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Anatomical Variations Of the Renal Artery in Humans and Their Clinical and Surgical Implications

Sarah Lorrayne Palmeira Pimentel[1], Ana Beatriz Marques Barbosa[1], Diego Neves Araujo[2], Thiago de Oliveira Assis[3]

[1]Physiotherapist from UNIFACISA University Center, Campina Grande - PB, Brazil
[2]Professor of Medicine at UNIFACISA University Center, Campina Grande - PB, Brazil
[3]Professor at the Department of Biology, State University of Paraíba (UEPB), Professor at the Health Sciences Unit of Federal University of Campina Grande (UFCG), and Professor of Medicine at UNIFACISA University Center, Campina Grande - PB, Brazil

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ABSTRACT
Introduction: the renal artery (RA) has its origin from the lateral surface of the abdominal aorta with constant position and course until it forms the hilum, responsible for the irrigation of the renal structures. A failure in the degeneration of the primitive vessels can cause the anatomical variation of these arteries. Thus, knowledge of possible anatomical variations in this vessel contributes to proper exploration and treatment in this region. To analyze the RA anatomical variations in humans and the possible clinical implications. This is a systematic review of studies indexed in PubMed, SciELO, SPRINGERLINK, SCIENCE DIRECT, BVS and Google Scholar databases, from April to July 2019. Original studies involving RA variations in humans were included. The following outcomes were considered: RA presence, level, origin and its terminal branches. Renal artery variations are not uncommon findings and their reports in the scientific literature demonstrate great importance for the development of important clinical conditions, therefore knowing about this subject is relevant for surgeons and professionals working in this area.
Keywords: Renal artery; anatomy; variation.

Introduction

The kidneys are paired organs positioned side by side and located retroperitoneally in the posterior abdominal wall (PALMIERI, 2011). These organs have characteristic shapes in which it is possible to observe an upper pole and a lower pole with a lateral convex edge and a medial concave edge. In addition, on the medial border there is a marked depression, the hilum, where the renal vessels are found (SAMPAIO, 2000).

According to the normal anatomical pattern, this organ is supplied by a single artery distributed on each side, the main renal artery, originating on the lateral surface of the abdominal aorta and with a relatively constant position and course until it forms the hilum, close to the level of the superior mesenteric artery at the level of L1 and L2 vertebrae. In general, the main renal artery has a length of 4-6 cm and a diameter that can vary from 5-6 mm (MELLO JÚNIOR, 2016).

However, a possible failure in the degeneration of the primitive vessels can result in multiple renal arteries (BUFFOLI, 2015). Variations of this artery can be described by different terms such as accessory, aberrant, anomalous, supernumerary, and supplementary. Its number can vary between two to six renal arteries and the nomenclature is according to the location it is supplying; therefore, they can be called hilar, superior polar and inferior polar (PALMIERI, 2011). Although there is a process of sequential involution of these structures, the most caudal arteries may persist in the already formed kidney, leading to the origin of inferior and superior polar arteries (MELLO JÚNIOR, 2016).

A study carried out with 855 patients, observed only one renal artery suppluing both kidneys in 76% of cases. And more than one renal artery supplying the kidneys in 202 (24%) patients. Renal artery variations included multiple arteries in 24%, bilateral multiple arteries in 5%, and initial splitting in 8% of cases. Among the extra renal arteries, the percentage of accessory and aberrant renal arteries were 49% and 51%, respectively (ÖZKAN *et al.*, 2006).

Understanding the vast possibility of anatomical variations in the renal arterial vasculature is vital for surgical planning or for performing renal procedures (CASES, 2017). In addition, this understanding is important in the exploration and treatment of some pathologies such as renal trauma, renal transplantation, renovascular hypertension, renal artery embolization, angioplasty, or vascular reconstruction for congenital and acquired lesions, surgery for abdominal aortic aneurysm, Takayasu's disease, conservative or radical renal surgery and uroradiological procedures (ÇIÇEKCIBASI, 2005).

In this context, knowing the existence of the variant anatomy, surgeons or interventionists can be

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helped, in order to avoid catastrophic complications and to promote safer surgery procedures for the patient (TORO, 2016). Therefore, knowing about these variations is essential, considering that their study and deepening are of great value and importance, especially for surgeons and professionals who work in this area, avoiding the emergence of complications and iatrogenic situations. Thus, this study aimed to analyze the anatomical variations of the renal artery in humans and their possible clinical and surgical implications.

Materials and Methods

This is a systematic review. The electronic search was performed from April to July 2019. For this study, the following databases were consulted: SciELO (Scientific Electronic Library Online), PubMed (National Library of Medicine), Science Direct, Springerlink, BVS (Virtual Health Library) and Google Scholar. Articles were selected without time restriction, in English and Portuguese. For the prospection of the studies, the descriptors were used in a combined way through Boolean operators (AND). In the databases, the following combination was considered: "left renal artery" AND "anatomical variation". Duplicates were checked. From the identified studies, those that met the criteria for inclusion were screened by titles and abstracts. Original articles involving the anatomical variations of the renal artery in humans were included in this review, prioritizing the most relevant studies. Review articles, renal vein studies and animal model studies were excluded.

Studies found in more than one of the databases were counted only once. In SciELO, 9 articles were found, 25 in Springerlink, 25 in Science Direct, 53 in BVS, 40 in PubMed and 20 in Google Scholar, totaling 172 articles. From these, the inclusion and exclusion criteria were applied and 39 were selected for analysis.

The search was performed by two independent reviewers, and the analysis of interobserver agreement was performed using the Kappa test, using the Bioestat V 5.0 software, according to the method of Landis and Koch (1977). The value found was K=0.77 (Substantial agreement).

The selected articles were critically analyzed using an interpretation guide, used to assess their individual quality, based on the studies by Greehalgh (1997) and adapted by Mcdermid *et al.* (2009). Items for assessing the quality of articles are expressed by scores in Table 1, where 0 = absent; 1 = incomplete; and 2 = complete.

Results

Table 1 presents the qualitative analysis of the included studies.

Table 1. Qualitative analysis of the studies on anatomical variations of the renal artery in humans and their possible clinical and surgical implications.

Studies	Assessment criteria												
	1	2	3	4	5	6	7	8	9	10	11	12	Total (%)
Arifuzzaman *et al.* (2017)	1	1	NA	0	2	NA	2	0	1	2	2	1	60
Tardo *et al.* (2017)	2	2	2	NA	2	NA	2	2	2	2	2	2	100
Rafailidis *et al.* (2016)	1	NA	2	1	1	NA	1	1	0	0	NA	2	50
Mazengenya (2016)	1	NA	2	0	1	NA	1	0	1	1	NA	1	44.4
Buffoli (2015)	2	NA	2	1	1	NA	1	1	1	1	NA	1	61.1
Nayak *et al.* (2013)	1	NA	2	0	1	NA	1	1	2	2	NA	2	66.7
Bouali *et al.* (2012)	1	2	2	NA	2	0	2	1	2	2	2	1	77.3
Panagouli *et al.* (2011)	1	NA	2	2	1	NA	2	2	2	2	NA	2	88.9
Costa *et al.* (2011)	1	1	1	0	2	NA	1	0	1	2	NA	1	50
Hlaing *et al.* (2010)	1	0	2	1	1	NA	1	1	1	2	0	2	54.5
Ciçekcibaşi *et al.* (2005)	2	1	1	0	1	NA	1	1	1	2	NA	1	55
Satyapal *et al.* (2001)	1	1	2	2	2	0	2	2	2	2	0	2	81.8
Anjamrooz et al. (2013)	2	NA	1	2	1	NA	1	2	1	2	NA	1	72.2
Lladó *et al* (2017)	2	1	2	0	1	NA	2	2	1	1	NA	2	70
Ferreira, Humberto (2014)	2	NA	2	0	1	NA	2	1	1	2	NA	2	72.2
Cruzat, C; Olave, E. (2013)	2	NA	2	NA	1	0	1	NA	1	1	NA	1	95.5
Saldarriaga *et al.* (2008)	2	2	2	2	2	NA	2	2	2	2	2	1	95.5
Haladaj, Robert *et al.* (2018)	2	NA	2	2	1	NA	2	2	1	1	NA	1	77.7
Pereira *et al.* (2017)	2	1	2	2	1	NA	1	2	1	2	NA	2	80

Nagato *et al.* (2013)	2	0	2	2	1	NA	2	2	1	2	2	0	72.7
Salve *et al.* (2011)	2	NA	1	1	1	NA	1	2	1	2	NA	1	66.7
Natsisa et al. (2010)	2	NA	2	1	1	NA	1	2	2	1	NA	1	72.2
Ranade *et al.* (2007)	1	NA	2	NA	1	NA	1	0	1	1	NA	2	56.2
Ribeiro *et al.* (2007)	1	NA	1	2	1	NA	1	2	1	2	NA	1	66.7
Baniel *et al.* (1995)	1	2	2	NA	1	NA	1	0	1	2	NA	1	61.1
Clara Cases *et al.* (2017)	2	1	2	0	2	0	2	2	2	2	2	2	79.1
Mutyalapati *et al.* (2016)	2	1	2	0	1	NA	2	0	2	2	NA	2	70
Anu Dogra *et al.* (2017)	2	0	2	0	1	0	2	0	1	2	NA	2	54.5
Juan *et al.* (2016)	2	1	2	0	2	0	2	0	2	2	2	1	72.7
Fabien Lareyre *et al.* (2019)	2	1	2	0	1	0	2	2	2	2	2	2	75
James Lawton *et al.* (2017)	2	2	2	1	1	0	2	2	2	2	2	1	79.2
Marcin Majos *et al.* (2018)	1	2	1	2	2	0	2	2	1	2	2	1	75
Sampaio, Passos (1992)	2	1	2	0	2	NA	1	0	1	2	1	2	70
Khamanarong *et al.* (2004)	1	0	1	0	2	NA	1	0	0	2	NA	2	45
Bordei *et al.* (2004)	1	0	1	1	2	NA	1	1	1	2	NA	2	60
Virendra *et al.* (2010)	1	0	2	0	1	NA	1	NA	1	2	0	2	50
Ugurel *et al.* (2010)	2	0	2	0	1	NA	2	0	1	2	2	2	63.6
Uğur Özkan *et al.* (2006)	2	1	2	0	2	NA	2	0	1	2	2	1	68.1
Lynn *et al.* (1978)	2	1	2	1	2	NA	1	0	1	2	0	2	63.6

NA: not applicable.
Assessment criteria: 1. Thorough literature review to define the research question; 2. Specific inclusion/exclusion criteria; 3. Specific hypotheses; 4. Appropriate range of psychometric properties; 5. Sample size; 6. Follow-up; 7. The authors referenced specific procedures for administering, scoring, and interpreting procedures; 8. Measurement techniques have been standardized; 9. Data were presented for each hypothesis; 10. Appropriate statistics - point estimates; 11. Appropriate statistical error estimates; 12. Valid conclusions and clinical recommendations.

A summary of the electronic search in the databases and the respective decision for inclusion is shown in Figure 1. Initially, 172 articles were identified, of which 118 were excluded because they were not relevant for the topic, duplicates or did not meet exclusion criteria. The remaining 54, which were submitted to a more careful analysis of titles and abstracts. Of these, 15 were excluded, and only 39 articles adequately met all the inclusion criteria and were thus selected for analysis.

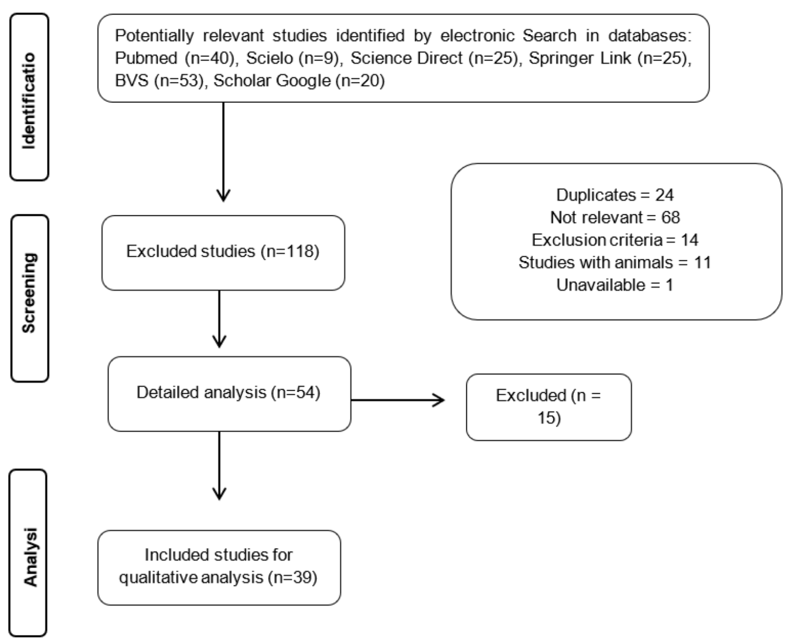

Figure 1. Flowchart of included and excluded studies in the review.

Table 2 presents a summary of the studies selection for analysis of findings related to anatomical variations of the renal artery in humans.

There was a total of 11 variant forms of RA found in the analysis of the included studies. They are described in Table 3.

Table 2. Characteristics of studies that evaluated anatomical variations of the renal artery in humans.

Study ID	Sample	Method	Main results
Arifuzzaman *et al.* (2017)	220 kidneys	Computed tomography angiography	Of the total of 110 patients, 69.1% (93 cases) were normal. Variation in the renal arterial system was observed in 15.5% of patients. Seven cases with two renal arteries on the left, seven cases with two renal arteries on the right, 2 cases with two bilateral renal arteries and 1 case with three left renal arteries.
Tardo *et al.* (2017)	594 kidneys	Computed tomography angiography and cadaveric dissection	Multiple renal arteries were discovered in 12.12% (72 kidneys) of the kidneys. The most common pattern observed was the presence of a variant renal artery in 67 cases, compared to two arteries in 4 cases and three multiple arteries in 1 case. In 24 cases, it was with superior polar artery and 16 cases with inferior polar artery.
Rafailidis *et al.* (2016)	2 kidneys	Computed tomography angiography	The investigation revealed the presence of the left kidney with three renal arteries originating from the abdominal aorta. And a renal artery in the right kidney.
Mazengenya (2016)	2 kidneys	Cadaveric dissection	This study reports a case with the right kidney presenting 3 hilar renal arteries. While only one left renal artery supplying the left kidney.
Buffoli (2015)	2 kidneys	Cadaveric dissection	In this case report, the right kidney had three renal arteries; and the left kidney, two renal arteries, one directed to the inferior pole.
Nayak *et al.* (2013)	2 kidneys	Cadaveric dissection	A left renal artery divided into anterior and posterior divisions just before reaching the hilum has been reported. The anterior division also divided into two segmental branches and the posterior division of the renal artery entered the kidney without forming other branches.
Bouali *et al.* (2012)	240 kidneys	Computed tomography	We found 86 patients with 1 right renal artery, 27 patients with 2 right renal arteries (7 cases of superior pole artery and 20 inferior pole), 6 patients with 3 right renal arteries and 1 patient with 4 right renal arteries. In addition, we found 88 patients with 1 left renal artery, 30 cases with two left renal arteries: 9 cases of superior pole artery, 18 cases of inferior pole accessory artery and 3 cases of codominant arteries. There were 2 cases of left triple renal arteries.
Panagouli *et al.* (2011)	2 kidneys	Cadaveric dissection	The left kidney had an inferior polar inferior left renal artery. On the right side, we did not find variations in the renal region.
Costa *et al.* (2011)	254 kidneys	Cadaveric dissection	In 25 cases (9.8%) the variation identified was the left artery: 2 arteries (n = 23), 3 arteries (n = 1) and 4 arteries (n = 1). In 22 cases (8.6%), the variation identified was in the right renal artery: 2 arteries (n=19), 3 arteries (n=3).
Hlaing *et al.* (2010)	50 kidneys	Cadaveric dissection	We found 2 kidneys (4%) with an accessory renal artery (ARA). In one left kidney, we observed, in addition to the common renal artery, an ARA near the lower pole of the kidney that divided into anterior and posterior branches. And in the right kidney, the presence of 1 additional simple renal artery in the superior pole and in the inferior pole.
Ciçekcibaşi *et al.* (2005)	180 kidneys	Cadaveric dissection	There were no variations in 52 fetuses, while the remaining 38 (42.2%) showed different patterns of variation. The morphological results presented are as follows: single hilar artery in 75% of cases, double hilar artery in 11.1%, inferior polar artery in 10.5% and superior polar artery in 3.3% of the specimens studied.
Satyapal *et al.* (2001)	440 kidneys	Cadaveric dissection and renal angiography	An additional single renal artery was found on the right side in 40 kidneys and on the left side in 62 kidneys. Two additional renal arteries were found in 10 kidneys on the left side and 10 kidneys on the right side. In addition, the bilateral incidence was 10.2%.
Anjamrooz *et al.* (2013)	2 kidneys	Cadaveric dissection	This study reports two superior and inferior segmental renal arteries on the left side and a superior polar artery and an inferior polar artery on the right side.

Lladó *et al* (2017)	42 kidneys	Computed tomography angiography	Twenty-one patients were evaluated. There was one case in which the examination observed a double main renal artery with the same surgical finding; and the examination found a single inferior polar artery in three cases.
Humberto (2014)	2 kidneys	Cadaveric dissection	The variations found was three bilateral renal arteries.
Cruzat *et al.* (2013)	2 kidneys	Computed tomography	In this study, it was observed that on the right side there were four renal arteries (RA), and on the left side, we observed two renal arteries.
Saldarriaga,B. (2008)	390 kidneys	Cadaveric dissection	In individuals with renal blocks, two hundred and ninety-two kidneys (74.9%) had a single renal artery and 98 (25.1%) had an additional renal artery.
Haladaj *et al.* (2018)	4 kidneys	Cadaveric dissection	An anatomical description showed a supernumerary renal artery located below the left main renal artery.
Pereira *et al.* (2017)	8 kidneys	Cadaveric dissection	Two right kidneys were observed to have double renal arteries.
Nagato *et al.* (2013)	48 kidneys	Cadaveric dissection	Anatomical variation was observed in 40% of the right kidneys, with the presence of accessory renal artery, ten variations of artery for the upper right pole and one for the lower right pole. For the left, a variation of 35% was observed, with six variations of accessory artery for the upper left pole and one for the lower left pole.
Salve *et al.* (2011)	2 kidneys	Cadaveric dissection	Bilateral aberrant renal arteries were found in the lower poles of both kidneys, originating from the abdominal aorta and bilateral aberrant renal arteries to the superior poles originating from the renal arteries.
Natsis *et al.* (2010)	2 kidneys	Cadaveric dissection	On the left side, there was a superior accessory renal artery that arose from the abdominal aorta above the left renal artery.
Ranade *et al.* (2007)	2 kidneys	Cadaveric dissection	Presence of double renal arteries on the left side.
Ribeiro *et al.* (2007)	2 kidneys	Cadaveric dissection	A male cadaver presented, on the left, two renal arteries from the abdominal aorta, both entering the kidney in the hilar region.
Baniel *et al.* (1995)	147 kidneys	Cadaveric dissection	Accessory renal arteries were found in 24 patients, 16 on the right side and 14 on the left side, totaling 30 kidneys, and 2 kidneys with two accessory renal arteries on the same side and the other 28 kidneys with one.
Cases *et al.* (2017)	1226 kidneys	Cadaveric dissection and computed tomography angiography	A total of 86 arteries (60 kidneys) were described in the cadaveric sample, while 1166 kidneys were analyzed in radiology. Five types (a–e) and standards (I–V) were established in the classification. Type a, hilar aortic artery, incidences were 79% in cadavers and 95% in CT; Type b, hilar superior polar artery, incidences were 10% in cadavers and 2% in CT; Type c, superior polar artery of the aorta, incidences were 5% in cadavers and 2% in CT; Type d, inferior polar aortic artery, incidences were 3% in cadavers and 1% on CT; Type e, hilar inferior polar artery, incidences were 2% in cadaver and less than 0.1% in CT. The pattern represents the number of arteries reaching a kidney. Patterns I to IV were found in cadavers, I: 40/60 and 1023/1166; II: 18/60 and 143/1166; III: 2/86; IV: 2/86.
Ramulu (2016)	50 kidneys	Cadaveric dissection	Accessory renal arteries were observed in 12 (24%) of the cases. Within the accessory, the hilar type was more common in 14% (7 cases, 4 on the right side and 3 on the left side), followed by inferior polar in 12% (3 on the right side and 3 on the left side) and superior polar in 2% (1 case on the left side) of the specimens.
Dogra *et al.* (2017)	200 kidneys	Computed tomography angiography	Accessory renal arteries (ARA) were present in 36% of cases (44% of the kidneys). In two cases on the left there was the presence of a triple renal artery, in 30 cases with ARB and 6 cases bilaterally.
Toro *et al.* (2016)	592 kidneys	Computed tomography angiography	Renal artery variations were present in 52% of patients (153 patients). Hilar accessory renal artery was present in 51 kidneys; polar accessory renal artery in 109 kidneys; double renal artery in 25 kidneys; and triple renal artery in 3 kidneys.

Lareyre *et al.* (2019)	83 kidneys	Computed tomography	Ten patients had polar renal artery coverage, in which 3 cases were towards the superior pole, 6 cases towards the inferior pole and 1 case towards the renal hilum. Among these ten patients, eight had one polar renal artery and two had two polar renal arteries.
Lawton *et al.* (2017)	110 kidneys	Computed tomography	Among 55 patients, twelve (22%) had one or two supernumerary renal arteries. Two with left renal artery and one with right renal artery were observed in four (7.2%) cases, two with right renal artery and one with left renal artery in two (3.6%) cases and two with right renal artery with two renal arteries left in three (5.4%) cases.
Majos *et al.* (2018)	496 kidneys	Computed tomography angiography	A total of 496 kidneys were analyzed. Prehilar renal artery was observed in 185 kidneys (37.30%) and multiple renal arteries in 96 kidneys (19.35%). Two renal arteries were on one side in 90 cases and three arteries in six cases.
Sampaio *et al.* (1992)	266 kidneys	Cadaveric dissection	The anatomical findings are presented: 1 hilar artery in 55.3% of cases (147 kidneys), 1 hilar artery with 1 superior extrahilar branch in 14.3% (38 kidneys), 2 hilar arteries in 7.9%(21 kidneys), 3 hilar arteries in 1.9%(5 kidneys), superior polar artery in 6.8%(18 kidneys), inferior polar artery in 5.3%(14 kidneys), two hilar arteries with one superior pole extra-hilar branch in 3.4% of cases (9 kidneys) and a hilar artery with early bifurcation in 2.6% of cases (7 kidneys).
Khamanarong *et al.* (2004)	534 kidneys	Cadaveric dissection	A single renal artery was detected in 436 (81.64%) of the 534 kidneys investigated. Double renal arteries were observed in 93 cases (17.43%); of these, 40 (7.5%) were two hilar arteries, 37 (6.93%) were a hilar artery combined with a superior polar artery, and 16 (3%) were a hilar artery combined with an inferior polar artery. Triple kidney arteries were found in five (0.93%); of these, two (0.37%) were two hilar arteries combined with a superior polar artery and three (0.56%) were two hilar arteries combined with an inferior polar artery.
Bordei *et al.* (2004)	272 kidneys	Cadaveric dissection	Of the 54 kidneys with double renal arteries, 42 were unilateral, with a predominance on the left (25 cases), and three had triple renal arteries on the opposite side. In six cases, there was bilateral double renal arteries. In 28 cases, the supplementary renal artery entered the kidney through the hilum (adequate renal artery), in 16 cases it was inferior polar, in five cases it was superior polar and in five cases the supplementary renal artery terminated into two branches, equal in caliber, one polar and another hilar.
Budhiraja *et al.* (2010)	100 kidneys	Cadaveric dissection	It was observed multiple bilateral prehilar ramifications of renal arteries in 11 (11.66%) cases, duplication of renal arteries in eight (8.33%) cases, superior polar arteries in seven (6.66%) cases. Duplicate renal arteries were observed on both sides. On the right side, they were seen in five of eight cases (62.5%) and three of eight cases (37.5%) on the left side. They have been found running as anterior and posterior renal arteries, as well as accessory renal arteries.
Ugurel *et al.* (2010)	200 kidneys	Computed tomography angiography	One renal artery was found in each kidney in 58 of the 100 patients and more than one renal artery in 42 patients. In 18 cases two renal arteries on the right side, in 15 cases two renal arteries on the left side, 2 cases with three renal arteries on the left side, 4 cases of two renal arteries on each side and 3 cases of two renal arteries on the right and three left renal arteries.
Ozkan *et al.* (2006)	1697 kidneys	Angiography	Renal artery variants included two renal arteries in 231 kidneys; three renal arteries in 15 kidneys; and four renal arteries in 2 kidneys.
Harrison *et al.* (1978)	328 kidneys	Renal arteriography	The most common variation was the presence of multiple renal arteries supplying the same kidney, occurring in 32% of cases, with 22 cases on the left, 23 cases on the right and 8 cases bilaterally. In addition, 3 cases had three renal arteries. Prehilar segmental branching was the second most common variation, occurring in 17% of patients (28 cases). Bilateral single renal artery was present in 46% of patients (76 cases).

Among the 39 selected articles, 26 studies used cadaveric dissection as method for investigation, 13 used computed tomography angiography and, in 3 other studies, different methods were addressed, such as renal arteriography and angiography. We found 11 types of anatomical variations of the renal artery and the most common finding was the double renal artery and the triple renal artery, that 23 and 18 authors, respectively, reported on this finding. Other reported variation forms were inferior polar artery described by 12 authors, superior polar artery (11 authors), an accessory/variant/additional/supernumerary renal artery (7 authors), accessory hilar artery and four renal arteries (described by 5 authors), prehilar segmental branching (3 authors), and codominant arteries, arteries with anterior and posterior segmental divisions and early bifurcation described by 1 author each. A total of 1910 kidneys with anatomical variations in the renal artery were found.

Table 3. Variant forms of renal artery found in the included studies.

Type of Variation	Absolut frequency	Relative frequency
Two renal arteries	892	46.70%
Three renal arteries	82	4.30%
Four renal arteries	6	0.32%
One accessory/variant/additional/supernumerary renal artery	443	23.19%
Artery with anterior and posterior segmental divisions	1	0.05%
Inferior polar accessory artery	90	4.72%
Superior polar accessory artery	118	6.18%
Codominant artery	3	0.15%
Hilar accessory artery	49	2.56%
Early bifurcation	7	0.36%
Prehilar segmentary ramification	219	11.46%
Total	1910	100%

Discussion

The most prevalent anatomical variations were arterial variations, indicating a common occurrence. In this study, these variations were summarized in 11 findings, based on the results obtained from the included studies (COSTA *et al*. 2011; TARDO *et al*. 2017). Briefly, these variations are distributed according to the number of renal arteries arranged in the kidney, that usually ranges from two to six, but our investigation only found up to four renal arteries, where the main ones were the superior pole, the inferior pole and the renal hilum (PALMIERI *et al*., 2011).

Five studies selected for this review reported the presence of four renal arteries, proving to be an unusual finding compared to other variations in the number of arteries, these findings were confirmed by computed tomography angiography, cadaveric dissection, and angiography (CASES *et al* 2017; CRUZAT *et al*. 2013; BOUALI *et al*. 2012; COSTA *et al*. 2011; OZKAN *et al*. 2006). Although the anatomical variations of the renal arteries do not represent an absolute contraindication in performing the transplant, more than three arteries are considered a limiting factor, due to the possible association of the long operation time with a greater risk of complications such as hemorrhage and arterial infarction, thrombosis, stenosis in the suture lines and graft failure (SHIGUEOKA, 2016; TARDO *et al*., 2017).

During the process of renal evolution in the embryological period when the kidney migrates to the lumbar region, many arterial branches regress and a main renal artery (hilar) that originates from the abdominal aorta at the L1–L2 level becomes responsible for supplying blood to the renal parenchyma. In the supposed "normal" pattern, the kidneys are supplied by a single main renal artery. However, caudal arteries may persist in the fully formed kidney, evolving into superior and inferior polar artery (MELLO JÚNIOR *et al*., 2016).

Some authors, such as Panagouli; Tsaraklis; Veneratos (2011); Save; Ratanprabha (2011); Ramulu; Prasanna (2016); Sampaio; Passos (1992); Llado *et al*. (2017); Nagato *et al*. (2013); Lareyre *et al*. (2018); Khamanarong *et al*. (2004); Tardo *et al*. (2017); Çiçekcibaşi *et al*. (2005); Anjamrooz *et al*. (2013); Budhiraja; Rastogi; Asthana (2010); identified the additional renal artery by the irrigated site. These were classified into inferior polar artery and superior polar artery, noting the importance of knowing the distribution site of the artery, since prior knowledge of the existence of polar arteries can predict eventual renal damage (SHIGUEOKA, 2016). Accordingly, Gulas *et al*. (2018) states that the superior polar artery shows a greater risk due to its location, and there may be a mistake on the part of surgeons, when identifying it as surrounding connective tissue, possibly tearing it, and leading to a hemorrhagic process that may result in a harmful state. Twelve studies with inferior polar artery findings were identified compared to 11 studies with superior polar artery, which demonstrates a significant number of polar variant arteries.

Another five studies identified the presence of the hilar accessory artery: Ramulu; Prasanna (2016); Toro *et al*. (2016); Lareyre *et al*. (2019); Khamanarong *et al*. (2004) and Natsis *et al*. (2010), proving to be a prevalent and common finding, because in cases of double renal arteries, usually one artery follows the hilar path and the other in a superior or inferior polar direction, and so on successively.

Furthermore, it was identified in other studies, based on cadaver analysis, the early bifurcation of the renal artery in seven kidneys (SAMPAIO, 1992), that is, the presence of segmental branches at about 1.5–2.0 cm from their origin. It is mentioned as a limiting factor for the vascular anastomosis in the recipient, since there would not be a long pedicle for the renal artery anastomosis (SHIGUEOKA, 2016).

Twenty-three studies were identified with the finding of a double renal artery, according to the literature, the kidneys classified as having a double renal artery, that is, a variant renal artery and a main renal artery is the most common and prevalent finding (HUMBERTO, 2014; BUFFOLI *et al.* al., 2015). Eighteen studies reported triple renal artery observed by computed tomography angiography. Most of these arteries had the termination point in the renal hilum, which demonstrates the arterial pattern (TARDO *et al.* 2017).

According to the study by Lareyre, *et al.* (2019), patients with variant renal arteries had a higher rate of postoperative renal infarction compared to patients without variant arteries. In view of this, performing a preoperative evaluation with computed tomography will help to identify the presence and number of these variant vascular structures in order to prevent possible operative injuries and facilitate surgical planning (TARDO *et al.*, 2017).

The type and knowledge of anatomy are of prime importance for optimal preoperative planning in a surgical or radiological procedure (ARIFUZZAMAN *et al.* 2017). According to Costa *et al.* (2011), knowing these variations is extremely important, as it will help prevent injuries and reduce procedure-related morbidities (LAWTON *et al.* 2016).

Recognizing the presence of multiple renal arteries is of great clinical importance for surgeries and for physicians due to the clinical implications associated with the presence of these vessels, knowledge of renal anatomy and its variations will help in the preoperative planning process, especially for laparoscopic methods, kidney transplants, angiographic interventions and surgeries of the renal region, reducing the risk of fatal events (GULAS *et al.*, 2018; TARDO *et al.* 2017; BUFFOLI *et al.*, 2015). Anatomical variations of the renal arteries, as well as the pattern of their prehilar divisions, should be evaluated, due to their importance regarding renal irrigation and for influencing the dissection plans and access to the renal hilum (PALMIERI *et al.*, 2011).

For Mello Júnior *et al.* (2016), knowing these vessels in advance can change the surgical approach once they can make it difficult to perform endoscopic procedures and reduce the success rate of conventional treatment. Yet, the presence of accessory renal arteries may be also considered a contraindication in transplant surgery (GULAS *et al.*, 2018).

In addition, it is also essential for radiologists to know the variation of these structures, as it will influence the diagnostic process and planning therapy for many vascular diseases (MELLO JÚNIOR *et al.* 2016).

Seven authors: Haladaj, Robert *et al.* (2018); Baniel, J; Foster, RS; Donohue, JP (1995); Anu Dogra *et al.* (2017); Satyapal KS *et al.* (2001); Saldarriaga, Bladimir; Pinto, Sergio A; Ballesteros, Luis E. (2008); James Lawton *et al.* (2017); Juan S. Calle Toro *et al.* (2016), reported the presence of a variant artery. This artery has been described in different ways, as stated by Tardo et al. (2017), with different terms, such as “aberrant”, “accessory”, “additional”, “extra”, “multiple”, and “supernumerary”.

Mello Júnior *et al.* (2016) states that the existence of a single renal artery is favorable and decreases the rates of complications in renal transplantation, since the presence of renal artery variation indicates an increase in the incidence of complications, like vascular thrombosis and difficulty of performing anastomoses. But on the other hand, the graft rejection rate in the first year and the graft survival rate at five years do not seem to be affected by the presence of arterial anatomical variations.

In contrast to what Gulas *et al.* (2018) reports, some studies do not demonstrate an association between the risk of vascular complications and the variation of renal arteries. Concluding that the multiplicity of renal arteries does not interfere negatively in the use of grafts in renal transplantation, in view of vascular, urological complications and patient survival. The study by Budhiraja, Rastogi and Asthana (2010) assures that the use of grafts has become a necessity due to the increasing number of transplants, so the present study states that the graft can be implanted as long as the best surgical technique is observed for the situation, in addition to performing a computed tomography, angiography and arteriography before nephrectomy, in order to avoid complications.

Understanding the variations in renal arterial anatomy becomes important due to the increasing number of renal transplants, renal exploration, vascular reconstructions, renal surgical techniques and uroradiological procedures. Therefore, it is essential to bring awareness about the best surgical management or most appropriate procedure in the aforementioned variants (GULAS *et al.*, 2018; Cicekcibasi *et al.*, 2005).

Conclusion

It is concluded that a higher prevalence of the normal anatomical pattern was observed, with an occurrence greater than 50%. Besides, the most frequent anatomical variation was the presence of a double renal artery with an approximate occurrence of 46%, demonstrated to be a common finding. Thus, prior knowledge of the anatomical variations in renal irrigation may facilitate surgical planning and management, so as not to jeopardize any clinical and surgical approach.

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Mini Curriculum and Author's Contribution

1. Sarah Lorrayne Palmeira Pimentel, FT. post graduate. Contribution: Database search, organization of tables and flowcharts as well as writing of textual elements. ORCID: 0000-0002-4820-4892

2. Ana Beatriz Marques Barbosa, FT. post graduate. Contribution: Database search, organization of tables and flowcharts as well as writing of textual elements. ORCID: 0000-0002-5427-8476

3. Diego Neves Araujo, FT. Contribution: Responsible for translating the article into English. Critical reviewer of textual elements. ORCID: 0000-0002-9541-5852

4. Thiago de Oliveira Assis, FT. Contribution: Responsible for the technical direction of the article. Group guide. Also responsible for statistical execution. Critical reviewer of textual elements. ORCID: 0000-0001-8725-0456

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Corresponding author
Thiago de Oliveira Assis
E-mail: thiago.oa@hotmail.com