>
<td>Age category [years]</td>
<td>0-20</td>
<td>21-40</td>
<td>41-60</td>
<td>61+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
<td>------</td>
<td>-------</td>
<td>-------</td>
<td>-----</td>
<td></td>
<td></td>
</tr>
<tr>
<td>right side</td>
<td>mean±SD [cm]</td>
<td>0.33±0.25</td>
<td>0.60±0.52</td>
<td>0.53±0.44</td>
<td>0.78±0.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>left side</td>
<td>mean±SD [cm]</td>
<td>0.41±0.37</td>
<td>0.61±0.49</td>
<td>0.68±0.45</td>
<td>0.74±0.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanation: N - number of arteries, mean – mean value, SD – standard deviation.
Table 4. Mean distance (cm) between renal arteries and SMA in case of main and supernumerary renal arteries according to age categories (group B)

<table>
<thead>
<tr>
<th>Main artery</th>
<th>Age category years</th>
<th>0-20</th>
<th>21-40</th>
<th>41-60</th>
<th>61+</th>
</tr>
</thead>
<tbody>
<tr>
<td>right side</td>
<td>N</td>
<td>11</td>
<td>16</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>0.39±0.28</td>
<td>0.81±0.36</td>
<td>0.49±0.48</td>
<td>0.81±1.09</td>
</tr>
<tr>
<td>left side</td>
<td>N</td>
<td>11</td>
<td>16</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>mean± SD [cm]</td>
<td>0.53±0.31</td>
<td>0.73±0.53</td>
<td>0.58±0.53</td>
<td>0.76±0.46</td>
</tr>
<tr>
<td>Ad.</td>
<td>N</td>
<td>4</td>
<td>9</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>mean± SD [cm]</td>
<td>0.88±0.63</td>
<td>0.76±0.55</td>
<td>2.31±2.81</td>
<td>2.14±2.51</td>
</tr>
<tr>
<td>A.s.</td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>mean± SD [cm]</td>
<td>0.93±1.20</td>
<td>1.10±0.69</td>
<td>2.22±2.45</td>
<td>2.26±2.80</td>
</tr>
</tbody>
</table>

Explanation: N-number of arteries, mean – mean value, SD – standard deviation,

Ad.: accessory arteries on the right side, As: accessory renal arteries on the left side.
Fig. 1. Aortonephrogram “extra-situ” with both renal arteries in the isotopic position.
Fig. 2. Vasculorenal sample in the AP position with isotopic branching off main renal arteries (arrow) and bilateral, accessory renal arteries (arrowhead), running into the inferior pole of the kidneys.
Fig.3. Postmortal aortonephrogram „in situ” with the heterotopic branching off the main renal arteries (arrow) and with an accessory artery (arrowhead) on the right side in a three-year old girl.
Fig. 4. Vasculorenal sample in the AP position with heterotopic branching off the main renal arteries (arrow) and bilateral presence of accessory renal arteries (arrowhead). The left accessory renal artery branching off above the SMA and running into the inferior region of renal hilum.
Diag.1. Distance of the main isotopic and accessory renal arteries (AA) to superior mesenteric artery (SMA)(cm) in males (N=41).
31.7% multiple renal arteries branched off the lateral part of the aorta on the right and 20% on the left side; 23.3% branched off the ante-lateral side of the aorta right and 21.7% on the left side; 0% off the anterior side on the right and 3.3% on the left side of the aorta.
Diag. 2. Distance of the main (heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in males (N=39)

26.7% multiple renal arteries branched off the lateral part of the aorta on the right and 35% on the left side; 18.3% branched off the anterior-lateral side of the aorta right and 11.7% on the left side; 3.3% off the aorta anterior side on the right and 5% on the left side of the aorta.
**Diag. 3.** Distance of the main (isotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in females (N=28)

18.2% multiple renal arteries branched off the lateral part of the aorta on the right and 36.4% on the left side; 12.1% branched off the ante–lateral side of the aorta right and 30.3% on the left side; 0% off the anterior side on the right and 3.04% on the left side of the aorta.

[Graph depicting the distribution of renal arteries branched off different parts of the aorta.]
Diag. 4. Distance of the main (heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in females (N=25). 25% multiple renal arteries branched off the lateral part of the aorta on the right and 20% on the left side; 22.5% branched off the anterolateral side of the aorta right and 27.5% on the left side; 5% off the anterior side on the right and 0% on the left side of the aorta.