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Is three-dimensional laparoscopic spleen preserving splenic hilar lymphadenectomy for gastric cancer better than that of two-dimensional? Analysis of a prospective clinical research study

Zhi-Yu Liu[1,2] · Qi-Yue Chen[1,2] · Qing Zhong[1,2] · Jian-Wei Xie[1,2] · Jia-Bin Wang[1,2,3] · Jian-Xian Lin[1,2,3] · Jun Lu[1,2,3] · Long-Long Cao[1,2] · Mi Lin[1,2] · Ru-Hong Tu[1,2] · Ze-Ning Huang[1,2] · Ju-Li Lin[1,2] · Hua-Long Zheng[1,2] · Chao-Hui Zheng[1,2,3] · Chang-Ming Huang[1,2,3] · Ping Li[1,2,3]

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Abstract

Background Three-dimensional (3D) systems for laparoscopy provide surgeons with additional information on spatial depth not found in two-dimensional (2D) systems.

Methods This study enrolled 156 spleen-preserving splenic hilar lymphadenectomy (LSPSHL) patients in a randomized controlled trial (ClinicalTrials.gov Identifier NCT02327481) at the department of gastric surgery at Fujian Medical University Union Hospital between January 2015 and April 2016. The short-term efficacies were compared between the treatment groups. The unedited videos of 80 LSPSHL (40 procedures each for 3D and 2D) were rated for technical performance using the Generic Error Rating Tool.

Results The data for 156 LSPSHL patients indicate that the estimated blood loss (EBL) (3D vs 2D = 66.3 vs. 99.0, $P = 0.046$) was significantly less in the 3D group. The postoperative recovery and complication rates were similar ($P > 0.05$). And there were no deaths within 30 days of surgery. Two observers analyzed 80 videos of LSPSHL. The results showed that there were fewer grasping-errors made in the 3D group than in the 2D group when dissecting the inferior pole region of spleen (IPRS) ($P = 0.016$) and the superior pole region of spleen (SPRS) ($P = 0.022$). Additionally, the inter-rater reliability was high regarding grasping-errors in the IPRS (intraclass correlation coefficient (ICC) 0.92) and in the SPRS (ICC 0.83). The ICC for the total number of errors was 0.82. The mean of errors in the 3D group (3D vs. 2D = 20.7 vs. 23.5, $P = 0.022$) was less than the 2D group.

Conclusions Compared with 2D LSPSHL, 3D technology reduces EBL and technical errors during splenic hilar dissection.

Keywords 3D · Laparoscopy · Short-term efficacy · Technical errors · Splenic hilar lymphadenectomy

Zhi-Yu Liu and Qi-Yue Chen contributed equally to this work.

Zhi-Yu Liu and Qi-Yue Chen should be considered co-first authors.

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✉ Chao-Hui Zheng
wwkzch@163.com

✉ Chang-Ming Huang
hcmlr2002@163.com

✉ Ping Li
pingli811002@163.com

Extended author information available on the last page of the article

Minimally invasive surgery has been gradually accepted for treating gastric cancer since 1994 when Kitano [1] first reported the application of laparoscopy in early gastric cancer. Lymph node (LN) dissection is the key of radical gastrectomy and is closely associated with the patient prognosis. In 2008, Hyung [2] et al. first reported the application of LSPSHL in gastric cancer. However, the unfavorable characteristics in the splenic hilar region such as the narrow space, complicated vessels, and variable anatomy represent a challenge for surgeons to maneuver and perform a complete dissection. The common laparoscopic systems only provide views with a 2D image, which lacks spatial depth information [3–5]. Thus, to overcome these shortcomings, the 3D laparoscopic video system was introduced into the surgical field of gastric cancer. Recently, numerous studies have indicated that 3D technology reduces the operative time, EBL, and the surgeon's laparoscopic learning curve compared to 2D laparoscopic surgery [6–12]. Previous studies have noted that high-performance and high-risk operations involving complex laparoscopic surgery should be analyzed for common indexes such as operative time, EBL and postoperative complications in addition to human errors and surgical events as valid and objective assessments. However, there are only a sparse number of retrospective studies on the technical performance of 3D laparoscopy in elaborate and complicated surgeries such as gastric cancer. Furthermore, there is a lack of prospective studies evaluating the short-term efficacy and the difference in intraoperative technical errors. Thus, the aim of our study was to analyze the short-term efficacies and technical errors to explore the relative safety and effectiveness of 3D and 2D LSPSHL in a prospective data set by using an effective and reliable error assessment tool.

Materials and methods

This phase 3 randomized controlled trial (RCT) [13] (ClinicalTrials.gov identifier NCT02327481) collected and analyzed clinical data of 438 candidates from the department of gastric surgery at Fujian Medical University Union Hospital. The main purpose was to investigate whether 3D surgery can shorten the surgical time compared with 2D surgery. This study was approved by the appropriate Ethics Committee (Fujian Medical University Union Hospital). All the patients were well informed and gave their full consent after receiving a verbal explanation of this study and an information document. This single-center study is a subgroup analysis from the prospective RCT. A more elaborate description of the study methodology has been previously described [13]. This study mainly aimed to further explore whether the performance of 3D surgery is superior to that of 2D surgery in complex LSPSHL. Consequently, we excluded 189 patients who did not meet the criteria, including 1 case of withdrawn consent, 8 cases of locally advanced cancer, 10 cases of implantation metastasis, and 170 cases of partial gastrectomy. The study inclusion/exclusion criteria for patient recruitment are shown in Fig. 1. The primary study endpoint was the duration of operation time. The secondary endpoints included postoperative complications, EBL, postoperative rehabilitation and technical errors.

According to the Japanese gastric cancer treatment guidelines [14], a negative margin of at least 3 cm is recommended for T2 or deeper tumors. Therefore, the indications for total gastrectomy in our center are as follows: the tumor is located in the upper part of the stomach; or the center of the tumor is located in the middle and lower part of the stomach, but the invasive range of the tumor is large, and the upper margin of the tumor is high such that distal gastrectomy cannot guarantee a sufficient proximal margin. A D2 lymphadenectomy for radical total gastrectomy includes

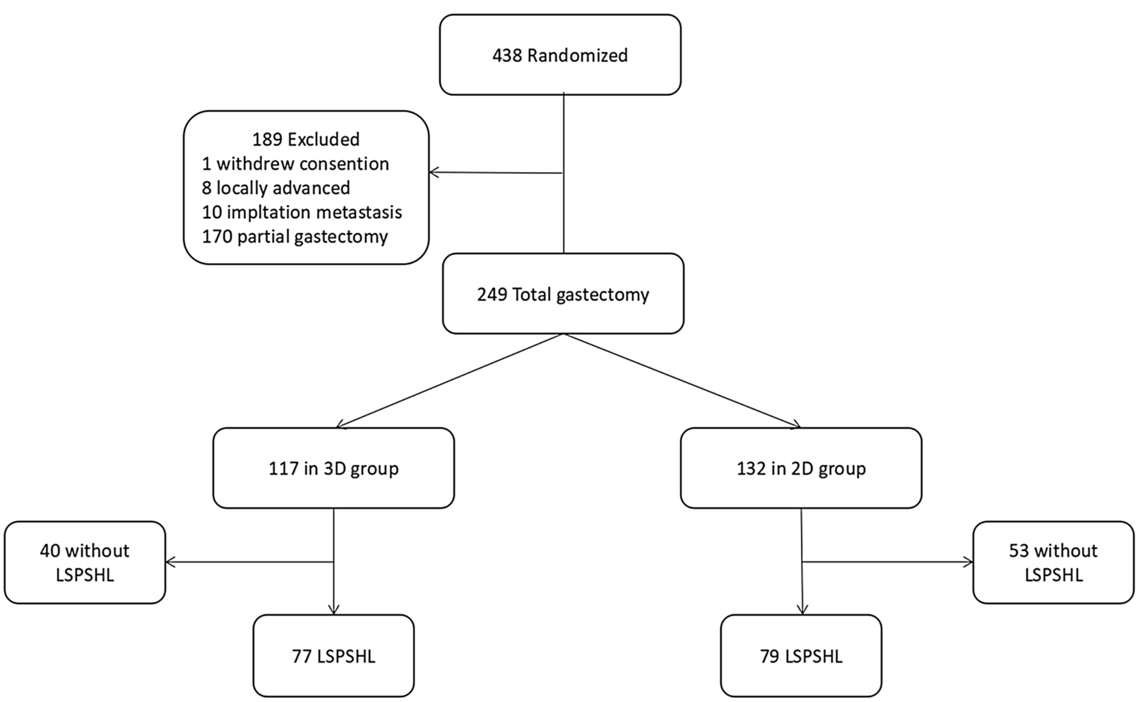

Fig. 1 Patient recruitment

the No. 10 lymph nodes [14]. In our center, LSPSHL is indicated for advanced gastric cancer patients undergoing radical total gastrectomy but not for cT1-stage gastric cancer patients who were excluded from the analysis.

Preoperative imaging examinations were routinely performed following endoscopic and upper gastrointestinal examinations with contrast to verify the tumor location. The examinations also included chest radiography, ultrasonography (US), and computed tomography (CT) scanning of the abdomen and bone scanning and positron emission tomography–computed tomography (PET-CT) as necessary to evaluate the clinical stage. Patients with a tumor located in the upper or middle region of the stomach, gastroesophageal junction, or cardia were diagnosed with tumor invasion into or beyond the muscle layers. The extent of LN dissection was based on the Japanese gastric cancer treatment guidelines [14]. Comorbidity was evaluated according to the Charlson score. The 7th edition of the International Union Against Cancer (UICC) classification system was used to assess the clinical and pathologic stages. All the patients received the same clinical protocol after surgery.

Procedure and definition

The surgical procedures were the same with each group where Huang's three-step maneuver [15, 16] was performed in dissecting the region of splenic hilar (the procedure description is in Table 1). Each step of Huang's three-step maneuver starts with initial transection of the tissues and ends with dividing tissues in the subsequent-step of the maneuver using an ultrasonic scalpel. The operative time was measured from the trocar insertion to the closure of the abdomen. EBL and splenic hilar blood loss (SHBL) were confirmed by calculating the volume of blood in the

Table 1 Operative steps of LSPSHL

Procedure	Start (S) and endpoint (E)		Standard skills and tasks observed	
Step one	S	Separation of the gastrosplenic ligament using an ultrasonic scalpel	Grasping	
	E	Transecting the branches of the SGVs issuing from the SLLV (1–2 branches in common)	Finding fascia	
			Revealing and bare the vessels	Left Gastroepiploic Vessel
				Spleen Lower Lobe Vessel/Inferior Splenic Vessel
				Short Gastric Vessel
			Clipping	
			Dissection	The LNs in the inferior pole region of the spleen
			Use of energy device	
Step two	S	Denuding the trunk of the SpA along the latent anatomic space on its surface toward the splenic hilar	Grasping	
	E	Reaching the fork of the splenic lobar arteries	Revealing and bare the vessels	Splenic artery (SpA)
				Lobar vessels of the spleen
			Clipping	
			Dissection	LNs in the trunk of SpA region
			Use of energy device	
Step three	S	Dissection of the fork of the splenic lobar arteries	Grasping	
	E	Division of the last SGV	Revealing and bare the vessels	Superior splenic artery
				Short gastric vessel
			Clipping	
			Dissection	LNs in the superior pole region of the spleen
			Use of energy device	
Other	All time periods outside defined steps			

Step one for the inferior pole region of spleen, Step two for the region of splenic trunk, Step three for the superior pole region of the spleen

SGV short gastric vessel, *SLLV* spleen lower lobe vessel, *SpA* splenic artery, aspirator and the number of gauzes. Splenic hilar dissection time (SHDT) begins with cutting the gastrosplenic ligament and ends with the division of the last short gastric vessel (SGV). There are two types of splenic arteries [16]: the distributed type and the concentrated type. The distributed type was generally present when the splenic artery divided into its terminal branches greater than 2 cm from the splenic hilum. If the distance was < 2 cm, the artery was considered to be the concentrated type. Each individual case parameter was evaluated routinely after surgery as soon as possible. Noncompliance was defined as a case with more than 1 empty LN station based on the protocol of the Japanese Gastric Cancer Association [17]. Based on the literature [18, 19], complications were graded according to the Clavien-Dindo classification. In addition, each patient was evaluated by the surgeons to guarantee that there was no evidence of complications.

Design of generic error rating tool

Following a literature analysis [20, 21], we developed the special framework as shown in Table 1 and modified it for the characteristics of Huang's three-step maneuver, which is proposed as the Generic Error Rating Tool (GERT). Six generic surgical tasks were summarized and all were applicable to LSPSHL. An error could be defined as any of the following issues: grasping, finding fascia, revealing and bare the vessels, clipping, dissection, use of energy device, or other unclassified errors. The latter group was included to allow for any additional remarks. The following four modified error modes were used: inadequate use of force or distance (too much), inadequate use of force or distance (too little), inadequate visualization, and wrong orientation of dissection plane or instrument. An error was defined as a failure of a planned action (e.g., slip of a gastric grasper) [20–22]. An event was defined as any deviation that caused injury (e.g., a slipped bowel grasper causing a serosal tear) [20, 21].

Determination of errors and events

Two observers with expertise in gastrectomy and surgical education independently reviewed the unedited LSPSHL videos. The observed errors and events were time-stamped to the moment of occurrence. The videos were retrieved arbitrarily from an educational video library containing anonymous recordings of 156 LSPSHL procedures. The video files contained only laparoscopic views and there was no audio, patient, or surgeon information. The observers were blinded to the origin of the video, the level of the operating surgeon, and to the patient outcome. The observers were instructed regarding the definitions of error modes and events by reviewing video examples.

Follow-up

The overall survival (OS) was calculated from the date of surgery until death or until the date of final follow-up, whichever occurred first. The recurrence-free survival (RFS) time was defined as the period from the day of surgery to the date of recurrence or final follow-up. The cutoff date for this study is April 2016 and all patients had reached a minimum of 24 months of follow-up. The median follow-up was 24 months since randomization (range from 3 to 35 months). The postoperative follow-up was performed in the outpatient department every 3 months for first 2 years. The routine patient follow-up appointments included a physical examination, laboratory tests, chest radiography, abdominopelvic US or CT, and an annual endoscopic examination.

Statistical analysis

The SPSS 20.0 (SPSS Inc. Chicago, IL, USA) software program was used for all statistical analyses. The continuous data were analyzed using Student's *t* test or the Mann–Whitney *U* test, and the categorical variables are compared by a $\chi 2$-test or Fisher's exact test. The cumulative survival rates were compared using a Kaplan–Meier curve and the log-rank test. We used Cox proportional hazards regression model together with a stepwise backward variable removal to identify the most accurate and parsimonious set of predictors in the multivariate analyses. Additionally, the inter-rater reliability was calculated using the ICC. All P-values < 0.05 were considered significantly different.

Results

Clinicopathologic characteristics

In the 156 LSPSHL patients, there was a significant difference in sex and previous abdominal surgery between the 3D ($n = 77$) and 2D ($n = 79$) groups ($P < 0.05$). There were no differences for the following characteristics: age, BMI, ASA, Charlson scores, cT/cN/cTNM, pT/pN/pTNM, tumor location, tumor size, vascular/nerve/lymphatic invasion and chemotherapy (all $P > 0.05$) (Table 2).

Operative outcomes and LN dissection

The EBL in the 3D group was significantly less than the 2D group for the patients of LSPSHL ($P < 0.05$). The outcomes were similar in terms of operative time, total retrieved LNs, complications, R0 margin, and length of stay (LOS) between groups (all $P > 0.05$). There were no deaths within 30 days of surgery (Table 3). Supplementary Table 3 showed that there were no significant differences in operation time or EBL

Table 2 Comparison of 3D vs. 2D Group: Clinicopathologic Characteristics

Variables	LSPSHL		
	2D (*n* = 79)	3D (*n* = 77)	*P* value
Age, year*	61.1 ± 9.0	59.0 ± 11.0	0.181
Sex			0.047
Female	20 (25.3)	31 (40.3)	
Male	59 (74.7)	46 (59.7)	
BMI, kg/m^2*	22.6 ± 2.8	22.5 ± 3.1	0.976
ASA score			0.935
I	31 (39.2)	29 (37.7)	
II	47 (59.5)	47 (61)	
III	1 (1.3)	1 (1.3)	
Previous abdominal surgery			0.030
No	75 (94.9)	65 (84.4)	
Yes	4 (5.1)	12 (15.6)	
Charlson scores			0.347
0	53 (67.1)	43 (55.8)	
1	20 (25.3)	27 (35.1)	
2	6 (7.6)	6 (7.8)	
3	0 (0)	1 (1.3)	
cT classification			0.239
T1a/T1b	–	–	
T2	23 (29.1)	15 (19..5)	
T3	24 (30.4)	32 (41.5)	
T4a	32 (40.5)	30 (39)	
cN classification			0.168
N0	26 (32.9)	25 (32.5)	
N1	26 (32.9)	20 (26)	
N2	21 (26.6)	17 (22.1)	
N3	6 (7.6)	15 (19.4)	
cTNM Stage			0.791
IA	–	–	
IB	15 (19.0)	12 (15.6)	
IIA	18 (22.8)	13 (16.9)	
IIB	9 (11.4)	11 (14.3)	
IIIA	17 (21.5)	15 (19.5)	
IIIB	15 (19)	18 (23.3)	
IIIC	5 (6.3)	8 (10.4)	
Depth of invasion			0.612
pT1a/pT1b	13 (16.5)	9 (11.7)	
pT2	10 (12.7)	7 (9.1)	
pT3	37 (46.8)	37 (48.1)	
pT4a	19 (24)	24 (31.1)	
Metastatic LNs			0.796
N0	27 (34.2)	25 (32.5)	
N1	13 (16.5)	11 (14.3)	
N2	15 (19)	12 (15.6)	
N3	24 (30.3)	29 (37.6)	
pTNM stage			0.788
IA	8 (10.1)	8 (10.4)	
IB	9 (11.4)	6 (7.8)	
IIA	16 (20.3)	13 (16.9)	
IIB	7 (8.9)	3 (3.9)	
IIIA	10 (12.7)	13 (16.9)	
IIIB	17 (21.5)	20 (26)	
IIIC	12 (15.1)	14 (18.1)	
Tumor location			0.291
Upper	40 (50.0)	34 (47.2)	
Middle	19 (23.8)	22 (30.6)	
Lower	14 (17.5)	8 (11.1)	
≥ 2 areas	7 (8.8)	8 (11.1)	
Tumor size, mm			
Horizontal*	40.5 ± 21.5	43.6 ± 22.6	0.382
Vertical*	40.1 ± 22.1	45.4 ± 24.6	0.156
Vascular/nerve/lymphatic invasion			0.992
No	37 (46.8)	36 (46.8)	
Yes	42 (53.2)	41 (53.2)	
Chemotherapy			0.623
No	22 (27.8)	23 (29.9)	
Yes	57 (72.2)	54 (70.1)	
Follow-up, month			
Median	24		
Range	3–35		

Categorical variables are expressed as *n* (%)

BMI body mass index, *ASA* American Society of Anesthesiologists

*Values are mean ± SD

Table 3 Operative and postoperative outcomes of 3D and 2D surgery

Variable	LSPSHL		
	2D (*n* = 79)	3D (*n* = 77)	*P* value
Operation time, min*	180.2 ± 33.5	178.3 ± 32.4	0.719
EBL, ml*	99.0 ± 119.7	66.3 ± 79.3	0.046
Total retrieved LNs*	40.1 ± 14.8	39.6 ± 14.2	0.821
Complication	12 (15.2)	14 (18.2)	0.616
30-day mortality	0	0	–
R0 margin	0	0	–
LOS, day*	13.4 ± 8.7	13.6 ± 9.3	0.872

Categorical variables are expressed as *n* (%)

EBL estimated blood loss, *SHDT* splenic hilar dissection time, *SHBL* splenic hilar blood loss, *LOS* length of stay

*Values are mean ± SD

between the sexes in either the 3D group or the 2D group ($P > 0.05$). The operative outcomes of LSPSHL were further stratified by anatomy region. However, there were no differences for the following parameters: SHDT, IPRS dissection time, splenic trunk dissection time, SPRS dissection time, SHBL, anatomy of spleen hilar, No.10 and total retrieved LNs (Table 4). The overall noncompliance of LSPSHL for 3D and 2D was 64.9% (50/77) and 63.3% (50/79), respectively, ($P=0.831$). The noncompliance was further stratified by pathological stages or BMIs, but none of the differences were significantly different between groups (Supplementary Fig. 1 and Supplementary Fig. 2).

Postoperative outcomes

The data in Table 5 show the LSPSHL patients had no significant differences in terms of the times to ambulation, flatus passage, liquid/soft diet and LOS. The complication rates in the 3D and 2D groups were 18.2% and 15.5%, respectively ($P=0.616$). The complication grades were also similar ($P=0.809$). The OS curve in 3D and 2D group revealed that all OS rates were similar in patients with LSPSHL ($P>0.05$) (Supplementary Fig. 3). There were no significant differences in the RFS curve of the LSPSHL patients ($P>0.05$). The univariate and further multivariate analyses (including stepwise backward variable removal) demonstrated that pN and No.10 LNs metastasis independently affected the OS of LSPSHL patients ($P<0.05$). However, both 3D and 2D surgery were a negative factor in independently predicting the OS of patients (Supplementary Table 1).

Inter-rater reliability

The inter-rater reliability was high for the total number of errors (ICC 0.82) and events (ICC 0.86).

Additionally, there were high agreements observed for step one in the total number of errors during the surgical tasks 'grasping,' 'revealing and bare the vessels,' and 'use of energy device.' Similarly, there was agreement in step two for the total number of errors during the surgical tasks 'grasping,' 'revealing and bare the vessels,' 'dissection,' 'use of energy device' and step three in the total number of errors during the surgical tasks 'grasping,' and 'revealing and bare the vessels' (all ICC more than 0.75). The ICC of the remnant surgical tasks ranged from 0.4 to 0.75 (Table 6).

Error and event rates

Two observers analyzed the unedited videos of 80 LSPSHL-procedures (Table 6). The total number of errors in the 3D and 2D groups was 827 and 938, respectively (824 vs. 912 counted by Observer 1; 831 vs. 964 counted by Observer 2). The total number of events in the 3D and 2D groups was 196 and 195 (194 vs. 198 a counted by Observer 1; 199 vs. 192 counted by Observer 2), respectively. The mean number of errors in the 3D group was less than in the 2D group ($P=0.022$) and there were no significant differences

Table 4 Operative outcomes of LSPSHL

Variable	2D ($n=79$)	3D ($n=77$)	P value
SHDT, min*	23.1 ± 7.6	22.1 ± 8.5	0.546
The inferior pole region of spleen, min*	13.9 ± 4.5	13.3 ± 4.9	0.427
The region of splenic trunk, min*	5.8 ± 3.0	5.5 ± 2.5	0.499
The superior pole region of the spleen, min*	3.4 ± 1.7	3.3 ± 2.0	0.737
SHBL, ml*	8.5 ± 7.6	9.4 ± 5.9	0.491
No. of SGVs*	3.4 ± 1.1	3.3 ± 1.0	0.687
No. of PGAs (yes/no)	49/30	49/28	0.835
No. of SUPAs (yes/no)	10/69	12/65	0.600
No. of SLPAs (yes/no)	5/74	3/74	0.745
Terminal branches of SpA			0.317
Concentrated type	36 (45.6)	29 (37.7)	
Distributed type	43 (54.4)	48 (62.3)	
Type of SpA			0.317
Single branch SpA	7 (8.9)	5 (6.5)	
2-branched SpA	56 (70.9)	65 (84.4)	
3-branched SpA	16 (20.2)	7 (9.1)	
No. 10 LNs metastasis	7 (8.9)	8 (10.4)	0.746
No. 10 retrieved LNs*	3.1 ± 2.9	3.0 ± 2.5	0.866

Categorical variables are expressed as n (%)

EBL estimated blood loss, *SHDT* splenic hilar dissection time, *SHBL* splenic hilar blood loss, *SGV* short gastric vessel, *PGA* post-gastric artery, *SUPA* splenic upper pole artery, *SLPA* splenic lower pole artery, *SpA* splenic artery

*Values are mean ± SD

Table 5 Short-term operative outcomes and postoperative complications according to Clavien–Dindo classification

Variable	2D ($n=79$)	3D ($n=77$)	P value
Times to ambulation, day*	2.2 ± 1.0	2.2 ± 0.8	0.886
Flatus passage, day*	3.5 ± 0.9	3.7 ± 1.0	0.229
Liquid diet, day*	5.6 ± 3.0	5.3 ± 2.4	0.515
Soft diet, day*	8.9 ± 3.9	9.5 ± 8.6	0.552
Drain removal, day*	11.7 ± 8.4	11.9 ± 7.2	0.922
Nasogastric tube removal, day*	4.6 ± 2.3	5.2 ± 6.5	0.394
LOS, day*	13.4 ± 8.7	13.6 ± 9.3	0.872
Overall complications	12 (15.2)	14 (18.2)	0.616
Clavien–Dindo			0.809
Grade I	0 (0)	1 (1.3)	
Grade II	10 (12.7)	11 (14.3)	
Grade IIIa	1 (1.3)	2 (2.6)	
Grade IIIb	0 (0)	0 (0)	
Grade IVa	1 (1.3)	0 (0)	
Grade IVb	0 (0)	0 (0)	
Grade V	0 (0)	0 (0)	
Major complications	2 (2.5)	2 (2.6)	0.979
Abdominal infection	1 (1.3)	0 (0)	
Chylous leak	1 (1.3)	1 (1.3)	
Intra-abdominal bleeding	0 (0)	1 (1.3)	
Operative complications			
Abdominal infection	2 (2.5)	7 (9.1)	0.096
Anastomotic leakage	5 (6.3)	4 (5.2)	1
Intra-abdominal bleeding	1 (1.3)	0 (0)	1
Intestinal obstruction	0 (0)	1 (1.3)	0.494
Wound infection	0 (0)	1 (1.3)	0.494
Chylous leak	6 (7.6)	5 (6.5)	0.788
System complications			
Pneumonia	9 (11.4)	9 (11.7)	0.954
Hepatic dysfunction	1 (1.3)	0 (0)	1
Urinary tract infection	0	0	

Categorical variables are expressed as n (%)

LOS length of stay

*Values are mean ± SD

between the groups regarding the mean number of events and other unclassified errors ($P>0.05$). In step one, we found there were fewer grasping-errors in the 3D group than in the 2D group ($P=0.016$). There were no significant differences for the following tasks: finding fascia, revealing and bare the vessels, clipping, dissection, and use of energy device (all $P>0.05$). In step two, the outcomes of five surgical tasks were similar ($P>0.05$). In step three, there were fewer errors for the surgical task of grasping in the 3D group than in the 2D group ($P=0.022$). There were no significant differences between groups for revealing and bare the vessels, clipping, dissection, or use of energy device ($P>0.05$) (Fig. 2). A stratified analysis by sex showed that there were no significant differences in technical errors of each step between the sexes in either the 3D group or the 2D group (all $P>0.05$) (Supplementary Table 2).

Discussion

As early as the 1980s, Buess [23] emphasized that stereoscopic vision is important in minimally invasive surgery. The technology needed for 3D laparoscopic surgery has developed rapidly and has overcome the past technical deficiencies [24, 25]. As a result, 3D service can cover the majority of surgical fields. However, most 3D studies focused on the surgical test model of a non-living system [6, 8–12]. In addition, there are only a limited number of reports describing the application of laparoscopic surgery for gastric cancer, especially complex LSPSHL. Therefore, we focused on the performance of 3D technology in LSPSHL by analyzing data from an RCT.

Several studies have shown that 3D laparoscopy improves the localization and spatial depth during surgery relative to 2D approaches and this results in shortening the operation time [9–11, 26]. Our study shows that there is no advantage for 3D laparoscopy in decreasing operative time compared with common laparoscopic surgery. We think that this finding may be because LSPSHL itself has a high degree of difficulty that results in the operation time being longer than 170 min in both the 2D and 3D groups. Therefore, despite there being fewer technical errors in the 3D group, the decreased time using the 3D technique is not evident in the statistics when compared to the 2D group. Furthermore, both the postoperative recovery and the complication rates were similar between 3D and 2D groups. One possible explanation is the patients received the same clinical protocol after surgery in our center. Additionally, Alaraimi B et al [10] also reported that there was no significant difference in the operative time if the surgeon performed 3D surgery based on abundant 2D surgical experience. Our data did indicate that 3D technology has better performance in reducing EBL. High-definition amplification, stereoscopic view, and coordination with tactile feedback would be more convenient for surgeons conducting elaborate operations and improve the hand-eye coordination. As a result, there was less EBL and rapid hemostasis after hemorrhage. A further stratified analysis found that the outcomes of 3D and 2D LSPSHL were similar in SHDT, SHBL, No.10 and total retrieved LNs. Our study is the first to stratify dissecting each region of splenic hilar to compare the differences of efficacy between 3D and 2D surgery. One possible reason for our results is the small patient sample size. Additionally, our center is a single center with a rich surgical experience and the surgical team and procedures are quite mature (more than 300

Table 6 Number of errors and events in 3D and 2D procedures for LSPSHL

Procedure	Observer 1		Observer 2		Mean		Observer 1	Observer 2	Intraclass correlation
	3D ($n=40$)	2D ($n=40$)	3D ($n=40$)	2D ($n=40$)	3D ($n=40$)	2D ($n=40$)	Total (3D+2D)		
First step									
Grasping	134	175	124	173	129	174	309	297	0.92
Finding fascia	7	10	11	8	9	9	17	19	0.49
Revealing and bare the vessels	44	47	46	54	45	51	91	100	0.78
Clipping	4	5	7	6	5	6	9	13	0.73
Dissection	69	63	67	68	68	66	132	135	0.51
Use of energy device	7	14	7	15	7	14	21	22	0.89
Second step									
Grasping	120	135	124	135	122	135	255	259	0.94
Revealing and bare the vessels	33	33	36	40	35	36	66	76	0.89
Clipping	8	7	11	12	9	10	15	23	0.50
Dissection	65	69	65	73	65	71	134	138	0.77
Use of energy device	4	4	4	6	4	5	8	10	0.78
Third step									
Grasping	109	122	109	138	109	130	231	247	0.83
Revealing and bare the vessels	18	16	19	17	19	17	34	36	0.82
Clipping	5	7	4	7	4	7	12	11	0.63
Dissection	65	67	69	76	67	72	132	145	0.61
Use of energy device	4	11	4	9	4	10	15	13	0.70
Other unclassified	128	127	124	127	126	127	255	251	0.73
Total no. of errors observed	824	912	831	964	827	938	1736	1795	0.82
Total no. of events observed	194	198	199	192	196	195	392	391	0.86

LSPSHL laparoscopic spleen preserving splenic hilar lymphadenectomy

$n_{\text{Mean}} = (n_{\text{Observer1}} + n_{\text{Oberver2}})/2$

2D-LSPSHL have been performed). Thus, the advantages of 3D LSPSHL may be masked to some extent.

The use of 3D vision improves the surgeon's spatial depth and control of spatial resolution [27–29]. As a result, there is potential for fewer technical errors during operations. Reports on surgical technical errors were initially published in the 1960s [30–33], and preliminary studies showed 3D technology can reduce intraoperative errors [34–36]. However, prospective analyses of technical surgical errors demonstrated that minor intraoperative events can lead to a higher rate of patient morbidity and mortality [37]. Thus, intraoperative technical errors remain an important subject of discussion and research. Scholars initially published that 3D technology improved the performance of simple operations during surgery. In 2012, Pirmin Storz et al [6] reported that operators can complete difficult surgical tasks more efficiently with the help of 3D technology. However, there is still no unified method for quantitative measurements of technical error in 3D surgery. Consequently, there are no effective data to establish the gold standards for errors and adverse events in complicated laparoscopic surgery. GERT [20] is a powerful tool for identifying intermediate safety outcomes such as type and number of errors made and can be used for specific, individualized feedback. There are currently no reports using GERT to study LSPSHL. This is the first study to use GERT to report technical errors for 3D surgery in gastric cancer. The results showed that there were fewer errors in the 3D group and our ICC analysis for the two observers led us to conclude that this result is reliable and effective. The study showed that 3D technology has better performance in intraoperative grasping during splenic hilar dissection, especially in the IPRS and SPRS. When using Huang's three-step maneuver to complete LN dissection, the surgeon needs to grasp and control the omentum and the gastrosplenic ligament to facilitate full exposure of the operative field. Precise grasping also means that the

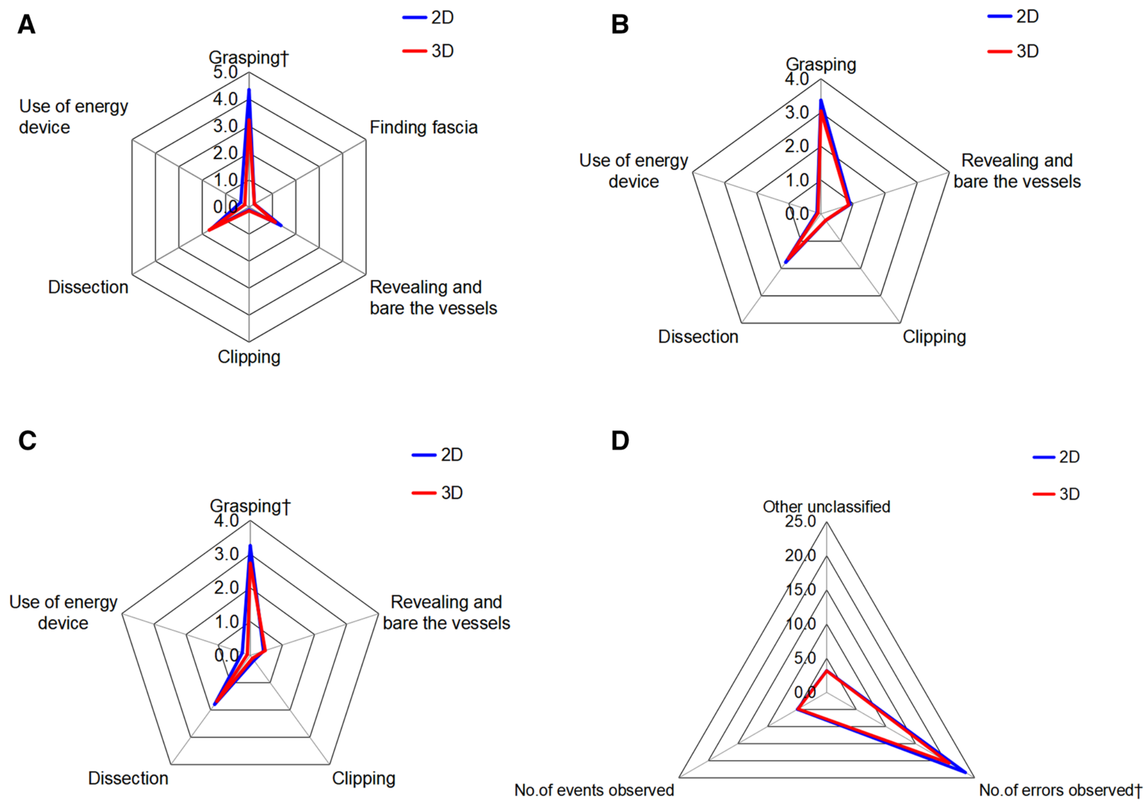

Fig. 2 Huang's using a three-step maneuver using with the Generic Error Rating Tool. (A: step one; B: step two; C: step three; D: total errors and events observed). †*P* value < 0.05

surgeon can accurately pull the fat or lymph tissue on the surface of the blood vessels, which helps maintain a rhythm. The advantages of 3D laparoscopy can be fully reflected when assisting surgeons perform complicated surgery more safely and complete intricate and delicate skills more favorably. These skills include internal suturing or difficult stripping, especially in cases with emergency bleeding. Our results also showed that there was significantly less EBL in the 3D group.

This research study has several limitations. First, this was a single-center study of an Eastern population and the patient population was too small. Second, this study only included experienced surgeons. The conclusions may not be applicable to the centers with low LSPSHL. Third, we did not evaluate the effect of 3D LSPSHL on long-term outcomes because we lack the 5-year follow-up data. What is more, all patients of this study were normal weight, and the splenic hilum dissection in overweight or obese patient can be a nightmare. At last, because this study is a reanalysis of prospective research, and because our prospective study did not perform any corresponding stratification before randomization, there was a difference in sex ratio between the 3D group and the 2D group. Although the differences in sex ratio between the two groups may lead to some bias in the results, the final conclusion of this study remains the same. We hope that the real impact of advanced video technology (3D) should be evaluated in difficult patients in the future. Despite these limitations, our study is still the first prospective study to investigate the short-term efficacy and technical errors between 3D and 2D LSPSHL in gastric cancer. Thus, we believe that it is necessary to conduct further prospective multicenter studies on 3D LSPSHL.

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Compliance with ethical standards

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Affiliations

Zhi-Yu Liu[1,2] · Qi-Yue Chen[1,2] · Qing Zhong[1,2] · Jian-Wei Xie[1,2] · Jia-Bin Wang[1,2,3] · Jian-Xian Lin[1,2,3] · Jun Lu[1,2,3] · Long-Long Cao[1,2] · Mi Lin[1,2] · Ru-Hong Tu[1,2] · Ze-Ning Huang[1,2] · Ju-Li Lin[1,2] · Hua-Long Zheng[1,2] · Chao-Hui Zheng[1,2,3] · Chang-Ming Huang[1,2,3] · Ping Li[1,2,3]

[1] Department of Gastric Surgery, Fujian Medical University Union Hospital, No. 29 Xinquan Road, Fuzhou 350001, Fujian Province, China

[2] Department of General Surgery, Fujian Medical University Union Hospital, Fuzhou, China

[3] Key Laboratory of Ministry of Education of Gastrointestinal Cancer, Fujian Medical University, Fuzhou, China