Genitourinary Cancer

Laparoscopic Radical Nephrectomy in the Current Era: Technical Difficulties, Troubleshoots, a Guide to the Apprentice, and the Current Learning Curve

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Abstract

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Objectives The main aim of this study is to present our experience with laparoscopic radical nephrectomy (LRN) and share practical solutions to various surgical challenges and the learning curve we realized.

Materials and Methods We retrospectively analyzed our LRN database for relevant demographic, clinical, imaging, operative, and postoperative data, including operative videos. We described various complications, vascular anomalies, intraoperative difficulties, and our improvisations to improve safety and outcomes.

Statistical Analysis We evaluated the learning curve, comparing the initial half cases (group 1) against the latter half (group 2), using the chi-squared test for categorical variables and Student's *t*-test for continuous variables.

Results Of the 106 patients included, LRN was successful in 95% ($n = 101$), and five cases converted to open surgical approach. The mean tumor size was 7.4 cm, 42% incidentally detected. The cumulative complication rate was 15%, including five main renal vein injuries. Intraoperative difficulties included ureter identification ($n = 6$), venous bleed during hilar dissection ($n = 11$), double renal arteries ($n = 23$), and venous anomalies ($n = 20$). Arterial anatomy had 95% concordance with the imaging findings. We describe various trade tricks to perform hilar dissection, identify and control anomalous vasculature, handle venous bleed, confirm arterial control, and improve decisions using imaging, technology, and guidance of a mentor. No statistically significant difference in the learning curve was observed between the study groups.

Conclusion With LRN already established as the current standard of care, our description intends to share the trade tricks and inspire novice urologists, who can assimilate training and reproduce good results under proper guidance. The steep learning curve described in the past may not be apparent in the current era of training and technological advancement.

Keywords

- laparoscopic radical nephrectomy
- learning curve
- radical nephrectomy
- renal cell carcinoma

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Introduction

Radical nephrectomy is the standard of care for localized renal cell carcinoma (RCC), not amenable for partial nephrectomy (PN).[1] Laparoscopic radical nephrectomy (LRN) is the recommended approach unless it compromises the feasibility of PN or oncological outcomes. The transition from open radical nephrectomy training obtained during residency to LRN during early urological practice has been difficult for novice surgeons. This article shares our experience with the procedure, discussing various intraoperative challenges and tackling them with adequate planning and methodical execution. We also analyze the feasibility, reproducibility, and learning curve associated with LRN.

Materials and Methods

We performed a retrospective analysis of the prospectively maintained renal malignancy patients' database at our center from September 2016 to November 2020 and included all patients who underwent LRN. Preoperative evaluation included detailed clinical history, relevant clinical examination, computed tomography angiography (CTA) imaging, and relevant laboratory investigations. All surgeries utilized a transperitoneal approach using a 90-degree lateral decubitus patient positioning, as described by Clayman et al.[2] Initial access was routinely taken offset from the umbilicus with the Hasson open technique, and two working ports were then placed by triangulation. An additional port for the liver retraction in right-sided tumors and an iliac fossa incision for specimen retrieval were used.

Descriptive analyses of various patient and tumor characteristics were done, along with a detailed illustration of various complications encountered and their management. Variations in renal vascular anatomy and their correlation with imaging findings were correlated. Pearson's correlation coefficient was applied to evaluate the association between the size of the tumor, duration of surgery, and blood loss. For evaluation of the learning curve, the initial half of the cases was included in group 1, against which we compared the later half included in group 2. The selected defining parameters for the LRN learning curve were surgery duration, estimated blood loss, additional hand port placement, conversion to an open surgical approach, need for blood transfusion, rate of Clavien–Dindo grade II to IV complications, and hospital stay. Chi-squared test was used for categorical variables, Student's *t*-test for continuous variables, and STATA 12 software for statistical analyses.

Results

A total of 106 LRNs performed at our center since our first case in September 2016 till November 2020 were included for analysis. The mean age of the study population was 55 years, with a male predominance of 3:1. The mean size of the renal mass was 7.4 cm, and right-side tumors were 1.8 times more common than the left. The cumulative rate of various recorded complications was 15% ($n = 16$), with no procedure-related mortality observed.

The incidentally detected tumors contributed to 42% ($n = 45$), a rate significantly higher than prior reports.[3] These asymptomatic tumors had a smaller mean size (5.6 ± 1.5 vs. 8.8 ± 2.6cm) and were associated with a lower surgery duration and lower blood loss. Indeed, the size of the tumor had a linear relation with the duration of surgery (correlation coefficient = 0.731; 95% confidence interval [CI]: 0.628–0.809), and the blood loss (correlation coefficient = 0.764; 95% CI: 0.671–0.833) (►Fig. 1).

Conversion to open procedure was deemed necessary in five procedures, and in another three cases, an additional hand port facilitated laparoscopic surgery. Thus, LRN was feasible in 92% of cases ($n = 98$), or even 95% if we include the cases managed with hand ports as these ports replaced the specimen retrieval incisions. Of the five cases converted to open surgical approach, two patients had bulky tumors causing significant hindrance and inability to progress with the laparoscopic approach. Uncontrolled bleeding triggered the other three conversions to open surgical approach, caused by renal vein (RV) injury in two cases and a case of superior mesenteric artery injury.

In six cases, we struggled with ureter identification, which we subsequently traced from the pelvic brim in four and from the renal pelvis in two cases. Significant venous bleeding was encountered in 11 cases, seven involving the RV, three with the Lumbar vein, and one with the

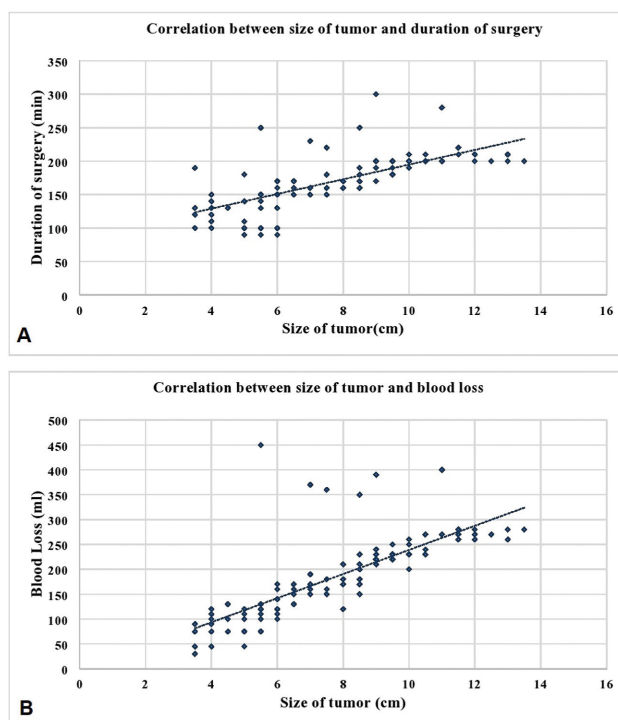

Fig. 1 Scatter plots depicting the relationship between (A) size of tumor and duration of surgery (correlation coefficient = 0.731; 95% CI: 0.628–0.809, $p < 0.01$) and (B) size of tumor and blood loss (correlation coefficient = 0.764; 95% CI: 0.671–0.833, $p < 0.01$). CI, confidence interval.

Adrenal vein. Five significant RV bleeding instances required conversion to open surgical approach ($n=2$) or an additional hand port placement ($n=3$). In both the cases converted to open surgical approach, the RV sustained injury close to the inferior vena cava (IVC) during hilar dissection in one case and during clip application. Both patients had short RVs and required partial IVC clamping and repair. Hand ports assisted hemostasis in the other three cases by rapid hemorrhage control using direct manual compression, thus improving visibility to allow clip application. A vascular stapler was used for hilar control in seven cases with large-caliber RV, with no stapler-related complications.

Two patients sustained a right diaphragmatic injury during mobilization of right upper polar masses and were repaired laparoscopically. The superior mesenteric artery was injured in one patient undergoing left LRN triggering conversion to an open surgical approach. The injury occurred during dissection posterior to the RV, mistaking the artery as fibrotic tissue and cutting it using the energy device. The cut end of the artery led to a torrential bleeding necessitating conversion to open surgical approach and controlling the bleeding with suture ligation of the artery. Later on, the renal artery (RA) was found still posteriorly, when we realized that the previously cut vessel was the superior mesenteric artery. Gastrointestinal surgeon's help was sought and they advised against any further intervention for the injury due to lack of any ischemic changes in the small bowel. This was because the injury was proximal to the collateral circulation from the inferior mesenteric artery and bowel vascularity was still preserved. A splenic injury that occurred during left upper polar renal mass mobilization was repaired laparoscopically. A hepatic capsular tear during mobilization of a large right mid-polar renal mass was controlled with topical hemostatic agents.

Given the high variability of the renal vascular anatomy, we routinely developed both superior and inferior windows during hilar dissection to delineate the vasculature (►Fig. 2A). Double RA was seen in 23 patients (►Fig. 2B), and the cephalad branch was the dominant arterial supply in 16 of these cases. Five cases of double RA were missed on preoperative CTA, three reported as early bifurcations, and two completely missed accessory arteries. Venous

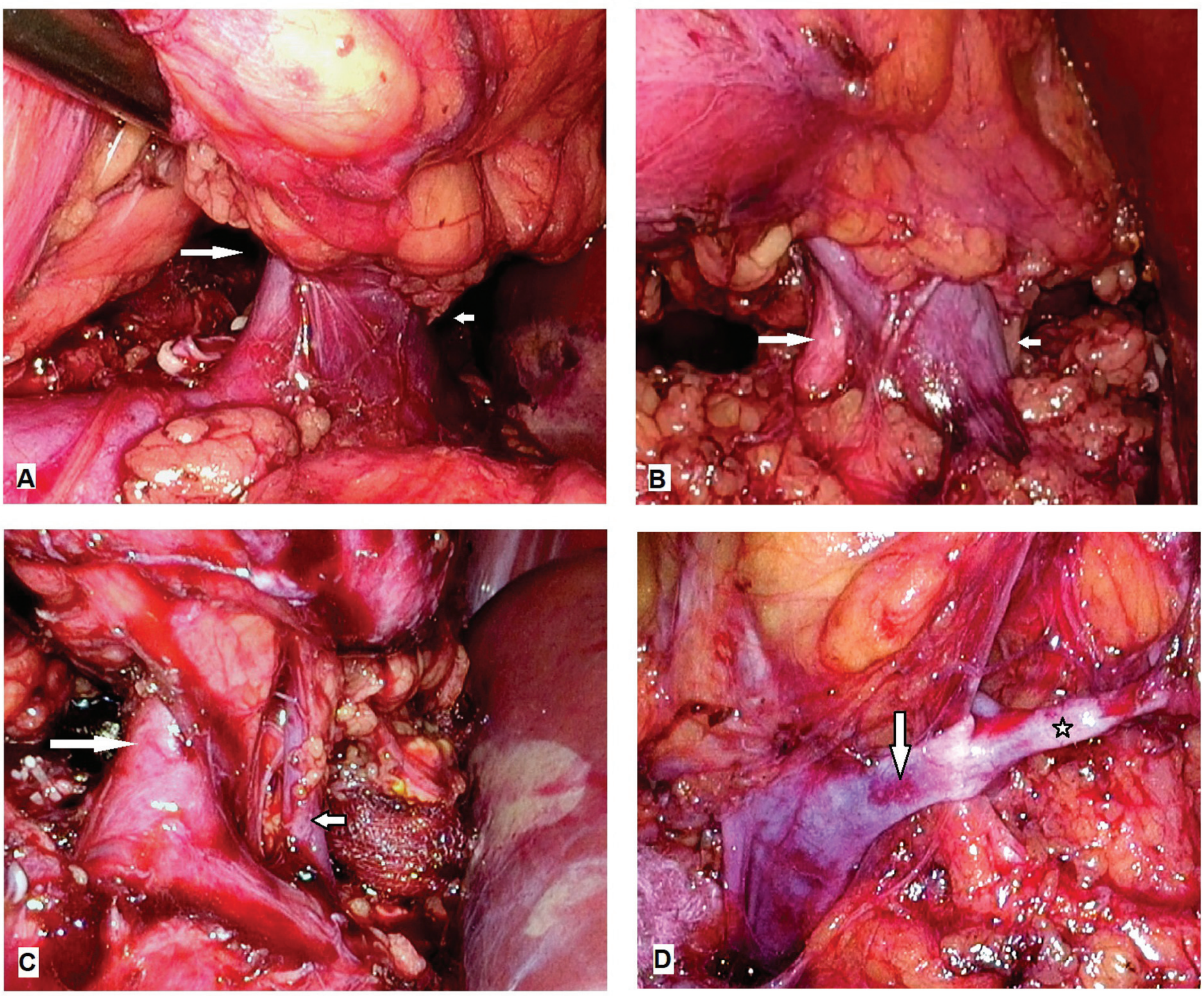

Fig. 2 Renal hilar dissection demonstrating (**A**) delineation of both superior (smaller arrow) and inferior (larger arrow) windows, (**B**) double renal arteries (arrows), (**C**) double renal veins (arrows), and (**D**) complex venous anatomy with left gonadal vein (star) joining the lower division of the renal vein (arrow).

Table 1 Comparison of the baseline patient and tumor characteristics between the two study groups

	Total ($n = 106$)	Group 1 ($n = 53$)	Group 2 ($n = 53$)	*p*-Value
Age ± SD (y)	55.3 ± 12.2	56.3 ± 12.1	54.3 ± 12.3	0.41
Sex (male:female)	79:27	41:12	38:15	0.51
BMI ± SD (kg/m^2)	24.7 ± 3.7	24.5 ± 3.6	25 ± 3.9	0.50
Hypertension	28	13	15	0.64
Diabetes mellitus	33	19	14	0.27
Smoking	29	17	12	0.30
Symptoms				
Incidental	45	26	19	0.18
Pain	34	15	19	0.38
Hematuria	27	12	15	0.55
Tumor size ± SD (cm)	7.4 ± 2.7	7.3 ± 2.7	7.6 ± 2.6	0.52
Laterality of tumor				
Right	68	33	35	0.66
Left	38	20	18	0.67
Site of tumor				
Upper	40	22	18	0.46
Mid	29	17	12	0.25
Lower	37	14	23	0.07
Tumor histopathology				
Clear cell carcinoma	84	40	44	0.31
Type-2 papillary RCC	11	7	4	0.35
Chromophobe RCC	7	4	3	0.69
Others	4	2	2	1.0

Abbreviations: BMI, body mass index; RCC, renal cell carcinoma; SD, standard deviation.

anatomical variations were encountered in 20 cases, mostly associated with the left kidney ($n = 14$). Lumbar veins were observed in 11 cases, single in 10 cases, and double in one. Accessory RVs were present in seven cases (►Fig. 2C). In one case, the right gonadal vein was seen joining the RV, while the left gonadal vein was seen joining the lower division of the left RV in another case (►Fig. 2D).

The final histopathology was predominantly clear cell carcinoma (n = 84; 79%), followed by type-2 papillary RCC ($n = 11$; 10%), chromophobe RCC ($n = 7$; 6.6%), mixed RCC ($n = 2$), and one case each of a primitive neuroectodermal tumor and a leiomyosarcoma (►Table 1).

The learning curve was analyzed between group 1 comprising the first 53 cases and group 2 the latter 53 cases. The baseline patient and tumor characteristics were comparable between the two groups (►Table 1). The outcome analysis failed to demonstrate any significant learning curve for the procedure (►Fig. 3). The mean surgery duration was 170 ± 39 min for group 1 and 163 ± 41 min for group 2, with no significant difference ($p = 0.311$). Likewise, the mean intraoperative blood loss was similar between group 1 (183 ± 86 mL) and group 2 (171 ± 83 mL) ($p = 0.484$). Blood transfusion rate (7.5 and 9.4%) and mean hospital stay (5.8 ± 1.7 and 5.7 ± 1.4 days; $p = 0.620$) had no significant difference between the two groups. The complication rates were 17% ($n = 9$) for group 1 and 13% ($n = 7$) for group 2 ($p = 0.57$), with respective open conversion rates being 5.7 and 3.8% ($p = 0.65$) (►Fig. 3).

Discussion

Thirty years after its first description in 1990 by Clayman et al,[2] LRN has become the standard of care and has far surpassed the open surgical approach. LRN is effective and safe even in patients with large tumors, with comparable long-term outcomes and added benefits of lower blood loss, decreased pain, and shorter convalescence.[4] Transperitoneal and retroperitoneal LRN approaches are routinely used across various centers and have shown comparable efficacy, safety, and patient outcomes.[5]

While the surgical descriptions and videos of LRN are widely published and accessible, a novice urologist's uncertainty and apprehension toward the procedure are pretty understandable, especially in the early phase of a career. In the following sections, we discuss the various practical difficulties encountered during LRN from our experience and ways to overcome them.

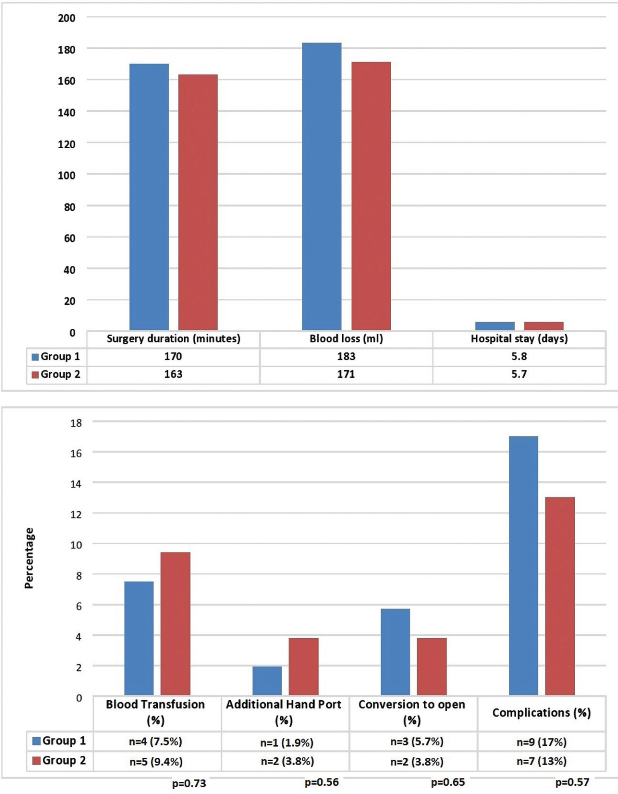

Fig. 3 Bar graphs comparing the patient outcomes and complications between the study groups.

Difficulty Identifying the Ureter

After reflection of the colon medially, the ureter is usually identifiable as a white glistening tubular structure with longitudinal vascular patterns over it. However, if the dissection plane is close to the psoas muscle, the ureter may go with the colonic reflection, which should be avoided. The ureter may be confused with the gonadal vein, which usually has a thinner wall and a blueish hue. In complex cases, the ureter may be traced from the pelvic brim or directly proceed with hilar dissection and trace the ureter from the renal pelvis.

Hilar Dissection and Venous Injury

Hilar dissection is the most critical step of LRN, and we routinely develop both superior and inferior windows to delineate the vascular anatomy, as described by Chiruvella et al.[6] The para-renal fat is light yellow colored and fine-textured in contrast to the deep yellow and granular Gerota fat. In case of difficult dissection with adhesions, the suction cannula can greatly assist blunt hilar dissection. We routinely use hem-o-lok clips for hilar vascular control. Should the clips be removed, we advocate using an energy device to cut the clip at its hinge rather than struggling with a scissor, leading to vascular injury. Various maneuvers help control the venous bleed:

- **Direct compression:** Gauge piece effectively controls minor bleeding through direct compression, and we recommend keeping one close by during hilar dissection. Increasing pneumoperitoneum to 16 to 18 mmHg also decreases bleeding, improves visibility, and allows time to secure hemostasis.
- **Altering stretch on the vein:** A bulky renal mass may increase the size of a venous rent perpendicular to its long axis due to stretching, which can be avoided by supporting the kidney and reducing traction on the vein, thereby preventing tear. Conversely, if a venous injury is along the long axis of the RV, gentle traction on the vein helps reduce bleeding by collapsing the thin-walled vessel, giving just enough opportunity to clip the vein.
- **Rescue stitch:** We advocate keeping a 6-0 polypropylene suture parked in the abdominal wall with a hem-o-lok clip applied to the open end for emergency usage in patients with complex venous anatomy.
- **Vascular stapler:** Vascular staplers are helpful in cases with a large caliber RV and if the RA was inaccessible for clipping due to overlying RV. With improved technology, stapler malfunction is seldom encountered, and concerns of arteriovenous fistula are theoretical.[7]
- **Hand port:** Hand ports, as described by Mahesan et al,[8] can be used to salvage RV injuries by strategically placing the port incision over the bleeding vessel to allow rapid control. Surgical gloves can replace a hand-assisted laparoscopy device to prevent loss of pneumoperitoneum.
- **Conversion to open:** The importance of timely conversion to an open surgical approach cannot be overemphasized. It should not be considered a failure but a successful surgeon's successful judgment.

Renal Artery Identification

We recommend routine preoperative CTA to evaluate renal vascular anatomy.[9] If the RA origin is seen caudal to RV, a second artery's probability should be considered. In these cases, complete superior dissection should be done before venous clipping, especially if the caudal artery is of a small caliber.[10] In case of difficult access to the cephalad artery, one can place a clip initially to clamp the artery and then complete its ligation and division later under vision after dividing the vein. However, any caudal artery should be dealt with entirely before embarking on the vein to enhance exposure and safety.

Anomalous Veins

The presence of anomalous venous anatomy is a warning sign and warrants meticulous dissection in such cases to avoid dreaded venous bleeding. We routinely obtain preoperative venous phase CT images to elucidate the venous anatomy. Lumbar veins can be a source of a significant bleeding, and to delineate them, one should complete the hilar dissection to visualize vascular anatomy before ligating any vessel. The adrenal vein should also be considered while dissecting the superior hilar window.

Confirmation of Arterial Control

In case of a high degree of suspicion of missed second RA, a vascular clamp may be applied over the RV after RA ligation. Distention of RV in such circumstances suggests a missed second RA. Changes in the color and turgidity of renal parenchyma and a decrease in the fulness of the pelvicalyceal system are other indirect evidence of adequate arterial clamping.

Techniques to Avoid Injury to Surrounding Structures

Hepatic, splenic, and diaphragmatic injuries should be anticipated in upper polar renal masses. The hepatorenal or the lienorenal ligament should be divided entirely and close to the kidney to avoid capsular tears caused by traction. The traction should be gentle and with closed instruments. To avoid diaphragmatic injuries, one should remain close to the kidney during dissection. Toward the end of division of the hepatorenal or the lienorenal ligament, one should remain close to the liver or spleen respectively. Superior mesenteric artery injury is rare and more likely on the left side. The origin of the suspected artery should be traced in cases of doubt and while RA typically has a lateral origin, superior mesenteric artery has an anterior origin. No random ligation of vascular structures should be performed, and the hilar anatomy should be adequately defined before ligation. In case of suspected injury, prompt conversion to open and call for help should not be delayed. Additional port for retraction by assistant may be placed in difficult cases with large tumors and we strategically place the additional port at the drain site.

Indications of Blood Transfusion

Intraoperative transfusions should be based on the patient's blood loss and hemodynamic status, while postoperative transfusions should be avoided if hemoglobin remains above eight mg/dL. We did not find any evidence of delayed wound healing with this approach.

Positioning-Related Complications

We recommend against using the flexed lateral positioning for transperitoneal LRN due to lumbar plexopathy and rhabdomyolysis concerns.[11] Brachial plexopathy is avoidable by proper padding, adequate head support, and avoiding overstretching of arms. A full 90 degrees lateral position is preferable over a partial lateral tilt, as it simplifies colon mobilization and fixes the patient more securely to the operating table allowing table maneuverability.

Concordance of Intraoperative RA Anatomy with CTA

The CTA accurately elucidated arterial anatomy in 95% of patients, similar to the previous reports,[12] Most discrepancies were caused by the branching pattern of RA appearing as a predominant single main RA on imaging. However, the branching patterns appearing distal on the CTA were confirmed to be more proximal intraoperatively with double RA. This may be related to the anatomical changes in the lateral position used for LRN compared to the supine position while performing CTA. One small accessory RA was entirely missed on CTA. Early RA branching should be looked for as one may encounter double RA in such cases.

Technological Assistance

Technological advances, including three-dimensional laparoscopy and energy devices,[13,14] increase safety and decrease the difficulty by improving vision and depth perception and reducing blood loss and operative duration. We use a three-dimensional laparoscopy system and a Thunderbeat energy device, which have immensely simplified the procedure.

Role of Mentor

While technical skills can be acquired by practice, a mentor's role is to impart critical nontechnical skills necessary to overcome laparoscopic surgery's learning curve and guide the trainee through his mistakes during the initial learning phase.[15] Operating in a fellow urologist's presence is also helpful, with the benefits of both surgeons' combined experiences and increased operating surgeon's confidence. The best mentors are often our own mistakes, and we advocate watching recorded operative videos for all cases to identify and correct the past inaccuracies.

The safety and efficacy of LRN have vastly improved in the last decade, attributable to increased usage, early training in residency programs, improved technology, and reduced cost. The high-volume centers may offer further improved outcomes.[16] The procedure does not require such high-level skills as laparoscopic suturing and can be learned and practiced on widely available training modules.[17] The average operated cases are also on the rise due to increased rates of incidentally detected tumors, given the wide availability and increased cross-sectional imaging usage.

Multiple studies have reported LRN's learning curve with a trend toward decreased operative duration, lower blood loss, and fewer complications as the surgeons gain more experience.[18,19] With the widespread use of laparoscopy in urology and ground-breaking technological advances that have enormously improved efficacy and safety, we expected changes in the current era's learning curve for LRN. In contrast to the previous reports, we had focused only on malignant renal masses operated using the transperitoneal approach for LRN to ensure homogeneity in the operative challenge.

In our study population comprising 106 patients operated on in the last 4 years, 92% ($n = 98$) successfully underwent LRN without conversion to open surgical approach, and another 3% did so with the assistance of a hand port. The illustrated results are the combined efforts of three independent surgeons performing LRN at our center, all of them previously exposed to basic laparoscopic training during their residency and were trained under the observation of mentors after residency. The increased exposure and training in laparoscopic surgery early in residency programs and later on may explain the lack of a demonstrable learning curve between the two groups in our study.

The study's primary limitations were its relatively smaller sample size, retrospective evaluation, and lack of direct comparison with the open surgical approach. Retroperitoneal approach and simple nephrectomy were also not included to allow comparability with a homogeneous operative challenge. The patients' detailed follow-up data were not illustrated as we intended to focus on the perioperative details.

Our study illustrates the combined efforts of novice laparoscopic surgeons who delivered acceptable outcomes consistently for over 100 LRNs, following the tenets of laparoscopic surgery and improving upon their skills and experience. Sharing our experience, we hope to inspire young urologists to take on the endeavor of furthering their knowledge and skills. The description exemplifies how the classical steep learning curve previously associated with laparoscopic surgery, specifically LRN, may not be readily evident in the current era. We must remember that learning is a perpetual process, and no learning curve can capture the experience gained by a surgeon throughout their career.

Conclusion

LRN is feasible in 95% of cases with a mean tumor size of up to 7.5cm, with an acceptable complication rate and improved outcomes, in appropriately selected patients. The assumed steep learning curve of the procedure reported in the past might not be evident anymore due to improved training and technology.

Authors' Contributions

A.P. contributed to design of the study; data acquisition, analysis, and interpretation; drafting, revising, and editing the manuscript; final approval of the version to be published, and agreed to be accountable for all aspects of the work. S.M. was involved in conception and design of the work, revising the manuscript critically, final approval of the version to be published, and agreed to be accountable for all aspects of the work. M.K.D. was involved in data interpretation, revising the manuscript critically, final approval of the version to be published, and agreed to be accountable for all aspects of the work. P.N. contributed to design of the work, revision of the manuscript critically, final approval of the version to be published, and agreed to be accountable for all aspects of the work.

Ethical Approval

The authors declare that the study was approved by the institutional ethical committee on human research and conformed to the approved guidelines by the Declaration of Helsinki.

Conflict of Interest

None declared.

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