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A Systematic Review of the Prevalence of Anatomical Variations of the Renal Artery

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Abstract

Background: The presence of one or more additional artery is the commonest arterial anatomical variation of the kidneys, the main aim of this systemic review is to establish the actual prevalence of renal artery variations regarding, Level of origin and accessory renal arteries to increase awareness about them.

Methodology: PubMed, EMBASE, Science Direct, Scopus, Web of Science, and Cochrane Library databases were searched to identify articles that studied the prevalence of the renal artery variations.

Results: We included 51 articles in the final analysis of prevalence, of which 46 contained data about the branches pattern of the renal artery, 5 about the vertebral level of origin of the renal artery, and 9 articles contained data about the pattern branches and level of origin of the renal artery. The pooled prevalence rates of the single main renal artery, accessory hilar artery, superior polar artery, and inferior polar artery were (81.05%; 95% CI 78.55, 83.55), (11.97%; 95%CI 10.22, 13.72), (6.46%; 95%CI 4.96, 7.96), and (6.24%; 95%CI 5.74, 6.24), respectively. The prevalence of level of origin of the main renal artery were 0.38% (95% CI: 0.38%, 0.39%) at level of T12, 20.37%, (95% CI: 20.36%, 20.36%) at level of L1, 14.16% (95% CI: 14.15%, 14.16%) at level of disc between L1- L2, and 16.60% (95% CI: 16.59%, 16.60%) at level of L2.

Conclusions: Accessory hilar arteries is a common type of anatomical variations of the renal artery among the population. Considerations of this arteries is important to prevent possible intraoperative complications.

Keywords: Kidney; Renal Artery; Origin; Variation

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Introduction

Several studies indicate that there is a significant variation in the anatomy of the renal arteries. These anatomical variations are of clinical and scientific interest, not only because knowledge of them is necessary when performing renal surgery or transplantation, but also awareness of the presence of renal artery (RA) variations prior to renal donor laparoscopic nephrectomy or partial nephrectomy is important to prevent possible intraoperative complications [1].

Anatomy of the main renal artery (MRA)

Renal arteries arise from the lateral wall of the abdominal aorta at the level of L1 or L2 vertebra, 1.5 cm below the superior mesenteric artery [2]. The main renal artery penetrates the kidney in the hilum region and, only in the hilum or renal sinus, offers presegmental branches [3].

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 emphasized that the number of renal arteries is the most frequently occurring variation; some people have presented from 2 to 4 additional renal arteries. Renal artery morphology variants in number and origin from abdominal aorta [4].

In most of cases variations are discovered only at the time of intervention. Sampion and Passos (1992) named them as multiple renal arteries and accordingly they are named as-hilar, superior polar and inferior polar are called, according to the point where they enter the renal parenchyma [5]. Variations in renal arteries have been called aberrant, supernumerary, supplementary, accessory, among other terms. It is therefore necessary that the morphology and the nomenclature of these vessels are standardized. According to Sampaio and Passos (1992) these arteries should be called multiple, since they are segmental vessels for the kidneys, without anastomoses between themselves and they should be named according to the territory supplied by them as- hilar, superior polar and inferior polar [6].

Accessory hilar renal artery

Two or more branches which emerge from the aorta and penetrate the kidney in the hilum region. The caliber of these arteries will provide the term "dominant", while the smaller arteries should be labeled as "accessory". When designating its topography, for instance, one can use the following nomenclature: double hilar artery; superior dominant; inferior accessory. When caliber differences are not evident, they should be called co dominant. Accessory hilar renal arteries can arise from the abdominal aorta above the main branch or as low (inferiorly) as the internal iliac artery [7] (Figure 1).

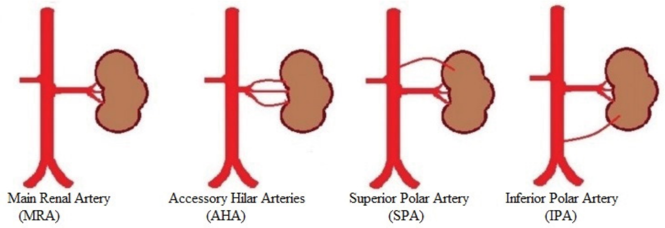

Figure 1: Shows the different types of renal artery variations.

Superior & inferior polar arteries (PA)

The most frequent accessory artery is a polar arteries arising from the aorta, close to the origin of the main renal branch, and supplies the inferior renal pole. The second most frequent supplementary artery irrigates the upper pole, which is normally a small segment [8]. Some authors call polar arteries those that attain any of the kidney poles with independence of its origin. It may be helpful, strictly from a labelling point of view, to distinguish between these polar arteries, tagging them as polar branches when they arise from the main renal artery and polar accessory arteries when they have a separate origin [8] The importance of polar arteries is shown in the fact that they supply renal parenchyma, and when damaged during nephrectomy it can cause arterial bleeding or renal infarction. A case particularly worth mentioning is inferior polar arteries that provide vessels for the upper excretory system. A section of an inferior polar artery can cause pyeloureteral necrosis of the graft leading to stenosis or urinary tract leakage [9].

This study aims to systematically review and analyze the literature regarding the Renal Artery and its branching patterns in order to present comprehensive anatomical data essential to reducing iatrogenic injury during surgical procedures involving the kidneys.

Material and Methods

We performed the study according to the PRISMA guidelines for reporting systematic reviews and Meta-analyzes of observational studies in epidemiology [10].

Search Strategy

We performed a literature search until December 2019, through the electronic databases PubMed, EMBASE, Science Direct, Scopus, Web of Science, and Cochrane Library, to identify studies eligible for the systemic review. Using the following terminologies: (Multiple renal artery, renal artery variations. anatomical variations, accessory renal variations, aortic branches variations, blood supply of the kidney, renal vascular) .The reference list of each relevant one was scrutinized for other relevant studies to be included in the study.

Criteria for Study Selection

Studies will consider eligible for inclusion in the meta-analysis if they: Report extractable prevalence data related to renal artery variation, have clearly defined descriptions of renal artery variations. Was a cadaveric or a prospective intraoperative study.

Exclusion criteria include

Missing data or incomplete data sets, Data not able to be classified according to the documented classification of the renal artery variations, Reviews, Case Report/ Serious, Duplicates/ Patients overlap, and Letter to editor.

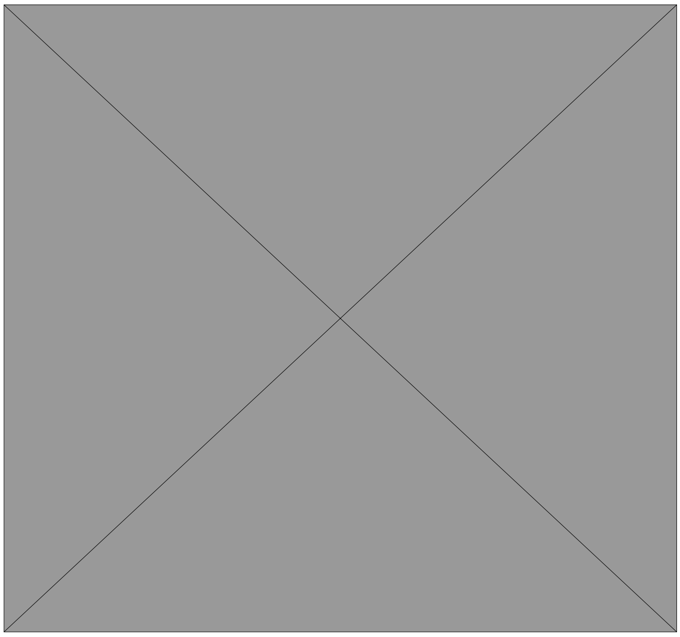

Figure 2: Search synthesis. PRISMA flow diagram study identification, evaluation and inclusion in the review.

Data Extractions

For each study, two reviewers, working independently, performed the database research, extracted the data and included it in Excel Datasheets. If discrepancies were found, the articles into question were reviewed by a third reviewer. We summarized the following information: study, name of the authors, year, and total number of cases, the general inclusion and exclusion criteria, the number of cases with various types of renal artery variations (Level of origin, main renal artery, accessory renal artery, and superior and inferior polar arteries).

Quality Assessment

We performed the quality assessment using four scales from the Quality in Prognostic Studies Tool16 (participants, outcome measurement, confounding, statistical analysis and reporting). For each remained subscale (study participation, prognostic factor measurement, outcome measurement, study confounding, statistical analysis and reporting), we graded each study as low quality (0 points), intermediate quality (1 point) or high quality (2 points). This method was previously used by the authors in meta-analyses of prevalence [11].

Statistical Analysis

All analyzes were performed using a random effects model. The Chi2 test and I2 statistic were used to assess heterogeneity among the studies. For the Chi2 test, a p-value of < 0.10 was considered to indicate statistically significant heterogeneity between studies [12].

Results

Search Synthesis

During the initial database research, we obtained 1172 articles from which, after deleting duplicates and irrelevant studies we selected 357 to be further scrutinized. By analyzing their references, we found another 6 potentially relevant articles that were also downloaded and added. From the 372 articles, 51 were included in the final analysis of prevalence of the renal artery, of which 46 contained data about the pattern branching of the renal artery, and 14 about the variations of the level of the origin of the renal artery.

Quality and Risk of Bias

Based on the inclusion criteria, we obtained a total number of 51 studies, of which of a high quality (between 6 and 8 points) were considered 21 articles, of a medium quality (between 3 and 5 points) -25 articles, of a low quality (between 0 and 2 points) 5 articles.

Multiple Renal Artery Variations

A total number of 21 studies allowed us to estimate the prevalence of different types of variation of the renal artery, after the final pooling of data from all articles, a total of 11,563 kidneys were included in this study. Of those, 9,372 (81.05%; 95% CI 78.55, 83.55) showed a single main artery originate from aorta and enter the kidney through the hilum, 1,385 (11.97%; 95%CI 10.22, 13.72) showed an accessory hilaur arteries originate from aorta and enter the kidney through the hilum, 722 (6.24%; 95%CI 5.74, 6.24) showed a superior polar artery originate from aorta and enter the upper pole of the kidney through parenchyma of the kidney, and 513 (4.43%; 95%CI 3.93, 4.93) showed an inferior polar artery originate from aorta and enter the lower pole of the kidney through the kidney parenchyma.

A total number of 25 articles allowed us to estimate the laterality of prevalence of multiple renal arteries, containing 10,716 kidneys. Single main renal arteries were identified in 3.998 on the right side (37.30%; 95%CI 35.8, 38.8) (RMRA) and 4002 (37.34%; 95%CI 35.84, 38.84) on the left side (LMRA). Accessory hilar arteries (AHA) were (648 (6.04%; 95%CI 4.54, 7.54) on the right and 811 (7.56%; 95%CI 9.06, 6.06) on the left side), superior polar arteries (SPA) were (307 (2.86%; 95%CI 2.36, 3.36) on the right and 278 (2.59%; 95%CI 2.09, 3.09) on the left side), and inferior polar arteries (IPA) were (285 (2.65%; 95%CI 2.15, 3.15) on the right and 287 (2.67%; 95%CI 2.26,3.17) on the left side). The difference between of branches pattern of the renal artery between the right and left side was not statistically significant. (p =0.001).

Table 1: Shows the overall variation of the pattern branches of the renal artery.

Author	Year	N	MRA	AHRA	SPA	IPA
Clara Cases [13]	2017	86	68	16	0	0
Clara Cases	2017	1166	1111	144	122	35
Shimon Degani [14]	2009	120	117	3	0	0
Sharmila Ari [6]	2013	30	226	4	1	3
Julius A [15]	2010	356	272	30	20	33
Bali Sharma [16]	2018	80	47	13	8	12
Zelalem Animaw [17]	2018	60	50	2	0	8
Marcin Majos [18]	2018	496	400	96	0	0
Sabina Prevljak [19]	2017	2714	2139	476	218	92
Krunal Chauhan [20]	2013	80	40	20	10	10
P. Bordei [21]	2004	272	218	33	5	29
S.N. Rajakumari [22]	2019	40	21	12	1	6
Anu Dogra [23]	2017	200	112	36	24	28
A Reginelli [5]	2015	1835	1523	312	0	0
Weinstein et al. [24]	1940	656	399	15	88	126
Merklin & Michels [25]	1958	260	219	21	37	3
Geyer & Poutasse [26]	1962	866	824	20	11	11
Sampaio & Passos [27]	1992	406	301	18	66	21
Khamanarong et al.[28]	2004	637	560	19	39	19
Kornafel et al. [29]	2010	459	388	15	20	36
Jamaus	1962	744	536	115	52	41
Total		**11563**	**9372**	**1385**	**722**	**531**

Table 2: Shows the frequency of prevalence variation of the renal artery on the right and left side.

			Left Kidney				**Right Kidney**			
Author	**Year**	**N**	**MRA**	**AHR**	**SPA**	**IPA**	**MRA**	**AHR**	**SPA**	**IPA**
Uğur Özkan [30]	2006	1716	736	114	3	3	713	135	6	6
Pradip Chauhan [20]	2016	50	13	18	2	4	11	20	3	5
Aunier Emine [31]	2005	180	74	6	3	7	61	14	3	12
Daniel T Tardo [32]	2017	594	151	15	14	22	168	13	8	13
Olga Kornafel [29]	2010	402	151	15	13	22	168	13	7	13
Elvira Talović [7]	2007	78	25	11	0	3	18	14	2	5
B. Saldarriaga [33]	2008	390	141	21	19	5	151	22	26	5
Breno José [34]	2011	200	51	36	11	2	76	15	8	1
Budhiraja V [35]	2013	84	20	16	4	2	18	13	7	4
Ourdia Bouali [36]	2012	240	88	5	9	18	86	7	7	20
OC Famurewa [37]	2018	400	100	52	8	40	116	40	22	22
Peter B Johnson [38]	2013	604	231	36	17	27	231	22	14	26
Al-Moatasem [39]	2019	200	90	6	1	3	88	7	3	2
C.Cınar [40]	2016	905	346	90	10	10	346	90	9	4
Serghei Covantev [41]	2018	56	16	4	9	0	17	7	3	0
Serghei Covantev	2018	186	72	11	4	1	72	19	6	1
Anand A [42]	2017	1060	410	0	80	40	385	153	42	50
XY Zhao[43]	2015	273	58	27	35	21	70	25	21	30
Juan S [44]	2019	592	202	31	24	25	202	48	30	30
Khamanarong [28]	2004	534	228	14	16	9	208	26	23	10
Apurba Patra [1]	2015	80	25	8	7	0	28	7	4	1
Gümüş et al. [45]	2012	1636	681	105	16	16	684	90	22	22
Mutyalapati [8]	2015	100	18	3	1	3	18	4	0	3
Lama [46]	2019	30	12	1	0	2	12	1	2	0
S.S. Hassan [47]	2017	126	59	3	1	0	55	6	0	2
Total		**10716**	**3998**	**648**	**307**	**285**	**4002**	**811**	**278**	**287**

Variations of the level of origin of the renal artery

The second search on the prevalence of the level of origin of the renal artery returned a total of 14 studies (n=7533 kidneys), reported prevalence data on the level of origin of the main renal artery. The most common vertebral level of the renal artery was L_1, with a pooled prevalence of 20.37%, (95% CI: 20.36%, 20.36%). The second most common vertebral level of the renal artery was L_2 with a pooled prevalence of 16.60% (95% CI: 16.59%, 16.60%), the third most common vertebral level of the renal artery was disc between L_1 and L_2 with a pooled prevalence of 14.16% (95% CI: 14.15%, 14.16%), while the least common vertebral level was T_{12} with a pooled prevalence = 0.38% (95% CI: 0.38%, 0.39%).

The difference between of vertebral level of the renal artery between the right and left side was not statistically significant. (p =0.001).

Discussion

This systematic review reviewed the anatomical variation of the renal artery regarding the level of origin and pattern branching from 53 studies. Variations in renal arteries are common among populations [33]. These variations are classified as accessory or aberrant renal arteries. Accessory renal arteries are additional arteries which pass

Table 3: Shows the variation of the vertebral level of the main renal artery.

			Left Kidney				**Right Kidney**			
Author	**Year**	**N**	**T12**	**L1**	**L1-L2**	**L2**	**T12**	**L1**	**L1-L2**	**L2**
Uğur Özkan [30]	2006	1716	5	317	188	346	3	369	198	290
Aunier Emine [31]	2005	180	2	48	36	4	4	68	14	4
Breno José [34]	2011	200	1	30	36	33	1	38	39	22
Shimon Degani [14]	2009	120	10	104	0	2	15	99	0	3
Ulku Cenk [48]	2009	798	7	156	115	130	3	152	111	126
Al-Moatasem [39]	2019	200	1	54	10	36	2	56	12	29
Zelalem Animaw [17]	2018	60	0	15	11	4	0	47	12	2
Kishwor Bha [49]	2014	100	0	25	30	13	0	47	12	2
Hatice Gümü [45]	2012	1586	2	351	319	146	2	385	303	128
Anu Dogra [23]	2017	200	0	28	36	36	0	32	39	29
JP Beregil [50]	1999	200	0	23	22	55	0	32	17	51
Archana Srivastava [51]	2018	200	0	44	9	47	0	78	8	14
Ewlna	2016	138	0	25	22	20	0	31	20	20
A Reginelli [5]	2015	1835	0	202	266	450	0	211	248	459
Total		**7533**	**28**	**1422**	**1100**	**1322**	**30**	**1645**	**1033**	**1179**

along with normal renal arteries through the hilum. Aberrant arteries are those which enter the kidney by piercing the substance of the kidney, either through upper pole or lower pole as polar arteries [1]. All these variations can be explained on embryological basis. Renal, suprarenal and gonadal organs are supplied by dorsal aorta, by lateral mesonephric arteries. These lateral mesonephric arteries are divided into upper, middle and lower groups. The middle group, namely 6-9th segment, gives rise to renal arteries. Persistence of more than one renal artery in the middle group results in accessory renal arteries [35].

The accessory or aberrant renal arteries may be important for the clinicians, since they have a vital role to play in causation of hydronephrosis, renal transplantations and in micro vascular surgeries [21]. Anatomical variations in the origin of the renal arteries may have importance for the urologists while performing nephron-preserving surgery, and the management of renal vascular hypertension [6]. A thorough knowledge of variations in branching pattern of renal arteries has grown in importance with the increasing number of renal transplants and other uroradiological procedures. Normal renal arterial information is useful not only for planning but also for performing endovascular, laparoscopic uroradiological procedures and renal transplants, in order to facilitate the clinical approaches.

The incidence of accessory renal arteries presents a wide variability with a range from 8.7 to 75.7% (median 28.2%) [26]. they are commonly detected unilaterally (30%) than bilaterally (10%), [52]. There is a great controversy about the accessory arteries incidence according to side. Some investigators reported that accessory renal arteries are frequently left-sided [53,54], while others contradict that the right side predominates [55]. In addition, accessory renal arteries were found to occur bilaterally with a variable incidence from 1.6 to 41% [21]. Our study showed that the incidence of the accessory renal arteries among population is 19%, with high rate of hilar accessory arteries incidence (11.97%). Our review indicate that, there is no significant difference in the incidence of the between the right and left sides.

The two main RAs normally arise from AA, the right originating higher, a significant disparity in the origin may occur [23]. Kadir mentioned that in 75%, the RA arises from AA, at L1- L2 level [30]. Beregi JP, et al. (1999) mentioned that in the RA arose between the L1 lower third and the L2 lower border [50]. Ozkan U, et al. (2006) reported that the main RA originated between the upper margin of L1 and lower border of L2 [55]. The same finding has been mention by Palmieri et al. in 94.8% on the right and 91.4% on the left side [56,57]. Zağyapan et al. (2009) found that, the RA originated from AA (T12-L2 level). Ulku Cenk et al. found that RAs were situated between the lower third of T12 and upper third of L1. Our review showed that, the median level of the main RA originated between the upper margin of L1 and lower margin of L_2, on each side, with the level of L2 is most common level of origin of the renal artery on the right and left sides.

Conclusion

The detailed information of the accessory renal vessels will reduce the chance of hemorrhage due to accidental trauma to this vessels. This emphasizes the necessity of the knowledge of renal vasculature to a surgeon operating on the kidney. With the advent of laparoscopic renal surgeries and donor nephrectomies, it becomes mandatory for the surgeon to understand the abnormality or variations in the renal vasculature. We believe that awareness of variations is necessary for surgical management.

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Ethical Approval Number

The study was approved by the institutional review board (IRB) of college of Medicine, Dar Al Uloom University, Riyadh, Saudi Arabia. IRB Number:- DAU, KSA, Pro19030004.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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