Surgical management of pediatric renal masses: surgeon subspecialty practice patterns

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Introduction: *Management of pediatric renal masses has lagged behind adult paradigms adopting minimally invasive surgery (MIS) and nephron-sparing surgery (NSS). This study investigated national practice patterns between pediatric urologists (PU) and pediatric surgeons (PS) in pediatric renal malignancy.*

Materials and methods: *The Pediatric National Surgical Quality Improvement Program database was queried for CPT codes for radical/partial nephrectomy from 2012-2017 performed for renal malignancy. Patients were grouped by specialty and operative approach.*

Results: *PU managed 175 (17%) patients while PS managed 811 (77%). PU were more likely to use MIS (14% versus 5%, $p < 0.001$) and NSS (33% versus 13%, $p < 0.001$) compared to PS. PS more commonly performed lymph node (LN) sampling/tumor thrombectomy, especially in MIS cases (67% versus 35%, $p = 0.008$). PS operated on younger patients with higher ASA class compared to PU, but had higher transfusion rates and longer length of stay. Central venous access surgery was more commonly performed on patients operated on by PS, while PU performed more cystoscopy/retrograde pyelography. Patients who underwent NSS compared to radical nephrectomy were less likely to undergo LN sampling, while LN sampling did not differ between open and MIS groups.*

Conclusions: *PU were likely to perform MIS and NSS than PS for pediatric renal masses in this national database. This likely results from inherent training differences between PS and PU and reflects emerging data on safety and efficacy of these advanced surgical techniques. Further investigation into the impact on oncologic and clinical outcomes by surgical specialty and operative approach is necessary.*

Key Words: pediatric renal mass, laparoscopic, minimally-invasive surgery, partial nephrectomy, nephron-sparing surgery

Introduction

Driven largely by cooperative group protocols and retrospective data, pediatric renal masses are conventionally managed with open, radical nephrectomy. Contrary to the management of adult renal masses, little emphasis is placed on nephron-sparing surgery (NSS) and minimally invasive surgery (MIS) techniques, except in very specific scenarios. The Children's Oncology Group (COG) cite limited data substantiating these advanced surgical techniques, limited largely to off-protocol, single institution case series. There have been significant advances in survival for children with renal masses over the last century, undoubtedly because of rigorous study by this group, among others. According to COG protocols, NSS is reserved for patients with solitary kidneys, bilateral masses and syndromic patients, and is often combined with neoadjuvant chemotherapy to facilitate tumor shrinkage and nephron preservation.[1] Concerns for port-site seeding, tumor rupture, and omission of lymph node sampling with MIS, in addition to its unproven equivalent oncologic outcomes, has limited its routine adoption.[2] Conversely, recent

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recognition of the efficacy and safety of both NSS and MIS in the treatment of select unilateral, non-syndromic pediatric renal masses is reflected in guidelines published from the International Society of Pediatric Oncology (SIOP).[3-5]

Pediatric renal masses are managed by pediatric surgeons (PS) and pediatric urologists (PU) depending on institutional practice. Prior studies have examined differences in training[6] and surgical volume[7-10] with respect to surgical management of pediatric renal masses between PS and PU. Two studies by Suson et al investigated national practice patterns comparing the utilization of radical nephrectomy and NSS in the management of both benign and malignant pediatric renal disease.[11,12] This study investigated the utilization differences of advanced surgical techniques between PS and PU in the management of pediatric renal masses, including clinical variables and short-term outcomes stratified by surgeon specialty, operative approach and surgical modality. We hypothesized that PU more commonly implement the advanced surgical techniques of MIS and NSS in the management of pediatric renal masses.

Materials and methods

Database description and patient selection

The American College of Surgeons Pediatric National Surgical Quality Improvement Program (ACS NSQIP) database is a prospectively maintained, national database designed to compare clinical data and surgical outcomes in the care of pediatric patients among 129 participating institutions in North America. Data are collected on patients < 18 years of age who are undergoing major surgical procedures, and outcomes are assessed for 30 days following the procedure. The database was queried for CPT codes corresponding to radical or partial nephrectomy from 01/01/2012 (database inception) through 12/31/2017. CPT codes utilized for the initial screening are included in Table 1. This study was exempt under local Institutional Review Board regulations.

TABLE 1. **CPT codes for procedures included in analysis**

CPT Code	Procedure
Extirpative renal surgery	
50546	Laparoscopy, surgical; nephrectomy, including partial ureterectomy
50220	Nephrectomy, including partial ureterectomy, any open approach including rib resection
50240	Nephrectomy, partial
50230	Nephrectomy, including partial ureterectomy, any open approach including rib resection; radical, with regional lymphadenectomy and/or vena caval thrombectomy
50236	Nephrectomy with total ureterectomy and bladder cuff; through separate incision
50548	Laparoscopy, surgical; nephrectomy with total ureterectomy
50543	Laparoscopy, surgical; partial nephrectomy
50225	Nephrectomy, including partial ureterectomy, any open approach including rib resection; complicated because of previous surgery on same kidney
50234	Nephrectomy with total ureterectomy and bladder cuff; through same incision
50545	Laparoscopy, surgical; radical nephrectomy (includes removal of Gerota's fascia and surrounding fatty tissue, removal of regional lymph nodes, and adrenalectomy)
Lymph node sampling (includes 50230, 50545)	
38747	Abdominal lymphadenectomy, regional, including celiac, gastric, portal, peripancreatic, with or without para-aortic and vena caval nodes
38505	Biopsy or excision of lymph node(s)
38562	Limited lymphadenectomy for staging; pelvic and para-aortic
38564	Limited lymphadenectomy for staging; retroperitoneal (aortic and/or splenic)
38780	Retroperitoneal transabdominal lymphadenectomy, extensive, including pelvic, aortic, and renal nodes

Patients were included for study if they met the following criteria: (1) the patient's primary ICD-9 code included "malignant neoplasm of the kidney" or similar, or (2) the patient's primary ICD-9 code included "abdominal mass" or "other disease of the kidney and ureter" and the patient was also characterized as having "current cancer or active treatment of cancer" as a separate designation. There were no exclusion criteria, and complete data were was available for every patient included in the study for the datapoints collected: surgeon specialty, surgical modality (open versus MIS; data did not differentiate between conventional laparoscopy and robot-assistance), operative approach (NSS versus radical nephrectomy), concomitant procedures (including "central venous access procedures," defined as central venous port placement and/or removal, and cystoscopy with retrograde pyelography), age, operative time, American Association of Anesthesiologists (ASA) physical classification status, length of stay, transfusion rates, and rates of 30-day postoperative complications, unplanned readmission and reoperations. The database did not differentiate between LN sampling and tumor thrombectomy, which were combined in an inclusive CPT code. CPT codes used to define lymph node sampling are listed in Table 1. No oncologic outcome data in terms of histologic diagnosis, adjuvant therapy, recurrence or survival is available in the NSQIP database and thus oncologic outcomes were not studied.

Statistical analysis

Patients were grouped by surgeon specialty (PU versus PS), surgical modality (MIS versus open), and by operative approach (NSS versus radical nephrectomy). Proportions of categorical variables were compared using Chi-square and Fisher's exact tests, as appropriate, and continuous variables using the Wilcoxon Rank-Sum test. Statistical significance was set at $p < 0.05$. Analysis by operative approach and surgical modality pooled data from both surgical specialties was used to investigate national practice patterns.

Results

Comparison by surgeon specialty

Between 2012 and 2017 there were 2,394 patients registered in the database who underwent NSS or radical nephrectomy. The 1,033 operations performed for malignancy were included in the analysis. Patient breakdown by surgeon specialty was as follows: PU 175 (17%), PS 811 (79%), adult urology 18 (2%), and adult general surgery 29 (3%).

Table 2 compares intra-operative variables, operative approach and surgical modality between PU and PS. With regards to surgical modality, PU more commonly performed MIS (14% versus 5%, $p < 0.001$) and NSS (33% versus 13%, $p < 0.001$) compared to PS. PU less commonly performed lymphadenectomy/

TABLE 2. **Operative technique, PU versus PS. Comparison between pediatric urologists (PU) and pediatric surgeons (PS) with regards to surgical modality and operative technique**

	PU	PS	p value
N	175 (17%)	811 (79%)	
MIS	26 (14%)	43 (5%)	< 0.001
Open	149 (86%)	768 (95%)	< 0.001
NSS	58 (33%)	104 (13%)	< 0.001
Radical nephrectomy	117 (67%)	707 (87%)	< 0.001
LN sampling and/or tumor thrombectomy	99 (57%)	536 (66%)	0.017
MIS (% of MIS cases)	9 (35%)	29 (67%)	0.008
Open (% of open cases)	90 (60%)	507 (66%)	0.188
NSS (% of NSS)	19 (33%)	28 (27%)	0.433
Radical (% of radical nephrectomies)	80 (68%)	508 (72%)	0.441
Concomitant procedures			
Central venous access procedures	22 (13%)	263 (32%)	< 0.001
Cystoscopy/retrograde pyelogram	14 (8%)	16 (2%)	< 0.001
Operating room time, min (SD)	234.6 (106.7)	237.4 (110.0)	0.85

MIS = minimally-invasive surgery; NSS = nephron-sparing surgery; LN = lymph node; SD = standard deviation

TABLE 3. **Perioperative consideration, PU versus PS. Comparison between pediatric urologists (PU) and pediatric surgeons (PS) with respect to preoperative patient characteristics and postoperative complications**

	PU	PS	p value
N	175 (17%)	811 (77%)	
Patient age, years (SD)	6.0 (5.0)	4.2 (3.4)	0.002
ASA class			< 0.001*
I	4 (2%)	13 (2%)	
II	66 (38%)	181 (22%)	
III	99 (57%)	566 (70%)	
IV	6 (3%)	49 (6%)	
V	0	2 (< 1%)	
Length of stay, days (SD)	6.5 (6.8)	8.3 (8.9)	< 0.001
Surgical site infection	0	2 (<1%)	> 0.050
Pneumonia	0	7 (1%)	> 0.050
Urinary tract infection	1 (< 1%)	10 (1%)	> 0.050
Transfusion	2 (1%)	46 (6%)	0.010
30-day parameters			
Mortality	0	3 (< 1%)	> 0.050
Re-operation	8 (5%)	35 (4%)	> 0.050
Unplanned readmission	15 (9%)	84 (10%)	> 0.050

*p value represents Chi-square analysis of ASA Class I-II
SD = standard deviation; ASA = American Association of Anesthesiologists

tumor thrombectomy compared to PS, especially in MIS cases (35% versus 67% respectively in MIS cases, p = 0.008). While concomitant central venous access procedures were more commonly performed in cases completed by PS, cystoscopy/retrograde pyelography was more commonly performed in cases completed by PU (p < 0.001 for both).

Pre-operative patient characteristics and post-operative complications were then analyzed by surgical specialty, Table 3. The average patient age for PU was 6.0 compared to 4.2 years for PS (p = 0.002). PS operated on patients with higher ASA class, with 77% of patients being ASA ≥ 3 compared to 60% of patients with ASA ≥ 3 in the PU cohort (p < 0.001). There was a lower transfusion rate (1% versus 6%, p = 0.01) and shorter length of stay (6.5 versus 8.3 days, p < 0.001) for PU relative to PS. Other postoperative complications, including re-operation and re-admission rates, were low and comparable between surgical specialties.

TABLE 4. **Operative technique comparison, NSS versus radical nephrectomy. Comparison of operative technique and patient characteristics by use of nephron-sparing surgery (NSS) compared to radical nephrectomy. SD: standard deviation**

	NSS	Radical nephrectomy	p value
N	169 (16%)	864 (84%)	
MIS	20 (12%)	56 (6%)	0.015
LN sampling and/or tumor thrombectomy	48 (28%)	621 (72%)	< 0.001
Patient age, years (SD)	5.2 (4.6)	4.4 (3.7)	0.247

MIS = minimally-invasive surgery; SD = standard deviation

TABLE 5. **Operative technique comparison, MIS versus open surgery. Comparison of operative technique and patient characteristics by use of minimally-invasive surgery (MIS) compared to open surgery**

	MIS	**Open**	**p value**
N	76 (7%)	957 (93%)	
NSS	20 (26%)	149 (16%)	0.013
LN sampling and/or tumor thrombectomy	42 (55%)	627 (66%)	0.072
Patient age, years (SD)	7.2 (5.4)	4.4 (3.7)	< 0.001

NSS = nephron-sparing surgery; LN = lymph node; SD = standard deviation

Comparison by operative approach and surgical modality

When pooling both PU and PS cases, Tables 4 and 5, the majority of NSS were performed using an open approach (88%). Lymphadenectomy/tumor thrombectomy were less commonly performed during partial nephrectomy compared to radical nephrectomy (28% versus 72%, respectively, $p < 0.001$; Table 4. However, lymphadenectomy/tumor thrombectomy were performed at similar rates when comparing MIS and open approaches (55% versus 66% respectively, $p = 0.072$). MIS techniques were, on average, implemented in older children compared to open surgery (7.2 versus 4.4 years respectively, $p < 0.0001$).

Discussion

The majority of surgery for pediatric renal masses in the North America is performed by PS. In this study, PU more commonly employed NSS and MIS techniques compared to PS in the management of pediatric renal masses. PS were more likely to perform lymph node sampling, noting the wide variability in previously reported rates of LN sampling omission in the literature.[13-15] Notable trends in these data identified previously unreported differences with regard to patient demographics and utilization of concomitant procedures during renal extirpation, which have implications with regards to cooperative group protocol adherence and best practices. In the present study, PS operated on younger and sicker patients (higher ASA class). While these differences may account for higher transfusion rates and longer length of stay in patients operated on by PS, there were no differences with respect to operative time and postoperative complications between surgical specialties.

Central venous access procedures were performed at the time of extirpative surgery performed by PS at rates more than twice that compared to PU, which has implications in subspecialty referral in cases of newly diagnosed renal masses. It is prudent for any child with a renal mass exhibiting gross hematuria to be considered for retrograde pyelography to evaluate possible ureteral tumor extension, which has been identified in 2%-5% of Wilms tumor patients.[2] In the present study, concomitant cystoscopy/retrograde pyelography was more likely to be completed in procedures performed by PU, likely a reflection of surgeon experience and comfort with interpretation of endoscopic urologic evaluation. The importance of this lies in the information gained by the surgeon. If ureteral tumor extension exists, it can be identified prior to resection and allow for complete excision with negative margins, rather than intraoperative tumor spillage which upstages the patients and mandates chemotherapy intensification and radiation therapy.[2]

Investigation by Suson et al of the Pediatric Health Information System (PHIS) database from 2005-2013 indicated that PU were more likely to perform nephrectomy for benign reasons while PS more commonly performed both radical and partial nephrectomy for malignancy.[11,12] In cases of nephrectomy for malignancy, PS operated on younger patients with more comorbidities compared to PU, trends confirmed in the present study. Other similarities include the low, but comparable rates of surgical complications and mortality between the surgical specialties. These studies did not investigate the utilization of MIS techniques and were unable to place into context the rate of NSS use by surgeon specialty.

The more liberal use of NSS and MIS techniques by PU may be a reflection of surgical training. Prior data indicate that PU have more extirpative renal surgical volume during both residency and fellowship training than PS.[6] While breakdown by surgical modality was not performed, it is reasonable to extrapolate that standard of care MIS techniques (pure laparoscopy, hand-assistance, and robot-assistance) and NSS techniques (partial nephrectomy and enucleation) acquired by a well-trained urologist can at least partially be transferred to pediatric patients, despite the different nature of the tumors. Review of PS board recertification case log data indicated the mean number of kidney tumor resections per year by PS was 1.2 nationally, with almost half (45%) of PS logging zero cases over the study period.[10] Similar investigation into PU case logs submitted to the American Board of Urology indicate that a minority of PU perform pediatric oncology surgery of any kind, with 53% of surgeons logging zero oncology cases over the 12 month study period,[7] and similar trends were recapitulated in a survey study completed by Society of Pediatric Urology members.[9]

In North America, NSS is generally reserved for bilateral disease, tumors in solitary kidneys or in patients genetically predisposed to renal tumors. Performing NSS in unilateral, non-syndromic patients is off protocol according to COG guidelines.[1] However, the renal tumor study group of SIOP suggest a possible role for NSS in such patients provided specific criteria are met.[3] Similarly, while COG protocols do not advocate a role for MIS approaches, SIOP protocols suggest a possible role for MIS techniques, again in very specific scenarios. It is thus reasonable to suggest that the true value of MIS and NSS in North America has not yet been adequately studied.

Routine lymph node sampling for staging and prognostic purposes is endorsed by both cooperative groups in all pediatric renal mass cases, regardless of modality or approach. Notably, PS more commonly performed lymphadenectomy than PU, especially in MIS cases. This study suggests that patients undergoing NSS are significantly less likely to undergo lymphadenectomy compared to those undergoing radical nephrectomy. This protocol violation has been the subject of prior investigation and offers opportunity for quality improvement. Retrospective review of patients enrolled in NWTS/COG protocols indicated that surgical protocol violations occurred in 14% of enrolled patients, with omission of lymph node sampling being the most common, ranging from 9% in the NWTS-5 protocol and 65% in the AREN03B2 protocol.[13,14] Survey of the National Cancer Database indicated LN sampling omission in 88% of children, adolescents and young adults with clinically organ-confined renal cell carcinoma at the time of extirpative surgery.[15] Surgeon specialty was not reported in these studies. These data are in stark contrast to a survey study in which 90% of PU and PS correctly identified the necessity of lymph node sampling during renal mass surgery,[8] suggesting that this disparity is not likely related to a knowledge gap. Rates of LN omission in the present NSQIP analysis included 43% omission by PU and 34% by PS, well within the wide range in the reported literature. However, these data should be interpreted with caution given our inability to differentiate between LN sampling and tumor thrombectomy.

Differences in operative volume for pediatric renal extirpation between surgical subspecialty is unlikely solely explained by the underrepresentation of PU providers compared to PS. Referral patterns may be impacted by institutional tradition and the ability and willingness of a single surgeon/service to perform central venous port access in the newly diagnosed patient, a service not commonly performed by PU. Additionally, prior studies have indicated that PS are more likely to be involved in pediatric tumor boards and stay current on cooperative group protocols for pediatric renal masses compared to PU.[8] This is substantiated in our findings that PS more strictly adhere to established COG protocols with respect to surgical modality, operative approach and lymph node sampling. The higher relative volume of MIS and NSS cases by PU could also be related to their biased referral in masses amenable to these techniques.

Recent evidence suggests inferior oncologic outcomes with robotic surgery compared to open techniques in adult gynecological malignancies,[16] prompting a 2019 U.S. Food and Drug Administration warning against the use of robotic surgery in select malignancies and in inexperienced hands. Despite recent SIOP protocol adoption of these techniques in the highly selected patient, opponents argue that conveniences of MIS techniques should not come at the expense of oncologic control, and the proven advantages of MIS and NSS techniques in adults should not be misappropriated to pediatric renal malignancies. However, considering greater than 90% overall survival for organ-confined favorable histology Wilms tumor and pediatric renal cell carcinoma,[2] it is paramount that surgeons and oncologists continually seek treatment strategies that limited morbidity while maintaining and optimizing therapeutic efficacy.

There are several fundamental limitations to this study, including its use of a national database with inherent limitations, such reporting errors and selection bias. The database was not designed for this study and allows only secondary analysis. The inability to extract histologic diagnosis, tumor stage, and histologic grade limit generalizability, although COG protocols are uniform at the time of extirpative surgery for any pediatric renal mass because a definitive pre-operative tissue diagnosis is not routinely known. Tumor size and location also were unavailable and play critical role in operative planning for NSS techniques. Concomitant procedures listed with the renal extirpative surgery did not specify whether they were performed by a separate surgeon or subspecialist. Oncologic outcomes, arguably the most important aspect to any study involving patients with cancer, was not recorded by this dataset and thus could not be reported. Additionally, the combined tumor thrombectomy/lymphadenectomy CPT code did not allow more granular analysis of these procedures. The database did not differentiate whether an individual patient received multiple kidney surgeries, in which case lymphadenectomy may have been performed in the index operation and not indicated in subsequent procedures. Additionally, the database did not provide information on surgeon or institution volume, and it is feasible that a select few surgeons performed the majority of MIS and NSS cases. It is possible that surgeons contributing to this database may be more likely to perform renal extirpation than others who may perform just a few annually. It is possible that the PHIS (previously studied) and NSQIP databases included some of the same patients, which limits the ability to verify prior findings. However, the NSQIP database encompasses more pediatric hospitals (129 hospitals) than the PHIS database (roughly 45 hospitals), so it reasonable to assume that the populations are not entirely the same. The COG database would be the best resource to verify these findings, but given the restrictions of funding and general unavailability of these data for study outside of COG committee priorities, the pediatric NSQIP database is the next best available dataset. Perhaps the present study can provide some pilot data to spark future study by these cooperative groups.

Conclusions

This study verifies and reports new trends between surgical subspecialty in the management of pediatric renal masses. PU were more likely to utilize advanced surgical techniques of NSS and MIS compared to PS, although in North America, this is at the expense of cooperative group protocols. These trends in North American practice may reflect an apparent drift away from strict COG requirements and towards SIOP principles, with emerging evidence on the efficacy and safety of NSS and MIS in the management of pediatric renal masses. Further studies into the temporal trends and oncologic outcomes by surgical modality and surgeon subspecialty is necessary.

Multidisciplinary management of pediatric renal masses is paramount in ensuring favorable oncologic outcomes. It should be emphasized that the differences in training and practice among surgical subspecialties highlighted in the present study are not derogatory; rather, they should be exploited as opportunities to build stronger multidisciplinary teams, especially in low-volume centers. □

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