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Experimental Model of Upper-Pole Nephrectomy Using Human Tridimensional Endocasts: Analysis of Vascular Injuries

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Abstract

Purpose: The aim of the study is to establish an experimental model for upper-pole nephrectomy using tridimensional endocasts of human kidneys.

Materials and Methods: We studied 104 kidneys from 52 adults. The ureters, veins, and arteries were dissected and injected with yellow, blue, and red polyester resin, respectively. While this resin was still in the gel state, we performed upper-pole guillotine sections at various distances from the hilar zone, thereby dividing our sample in four groups: A. Hilar zone: 22 kidneys (10 with vein and ureter injection); B. 0.5 cm from the hilar zone, 32 kidneys (9 with vein and ureter); C. 1.0 cm from the hilar zone, 24 kidneys (11 with vein and ureter); and D. 1.5 cm from the hilar zone, 26 kidneys (6 with vein and ureter). We also determined the mean distance from the retropelvic artery to the section plane.

Results: Sections performed at the hilar region and at 0.5 cm from hilar region had an alarming rate of injuries to the retropelvic artery and vein, upper segmental artery, and upper venous trunk. In both groups, the distance between the section plane and retropelvic artery was a mean less than 1.0 cm. Sections performed at 1.0 cm and at 1.5 cm from the hilar region had a significantly lower injury rate, with mean distance between section plane and retropelvic artery more than 1.0 cm.

Conclusions: Upper-pole nephrectomies performed at less than 1.0 cm from the hilar zone had a significantly high incidence of injuries in larger arteries. Nephrectomies at this level should therefore be avoided or performed with maximum care.

Introduction

Partial nephrectomy may be performed both in benign and malignant conditions. In patients who present with benign disease that is limited to specific regions of the kidney, partial nephrectomy is a sounder method than total nephrectomy. For renal tumors, radical nephrectomy is still the treatment of choice.[1] There are, however, classic indications for partial nephrectomy in patients with renal tumor: Tumor in a solitary kidney, bilateral tumors, or in patients with progressive benign disease that is contralateral to the tumor.[1,2–4]

With the introduction of imaging diagnostic methods and their routine use, early diagnosis of renal masses is becoming usual. Localized small tumors (smaller than 4 cm) in patients with a normal contralateral kidney are cases in which partial nephrectomy may be considered.[5–7] The first laparoscopic nephrectomy was performed in early 1990s.[8] Since then, several urologic procedures have been performed with this method, including partial nephrectomy.[9]

To perform a partial nephrectomy via the conventional route or laparoscopically, the most relevant issue is the understanding of intrarenal anatomy, especially the anatomy of the upper pole of the kidney. Perfect knowledge and identification of intrarenal anatomy may allow complete removal of the affected area with maximal preservation of functioning renal parenchyma.

Previous studies[10–15] assessed intrarenal anatomy and anatomy of the upper pole of the kidney quite well, becoming a base for various urologic procedures, including partial nephrectomy. Accurate knowledge of intrarenal anatomy and the use of experimental models are of great value to better understanding and an adequate performance of partial nephrectomy.

Anatomic studies of intrarenal anatomy of the upper pole of the kidney are extensive. The performance of upper-pole nephrectomy in experimental models using human kidneys, with an accurate analysis of the vascular damage, are uncommon.

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The aim of this study is to arrive at an anatomic model applied to upper-pole partial nephrectomy to assess the section plane at which the greatest risk of vascular damage occurs.

Materials and Methods

One hundred and four kidneys were studied from 52 adults whose genitourinary system had no macroscopically detectable pathologies. The material was obtained from necropsies performed within 6 and 24 hours after death. Ureters, renal arteries, and veins were dissected and injected with resin to obtain tridimensional endocasts, according to the technique previously described.[10–15] After injection, the kidneys were cleaned to perform morphometric measurements. In 68 kidneys, we injected the arteries and the ureter, and in 36 kidneys, we injected the veins and the ureter.

The following measures were obtained: Kidney length, upper-pole width, inferior pole width, hilar width, hilar length and thickness. All measurements were performed with a 0.01 cm precision pachymeter.

While the resin was still in the gel state, we performed upper-pole guillotine sections at various distances from the hilar zone (Fig. 1). Our sample was then divided in four groups, accordingly to the point of the section:

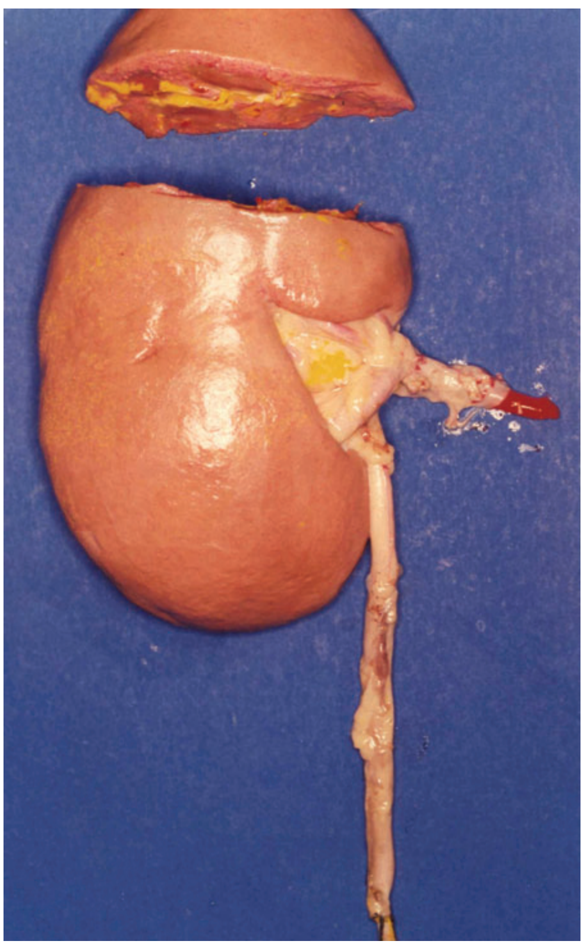

FIG. 1. The kidney was injected with yellow resin (ureter) and red resin (renal artery). While the resin was still in the gel state, we performed upper-pole guillotine section at 1.0 cm from the hilar zone.

A. Hilar zone: 22 kidneys (10 with vein and ureter injection).
B. 0.5 cm from the hilar zone; 32 kidneys (9 with vein and ureter).
C. 1.0 cm from the hilar zone; 24 kidneys (11 with vein and ureter).
D. 1.5 cm from the hilar zone; 26 kidneys (6 with vein and ureter).

After polymerization of the resin, kidney samples were placed in HCl for corrosion of organic matter, which yielded tridimensional endocasts of the arterial and collecting systems and venous and arterial systems. We then examined the casts for damaged structures at the different section planes. The structures evaluated were:

1. Arteries: Upper segmental, posterior segmental (retropelvic), and infundibular arteries; we also determined the mean distance from the retropelvic artery to the section plane (DRASP).
2. Veins: Stellate, arcuate veins, infundibular, main venous trunk, and retropelvic vein.

To perform the contingence analysis of the populations studied, we used the Fisher exact test ($P < 0.05$). This study was approved by the Bioethics Committee of our hospital.

Results

From 68 kidneys in which the arteries and collecting system were studied, 57 (83.8%) had one artery, 9 (13.2%) had two arteries, and 2 (2.9%) had three arteries. Kidneys with multiple arteries were excluded from the study. The values for DRASP in this group are shown in Table 1. Arterial and venous damages in the four groups studied are described below.

Section plane at hilar zone

This group includes 20 kidneys: 10 with injection of the artery and collecting system, and 10 with injection of the vein and collecting system.

Arteries. In two (20%) cases, retropelvic artery damage occurred (Fig. 2). In eight (80%) cases, the upper segmental artery was injured (Fig. 3). All cases in this group had injury of the infundibular arteries. DRASP in this group ranged from 0.1 to 1.2 cm (mean 0.43 cm).

Veins. In two (20%) cases, damage of the upper venous trunk occurred (Fig. 4). The retropelvic vein was present in eight cases, and in two (25%), injury occurred (Fig. 5). All cases in this group had damage of the interlobular, arcuate, and stellate veins.

Table 1. Range and Mean of the Distance from Retropelvic Artery to Section Plane in Experimental Partial Nephrectomy for Four Groups

Section plane	*DRASP (range)*	*DRASP (mean)*
Hilus	0.1 to 1.2 cm	0.43 cm
0.5 cm	0.1 to 1.6 cm	0.71 cm
1.0 cm	0.2 to 2.3 cm	1.14 cm
1.5 cm	0.1 to 3.9 cm	1.3 cm

DRASP = distance from the retropelvic artery to the section plane.

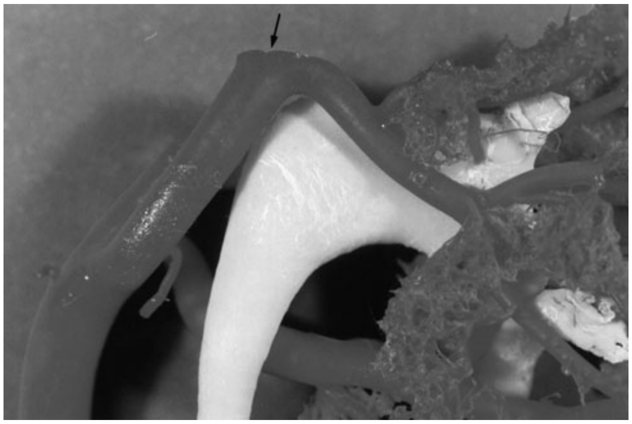

FIG. 2. Tridimensional cast of arterial and collecting systems, with a section at the hilar region. Note injury to the retropelvic artery (arrow).

Section plane at 0.5 cm from the hilar zone

This group includes 29 kidneys: 20 with injection of artery and collecting system, and 9 with injection of vein and collecting system.

Arteries. We observed damage to the retropelvic artery in one (5%) case. The upper segmental artery was injured in four (20%) cases (Fig. 6). In all cases, the infundibular arteries were damaged. DRASP ranged in this group from 0.1 to 1.6 cm (mean 0.71 cm).

Veins. In two (22%) cases, damage to the upper venous trunk occurred. The retropelvic vein was present in seven cases, and in one (14.2%), injury occurred. All cases in this group had damage to the interlobular, arcuate, and stellate veins.

Section plane at 1.0 cm from the hilar zone

This group includes 22 kidneys: 11 with injection of the artery and collecting system, and 11 with injection of the vein and collecting system.

Arteries. The retropelvic artery was not damaged in this group. In one (9%) case, the upper segmental artery was injured (Fig. 7). In all cases, the infundibular arteries were damaged (Fig. 8). DRASP ranged in this group from 0.2 to 2.3 cm (mean 1.14 cm).

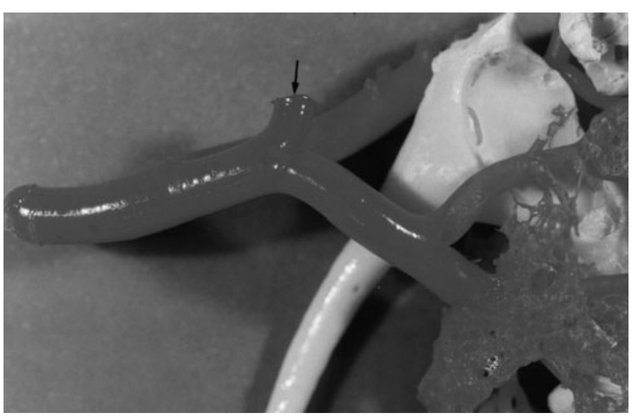

FIG. 3. Tridimensional cast of arterial and collecting systems, with a section at the hilar region. Note injury to the upper segmental artery (arrow).

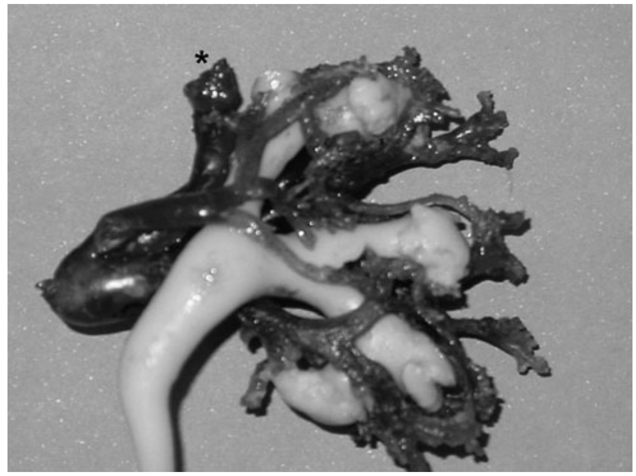

FIG. 4. Tridimensional cast of venous and collecting systems, with a section at the hilar region. Note injury to the upper venous trunk (asterisk).

Veins. In 1 (9%) case, damage to the upper venous trunk occurred. The retropelvic vein was present in nine cases, and no injury occurred. The interlobular veins were damaged in 10 of 11 (90.9%) cases (Fig. 9). All cases in this group had damage to the arcuate and stellate veins.

Section plane at 1.5 cm from the hilar zone

This group includes 22 kidneys: 16 with injection of the artery and collecting system, and 6 with injection of the vein and collecting system.

Arteries. The retropelvic artery and upper segmental artery were not damaged in this group. In all cases, we observed damage to the infundibular arteries. DRASP ranged in this group from 0.1 to 3.9 cm (mean 1.3 cm).

FIG. 5. Tridimensional cast of venous and collecting systems, with a section at the hilar region. The section is very close to the retropelvic vein (asterisk).

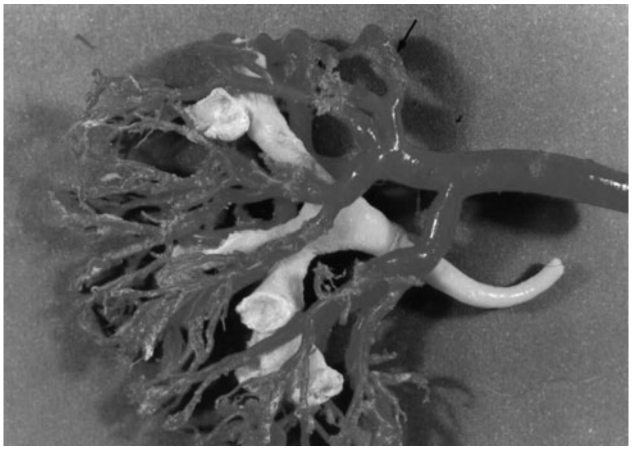

FIG. 6. Tridimensional cast of arterial and collecting systems, with a section at 0.5 cm from the hilar region. Note injury to the upper segmental artery (arrow).

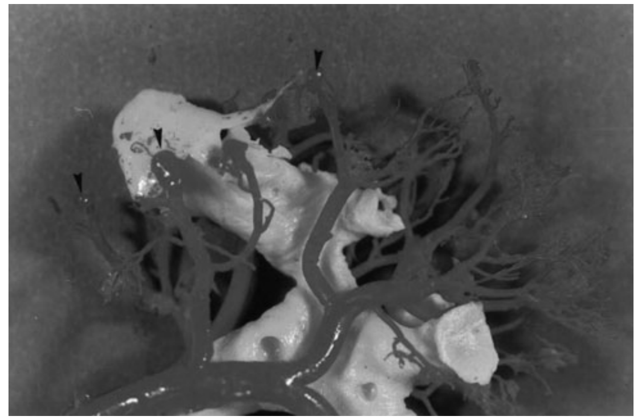

FIG. 8. Tridimensional cast of arterial and collecting systems, with a section at 1.0 cm from the hilar region. Note injury to the infundibular arteries (arrows).

Veins. There was no damage to the upper venous trunk, interlobar veins, and retropelvic vein that was present in all cases. Arcuate veins were damaged in four of six (66%) cases. All cases in this group had damage to the stellate veins.

The arteries and veins damaged in the various groups studied are shown in Tables 2 and 3.

Discussion

In most (86.6%) cases, the arterial supply to the upper pole originates from two arteries—one from the anterior division and the other from the posterior division of the renal artery.[11] The upper infundibulum is surrounded by these two arterial trunks. An important anatomic feature of the upper pole of the kidney is the position of the posterior segmental artery or retropelvic.[11,15] In 57% of the cases, there is a close relation between the retropelvic artery and the upper infundibulum, or with its junction with the renal pelvis.[11]

Venous draining of the upper pole is accomplished by two plexuses located anteriorly and posteriorly to the upper infundibulum, respectively.[12] The retropelvic vein that is draining the posterior area of the kidney is present in approximately 70% of cases.[12]

Knowledge of upper-pole anatomy is of the utmost importance for the performance of partial nephrectomy, because the retropelvic artery may be responsible for the supply of up to 50% of the renal parenchyma,[16] and the infundibular arteries, the venous plexus (upper venous trunk and interlobar veins), and the retropelvic vein may be injured during partial nephrectomy, both conventional and laparoscopic.[17]

Partial nephrectomy by laparoscopy is an efficient method, with the benefit of being minimally invasive.[18] The understanding of intravascular renal anatomy is one of the most important factors for performing this procedure, as well as the determining factor for performing laparoscopic renal cryosurgeries.[19]

The anatomic bases are very important during the execution of surgical interventions. Information about local anatomy and the probable place where injuries are more significant are crucial to the surgeon. Because of the scarceness in medical literature of experimental models with human

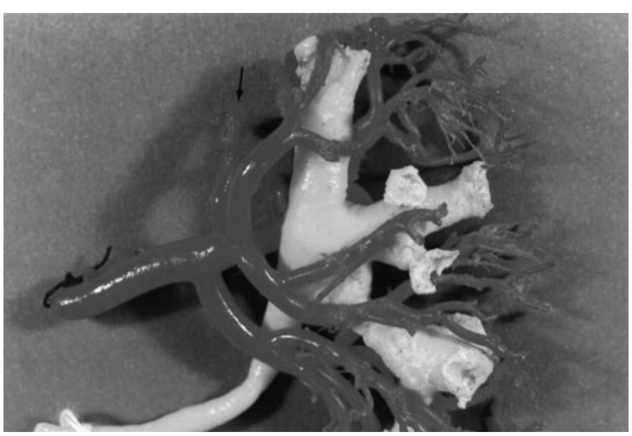

FIG. 7. Tridimensional cast of arterial and collecting systems, with a section at 1.0 cm from the hilar region. Note injury to the upper segmental artery (arrow).

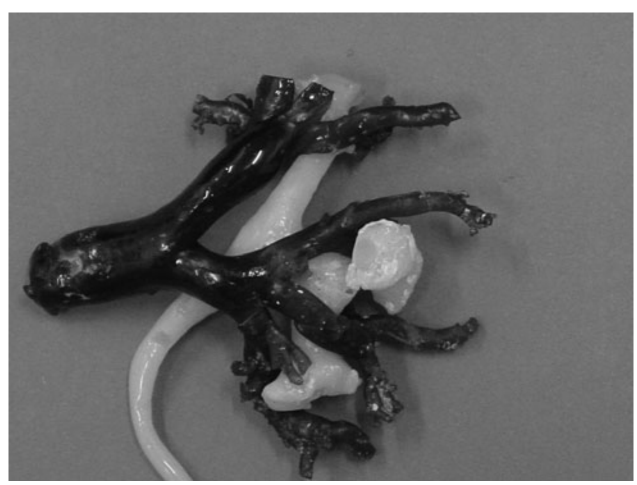

FIG. 9. Tridimensional cast of venous and collecting systems, with a section at 1.0 cm from the hilar region. Note injury to the interlobar veins.

Table 2. Incidence of Arterial Injury at Various Section Planes

Arterial injuries	*Hilus*	*0.5 cm*	*1.0 cm*	*1.5 cm*
Retropelvic	20%	5%	0	0
Upper seg.	80%	20%	9%	0
Infundibular	100%	100%	100%	100%

Upper seg = upper segmental artery.

kidneys applied to partial nephrectomy of the upper pole, this article presents results that may serve as a basis to assist this kind of intervention, indicating the spots where vascular lesions are more frequent and serious.

Regarding the arteries, we observed the presence of a solitary artery in 83.8%, which is consistent with previous anatomic studies.[13] In cases with a solitary artery that underwent experimental partial nephrectomy at the hilar region, we observed a high rate of larger arterial trunks injury. The retropelvic artery was injured in 20% of cases, and the upper segmental artery was incised in 80% of cases. In the group of section plane at the hilar region, we observed an upper venous trunk lesion in 20% of cases and of the retropelvic vein in 25%. These figures show that hilar sections are significantly hazardous, potentially leading to larger vessels injury (arteries or veins) in up to 70% of cases.

In nephrectomies that are performed at 0.5 cm from the hilar region, there were lower injury rates, although still significant. We observed upper trunk venous injury in 22% of cases and of the retropelvic vein in 14%. The retropelvic artery was injured in 5% of cases and the segmental superior artery in 20%. In both groups (hilar region and at 0.5 cm from hilar region sections), the mean DRASP was less than 1 cm, a small space between the section plane and retropelvic artery. Sections performed at this plane injured larger vessels in 27.5% of cases.

In groups with sections performed at 1.0 and 1.5 cm from the hilar region, we did not observe a retropelvic artery or vein lesion in any case. In the group with the section performed at 1.0 cm from the hilar region, upper segmental artery injury was observed just in 1 (9%) case and upper venous trunk injury in 1 (9%) case. In both groups, the mean DRASP was more than 1.0 cm. The injury rate of larger vessels in both groups was small—merely 4.1%.

Section plane performed at the hilar region and at 0.5 cm from the hilar region had an alarming rate of injuries to the retropelvic artery and vein, upper segmental artery, and upper venous trunk. In both groups, the distance between the section plane and retropelvic artery had a mean less than 1.0 cm, a significantly small space.

Sections performed at 1.0 cm and at 1.5 cm from the hilar region had a significantly lower injury rate, with the mean distance between the section plane and retropelvic artery more than 1.0 cm.

Table 3. Incidence of Venous Injuries at Various Section Planes

Venous injuries	*Hilus*	*0.5 cm*	*1.0 cm*	*1.5 cm*
Retropelvic	25%	14.2%	0	0
UVT	20%	22%	9%	0
Interlobar	100%	100%	90.9%	0
Arcuate	100%	100%	100%	66.6%
Stellate	100%	100%	100%	100%

UVT = upper venous trunk.

Conclusion

This experimental model shows that partial nephrectomies performed at less than 1.0 cm of the hilar region present a high incidence of important arteries and veins. Partial nephrectomies in this region should be avoided or performed with maximum care.

Acknowledgment

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Disclosure Statement

No competing financial interests exist.

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Abbreviation Used

DRASP = distance from the retropelvic artery to the section plane