

Original Article

Application of laparoscopy in urology: a study on the learning curve in experience at a large center including 4707 cases

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Abstract: Purpose: To analyze the effects of a learning curve in laparoscopic approaches in urological surgery and the prevalence of complications in a large medical center. Materials and methods: Clinical data of all patients who underwent laparoscopic surgery at the Department of Urology, West China Hospital, from March 2003 to December 2012 were retrospectively reviewed. All postoperative complications were recorded and classified according to the Clavien-Dindo system, and the parameters of average operating time (OT), estimated blood loss (EBL), length of hospital stay after operation (LOSO), and rate of complication (RC) were analyzed statistically. Results: Of a total of 4707 patients selected, 4293 (91.2%) were treated by a retroperitoneal approach and 414 were treated by a transperitoneal approach. With the gradual maturity of technologies, OT, EBL, LOSO, and RC significantly decreased ($P < 0.001$). RC reached a plateau after the 3rd year. Furthermore, all postoperative complications according to the Clavien-Dindo system revealed that complications occurred in 778 (16.5%) cases, 78 during surgery and 700 after surgery. Conclusions: Trends in OT, EBL, LOSO, and intra- and postoperative RCs significantly decreased throughout the study period. The 3rd year was regarded as a turning point in the learning curve for laparoscopic surgery. However, the applied range expanded along with an increase in difficult and complicated procedures. Complications may be efficiently reduced by summarizing RC and analysis of treatments and characteristics of the learning curve.

Keywords: Clavien-dindo, laparoscopy, learning curve, urology

Introduction

The application of Laparoscopic techniques will decrease the extent of trauma, the rate of complication (RC), and the length of hospital stay after operation (LOSO) [1]. Although the original intention of adopting laparoscopic techniques in urological surgery was to minimize invasiveness, an increasing number of perioperative complications occur because of the greater prevalence of complicated surgeries encountered along with the maturity of technologies [2, 3]. Parsons et al. [4] reported a RC of 4.4%-19.0%, but this rate could have been easily influenced by multiple factors, such as the proficiency of the surgeon, level of difficulty, and number of surgical sites.

In 1992, a hierarchy of postoperative complications was proposed by Clavien et al. [5], which was modified in 2004 and renamed as the Clavien-Dindo system. This system is used to

classify postoperative complications into 5 grades (I-V) according to severity from slightest pain to death, in which grades III and IV were further divided into two subgroups [5, 6]. Further, grades I and II were merged as minor complications, whereas grades III and IV are considered as major complications [7].

Here we summarize a learning curve in laparoscopic techniques in urological surgery since first adopting these techniques in March 2003 to December 2012 to share our experience and provide possible guidance for the classification of postoperative complications according to the Clavien-Dindo system.

Materials and methods

We retrospectively reviewed data of all urological patients who underwent laparoscopic surgery in our institution from March 2003 to December 2012.

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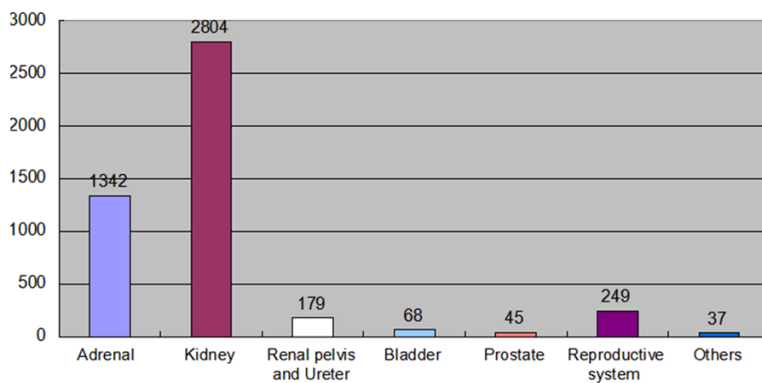


Figure 1. Composition of surgeries in each location.

Surgical technique

All patients received general anesthesia by tracheal cannulation and were assigned to one of two groups according to the surgical approach, i.e., transperitoneal group and retroperitoneal group. In the transperitoneal group, patients were placed in a horizontal position for surgeries targeting the bladder, prostate, spermatic cords, etc., or a semi-lateral position for surgeries targeting the kidneys, ureters, adrenals, and retroperitoneal cavity. Initially, a vertical 3-5-cm incision below the umbilicus was made through the peritoneum into the abdominal cavity. A 10-mm Trocar sheath was then imbedded, after which pneumoperitoneum was established with carbon dioxide at a pressure of 12-15 mmHg. An additional 2 or 3 sheathes were placed within sight of the laparoscope.

For the retroperitoneal group, the waist was elevated to expose the affected side after procedures in the lateral position were completed. The main port was placed on the midaxillary line 2-3 cm cephalad to the iliac crest. A 2-3-cm incision was made through the skin and the three muscle layers of the abdominal wall were separated using a vessel clamp to expose the exterior Gerota's fascia. When necessary, the surgeon could extend the space by using a finger. Then, 5- and 10-mm Trocar sheathes were placed into the extended retro-peritoneal space at the subcostal points of the posterior and anterior axillary lines, respectively. Finally, the main sheath was implanted and then fixed with sutures to prevent air leakage. The pneumoperitoneum was maintained at a pressure of <12-15 mmHg. The incisions were extended according to the size of the excised specimens.

Statistical analysis

SPSS 17.0 software (IBM SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses. All results are presented as means (\pm standard deviations; SD) and rates. To analyze complications systematically, we arbitrarily divided the 10-year period of 2003-2012 into three phases: phase I (the first 3 years), phase II (the second 3 years), and phase III (the last 4

years). Rates of converting to open surgery in three phases were compared using the chi-squared test. Linear regression analysis was performed to identify trends in operating time (OT), estimated blood loss (EBL), and LOSO. Changes in trends in intra- and postoperative complications were assessed using the chi-squared test. A probability (P) value <0.05 was considered statistically significant.

Moreover, data were recorded separately for surgeries involving multiple organs unilaterally or bilaterally and for repeated or staging procedures for the same patient. For multiple complications in 1 patient, the most severe complication was included for analysis.

Results

A total of 4724 surgeries were performed for 4707 patients, 4293 (91.2%) were treated by a retroperitoneal approach and 414 (8.8%) by a transperitoneal approach. Of these, 1342 (28.4%) focus on adrenal, 2804 (59.3%) for kidney, 179 (3.8%) for renal pelvis and ureter, 68 (1.4%) for bladder, 45 (1.0%) for prostate, 249 (5.3%) for reproductive system disease and others 37 (0.8%) (**Figure 1**). Seventeen cases underwent 2 surgeries because lesions in two sites were treated simultaneously. No repeated or staging procedures were performed. All basic patient data are summarized in **Tables 1** and **2**.

Complications were encountered in 778 (16.5%) cases and laparoscopy was converted to open surgery in 90 (1.9%). Regression analysis showed significant differences and decreasing trends in OT, EBL, and LOSO ($t = -4.580$, $P <$

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Table 1. The basic information, operation approaches and complications of patients

Year	Case		Gender		Age		Trans-peritoneal surgery		Retro-peritoneal surgery		Intraoperative complications		Postoperative complications according to Clavien-Dindo system							Total complication	
	N	%	Male	Female	Mean	SD	N	%	N	%	N	%	I	II	IIIa	IIIb	IVa	IVb	V	N	%
2003	54	1.1	37	17	42.07	13.41	9	16.7	45	83.3	12	22.2	0	2	2	0	1	1	0	18	33.3
2004	145	3.1	60	85	45.99	14.25	9	6.2	136	93.8	8	5.5	31	12	0	1	1	0	0	53	36.5
2005	252	5.4	125	127	49.15	15.06	11	4.4	241	95.6	6	2.4	38	16	1	1	3	2	0	67	26.6
2006	275	5.8	145	130	48.51	15.92	15	5.5	260	94.5	6	2.2	38	16	0	1	1	1	0	63	22.9
2007	305	6.5	160	145	50.48	14.85	25	8.2	280	91.8	7	2.3	42	15	1	0	2	0	0	67	22.0
2008	401	8.5	210	191	50.85	15.17	21	5.2	380	94.8	4	1.0	49	14	0	1	3	1	0	72	18.0
2009	528	11.2	249	279	50.06	14.73	28	5.3	500	94.7	5	0.9	37	21	1	0	1	0	0	65	12.3
2010	581	12.3	299	282	49.06	14.78	52	9.0	529	91.0	8	1.4	51	27	1	1	1	0	0	89	15.3
2011	1001	21.3	500	501	49.46	15.05	108	10.8	893	89.2	11	1.1	76	44	2	1	2	0	0	136	13.6
2012	1165	24.8	641	524	48.59	15.09	136	11.7	1029	88.3	11	0.9	87	47	1	1	1	0	0	148	12.7
Total	4707	100	2426	2281	49.18	15.03	414	8.8	4293	91.2	78	1.7	449	214	9	7	16	5	0	778	16.5

N = number; SD = standard deviations.

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Table 2. Number of laparoscopic cases, reconstruction operation ratio, lower urinary tract operation ratio by stage

Procedures	Stage I	Stage II	Stage III	Total
Adrenalectomy	134	286	922	1342
Renal cyst decortication	199	499	944	1642
Simple nephrectomy	37	57	587	681
Partial nephrectomy	3	20	189	212
Duplex kidney excision	1	3	3	7
Radical nephrectomy	23	26	197	246
Nephroureterectomy	4	13	36	53
Pyelolithotomy/Ureterolithotomy	25	24	61	110
laparoscopic pyeloplasty	2	2	16	20
Cystectomy	1	9	58	68
Radical prostatectomy	1	0	42	43
Ligation of spermatic vein	14	21	180	215
Lymph node dissection	3	3	5	11
Spermatic mass excision	3	5	8	16
Retroperitoneal mass excision	3	5	14	22
Others	2	15	19	36
Total	455	988	3281	4724
Reconstruction operation	6 (1.3%)	12 (1.2%)	115 (3.5%)	133 (2.8%)
Lower urinary tract operation	20 (4.4%)	50 (5.1%)	305 (9.3%)	375 (7.9%)

0.001; $t = -4.438$, $P < 0.001$; and $t = -10.410$, $P < 0.001$, respectively). The chi-squared test revealed significant differences in the incidence of intra- and postoperative complications ($\chi^2 = 46.611$, $P < 0.001$ and $\chi^2 = 56.843$, $P < 0.001$, respectively) with a significant plateau exhibited after the 3rd year, indicating a turning point. Further, a second plateau was observed in the incidence of postoperative complications after phase II (the 2nd 3-year period) (**Figure 2**). Percentages of reconstruction and lower urinary tract surgeries were increased because of continuously extended ranges (**Table 2**).

Prevalence and treatment of intraoperative complications

At least one complication occurred in 78 cases, accounting for 1.7% of surgeries, which included the following (**Figure 3**).

Vessel injury in 23 cases (7 involving the inferior vena cava, 6 of which were repaired by open surgery; 7 involving the renal vessels, which were all repaired by open surgery; 2 involving the central adrenal veins, 1 of which was repaired by converting the procedure to open surgery; 2 involving the iliac ves-

sels, 1 of which was repaired by open surgery; and 5 cases of neoplastic bleeding, of which 4 were repaired converting the procedure to open surgery). Emergency intraoperative transfusion was necessary in 16 cases (mean, 3.6 U; range, 2-10 U).

Peritoneum injury occurred in 21 patients, 1 due to a puncture wound caused by a sheath and 20 during placement. Extensive peritoneal trauma occurred in 20 patients, and in 1 patient, the procedure was converted to open surgery because of severe synechia.

Severe synechia and tissue damage occurred in 15 patients, for which a hand-assisted approach was adopted in 4 cases, while in 11 patients the procedure was converted to open surgery.

Organic injuries occurred in 5 cases (renal parenchyma injury in 1 patient with a cyst and left adrenal mass and liver injury in 1 patient with right adrenal pheochromocytoma), all of which were repaired by conversion to open surgery. Moreover, gastric and rectal injury occurred in 1 patient with a large retroperitoneal mass and in 1 during radical prostatectomy, respectively, both of which were repaired without using laparoscopy.

A second complication occurred in 14 patients, including three instances of hypercapnia, 2 of translocation of calculus, 3 of pleural damage, and 1 of fluctuation of blood pressure.

In our series, in 16 (3.5%) cases the procedure was converted to open surgery during stage I, in 18 (1.8%) during stage II, and in 56 (1.7%) during stage III. Further, pairwise comparisons revealed a significant difference between stages I and III ($\chi^2 = 7.178$, $P = 0.028$).

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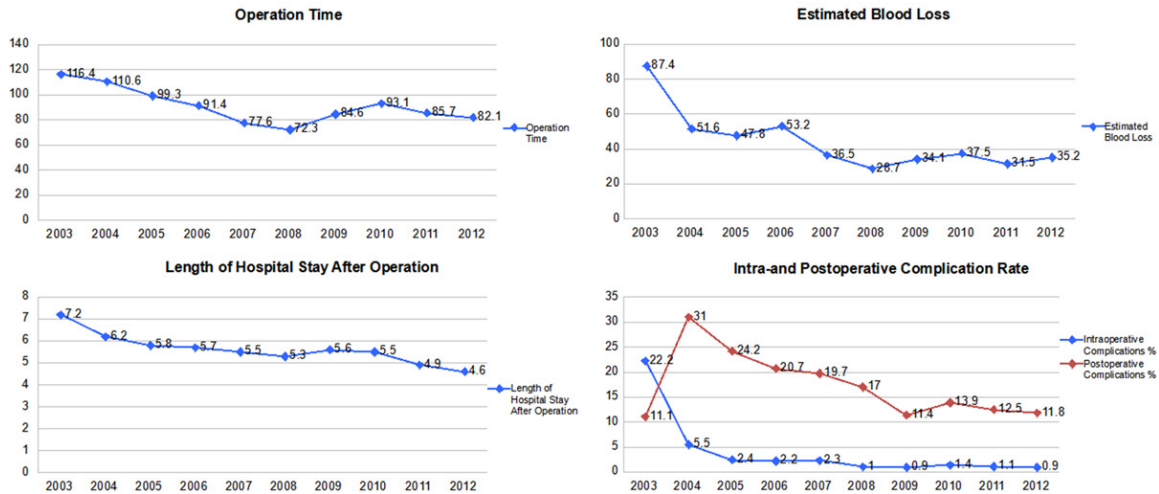


Figure 2. Trends of average operation time (OT), estimated blood loss (EBL), length of hospital stay after operation (LOSO), intra- and postoperative complication rate gradually.

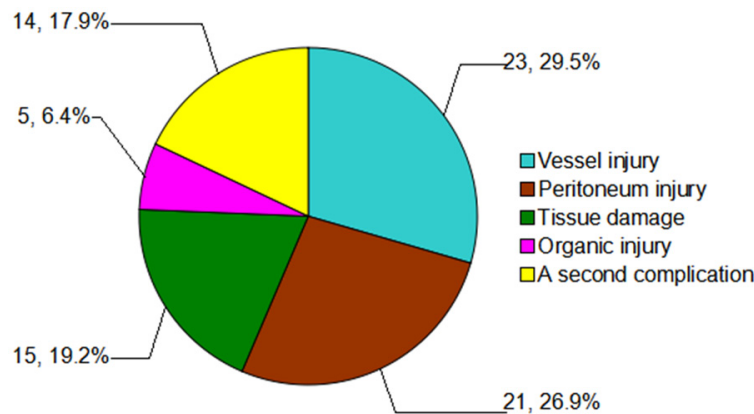


Figure 3. Constitution of intraoperative complications.

Prevalence and treatment of postoperative complications

Postoperative complications occurred in a total of 700 patients, which were classified according to a modification of the Clavien-Dindo system. Of these, 663 (94.7%) were regarded as minor complications [449 (64.1%) grade I and 214 (30.6%) grade II] and 37 as major complications [9 (1.3%), 7 (1.0%), 16 (2.3%), and 5 (0.7%) were categorized as grade IIIa, IIIb, IVa, and IVb, respectively] (**Figure 4**) as described below.

Grade I: Three hundred and ninety cases classified as grade I were treated with drugs, which included antiemetics, antipyretics, analgesics, diuretics, and electrolytes. Incision infection,

non-infectious diarrhea, delirium, bowel obstruction, subcutaneous emphysema, pulmonary atelectasis, and atrial fibrillation occurred in 15, 10, 10, 9, 6, 5, and 4 cases, respectively.

Grade II: Parenteral nutrition was administered in 79 cases, of which 29 developed pulmonary infections. Expanded antibiotic regimens were administered to 22 cases with incision infections and 9 cases with urinary infections. Gastric mucosal lesions and exposure keratitis

was observed in 7 and 4 cases, respectively. Bowel obstruction was treated by gastric intubation or use of an anal tube in 19 cases. Moreover, transfusions were necessary in 15 cases. Deep venous thrombosis of the lower limbs and muscular venous thrombosis was diagnosed in 1 patient each, respectively. Other complications exceeding grade I, which were treated by drug administration, were observed in 27 cases.

Grade IIIa: Urinary leakage occurred in 3 patients after ureterolithotomy due to disconnection of a double-J catheter. All instances of urinary leakage were treated by cystoscopic-assisted ureteral stent implantation. Hydro-pneumothorax developed in 1 patient after cystectomy of the left kidney. Ectopia of a double-J

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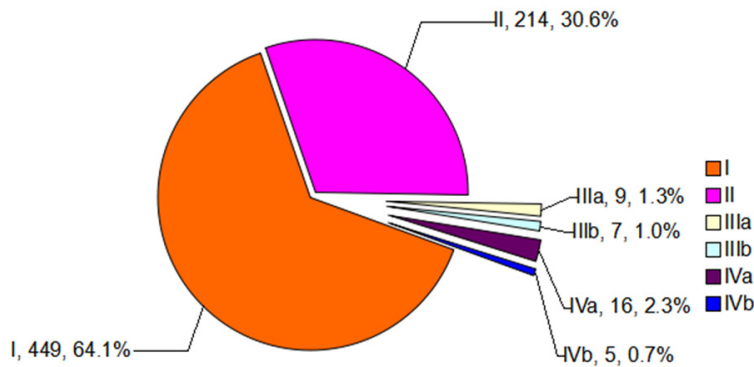


Figure 4. Postoperative complications according to the Clavien-Dindo classification system.

catheter was observed in 1 patient following radical cystectomy and ileal outflow tract obstruction, which was adjusted by radiological guidance. Fracture of a drainage tube occurred in 1 case, which was removed by reoperation. Continuous hematuria derived from the renal segmental artery occurred in 1 patient, which was treated by interventional embolization. Anastomotic leakage between the bladder and urethra was observed in 1 patient following radical prostatectomy, which was recovered by conservative management.

Grade IIIb: Hemorrhaging developed in 3 cases after adrenalectomy, 1 after radical nephrectomy and 1 after radical nephroureterectomy, all of which were cured by an open approach. Reoperation was performed in 1 patient because of leakage after cystectomy of the left kidney, whereas herniorrhaphy of the ileal conduit was performed in 1 patient following by radical cystectomy.

Grade IVa: Cardiovascular dysfunction developed in 5 patients, pulmonary dysfunction in 4, adrenal crisis in 2, and kidney failure requiring dialysis in 1 after adrenalectomy. Pulmonary dysfunction after radical cystectomy, kidney failure requiring dialysis after radical nephrectomy, and heart failure after simple nephrectomy occurred in 1, 2, and 1 patient, respectively.

Grade IVb: Multiple organ dysfunction syndrome was diagnosed in 2 patients after radical nephrectomy, 2 after adrenalectomy, and 1 after simple nephrectomy, who were all treated in intensive care units. There was no instance of procedure-related mortality.

Discussion

The use of laparoscopic procedures has been prevalent in urology for more than 20 years [8-11] and widespread in most of China since the beginning of 21 century [12]. As with all new surgical techniques, there is a learning curve in the development of surgical skills [8, 13-15]. However, this technique was adopted in our hospital in 2003 and 4724 urological surgeries have been performed by the end of 2012. The

results of our study, 16.5% for overall complications and 1.96% for cases in which the procedure was converted to open surgery, were in accordance with the results reported by Inoue et al. (14.6% and 1.9%, respectively) [16].

It is anticipated that the RC will significantly decrease with the acquisition of surgical experience [16-18]. In our study, the 3rd year was regarded as a turning point, as similarly reported by Akin et al. [18]. In addition, a study conducted in 4 centers reported a RC of 13.3% after the first 100 laparoscopic surgeries, which rapidly decreased to 3.6% thereafter [3].

On the other hand, the application of laparoscopic surgery was also changed besides the increase in the number of cases. In our study, percentages of 1.3%, 1.2%, 3.5% in surgeries referring to reconstruction and 4.4%, 5.1%, 9.3% in surgeries focusing on the lower urinary tract in three stages were respectively reported. It showed that, with the accumulating of surgical proficiency, tendencies of challenging more difficult reconstructive and lower tract surgeries were gradually favored. More importantly, increasing OT, EBL, LOSO, and RC could not be presented. Meanwhile, the rate of conversion to open surgery decreased significantly. Moreover, the intra- and postoperative RCs plateaued after the second 3-year period, which is the reason we divided the 10-year study period into three phases. However, these tendencies would be largely influenced by updated equipment and improved cooperation between surgeons and nurses apart from surgical skills.

Approximately 15 years ago, Guillonneau et al. [19] and Ghavamian et al. [20] reported a sig-

nificant decrease in OT in laparoscopic prostatectomy. However, this trend could be similar to the results of our study, which showed that a longer OT may be associated with insufficient skills during stage I, and a significant decrease in OT was shown in stage II because of accumulating experience. Furthermore, the slight increase in OT in stage III compared with stage II could be caused by encountering more difficult diseases. Moreover, similar decreasing trends were observed in EBL and LOSO [21]; however, there was no increase in EBL or LOSO in stages II and III even though more difficult procedures were performed.

Although laparoscopy is considered very safe, complications remain common, regardless of experience. The concepts of minimally invasive surgery and open surgery should not be confused, as the main complications can be fatal [8]. Although the overall intraoperative complication rate was only 10% (78 cases) in this study, vascular injury was the most common and serious complication, often requiring conversion to open surgery [22]. In our study, vascular injury, mostly involving the great vessels, occurred in 23 cases, and in 19 of which the procedure was converted to open surgery. In our opinion, laparoscopic-assisted suturing could be attempted to stop small venous bleeding, during which an appropriate increase in pneumoperitoneum pressure could be helpful. However, this procedure is suitable only for experienced surgeons. On the other hand, conversion to open surgery should be considered as the first choice for arterial bleeding or massive hemorrhaging after rapid clamping. In this series, no patient died due to vascular injury.

However, organic injuries occurred in 5 patients during surgery, while synechia and severe tissue damage occurred in 15 cases, in 4 of which the procedure was completed using hand-assisted procedures, while in the other 11 the procedure was converted to open surgery. In our opinion, a semi-open laparoscopic approach with hand-assisted procedures is an efficient method initially and could also accelerate the learning process. Through the acquisition of experience, open surgery could be also the first choice for patients with unclear anatomical structures caused by severe adhesions, which could shorten OT and decrease EBL and RCs.

Unlike other countries, most urological procedures in China employ an extraperitoneal

approach [23], through which less influence on abdominal viscera could be considered compared with those through transperitoneal approach. A previous retrospective study of 883 cases in our center to compare extraperitoneal and transperitoneal approaches concluded that differences in complication rates between these two approaches were insignificant, and longer OT and LOSO were observed in the transperitoneal group [24]. In our study, 4293 (91.2%) surgeries were performed through an extraperitoneal approach and peritoneal injury was observed in only 21 cases performed through the retroperitoneal approach, of which only 1 was due to a puncture caused by hand-manipulation of a sheath [8, 25]. Furthermore, in cases where the peritoneum is opened carelessly, the surgery can be continued without conversion to open surgery. For large lesions of the adrenals, kidneys, or retroperitoneal cavity, or cases of intraoperative peritoneal injury, we formerly adopted a translumbar/peritoneal joint approach with balanced pressure after expanding the incision to the peritoneum.

The Clavien-Dindo system is increasingly used to classify complications following urological procedures. An increasing number of centers have begun to classify complications based on this system to standardize data and promote the quality of evaluation [26-31]. All complications in our study were evaluated using the Clavien-Dindo system, in which 663 (94.7%) cases were considered minor complications, which was a higher percentage than 76.6% as reported by Akin et al. [18]. However, multiple factors may have contributed to this result. First, the administration of data may have been easily influenced because the data was collected from different centers and surgeons. This is particularly true for minor complications, which may be easily overlooked. Second, this evaluation system is not quantitative, which could induce classification bias. Furthermore, differences in therapeutic choices between developing and developed countries may affect conclusions [31]. Besides, different constituent ratios in morbid composition may contribute to classification complications. For example, 3665 (77.9%) cases underwent relatively easy procedures of total or partial adrenalectomy, renal cyst decortication, or simple nephrectomy, which are easily mastered and associated with low complication rates.

Conclusion

Parameters of OT, EBL, LOSO, and prevalence of intra- and postoperative complications are expected to significantly decrease with the maturity of skills. A plateau in complications was observed after the 3rd year, which could be regarded as a turning point in the learning curve. Moreover, the incidence of puncture-related complications could be effectively decreased through the application of hand-guided techniques in retroperitoneal surgeries. For large retroperitoneal lesions or intraoperative peritoneal injury, a translumbar/peritoneal joint approach with balanced pressure after expanding trauma at peritoneum should be considered. The Clavien-Dindo system is efficient for classification of postoperative complications and helpful to summarize and guide the choice of laparoscopic procedures.

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Discloser of conflict of interest

None.

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