Nephron-Sparing Surgery

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Renal cell carcinoma (RCC) is a common malignancy with an increasing incidence.[1,2] The classic triad of abdominal mass, hematuria, and flank pain accompanied by the various associated paraneoplastic syndromes (or the "internist's tumor") are rare presentations of contemporary kidney cancer. With the current use and practice of modern abdominal imaging, more than half of all renal tumors are incidentally discovered at a low stage during evaluation for other conditions. The renal mass has become increasingly amenable to treatment given this stage migration. Therefore, in the modern era, it might be more appropriate to refer to RCC as the "radiologist's tumor" rather than the internists.

The International Union Against Cancer staging system for RCC defines a stage 1 renal mass as an organ-confined tumor up to 4.0 cm in diameter (T1a), and between 4.1 and 7.0 cm in diameter (T1b). The American Urological Association (AUA) published guidelines for the management of stage 1 renal mass in 2009 and had validity confirmed in 2010.[3] The AUA's thorough review is a must read for any practitioner treating renal masses. The National Comprehensive Cancer Network (NCCN) also provides guidance on the management of stage 1 renal masses.[4] In this review, a small renal mass (SRM) is considered a T1a renal mass. The majority of SRMs will be RCCs; however many, approximately 20% will have benign histology.[5] Even many of those classified as kidney cancer may have an indolent clinical course with limited growth and low risk of metastasis.[6] Malignant potential is an important consideration when contemplating the permanent removal of a renal unit.

Stage 1 renal masses are often successfully treated with nephron-sparing surgery (NSS) and this is the preferred approach to the resectable SRM. For this article, NSS will include only surgical partial nephrectomy, but ablative therapies such as cryoablation and radiofrequency ablation are also successfully used to preserve renal tissue on an ipsilateral renal unit. NSS was proven feasible decades ago for patients with imperative indications to preserve maximum kidney function, for instance solitary kidney, bilateral renal tumors, or moderate/severe chronic kidney disease (CKD).[7] This allowed for expansion of NSS into general use for the stage 1 renal mass. Pathologic studies have shown underlying renal disease is commonly present in presumably "normal" kidneys, and outcomes studies clearly demonstrate new CKD development after nephrectomy.[8] CKD has been linked to cardiovascular disease, hospitalization, and death in a population-based study of more than 1 million patients.[9] This study challenges the notion that the loss of a renal unit does not significantly impact long-term health outcomes.

Unfortunately NSS is widely underutilized. An evaluation of a nationwide hospital database determined only 9% of patients with surgically treatable renal tumors were treated with NSS.[7] There are varied reasons for the underuse of NSS; the complexity of the surgical endeavor, an under appreciation for the impact of radical nephrectomy (RN) on health outcomes, and peculiar financial incentives seem to contribute to underutilization. NSS does have more short-term complications compared with total nephrectomy, and the oncologic efficacy had not been proven in a randomized trial. Starting in 1992, the European Organization for Research and Treatment of Cancer (EORTC) attempted to perform a randomized trial of elective NSS and RN for renal masses 5 cm or smaller[10]; however, the study closed early due to poor accrual and has raised many statistical questions. The published data, however, should be carefully considered, and one safe conclusion from the trial is that both RN and NSS provide excellent oncologic control. There were more local recurrences (albeit few in total) in the NSS group.

Indications

Absolute indications for NSS include conditions rendering the patient dialysis dependent with complete resection of a tumor-bearing kidney. These conditions include bilateral tumors or a tumor in a solitary functioning kidney. Relative indications for NSS include conditions that present any current or future risk to renal function. These risks include, but are not limited to, calculus disease, renal artery stenosis, chronic pyelonephritis, ureteric reflux, diabetes, and hypertension.

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General guidelines suggest that peripheral tumors 7 cm and smaller are more amenable to NSS. Better outcomes are observed with solitary clinical stage T1 tumors. The AUA and NCCN clinical guidelines prefer partial nephrectomy to RN for the feasibly resectable T1a renal mass. RN and NSS are equivalent treatment alternatives for the T1b renal mass. Partial nephrectomy has a higher local recurrence rate for tumors larger than 7 cm but is possible when imperative indications exist. With lower oncologic efficacy in T2 tumors, NSS should be used in limited situations.

Evaluation

For patients suspected of having RCC, a complete history and physical exam must be performed. An adjusted life expectancy estimation should be made. Additional evaluation should include testing for hematuria and/or proteinuria using urine analysis or urine dipstick testing. Recommended imaging includes a chest X-ray or computed tomogram (CT) and abdominal CT or magnetic resonance imaging (MRI) to exclude locally advanced or metastatic disease. Three-dimensional reconstruction of CT or MRI can be useful to accurately visualize vascular anatomy and the relation of tumor to normal renal parenchyma. Care is taken to observe for any evidence of lymphadenopathy, or segmental or renal vein invasion.

The approach to a SRM is based on tumor size, stage, and location. The RENAL Nephrometry and PADUA scores provide useful scoring systems based on the aforementioned factors and can be quickly calculated. The RENAL Nephrometry score provides values from 4 to 12 and accounts for an anterior/posterior (a/p) relationship of the tumor as well as proximity to the renal vessels (h).[11] The PADUA scores range from 6 to 14 and similarly accounts for a/p position.[12] The main differences between the RENAL Nephrometry and PADUA scores are hierarchical scaling for localization of the tumors. These scores predict operative time, warm ischemic time (WIT), change in glomerular filtration rate, and conversion to nephrectomy.[13–15] Higher body mass index and increased intra-abdominal fat are also predictive for perioperative complications and/or surgical difficulty for patients with SRMs.[16] For completely endophytic tumors, a preoperative renal ultrasound is a useful adjunct; tumors that are isoechoic to kidney tissue on ultrasound may be very difficult to identify intraoperatively.

The discussion with the patient can be complex. Patient counseling involves a review of the alternatives including active surveillance, ablative therapies, option of renal mass biopsy (RMB), NSS, and RN. Healthy, thin patients with RENAL Nephrometry scores of 8 or less are more straightforward with lower risks of complications from NSS. Patients with abundant perirenal fat or higher RENAL Nephrometry scores (9–12 or +h) are counseled about higher risks of complications and longer operative times. Stronger considerations for either observation or RN are made in morbid patients with SRMs or T1b renal masses, respectively. In a retrospective analysis of the SEER database, intervention may have inferior survival outcomes when compared with observation in Medicare-aged patients.[17] If confirmed, this outcome would suggest that older patients with SRMs should pursue less aggressive treatment strategies.

Percutaneous RMB can be a useful adjunct with sensitivity, specificity, positive predictive value, and negative predictive value (NPV) of 89, 60, 100, and 75%, respectively.[18] Biopsy tract seeding can occur, but is seemingly rare as it has not been observed in larger studies of percutaneous RMB. Patients with benign pathology on biopsy are preferably observed.

Technique for Nephron-Sparing Surgery

The goal of partial nephrectomy is complete excision of potentially malignant tissue without malignant cells at the border of the surgical specimen, with maximum preservation of nearby normal renal parenchyma. Complete excisions are essential, but excision of excess nearby normal tissue for wider margins does not seem to matter. Most NSS requires renal vessel occlusion during the excision, and renal tubular tissue is particularly sensitive to ischemia; the WIT, therefore, should be minimized. Damage to renal tubular tissue is directly related to WIT. Although the upper limit of WIT is debatable and probably has other patient variables, a limit of 20 minutes is a generally accepted guideline. If the WIT is expected to be longer than 20 minutes, thought should be given to cooling the kidney tissue with ice slush, as lowering the renal parenchymal temperature allows for longer periods of excision. In addition, application of renal cooling should be strongly considered in patients with imperative indications for partial nephrectomy.

There are techniques for limiting renal ischemia during partial nephrectomy that include selective clamping of segmental renal vessels or parenchymal compression that limits WIT to areas of polar excision. Intraoperative ultrasound with Doppler can be useful for not only illuminating the planes for planned excision but also to determine arterial inflow for the tumor. A process for a zero ischemia partial nephrectomy has been described that uses anesthetic permissive hypotension with meticulous dissection and clipping of the intrarenal vasculature.[19] Renal autotransplantation with ex vivo tumor excision has also been described in rare instances.[20] It is worth noting that tumors of nearly all sizes and locations have been treated with NSS, including some with renal vein invasion.

The kidney can be approached with traditional "open" surgery or laparoscopically. For SRMs appropriate for NSS, open partial nephrectomy represents the gold standard. This approach has the most data regarding oncologic and renal function outcomes, with long-term cancer-specific survival rates exceeding 90%.[21,22] Laparoscopic partial nephrectomy is also a well-established approach, but requires extensive training in laparoscopic or robotic surgery. Laparoscopic partial nephrectomy was reserved for more straightforward excisions of polar or exophytic T1 renal masses; however, more challenging SRMs near the renal hilum are being removed laparoscopically with successful outcomes.[23,24] The da Vinci surgical robot is often used for laparoscopic partial nephrectomy given the advantages it offers with three-dimensional viewing and wristed instrumentation. Laparoscopy can be done through the peritoneum, which requires mobilization and rotation of the nearby abdominal viscera, or more directly through the retroperitoneum. In general, tumors situated medially and anteriorly are amenable to removal through the peritoneum, while those positioned more laterally and posteriorly are more easily removed via a retroperitoneal approach. As the retroperitoneal approach offers ready access to the renal artery and minimizes dissection necessary to isolate the kidney, it is the preferred laparoscopic approach at the authors' institution.

Open and laparoscopic NSS have not been compared in a randomized trial. Given that the fundamentals of tumor excision are the same, it seems doubtful that an oncologic noninferiority trial would be informative. In retrospective and prospective studies, laparoscopic surgery reliably has shorter hospital stays and similar complication rates.[25,26] Open surgery has some clear advantages with easier application of tissue cooling and more varied instrumentation available; these techniques are advantageous when treating more complicated renal masses.

Conclusion

The interventional radiologist should understand NSS and the current state of the art in the management of clinical stage 1 renal masses. As outlined in most clinical guidelines, NSS is the treatment of choice for the SRM in a healthy patient. Patient selection and preoperative preparation are critical for successful outcomes with NSS. RMB has a role, but has a nondiagnostic rate of around 10% as well as a NPV of only 75%, which cannot eliminate follow-up. Observation and ablation are reasonable treatment alternatives in the well-counseled patient.

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