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Huang's three-step maneuver shortens the learning curve of laparoscopic spleen-preserving splenic hilar lymphadenectomy

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Background: The goal of this study was to investigate the difference between the learning curves of different maneuvers in laparoscopic spleen-preserving splenic hilar lymphadenectomy for advanced upper gastric cancer.
Methods: From January 2010 to April 2014, 53 consecutive patients who underwent laparoscopic spleen-preserving splenic hilar lymphadenectomy via the traditional-step maneuver (group A) and 53 consecutive patients via Huang's three-step maneuver (group B) were retrospectively analyzed.
Results: No significant difference in patient characteristics were found between the two groups. The learning curves of groups A and B were divided into phase 1 (1–43 cases and 1–30 cases, respectively) and phase 2 (44–53 cases and 31–53 cases, respectively). Compared with group A, the dissection time, bleeding loss and vascular injury were significantly decreased in group B. No significant differences in short-term outcomes were found between the two maneuvers. The multivariate analysis indicated that the body mass index, short gastric vessels, splenic artery type and maneuver were significantly associated with the dissection time in group B. No significant difference in the survival curve was found between the maneuvers.
Conclusions: The learning curve of Huang's three-step maneuver was shorter than that of the traditional-step maneuver, and the former represents an ideal maneuver for laparoscopic spleen-preserving splenic hilar lymphadenectomy.To shorten the learning curve at the beginning of laparoscopic spleen-preserving splenic hilar lymphadenectomy, beginners should beneficially use Huang's three-step maneuver and select patients with advanced upper gastric cancer with a body mass index of less than 25 kg/m^2 and the concentrated type of splenic artery.

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1. Introduction

With the development of laparoscopic techniques, the safety and feasibility of laparoscopic spleen-preserving splenic hilar lymphadenectomy (LSPL) have been increasingly accepted [1–4]. On this basis, the identification of an appropriate operative approach is conducive to LSPL. Therefore, scholars have developed a medial or retropancreatic approach [5,6]. Since January 2010, our center has utilized the left-sided approach, in which the retro-pancreatic splenic artery is entered along the superior border of the pancreatic tail to perform LSPL; this approach is referred to as the traditional-step maneuver. Moreover, we summarized a programmed procedure of LSPL after more than 100 cases of accumulated experience in April 2012. We divided the originally complex operative steps into the following three steps: the first step includes the dissection of lymph nodes (LNs) in the inferior pole region of the spleen; the second step includes the dissection of LNs in the region of the splenic artery trunk; and the third step includes the dissection of LNs in the superior pole region of the spleen. This operation is referred to as Huang's three-step maneuver [7,8]. The characteristics of Huang's three-step maneuver are clear in procedure and division, which can help beginners master the operation more easily than the traditional maneuver. However, there are no reports comparing the learning curves of these two maneuvers. Therefore, this study used the cumulative sum method (CUSUM) to systematically compare the learning curves of the application of Huang's three-step maneuver and the traditional maneuver in LSPL for advanced upper gastric cancer and to select suitable cases to help beginners accelerate the learning curve.

2. Materials and methods

2.1. Study population and evaluation parameters

Two groups of consecutive patients who underwent LSPL via the traditional-step maneuver (group A, n = 53) [9] or via Huang's three-step maneuver (group B, n = 53) (video) [7,8] at Union Hospital of Fujian Medical University between January 2010 and April 2014 were evaluated in this study. The advantages and disadvantages of the procedures were explained to the patients prior to surgery, and an informed consent form was signed by the patient and his or her family.

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.suronc.2017.07.010.

The dissection time (DT) represented the time from the dissection of the gastrosplenic ligament to the division of the last short gastric vessel (SGV). Blood loss (BL) was estimated according to the volume of blood absorbed by the gauze and suction pumped following subtraction of the fluid volume used for irrigation. There were two types of splenic artery, the concentrated type and the distributed type [10]. The concentrated type was present when the splenic artery divided into its terminal branches less than 2 cm from the splenic hilum. If the distance was equal to or greater than 2 cm, the case was considered the distributed type. The splenic lobar artery refers to the terminal branch of the splenic artery at the splenic hilum and is divided into four types [10]. The preoperative status of the patients was assessed by the American Society of Anesthesiologists (ASA) classification, and postoperative complications were classified as morbidities within 30 postoperative days. Vascular injuries were characterized by intraoperative vascular bleeding as a result of the operation that required electric coagulation or a titanium clip stanch. The $CUSUM_{DT}$ and $CUSUM_{BL}$ or the moving average $method_{DT}$ (MA_{DT}) and MA_{BL} were defined as the CUSUM or moving average (MA) based on the DT or BL, respectively.

Follow-up was performed by trained investigators through telephone calls, recording patient consultations at the outpatient clinic, mailings or patient visits every 6 months. The follow-up period ended in August 2015. Survival time was defined as the time from the surgical intervention to the last contact or date of death.

2.2. Statistical analysis

All of the statistical analyses were performed using SPSS (Statistical Package for the Social Sciences 18 for Windows; SPSS Inc., Chicago, IL, USA) with the exception of the MA and CUSUM plots, which were generated in Excel 2010 (Microsoft, Redmond, WA, USA). Continuous data are reported as the means ± standard deviations and were compared using t-tests. Qualitative data were compared using Chi-squared or Fisher's exact tests.

Variables with a $P < 0.05$ were selected for multivariate stepwise logistic regression. The survival rate was calculated using the Kaplan-Meier method and was compared using the log-rank test. $P < 0.05$ was considered statistically significant.

In this study, we analyzed the DT and BL to evaluate the learning curves using two statistical methods, including the (MA) method and the CUSUM.

2.2.1. MA

The MA is created by an average of subsets, which were modified by adding new data to the subsets and then shifting forward all of the datasets. In this study, the MA was defined as the average of the DT or BL, as subsequently described, in which x_n is either the DT or BL. In this study, an MA order of 20 was used.

$$\mathrm{MAn} = \frac{xn + xn + 1 + xn + 2 + \ldots + xn + 19}{20}$$

2.2.2. CUSUM

CUSUM is a statistical technique that indicates the sequential difference between individual data and the mean value. In this study, the CUSUM technique was applied via the following equation, where xi is an individual DT or BL, and μ is the mean overall operation time.

$$\mathrm{CUSUM} = \sum_{i=1}^{n} (xi - \mu)$$

3. Results

3.1. Comparisons of overall patient characteristics between groups

According to the comparisons of the two groups, the age, gender and body mass index (BMI) were not significantly different (Table 1).

3.2. Learning curve determination

The learning curves of group A and B were based on the DT and BL.

The first step determined the overall trends of the MA_{DT} and MA_{BL}. As shown in Fig. 1, the accumulation of cases revealed a trend toward a gradual decrease in the MA_{DT} and MA_{BL} of group A and B, which indicates a learning curve in the two groups.

The second step was based on the $CUSUM_{DT}$; there was a peak point at the 43rd case (62.5 min) in group A and at the 30th case (134 min) in group B. Based on the $CUSUM_{BL}$, there was a peak point at the 35th case (176 min) in group A and at the 26th case (156.4 min) in group B(Fig. 2). There were inaccuracies in the visual calculation of the BL [11,12], whereas the DT was relatively accurate. Thus, we chose the DT to determine the learning curve. As a result, phase 1 (initial learning period) of group A comprised the 1st - 43rd cases, whereas phase 1 of group B included the 1st - 30th cases.

Table 1
Clinicopathological characteristics of groups A and B.

	Group A	Group B	*P*
Gender			0.822
Male	39	41	
Female	14	12	
Age, years	60.9 ± 8.9	59.3 ± 9.3	0.390
BMI, kg/m^2	22.2 ± 3.2	22.6 ± 3.2	0.575
ASA score			1.000
2	49	48	
3	4	5	
Tumor size, mm	37.6 ± 9.1	50.3 ± 26.0	0.001
TNM stage			0.480
IA	3	1	
IB	3	5	
IIA	8	5	
IIB	9	4	
IIIA	6	11	
IIIB	10	11	
IIIC	14	16	
DT, min	33.6 ± 3.8	21.5 ± 7.7	<0.001
BLV, ml	31.4 ± 9.8	21.5 ± 7.7	<0.001
No. of SHLNs harvested	2.8 ± 1.0	2.4 ± 1.9	0.285
No. of SGVs	3.5 ± 1.4	3.7 ± 0.9	0.353
No. of PGAs	30	35	0.425
No. of SUPAs	16	11	0.373
No. of SLPAs	5	9	0.390
Terminal branches of the splenic artery			0.691
Distributed type	22	20	
Concentrated type	31	33	
Bleeding	6	3	0.488
Day of first flatus, d	3.5 ± 1.2	3.6 ± 0.6	0.918
Day of first fluid diet, d	4.0 ± 1.1	4.3 ± 1.0	0.087
Day of first semifluid diet, d	7.3 ± 0.8	7.7 ± 2.5	0.330
No. of SHLNs metastasis	0.5 ± 0.9	0.4 ± 0.7	0.903
Postoperative complications	12	10	0.811
Hospital stay, days	13.1 ± 1.9	13.4 ± 8.1	0.805
Metastasis	14	6	0.081

Group A: traditional-step maneuver, Group B: Huang's three-step maneuver, BMI: body mass index, ASA: American Society of Anesthesiologists, DT: dissection time, BLV: blood loss volume, SHLN: splenic hilar lymph node, SGV: short gastric vessel, PGA: posterior gastric artery, SUPA: splenic upper pole artery, SLPA: splenic lower pole artery.

3.3. Comparisons of clinicopathological characteristics in the same phase between groups

Comparisons of the same phase between the groups indicated that age, gender and BMI were not significantly different between the groups. The tumor size in phase 1 and the mean number of SGVs in phase 2 were significantly increased in group B compared with group A ($P < 0.050$; Table 2).

3.4. Comparisons of perioperative and pathological outcomes in the same phase between groups

The DT and BL of phases 1 and 2 were significantly less in group B than in group A ($P < 0.001$). Furthermore, the intraoperative vascular injuries in phase 2 were significantly fewer in number in group B compared with group A ($P = 0.001$), and the DT and BL of phases 1 and 2 were significantly less in group B than in group A. There were no significant differences in the time to first flatus, time to fluid diet, time to soft diet, postoperative complications, hospital stay or metastasis between the groups ($P > 0.05$) (Table 3).

3.5. Comparisons of survival rate and metastasis between groups

The median follow-up for the entire cohort was 30.0 months (range = 1–67 months); in group A and B, the median follow-up was 48 months (3–67 months) and 28 months (3–27 months), respectively. The follow-up rate was 96.2%, corresponding to 102 patients. During the follow-up period, there were 20 cases with metastasis, 12 cases with LN metastasis, 4 cases with peritoneal metastasis, 7 cases with liver metastasis, 2 cases with pulmonary metastasis and 3 cases with osseous metastasis. Fourteen and 6 of these cases were in group A and B, respectively, with no significant difference between the groups. There was no significant difference in the survival curve between the groups ($P = 0.083$).

3.6. Univariate and multivariate analyses of DT in group B

To identify the factors that affected the DT in group B, the cases were divided into two groups according to the mean DT: < 22 min (n = 33) for a short DT and ≥22 min (n = 20) for a long DT. The univariate and multivariate analyses indicated that a BMI ≥25 kg/m^2 ($P = 0.034$) and the concentrated type of splenic artery ($P = 0.014$) were independent, significant and prognostic parameters of DT in group B (Table 4).

4. Discussion

Recent research has demonstrated that the spleen participates in the normal operation of circulation and immune regulation, including the immune and endocrine systems, and the effects of spleen-preserving splenic hilar lymphadenectomy have gradually been recognized [13,14]. However, because of the deep location of the splenic hilum, the narrow operative space, the fragile texture of the spleen, the tortuosity of the splenic vessels and the complicated branching of the splenic lobar artery, surgeons often must free the spleen and pancreatic tail from the abdominal cavity during open surgery. A laparoscope can enlarge the surgical field and has a relatively wide operation splenic artery, which improves visibility during the operation and enables a more sophisticated operative ability in LSPL. Since Hyung et al. [5] first reported LSPL in 2008, Japanese scholars and our center have subsequently provided reports of this operation [15,16]. In contrast to other reports, we used a traditional-step approach [9], which facilitates the maintenance of proper tension in the operative field by drawing the gastrosplenic ligament to provide better exposure. Furthermore, the

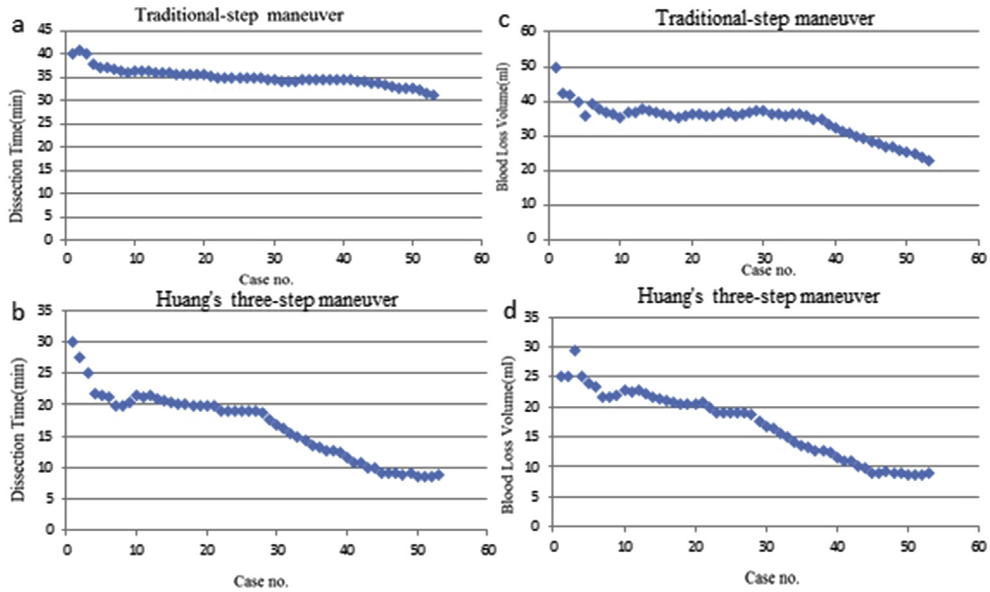

Fig. 1. Moving average of the traditional-step maneuver and Huang's three-step maneuver based on dissection time and blood loss volume.

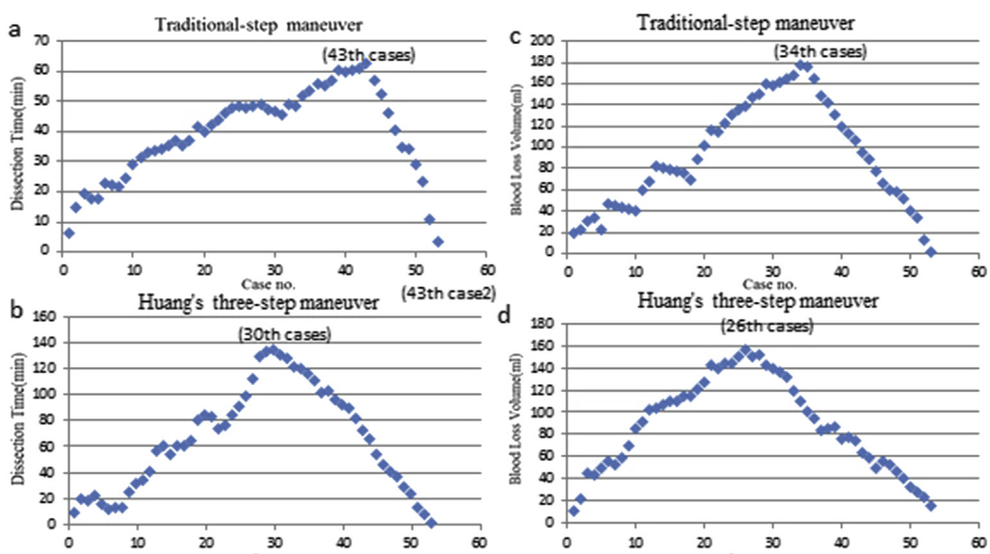

Fig. 2. Cumulative sum method of the traditional-step maneuver and Huang's three-step maneuver based on dissection time and blood loss volume.

traditional-step maneuver enters the pancreas posterior space along the superior border of the pancreatic tail and severs the SGVs at their roots, which enables the complete removal of the LNs and stomach and is consistent with the concept of oncological radical resection. We determined that the unfixed operating procedure led the assistant to frequently change the drawing position to provide better exposure, which not only affected the operation process but also prolonged the time of adjustment of the surgeon and assistant. Thus, we summarized the characteristics of LSPL in subsequent clinical practice and implemented Huang's three-step maneuver, which uses a procedural operation process and clearly divides the work of the surgeon and assistant to optimize the operation process and improve the ease of the surgery.

In recent years, the CUSUM and MA have been widely used to investigate learning curves [17–20]. The MA represents the mean value of a particular data point, which can eliminate the effects of cyclic fluctuations and chance fluctuations in a single dataset. Accordingly, the MA can demonstrate the developmental direction of an event and forecast long-term trends. The CUSUM monitors small changes in each data point and can be used to rapidly analyze its continuous variation trend. In a previous study, Jung and Yamaguchi et al. investigated the learning curve based on the operation time [21–24]. This study also used the operation time to assess learning curves. As a result, phase 1 in the two groups comprised the 1st - 43rd cases and the 1st - 30th cases, respectively (Fig. 2a and b). At the same time, on the premise that the number of SGVs in phase 2 was significantly greater in group B than in group A, the DT and BL of group B were significantly less than those of group A in both phases 1 and 2, and the vascular injuries in phase 1 were significantly less in group B than in group A. We considered it beneficial for the surgeon to create movement memory due to the procedural process of Huang's three-step maneuver. Moreover, this

Table 2
Comparison of clinicopathologic characteristics in phases 1 and 2 between group A and B.

	Phase 1			Phase 2		
	Group A (n = 43)	Group B (n = 30)	*P*	Group A (n = 10)	Group B (n = 23)	*P*
Gender			0.583			1.000
Male	21	24		8	17	
Female	12	6		2	16	
Age, years	61.4 ± 9.3	57.8 ± 10.8	0.140	58.8 ± 7.0	61.3 ± 6.8	0.343
BMI (kg/m^2)	22.1 ± 3.3	22.8 ± 3.7	0.365	22.7 ± 2.8	22.2 ± 2.3	0.556
ASA score			0.685			1.000
2	40	27		9	21	
3	3	3		1	2	
Tumor size, mm	37.4 ± 8.4	51.0 ± 23.4	0.001	38.7 ± 12.3	49.4 ± 29.6	0.284
TNM stage			0.191			0.555
IA	3	1		0	0	
IB	2	3		1	2	
IIA	7	1		1	4	
IIB	9	2		0	2	
IIIA	6	8		0	3	
IIIB	6	7		4	4	
IIIC	10	8		4	8	
No. of SHLNs harvested	2.8 ± 1.0	2.8 ± 1.7	0.965	2.5 ± 0.7	2.0 ± 2.0	0.443
No. of SGVs	3.6 ± 1.4	3.5 ± 0.9	0.805	3.0 ± 1.2	3.9 ± 0.8	0.016
No. of PGAs	24	20	0.467	6	15	1.000
No. of SUPAs	14	5	0.128	2	6	1.000
No. of SLPAs	4	8	0.061	1	1	0.521
Terminal branches of the splenic artery			0.811			1.000
Distributed type	21	16		1	4	
Concentrated type	22	14		9	19	

Group A: traditional-step maneuver, Group B: Huang's three-step maneuver, BMI: body mass index, ASA: American Society of Anesthesiologists, DT: dissection time, BLV: blood loss volume, SHLN: splenic hilar lymph node, SGV: short gastric vessel, PGA: posterior gastric artery, SUPA: splenic upper pole artery, SLPA: splenic lower pole artery.

Table 3
Comparison of perioperative and pathologic outcomes in phases 1 and 2 between group A and B.

	Phase 1			Phase 2		
	Group A (n = 43)	Group B (n = 30)	*P*	Group A (n = 10)	Group B (n = 23)	*P*
DT, min	35.0 ± 2.3	26.1 ± 7.0	<0.001	27.6 ± 3.0	15.5 ± 3.0	<0.001
BLV, ml	33.6 ± 9.3	18.8 ± 6.9	<0.001	22.0 ± 5.4	8.7 ± 4.6	<0.001
Vascular injuries			0.206			0.023
No	20	16		5	20	
LGEVs	4	2		0	0	
SGVs	15	8		4	2	
PGAs	4	1		1	0	
SLVs	0	3		0	0	
Day of first flatus, d	3.5 ± 1.2	3.6 ± 0.7	0.786	3.5 ± 1.2	3.5 ± 0.6	0.944
Day of first fluid diet, d	4.0 ± 1.1	4.3 ± 1.1	0.214	4.0 ± 0.9	4.4 ± 1.1	0.342
Day of first semifluid diet, d	7.3 ± 0.9	7.9 ± 3.3	0.282	7.3 ± 0.5	7.4 ± 1.1	0.718
No. of SHLNs harvested	0.5 ± 0.9	0.4 ± 0.6	0.114	0.4 ± 0.7	0.4 ± 0.8	0.910
Lymphovascular invasion	16	18	0.062	4	10	1.000
Postoperative complications	9	6	1.000	3	4	0.606
Hospital stay, days	13.1 ± 1.9	13.2 ± 8.4	0.964	13.0 ± 1.7	13.7 ± 7.9	0.709
Recurrence	12	4	0.162	2	2	0.567

Group A: traditional-step maneuver, Group B: Huang's three-step maneuver, DT: dissection time, BLV: blood loss volume, LGEV: left gastroepiploic vessel, SGV: short gastric vessel, PGA: posterior gastric artery, SLV: splenic lobe vessel, SHLN: splenic hilar lymph node.

technique shortens the learning curve by clearly dividing the work of the surgeon and the assistant in every surgical region. Furthermore, Huang's three-step maneuver divides the process of LSPL into three well-aligned components, which is beneficial for the surgeon to maintain a smooth conception. These findings indicate that Huang's three-step maneuver is more conducive for beginners to master and has a better operation process than the traditional-step maneuver.

The operation time was associated with the operation difficulty. According to our previous report, the DT was related to the pathological characteristics of the patient [10]; however, no previous study has investigated the factors that affect the DT in Huang's three-step maneuver. In this study, a BMI ≥25 kg/m^2 and the concentrated type of splenic artery were identified as risk factors for a prolonged DT. We considered that the well-developed greater omentum and adipose tissue in the abdominal cavity of obese patients affected the exposure of the surgical field and limited the operation of the splenic artery; furthermore, adipose tissue with high brittleness and vulnerability to bleeding prolonged the DT [25]. Furthermore, the concentrated type of splenic artery shortens the DT because the splenic lobe vessels (SLVs) of the concentrated type are longer and wider than those of the distributed type, which is beneficial for LN dissection [10,26]. Therefore, we hold the opinion that the use of Huang's three-step maneuver and the selection of patients with advanced upper gastric cancer whose BMI is < 25 kg/m^2 and who exhibit the concentrated type of splenic

Table 4
Univariate and Multivariate analysis of factors impacting dissection time in "Huang's three-step maneuver".

	Univariate analysis			Multivariate analysis		
	DT < 22min(n = 33) *vs.* DT ≥ 22min(n = 20)			DT < 22 min (n = 33) *vs.* DT ≥ 22 min (n = 20)		
	OR	95%CI	*P*	OR	95% CI	*P*
Gender(male)	1.3	0.3–5.0	0.721			
Age, year(≥60)	0.9	0.3–2.9	0.915			
BMI(≥25 kg/m^2)	5.9	1.5–23.3	0.011	6.1	1.2–32.4	0.034
NACT(no)	0.0	0.0–-	1.000			
ASA score(3)	2.7	0.4–18.0	0.295			
TNM stage						
I	1					
II	0.7	0.1–4.2	0.686			
III	0.4	0.1–2.2	0.281			
Tumor size(≥44 mm)	0.8	0.2–2.5	0.636			
No. of SGVs(≥3)	1.5	0.5–5.0	0.491			
No. of PGAs(yes)	1.3	0.4–4.4	0.636			
No. of SUPAs(yes)	0.9	0.2–3.7	0.916			
No. of SLPAs(yes)	21.3	2.4–189.1	0.006	9.5	0.8–109.9	0.072
Terminal branches of the splenic artery (distributed type)	2.6	1.7–13.7	0.041	6.6	1.5–29.6	0.014

BMI: body mass index, NACT: neoadjuvant chemotherapy, ASA: American Society of Anesthesiologists, DT: dissection time, BLV: blood loss volume, SHLN: splenic hilar lymph node, SGV: short gastric vessel, PGA: posterior gastric artery, SUPA: splenic upper pole artery, SLPA: splenic lower pole artery, SpA: splenic artery.

artery can help beginners gain experience in successful cases, establish self-confidence and shorten the learning curve.

Conflict of interest statement

There are no financial disclosures from any authors.

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