Zero Ischemia Anatomical Partial Nephrectomy: A Novel Approach

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Purpose: We present a novel concept of zero ischemia anatomical robotic and laparoscopic partial nephrectomy.

Materials and Methods: Our technique primarily involves anatomical vascular microdissection and preemptive control of tumor specific, tertiary or higher order renal arterial branch(es) using neurosurgical aneurysm micro-bulldog clamps. In 58 consecutive patients the majority (70%) had anatomically complex tumors including central (67%), hilar (26%), completely intrarenal (23%), pT1b (18%) and solitary kidney (7%). Data were prospectively collected and analyzed from an institutional review board approved database.

Results: Of 58 cases undergoing zero ischemia robotic (15) or laparoscopic (43) partial nephrectomy, 57 (98%) were completed without hilar clamping. Mean tumor size was 3.2 cm, mean ± SD R.E.N.A.L. score 7.0 ± 1.9, C-index 2.9 ± 2.4, operative time 4.4 hours, blood loss 206 cc and hospital stay 3.9 days. There were no intraoperative complications. Postoperative complications (22.8%) were low grade (Clavien grade 1 to 2) in 19.3% and high grade (Clavien grade 3 to 5) in 3.5%. All patients had negative cancer surgical margins (100%). Mean absolute and percent change in preoperative vs 4-month postoperative serum creatinine (0.2 mg/dl, 18%), estimated glomerular filtration rate (−11.4 ml/minute/1.73 m^2, 13%), and ipsilateral kidney function on radionuclide scanning at 6 months (−10%) correlated with mean percent kidney excised intraoperatively (18%). Although 21% of patients received a perioperative blood transfusion, no patient had acute or delayed renal hemorrhage, or lost a kidney.

Conclusions: The concept of zero ischemia robotic and laparoscopic partial nephrectomy is presented. This anatomical vascular microdissection of the artery first and then tumor allows even complex tumors to be excised without hilar clamping. Global surgical renal ischemia is unnecessary for the majority of patients undergoing robotic and laparoscopic partial nephrectomy at our institution.

Key Words: nephrectomy, laparoscopy, robotics, ischemia

Abbreviations and Acronyms

3-D = 3-dimensional

CKD = chronic kidney disease

CT = computerized tomography

eGFR = estimated glomerular filtration rate

MAG-3 = mercaptoacetyl-triglycine

PN = partial nephrectomy

RCC = renal cell carcinoma

sCr = serum creatinine

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SMALL renal mass is a common contemporary clinical diagnosis.[1] In patients deemed to be surgical candidates, nephron sparing strategies are the preferred treatment option, with partial nephrectomy being the reference standard. This is based on the oncologic equivalence and functional superiority of partial vs radical nephrectomy.[2]

An increasingly important contemporary issue during PN is the intra-

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operative ischemic injury sustained by the healthy, uninvolved kidney. Although the functional sequelae from 20 to 30 minutes of renal ischemia are believed to be transient, contemporary reports indicate that every minute of ischemia may count.[3] This might assume particular relevance in the approximately 30% of patients who present with concomitant chronic kidney disease.[4]

A focus during laparoscopic/robotic PN has been the development of techniques to minimize renal ischemia. Development of the early unclamping technique decreased our mean ischemia times from 31 minutes (1998 to 2005) to 14.4 minutes (2006 to 2008), with a commensurate improvement in renal functional outcomes.[5] More than 92% of patients had an ischemia time of 20 minutes or less, with 100% of our most recent 500 consecutive robotic/laparoscopic partial nephrectomy cases having ischemia times less than 30 minutes (unpublished data).

Elimination of global surgical ischemia during partial nephrectomy is a worthy goal. Therefore, we developed a novel technique of zero ischemia partial nephrectomy,[6] which is applicable even for complex tumors. We present a prospective series of 58 consecutive patients undergoing robotic/laparoscopic partial nephrectomy, of which 70% was for complex tumors and 98% was performed without hilar crossclamping.

MATERIALS AND METHODS

Data were prospectively collected and entered into our institutional review board approved departmental database. Inclusion criteria comprised an enhancing tumor suspicious for cancer or a large (greater than 5 cm) angiomyolipoma at risk for hemorrhage. Exclusion criteria were severe cardiopulmonary or cerebrovascular disease, nonavailability of designated anesthesiologist (DT), multiple (more than 3) tumors and uncorrected coagulopathy. All patients deemed candidates for PN who fulfilled the inclusion criteria were included in analysis, and no patient was excluded for reasons of tumor or technical complexity. During the study period (March 2010 to January 2011) 58 of 70 consecutive patients (83%) referred to 1 surgeon (ISG) satisfied the inclusion criteria for zero ischemia partial nephrectomy whereas 12 did not meet inclusion criteria (table 1).

Indications for partial nephrectomy were elective (22, 38%), relative (26, 45%) or absolute (10, 17%). Of the 58 patients 41 (70%) had challenging tumors including central (67%), hilar (26%), completely intrarenal (23%), pT1b (18%), solitary kidney (7%) or with baseline CKD stage 3 or greater (16%) (fig. 1). Many patients had more than 1 element of tumor complexity. Central tumors were defined as those abutting the renal central sinus fat and/or pelvicalyceal system on preoperative CT. Hilar tumors were those physically abutting the extra-renal artery/vein on preoperative CT.

Table 1. *Patient demographics, tumor characteristics and intraoperative data*

Pt demographics:		
Mean age (range)	57	(32–79)
Mean kg/m^2 body mass index (range)	29	(18.5–47.9)
No. male gender (%)	37	(65)
Mean Anesthesiologists Society of America score (range)	2.4	(1–3)
Mean Charlson comorbidity index (range)	0.8	(0–4)
Tumor characteristics:		
No. lt kidney (%)	39	(68)
Mean cm tumor size (range)	3.2	(0.9–13.0)
No. superficial tumors (%)	17	(30)
No. complex tumors (%)	41	(70)
Mean ± SD C-index score	2.9 ± 2.4	
Mean ± SD R.E.N.A.L. score	7.0 ± 1.9	
No. central tumor (%)	38	(67)
No. hilar tumor (%)	15	(26)
No. completely intrarenal tumor (%)	13	(23)
No. tumor size greater than 4 cm (%)	10	(18)
No. solitary kidney (%)	4	(7)
No. baseline CKD stage 3 or greater	9	(16)
Intraop data:		
No. laparoscopic/robotic approach (%)	42 (74)/15 (26)	
Mean mins warm ischemia (range)	0	(0–0)
Mean operative hrs (range)	4.4	(2.1–8)
Mean mL blood loss (range)	206	(25–1,000)
Mean % kidney excised (range)	22	(5–70)
No. undergoing pelvicalyceal repair (%)	45	(79)
Mean days hospital stay (range)	3.9	(2–19)

Of 70 consecutive patients referred for PN to 1 surgeon during the study period 12 (17%) did not meet inclusion criteria for zero ischemia PN because of multiple bilateral tumors including familial RCC disorders (5), nonavailability of designated anesthesiologist (2), hematologic risk (history of bleeding diathesis or hypercoagulability, 2), presence of ventriculoperitoneal shunt, horseshoe kidney undergoing concomitant isthmectomy (1) and hypertrophic cardiomyopathy (1).

Perioperative data of the patient with a solitary kidney who required hilar clamping to successfully complete laparoscopic PN were 2 tumors (3.8 and 2 cm) which were central, irregularly shaped, completely endophytic, hilar, located within the branches of the main renal artery/vein; total ischemia time 28 minutes; blood loss 1,500 cc; pathology confirmed 2 pT1a clear cell RCCs with negative margins; and preoperative and 9-month postoperative sCr 1.5 and 2.2 mg/dL, respectively.

Patients underwent kidney dedicated 3-D CT (0.5 mm cuts) to delineate detailed renovascular (main trunk and branches) and tumor anatomy (location, depth, proximity to sinus fat and collecting system). For particularly challenging tumors we used our developed prototype software to reconstruct a detailed 3-D video road map from CT images (fig. 2). Routine laboratory testing and strict cardiopulmonary evaluation were obtained.

Our technique of minimally invasive partial nephrectomy has been described previously.[5] In this report we focus on specific aspects unique to zero ischemia surgery.[6] For medially located tumors, delicate, selective anatomical vascular microdissection of tumor specific arterial branches (tertiary, quaternary or higher order) is performed deep into the renal hilum. To minimize/counteract any vasospasm, topical papaverine is sprayed on the renal hilar vessels. This anatomical arterial microdissection can be extended into the kidney by 1) dissection into the renal sinus by developing the plane of Gil-Vernet, and 2) a small radial nephrotomy incision (1 to 2 cm) of the concave, hilar edge of the kidney directly overlying the targeted arterial