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Renal artery variations: a 20.782 kidneys review

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Abstract

Introduction: vascular anatomy variations are important in academic, clinical and surgical areas as well as nephrology, urology, oncological and vascular surgery, among others. The main objective of this review is to know the real prevalence of multiple renal arteries in a wide, multiethnic population. Secondary objectives are to establish the prevalence of early branching of the renal artery and the prevalence of these variations in left and right kidneys. **Methods:** this study analyzes the renal arterial anatomy of 20.782 kidneys from 64 anatomical and radiological studies. **Results:** Multiple renal arteries (MRA) were present in 19,95% of the total kidneys, in number of 2 to 6 arteries arriving to the hilum. The most frequent number of MRA was 2 renal arteries (89,48%), followed by 3 (9,31%), 4 (1,06%), 5 (0,02%) and 6 (0,005%). This last one being found in only one kidney. Reported data on the lateralization of the MRA are rather poor, and among these no side's predilection was found: MRA were found in 49,83% on the right side and 50,17% of left kidneys. Early branching patterns were described in only one third of the published data, being present in 11,4% of the total kidneys from those data (corresponding in 4,23% of right kidney cases and in 4,52% of left kidney cases; 2,66% had no right/left information). **Discussion:** the most difficult part was to merge the results from the different studies due to the heterogeneity of their descriptions. A universally accepted medical nomenclature is needed in order to allow a more precise lecture and transmission of results in clinical practice. Renal anatomical variations have clinical and surgical implications in renal transplantation, correctable hydronephrosis, ablation treatment for refractory hypertension or endovascular reconstructions and should be taken into account by every physician.

Keywords

Renal artery branching pattern, renal vascular anatomy, kidney arterial blood supply, renal artery variations.

Introduction

Several attempts to study the frequency of occurrence of renal vascular variations have been made, being the first one that from the Anatomical Society of Great Britain and Ireland in 1891 (Thomson et al., 1889). Most of the works published up to now included small groups or narrowed ethnicities. The present article reviews more than 20.000 kidneys of people from 31 countries on the five continents. To our knowledge is the most extensive and varied review ever performed.

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The continuously changing blood supply of the kidneys as they ascend from the pelvis to their final location during the embryological development explains the high incidence of anatomical variations.

The first description of accessory renal arteries was given in 1564 by Eustachi, and since then renal artery terminology has been controversial and unclear (Gulas et al., 2018). Nowadays there is no universally accepted nomenclature to describe arteries arriving to the kidneys other than the "normal main renal artery". Additional renal arteries have been variously described as accessory, aberrant, anomalous, supernumerary, supplementary, multiple and many other terms (Satyapal et al., 2001).

Authors like Satyapal et al. propose and use the following definition: an additional renal artery, other than the main renal artery, is one which arises from the aorta and terminates in the kidney. Other authors like Klatte et al.(2015) referred as accessory artery to any supernumerary artery that reaches the kidney. If the artery does not enter the kidney at the hilum, it is called as aberrant .

Bergman et al. (2018) said that additional renal arteries, varying in size and generally derived from the aorta, are found in 26 to 30% of kidneys entering at almost any point of the parenchyma. They sustain it is a misnomer to call such vessels accessory renal arteries because they are not extra but essential, tissue-sustaining arteries and cannot be bound without consequences.

Variations on the renal arteries not only refers to the number, but also to the division point. For example, Sampaio and Passos (1992) "limited" the early division to 1 cm from the aorta, whereas Saldarriaga et al. (2008) "expanded" this distance to 2 cm, with profound differences in their results.

Due to the multiple definitions found in literature, a consensus between the authors allowed to define an accessory renal artery as any branch from the aorta or other main arteries that enters the kidney through the hilum, including those arteries born from the division of the main renal artery into different branches. The polar arteries were defined as those arteries that have their origin in the aorta or other main arteries different from the renal artery that enter the kidney through the upper or the lower pole.

The occurrence of accessory renal arteries may be concomitant not only to other atypical variants of vascularization, especially those of the genitourinary system, but also to some specific medical conditions (Anjamrooz et al., 2013).

Precise knowledge of the most frequent types of renal vascular anatomical variations is needed due to the continuous growing and development of surgical procedures such as renal transplants, aneurysms repair, oncologic partial nephrectomy, ablation treatment for refractory hypertension and vascular reconstructions (Gulas et al., 2018; Klatte et al., 2015; Aldana et al., 2010; Urban et al., 2001; Benedetti et al., 1995; Ali-El-Dein et al., 2003; Abbasi et al., 2011; Mendes et al., 2016).

In any surgical technique, laparoscopic or classical open approach, unawareness of the presence of an additional renal artery may result in a fatal outcome and many studies tried to understand the real impact of these anatomical variations.

The main objective of this review is to know the real prevalence of multiple renal arteries in a wide, multiethnic population. The secondary objectives are to establish the prevalence of early branching of the renal artery and the prevalence of these variations in left and right kidneys.

Materials and methods

During the pre-analytical stage, we performed a wide range research. Classic research databases such as Medline, Embase, and Web of Science databases were screened. Also other well known online libraries such as Scientific Electronic Library Online (www.scielo.org) and Europe Pubmed Central (www.europepmc.org) were screened. Due to the low number of cases found, we decided to extend the search into several Anatomy and Morphology sciences journals, such as Scholar Science Journals (www.ssjournals.com), Hindawi Publishing Corporation (www.hindawi.com), International Journals in Medical and Health Research (www.ijmhr.com), International Journal of Experimental and Clinical Anatomy (www.anatomy.org.tr), Romanian Journal of Morphology and Embryology (www.rjme.ro), African Journals Online (www.ajol.info), Asian Pacific Journal of Health Sciences (www.apjhs.com), Firenze University Press (www.fupress.net), American Journal of Roentgenology (www.ajronline.org), Via Medica Journals (www.journals.viamedica.pl), Impact Journals (www.impactjournals.us), Revista Argentina de Anatomía Clínica (www.anatclinar.com.ar).

Database research was performed without time limit using the keywords: "renal artery branching pattern", "renal vascular anatomy", "kidney arterial blood supply", "renal artery variations", "variaciones arteria renal", "vascularización renal", "variação arteria renal", "variantes anatómicas arterias renales".

The search was not limited to the English literature because authors are native speakers or have a bilingual level in languages such as Spanish, Greek, Italian, English, Portuguese, French or Romanian, and so literature analysis and/or interpretation would not be affected. Another reason that led us to include these articles was the fact that they would add not only a significant number of cases but also a biological diversity to this work, being the last one an invaluable characteristic in order to extrapolate the results to general population.

One hundred and thirty two articles passed the pre-selection. In a second stage, repeated articles or articles with incomplete information were discarded. Eighty articles were judged to be highly relevant by the individual authors and were circulated among the rest of the working group. A total of 20.782 kidneys were included in the present work.

Results

We have analyzed 64 articles with a total of 20.782 kidneys. Multiple renal arteries (MRA) were founded in 4.146 kidneys (19,95%) of the total. The number of MRA arriving to the kidney varied from two to six (Thomson et al., 1889; Satyapal et al., 2001; Sampaio et al., 1992; Saldarriaga et al., 2008; Ali-El-Dein et al., 2003; Katariya et al., 2015; Bordei et al., 2004; Raman et al., 2007; Çiçekcibaşi et al., 2005; Hung et al., 2012; Harrison et al., 1978; Ugurel et al., 2010; Kaneko et al., 2008; Virendra et al., 2010; Budhiraja, et al., 2013; Özkan et al., 2006; Natsis et al., 2014; Bouali et al., 2012; Stanca et al., 2009; Jacek et al., 2007; Kornafel et al., 2010; Aristotle et al., 2013; Tarzamni et al., 2008; Méndez López et al., 2014; Sofía et al., 2008; Olave et al., 2009; Shaikh et al., 2014; Vasi et al., 2015; Palmieri et al., 2011; Ayuso et al., 2006; Patil et al., 2001; Jee et al., 2008; Platt et al., 1997; Johnson et al., 2013; Soares et al., 2013; Talović

et al., 2007; Munnusamy et al., 2016; Zağyapan et al., 2009; Saritha et al., 2013; Vatsala et al., 2014; Zăhoi et al., 2015; Tayyba et al., 2016; Refaat et al., 2013; Aragão et al., 2012; Calle Toro et al., 2016; Khamanarong et al., 2004; Aubert et al., 1975; Holden et al., 2005; Janschek et al., 2004; Costa et al., 2011; Tyson et al., 2011; Kapoor et al., 2011; Tao et al., 2013; Kok et al., 2008; Han et al., 1998; Chabchoub et al., 2011; Sezer et al., 2012; Lloyd et al., 1935; Vilhova et al., 2001; Gümüş et al., 2012; Mustafa et al., 2016; Lawton et al., 2017; Cases et al., 2017).

Between those 4.146 kidneys, 3.710 (89,48%) had 2 arteries, 386 (9,31%) had 3 arteries, 44 kidneys had 4 arteries (1,06%), 5 kidneys had a total of 5 arteries (0,02%) and only 1 case described a kidney with 6 renal arteries (0,005%). Table 1 resumes these findings.

Only 34 of the articles made the distinction between right and left kidney with MRA. Among the 12.446 kidneys included in those articles, 2308 had MRA distributed 1150 (49,83%) in right kidneys and 1158 (50,17%) in left kidneys (Table 2) (Satyapal et al., 2001; Saldarriaga et al., 2008; Katariya et al., 2015; Bordei et al., 2004; Raman et al., 2007; Harrison et al., 1978; Ugurel et al., 2010; Kaneko et al., 2008; Özkan et al., 2006; Natsis et al., 2014; Bouali et al., 2012; Kornafel et al., 2010; Shaikh et al., 2014; Vasi et al., 2015; Ayuso et al., 2006; Patil et al., 2001; Johnson et al., 2013; Soares et al., 2013; Talović et al., 2007; Zağyapan et al., 2009; Saritha et al., 2013; Refaat et al., 2013; Aragão et al., 2012; Calle Toro et al., 2016; Khamanarong et al., 2004; Aubert et al., 1975; Holden et al., 2005; Costa et al., 2011; Tyson et al., 2011; Tao et al., 2013; Gümüş et al., 2012; Mustafa et al., 2016; Sungura et al., 2012).

Early branching was described in as few as 21 of the 64 articles, but no universal definition was used. Some of them defined early branching using an arbitrary limit of 1,5 or 2 cm between the aorta and the distance within the division of the main renal artery in MRA, while some others did not specify a limit. Between the 8769 kidneys described in those articles, 1000 (11,4%) presented an early branching (all definitions

Table 1. Number of kidneys with MRA and its prevalence.

	Number of MRA described					
	Two (%)	**Three (%)**	**Four (%)**	**Five (%)**	**Six (%)**	**Total (%)**
	3710 (89,48)	386 (9,31)	44 (1,06)	5 (0,12)	1 (0,02)	4146 (100)
% from the 20782 kidneys	17,85	1,86	0,21	0,02	0,01	19,95

Table 2. Prevalence of MRA in right and left kidneys.

	Number of MRA (%)				
	Two	**Three**	**Four**	**Five**	**Total (%)**
Right kidneys number (%)	1043 (45,19)	93 (4,03)	12 (0,52)	2 (0,09)	1150 (49,83)
Left kidneys number (%)	1055 (45,71)	87 (3,77)	14 (0,61)	2 (0,09)	1158 (50,17)
					2308 (100)

Table 3. Early branching prevalence.

	Early branching side			
Total Kidneys (%)	**Right (%)**	**Left (%)**	**Not specified**	**Total (%)**
8769 (100)	371 (4,23)	396 (4,52)	233 (2,66)	1000 (11,40)

considered together). Only a minority of the articles included lateralization information of the early branching: 371 (4,23%) were right kidneys and 396 (4,52%) were left kidneys. In 233 (2,66%) of the cases no right/left side was specified (Table 3) (Thomson et al., 1889; Sampaio et al., 1992; Raman et al., 2007; Hung et al., 2012; Budhiraja, et al., 2013; Özkan et al., 2006; Jacek et al., 2007; Kornafel et al., 2010; Tarzamni et al., 2008; Ayuso et al., 2006; Patil et al., 2001; Jee et al., 2008; Platt et al., 1997; Munnusamy et al., 2016; Tayyba et al., 2016; Refaat et al., 2013; Holden et al., 2005; Tao et al., 2013; Kok et al., 2008; Gümüş et al., 2012; Mustafa et al., 2016).

Discussion

Theoretically, a higher risk of surgical complications to the living donor and to the recipient is associated to the renal graft with accessory arteries. In the past, its presence was considered as a contraindication to the procedure, but nowadays most of the studies agree that MRA are not considered a problem anymore neither to open nor to laparoscopic nephrectomies (Benedetti et al., 1995; Ali-El-Dein et al., 2003; Abbasi et al., 2011; Mazzucchi et al., 2005; Carter et al., 2005). Some others still consider its presence as a contraindication to their use. They justify their position saying that as these are end-arteries they should all be re-implanted requiring several anastomoses with a prolonged ischemic time, leading to a theoretically higher incidence of renal failure, graft rejection, marked decrease in renographic clearance post-transplantation, and reduced graft function (Ashraf et al., 2013; Harraz et al., 2013).

Additional renal arteries might also condition aortic aneurysm endovascular repair, not only because of their presence, but also because of the amount of parenchyma perfused by them. According to Mendes et al. (2016), there is no consensus on how much renal parenchyma can be safely sacrificed during endovascular aortic repair. While some authors have proposed that sacrificing an entire kidney to seal the aneurysm is acceptable in difficult case (Satyapal et al., 2001), an arbitrary exclusion criteria for endovascular repair in fenestrated-branched devices trials was proposed by Mendes et al., they chose an open repair technique or other alternative treatment when more than 40% of one kidney or 25% of both kidneys need to be sacrificed to accomplish endovascular incorporation.

Renovascular hypertension is a form of secondary hypertension typically caused by atherosclerosis or fibromuscular dysplasia, but also by ureteropelvic junction obstruction caused by functional or anatomic anomalies. The extrinsic compression

of the ureteropelvic junction by an accessory renal artery can be found among the causes (Lee et al., 2015). Even if rare, this is a surgically reversible cause of secondary hypertension that should be researched and treated.

In a study of patients with resistant hypertension and their response to arterial denervation performed by Verloop et al. (2014), 34% of the patients had accessory renal arteries. Their results suggest that renal denervation is effective in patients with multiple renal vessels, especially in those patients with arteries which could all be treated. Due to these results and the high prevalence of MRA among patients with resistant hypertension, they concluded that it seems reasonable not to exclude patients with accessory arteries from this treatment .

Accessory renal arteries are also determinant in oncologic conservative surgery techniques. The incidence of renal tumors has increased over the past several decades. Most of the patients are diagnosed at clinical stage T1, making them electable to partial nephrectomy. Nowadays minimally invasive partial nephrectomy has become an alternative to open surgery, a detailed understanding of surgical anatomy is basic to optimize preoperative planning and operative technique to maximizing oncologic and functional outcomes (Klatte et al., 2015).

The presence of inferior polar renal arteries might also be implicated as an etiologic factor in some forms of hydronephrosis correctable by surgery (Bergman et al., 2018).

These, as so many other examples, can be quoted to underline the importance of vascular anatomy in common and uncommon medical conditions, as well as its importance in surgical planning and outcome. Last but not least, we want to mention the importance of a universally accepted medical nomenclature in order to allow a faster and a more precise lecture and transmission of results in clinical practice, which will also facilitate the construction of research data bases based on objective anatomical descriptions.

Conclusions

Almost 20% of the population has multiple renal arteries, being double renal arteries the most common variation. Lateralization of the MRA was described in only a minority of the reported data, and no side's predilection was found among them. Only 21 articles described early branching patterns. It was described in 11,4% of the kidneys taken into account in those articles (4,23% corresponded to right and 4,52% to left kidneys. In 2,66% of the early branching cases there was no right/left specifications).

Due to the importance in clinical and surgical areas as different as nephrology, urology, oncological or vascular surgery, among others, the existence of these variations and its clinical implications should be taken into account by every physician.

To our knowledge, the present work is the widest anatomical review on the renal artery, with the most varied population.

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