OPEN PARTIAL NEPHRECTOMY. PERSONAL TECHNIQUE AND CURRENT OUTCOMES

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Summary.- Modern imaging capabilities has created a renal tumor stage and size migration with approximately 70% of patients today detected incidentally with a median tumor size of 4cm or less. In addition, our current understanding indicates that renal cortical tumors are a family of neoplasms with distinct histopathological and cytogenetic features and variable metastatic potential. The conventional clear cell tumor has a malignant potential and accounts for only 54% of the total renal cortical tumors but 90% of those that metastasize. Radical nephrectomy, whether performed by open or minimally invasive surgical technique, plays an important role in the management of massive renal tumors that have replaced the normal renal parenchyma, invade the renal vein, and have associated regional lymphadenopathy or metastatic disease. Partial nephrectomy has emerged as the treatment of choice for patients with smaller tumors. This operation can be performed through a “miniflank” surgical incision without rib resection. Complications related to partial nephrectomy, including bleeding, urinary fistula and infection occur in less than 10% of cases. Radical nephrectomy should not be performed for the treatment of small renal tumors since it is associated with the causation or worsening of preexisting CKD which can cause an increased likelihood of cardiovascular morbidity and mortality. Despite a wealth of evidence supporting the more restricted indications for RN, strong evidence exists that it remains over utilized in the United States. Widespread education and training in kidney preserving surgical strategies is essential going forward.

Keywords: Partial nephrectomy. Kidney cancer. Chronic kidney disease.

Resumen.- La capacidad de las pruebas de imagen modernas ha creado una migración de estadio y tamaño de los tumores renales con aproximadamente un 70% de los pacientes actualmente siendo detectados de forma incidental con una mediana de tamaño del tumor de 4 cm o menos. Además, nuestro conocimiento actual indica que los tumores renales corticales son una familia de neoplasias con diferentes características histopatológicas y citogenéticas y un potencial metastásico variable. El tumor de células claras convencional tiene un potencial maligno y supone sólo el 54% del total de los tumores renales corticales pero el 90% de los que metastatizan. La nefrectomía radical, realizada con técnica
abierta o cirugía mínimamente invasiva juega un papel importante en el manejo de los tumores renales masivos que hayan reemplazado el parénquima renal normal, invadan la vena renal y tengan linfadenopatías regionales o metástasis. La nefrectomía parcial ha emergido como el tratamiento de elección de los pacientes con tumores más pequeños factibles. Esta operación puede realizarse a través de una mini-incisión de lumbaroto- 

sin resección costal. Las complicaciones relacionadas con la nefrectomía parcial, incluyendo hemorragia, fis- 

tula urinaria e infección ocurren en menos del 10% de los casos. No debería hacerse nefrectomía radical para tratamiento de tumores renales pequeños puesto que se asocia con el empeoramiento de una enfermedad renal crónica preexistente que puede producir un aumento de la probabilidad de morbilidad cardiovascular y mortalidad. A pesar de la abundancia de evidencia que apoya la restricción de las indicaciones de NR, existe evidencia de que sigue siendo utilizada en exceso en los Estados Unidos. La difusión de la educación y el entrenamiento en estrategias quirúrgicas de conservación renal es esencial para avanzar.


INTRODUCTION

Historically, partial nephrectomy (PN) was performed under restricted, essential conditions for patients with a tumor in a solitary kidney, bilateral kidney tumors, or for patients with chronic renal insufficiency due to intrinsic renal dysfunction or calculus disease. Due to the increased use of cross sectional imaging for non specific musculoskeletal or abdominal complaints or during unrelated cancer care, approximately 70% of renal tumors are now detected incidentally at a small size (< 4cm). Although the traditional radical nephrectomy (RN) was liberally used to resect these small tumors in patients with a normal contra lateral kidney, the realization that at least 20% of these tumors were benign and 25% were indolent coupled with equivalent oncological outcomes whether RN or PN was performed, lead to the current era of kidney or nephron sparing surgery. Recent data associating RN with the development of chronic kidney disease (CKD), cardiovascular morbidity, and worse overall survival when compared to PN has led to the recommendation by the 2009 AUA Guidelines committee that PN should be performed whenever technically feasible for the management of the T1 renal mass. In this chapter, a discussion of the pathological, oncological, and medical rationale for PN will ensue. In addition, a full discussion of intra operative and perioperative management of patients undergoing PN will be presented.

The Open Partial Nephrectomy: Historical Evolution

PN was first performed in 1887 when Czerny resected an angiosarcoma from the kidney of a 30 year old man. Subsequent animal experiments demonstrated that gentle pressure could control bleeding and that suture approximation of the kidney could lead to primary kidney healing often without urinary fistula. Important observations concerning compensatory hypertrophy and the minimal amount of overall renal tissue required to support life were also described. In the 1930's pathological studies indicated that only 7% of renal cancers less than 5 cm metastasized compared to 83% greater than 10 cm and it was observed that the local growth pattern of renal tumors was expansile from the renal cortex with rare adjacent organ invasion. In 1950, Vermooten proposed a 1 cm margin as adequate to achieve local tumor control when he performed a 10 cm PN. As more surgeons attempted PN, enthusiasm for the operation waned because of bleeding and urinary fistula complications while RN enjoyed increasing success especially when performed by urologists (1, 2).

Progress in open stone surgery in the 1960’s and 1970’s, an enhanced understanding of renal vascular and collecting system anatomy, utilization of techniques such as the Gil Vernet extended pyelolithotomy, anatrophic nephrolithotomy, and PN for urinary calculus, lead to a resurgence of interest in PN for renal tumors. Elaborate collecting system repairs of the kidney, kidney “splits” using ice slush reno protection, and methods to drain and stent the kidney were also described (3-5). In the 1980’s, kidney trauma surgeons described techniques to control major bleeding from penetrating injuries including early vascular control of the renal hilum, complete exposure of the kidney, partial polar nephrectomy, collecting system repair, omental pedicle flap to augment repairs, absorbable gelatin sponge bolsters to prevent tearing of the renal capsule during renorrhaphy, and direct vascular repair of injuries to the renal vein and artery (6). These techniques are fully integrated into contemporary PN, particularly in the resection of endophytic and peri-hilar renal tumors.

Modern radiological imaging techniques of CT, MRI, and renal ultrasound, often performed to evaluate abdominal and musculo-skeletal complaints, created a new class of small, incidentally detected
renal masses far different from the massive, symptomatic, and often metastatic tumors common earlier in the 20th century (7). Also, a shift in the principles of surgical oncology was occurring away from the radical Halstedian view toward one of organ preservation in the treatment of such malignancies as breast cancer and extremity sarcoma. Small, incidentally discovered kidney tumors were perfectly suitable for an organ sparing operations. Concerns for local tumor recurrence and the observation of small satellite tumors seen in RN specimens were voiced by skeptics as major objections to elective PN.

The phrase “nephron sparing” was introduced by Licht and Novick in 1993 in a report of 241 patients that underwent PN despite a normal contra lateral kidney from 1967-1991. With a median tumor size of 3.5 cm and a median follow up of 3 years, only 2 local recurrences were reported and survival was 95%. (8). Similar results were reported by Herr (9) and long term follow up from the Cleveland Clinic group indicated that elective PN was safe and effective (10). The use of hemostatic agents, argon beam coagulation for the cut renal surface, and intra operative ultrasound gave renal surgeons more tools to safely approach PN. Ice slush renoprotection allowed for resection of endophytic tumors, renal sinus tumors, and tumors in a solitary kidney. In the last decade an enhanced understanding of the diversity of renal cortical tumors histological sub types and their variable metastatic threats coupled with concerns that RN could cause chronic kidney disease (CKD) made the case for PN even stronger.

Small Renal Tumors: Pathological and Oncological Rationale for Partial Nephrectomy

Renal cortical tumors (RCT) are members of a complex family with unique histology’s, cytogenetic defects, and variable metastatic potentials ranging from the benign oncocytoma and metanephric adenoma, to the indolent papillary and chromophobe carcinomas, to the more potentially malignant conventional clear cell carcinoma (11, 12). Of 1863 surgically treated patients with malignant renal cortical tumors (excluding benign tumors such as oncocytoma) at MSKCC from 1989-2006, 72% were conventional clear cell carcinoma, 17% were papillary carcinoma, and 12% were chromophobe carcinoma. Of these, 187 patients developed metastasis, 161 (86%) had the conventional clear cell carcinoma, 17 (9.1%) had papillary renal cell carcinoma, and 9 (4.8%) had chromophobe carcinoma. On a multivariate analysis, chromophobe (HR 0.40) and papillary carcinomas (HR 0.62) were significantly associated with a better prognosis than clear cell carcinoma (13).

An active surveillance study of small renal tumors pooled 234 patients from 9 centers, followed for a mean of 34 months, indicated a mean growth rate of 0.28 cm/year (14). In another study 36% of tumors under active surveillance had zero growth but this feature alone did not predict for benign tumor histology in cases where tissue was obtained (15). Despite modern imaging techniques, none could predict tumor histology and between 16.4% and 23% of resected tumors were ultimately benign (16, 17, 18). Even a renal mass without evidence of macroscopic fat on non-contrast CT, despite a highly suspicious appearance, can still be benign angiomyolipoma (19). Of 2675 tumors resected at MSKCC, the incidence of benign tumors decreased from 38% for tumors of 1cm or less to 7% for tumors of 7 cm or greater and the incidence of high grade clear cell carcinoma increased from 0% for tumors of 1 cm or less to 59% for tumors of 7 cm or greater (20). Only 1 patient in 781 with a tumor less than 3 cm presented to the MSKCC Urology Service with metastatic disease (21). When taken together, the bulk of the clinical evidence now suggests that for small renal tumors referred to urologists without evidence of metastases, particularly those of < 3cm, the likelihood of a low grade, benign or indolent tumor with limited metastatic potential is extremely high creating the perfect conditions to utilize PN as means of achieving the dual goals of local tumor control and maximum organ preservation. Alternatively, these above described data linking small renal masses with a generally non-aggressive natural history provides an excellent basis for active surveillance strategies in elderly or co-morbidly ill patients (22, 23). The historical dual use of RN to achieve a diagnosis and treat the renal tumor must now be considered surgical overkill and potentially deleterious to the patient with the small renal mass.

Reports indicated that PN was not compromising the local tumor control or metastasis free survival when compared to RN for patients with T1a renal tumors [4 cm or less] across all histological sub-types (24 - 27) (Figure 1). The rationale for expanding PN to larger renal cortical tumors of 4-7 cm was articulated (28) and initial reports were met with similarly favorable results (29, 30, 31). Combining the Mayo Clinic and MSKCC data bases, investigators evaluated 1159 patients with renal tumor between 4-7 cm treated with RN (N=873, 75%) and PN (N=286, 25%) and demonstrated no significant difference in survival between the groups (54) (Figure 2). A series was reported of even larger PN for T2 disease performed in 34 patients in which 6 patients (16.2%) had benign masses and 12 patients (35%) had indolent (papillary or chromophobe) pathology. After 17 months of follow up, 71% of patients with
a malignant diagnosis are alive without evidence of disease. Although the resection of massive renal tumors (in this series up to 18 cm in diameter) is largely a function of favorable tumor location and careful case selection, it is clear that local tumor control can be effectively achieved with results similar to those found in series of tumors of 7 cm or less (33). Mayo Clinic investigators reported similar results in 276 patients with T2 or greater tumors treated with either PN (N=69) or RN (N=207) (34). These data indicate clearly that the ultimate oncological threat of a given tumor depends upon biological factors of the tumor including histological sub type, the presence or absence of symptoms, tumor grade, and tumor size with prognostic nomograms and algorithms available to predict outcomes with reasonable accuracy (35, 36).

Renal Medical Rationale for Partial Nephrectomy

A historical misconception exists that RN, can cause a permanent rise in serum creatinine due to the sacrifice of normal renal parenchyma not involved by tumor but will not cause serious long term side effects as long as the patient has a normal contra-lateral kidney. The renal transplant literature is cited as the clinical evidence to support this view since patients undergoing donor nephrectomy have not been reported to have higher rates of kidney failure requiring dialysis or death (37). However, distinct differences between kidney donors and kidney tumor patients exist. Donors tend to be carefully screened for medical co-morbidities and are generally young (age 45 or less) (38, 39). In contrast, renal tumor patients are not screened, are older (mean age 61 years), and many have significant co-morbidities affecting baseline kidney function including metabolic syndrome, hypertension, coronary artery disease, obesity, vascular disease, and diabetes. In addition, as patient’s age, particularly beyond the age of


60, nephrons atrophy and glomerular filtration rate progressively decreases (40). A study 110 nephrectomy specimens in which the non tumor bearing kidney was examined demonstrated unsuspected underlying renal disease including vascular sclerosis, diabetic nephropathy, glomerular hypertrophy, mesangial expansion, and diffuse glomerulosclerosis (41). Only 10% of patients had completely normal renal tissue adjacent to the tumor.

Evidence that RN could cause a significant rise in the serum creatinine when compared to PN in patients with renal cortical tumors of 4 cm or less was published by investigators from Mayo Clinic and MSKCC in 2000 and 2002, respectively. RN patients were more likely to have elevated serum creatinine levels to > 2.0 ng/ml and proteinuria (Mayo Study) (42), a persistent finding even when study patients were carefully matched for associated risk factors (MSKCC study) including diabetes, smoking history, pre-operative serum creatinine and ASA score (43). In both studies, oncological outcomes were highly favorable (>90% survival rates) whether PN or RN was done. CKD, defined as an estimated glomerular filtration rate (eGFR) of less than 60 min/min/1.73m², is increasingly viewed as a major public health problem in the United States and since 2003 is considered an independent cardiovascular risk factor (44-48). An estimated 19 million adults in the United States have CKD and by the year 2030, 2 million will be in need of chronic dialysis or renal transplantation (49). Traditional risk factors for CKD include age greater than 60, hypertension, diabetes, cardiovascular disease, and family history of renal disease, factors also common in the population of patients that develop renal cortical tumors.

A study involving 1,120,295 patients demonstrated a direct correlation between CKD and rates of hospitalization, cardiovascular events, and death, which occurred before overt renal failure requiring dialysis or renal transplantation (50). As kidney function deteriorated, the percentage of patients with 2 associated cardiovascular risk factors increased from 34.7% (Stage 1 and 2 CKD) to 83.6% (for stage 3) to 100% for stage 4 and 5 subjects. Patients with CKD are more likely to require medical interventions to treat cardiovascular disease than those with normal renal function. The low prevalence of patients with Stage 4 or 5 CKD is attributable to their five year survival rates of only 30%. (51).

A concern that the overzealous use of RN, particularly in patients with small renal masses and common co-morbidities that can affect renal function, could be causing or worsening preexisting CKD became a focus of intense research. MSKCC investigators used a widely available formula, the Modification in Diet and Renal Disease (MDRD) equation (52) http://www.nephron.com/MDRD_GFR.cgi, to estimate the glomerular filtration rate (eGFR) in a retrospective cohort study of 662 patients with a normal serum

PN vs RN for RCT < 4cmImpact on CKD

![Figure 2: Probability of freedom from new onset of GFR lower than 60 ml/min per 1.72 m², by operation type](Lancet Oncology 7:735-740, 2006)

![Figure 3: Probability of freedom from new onset of GFR lower than 45 ml/min per 1.72 m², by operation type](Lancet Oncol. 2006; 7:735-740)

creatinine and 2 healthy kidneys that underwent either elective PN or RN for a RCT 4 cm or less in diameter. To their surprise, 171 patients (26%) had pre-existing CKD (GFR < 60) prior to operation. Data was analyzed using two threshold definitions of CKD, a GFR < 60 ml/min/1.73 m² or a GFR < 45 ml/min/1.73 m². After surgery, the 3 year probability of freedom from new onset of GFR < 60 was 80% after PN but only 35% after RN. Corresponding values for 3 year probability of freedom from a GFR < 45, a more severe level of CKD, was 95% for PN and 64% for RN. Multivariable analysis indicated that RN was an independent risk factor for the development of new onset CKD (53) (Figure 3).

Mayo Clinic investigators identified 648 patients from 1989-2003 treated with RN or PN for a solitary renal tumor less than or equal to 4 cm with a normal contra lateral kidney. In 327 patients younger than 65 it was found that RN was significantly associated with an increased risk of death which persisted after adjusting for year of surgery, diabetes, Charlson-Romano index, and tumor histology (54). Using the Surveillance, Epidemiology and End Results cancer registry data linked with Medicare claims, MSKCC investigators studied 2991 patients older than 65 years for resected renal tumors of 4 cm or less from 1995-2002. A total of 2,547 patients (81%) underwent RN and 556 patients underwent PN. During a median follow up of 4 years, 609 patients experienced a cardiovascular event and 892 patients died. After adjusting for preoperative demographic and co-morbidity variables, RN was associated with a 1.38 times increased risk of overall mortality and a 1.4 times greater number of cardiovascular events (55) (Figure 4). Similar results were reported in patients undergoing laparoscopic RN and PN (56).

Because of these reports, urologists are now increasingly aware that CKD status can be created or pre-existing CKD significantly worsened by the liberal use of RN for the treatment of the small renal mass (57). Short term end points, including length of hospital stay, analgesic requirements, and cosmetic elements viewed by many as the reason to elect laparoscopic RN, must now be tempered by concerns that RN causes CKD and decreases overall patient survival. The most recent AUA guidelines for the management of the small renal tumor emphasize these points and strongly support the use of PN whenever technically feasible (58).

**Partial Nephrectomy: Pre Operative Assessment and Surgical Planning**

A careful history with a special emphasis on medical co-morbidities which can affect the cardiovascular system and kidney, including heavy cigarette smoking, hypertension, diabetes, and coronary artery disease and a physical examination are essential elements of the initial office visit. These factors can contribute to perioperative complications and may also be etiological factors in the development of kidney cancer (59, 60). Patients with cardiac disease need an evaluation including...
echocardiogram, stress test, and carotid duplex studies. Appropriate medical or surgical therapy of these conditions should be initiated as indicated prior to elective kidney surgery. In addition, calculation of eGFR should be done using the following web link for the MDRD equation http://www.nephron.com/MDRD_GFR.cgi and in approximately 26% of patients, many of whom were previously unaware, CKD will be diagnosed (53) because of an eGFR < 60 ml/min/1.73m². If so, the partial nephrectomy would be classified as essential rather than elective. A risk stratification system, SCORED (screening for occult renal disease), was created to predict patients likely to develop CKD after kidney surgery. Patients with high SCORED values were most in need of kidney sparing surgical approaches (61). A careful evaluation of outside imaging needs to be done. A surgeon should not operate on a renal mass without a non-contrast CT image to rule out the possibility of detecting macroscopic fat indicative of angiomyolipoma (7) and a contrast enhanced study (MRI, CT or renal perfusion/excretion scan) indicating bilateral renal function. Renal protocol CT imaging, which consists of 3 imaging sequences including pre contrast, corticomedullary phase, and late nephrogenic excretory phase, provides a high degree of diagnostic accuracy in diagnosing renal cortical tumors (100% specificity, 95% sensitivity) (62) but can not determine if the mass is benign or malignant. The degree to which a renal mass enhances is dependent on the CT scanner being utilized. For a single detector scanner 10 HU was considered suspicious for a renal cortical tumor but with more modern multi-detector scanners, “pseudo enhancement” of renal cysts secondary to volume averaging and beam hardening effects, particularly in smaller lesions, could lead to operation for a benign cyst. Enhancement of 10-20 HU in this setting may lead the radiologist to ask for further imaging often in the form of renal ultrasound with Doppler imaging to assess for vascular flow within the mass (63). Ultrasound can more fully characterize cystic lesions and serves as an effective template for intra operative ultrasound which can be highly effective in locating small sub-cortical renal tumors.

The surgeon should address the likelihood of executing a PN and its degree of difficulty, estimate post operative renal functional status, carefully review the major complications related to PN (bleeding, infection, urinary fistula and the need for a prolonged urinary drain) and discuss the likelihood of conversion

Pre Operative Nomogram Predicting Freedom From Recurrence 12 years after resection of RCT

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Preoperative nomogram predicting freedom from metastatic recurrence at 12 years following definitive surgical management


to RN if, for technical reasons, a PN can not be executed. A pre-operative nomogram, derived from data on 2517 patients, is highly effective in reassuring patients with small renal masses that a favorable long term prognosis is achievable with an effective resection [64] (Figure 5). A scoring system (R.E.N.A.L. for Radius of tumor, Exophytic/Endophytic, Nearness to collecting system or sinus, Anterior or posterior, and Location relative to the polar line) was developed as a means to document and describe surgical difficulty for a planned PN. Examples of scoring in the RENAL system are as follows; tumors that were 4 cm or less are given 1 point, 2 points for 4-7 cm, 3 points for greater than 7 cm. Tumors that are 50% or more exophytic are assigned 1 point, tumors less than 50% exophytic are assigned 2 points, and tumors that are endophytic are assigned 3 points. As more points are accumulated, the degree of difficulty to perform PN increases. The authors used their system to score 50 consecutive PN and RN performed by open, laparoscopic, or robotic assisted techniques and correlated the operative experience as the masses were deemed low (score 4-6), moderate (score 7-9) and high complexity (score 10-12). Few RN were performed by any technique for the low scored patients (65).

The likelihood of a subsequent ipsi-lateral (<5%) or contra lateral (<5%) tumor recurrence in a patient’s lifetime is also discussed. In the face of a small renal mass, if medical co-morbidities seem great, renal functional reserve minimal, and or the patient is elderly, a proposal for active surveillance can readily be made (15, 23, 66).

**Technical Features of Open Partial Nephrectomy: Supra 11th rib Mini-flank Surgical Incision**

The traditional open partial nephrectomy utilized a large flank incision with resection of the distal third of the eleventh rib. Although this approach provided wide exposure to the kidney and retro peritoneum, patients complained of significant post operative pain, a prolonged recovery, and for many an uncomfortable and unsightly flank bulge usually from muscle atony from nerve damage as opposed to fascial hernia. Canadian investigators described 70 patients that underwent formal flank or thoracoabdominal incision for RN (69%) or PN (31%). Fifty percent of patients experienced a flank bulge (67). Besides the associated discomfort and poor cosmetic appearance, associated parathesias and neuralgic pain around the incision were also reported. For the surgeon, resection of the rib and closure of the large incision also added significant operating time. These significant wound difficulties were major drivers for the development of laparoscopic RN for small renal tumors and a normal contra lateral kidney in the late 1990’s.

An effective alternative to the classic flank incision or laparoscopic RN for small renal tumors is the supra-eleventh rib “mini-flank” retroperitoneal approach which provides rapid and excellent exposure to the kidney without the need for a rib resection (68). With the patient in the standard flank position, an 8-10 cm extra-peritoneal incision is performed between the bed of the 10th and 11 ribs. (Figure 6) The latissimus dorsi, external oblique and internal oblique muscles are transected and the transversus abdominus is divided in the direction of its fibers while preserving the intercostal neurovascular bundle. Using blunt dissection, the peritoneal cavity is mobilized medially, the perinpehric soft tissues laterally, and the diaphragmatic fibers and pleural superiorly. A small incision in the plane between the soft tissues overlying the psoas muscle and Gerota’s fascia is then bluntly developed exposing the kidney, ureter, and ipsilateral great vessel (vena cava, aorta). The Bookwalter™ retractor (Codman and Shurtleff, Inc., Raynham, MA, USA) is placed using the bladder blade attachment to retract the 10th rib and rib cage superiorly, while the short right-angle blade retracts the 11th rib inferiorly. A malleable blade retracts the peritoneal cavity and its intestinal contents medially. Careful dissection is conducted to isolate the ureter, renal artery, and renal vein, each of which is surrounded by a different colored

**FIGURE 6.** Mini-flank surgical incision, approximately 8-10 cm, with incision above the 11th rib and in the space between the 10th rib. (Adapted from Diblasio CJ, Snyder ME, Russo P. Mini flank supra-eleventh incision for open partial or radical nephrectomy. BJU Int. 97:149-156. 2006.)
vessel loop (Figure 7). On the left side, division of the gonadal vein and adrenal vein liberate the renal vein more fully, facilitate identification and isolation of the renal artery, and allows for substantial upward mobilization of the renal hilum and easy access to the entire kidney. Dense lymphatic vessels that commonly surround the renal artery are ligated and divided further facilitating upward mobilization of the kidney which allows a decrease in venous bleeding during the tumor resection and allows easy identification and repairs of rents in renal sinus veins. After the renal hilum has been fully dissected, the upper pole of the kidney is separated from the adrenal using blunt dissection between the two and perforating vessels and soft tissues are ligated and divided.

With the kidney completely mobilized, careful palpation and inspection of its entire surface is performed in order to confirm the presence of the tumor and seek any satellite lesions. All pre operative imaging is available in the operating room and intra operative ultrasound is routinely utilized to confirm the presence of the tumor, seek satellite lesions, and assess the proximity of the tumor to intra renal veins and to determine if there is an intra renal vein thrombus or tumor encroachment upon the renal collecting system (68) (Figure 8). Occasionally, a polar segmental artery may feed the exact tumor bearing area of the kidney. Ligation and division of this artery allows for a “regional ischemia” and precise resection with little damage to non tumor bearing kidney. When there is a completely intra-renal tumor without any evidence on the renal cortical surface, measurements from each pole of the involved kidney in millimeters are made using the preoperative CT scan with subsequent corresponding marks made on the renal cortex, the position of the endophytic tumor is then confirmed precisely with the intraoperative ultrasound. For a purely exophytic tumor or in a patient with significant underlying CKD, resection of the tumor without renal artery occlusion is carried out. For other patients with large, endophytic, or peri hilar tumors who require renal artery occlusion, reno protective measures including mannitol infusion (12.5 gms/200 ml of normal saline) and ice slush are routinely used. It is no longer necessary to place the kidney in a plastic bag prior to ice slush placement since the small surgical mini-flank incision does not lead to patient hypothermia (Figure 10). In no cases of open PN is renal artery occlusion used without such reno protective measures recommended (warm ischemia).

Once the tumor is isolated with its surrounding perinephric fat, the renal cortex is scored with a 1 cm

![FIGURE 7. The renal vein and renal artery (arteries) are carefully dissected from surrounding lymphatic soft tissues and identified by red (artery) and blue (vein) vessel loops. During cold ischemia, a bulldog vascular clamp is applied to the renal artery.](image7)

![FIGURE 8. Intra operative ultrasound is routinely performed to locate endophytic tumors, assess kidney for satellite tumors, collecting system invasion, or branched renal vein thrombus invasion.](image8)
margin using the electrocautery (Figure 11). Sharp scissor dissection is utilized with a careful eye to keep the plane of surgical dissection within the renal cortex (pink kidney tissue) and not get too close to the renal tumor and its pseudo capsule. If dissection is too close, readjustment to a deeper plane of dissection is made. Once the renal sinus is entered beneath the tumor, 3-0 absorbable sutures are used to close any open small veins and arteries, or breaches in the collecting system both to secure these structures and provide upward traction on the kidney (Figure 12). A later search for venous bleeding can be accomplished by simply dropping the kidney into the wound and then raising it again. Once the specimen is delivered, it is carefully inspected to be certain that the lesion is intact and that there is a complete covering layer of kidney and soft tissue. The deep

tumor surgical margin is marked with a silk suture to orient the specimen which is then is delivered to the pathology department fresh and in sterile condition. Frozen section of the deep margin and specimen can provide immediate reassurance to the surgeon and the family but a final pathological diagnosis of the renal cortical tumor may not be available by frozen section

Recurrence free survival by margin status


Endophytic tumors can emanate from elements of the renal cortex facing the renal sinus and be impalpable. Intraoperative ultrasound is essential to precisely locate the tumor and plan the nephrotomy incision. Cold ischemia with ice slush is utilized. Access to the renal sinus is achieved by going through the cortex preferably in an avascular plane (Brodel's line) whereupon the renal tumor is palpated and carefully resected with care being taken not to get too close to the tumor or enter its pseudo capsule. Following ligation of all renal sinus vessels and collecting system repair, the argon-beam coagulator is used on the parenchymal surface and perinephric fat and hemostatic agents such as FloSeal™ (Baxter, Deerfield, IL, USA) and Surgicel packing (Johnson and Johnson, New Brunswick, NJ, USA) are then placed in the resection cavity. Once the bladder is closed using 4-0 absorbable suture in a sub-cuticular fashion.

It can be disconcerting to find a flank bulge at the incision site without hernia. In 204/2065 PN (10%) and 94/2065 RN (4.6%) patients undergoing open PN (n=133) or RN (n=34) from 2000-2003 using the supra-11th mini-flank incision, excellent kidney exposure without rib exposure with decreased intra-operative EBL and length of stay (LOS) as well as a better cosmetic results compared to traditional open techniques were obtained. In the original open PN group, the median length of stay was 4.5 days (range 2 – 8) and the median EBL was 375 cc (50-2000). At the median follow-up of 18 months, 3.6% of patients reported a bulge (no hernia but muscular atony) at the incision site, and 1 patient was diagnosed with an incisional hernia requiring surgical intervention. There were no intra-operative complications although 1 patient had a prolonged hospitalization due to a concomitant urinary fistula with a urinary tract infection, which also resulted in delayed removal of the drain (68). In an update of 280 additional cases of open PNs (4/03-1/07) using the supra-11th mini-flank incision, the median length of stay decreased further to 4 days (range 2 - 12) with a median EBL of 300 cc (range 50 - 3000). There was 1 reported major intra-operative complication (bleeding), but it did not result in loss of the kidney. At a median follow-up of 8 months for this cohort, 1.8% of patients reported a flank bulge (70). Muscle atony/bulge at the incision site without hernia can be a disconcerting finding ameliorated or improved completely by exercises that passively twist the upper torso (using an exercise bar, broom or golf club) which thereby strengthens collateral muscle groups leading to resolution of the bulge. For the rare flank hernia, complex repair with synthetic mesh is more effective than attempted primary repair which is much more prone to recurrence. Today, with the added benefit of clinical pathways, length of stay has been further reduced to 2.6 days.

With increasing PN experience surgeons have increasingly pursued more complex PN (large, endophytic, peri hilar) tumors which usually require clamping of the renal artery to limit blood loss and
facilitate necessary vascular and collecting system repairs. Renal metabolism is predominantly aerobic and hence the kidney is highly sensitive to warm ischemic damage. Historical investigations using canine models suggested that warm ischemia could be safely tolerated for 30-90 minutes (72), but the extrapolation of these studies to humans, the vast majority of whom have intrinsic renal abnormalities related to co-morbid diseases and the aging process (41), is speculative at best. Renal ischemia and re-perfusion injury has been extensively studied in the transplant donor setting with extrapolation to the PN setting. Following renal artery occlusion, immediate complex vascular, inflammatory and sub-lethal injury repair responses lead to arteriolar vasoconstriction, disruption of the counter current mechanisms, decreases in GFR and urinary production (73). Reactive oxygen radicals that result can further damage the glomerular components. Reno protective mannitol infusion may ameliorate these effects (74). Classic studies indicating that renal protective measures including ice slush could provide surface cooling, decrease renal energy expenditure and ameliorate the adverse impact of warm ischemia made cold ischemia an integral part of complex open stone surgery (anatrophic nephrolithotomy) and open PN (75). This element of the PN story is further complicated because of a lack of a precise marker, either urinary or serum, for renal ischemic damage with investigators having to rely upon the imprecise serum creatinine alone to measure the effects of ischemia. Further confusing matters is the difficulty in knowing the degree to which pre-existing conditions, such as hypertension, diabetes, and CKD coupled with the resection of healthy renal tissue as part of the PN, contributes to the final renal functional result.

MSKCC investigators evaluated 592 patients undergoing elective PN and separately evaluated 70 patients undergoing PN in a solitary kidney. Estimated GFR was obtained using the MDRD equation preoperatively, early in the post operative period, at 1 month, and at 12 months post operatively. Patients with a solitary kidney had a baseline eGFR 30% lower than patients undergoing elective PN. Median cold ischemia time was 35 minutes in the elective PN group and 31 minutes for patients with a solitary kidney. Patients with a solitary kidney experienced a greater decline in eGFR compared to elective PN patients in the early post operative period (30% vs. 16%), at 1 month (15% vs. 13%) and at 12 months (32% vs. 12%). Upon multivariate analysis, duration of cold ischemia and intra operative blood loss, both likely surrogates for difficult operations, were significantly associated with early changes in eGFR but by 12 months age was the only significant predictor of eGFR decrease in patients undergoing elective PN.

Although this study does not answer critical questions concerning long term renal damage in either group of patients, it is clear those patients with tumor in a solitary kidney and the elderly are more vulnerable to renal damage after PN (76). Investigators combined the Mayo and Cleveland Clinic 18 year experience with 458 patients undergoing PN in a solitary kidney and warm ischemia. No ischemia was used in 96 patients (21%) while 362 (79%) had a median of 21 minutes of warm ischemia. Warm ischemia patients were significantly more likely to develop acute renal failure and an eGFR of < than 15 ml/min per 1.73m2 and stage 4 CKD during a 3 year follow up when compared to patients whose resection was completed without hilar clamping (77). Another multi-institutional study retrospectively evaluated 537 patients with a solitary kidney and baseline CKD indicated that the rate of chronic renal insufficiency or more severe CKD (defined as serum creatinine > 2.0 ng/ml) was 26% when no renal artery occlusion was used, 30% after warm ischemia, and 41% after cold ischemia. In this study the cold ischemia may have been selectively utilized in more challenging cases. The authors felt a cut off of 20 minutes of warm ischemia could decrease the risk of severe CKD in this highly susceptible patient population (78).

Although, the precise degree of lasting renal damage caused by any form of ischemia and the unknown degree to which the non tumor bearing kidney compensates for the ischemic insult, most experts agree that working quickly in either warm or cold ischemic states is in the patient’s best interest (79). Until a more precise serum or urinary marker for ischemic renal injury is identified, the lasting impact of ischemic injury to the kidney will remain unknown. Sensible recommendations based on the literature at this time are:

1) If a tumor is in an exophytic location performing the PN without renal artery occlusion is likely to cause the least renal injury.

2) If warm ischemia is used (i.e. lap PN), tumor resection must be completed in less than 20 minutes.

3) For complex endophytic or perihilar tumors requiring extensive surgery and reconstruction, open PN with ice slush reno protection, preferably with less than 35 minutes of cold ischemia, would lessen the likelihood of lasting renal damage.

4) For tumors in a solitary kidney in an amenable position, PN without renal artery occlusion with exchange of intra operative blood loss for avoidance of acute renal failure and the need for post operative dialysis is preferable.
5) For patients undergoing open PN whose surgeon requires the use of renal artery occlusion to safely complete the operation in a solitary kidney or complex nephron sparing procedure, there is little rationale for using warm ischemia alone and cold ischemia should always be utilized.

Surgical Margins and the Difficult Partial Nephrectomy

A criticism of PN relates to the need for a 1 cm surgical margin of healthy tissue surrounding the tumor. Although this belief is felt to be founded in the basic principles of surgical oncology, no firm data exists to support this view. This issue is germane particularly when surgeons pursue endophytic tumors and peri hilar renal tumors, or renal tumors abutting the collecting system that would all be effectively excluded from PN if there was strict adherence to the 1 cm margin rule. Also, uncertain factors in pathology relating to the handling of the tumor specimen and fractures in its capsule may lead to an inked margin that is “positive”. MSKCC and Mayo Clinic investigators combined their data and analyzed 1344 patients undergoing 1390 PN from 1972-2005. Positive surgical margins were documented in 77 cases (5.5%) and were significantly associated with decreasing tumor size and presence of a solitary kidney. Interestingly, experienced surgeons from both centers describe small endophytic tumors, many of which are not palpable and can be located only by using intra operative ultrasound, as often difficult to find and resect and often associated with close or positive surgical margins. All patients with positive surgical margins were managed expectantly with an overall 10-year probability of freedom from local recurrence and metastatic recurrence of 93%. There was no significant difference in either local or metastatic recurrence between the patients with positive or negative surgical margins (Figure 13). Although the authors encourage a complete resection in every case, the argument for a subsequent completion nephrectomy when a positive margin is encountered on final pathology as well as a 1 cm surgical margin in all cases is unfounded (80).

During challenging PN, urological oncologists may encounter intra operative findings that previously would have triggered RN, yet with adherence to fundamental reconstructive and vascular surgical principles, PN can still be performed. Approximately 12% of renal cortical tumors will invade the collecting system and, although this may portend a worse prognosis, complete resection of the tumor and the involved collecting system can be done with suture repair and reconstruction (up to and including dismembered pyeloplasty over an internal stent) as needed. While performing the reconstruction, care must be taken not to exclude a renal papilla from the collecting system, an event which could lead to a urinary fistula without diversionary options (81). Most such leaks eventually close spontaneously but may take weeks or even months.

For tumors close to the renal hilar vessels or projecting into the renal sinus as an endophytic extension from the renal cortex, a troubling preoperative image may look far worse than what is encountered in the operating room. Fox Chase surgeons reported a series of 36 patients with central renal tumors that underwent successful PN. In their series 6 patients had benign tumors (17%), all tumors were pT1, and 34/36 (94%) were considered “low oncological risk” (82). The complete mobilization of the kidney upon the renal artery, renal vein and ureter, ligation and division of restraining polar vessels, and the use of the renal parenchymal elevating Gil Vernet type maneuver may allow ready access to the renal mass and its complete resection with minimal loss of healthy renal cortex. Also during PN, an intra renal vein tumor thrombus in a branched renal (T3b) may be encountered. If the thrombus does not extend to the main renal vein or inferior vena cava, complete resection can be achieved by adhering to the principles of vascular surgery and obtaining proximal and distal control with care to be certain that thrombus extraction is complete. The ultimate prognosis for these more complicated central tumors following complete resection depends upon tumor histology, size, and grade. Optical loupes and liberal use of intra operative ultrasound can aid the surgeon in these challenging cases (83).
Bilateral renal tumors are reported in between 1.5% of patients (84). In a study of 1082 non-metastatic renal tumors managed from 1989-2001, investigators identified 46 patients with bilateral tumors (4.25%) of which 33 (71.7%) were synchronous and 13 (28.3%) were asynchronous. Median tumor size for the synchronous group was 3.9 cm (range 1.0-12.5 cm). The first tumor in the asynchronous group had a median tumor size of 4.75 cm (range 2.5-12.5 cm) and the second asynchronous tumor had a median tumor size of 2.25 cm (range 1-4.0 cm) occurring at a median time of 84.5 months (range 28-240 months) from the contra lateral tumor. A total of 92 tumors were identified with a histological concordance rate of 76% between kidneys. Surgical management in this series was 42% RN and 58% PN with 7 patients undergoing bilateral PN. The most common histological sub-types were conventional clear cell in 66% and papillary in 14%. With a median follow up of 74 months, 72% of patients were disease free and 7 patients had recurrence (2 local, 5 metastatic). When this series of bilateral tumors, either synchronous or asynchronous, were compared to patients with unilateral disease, there was no difference in disease specific survival (85). For patients with bilateral synchronous tumors, controversy exists amongst urological oncologists regarding what operation to do and in what sequence. In a follow up study from MSKCC which focused only upon bilateral synchronous tumors, MSKCC investigators identified 73 (3%) out of 2777 patients with bilateral synchronous tumors from 1989-2008. Three patients underwent bilateral RN (all before 2003), 28 patients (38%) underwent a RN followed by a PN, and 32 (44%) underwent bilateral PN. As this team became increasingly committed to maximally preserving renal function, the use of bilateral PN increased (34% from 1995-2004 to 92% from 2004-2008). Forty five patients (62%) had the larger tumor removed first with a histological concordance rate between the kidneys of 70% (86). In this study too, there was no difference in overall survival between patients with unilateral vs. bilateral synchronous tumors. In general the larger tumor is pursued first since it is associated with greater metastatic potential.

Although multi-focal and bilateral tumors are part of hereditary and familial tumor syndromes such as von Hippel-Lindau Disease, hereditary papillary renal cancer, and Birt-Hogg-Dube syndrome, and may account for 3-5% of all renal cancers (87), multi-focal renal cortical tumors can also occur in sporadic renal tumor patients. MSKCC investigators evaluated 1071 RN specimens from 1989-2002 and found 57 (5.3%) with pathological evidence of tumor multi-focality including 6 (11%) that occurred in the bilateral synchronous setting. Preoperative imaging detected multi-focality in 19 patients (33%) and therefore occult multi-focality was detected 38/1071 (3.5%). Primary tumors in the multi-focal group were conventional clear cell (51%) followed by papillary (37%) and 74% had the same tumor histology in all lesions. Multivariate analysis demonstrated that bilaterality, papillary histology, advanced tumor stage, and lymph node metastases were associated with multi-focal tumors. After a median follow up of 40.5 months, disease free survival was not significantly different between multi-focal and uni-focal renal tumors (88). When faced with an index renal tumor and surrounding minute satellite tumors detected visually or with the aid of intra-operative ultrasound, the smaller tumors should be resected first without the use of cold ischemia by using a 15 blade on a long knife handle followed by argon beam coagulation of the renal cortical resection bases. When faced with larger tumors (>2 cm), formal PN with necessary collecting system or vascular repairs with or without cold ischemia, depending the tumor location, is performed. Multi-focal tumors that can be resected completely, even those requiring numerous excisions in the same kidney, should not trigger an automatic RN.

Another difficult problem is a renal tumor in the solitary kidney, a classical indication for PN, which can be due to a congenital absence of the contra lateral kidney or following contra lateral nephrectomy for tumor, stone disease, donor transplantation, or infection. When performed by experienced surgeons, PN in this setting can safely be performed with a low rate of temporary or permanent dialysis (89, 90). The largest experience with tumor in a solitary kidney is from the Cleveland Clinic which reported 400 cases from 1980-2002. In 323 patients (81%) the contra lateral kidney had been surgically removed and in 77 patients had a congenital solitary kidney. In 46% of these patients, evidence of renal insufficiency was present pre operatively. The authors used hilar clamping in 96% of the cases with a mean tumor size of 4.18 cm of which 92% were renal cancers. Interestingly, 36% of the patients had multi focal disease resected. Only 13 of the 82 patients that experienced disease recurrence had a local kidney recurrence. Following resection, 95% of patients had satisfactory long term renal function with only two patients requiring immediate dialysis and 18 others progressing to end stage renal disease requiring dialysis at a mean of 3.6 years after PN (91). The same group compared their LPN (N=30) and open PN (N=169) in renal tumors in a solitary kidney from 1999-2006 and reported that the laparoscopic cases had a significantly greater need for post operative dialysis, longer ischemic times, and twice the complication rate compared to open approach. This
expert team of laparoscopic surgeons concluded that the open PN may be the preferred approach in these patients at high risk for CKD (92). The increasing use of PN for T1 tumors, a good prognostic category in general with patients likely to survive a long time but remain at risk for a contra-lateral renal tumor, may decrease the need to perform PN in the solitary kidney in the future.

Repeat PN for new tumor formation is a difficult operation due to scar tissue from previous renal mobilization and peri-renal adhesions often involving the great vessels of the renal hilum. The National Cancer Institute, which commonly performs repeat PN in the management of with hereditary and familial cancer syndromes, reported a series of 51 attempted PN in 47 such patients from 1992-2006. There were major complications or re operations in 10 patients (19.6%), one perioperative death, and a significant increase in serum creatinine and decrease in creatinine clearance. Two patients required long term dialysis. Of the 46 surviving patients, median follow was 56 months (93).

Increasingly, urological oncologists are being asked to operate on renal masses with imaging evidence of viability following radiofrequency ablation or cryoablation. A Cleveland Clinic report documented recurrence rates for cryoablation of 13/175 cases (7.4%) and for RFA of 26 of 104 cases (25%). Mean pre-ablation tumor sizes were 3.0 and 2.8 cm respectively. Repeat ablations were performed in 26 patients but 12 patients were not candidates for repeat ablation due to large tumor size, disease progression, or repeat ablation failure. Of these, 10 patients underwent attempted resection and only 2 patients were able to undergo a PN (open) with 7 patients requiring RN. One operation was aborted (94). The NCI team recently reported their experience with 13 patients previously treated with radiofrequency ablation at a median time of 2.75 years prior using salvage PN. No patients were converted to RN but the salvage operations were very difficult due to extensive fibrosis and scarring. Median operative time was 7.8 hours (range 5-10.7 hrs) and median blood loss was 1500 ml (range 500-3500 ml) (95). This data indicates that a failed ablation in a patient originally eligible for a PN makes for a difficult surgical salvage and low likelihood of PN.

The resection of a renal tumor in a patient with metastatic renal cancer may be done with a PN, particularly if the tumor is in a functional or anatomic solitary kidney, and may be in conjunction with a metastasectomy or following induction systemic chemotherapy with excellent response in metastatic sites but tumor persistence in the kidney. In an initial experience with 15 patients, 9 of whom were previously treated for metastatic disease with either metastasectomy or systemic agents, excellent local tumor control and renal function sufficient to avoid dialysis was achieved in 14/15 patients (96).

Today, surgical resection after systemic therapy with targeted therapies (mTOR and tyrosine kinase inhibitors) is often requested by medical oncologists as part of an integrated multi modality treatment plan (97). Depending upon the size of the index tumor and its response to systemic therapy, surgeons may plan surgical resection. The Cleveland Clinic reported a preliminary experience of 21 operations in 19 patients treated systemic targeted therapies (including sunitinib, N=12, sorafenib N=3, and bevacizumab/ Il-2 N=4) followed by subsequent surgical resections in patients with either stable disease or partial clinical response. Operations included 9 RN, 3 PN, 6 local tumor recurrence resections, and 3 metastasectomies. Open operations were performed in 18 cases and laparoscopic operations in 3. Only one patient had a complete pathological response to the systemic therapy and 80% had viable conventional clear cell carcinoma in the resected specimen. Three patients had major complications (16%) including 2 major post operative bleeds leading to one post operative death and anastomotic bowel leak. At a median follow-up of 8 months, 16 patients (84%) were alive, 8 of whom (42%) had disease progression. Nine patients (50%) with metastatic disease or later disease progression were continued on systemic targeted therapy (98). The role of surgery in general and PN specifically in the face of metastatic disease will continue to evolve.

Complications of Open Partial Nephrectomy

Surgical complications related to PN were a major disincentive for many urologists and relate to three major categories; bleeding, urinary fistula, and infection. Using a graded scale of complications in 15 categories describing over 163 unique complications, MSKCC investigators evaluated 361 (34%) patients undergoing PN and 688 (66%) patients undergoing RN from 1995 to 2002. Procedure related complications included urinary leak, acute renal failure, retroperitoneal hemorrhage, pneumothorax, adjacent organ injury and small bowel obstruction. Urinary fistula was defined as persistent urine leak lasting beyond 7 post operative days or a collection requiring a percutaneous drain placement. Complications were graded using a five tiered system: grade 1- oral medication or bedside care; grade 2- intravenous therapy or thoracostomy tube; grade 3- intubation, interventional radiology, endoscopy, or reoperation; grade 4- major organ
resection or chronic disability; grade 5- death. In this study, 235 complications occurred in 180 patients (17%). Overall, 55% and 31% of the complications were grade 1 and 2 respectively. There were 3 perioperative deaths (0.2%). PN was not associated with more complications compared to RN but PN did have more procedure related complications (9% vs. 3%) due mainly to urinary fistula with re-intervention rates of 2.5% for PN vs. 0.6% vs. RN. All but one re-intervention involved endoscopy or interventional radiology. Neither tumor size, tumor location (central vs. polar) or imperative vs. elective indication was associated with complications of PN. Multivariate analysis indicated that operative time and solitary kidney were significantly associated with procedure related complications of PN (99).

A troubling complication is persistent urinary leakage, particularly when the patient must be discharged home with a drain (Figure 14). As urological surgeons perform more challenging PN involving the renal sinus, the likelihood of a persistent urine leak increases. Northwestern investigators analyzed 127 consecutive PN (70 OPN and 57 LPN) from 2001 to 2007 while defining a urine leak as drain output consistent with urine for greater than 48 hours. Overall, 21 patients (13.3%) experienced a urine leak. Factors associated with a greater likelihood of urine leak included larger tumor size, endophytic tumor location and repair of collecting system at the time of tumor resection. Factors not associated with urine leak included number of tumors resected, estimated blood loss, ischemia time, body mass index, age, or other surgical complications. The median duration of the leak was 20 days. Most urine leaks resolved with prolonged drainage with the median duration of the leak 20 days. Ten patients (38%) required a secondary intervention including a ureteral stent (N=8) and percutaneous nephrostomy (N=2). No nephrectomies or surgical re-explorations were required (100). In a larger study, MSKCC investigators analyzed 1118 PN defining persistent urinary leak as that lasting greater than 2 weeks or a patient that represents after drain removal with an urinoma requiring percutaneous drainage. Fifty-two patients developed a post operative urinary fistula (4.4%) with persistent leak accounting for 4% and delayed fistula presentation accounting for 0.4% of cases. Factors associated with urine leak were larger tumors (3.5 vs. 2.6 cm), more blood loss (400 ml vs. 300ml), and longer ischemia time (50 minutes vs. 39 minutes). Overall, 36 patients (69%) resolved the fistula without intervention while 16 patients (31%) underwent a procedure aimed at resolving the fistula including stent (N=8) and another drain (N=2). No patient lost their kidney or required a nephrectomy to manage the fistula (101). Urologists often debate in conferences whether closed suction or Penrose drainage is preferable after partial nephrectomy. MD Anderson surgeons evaluated 184 patients undergoing 197 PN at their center with drainage type based solely on surgeon preference. A Penrose drain was used in 74 patients (37.6%) and closed suction drain in 123 patients (62.4%). Clinical characteristics between the two groups were similar and mean tumor size was 3.1 cm. No significant difference in mean duration of drainage was noted between those receiving a Penrose drain (7.1 days) and those receiving a closed suction drain (7.8 days). In addition, no significant difference in post operative complications was noted between the groups (102).

On a practical level when faced with a persistent urinary leak, I encourage patients to eat three square meals per day, rest, and exercise in hopes of speeding natural wound healing. If urine leak continues greater than 6-8 weeks without any sign of gradual decline, a cystoscopy and retrograde pyelogram are done to exclude a distal ureteral obstruction or injury. A disconcerting finding on such a study could be a normal pyelocalyceal system yet persistent urinary drainage. In this case it must be assumed that there is an excluded renal papilla without a corresponding calyx causing the leak which may take several months to resolve until that papilla is no longer functional.

Pseudo aneurysm or iatrogenic arterial venous fistula forms when surgical repair of vascular rents fuses arteries and veins with direct communication between the two. On rare occasions a palpable thrill can be noticed over the resection site at the end of a PN. In this case, the situation needs to be addressed immediately with either re-exploration of the PN bed and ligation of the communicating vessels

![FIGURE 14. Renal protocol CT scan demonstrating post operative pseudoaneurysm of the left kidney with peri-nephric hemorrhage.](image-url)
or completion RN. Delayed post operative bleeding with peri-nephric hematoma can present with pain, gross hematuria, hypotension, flank mass, or flank discoloration from dissecting blood through the healing wound. Following appropriate resuscitation, CT renal protocol (Figure 14) is performed which will reveal arterial blood pooling in a closed space with or without perinephric hematoma, a finding which should initiate an urgent request to interventional radiology for a selective renal artery angiogram (Figure 15) and coil embolization. The interventional radiologist should make every effort to occlude a tertiary and quaternary branches of the renal artery as close to pseudo aneurysmal pocket as possible in order to limit collateral damage to viable, healthy renal tissue (Figure 16). Cohenpour and colleagues reported 5 such pseudo aneurysms (4 open, 1 lap) which presented 1-21 days post operatively. Selective coil embolization was successful in 4 of the 5 cases and RN was required in one case (103). Careful surgical technique during open or laparoscopic approaches with avoidance of deep hemostatic bites with large needles into the renal sinus will greatly diminish the likelihood of this complication.

**Partial Nephrectomy is Under-utilized**

In the United States in 2010 it is estimated that 58,240 patients will develop renal tumors and 13,040 deaths will be attributed to renal cancer. Approximately 70% are incidentally detected at a tumor size of 4 cm or less (104). Despite the above well described oncological and medical arguments in the contemporary literature supporting PN as an ideal treatment for such small renal masses, the urological oncology community continued to use RN as the predominant treatment of the T1a renal mass. A cross sectional view of clinical practice using the Nationwide Inpatient Sample, revealed that only 7.5% of kidney tumor operations in the United States 1988-2002 were PN (105). Using the Surveillance Epidemiology and End Results (SEER) data base, investigators from the University of Michigan reported from 2001, only 20% of all renal cortical tumors between 2-4 cm were treated by PN (106) and using the SEER data base linked to Medicare claims, Huang and colleagues from MSKCC reported a utilization rate of only 19% for T1a tumors (4cm or less) (55). Interestingly and for uncertain reasons, women and elderly patients are more likely to be treated with RN (107). Many urologists believe a “quick” RN in an elderly patient would expose the patient to fewer post operative complications than would a PN. However, MSKCC investigators evaluated age and type of procedure performed in 1712 patients with kidney tumors found the interactive term was not significant indicating a lack of statistical evidence that the risk of complications associated with PN increased with advancing age. Furthermore, no evidence was reported linking age to estimated blood loss or operative time. Given the advantages of renal functional preservation, the authors concluded that elderly patients should be perfectly eligible for PN (108). Although the urology literature has a great many articles written concerning the use of laparoscopic techniques to resect kidney tumors, the penetrence of laparoscopic RN according to the National Inpatient Sample from 1991 to 2003 was only 4.6% with a peak incidence of 16% in 2003. This data indicates that the bulk of “kidney wasting operations” are being done by traditional open surgical approaches (109). In England, a similar under-utilization of PN was reported in 2002 with only 108 (4%) PN out of 2671 nephrectomies performed (110). Investigators at MSKCC tracked nephrectomy use in 1533 patients between 2000-2007 excluding patients with bilateral tumors and tumors in a solitary kidney and including only patients with an eGFR of greater than 45 ml/min/1.73 m2. Overall 854 (56%)
patients underwent PN and 679 (44%) underwent RN. In the 820 patients with a renal tumor of 4 cm or less, the frequency of PN increased from 69% in 2000 to 89% in 2007. In the 365 patients with a renal tumor between 4.7 cm, the frequency of PN increased from 20% in 2000 to 60% in 2007. Despite a commitment to kidney sparing operations during this time frame by the MSKCC group, multivariate analysis indicated that PN was a significantly favored approach for males, younger patients, smaller tumors, and open surgeons (111).

CONCLUSION

Open PN, once an operation performed only for the essential indications of tumor in an anatomical or functional solitary kidney, has emerged as the preferred means of treating T1 renal masses. There is an enhanced understanding of the biology of renal cortical tumors which indicates that approximately 45% of the renal tumors are benign and indolent in nature. Due to abdominal imaging performed for non specific abdominal complaints, incidental renal tumor detection occurs in 70% of cases leading to a tumor size and stage migration to small tumors at the time of presentation. Well done studies demonstrate that PN provides equivalent oncological control to RN for tumors of 7 cm or less. PN is now considered the treatment of choice for small renal masses. A new appreciation for CKD, impaired renal function before the end stage renal disease which requires renal replacement therapy in the form of transplantation or dialysis, and its associated cardiovascular morbidity and mortality, now provides an added incentive for PN. RN is associated with worsening of pre existing chronic kidney disease, cardiovascular events, and worse overall survival. Despite these compelling arguments for the PN, gross under utilization in the United States and abroad exists and is largely due to the overzealous use of RN, a practice which now must be considered as detrimental to the long term health of a kidney tumor patient. Widespread training in PN and enhanced utilization is clearly indicated in the United States and abroad. Another avenue to kidney preservation in elderly or co-morbidly patients is active surveillance.

REFERENCES AND RECOMMENDED READINGS

(*of special interest, **of outstanding interest)


47. Ritz E., McClellan WW: Overview: increased


60. Lowrance WT, Thompson RH, Yee DS, Kaag M, Donat MS, Russo P: Obesity is associated with a higher risk of clear cell renal cell carcinoma than other histologies. BJU Int. 105:16-20, 2009.


*68.** Diblasio CJ, Snyder ME, Russo P. Mini flank supra-eleventh incision for open partial or radical nephrectomy. BJU Int. 2006; 97(1):149-156.


**74.** Sheridan AM, Bonventre JV: Cell biology and molecular mechanisms of injury in ischemic acute renal failure. Curr Opin in Neph and Hyperten-
86. Yossepowitch O, Eggener SE, Serio A, Huang WC, Snyder ME, Vickers AJ, Russo P: Tempor-


96. Lowrance WT, Yee DS, Maschino AC, Cronin AM, Bernstein M, Thompson HR, Russo P: Developments in the surgical management of spora-


