Urinary leak following partial nephrectomy: a contemporary review of 975 cases

Charles C. Peyton, MD,[1] Ali Hajiran, MD,[1] Kevin Morgan, MD,[2] Mounsif Azizi, MD,[1] Dominic Tang, MD,[1] Juan Chipollini, MD,[1] Scott M. Gilbert, MD,[1] Michael Poch, MD,[1] Wade J. Sexton, MD,[1] Philippe E. Spiess, MD[1]

[1]Department of Genitourinary Oncology, Moffitt Cancer Center, Tampa, Florida, USA
[2]University of South Florida, Morsani School of Medicine, Tampa, Florida, USA

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Introduction: *To describe the incidence, contemporary management, risk factors and outcomes of urinary leak following open and robotic partial nephrectomy at a tertiary care, comprehensive cancer center.*

Materials and methods: *We reviewed 975 patients who underwent partial nephrectomy at Moffitt Cancer Center from January 2009 to May 2017. Patient demographic, perioperative and follow up data was recorded and compared stratified for postoperative urine leak. Fisher's exact and Wilcoxon sum-rank testing were performed for categorical and continuous variables as indicated.*

Results: *Twenty-three of 975 (2.3%) patients experienced a urine leak after partial nephrectomy. Median nephrometry score for urine leak patients was 8 (SD ± 1.3). Median postoperative days to detection was 3.5 and most leaks were discovered due to high drain output. Operative factors associated with urinary leak included open surgery, estimated blood loss, and not using a sliding-clip renorrhaphy ($p < 0.05$). Ten (44%) were managed conservatively, 9 (39%) patients required ureteral stent placement, 3 (13%) needed a percutaneous nephrostomy tube, one patient (4%) required percutaneous drainage for urinoma (4%). One patient ultimately failed conservative management and required nephrectomy 45 days after the original surgery. Mean time to stent and drain removal was 40 ± 17 and 24 ± 7 days, respectively. Five patients with symptomatic leaks were readmitted with a mean length of stay of 3.2 ± 1.8 days.*

Conclusions: *The overall incidence of urinary leak after partial nephrectomy remains low regardless of surgical approach. Perioperative characteristics such as tumor complexity and high blood loss, in addition to open surgery and not using a sliding-clip bolstered renorrhaphy are associated with urine leak.*

Key Words: partial nephrectomy, nephron sparing surgery, urinary leak, urinary fistula, complications

Introduction

An increase in incidental detection of small renal masses has caused a robust stage migration shifting surgeons to prioritize nephron-sparing surgery and active surveillance.[1] Partial nephrectomy (PN) has demonstrated favorable oncologic control and renal function preservation. As such, the American Urological Association and European Association of Urology recommend nephron-sparing surgery as standard of care for small renal masses.[2,3] Urologic surgeons have adopted PN as a routine tool for treating renal masses and the complexity of tumors amendable to PN has increased along with a transition from open to laparoscopic to robotic PN. Therefore, complications specific to PN, such as urinary leak, have become more recognized.

Urinary leak is an uncommon but potentially problematic complication of PN that negatively impacts recovery. Original open partial nephrectomy (OPN) reports describe urinary leak rates as high as 17%.[4] However, with the refinement of surgical techniques, urinary leak rates usually range from 1%-4% today.[5] While surgeons have shifted towards favoring minimally invasive approaches, tumor complexity remains associated with higher likelihood of undergoing open

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Address correspondence to Dr. Ali Hajiran, Department of Genitourinary Oncology, Moffitt Cancer Center, 12902 Magnolia Drive, Tampa, FL 33612 USA

PN and increased odds of urinary leak, regardless of approach.[6,7] Some authors have suggested that this, in part, may explain the initial slow dispersion of minimally invasive PN in the community, a trend that has since improved.[8,9] Current literature largely focuses on complication reporting of robotic PN (RPN);[5,10] however, approximately one-quarter of PNs are still performed open.[11] Furthermore, the management of urinary leaks is not commonly addressed throughout the literature.

Our study examines the incidence, associated risk factors and management of urinary leak after PN in a large cohort of both open and robotic approaches at a tertiary care center. Additionally, we aimed to review our management of urinary leak after PN and provide a management algorithm.

Materials and methods

Following the approval of the Scientific Review Committee and Institutional Review Board at Moffitt Cancer Center, data was obtained from a prospectively maintained institutional database from January 2009 to May 2017. The database incorporates discrete data elements from clinical, administrative and cancer registry data sources. Data elements abstracted included demographic information, American Society of Anesthesiologists (ASA) status, treatment (approach and date of PN), operative details (blood loss, warm ischemia time, use of hemostatic agents), tumor characteristics (tumor size, T stage and nephrometry score for urinary leak patients[12]), histology, length of stay and outcomes. Of note, hemostatic agents were counted individually (i.e.: a combination use of two products counted as use of two agents) and included oxidized regenerated cellulose products, hemostatic matrix, absorbable gelatin sponges, and surgical adhesives. Urinary leak was defined as radiographic and/or presences of drain fluid consistent with urine (drain creatinine twofold higher than serum creatinine is generally acceptable[5,13]). Date of leak detection and management was determined with detailed chart review of inpatient and follow-up documentation.

Patients with postoperative urinary leaks were compared to patients without leaks across variables. Continuous variables were reported as mean (± standard deviation) or median (with interquartile range). Comparisons were performed using the chi-square, t-, or Wilcoxon rank sum tests, as appropriate. All urinary leak cases were carefully examined and a general consensus management algorithm was developed. A two-sided p value < .05 was considered significant. All analyses were performed with SPSS Statistics, version 24 software (IBM, Armonk, NY, USA).

Results

Patients and factors associated with urinary leak

A total of 975 patients were identified as having undergone partial nephrectomy between January 2009 and May 2017. There were 23 urine leaks identified (2.3%). Mean age at surgery was 61 ± 12 years. Sixty-one percent of the cohort was male. Over 90% of the patients were ASA 2 or 3. There were no differences comparing no-leak to urinary leak patients in terms of age, gender, race/ethnicity, ASA status or laterality of the renal mass ($p > 0.05$).

Mean warm ischemia time was 19.5 ± 9 minutes and mean tumor size was 3.6 ± 1.7 cm. Comparing no-leak and urinary leak patients, there was no difference in warm ischemia time, 19.5 ± 9.1 versus 21.2 ± 9.8 minutes ($p = 0.37$) and tumor size, 3.3 ± 1.7 versus 3.1 ± 1.1 cm ($p = 0.69$), respectively. Similarly, numbers of tumors, length of stay, number of postop blood transfusions were not different comparing the two groups, all $p > 0.05$. However, 20 (3%) of open PN patients compared to 3 (< 1%) RPN patients had postoperative urinary leaks, which was significantly different, $p = 0.045$. Also, urinary leak was associated with not utilizing a sliding-clip technique for renorrhaphy, higher mean estimated blood loss (EBL) and number of hemostatic agents used, all $p < 0.05$. No differences were noted in terms of T stage, grade, or histology. Demographic, tumor and surgical characteristics comparison between the no-leak and urinary leak groups are show in Table 1.

Urine leak presentation and management

Table 2 provides details related to presentation and management of patients who suffered a postoperative urinary leak. Mean nephrometry score for urinary leak was 8.6 ± 1.3 and median days to detection was 3.5 days. All but three leaks occurred in OPN and 13 (56%) of patients had documented collecting system repair. Leak detection was most commonly discovered through elevated Jackson-Pratt drain output consistent with urine (21 patients, 91%). Delayed leaks after drain removal presenting with pain, hematuria and/or infection were noted in two patients at 5 and 26 days postoperatively.

In terms of management, nine (39%) patients were treated conservatively with maintenance of surgical drain only. One patient had a delayed leak managed conservatively at a different institution, detailed records were not available. One patient required subsequent percutaneous drain placement for a surrounding urinoma after the surgical drain was removed. Nine (39%) required retrograde ureteral stent placement alone and three (13%) required stent placement and

TABLE 1. **Patient, tumor, and surgical characteristics**

Variables	No leak n = 952	Urine leak n = 23	p value
Age (mean, SD)	61 (12)	57 (10)	0.18
Gender, n (%)			1.0
Male	577 (97.6)	14 (2.4)	
Female	372 (97.6)	9 (2.4)	
ASA			0.41
1	15 (1.6)	1 (4.2)	
2	503 (53.1)	13 (54.2)	
3	420 (44.2)	8 (37.4)	
4	11 (1.2)	1 (4.2)	
Surgery			0.045
Open PN	641 (97)	20 (3)	
Robotic PN	311 (99)	3 (1)	
Mean (SD)			
EBL (mL)	247 (300)	405 (351)	0.013
Warm ischemia time (min)	19.5 (9.1)	21.2 (9.8)	0.37
Tumor size (cm)	3.26 (1.73)	3.1 (1.13)	0.69
Length of stay (days)	4.3 (2.8)	5.9 (2.3)	0.007
Number of tumors	1.07 (0.42)	1.04 (0.2)	0.74
Number of units BldTx post op	0.27 (1.07)	0.3 (0.82)	0.87
Number of hemostatic agents	2.49 (1.38)	3.1 (0.82)	0.028
Hemostatic agent, n (%)			0.061
No	127 (100)	0	
Yes	825 (97.3)	23 (2.7)	
Sliding clip technique			0.039
No	422 (96.6)	15 (3.4)	
Yes	528 (98.5)	8 (1.5)	
Multiple tumors			1.0
No	897 (97.6)	22 (2.4)	
Yes	55 (98.2)	1 (1.8)	
pT stage			1.0
T1a	601 (97.7)	14 (2.4)	
≥ T1b	229 (97.4)	6 (2.6)	
Tumor size			0.32
< 4.0 cm	732 (97.3)	20 (2.7)	
≥ 4.0 cm	220 (98.7)	3 (1.3)	
Histology			0.83
Clear cell	572 (97.8)	13 (2.2)	
Non-clear cell	380 (97.4)	10 (2.6)	

BldTx = blood transfusion; EBL = estimated blood loss; PN = partial nephrectomy

subsequent nephrostomy tube placement to maximize drainage. One of these patients ultimately failed drain management and required nephrectomy. Six (25%) patients required readmission with a mean length of stay of 3.2 days for management of their urinary leak. Surgical and/or percutaneous drains were kept in place an average of 24 ± 8 days. The mean number of days to secondary stent placement was 12.2 ± 7.6

Pt	Date of surgery	Age	Nephrometry score and location		Open or robotic	Collecting system repair	Method of detection	Post op day detected	Re-admission	Management	Days to secondary stent placement	Days to drain removal	Days to stent removal
1	2/3/2009	56	10	a	Open	Yes	Drain Cr	3		JP drain		23	
2	2/4/2009	65	8	p	Robo	Yes	Drain Cr	4		JP drain		22	
3	2/18/2009	59	8	a	Open	Yes	Drain Cr	4		JP drain		20	
4	3/3/2009	51	8	a	Open	Yes	Drain Cr	2		stent	24	24	41
5	3/4/2009	68	10	p	Robo	No	Drain Cr	5	Yes	stent	6	16	80†
6	3/18/2009	32	8	p	Open	No	Drain Cr	3		JP drain		14	
7	3/31/2009	45	7	p	Open	No	Drain Cr	3		JP drain		21	
8	5/27/2009	49	10	p	Open	Yes	Drain Cr	3		stent	23	38	38
9	10/12/2010	71	8	p	Open	Yes	Drain Cr	2	Yes	stent, nephrostomy	14	42 (JP drain)*	58
10	2/23/2011	55	7	p	Robo	No	Pain, hematuria	26		antibiotics∞		-	
11	2/6/2012	49	10	x	Open	Yes	Drain Cr	3		JP drain		21	
12	7/17/2012	55	10	p	Open	Yes	Drain Cr	7		JP drain		23	
13	8/27/2012	49	11	p	Open	Yes	Drain Cr	3	Yes	stent , nephrostomy	11		45**
14	1/22/2013	64	8	p	Open	Yes	Drain Cr	10		stent	22	15	57
15	3/4/2013	62	8	p	Open	No	Drain Cr	5		stent	14	16	35
16	5/29/2013	43	9	p	Open	Yes	Drain Cr	4		JP drain		29	
17	12/23/2013	68	10	p	Open	No	Pain, hematuria	5	Yes	percutaneous drain	5	26	
18	8/20/2014	58	10	p	Open	No	Drain Cr	1		stent, nephrostomy	5	14	45
19	12/2/2014	69	8	p	Open	No	Drain Cr	9		stent	21	21	16
20	11/11/2015	62	6	p	Open	Yes	Drain Cr	2		stent	6	20	30
21	12/15/2015	67	10	p	Open	Yes	Drain Cr, nausea	2		stent	2	16	35
22	2/23/2016	55	7	p	Open	No	Drain Cr	5	Yes	JP drain		5	
23	8/24/2016	68	8	a	Open	No	Drain Cr	2		stent	7	23	45‡

Cr = Creatinine; JP = Jackson-Pratt; Pt = patient.
*nephrostomy removed at 51 days; **leak and urinoma unresolved after stent, percutaneous nephrostomy, patient required nephrectomy performed approximately 45 days after original surgery; †postoperative pulmonary embolism delayed stent removal,;‡stent remained in place to facility stone management after partial nephrectomy; ∞management performed at outside hospital and records incomplete

Table 2. Presentation and course of urine leak.

days and the stent stayed in place for an average of 40 ± 18 days.

Discussion

Urinary leak is a complication unique to PN. The presentation and management of urinary leak after PN is infrequently addressed in the current literature, particularly when examining both open and robotic approaches. Although RPN is becoming commonplace, OPNs are still performed.[11] Herein we report our experience with 975 open and robotic PNs with regards to the associated diagnosis, management and associated risk factors of urine leaks.

Pioneers in open and laparoscopic renal surgery reported urinary leak rates ranging from 10%-17%.[4,14-16] However, clinically significant urinary leaks have become infrequent in the modern surgical era.[5,17] We observed urinary leaks in 2.3% of our PN patients, which is consistent with existing data reporting on combined OPN and RPN cohorts within the last decade, Table 3. Factors associated with urinary leak included OPN, EBL, number of hemostatic agents used, and not using the sliding-clip renorrhaphy technique previously described, regardless of open or robotic approach.[18] Interestingly, the majority of the urine leaks (n = 17/23) occurred during the first four years of the study (2009-2013). The decrease in number of urine leaks over recent years could possibly be attributed to the wider adoption of the sliding-clip technique in both minimally-invasive procedures as well as in open surgery.

Nephrometry score is a useful tool in determining the complexity of renal masses and higher nephrometry scores are associated with leak.[6] We observed a mean nephrometry score of 8.6 ± 1.3 for patients with urinary leak, indicating a moderate to highly complex mass. Blood loss, tumor size and warm ischemia time are often surrogates for tumor complexity.[17] In our study, the majority of the urine leaks occurred following surgery for tumors located on the posterior aspect of the kidney (n =18/23). Surprisingly, we did not observe a difference in tumor size and warm ischemia time, yet it is possible too few events were noted to detect a statistical difference. Potetzke et al have published one of the largest recent series and suggest tumor size, hilar location, operative time, warm ischemia time and collecting system repair are associated with urinary leak.[5] However, as is common with current literature, the patient cohort only included RPN patients.

Spanning 8 years of cases, we have consistently performed a significant number of OPN, in part, due to surgeon preference and tumor/patient complexity as a tertiary care referral center. Compared to OPN,

Study	Years of inclusion	No. patients	No. (%) Open	No. (%) urinary leak	Mean nephrometry score	Median tumor size (cm)	Management method, No. (%)	Factors associated with urine leak
Current study	2009-2017	975	661 (67.8)	Total: 24 (2.5) OPN: 21 (3.2) RPN: 3 (1)	8.6*	3.0	11 (45) conservative management 9 (38) stent 3 (13) percutaneous tube 1 (4) nephrectomy	†OPN, EBL, number of hemostatic agents used, not using sliding-clip technique
Erlich et al, 2017[13]	1988-2013	753	389 (51.7)	Total: 21 (2.8) OPN: 11 (2.8) LPN: 10 2.7)	Not reported	3.3	4 (18) conservative management 16 (76) stent 1 (5) nephrectomy	Hilar renal mass, high preoperative serum Cr
Tomazewski et al, 2014[26]	2007-2013	831	355 (42.7)	Total: 54 (6.5) OPN: 42 (11.8) RPN: 12 (2.5)	6.1	3.7**	24 (45) conservative management, 22 (40.7) stent 4 (7.4) nephrostomy tube 8 (14.8) percutaneous drain, 5 (9.3) nephrectomy, embolization or reconstruction	‡Intrarenal pelvis, exophytic/endophytic score, collecting system entry
Stroup et al, 2012[6]	2003-2011	284	153 (53.9)	Total: 19 (6.7) OPN: 15 (9.8) LPN: 3 (3) RPN: 1 (3.2)	OPN: 8 LPN: 6.3 RPN: 6.4	OPN: 4.2 LPN: 2.4 RPN: 2.0	Not reported	Decreasing BMI and nephrometry score
Kundu et al, 2010[17]	1989-2007	1118	1023 (92)	Total: 52 (4.7)	Not reported	2.6	36 (69) conservative management 8 (15) stent 2 (4) percutaneous drain 4 (8) other	†Tumor size, ischemia time and EBL
Marszalek et al, 2009[29]	Not reported	200	100 (50)	Total: 6 (3) OPN: 4 (4) LPN: 2 (2)	Not reported	OPN: 2.9 LPN: 2.8	Not reported	Not reported
Lane et al, 2008[30]	1999-2006	199	169 (85)	Total: 11 (5.5) OPN: 9 (5.3) LPN: 3 (10)	Not reported	OPN: 3.8 LPN: 2.8	6 (3) stent	Not reported
Gill et al, 2007[28]	1998-2005	1800	1028 (57)	Total: 48 (2.7) OPN: 24 (2.3) LPN: 24 (3.1)	Not reported	OPN: 3.5** LPN: 2.7**	45 (94) conservative management 3 (6) nephrectomy	Not reported

OPN = open partial nephrectomy; RPN = robotic partial nephrectomy; LPN = laparoscopic partial nephrectomy
*for urinary leak only; **mean; †univariable analysis; ‡multivariable analysis

Table 3. Studies reporting partial nephrectomy urinary leak.

RPN did not necessarily achieved as rapid widespread adoption and learning curve success that was witnessed with robotic assisted radical prostatectomy.[19] Additionally, surgeon preference for open PN still exists and the allocation of robotic surgery throughout the country has limitations.[20] Thus, observational data reports including open and robotic approaches are warranted to facilitate a comprehensive assessment.

The relationship of urine leak with open surgery, blood loss and number of hemostatic agents used is intuitive and likely associated with tumor complexity. Our data was consistent with this presumption; urine leaks were more commonly seen in OPN compared to RPN. However, regardless of surgical approach, for the 536 renorrhaphies performed using the sliding-clip technique, only 8 (1.5%) experienced a urinary leak as opposed to 16 of 437 (3.4%) who did not have a sliding-clip renorrhaphy, p = 0.039. Additionally, this technique (opposed to traditional pledget or bolster-based renorrhaphy) has allowed us to stop using intraoperative retrograde injection of methylene blue-saline to identify collecting system violations, which has not been shown to reduce the probability of postoperative urine leak.[7] Several studies confirm that the sliding-clip renorrhaphy has rendered this step unnecessary.[21,22]

The use of surgical drains during PN is routine for many surgeons and allows for the early detection of a leak; however, drainless PN has been described.[23] Advocates for drainless PN have become more common.[24] Irrespective of the surgical approach, surgical drain placement is warranted in patients with moderate to highly complex tumors (based on nephrometry score), blood loss ≥ 400 mL and collecting system violation. Closed suction or passive drain choice does not influence outcome according to a prior investigation,[25] but we consistently used closed suction drains to maximize drainage.

Our urine leak management algorithm is illustrated in Figure 1. Suspicious surgical drain output (e.g.: > 150 mL daily) with creatinine level consistent with urine enabled early detection in all but three patients within 3 days of surgery. Optimizing drainage should be the first priority when urinary leaks are detected and many patients can be conservatively managed with a drain until spontaneous resolution of the leak.[17,26] Consistent with prior reports, approximately 40% of urinary leaks were successfully managed exclusively with a surgical drain maintained for a median of 23 days.[13,17] Patients are asked to record output daily and return for weekly clinical visits to assess drain output and drain creatinine. Once the output is less that approximately 100 mL daily and drain creatinine < 2 x serum, it can be removed.

When drain output does not improve, additional intervention is necessary. Thirteen (56%) of our urinary leak patients required an intervention, Table 2, within a median of 11 days after surgery. A similar time frame for intervention was reported by Erlich et al amongst both open and minimally invasive PN (mean 8.5 ± 4.5 days elapsed from surgery to intervention).[13] Average length of ureteral stent duration in our cohort was 40

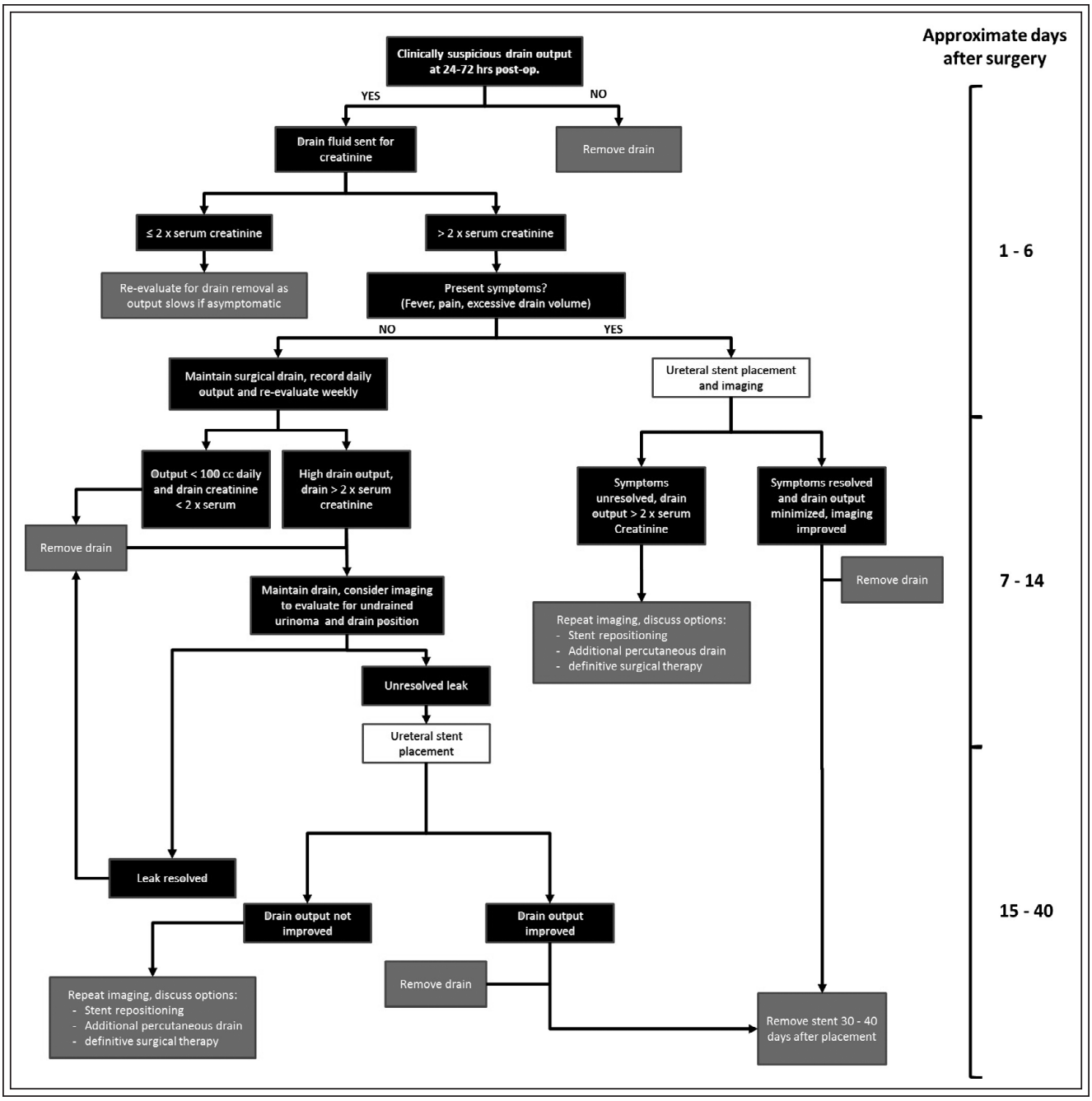

Figure 1. Urinary leak management algorithm.

± 18.3 days which is less time that previously reported by Erlich et al (68 ± 20.5 days of drainage) and Meeks et al (53 days).[13,27] However, because retrograde pyelography is not necessarily performed at the time of stent removal, one can only speculate as to the absolute minimal stent duration for adequate healing. In general, most series report stent duration between 30-60 days which is consistent with our practice, Figure 1.[5,13,17,27]

Overall, the management concepts for urine leaks after PN have remained unchanged over several decades.[5,13,17,28] Stents allow urine the path of least resistance to exit the collecting system. Once the drainage from the perinephric surgical drain resolves and there is no radiographic or clinical evidence of undrained urinoma, the collecting system will have an opportunity to heal. Occasionally patients require

additional nephrostomy tube drainage of an obstructed portion of the collecting system. Rarely is nephrectomy required, Table 3.[13,26,28] Conservative management or immediate intervention is multifactorial and case specific. Optimal management includes early leak detection, usually facilitated with a surgical drain, urine leak drainage, symptoms management, and ureteral stent placement for leaks that do not improve with drainage alone, Figure 1.

There are several limitations to our report including its retrospective nature and the inherent biases associated with such investigations. The number of robotic cases in our series is limited and may not reflect the national averages. As a referral center, it is possible that delayed urine leaks managed elsewhere were unaccounted for in our database. We acknowledge that the number of urine leaks is quite low which limits the statistical analysis that can be performed. Nonetheless, our observations further characterize patterns and management of urinary leak after partial nephrectomy.

In conclusion, the incidence of urinary leak after partial nephrectomy remains low, regardless of surgical approach. Perioperative variables suggestive of tumor complexity such as high blood loss or use of multiple hemostatic agents and not utilizing the sliding-clip renorrhaphy technique are associated with urine leak. Management should optimize urinary drainage to encourage healing of the collecting system. □

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