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

Luciano Alves Favorito, M.D., Djair Aquino Brito, M.D., and Francisco J.B. Sampaio, M.D.

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. 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.

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. The first laparoscopic nephrectomy was performed in early 1990s. Since then, several urologic procedures have been performed with this method, including partial nephrectomy.

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 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.
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. 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:

<table>
<thead>
<tr>
<th>Section plane at hilar zone</th>
<th>Number of Kidneys</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 cm from the hilar zone</td>
<td>32 kidneys (9 with vein and ureter)</td>
</tr>
<tr>
<td>1.0 cm from the hilar zone</td>
<td>24 kidneys (11 with vein and ureter)</td>
</tr>
<tr>
<td>1.5 cm from the hilar zone</td>
<td>26 kidneys (6 with vein and ureter)</td>
</tr>
</tbody>
</table>

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 (retro-pelvic), 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 contingency 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**

<table>
<thead>
<tr>
<th>Section plane</th>
<th>DRASP (range)</th>
<th>DRASP (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilar</td>
<td>0.1 to 1.2 cm</td>
<td>0.43 cm</td>
</tr>
<tr>
<td>0.5 cm</td>
<td>0.1 to 1.6 cm</td>
<td>0.71 cm</td>
</tr>
<tr>
<td>1.0 cm</td>
<td>0.2 to 2.3 cm</td>
<td>1.14 cm</td>
</tr>
<tr>
<td>1.5 cm</td>
<td>0.1 to 3.9 cm</td>
<td>1.3 cm</td>
</tr>
</tbody>
</table>

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

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).
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. 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. 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.

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

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, 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.

Partial nephrectomy by laparoscopy is an efficient method, with the benefit of being minimally invasive. 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.

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 scarcity in medical literature of experimental models with human
Table 2. Incidence of Arterial Injury at Various Section Planes

<table>
<thead>
<tr>
<th>Arterial injuries</th>
<th>Hilus</th>
<th>0.5 cm</th>
<th>1.0 cm</th>
<th>1.5 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retropelvic</td>
<td>20%</td>
<td>5%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Upper seg.</td>
<td>80%</td>
<td>20%</td>
<td>9%</td>
<td>0</td>
</tr>
<tr>
<td>Infundibular</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Upper seg = upper segmental artery.

Table 3. Incidence of Venous Injuries at Various Section Planes

<table>
<thead>
<tr>
<th>Venous injuries</th>
<th>Hilus</th>
<th>0.5 cm</th>
<th>1.0 cm</th>
<th>1.5 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retropelvic</td>
<td>25%</td>
<td>14.2%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UVT</td>
<td>20%</td>
<td>22%</td>
<td>9%</td>
<td>0</td>
</tr>
<tr>
<td>Interlobar</td>
<td>100%</td>
<td>100%</td>
<td>90.9%</td>
<td>0</td>
</tr>
<tr>
<td>Arcuate</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>66.6%</td>
</tr>
<tr>
<td>Stellate</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

UVT = upper venous trunk.

Address correspondence to:
Luciano Alves Favorito, M.D.
Urogenital Research Unit - UERJ
Rua Professor Gabizo
104/201 – Tijuca
Rio de Janeiro, RJ, 20551-030
Brazil
E-mail: favorito@uerj.br

Abbreviation Used
DRASP = distance from the retropelvic artery to the section plane