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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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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: *Three hundred twenty four vasculorenal 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 the 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 female A patients 0.80 ± 0.50 cm and 0.71 ± 0.89 cm, respectively (p = 0.615). In left-sided group B male patients the distance amounted to 0.87 ± 0.70 cm, and the right-sided distance 0.71 ± 0.60 cm (p = 0.291). Considering female patients results were as follows: 0.82 ± 0.51 cm (left) and 71 ± 1.21 cm (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.* (Folia Morphol 2020; 79, 1: 86–92)

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 of 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 superior mesenteric artery (SMA) [3, 16, 32]. Both renal arteries in the adult population are located below those

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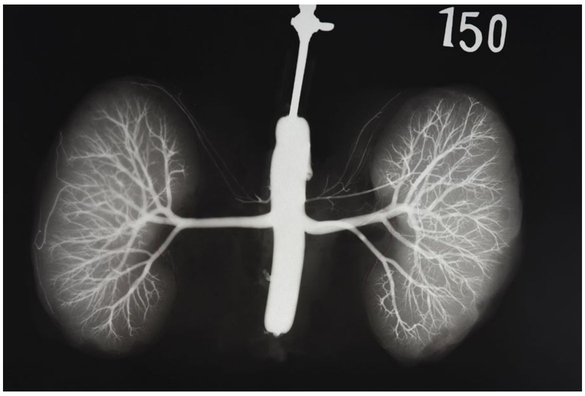

Figure 1. Aortonephrogram "extra-situ" with both renal arteries in the isotopic position.

Figure 2. Vasculorenal sample in the antero-posterior position with isotopic branching off of main renal arteries (arrow) and bilateral, accessory renal arteries (arrowhead), running into the inferior pole of the kidneys.

observed in the paediatric population, being localised at the level of 1/3 T12 and 1/3 L1 [2, 4].

Since the average renal arteries diameter is 4–5 mm and accessory arteries are considered to be smaller, up to 15% of vessels can be missed by 1–4 detector row computed tomography angiography [15]. Computed tomography 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 of the renal arteries, considering the Polish population.

MATERIALS AND METHODS

The study group comprised 324 corpses, including 180 (55.6%) male, aged between 0.1 and 88 years ($\bar{x}$ = 51.75 ± 20.1 years), as well as 144 (44.4%) female, aged between 1.5 and 90 years ($\bar{x}$ = 49.78 ± ± 23.5 years) (p = 0.79) (approval of the Bioethical Committee: No. 2/BOPD/2017 DIL).

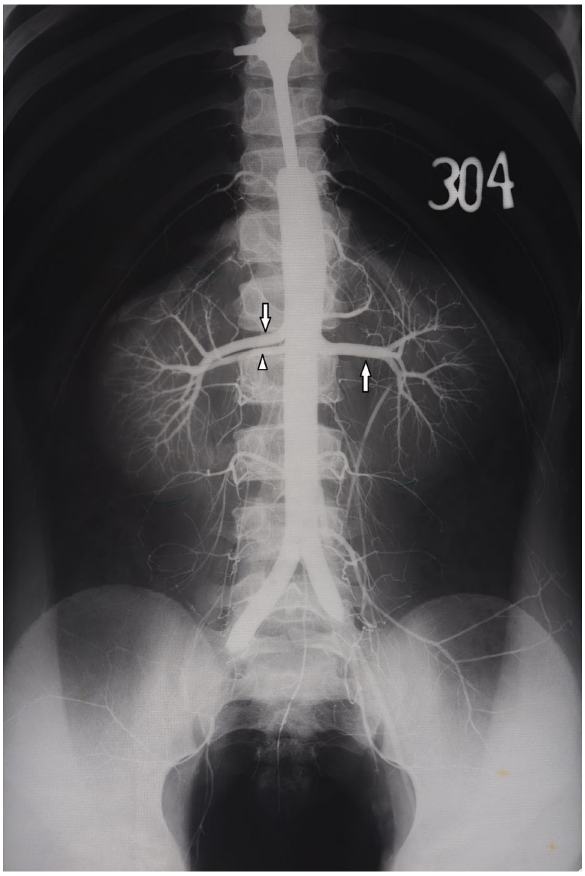

Figure 3. Postmortal aortonephrogram "in situ" with the heterotopic branching off of the main renal arteries (arrow) and with an accessory artery (arrowhead) on the right side in a 3-year-old girl.

Figure 4. Vasculorenal sample in the antero-posterior position with heterotopic branching off of the main renal arteries (arrow) and bilateral presence of accessory renal arteries (arrowhead). The left accessory renal artery branching off above the superior mesenteric artery and running into the inferior region of renal hilum.

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 (Figs. 1–4), according to previously described

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

No.	Subject	Male					t test	Female					Summary	
		No. of bodies	No. of arteries	Distance of AA to SMA [cm]				No. of bodies	No. of arteries	Distance of AA to SMA [cm]				
				Min	Max	$\bar{x} \pm SD$	P			Min	Max	$\bar{x} \pm SD$	N	%
1	Isotopic AA	64	128	0.0	1.5	0.60 ± 0.39	0.846	55	110	0.0	2.0	0.59 ± 0.45	119	62.3
2	Right-side heterotopic AA	36	36	0.0	5.5	0.73 ± 0.94	0.919	36	36	0.0	4.5	0.71 ± 0.89	72	37.7
	Left-side heterotopic AA	36	36	0.0	2.0	0.89 ± 0.56	0.440	36	36	0.0	2.2	0.80 ± 0.50	72	37.7
3	Total	100	200	0.0	5.5	0.68 ± 0.57	0.701	91	182	0.0	4.5	0.66 ± 0.58	191	100

$\bar{x} \pm SD$ — mean and standard deviation; min — minimal value; max — maximal value

Table 2. Distance of the main (isotopic and heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA)

No.	Subject	Male					t test	Female					Summary	
		No. of bodies	No. of arteries	Distance of AA to SMA [cm]				No. of bodies	No. of arteries	Distance of AA to SMA [cm]				
				Min	Max	$\bar{x} \pm SD$	P			Min	Max	$\bar{x} \pm SD$	N	%
1	Main AA isotopic	41	82	0.0	1.5	0.65 ± 0.38	0.012	28	56	0.0	1.0	0.50 ± 0.27	69	51.9
	Accessory AA		60	0.0	12.0	1.50 ± 2.53	0.699	28	33	0.0	12.0	1.72 ± 2.67	69	51.9
2	Main AA heterotopic right-side	39	39	0.0	2.2	0.71 ± 0.60	0.997	25	25	0.0	6.5	0.71 ± 1.27	64	48.1
	Main AA heterotopic left-side	39	39	0.0	2.5	0.87 ± 0.70	0.744	25	25	0.1	2.0	0.82 ± 0.51	64	48.1
	Accessory AA	39	61	0.0	10.5	3.05 ± 2.86	0.0374	25	40	0.0	8.5	1.94 ± 2.09	101	48.1
	Total	80	281	0.0	12.0	1.39 ± 2.03	0.138	53	179	0.0	12.0	1.39 ± 2.03	133	100

$\bar{x} \pm SD$ — mean and standard deviation; min — minimal value; max — maximal value

details [29]. The distances between the branching off of each renal artery from the SMA were measured by means of a rigid ruler parallel to the aorta in centimetres. In the 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 ± 0.25 cm), so their distance could be considered as negative, being rounded to the level of the SMA, equalling 0. The obtained data were subject to statistical analysis (MS Excel 2013 and Statistica 12 software: Student's t test, χ^2 test, analysis of variance (ANOVA), nonparametric ANOVA-Kruskal Wallis test and Turkey/s test).

RESULTS

Results were presented in two main groups, and two subgroups. Group A comprised cases of bilateral, single renal arteries (191/324; 58.9%; Table 1), while in group B additional renal arteries were observed (133/324; 41.1%; Table 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 of the renal arteries from the SMA ranged between 0.0 and 5.5 cm ($\bar{x}$ = 0.68 ± 0.57 cm) in group A, while in group B it was between 0.0 and 12.0 cm ($\bar{x}$ = 1.3 ± 2.03 cm; p = 0.0001). In women, the distance between the branching off of the renal arteries from the SMA in group A ranged between 0.0 and 4.5 cm ($\bar{x}$ = 0.66 ± 0.58 cm), while in group B it was between 0.0 and 12.0 cm ($\bar{x}$ =1.12 ± 1.70 cm; p = 0.006). In group A the distance was always statistically insignificantly lower in females as compared to male samples (Table 1). In group B, considering the isotopic position, the above-mentioned average distance was significantly greater in men ($\bar{x}$ = 0.65 ± 0.38 cm) as compared to female samples ($\bar{x}$ = 0.50 ± 0.27 cm; p = 0.012). Also, the average distance between the branching off of additional renal arteries from SMA in men was statistically greater ($\bar{x}$ = 3.05 ± 2.86 cm), as compared to women ($\bar{x}$ = 1.94 ± 2.09 cm; p = 0.0374). Apart from specified cases, no other significant differences

Table 3. Mean distance (cm) between main renal artery and superior mesenteric artery in the case of bilateral single renal artery according to age categories (group A)

Main artery	Age category [years]			
	0–20	21–40	41–60	61+
Number of arteries	22	22	38	56
Right side	0.33 ± 0.25	0.60 ± 0.52	0.53 ± 0.44	0.78 ± 0.86
Left side	0.41 ± 0.37	0.61 ± 0.49	0.68 ± 0.45	0.74 ± 0.51

Data are shown as mean value ± standard deviation.

were observed in 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 ± ± 0.94 cm (p = 0.382). In women, the above-mentioned was 0.80 ± 0.50 cm and 0.71 ± 0.89 cm, respectively (p = 0.615). In group B men, the left-sided distance was 0.87 ± 0.70 cm, as compared to the right side –0.71 ± 0.60 cm (p = 0.291). In women, the above-mentioned distance was 0.82 ± 0.51 cm 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, there was a statistically significant difference (right side: p = 0.034, and left side: p = 0.05) between the young (0–20 years) and the elderly patients (above 60 years). The classic one-way ANOVA test showed no significant difference between age categories in group B (Table 4).

In the study material, accessory renal arteries branched off the lateral side of the aorta in 54.12% of cases, the anterolateral side in 40.72%, and anterior side in 5.15%. The topography was differed insignificantly depending on gender. Accessory renal arteries branched off from 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 localisation 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 of renal arteries from the aorta. The above mentioned artery is relatively thick, and easily visualised 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 the case of adult samples, renal arteries branched off the aorta at the L1/L2 level [1, 3, 25, 33], and in children slightly higher (T12/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 of the renal arteries at the same level was observed in 32.7% of cases; according to Kosinski in 16% [19], Garcier et

Table 4. Mean distance (cm) between renal arteries and superior mesenteric artery in the case of main and supernumerary renal arteries according to age categories (group B)

Main artery	Age category [years]			
	0–20	21–40	41–60	61+
Right side [cm]	11 (0.39 ± 0.28)	16 (0.81 ± 0.36)	33 (0.49 ± 0.48)	34 (0.81 ± 1.09)
Left side [cm]	11 (0.53 ± 0.31)	16 (0.73 ± 0.53)	33 (0.58 ± 0.53)	34 (0.76 ± 0.46)
Accessory arteries o the right side [cm]	4 (0.88 ± 0.63)	9 (0.76 ± 0.55)	17 (2.31 ± 2.81)	18 (2.14 ± 2.51)
Accessory renal arteries on the left side [cm]	9 (0.93 ± 1.20)	10 (1.10 ± 0.69)	25 (2.22 ± 2.45)	24 (2.26 ± 2.80)

Data are shown as number of arteries and mean value ± standard deviation.

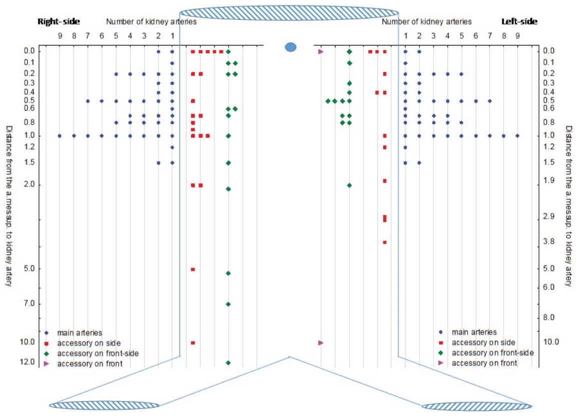

Diagram 1. Distance of the main (isotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in males (n = 41). 31.7% multiple renal arteries branched off the lateral part of the aorta on the right and 20% on the left side; 23.3% branched off the ante-lateral side of the aorta 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.

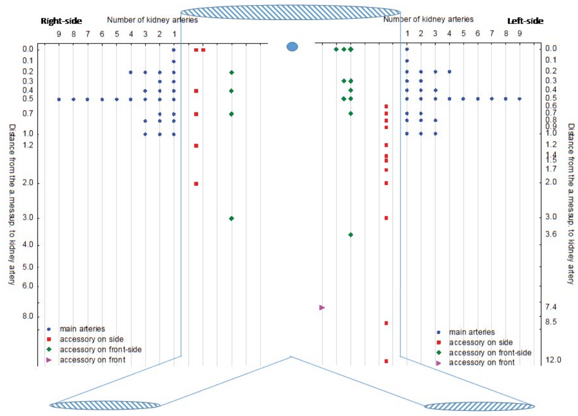

Diagram 3. Distance of the main (isotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in females (n = 28). 18.2% multiple renal arteries branched off the lateral part of the aorta on the right and 36.4% on the left side; 12.1% branched off the antero-lateral side of the 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.

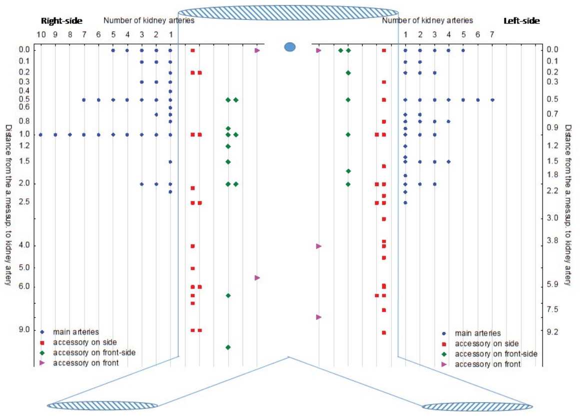

Diagram 2. Distance of the main (heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in males (n = 39). 26.7% multiple renal arteries branched off the lateral part of the aorta on the right ad 35% on the left side; 18.3% branched off the antero-lateral side of the 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.

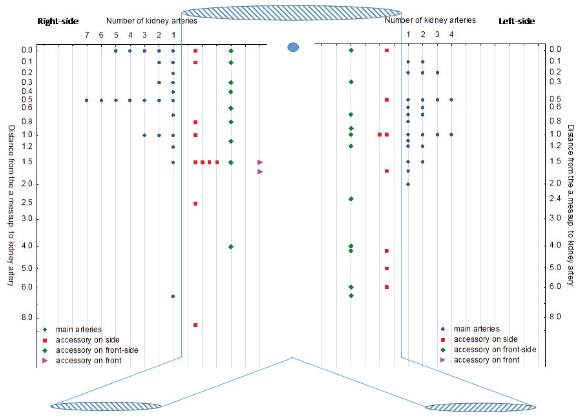

Diagram 4. Distance of the main (heterotopic) and accessory renal arteries (AA) to superior mesenteric artery (SMA) (cm) in females (n = 25). 25% multiple renal arteries branched off the lateral part of the aorta on the right and 20% on the left side; 22.5% branched off the antero-lateral side of the 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.

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 of 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 the case of foetuses, 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 T11 and L4 [33]. As compared to the diameter of the aorta, the branching off of 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 the case of foetuses, 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 of 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 of the renal arteries from the aorta is most easily explained by the complex development of the genitourinary system arteries [5, 14]. The 7 mm mesonephros receives symmetrical numerous arteries from the aorta, which form 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 urogenitale". 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 of 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 of the renal arteries from the aorta (T11) [30], the branching off of 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 of the testicular artery from some of the above-mentioned.

Knowledge of the described anatomy is a prerequisite in the proper use of correct angionephrographic 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 of the renal arteries from the aorta and SMA is significantly greater in patients with multiple renal arteries as compared to patients with bilateral, single, renal arteries. The branching off of the left renal artery in relation to SMA, independently of gender, is insignificantly lower, as compared to the right artery. Topographically, the branching off of the renal arteries differs insignificantly between sexes, 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.

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