



True learning curve of laparoscopic spleen-preserving distal pancreatectomy with splenic vessel preservation

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Abstract

Background Laparoscopic distal pancreatectomy (LDP) is generally the treatment of choice for diseases of the pancreatic body and tail. Most surgeons prefer the spleen- and splenic vessel-preserving technique (SPVP-LDP) in benign/borderline pancreatic disease because complications of splenic infarction and gastric varices can arise after Warshaw technique. This study was aimed to determine the true learning curve of the SPVP-LDP procedure not LDP including Warshaw technique.

Methods Data were collected retrospectively from all patients who underwent a LDP between June 2007 and April 2017 at Gangnam Severance Hospital. We used cumulative sum control chart (CUSUM) analysis to assess the learning curve for the SPVP-LDP technique.

Results Eight-three patients were performed LDP and we excluded patients who underwent robotic approach ($N=10$) and open conversion DP ($N=8$). Patients who underwent SPVP-LDP procedures were categorized into Group 1 (primary endpoint). Those who underwent LDP procedures with splenectomy and the Warshaw technique were categorized into Group 2. We found that the 16th case was the cutoff point and the mean length of hospital stay was 13.0 days in the first period and 8.7 days in the second period ($p < 0.001$).

Conclusions These results indicated that the frequency of SPVP-LDPs had increased and that technological progress had been made over time. The true learning curve for SPVP-LDP was indicated as 16 cases in a group of surgeons with no experience of laparoscopic pancreatic surgery.

Keywords Laparoscopic pancreatic surgery · Splenic preservation · Learning curve

The recent improvement of minimally invasive surgical techniques has resulted in an increased amount of laparoscopic and robotic surgery for pancreatic diseases. Many studies have reported that the laparoscopic distal pancreatectomy (LDP) technique is safe and cases of LDP are increasing [1–3]. LDP is mainly performed in patients with benign/borderline pancreatic disease. Most surgeons prefer the use of this spleen-preserving technique. On the other hand, several publications have verified that preservation of the spleen utilizing the Warshaw operation is associated with shorter surgical time, while being safe and effective [4, 5]. After

the operation, however, complications can include splenic infarction and gastric fundal varices [6, 7]. Therefore, surgeons often prefer the spleen-preserving LDP approach, which conserves the splenic artery and vein. Due to technical problems, surgical training to carry out this operation performed by a single surgeon or a single center requires a learning curve period. Studies regarding the LDP (including the Warshaw technique) learning curve have been published; however, there are no publications examining the learning curve of the spleen- and splenic vessel-preserving LDP technique. The aim of the present study was to classify and analyze laparoscopic spleen- and splenic vessel-preserving distal pancreatectomies (SPVP-LDP) and define the learning curve period.

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Methods

Patients

Eight-three patients were performed laparoscopic/robotic distal pancreatectomies (robotic approach; 10 cases) at Gangnam Severance Hospital from June 2007 to April 2017. We excluded patients who underwent robotic approach ($N=10$) and open conversion DP ($N=8$). Therefore, we retrospectively reviewed the clinical outcomes of 65 patients. The Institutional Review Board of Gangnam Severance Hospital approved this study.

Definition

As a policy of our department, we performed LDP in all pre-operatively diagnosed cases of benign/borderline or metastatic pancreatic lesions, except in cases of pancreatic adenocarcinoma. We defined patients who underwent SPVP-LDP as Group 1 (primary end-point operation) and patients who underwent LDP with splenectomy and the Warshaw technique (spleen preserving; splenic vein ligation and/or splenic artery ligation) as Group 2. Major complications were defined as Clavien–Dindo classification grade III and IV surgical complications [8]. Postoperative pancreatic fistulas were scored using the International Study Group on Pancreatic Fistula (ISGPF) definition [9].

Period

We defined the spleen-preserving distal pancreatectomy with conservation of the splenic artery and vein as the primary end-point for LDP. To confirm the learning curve, time periods were sorted by the approach, operation time, and blood loss. We used the cumulative sum control chart (CUSUM) method to sort the periods by SPVP-LDP case number and found that the 16th case was the cutoff point.

Surgical technique

Laparoscopic distal pancreatectomy was performed using 4 trocars (two 12-mm trocars and two 5-mm trocars). The lesser sac was opened by transecting the gastrocolic ligament. After we found superior mesenteric vein, the pancreatic margin was mobilized and 1 umbilical tape was placed around the pancreas. The body-tail of the pancreas was transected only by stapler using Endo-GIA. The type of cartridge was selected according to the thickness and texture of the pancreas during operation. After transection of pancreas parenchyme, fibrin glue was applied on the cut surface

of pancreas in all patients. Before closure, closed suction drain was inserted into the bed of the removed portion of the pancreas [10].

Statistical analysis

Categorical variables were compared by Chi-squared or Fisher's exact test. Continuous variables are presented as mean (\pm standard deviation [SD]) and median (Q1, 25th percentile–Q3, 75th percentile: range) and were compared using an independent two sample *t* test or the Mann–Whitney *U* test. *p* values <0.05 were considered statistically significant. All statistical analyses were performed using the statistical software SPSS (version 22; Chicago, IL, USA).

Results

Patients characteristics

Sixty-five consecutive laparoscopic distal pancreatectomy patients were enrolled in this study. Table 1 shows the clinical pathological features and outcomes of Group 1 and Group 2. There were significant difference in tumor location, blood loss, and tumor size between two groups; 18 (58.1%) patients had a tumor in the body of the pancreas in Group 1 and 11 (32.4%) patients in Group 2 ($p=0.037$). The median estimated blood loss was 250 ml in Group 1 and 500 ml in Group 2 ($p=0.034$). The mean value of the tumor size was 2.9 cm in Group 1 and 4.3 cm in Group 2 ($p=0.001$). There were no statistically significant differences between the other features.

Learning curve based on CUSUM

Changes in the rate of a specific operation can be analyzed by the CUSUM technique. CUSUM was defined as $\sum (X_i - X_0)$, where X_i is an individual trial and X_0 was the reference or target value for the procedure; $X_i = 1$ for failure (complication) and $X_i = 0$ for success (no complication). In this study, we defined $X_i = 1$ for a SPVP-LDP case and $X_i = 0$ for LDP with splenectomy and the Warshaw technique. The X_0 for a specific operation rate was set at 0.5 (31/65). On the chart, a positive slope indicated that the SPVP-LDP cases increased, and a negative slope indicated that other cases increased. In addition, we analyzed the operation time and blood loss by the CUSUM technique (X_0 for the mean value).

Using the CUSUM method to deduce the learning curve from the number of cases, there were two periods; the 1st to 16th case and the 17th to 65th case (Fig. 1). The CUSUM slope for cases 1 to 16 gradually decreased, whereas the slope had a tendency to increase from case 17 to 65. We

Table 1 Clinical characteristics of Groups 1 and 2

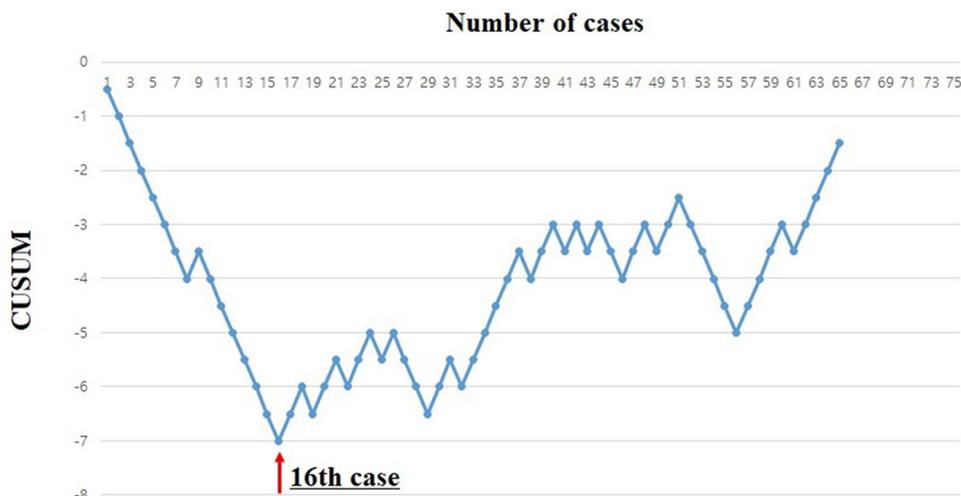
	Group 1 (N=31)	Group 2 (N=34)	p Value
Age, years, median, [Q1–Q3]	54 [47–66]	55.5 [30–66]	0.379
Male, n (%)	9 (29%)	10 (29.4%)	0.973
Female, n (%)	22 (71%)	24 (70.6%)	
Preoperative BMI, kg/m ² , mean ± SD	23.4 ± 3.0	22.7 ± 3.8	0.355
Non prior abdominal surgery, n (%)	23 (74.2%)	21 (61.8%)	0.750
Prior abdominal surgery, n (%)	8 (25.8%)	13 (38.2%)	
Diagnosis			0.812
Cystic disease (IPMN, SCN, MCN, Simple cyst), n (%)	16 (51.6%)	19 (55.9%)	
SPT, n (%)	5 (16.1%)	7 (20.6%)	
PNET, n (%)	5 (16.1%)	3 (8.8%)	
Other (metastatic disease), n (%)	5 (16.1%)	5 (14.7%)	
Tumor location			0.037
Body, n (%)	18 (58.1%)	11 (34.4%)	
Tail, n (%)	13 (41.9%)	23 (67.6%)	
Operation time, min, median, [Q1–Q3]	280 [240–365]	285 [250.3–341.3]	0.787
Blood loss, ml, median, [Q1–Q3]	250 [100–500]	500 [300–587.5]	0.034
Hospital stay, days, mean ± SD	8.9 ± 3.6	10.5 ± 8.8	0.196
Tumor size, cm, mean ± SD	2.9 ± 1.3	4.3 ± 2.6	0.001
POPF			0.672
None, n (%)	16 (51.6%)	20 (58.8%)	
A, n (%)	14 (45.2%)	12 (35.3%)	
B, n (%)	1 (3.2%)	2 (5.9%)	
C, n (%)	0 (0%)	0 (0%)	
Complications			0.170
No or Clavien I–II, n (%)	31 (100%)	32 (94.1%)	
Clavien III–IV, n (%)	0 (0%)	2 (5.9%)	

Group 1: laparoscopic spleen- and splenic vessel-preserving distal pancreatectomy (SPVP-LDP)

Group 2: laparoscopic distal pancreatectomy with splenectomy and the Warshaw technique (spleen preserving; splenic vein ligation and/or splenic artery ligation)

IPMN intrapapillary mucinous neoplasm, SCN serous cystic neoplasm, MCN mucinous cystic neoplasm, SPT solitary pseudopapillary tumor, PNET pancreatic neuroendocrine tumor, POPF postoperative pancreatic fistula, SD standard deviation, Q1 25th percentile, Q3 75th percentile

Fig. 1 CUSUM graph. Using the CUSUM method to deduce the learning curve from the number of cases, there were two periods: the 1st to 16th case and the 17th to 65th case



determined that the 16th case was defined as the starting point for SPVP-LDP in the serial LDP cases at our single center. During the period of the 17th to the 65th case, there was an increased pattern of SPVP-LDP.

The median patient age in the first period was 48 (27.5–60) years and in the second period was 59 (46–67) years ($p=0.082$) (Table 2).

The mean length of hospital stay was 13.0 days in the first period and 8.7 days in the second period ($p<0.001$). The number of cases with major complications was 2 (12.5%) in the first period and 0 (0%) in the second period ($p=0.012$). There were no statistically significant differences observed for the other patient features (diagnosis, tumor location, tumor size, operation time, estimated blood loss) between the two periods.

Discussion

Several studies reported that the minimally invasive distal pancreatectomy and open distal pancreatectomy techniques had similar short-term outcomes in pancreatic cancer [11, 12]. There are currently no known studies for the long-term outcomes in pancreatic cancer [13]; however, in a comparative multicenter study, due to favorable perioperative outcomes over those of an open distal pancreatectomy, LDP was preferred in benign cases of pancreatic disease [14, 15].

The Warshaw technique is deemed a safe operation for both benign and malignant lesions of the pancreas, with a low risk of failure and short operation time; however, there were some recognized complications reported in follow-up imaging studies, such as perigastric varices and splenic infarction. The blood supply to the spleen is recovered after the Warshaw operation through the augmentation of the collaterals. The increased flow through these collaterals may result in the aggrandizement of the veins along the gastric wall, which can be a risk factor for gastric bleeding [16–18].

Table 2 Clinical characteristics during the first period (1–16th cases) and the second period (17–65th cases)

	First period (1st–16th cases) ($N=16$)	Second period (17th–65th cases) ($N=49$)	p Value
Age, years, median, [Q1–Q3]	48 [27.5–60]	59 [46–67]	0.082
Male, n (%)	4 (25%)	15 (30.6%)	0.668
Female, n (%)	12 (75%)	34 (69.4%)	
Preoperative BMI, kg/m^2 , mean \pm SD	21.8 \pm 3.7	23.4 \pm 3.3	0.405
Non prior abdominal surgery, n (%)	9 (56.3%)	35 (71.4%)	0.260
Prior abdominal surgery, n (%)	7 (43.8%)	14 (28.6%)	
Diagnosis			0.642
Cystic disease (IPMN, SCN, MCN, Simple cyst), n (%)	7 (43.8%)	28 (57.1%)	
SPT, n (%)	3 (18.8%)	9 (18.4%)	
PNET, n (%)	2 (12.5%)	6 (12.2%)	
Other (metastatic disease), n (%)	4 (25%)	6 (12.2%)	
Tumor location			0.510
Body, n (%)	6 (37.5%)	23 (46.9%)	
Tail, n (%)	10 (62.5%)	26 (53.1%)	
Operation time, min, median, [Q1–Q3]	307 [251.3–347.8]	280 [250–360]	0.836
Blood loss, ml, median, [Q1–Q3]	425 [225–525]	300 [280–550]	0.679
Hospital stay, days, mean \pm SD	13.0 \pm 12.3	8.7 \pm 3.2	<0.001
Tumor size, cm, mean \pm SD	3.8 \pm 2.5	3.6 \pm 2.0	0.413
POPF			0.223
None, n (%)	8 (50%)	28 (57.1%)	
A, n (%)	6 (37.5%)	20 (40.8%)	
B, n (%)	2 (12.5%)	1 (2.0%)	
C, n (%)	0 (0%)	0 (0%)	
Complications			0.012
No or Clavien I–II, n (%)	14 (87.5%)	49 (100%)	
Clavien III–IV, n (%)	2 (12.5%)	0 (0%)	

The prevalence of these complications was reported to be 10% after the Warshaw operation [19]. At our institution, there have been 4 cases of gastric varices and 2 cases of splenic infarction following 9 Warshaw procedures; therefore, after overcoming technical problems, most surgeons performed splenic vessel preservation during LDP for benign/borderline pancreatic disease.

Commonly, the surgical learning curve is assessed by means of improvement in the operative time and decrease in blood loss; however, this study defined the surgical learning curve by the number of SPVP-LDP cases. The CUSUM technique has been effectively used to evaluate learning curves for many surgical procedures.

There are ‘CUSUM’ and ‘Moving average’ methods to evaluate the learning curve [20].

‘Moving average’ is a method that can be applied to continuous data. In the data obtained, the patients who underwent surgery were listed in order, and five patients are grouped together and averaged. We can get a single graph through the linked data of these averages.

‘CUSUM’ can be applied to continuous data and categorical data. In case of continuous data, the difference value of the average is continuously accumulated. As the value decrease, the learning effect appears. As the value increases, the learning effect does not appear. For categorical data, we define acceptable failure rates in advance. We defined specific event (complication or specific operation in our study) = 1 and no specific event (no complication or failure of specific operation in our study) = 0. We accumulated the value obtained by subtracting the rate of a specific event from the previous value. We make a graph with those values. In the case of complications, the declining state of the graph means that the learning effect is good. In our study, we defined specific event = 1, the increasing state of the graph means that the learning effect of specific operation is good.

Our data are categorical data because we made a graph by applying the successful cases of SPVP-LDP. In this case, ‘moving average’ cannot be applied. So we proceeded to the most suitable CUSUM.

A few studies have published the learning curve for the LDP [21]. Shakir et al. reported that the learning curve for a robotic distal pancreatectomy was 20 to 40 cases, as assessed by the operation time and readmission rate [22]. In another study, the learning curve was reported to be 30 cases, as assessed by perioperative outcomes such as complications and length of hospital stay [23]. At our institution, the learning curve of the LDP (including splenectomy and Warshaw technique) was approximately 20 cases, as assessed by operation time (unpublished data). Our learning curve has 16th cutoff points, which is similar the 20th cutoff points mentioned above. This is because our primary end-point was splenic vessel-preserving technique rather than reduced operation time or estimated blood loss.

In this study, the CUSUM results indicated that the point at which the number of SPVP-LDP cases increased was the true learning curve point; however, no significant points could be found when assessing the operative time or estimated blood loss.

There were no statistically significant differences in the clinical characteristics between Group 1 and Group 2, except for the tumor size, tumor location in the pancreas, and the estimated blood loss. Originally, Warshaw technique is favorable when the tumor size is large or the tumor location is close to the tail. It is known that the operation time is shorter in the Warshaw operation, which is not consistent with the results of this study because all operation was aimed at SPVP-LDP in this study. SPVP-LDP cannot be performed when there is excessive blood loss or difficult cases to dissect during operation, in that case, Warshaw technique or splenectomy was performed in our study. So, we obtained the contrary results. We tried to perform SPVP-LDP in the second period, even if the tumor location was close to the tail, and the success rate of SPVP-LDP was high. Thus, operation time or estimated blood loss was not different between the first and second periods.

And, the length of hospital stay and number of cases with major complications were lesser in second period than in first period ($p < 0.05$).

As the experience of laparoscopic distal pancreatectomy increased, our results showed less complications and better clinical outcomes in the second period.

This learning curve by SPVP-LDP case number was not correlated with operation time or estimated blood loss. In general, a learning curve in a specific procedure is defined by operation time or complication; thus, a different institution’s laparoscopic approach may be different from our concept for benign pancreatic surgeries.

In conclusion, this study reports the true learning curve for the SPVP-LDP procedure to be 16 cases in a group of surgeons with no experience of laparoscopic pancreatic surgery. The SPVP-LDP technique should be considered in patients with benign pancreatic disease; however, a sufficient period of time and experience is required to learn the procedure. In the early period, surgeons must consider the Warshaw technique for spleen preservation in LDPs for benign pancreatic disease.

Compliance with ethical standards

Disclosures Hyung Sun Kim, Joon Seong Park, and Dong Sup Yoon have no conflicts of interest or financial ties to disclose.

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