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**TITLE:** Anatomical variations of the renal arterial vasculature: An Australian perspective

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**RUNNING TITLE:** Renal arterial variations in Australia

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37 **ABSTRACT:**

38 **Introduction:** Variations of the renal arteries have been studied and published across various  
39 population groups, but similar information for the ethnically diverse nation of Australia is lacking.  
40 This study describes the pattern of renal artery anomalies in a section of the Australian  
41 population based on computed tomography (CT) angiograms of the abdomen and cadaveric  
42 dissection.

43  
44 **Methods:** The renal arterial vasculature of 594 kidneys from 300 subjects (28 cadavers, 272  
45 CT) was studied. The number and pattern of renal arteries were categorised on the basis of  
46 laterality, point of origin and termination in the kidney (superior pole, hilum, inferior pole),  
47 symmetry and sex.

48  
49 **Results:** Multiple renal arteries were discovered in 22% of subjects and 12.12% of kidneys. The  
50 most common pattern observed was the presence of one **variant** renal artery (93.1%),  
51 compared to the finding of two (5.6%) and three (1.4%) **multiple** arteries. The aorta was the  
52 most frequent site of origin for anomalous vessels, whilst the hilum was the predominant point  
53 of entry. No significant difference was established between left and right-sided kidneys (13.8%  
54 versus 12.5%;  $p = 0.627$ ); however, unilateral distribution was more common than bilateral  
55 additional renal arteries (16.7% versus 3.4%;  $p < 0.01$ ), and variations amongst males were  
56 more than females (27.2% versus 15.2%;  $p < 0.05$ ). A higher rate of multiple renal arteries was  
57 noted in cadaveric dissections compared to CT images (46.4% versus 19.5%;  $p < 0.01$ ).

58  
59 **Conclusions:** These findings provide application of an evidence-based teaching tool that  
60 facilitates education regarding renal arterial variations in Australia.

61  
62  
63 **Key words:** renal artery; renal vasculature; kidney; multiple; variation  
64  
65

## 66 INTRODUCTION

67 The traditional teaching of renal arterial variations provided in standard anatomical textbooks  
68 describes these structures as vessels existing in addition to the normal, single, high-calibre  
69 main renal artery and presence of anomalous vessels. 25-30%<sup>(1-3)</sup>. This frequent rate of  
70 incidence reflects the manner in which the renal blood supply is continually changed during  
71 embryonic and early foetal life as a result of migration of kidneys cranially from the pelvis to  
72 where they receive new branches from a more superior aspect of the aorta. The preceding  
73 caudal vessels then usually regress and disappear, but failure to regress leads to anomalous  
74 renal arteries<sup>(4)</sup>.

75  
76 Numerous terms have been utilised in reference to these anomalous arteries, including  
77 “aberrant”, “abnormal”, “accessory”, “additional”, “extra”, “multiple”, “supernumerary”; and  
78 “supplementary”<sup>(1,3,5)</sup>. Whilst the literature has attempted to amalgamate these different names,  
79 alternate perspectives have been promoted regarding their use in recent times<sup>(5-7)</sup>. Papaloucas  
80 and colleagues<sup>(6)</sup> recommend adopting the universal terminology of ‘additional’ as proposed by  
81 Satyapal et al.<sup>(7)</sup> to describe all renal arterial anomalies for greater clarity.

82  
83 By contrast, the use of ‘multiple’ is encouraged as opposed to ‘additional’ to reinforce the  
84 significance of these vessels as independent vascular entities<sup>(7)</sup>. Such a notion highlights the  
85 clinical importance of this structural anomaly and how they are inextricably linked to a key  
86 anatomical principle, that being additional renal arteries act as end arteries. Functionally, this  
87 means that they are responsible for the segmental blood supply of a particular portion of the  
88 renal parenchyma, in the absence of collateral circulation<sup>(5,8)</sup>. The term ‘additional’ may be  
89 perceived as something which can be dispensed with as a non-essential structure. However,  
90 given that these arterial structures are end arteries, disease, obstruction or their ligation result in  
91 diminished blood supply to the segmental tissue. Hence, the term multiple will be adopted  
92 throughout this article.

93  
94 Some examples of their clinical relevance include intraoperative injury or ligation, and occlusion  
95 at their origin during endovascular procedures; or stenosis caused by atherosclerosis,  
96 fibromuscular dysplasia or vasculitis. The sequential repercussions begin with ischemic injury  
97 and focal necrosis, which subsequently leads to a reduction in renal function in addition to  
98 resultant renovascular hypertension<sup>(9)</sup>. As such, awareness of their existence and a clear  
99 attempt to preserve them is essential.

100  
101 Yammine<sup>(10)</sup> recently recommended applying the concept of evidence-based anatomy to the  
102 study of anatomical variations to ensure safe medical practice. This relates directly to additional  
103 renal arteries, encouraging a shift towards the use of research based teaching resources that  
104 are specific to population groups of interest, rather than following generalised incidence rates as

105 stated in textbooks. Variations of the renal arteries have been studied extensively both in  
106 original research articles and case reports, using kidneys from cadavers, radiological  
107 investigations and surgical patients, or various combinations of these modalities of data.

108

109 Previous findings indicate substantial variability in incidence beyond standard teaching, ranging  
110 from 4%<sup>(11)</sup> to 61%<sup>(12)</sup>. The breadth of these data spans studies with samples from 32 different  
111 population groups as reported in a recent publication indicating that considerable ethnic  
112 diversity exists not only between, but also within, these populations<sup>(5)</sup>.

113

114 Determination of the presence of variations according to sex, laterality and symmetry in a given  
115 study has occurred inconsistently. Furthermore, investigations into whether differences exist for  
116 each of these subsets of data based on statistical comparisons are rare. However, pooled  
117 results for each variable are available, which reveal specific trends. With regards to sex,  
118 variations tend to occur more commonly in males<sup>(12-16)</sup> have shown that no difference exists  
119 between the two sexes.

120

121 Most studies show that there is no difference on the basis of laterality<sup>(5,12,13,15-17)</sup>. However, there  
122 is disagreement in the literature with some evidence pointing towards a statistically significant  
123 predominance of variations in both the left<sup>(7)</sup> and right<sup>(18,19)</sup> kidneys. Whilst few studies have  
124 examined symmetry amongst their included variables, the presence of bilateral renal arterial  
125 variations has been shown to range between 10.2%<sup>(7,20)</sup> and 16%<sup>(9)</sup>.

126

127 Despite the large volume of previous relevant work examining the relation between ethnicity and  
128 renal artery variation showing significant variability across different nationalities, data is still  
129 lacking for the ethnically diverse Australian population<sup>(21)</sup>. This study aims to redress this by  
130 conducting a systematic investigation incorporating a thorough description of the variations in  
131 the renal arterial vasculature variations by cataloguing the presence of multiple renal arteries  
132 from both cadaveric and CT samples in an Australian population.

133

## 134 **MATERIALS AND METHODS**

### 135 **Participants and study design**

136 Three hundred subjects (164 females, 136 males; mean age 66 years; range 22–99 years)  
137 were sampled by abdominal CT angiograms (n=272) and cadaveric dissection (n=28), providing  
138 a total of 594 kidneys (297 right, 297 left). Cross-institutional approval by the St John of God  
139 Hospital Ballarat, University of Melbourne Health Sciences; and University of Notre Dame  
140 Australia Human Research Ethics Committees was obtained for this investigation. Given the  
141 retrospective design of the study, consent requirements were satisfied using a standardised  
142 hospital-based waiver signed by all patients for use of the radiological images and the well-  
143 established body donor program in accordance with Australian Federal and State Law through  
144 the University of Melbourne for cadavers.

145

### 146 **Sample size calculation**

147 Previously detected prevalence rates of renal arterial variations provided the basis for the power  
148 calculations, those being 11.2%<sup>(5)</sup>, 36.1%<sup>(17)</sup> and 59.5%<sup>(22)</sup>. A sample size between 152 and 364  
149 would provide an alpha level of 0.05 which was considered sufficient.

150

### 151 **Inclusion and exclusion criteria**

152 Selected abdominal CT angiograms, undertaken for varied clinical indications, had to  
153 demonstrate adequate arterial phase coverage of the abdominal aorta, associated arterial  
154 branches and the iliac arteries. Inclusion of cadavers was dependent upon being newly donated  
155 and thus available for complete dissection. Exclusion criteria relevant to both data sets were  
156 incomplete demographic data, the presence of renal pathology that distorted the gross anatomy  
157 of a kidney's vasculature (for example renal cell carcinoma or crossed fused ectopic and  
158 horseshoe kidney); and previous donor nephrectomy or recipients of renal transplantation. CT  
159 scans which were duplicates or displayed inadequate arterial phase coverage were also  
160 excluded.

161

### 162 **Classification of renal arterial variations**

163 Multiple renal arteries, identified as being independent of the main renal artery, were  
164 categorised according to the Merklin and Michels classification system<sup>(5,9,17,22)</sup>. This system  
165 outlines these anatomical variants based on origin, including the abdominal aorta and the main  
166 renal artery as well as other sources (for example the common iliac artery) and point of  
167 termination in the kidney, whether they are superior polar, inferior polar or hila(9).

168

### 169 **Data collection**

170 The retroperitoneum was visualised by standard anterior dissection of the abdominal cavity at  
171 the University of Melbourne's Department of Anatomy and Neuroscience under the supervision  
172 of experienced prosectors. New cadavers were selected for complete dissection ensuring the

173 relevant renal anatomy had not been distorted. Consecutive CT abdominal and pelvic  
174 angiograms were accessed retrospectively via the PACS (Picture Archiving and Communication  
175 System, Siemens) program and Visage software (Visage 7 Imaging Platform) at the St John of  
176 God Hospital Ballarat. These images had been collected using a 128-slice multi-detector CT  
177 scanner (SOMATOM Definition Edge, Siemens) after the injection of iodine-containing contrast  
178 medium as per hospital protocols. Consecutive selected scans spanned a four-year period from  
179 July 17, 2011 to July 17, 2015 and were reviewed by a current practicing radiologist. Variables  
180 collected for each kidney included the number of renal arteries, their points of origin and  
181 termination and sex.

182

### 183 **Statistical analysis**

184 Incidence rates for each of these variables were recorded using Microsoft Excel. Statistical  
185 comparisons based on laterality (left kidney, right kidney), sex (female, male), symmetry  
186 (unilateral, bilateral) and data sets (CT angiogram, cadaveric dissection) were undertaken using  
187 chi-square analyses (SPSS software, IBM SPSS Statistics for Windows, Version 22.0). An  
188 alpha level of 0.05 was set as the level of significance.

189

190

191

## 192 RESULTS

193 Renal arterial variations were identified in 66 of the 300 participants (22%) and 72 of the 594  
194 kidneys (12.12%) examined in this study. Out of the 72 kidneys with variations present, 67  
195 (93.1%) had one multiple renal artery, four (5.6%) had two multiple arteries and one had three  
196 multiple arteries (1.4%) (Fig. 1). Table 1 summarises the distribution of normal and multiple  
197 renal arteries for left-sided and right-sided kidneys. Findings for laterality demonstrated that of  
198 the 297 left-sided and right-sided kidneys 37(12.5%) and 41 (13.8%) were found to have  
199 multiple renal arteries respectively. No statistically significant difference was found on the basis  
200 of laterality ( $p = 0.071$ ) (Table 2).

201  
202 All subjects had at least one single, dominant renal artery originating from the abdominal aorta.  
203 In the majority of cases multiple renal arteries were found to originate from the aorta. Eight  
204 participants (5 left, 3 right) were found to have the multiple artery originating from the main renal  
205 artery itself. One participant had a right-sided multiple renal artery with its origin at the common  
206 iliac artery, supplying the inferior pole of the right kidney (Table 1).

207  
208 The hilum was the predominant point of termination for renal arterial variations, with a total of 38  
209 (19 left, 19 right) multiple hilar arteries having been detected. Multiple superior polar arteries  
210 were encountered on 24 occasions (8 left, 16 right), whereas the inferior pole received  
211 additional blood supply in 16 participants (10 left, 6 right). Amongst the 294 participants  
212 possessing two kidneys, 49 (16.7%) were found to have unilateral variations, whereas a  
213 significantly smaller number of only 10 (3.4%) had multiple renal arteries bilaterally ( $p < 0.01$ )  
214 (Table 2, Fig. 2).

215  
216 A greater proportion of males possessed multiple renal arteries when compared to their female  
217 counterparts ( $p < 0.05$ ) (Table 2). Specifically, of the 136 male participants 37 (27.2%)  
218 demonstrated the presence of variations, whereas multiple renal arteries were detected in only  
219 25 (15.2%) of the 164 females. When comparing modalities of data collection, a significantly  
220 greater number of variations were found in the cadaveric dissections as opposed to the CT  
221 images (46.4% vs. 19.5%,  $p < 0.01$ ) (Table 2).

222

223

## 224 DISCUSSION

225 This study used both cadaveric dissections and retrospectively reviewed radiological data from  
226 CT angiograms to determine the incidence and pattern of renal arterial variations within an  
227 Australian based population. We used an evidence-based approach, as recommended by  
228 Yammine<sup>(10)</sup>, by supplementing this data collection with statistical comparisons to profile  
229 differences between the specific variables of laterality, symmetry, sex; and data type. We found  
230 additional renal arteries in 22% of participants and 12.12% of the kidneys examined. This result  
231 reflects the standard teaching within primary anatomy based educational resources that state  
232 renal arterial variations present with a common incidence of 25-30%<sup>(1-3)</sup>. Further, these findings  
233 also support the collective results demonstrated in independent literature reviews by Natsis et  
234 al<sup>(5)</sup>, Satyapal et al.<sup>(7)</sup>; and Merklin and Michels<sup>(9)</sup> of 23.3%, 28.1%; and 28% respectively.

235  
236 Despite similarities in the mean number of multiple renal arteries between the current and  
237 aforementioned studies, the literature demonstrates distinct differences have been identified on  
238 the basis of ethnic diversity. In an extensive review article covering the thirty-one major  
239 countries studied to date Natsis et al.<sup>(5)</sup> reported on findings ranging from an incidence as low  
240 as 4%<sup>(11)</sup> in a Malaysian sample, to 61.5%<sup>(12)</sup> in a Brazilian population. Overall, previous work  
241 points towards clear variability existing between population samples.

242  
243 Given this trend and Australia's ethnic diversity, as demonstrated in the most recent census  
244 data showing 28.2% of the country's inhabitants were born overseas<sup>(21)</sup>, it is thus an interesting  
245 population to examine. One would have expected a higher variation in a cross section of  
246 Australia's inhabitants reflecting this ethnic diversity. However, in this investigation renal arterial  
247 variations are comparable to previous studies.

248  
249 Previously reported limitations (for example insufficient sample size in addition to a lack of  
250 inclusion criteria, clear renal artery definitions, standardisation of methodology; and statistical  
251 analyses) concerning study design could explain the outlying differences observed in population  
252 incidence rates. In particular, the lack of non-standardised definitions for renal arterial  
253 variations, influencing which vessels are selected as samples, as well as varied modalities and  
254 methods of data collection<sup>(5,10)</sup> may mean that the results ascertained for different populations  
255 may, in fact not be directly comparable.

256  
257 The current study attempted to overcome the methodological differences outlined above in a  
258 number of ways. Firstly, the novel approach of sample size calculations were utilised to ensure  
259 adequate power, which is a technique overlooked by all previous studies on this topic. Further,  
260 a clear and accepted classification system for describing the variations was adopted, in a  
261 standardised sampling process with clearly defined inclusion and exclusion criteria. Lastly, all  
262 key variables (that is, laterality, sex and symmetry) that had been explored inconsistently across

263 previous studies were selected and compared statistically, to ensure epidemiological  
264 completeness for this population sample.

265

266 It is possible that a molecular explanation may underpin observed differences in variations  
267 across respective ethnic groups on a genetic level<sup>(5)</sup>. For example the production of vascular  
268 endothelial growth factor (VEGF), which is present in embryonal arteries and known to play a  
269 primary role in the proliferation of blood vessels at this early stage of development, is heavily  
270 influenced by genetic and physiologic controls<sup>(23)</sup>.

271

272 The number of multiple renal arteries detected for a given kidney in this study reached a  
273 maximum of three in one individual/subject (1.4%). Of the remaining subjects four possessed  
274 two vessels (5.6%) and 93.1% were found to have one multiple artery. This is in accord with the  
275 literature, which shows that multiple renal arteries usually range from one to three<sup>(5,24)</sup>.  
276 Interestingly, cases of four<sup>(9,20,24,25)</sup> and five<sup>(20,26)</sup> arteries per kidney have been documented in  
277 previous reports, in addition to the presence of seven<sup>(25)</sup> and ten<sup>(26)</sup> renal arteries in both  
278 kidneys for a single individual.

279

280 Clinical implications associated with multiple renal arteries are both medical and surgical in  
281 nature. From a medical perspective renal artery stenosis caused by atherosclerosis or other  
282 vascular diseases, such as fibromuscular dysplasia, pseudoaneurysms, spontaneous renal  
283 artery dissection and vasculitis (for example Takayasu's arteritis), are capable of impairing any  
284 additional vessel thus impeding segmental blood supply and causing ischaemic  
285 nephropathy<sup>(7,27)</sup>. In the case of bilateral renal artery stenosis involving multiple small arteries,  
286 the risk of renal organ failure is significant enough to warrant surgical intervention<sup>(27)</sup>.

287

288 Surgically, multiple renal arteries are considered a relative contraindication to transplantation,  
289 an associated increase in operating time and a greater risk of complications, such as  
290 haemorrhage and infarction, arterial thrombosis, stenosis at suture lines; and graft failure<sup>(27,28)</sup>.

291 As such, preoperative assessment with CT imaging plays an important role in identification of  
292 the presence and number of these variant vascular structures to prevent operative injuries  
293 during laparoscopic surgery with limited visibility and facilitates better surgical planning<sup>(27)</sup>.

294

295 Multiple renal arteries primarily originated from the aorta in the present study, with the exception  
296 in eight samples taking their origin from the main renal artery and in one case branching from  
297 the common iliac artery. The literature reports a number of alternative points of origin for  
298 multiple renal arteries. In addition to the main renal artery<sup>(22)</sup> and common iliac artery<sup>(9)</sup> as  
299 shown in the current investigation, other sites have included the celiac trunk, inferior and  
300 superior mesenteric arteries, thoracic aorta, suprarenal artery, contralateral kidney, splenic,  
301 right hepatic, inferior phrenic, twelfth intercostal, lumbar, middle sacral, gonadal; and right colic

302 arteries<sup>(5,9)</sup>. Variations in origin principally relate to surgical applications. In the context of  
303 correcting abdominal aortic aneurysms, endovascular stents and aortic grafts must be  
304 constructed in a personalised manner to suit the specific arterial anatomy of the individual. In  
305 doing so the patency of the multiple arteries is guaranteed, preventing occlusion of the renal  
306 ostium at the aorta, which should be confirmed by performing a completion angiogram following  
307 the procedure<sup>(29)</sup>.

308  
309 The point of termination for multiple renal arteries in this study was found to be the hilum of the  
310 kidney in 48.7% of cases, whereas the inferior and superior poles received these vessels at a  
311 rate of 20.5% and 30.8% respectively. Studies do however indicate that multiple renal arteries  
312 enter both poles in previous investigation which reported inferior polar variations are more  
313 common in Caribbean and British population samples<sup>(17,20)</sup>. Inferior polar arteries appear to be  
314 of greater clinical significance than superior polar arteries for two important reasons. Firstly, the  
315 upper part of the ureter receives critical blood supply from a branch of the inferior polar artery if  
316 one is present<sup>(9,17)</sup>. Damage to this vessel will result in ureteric necrosis and subsequent  
317 paralysis, or the development of urinary leak<sup>(9,17)</sup>.

318  
319 Secondly, there is a reported risk of ureteropelvic obstruction occurring if the inferior polar artery  
320 originates from the aorta and passes the ureter either anteriorly or posteriorly<sup>(9,17)</sup>.  
321 Consequently, this can lead to the development of hydronephrosis which in time has the  
322 potential to progress to pyelonephritis<sup>(9,17)</sup>.

323  
324 The current study showed left-sided and right-sided variations were present to a similar extent,  
325 being detected at rates of 12.5% and 13.8% respectively ( $p = 0.071$ ). Despite the  
326 inconsistencies evident in previous work, these results agree with the majority of the  
327 literature<sup>(5,12,13,15-17)</sup> which indicates that there is no difference based on laterality. The lack of  
328 dominance regarding left or right-sided variations suggests alternative criteria should be  
329 considered when it comes to surgical decision-making, such as in the case of donor  
330 nephrectomies.

331  
332 Whilst limited data is available regarding symmetry of variations across both kidneys in a given  
333 individual, it has been shown that bilateral variations are less common than unilateral findings  
334 generally occurring between 10.2%<sup>(7,20)</sup> to 16%<sup>(9)</sup>. In this study, bilateral variations were present  
335 in 3.4% of the participants who possessed two kidneys. This result was significantly less than  
336 the 16.7% of subjects with unilateral variations ( $p < 0.01$ ), reflecting trends in earlier studies.

337  
338 This study found multiple renal arteries to be significantly more prevalent in males compared to  
339 females ( $p < 0.05$ ), supporting previous observations<sup>(7,13,14)</sup>. By contrast, Natsis et al.<sup>(5)</sup> indicated  
340 that there is no difference on the basis of sex. Awareness of a higher incidence of variations in

341 males is of note clinically as men are more likely to undergo kidney transplantation since they  
342 are affected by end-stage renal disease more commonly than females<sup>(28)</sup>.

343

344 The efficacy of CT angiograms in detecting additional renal arteries is well established<sup>(24)</sup>.  
345 Despite this demonstrated utility, the comparison between modalities of data collection in this  
346 study demonstrates that variations were significantly more common amongst cadaveric  
347 dissections as opposed to CT angiograms ( $p < 0.01$ ), as reflected elsewhere in the  
348 literature<sup>(5,30,31)</sup>. It is possible that this difference was due to the variation between data sample  
349 sizes, which specifically included 272 CT angiograms compared to 28 cadaveric dissections.  
350 However, the limited availability of cadavers at the time of this investigation required a greater  
351 proportion of the data to be sampled with radiological imaging. Alternatively, some multiple  
352 vessels potentially may have been missed during assessment of the CT images despite being  
353 assessed by a skilled reviewer. Whilst this explanation is unlikely, it is still possible particularly  
354 in the case of small additional arteries. This was shown in one particular investigation whereby  
355 two particular diminutive arteries, measuring less than 2 mm in diameter, were missed on CT by  
356 all three expert reviewers in comparison to intraoperative observations<sup>(31)</sup>.

357

358 These results need to be interpreted within the appropriate context. The current study included  
359 a small population sampling from one state in Australia and unfortunately, due to lack of  
360 information on the subjects' ethnicity we were unable to compare variations on the basis of  
361 ethnicity between subjects in this study with other population groups. Further, the current  
362 investigation did not explore morphometric data, as the focus of our investigation was to  
363 determine the presence and profile of variations amongst subjects. Following the suggestion of  
364 Yammine<sup>(10)</sup>, further work should be directed towards pooling results throughout the current  
365 literature by means of a meta-analysis to more accurately reflect population statistics.

366

367 The incidence of renal arterial variations in the Australian population examined in this study was  
368 22%, consistent with the available body of literature. From a clinical perspective, since the  
369 presence of these structures is so common, there is a small chance they may be missed on CT  
370 angiography; and functionally they act as end arteries, in the intraoperative setting it would be  
371 safest to assume renal arterial variations are present until proven otherwise upon careful  
372 dissection. We believe that this study will encourage further research towards an evidence-  
373 based teaching content of anatomical variations in the Australian context.

374

375

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382

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383 **CONFLICT OF INTEREST**

384 None declared.

385

386

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492

493 **FIGURE LEGENDS**

494

495 **Fig. 1** Cadaveric dissection identifying a single, unilateral multiple renal artery arising from the  
496 aorta and supplying the lower pole of the left kidney

497

498 **Fig. 2** Arterial phase coronal maximum intensity projection (MIP) computed tomography (CT)  
499 image demonstrating bilateral multiple arteries. Both multiple vessels originate from the aorta,  
500 supplying the superior pole of the left kidney and hilum of the right kidney

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502 TABLES

503

504 **Table 1.** Renal artery variations in left and right-sided kidneys.

505

	CT	Cadaveric	Total
<b>LEFT KIDNEY</b>			
<b>Point of Origin</b>	270	27	297
<b>Aortic</b>	270	27	297
<b>Renal artery</b>	3 (1.1%)	2 (7.4%)	5 (1.7%)
<b>Point of Termination</b>			
<b>Superior Polar</b>	3	5	8
<b>Hilar</b>	270	27	297
<b>Single artery</b>	255 (94.4%)	23 (85.2%)	278 (93.6%)
<b>Two arteries</b>	15 (5.6%)	4 (14.8%)	19 (6.4%)
<b>Inferior Polar</b>	5	5	10
<b>RIGHT KIDNEY</b>			
<b>Point of Origin</b>	272	25	297
<b>Aortic</b>	272	25	297
<b>Renal artery</b>	3 (1%)	0	3 (1%)
<b>Common iliac artery</b>	1 (0.4%)	0	1 (0.34%)
<b>Point of Termination</b>			
<b>Superior Polar</b>	8	8	16
<b>Hilar</b>	272	25	297
<b>Single artery</b>	256 (94%)	22 (88%)	278 (93.6%)
<b>Two arteries</b>	16 (5.9%)	3 (12%)	19 (6.4%)
<b>Inferior Polar</b>	4	2	6

506

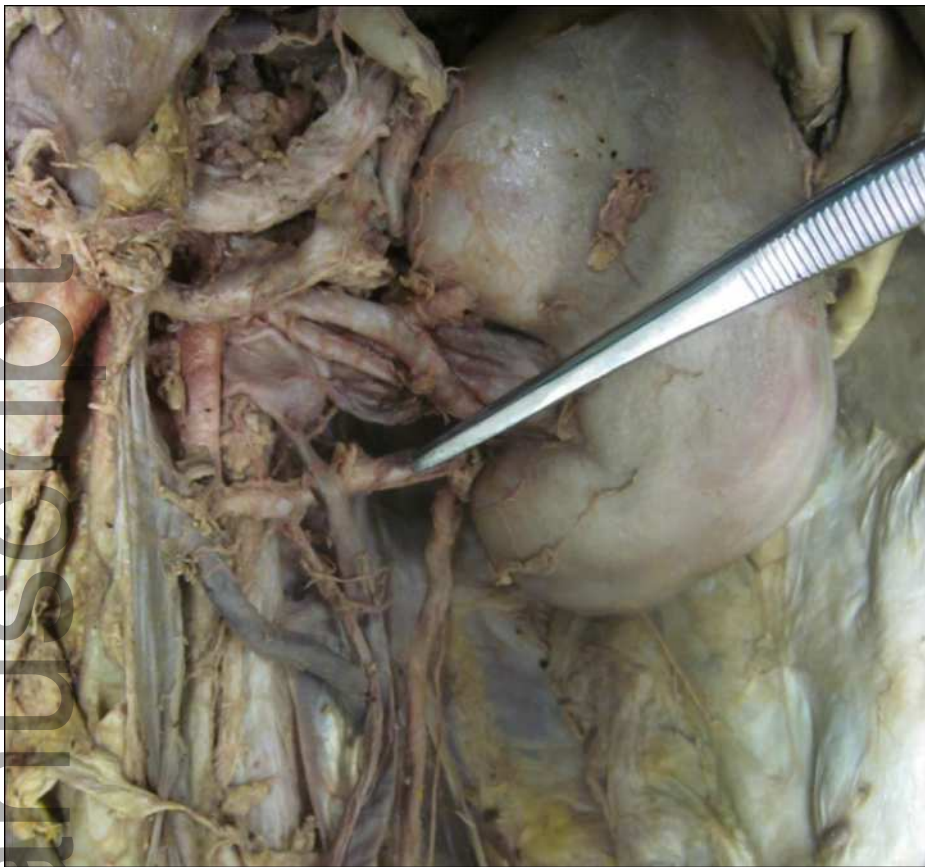
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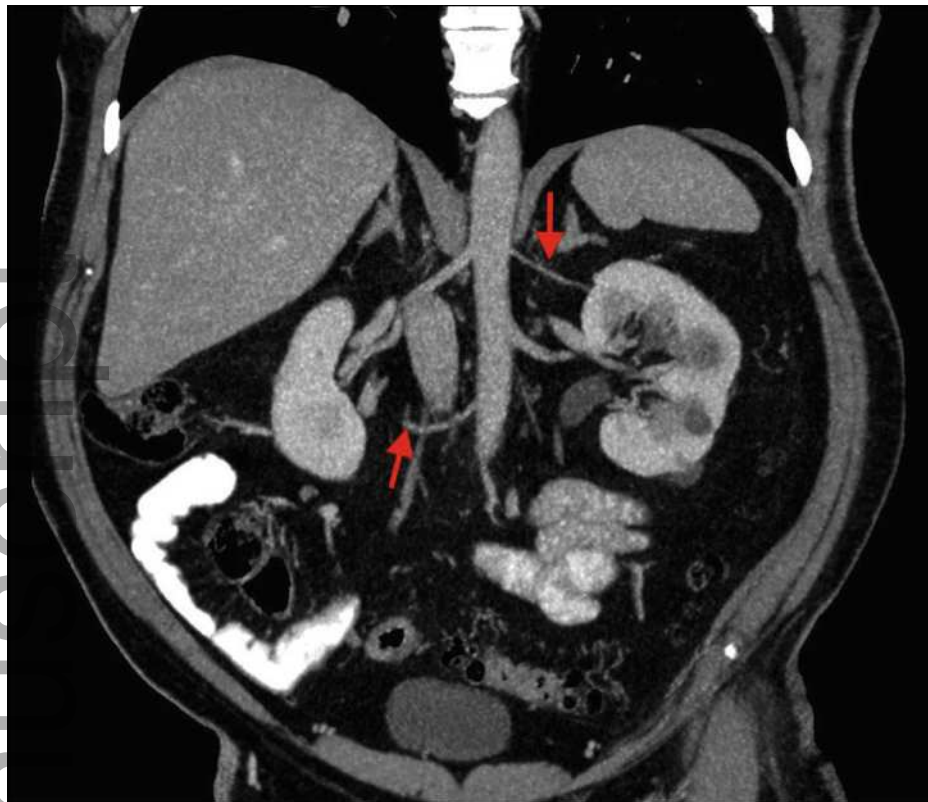
509 **Table 2.** Differences in the presentation of variations in renal arteries based on laterality (left vs.  
 510 right), sex (female vs. male), symmetry (unilateral vs. bilateral) and data modality (CT vs.  
 511 cadaveric) with an alpha value set at  $p < 0.05$ .

512	<b>Variable</b>	<b>Number of Variations</b>	<b>p-value</b>
513	<b>Laterality</b>		
514	<b>Left-sided</b>	37/297 (12.5%)	0.627
515	<b>Right-sided</b>	41/297 (13.8%)	
516			
517	<b>Sex</b>		
518	<b>Female</b>	25/164 (15.2%)	0.011*
519	<b>Male</b>	37/136 (27.2%)	
520			
521	<b>Symmetry</b>		
522	<b>Unilateral</b>	49/294 (16.7%)	< 0.001*
	<b>Bilateral</b>	10/294 (3.4%)	
	<b>Data Modality</b>		
	<b>CT</b>	53/272 (19.5%)	0.001*
	<b>Cadaveric</b>	13/28 (46.4%)	

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