

EXTRARENAL VASCULAR ANATOMY OF KIDNEY: ASSESSMENT OF VARIATIONS AND THEIR RELEVANCE TO PARTIAL NEPHRECTOMY

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ABSTRACT

Objectives. To evaluate the feasibility of selective segmental artery clamping during partial nephrectomy.

Methods. Precise extraparenchymal renal hilar dissection was performed on 73 fixed cadaveric kidneys. The surgical accessibility to clamping of each presegmental and segmental artery from the anterior and posterior approaches was determined on the basis of vessel length, position within the renal hilum, and degree of overlying collecting system or venous structures.

Results. The vascular anatomy consisted of zero, one, or two presegmental arteries (extrarenal main renal artery branches that split into two or more segmental arteries) in 49.3%, 31.5%, and 19.2% of the kidneys, respectively. From a posterior approach, the posterior segmental artery was accessible to isolated clamping in 81.8% of the kidneys (segmental accessibility rate) and was accessible to clamping at the presegmental level in 12.7% (presegmental accessibility rate) for a total accessibility rate of 90.9%. The total accessibility rate for the inferior segmental artery was 88.5% from an anterior and 66.7% from a posterior surgical approach. The apical artery total accessibility rate was 72.3% and 40.5% from an anterior and posterior approach, respectively. The corresponding middle and superior segmental artery total accessibility rates were 50.8% and 32.8%.

Conclusions. In this cadaveric model, hilar dissection and clamping of the renal segmental arteries is anatomically feasible in most cases. Posterior and polar tumors will likely be more amenable to segmental vascular control. Selective segmental vascular control may offer the benefits of total hilar control while reducing overall renal ischemic injury. UROLOGY 66: 985-989, 2005. © 2005 Elsevier Inc.

Nephron-sparing surgery for tumors less than 4 cm offers recurrence and survival rates comparable to radical nephrectomy.¹ Although initially performed with an open approach, with advancement of laparoscopic technology, laparoscopic partial nephrectomy has become a viable alternative for patients with renal tumors.²⁻⁴ The proven techniques of open nephron-sparing surgery have been duplicated in laparoscopic partial nephrectomy.⁵

A technique commonly used in open and laparoscopic partial nephrectomy is the temporary atraumatic occlusion of the main renal artery. With vas-

cular control, visibility is improved, allowing for tumor excision and collecting system reconstruction in a bloodless field.

Renal ischemic injury is a risk of arterial occlusion. Clamping a branch of the main renal artery may provide a bloodless operative field and obviate the risk of ischemic injury to most of the kidney. Graves⁶ provided the first detailed account of renal vascular segmentation in 1954 and described five segments: (a) apical, encompassing the superior pole; (b) superior, including the remainder of the anteromedial portion of the superior pole; (c) inferior, occupying the lower pole; (d) middle, occupying the anteromedial portion between the superior and inferior segments; and (e) posterior, including the whole posterior region between the apical and inferior segments (Fig. 1). His terminology was adopted by subsequent surgeons and continues to serve as the current teaching model.

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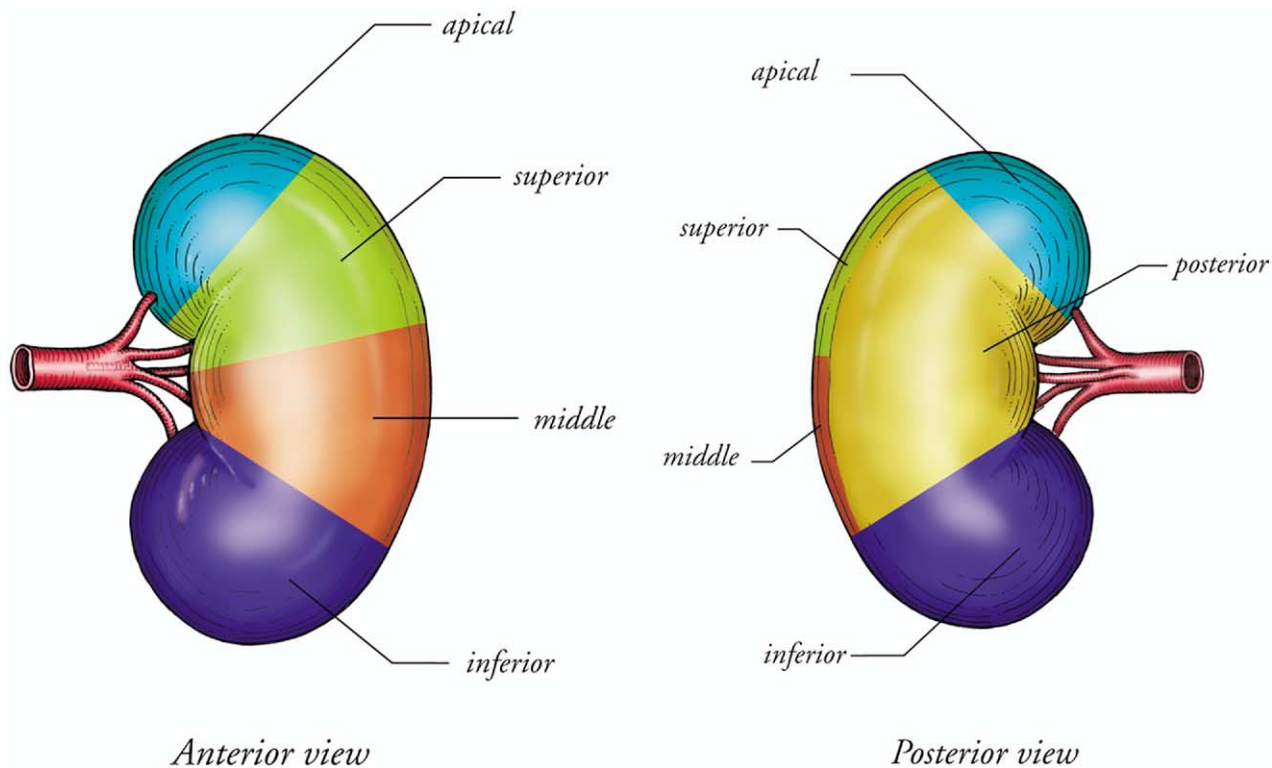


FIGURE 1. Graves' classic description of renal vascular segmentation.

Despite the extensive dissections and descriptions of Graves,⁶ vascular variances have not been well described. Because hilar occlusion during open nephron-sparing surgery could be accomplished en bloc and with cold ischemia, the clinical relevance of such anomalies was not readily apparent. With the advent of laparoscopic partial nephrectomy, warm ischemia becomes an increasing concern, because of the challenges with renal hypothermia using the laparoscopic approach. Additionally, owing to the improved surgical field illumination and magnification associated with laparoscopy, we frequently identify, and occasionally selectively ligate, segmental and presegmental renal vasculature with precise opercular hilar dissection. As such, with our improved ability to dissect and identify components of the renal hilar vasculature safely, selective arterial occlusion may be a preferred method of vascular control. The objective of this study was to evaluate the variations in extrarenal anatomy for the assessment of feasibility of selective segmental artery clamping during partial nephrectomy.

MATERIAL AND METHODS

A total of 73 formalin-preserved cadaveric kidneys were harvested by transecting vascular structures at their origin from the aorta and inferior vena cava. Meticulous bench dissection of the extraparenchymal hilar structures was performed. Presegmental (main renal artery branch that splits into two or more segmental arteries) and segmental (branch

that enters the parenchyma) branches of the main renal artery were identified. The distribution and length of each arterial branch were recorded. The accessibility to clamping of each presegmental and segmental artery was determined by an experienced renal surgeon based on vessel length, position within the renal hilum, and degree of overlying collecting system or venous structures.

The segmental accessibility rate was calculated by dividing the number of accessible segmental arteries by the total number of segmental arteries. The presegmental accessibility rate was defined as the number of segmental arteries arising from an accessible presegmental artery divided by the number of segmental arteries. The total segmental accessibility rate was defined as the rate at which it was feasible to achieve selective vascular control of a particular renal segment by clamping either the segmental or presegmental branches. As some segmental branches are accessible to clamping at the presegmental and segmental levels, the total accessibility rate was somewhat less than the sum of the segmental and presegmental accessibility rates.

Statistical analyses were performed with two-tailed *t* test comparisons.

RESULTS

Of the 73 kidneys, 64 (87.7%) had a solitary renal artery and 9 (12.3%) had two main renal arteries defined as an artery traveling from the aorta to the renal hilum. The average diameter of a main renal artery was 7.9 mm (range 4 to 12). Accessory polar arteries were defined as arteries originating from the aorta and entering the superior or inferior pole away from the hilum. Of the 73 kidneys, 55 (75.3%) had no polar arteries, 11 (15.1%) had in-

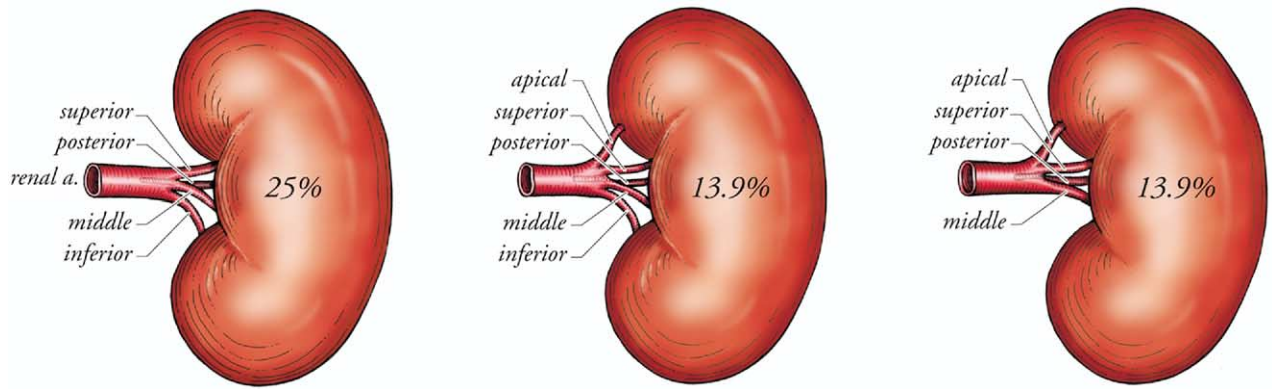


FIGURE 2. Most common vascular configurations among kidneys without presegmental branches and their frequency of occurrence.

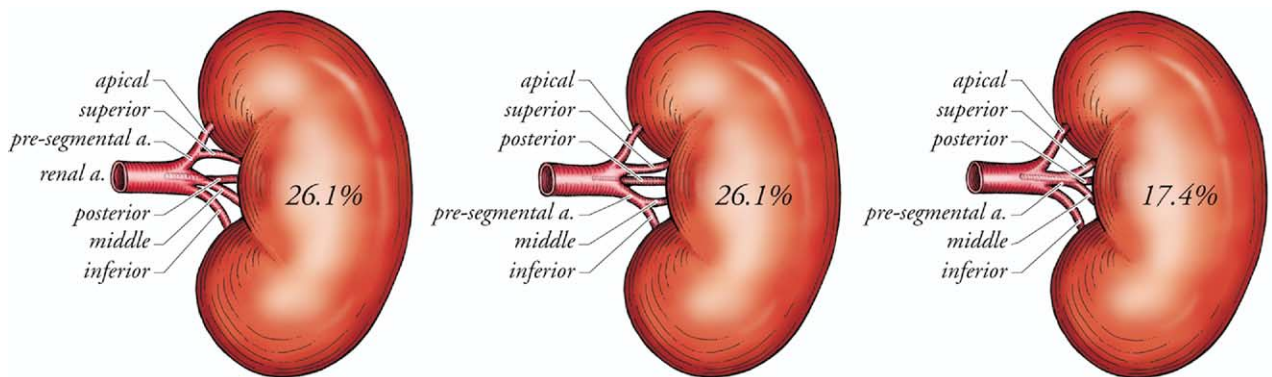


FIGURE 3. Most common vascular configurations among kidneys with one presegmental branch and their frequency of occurrence.

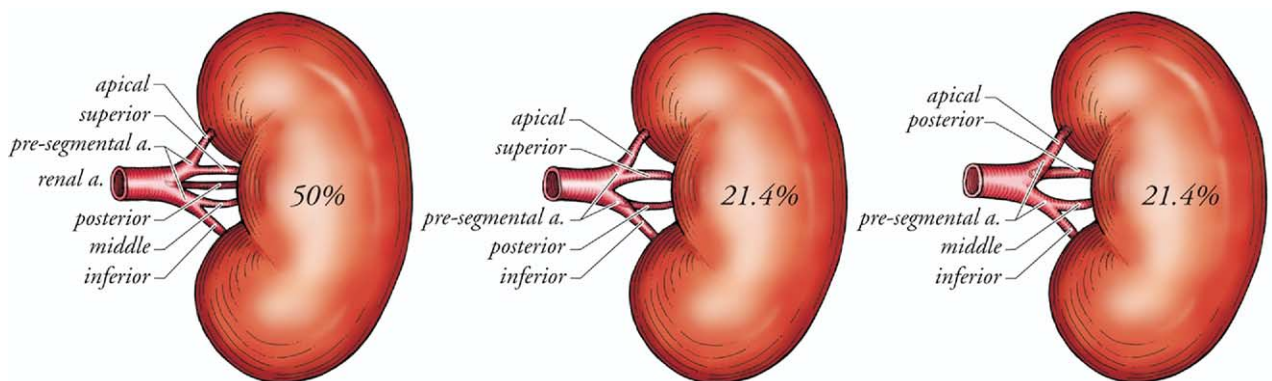


FIGURE 4. Most common vascular configurations among kidneys with two presegmental branches and their frequency of occurrence.

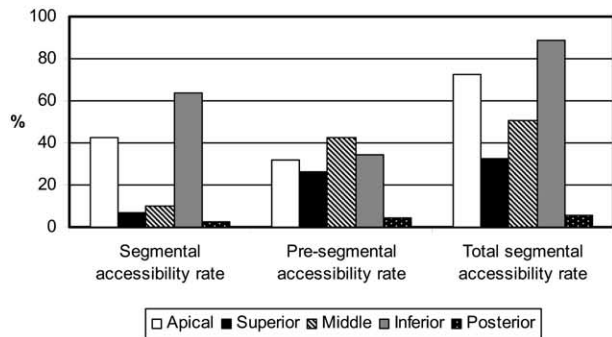
ferior pole arteries, and 7 (9.6%) had superior pole arteries. A total of 43 kidneys had main renal arteries with a clearly discernible first branch: 32 (74.4%) posterior, 7 (16.3%) apical, and 3 (7.0%) inferior segmental branches.

Most kidneys had 3 (21.9%), 4 (34.2%), or 5 (31.5%) segmental arteries. Superior, middle, and inferior segmental branches were each found in 61 (83.6%) kidneys. Kidneys were less likely to pos-

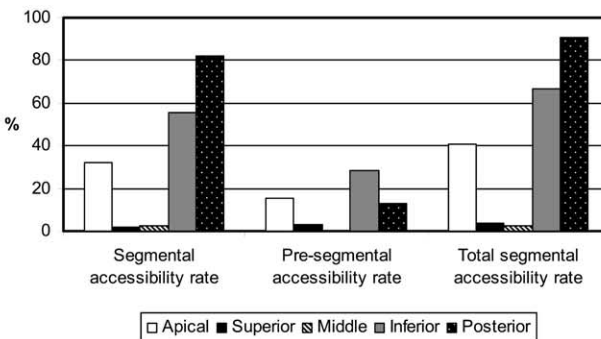
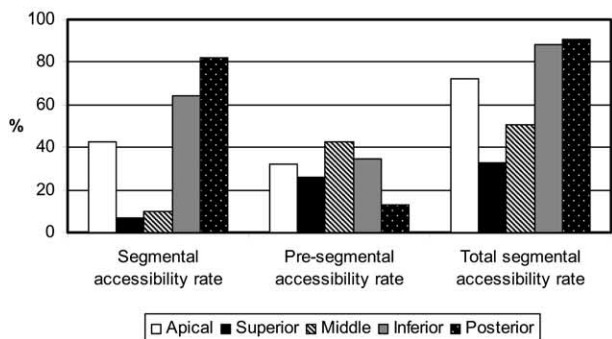
sess posterior or apical segmental arteries (75.3% and 64.4%, respectively).

Of the 73 kidneys, 36 (49.3%) had no presegmental arteries (Fig. 2), 23 (31.5%) had one presegmental artery (Fig. 3), and 14 (19.2%) had two presegmental arteries (Fig. 4).

The average length of the segmental arteries that was accessible and inaccessible to selective clamping was 30 mm (range 12 to 38) and 13 mm (range



A



B

C

FIGURE 5. (A) Segmental artery accessibility rates from an anterior surgical approach. (B) Segmental artery accessibility rates from a posterior surgical approach. (C) Segmental artery accessibility rates regardless of surgical approach.

3 to 19), respectively ($P < 0.01$). The average length of the combined presegmental and segmental arteries that was accessible and inaccessible to selective clamping was 31 mm (range 23 to 82) and 18 mm (range 10 to 43), respectively ($P < 0.01$). Figure 5 summarizes the accessibility rates of the segmental and presegmental arteries according to surgical approach.

COMMENT

The accessibility of a segmental artery from a particular approach has become particularly relevant to laparoscopic procedures. As our institutional experience with laparoscopic partial nephrectomy has grown, precise hilar dissection, including dissection of the segmental arteries, has been safely performed on a routine basis. It has become relatively common practice to dissect, and occasionally selectively ligate, renal segmental vessels during challenging hilar partial nephrectomies. Combined with the increasing application of laparoscopic duplex ultrasonography to evaluate the areas of renal ischemia achieved with selective hilar clamping, segmental vessel control may become a routine technique for performing open and laparoscopic partial nephrectomy while protecting most of the kidney from any ischemic insult.

Laparoscopic partial nephrectomies are approached from either a transperitoneal approach with anterior access to the hilum or a retroperitoneal approach with posterior access to the hilum.

In open procedures, anterior or posterior hilar access can usually be obtained. Therefore, when selective segmental artery clamping is planned, the data in Figure 5A and 5B are helpful in planning a laparoscopic surgical approach; the accessibility rates regardless of surgical approach shown in Figure 5C are most relevant to open procedures.

The artery length is a statistically significant objective factor in determining the accessibility to vessel clamping. Other factors influencing accessibility to clamping were more subjective, but an experienced surgeon performed all dissections and determinations of vessel accessibility. These subjective factors included vessel position within the hilum and degree of overlying structures. The influence of these factors was evidenced by segmental accessibility rates of less than 10% for the centrally located superior and middle arteries deep within the hilum, regardless of the direction of the surgical approach (Fig. 5). However, the apical and inferior segmental accessibility rates were greater (ranging from 32.1% to 63.9%, depending on the approach) owing to their more peripheral location. The apical segmental artery was more accessible from an anterior surgical approach (72.3%) than from a posterior approach (40.5%). The inferior segmental artery was accessible in most kidneys from the anterior (88.5%) and posterior (66.7%) approaches. The posterior artery has a high segmental accessibility rate (81.8%) because of its prominence from the posterior approach.

A limitation of the current study involved the use of fixed *ex vivo* kidneys for evaluation. Alterations in the renal anatomy during the removal and fixation of the kidneys may have occurred. However, care was taken to transect the main renal artery and vein at their origin from the great vessels to preserve the hilar anatomy as much as possible.

One half of the kidneys in this series possessed an arterial configuration consisting of one or two presegmental vessels. We defined a presegmental vessel as a branch of the main renal artery that divided into two or more segmental arteries. The segmental arteries then enter the renal parenchyma. To our knowledge, presegmental renal vasculature has not previously been described. Clamping segmental arteries offers a highly selective interruption of renal blood flow to a solitary renal segment. Presegmental arteries are also amenable to clamping. Occlusion of a presegmental artery offers less selective renal blood flow interruption because two or more segments of the kidney will be affected.

However, clamping a presegmental artery may be advantageous for larger tumors or tumors that overlap renal segments. For these tumors, selective clamping can be performed with simultaneous observation of the renal parenchyma. A line demarcating the perfused and nonperfused parenchyma is usually apparent by visual inspection. Alternatively, we have used laparoscopic duplex ultrasonography to confirm transient devascularization of the renal parenchyma if inspection of the kidney is not definitive. If selective clamping is not sufficient as determined from this intraoperative observation, clamping a less selective presegmental artery may be an option or main renal artery clamping may be required. Additionally, if access to a segmental artery is challenging, presegmental arterial control can still spare most of the kidney from an ischemic challenge.

In our practice, with extensive experience, the excellent illumination of the operative field and magnified vision associated with a laparoscopic approach have made renal hilar dissection of some segmental renal artery branches feasible with minimal risk. We currently are compiling laparoscopic partial nephrectomy cases in which a segmental or presegmental artery was temporarily clamped or clipped for tumors consuming the entire renal seg-

ment. We have achieved safe nephron-sparing excision with selective vascular control in 7 cases to date. Certainly, dissection of the renal segmental vasculature is associated with the risk of vascular injury and hemorrhage. As such, each surgeon must balance the benefits of renal parenchymal preservation associated with selective renal segmental arterial control with the risk of hemorrhage.

Extensive opercular hilar dissection with selective renal segmental or presegmental vascular occlusion may serve as another tool in the renal surgeon's armamentarium. Selective renal artery occlusion or ligation, particularly of the lower pole segmental and presegmental arteries, may allow laparoscopic partial nephrectomy to be performed with minimal ischemic risk to the kidney remnant. Additional *in vivo* studies are needed to address the utility and safety of selective hilar vascular control.

CONCLUSIONS

The extrarenal arterial anatomy consists of presegmental and segmental branches of the main renal artery. Segmental artery clamping is anatomically feasible and minimizes the number of nephrons exposed to potential ischemic injury. If selective segmental clamping is not sufficient, clamping a less selective presegmental artery may be a viable option. Segmental accessibility rates may factor into the choice of laparoscopic surgical approach.

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