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Original Article

Three-step hand-assisted laparoscopic surgery for radical distal gastrectomy: an effective surgical approach

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Abstract: Objective: Three-step hand-assisted laparoscopic D2 radical gastrectomy (HALG) is a modified surgical technique based on hand-assisted laparoscopic surgery (HALS) for the treatment of gastric cancer. This surgical approach is particularly easy and convenient for radical distal gastrectomy. In order to thoroughly understand the advantages of applying "three-step HALG" in distal gastrectomy, our center conducted a retrospective study to analyze data from patients who underwent HALG and laparoscopic-assisted D2 radical gastrectomy (LAG) during the corresponding time period. Methods: The HALG procedure is performed in three steps, namely the operation performed through an auxiliary incision under direct vision, hand-assisted laparoscopic operation, and gastrointestinal tract reconstruction through the auxiliary incision under direct vision. This study performed comprehensive, in-depth comparative analyses on the clinical data of two groups of patients who underwent HALG and LAG. Results: The auxiliary incision under the xiphoid was maximally utilized in the HALG procedure. The rate of conversion to open surgery in HALG group patients was significantly lower than in the LAG group ($P = 0.03$), and the operating time was significantly shorter in the HALG group than in the LAG group ($P = 0.00$). There was no significant difference in the pain rate score on postoperative day 2 and on the day of discharge between the HALG and LAG groups ($P > 0.05$). No statistically significant difference was found in the time to recovery of bowel function, postoperative hospital stay, or postoperative complications ($P > 0.05$), although the values were all lower in the HALG group than in the LAG group. Conclusion: "Three-step HALG" is a highly feasible surgical approach for radical distal gastrectomy.

Keywords: Hand-assisted laparoscopic surgery, three-step hand-assisted laparoscopic D2 radical gastrectomy, laparoscopic-assisted D2 radical gastrectomy, distal gastrectomy

Introduction

Laparoscopic-assisted D2 radical gastrectomy (LAG) has similar radicality and surgical safety to laparotomy for the treatment of advanced gastric cancer. It has been widely accepted by the majority of surgeons [1-3]. Hand-assisted laparoscopic surgery (HALS) is a surgical technique that has been developing rapidly in recent years. Compared with complete laparoscopic surgery, HALS preserves the tactile sensation of the surgeon's hand. Taking advantage of the laparoscopy-assisted open surgical field and the high resolution of laparoscopy, HALS combines the application advantages of laparoscopic surgery and laparotomy. In addition, it also has the advantages of a short-learning curve, relatively low risk, and high operative safety [4, 5]. In recent years, HALS has been widely applied in colorectal surgery, but its application in gastric cancer is seldom reported and has not yet been systematically studied [6-8]. As early as a decade ago, Hunter JG published a paper in the *Journal of The American College of Surgeons* that optimistically predicted the future prospects of the application of HALS in gastrectomy [9]. Since July 2008, we have used the surgical features of hand-assisted laparoscopic colectomy as a reference [5, 10], modified the surgical approach, and developed hand-assisted laparoscopic D2 radical gastrectomy (HALG), which has formed the unique surgical approach of "three-step HALG". The preliminary results have been reported in

Table 1. Comparison of general data for HALG and LAG

	HALG (n = 61)	LAG (n = 59)	*P* Value
Age (y), mean ± SD	59.23 ± 9.56	58.34 ± 12.17	P = 0.66
Median (Range)	56 (34-75)	62 (39-73)	
Sex ratio (male to female)	35:26	37:22	P = 0.68
BMI, mean ± SD	23.45 ± 2.67	24.26 ± 2.78	P = 0.11
Median (Range)	25 (19-32)	25 (19-33)	
ASA			P = 0.63
I	6	9	
II	39	37	
III	16	13	
Previous abdominal operation	6	5	P = 0.95
Size of tumor (cm), mean ± SD	4.25 ± 2.56	3.99 ± 1.92	P = 0.53
Median (Range)	4.3 (1.9-6.5)	4.1 (2.1-6.0)	
TNM stage			P = 0.55
I	7	5	
II	11	11	
III A	11	18	
III B	12	8	
IV	20	17	
Open conversion (n%)	0	6 (10.2%)	P = 0.03

ASA: American Society of Anesthesiologists, BMI: body mass index (calculated as kg/m^2), TNM: tumor-node-metastasis, HALG: hand-assisted laparoscopic D2 radical gastrectomy.

Chinese scientific journals and attracted intensive attention from medical counterparts in China [11, 12]. We found that "three-step HALG" not only preserves the advantages of laparoscopic-assisted gastrectomy and laparotomy but also is easily and conveniently applied to distal gastrectomy. To thoroughly understand the application advantages of "three-step HALG" in distal gastrectomy, this study conducted a systematic retrospective analysis and summary of the medical records of patients who underwent HALG or LAG for distal gastrectomy during the same time period, and try to draw scientific conclusions.

Materials and methods

General clinical data

Our center randomly selected 61 patients who underwent HALG and 59 patients who underwent LAG from July 2008 to June 2013. All patients had a diagnosis of distal gastric cancer according to a gastroscopic histopathological examination. All patients underwent preoperative upper gastrointestinal imaging, chest X-ray, and abdominal CT examination to exclude distant metastases to the liver and lung and invasion to adjacent organs, and the gastric cancer was resectable. The general data on the patients are shown in **Table 1**, including age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification [13], history of abdominal surgery, tumor size, tumor node metastasis (TNM) stage of tumor, and the rate of conversion of laparoscopic surgery to open surgery. All surgeries were performed by two groups of surgeons with similar qualifications and extensive clinical experience. All patients received integrated treatment care and discharge standards.

Surgical procedure

Tumor staging was based on abdominal exploration. The dissection of the lymph nodes (LNs) around the gastric area was performed in accordance with the Japanese edition of the "*Statute of gastric cancer treatment*", and D2 radical gastrectomy was performed. The surgical incision and location of trocars are shown in **Figure 1**. The conventional LAG procedure is very mature and uses the "5-hole method"; the procedure was completed under laparoscopic guidance. The incision was at approximately 6 cm below the xiphoid. The tissue resection and gastrointestinal tract reconstruction were completed. The "three-step HALG method" was divided into three stages (**Figure 2**): hand-assisted incision surgeries under direct vision, hand-assisted laparoscopic surgeries, and digestive tract reconstruction. This surgical procedure has been published in *Surgical Endoscopy* [14].

Measured parameters

All parameters were measured and recorded by specialists in our center, and statistical analysis was performed. The comparative analysis was performed between two groups, primarily including operation time, blood loss, length of skin incision, number of harvested lymph nodes, and unexpected injury. The postoperative parameters were measured, including the postoperative pain score (postoperative day 1,

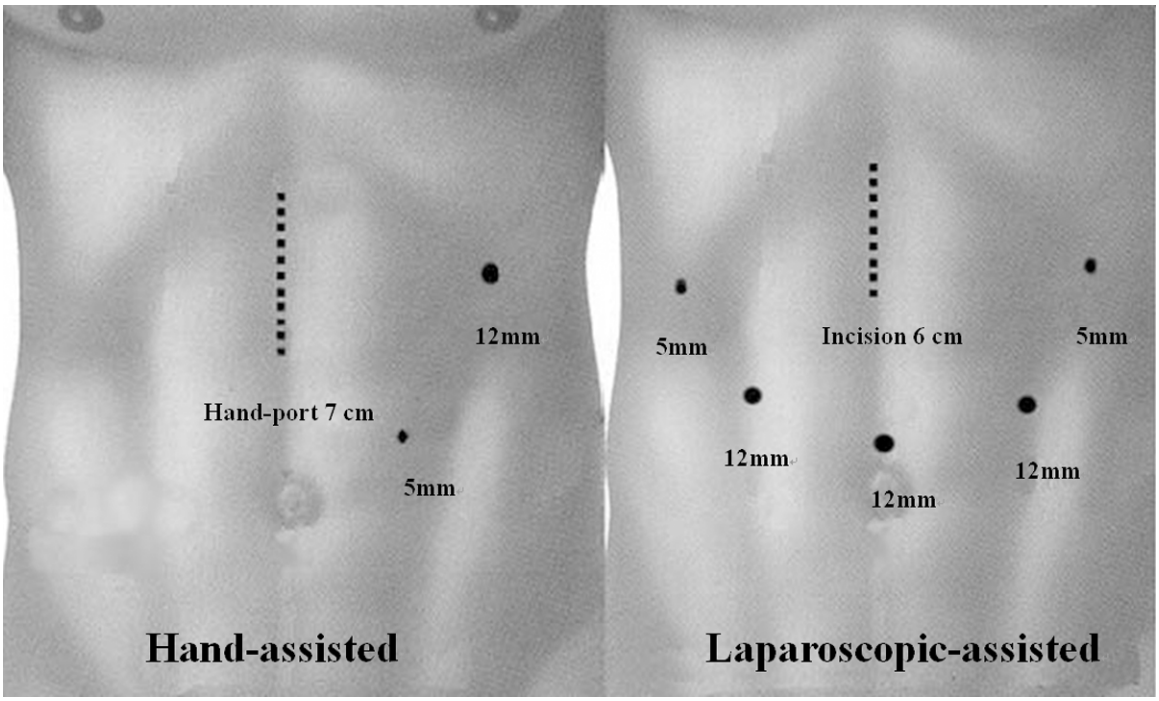

Figure 1. Sites of the trocars and the skin incision for the LapDisc or for extracting the tumor-bearing specimen.

day 2, and the day of discharge), time to return of bowel movement, length of postoperative hospitalization, postoperative complications (pulmonary infection, cardiac arrhythmias, venous thrombosis, gastrointestinal fistula, gastrointestinal disorders, biliary reflux, intra-abdominal infection, and wound infection), reoperation rate, 30-day readmission rate, and mortality. LNs were removed individually from the specimens by an individual who is both a pathologist and surgeon, who classified them and performed the pathological examination. The postoperative pain index was assessed according to the references. The visual analogue scale (VAS) was applied to evaluate the postoperative pain [15]. The pain score was recorded three times every day on postoperative day 1, day 2, and the day of discharge, with the highest score recorded as the score of the day. To facilitate the statistical analysis, the intraoperative and postoperative parameters of patients with laparotomy due to failure of the laparoscopic surgery were excluded from further analysis.

Statistical analysis

All the statistical analyses were performed using SPSS 17.0. The quantitative data are expressed as the mean ± standard deviation, and one-way ANOVA was used for analysis. The chi-squared test or Fisher's exact test was used to analyze count data. The accepted level of significance was P value less than 0.05.

Results

General data

This study divided the patients into HALG and LAG groups, with 61 patients in the HALG group and 59 patients in the LAG group. We described and compared data on 8 demographic and characteristic features of the patients, including age, gender, body mass index (BMI), ASA physical status classification, history of abdominal surgery, tumor size, TNM stage of tumor, and the conversion rate of laparoscopic surgery to open surgery. As shown in **Table 1**, no significant difference ($P > 0.05$) was found in the first 7 parameters. There was no case with open laparotomy conversion in the HALG group. There were laparotomy conversions in 6 patients in the LAG group, accounting for 10.2% of the group. Among them, 4 cases had intraoperative bleeding. Tumor invasion to the root of the middle colic artery was found during operation in one case. Gastricantral cancer invasion to the duodenum was found intraoperatively in one case. The difference was significant between two groups ($P = 0.03$). The cases with

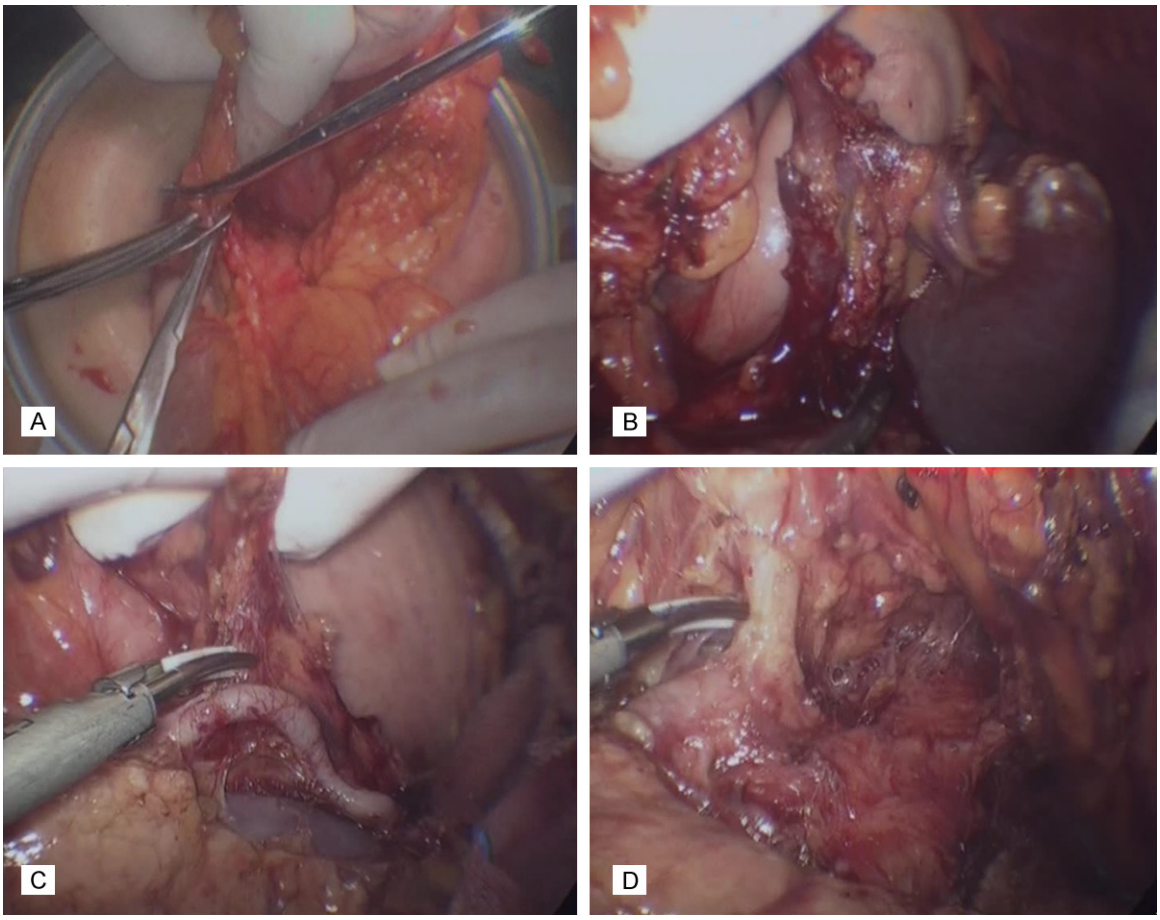

Figure 2. Hand-assisted laparoscopic surgery for radical distal gastrectomy. A. The NO. 6 lymph nodes were dissected, and right gastroepiploic artery was transected; B. NO. 4 lymph nodes were dissected, and left gastroepiploic artery was revealed; C. NO. 11 lymph nodes were dissected, and splenic artery was revealed; D. NO. 7, 8 and 9 lymph nodes were dissected, and left gastric artery was revealed.

laparotomy conversion in either laparoscopic group were not included in the intraoperative and postoperative statistical analysis. Therefore, 61 cases in the HALG group and 53 cases in the LAG group were included in the intraoperative and postoperative analysis.

Intraoperative changes

The intraoperatively measured parameters included the length of operation time, blood loss, length of skin incision, number of harvested lymph nodes, and operation-related injury. As shown in **Table 2**, the operating time for the HALG group was 37 minutes shorter than the LAG group, which reached statistical significance (P = 0.00); the blood loss was 10 ml more in the HALG group than in the LAG group, but the difference was not statistically significant (P = 0.69); and the mean length of the skin incision in the HALG group was 1.0 cm longer than in the LAG group, which reached statistical significance (P = 0.00). The number of harvested lymph nodes in the HALG group was 2 more than in the LAG group, but the difference was not statistically significant (P = 0.15). No other surgical-related injury presented in the HALG group, while intraoperative unexpected-injury was found in two cases of the LAG group, accounting for 3.77% of the LAG group, of which one case had vascular injury with transverse mesocolon, and partial transection of the transverse colon was performed intraoperatively. The lower pole of the splenic laceration was reported in one case, and hemostatic gauze was applied for pressure until the bleeding stopped. There was no significant difference between the two groups (P = 0.41).

Postoperative changes

The postoperative data included 7 measured parameters: postoperative pain score (postop-

Table 2. Comparison of intraoperative data for HALG and LAG

	HALG (n = 61)	LAG (n = 53)	*P* Value
Operative time (min), mean ± SD	165.26 ± 17.73	203.68 ± 14.52	*P* = 0.00
Median, Rang	161 (134-187)	198 (172-235)	
Blood loss (mL), mean ± SD	223.51 ± 91.27	231.26 ± 112.87	*P* = 0.69
Median, Rang	235 (121-323)	225 (112-345)	
Incision length (cm), mean ± SD	6.82 ± 0.24	5.79 ± 1.10	*P* = 0.00
Median, Rang	6.8 (6.7-7.2)	5.8 (4.8-6.9)	
Lymph nodes harvested, mean ± SD	16.52 ± 6.12	14.95 ± 5.24	*P* = 0.15
Median, Rang	17 (10-23)	15 (8-18)	
Unexpected-injury	0	2 (3.77%)	*P* = 0.41

HALG: hand-assisted laparoscopic D2 radical gastrectomy, LAG: laparoscopy-assisted D2 radical gastrectomy.

Table 3. Comparison of postoperative data for HALG and LAG

	HALG (n =61)	LAG (n =53)	*P* Value
VAS, mean ± SD			
D1	5.43 ± 1.31	4.11 ± 1.47	*P* = 0.00
D2	4.14 ± 0.56	3.91±0.94	*P* = 0.11
Discharge	1.28 ± 0.58	1.21 ± 0.63	*P* = 0.54
Length of stay (d), mean ± SD	9.45 ± 1.69	10.01 ± 1.41	*P* = 0.06
Median, Range	9 (6-13)	10 (8-14)	
Functional recovered of bowel (h)			
Mean ± SD	56.98 ± 18.38	56.70 ± 14.77	*P* = 0.93
Median, Range	59 (38-85)	60 (31-82)	
Complication (n%)	8 (13.11%)	14 (26.42%)	P = 0.12
Pulmonary infection	1	1	
arrhythmia	1	1	
Venous thrombosis	0	1	
Anastomotic leak	1	2	
Gastrointestinal dysfunction	2	4	
Bile back flow	1	2	
Abdominal cavity infection	0	1	
Wound infect	2	2	
Reoperation (n%)	1 (1.64%)	1 (1.87%)	P = 0.54
Readmission (n%)	3 (4.92%)	3 (5.66%)	P = 0.81
Mortality	0	0	

VAS: Visual Analogue Scale, HALG: hand-assisted laparoscopic D2 radical gastrectomy, LAG: laparoscopy-assisted D2 radical gastrectomy.

erative day 1, day 2, and the day of discharge), time to return of bowel movement, the length of postoperative hospitalization, postoperative complications (pulmonary infection, cardiac arrhythmias, venous thrombosis, gastrointestinal fistula, gastrointestinal disorders, biliary reflux, intra-abdominal infection, and wound infection), reoperation rate, 30-day readmission rate, and mortality. As shown in **Table 3**, the VAS score of day 1 was significantly higher in the HALG group than in the LAG group (*P* = 0.00). No significant difference was found on postoperative day 2 and the day of discharge (*P* > 0.05). The postoperative hospital stay was one day shorter for the HALG group than for the LAG group, which did not reach statistical significance (*P* = 0.06). Compared with the LAG group, the time to return of bowel function was reduced by less than one hour in the HALG group, which did not reach statistical significance (*P* = 0.93). The postoperative complications were reported in 8 cases in the HALG group, accounting for 13.11% of the group, while 14 cases were reported in the LAG group, accounting for 26.42% of the group. There was no statistically significant difference between the two groups (*P* = 0.12). One patient in the HALG group was diagnosed as duodenal stump fistula, while 2 patients in the LAG group developed gastrointestinal fistula, one case of gastrojejunostomy fistula and the other of duodenal stump fistula. One case of reoperation was performed for drainage in HALG group. Two patients in the LAG group received ultrasound-guided abdominal drainage treatment, and the patients recovered fully. One patient in the HALG group developed acute postoperative peritonitis caused by duodenal stump fistula, and a second surgery was performed. One patient of the LAG group required second surgery due to postoperative bleeding. Both

patients were fully recovered at discharge. No statistically significant difference was found between the two groups (P = 0.54). Within 30 days postoperatively, there were 3 cases re-admitted into the hospital in each group, HALG and LAG, accounting for 4.92% and 5.66%, respectively. The difference was not statistically significant (P = 0.81). Among them, 2 patients of the HALG group were re-admitted into the hospital with abdominal adhesion, and the third case was re-admitted into the hospital with abdominal distention after eating. Two patients in the LAG group were hospitalized due to adhesion, and the third case was re-admitted due to gastrojejunal anastomotic bleeding. The symptoms were alleviated after 2~5 days of treatment in the above patients, and they were discharged from the hospital. No deaths were reported in either group.

Discussion

During the conventional LAG laparoscopic operation, an approximately 6 cm incision was made below the xiphoid, which is only done for tissue dissection, removal, and gastrointestinal tract reconstruction. The "three-step HALG" surgery created an approximately 7 cm incision below the xiphoid. In contrast to LAG, the incision could be maximally utilized in "three step HALG", reflecting its important role in the operation. This study included a total of 61 patients who underwent HALG and 59 patients who underwent LAG. A comparative analysis of the general data of the patients (including age, gender, BMI, ASA physical status classification, history of abdominal surgery, tumor size, and TNM stage of tumor) showed no significant difference between the two groups. We further analyzed and studied the intraoperative and postoperative data and found that "three-step HALG" is similar to LAG in terms of its degree of radicality and being minimally invasive, but it has improved surgical safety. Therefore, we think "three-step HALG" is a highly feasible surgical approach to radical distal gastrectomy.

Important role of the hand-assisted port can be maximally utilized

During LAG, the tissue separation and LNs dissection are completed under laparoscopic guidance. In contrast to LAG, the HALG procedure starts from an approximately 7 cm incision below the xiphoid. The length of the incision in the HALG group was 6.82 ± 0.24 cm. Although significantly different from the LAG group (P = 0.00), it was only 1 cm longer than that in LAG group. The important role of the hand-assisted port can be maximized: (1) this operative procedure has the specific advantage that the LNs dissection and tissue separation are conducted through the hand-assisted port under direct view. With the support of the LapDisc hand-assisted device, an abdominal circular opening with approximately 6 cm diameter was created by the 7 cm incision below the xiphoid. With the assistance of the stretch device, the operative field can be further exposed. The surgeon can, with relative ease, divide the greater omentum, the anterior lobe of the transverse mesocolon, and part of the pancreatic capsule. The duodenal bulb is completely separated. NO. 5, 8a, 12a, and 14v LNs can be dissected under direct operative view, and NO. 6 LNs also can be dissected, which is considered to be the most difficult procedure in laparoscopic surgery [16]. The surgical skills of tissue separation and LNs dissection are completely identical to laparotomy. (2) With hand assistance, the laparoscopic technique is easier. In LAG surgery, the dissection of NO.7, 9 and 11p LNs are the surgical challenges in the operation [17, 18]. In the HALG procedure, the stomach and omentum tissue are lifted by the back of the hand: the thumb and index finger of the assisting hand reversely retracts the necessarily exposed tissue, while the remaining three fingers can form a triangle to provide support and to fully expose the operative field. These characteristics provide an important advantage in the dissection of the lesser curvature of the stomach, splenic artery, and stomach cardia. In addition, the tactile sensation of the index finger is protective for major vessels and tissues. The surgical complexity and risk are significantly lower than in LAG. (3) The tissue separation, removal, and gastrointestinal reconstruction can be relatively easily performed through the assisted incision. The assisted incision is longer in the HALG group than in the LAG group, which more fully exposes the operative field. This procedure allows easy and convenient separation between duodenal bulb and stomach tissue for gastrointestinal reconstruction.

HALG procedure has similar degrees of radicality and minimal invasiveness as LAG but with better surgical safety

The number of gastric LNs dissected is an important parameter to evaluate the thorough-

ness and radicality of gastric surgery [19, 20]. This study showed that the number of harvested LNs in the HALG group was 16.52 ± 6.12, which was not significantly different from the LAG group (P = 0.15). However, the number of harvested lymph nodes in the HALG group was 2 more than in the LAG group. We further analyzed the possible causes of this result. Considering that NO. 6, 7, 8a, 9, and 11p LNs were close to well-known major blood vessels or the pancreas, the dissection of these LNs could easily cause serious surgical-related injury. Therefore, the dissection of these LNs is considered to be the surgical challenge in the LAG procedure [16-18]. NO. 6 and 8a LNs could be dissected under direct operative view. When performing laparoscopic surgery, the assisting hand disclosed and protected the major vessels and organs. Combined with the tactile sensation of the surgical hand, the laparoscopy-assisted open operative field, and the higher solution of laparoscopy, the ultrasonic scalpel could function well, significantly decreasing the complexity of the surgery. Therefore, the LNs dissection was similarly thorough.

Many researchers have conducted clinical studies on HALS, considering it to be a minimally invasive procedure for most patients [21, 22]. This study showed the no significant difference in intraoperative blood loss between the groups (P = 0.69). The VAS score was significantly higher in the HALG group than in the LAG group (P = 0.00) on postoperative day 1. No significant difference was found on postoperative day 2 and the discharge day (P > 0.05), which suggests that HALG has a relatively strong pain-control effect, which is similar to LAG. The length of the incision was 6.82 ± 0.24 cm in the HALG group, which is 1 cm longer than in the LAG group. The difference was statistically significant (P = 0.00). To determine whether this result suggested that HALG is not a minimally invasive surgery, the operating times were compared. The mean operating time of the HALG group was 161 min, which was 37 minutes shorter than that of the LAG group. The difference was statistically significant (P = 0.00) and is closely associated with the maximal application of the hand-assisted port, greatly reducing the time of the laparoscopic procedure. This reduction in operating time leads to minimal invasiveness for the patients. The postoperative hospital stay and the time to return of bowel function in the HALG group were not significantly different from the LAG group patients (P > 0.05), although the values were smaller in the HALG group. Therefore, the statistical data analysis in this study suggests that the HALG procedure is similarly minimally invasive compared with the LAG procedure. However, studies show that surgical trauma is closely related to the stability of the internal environment. Minimally invasive surgery shows low plasma concentrations of inflammatory cytokines, such as IL-6, IL-10, C-reactive protein, and TNF-alpha. The stability of a consistent internal environment is associated with a reduced inflammatory response [23, 24]. Therefore, further comprehensive studies regarding the stability of the postoperative internal environment are required to evaluate the minimal invasiveness of HALG.

Numerous studies have shown that HALS is a safer procedure than the laparoscopic-assisted technique [25, 26], but it is important to determine whether HALG has a similar surgical safety as HALS. Wong SK and Zhang GT et al. conducted clinical investigations of the application of HALS in gastric cancer surgery and found that HALS is a safe, effective, and feasible surgical procedure for radical gastrectomy [7, 8]. In this study, no cases of death were reported in the HALG group or the LAG group. In addition, there was no significant difference in intraoperative blood loss, rate of reoperation after laparoscopic surgery, or readmission rate within 30 days postoperative between the two groups (P > 0.05). There was no statistically significant difference in intraoperative unexpected-injury between the groups (P = 0.41). However, no cases of intraoperative unexpected-injury were reported in the HALG group, while 2 cases were reported in the LAG group, accounting for 3.77% of the LAG group. The postoperative complications included pulmonary infection, cardiac arrhythmias, venous thrombosis, gastrointestinal fistula, gastrointestinal disorders, biliary reflux, intra-abdominal infection, and wound infection. There was no statistically significant difference between the two groups (P = 0.12). Postoperative complications were reported in 8 cases in HALG, accounting for 13.11% of the group, which was lower than the occurrence rate in the LAG group, and in which, 14 cases were reported, accounting for 26.42% of the group. No patients

in the HALG group underwent conversion of laparoscopic surgery to open surgery, while, 6 cases occurred in the LAG group, accounting for 10.17%. The difference was statistically significant (P = 0.03). The operating time was significantly shorter in the HALG group than that in the LAG group (P = 0.00). These results indicate that the auxiliary incision in HALG plays an important role during the procedure. Furthermore, the hand that is introduced into the peritoneal cavity could protect important structures within abdomen cavity and help to prevent damage to the intra-abdominal tissue and organs. Because the auxiliary hand directly participates in structural dissection and separation during the laparoscopic procedure, the target organ can be directly and accurately exposed, and the control of intraoperative bleeding can be assisted directly by hand. Therefore, compared with LAG, HALG has a better surgical safety.

Disclosure of conflict of interest

None.

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