Study On The Application of Preoperative Three-Dimensional CT Angiography of Perigastric Arteries In Laparoscopic Radical Gastrectomy

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Research Article

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Abstract

Objection: To investigate the clinical value and significance of preoperative three-dimensional computerized tomography angiography (CTA) in laparoscopic radical gastrectomy for gastric cancer.

Methods: The clinical data were analyzed retrospectively from 214 gastric cancer patients. We grouped according to whether to perform CTA. The gastric peripheral artery was classified according to CTA images of patients in the CTA group, and we compared and analyzed the difference of the data between the two groups.

Results: The celiac trunk was classified according to Adachi classification: Type I (118/125, 94.4%), Type II (3/125, 2.4%), Type III (0/125, 0%), Type IV (1/125, 0.8%), Type V (2/125, 1.6%), Type VI (1/125, 0.8%). Hepatic artery classification was performed according to Hiatt classification standard: Type I (102/125, 81.6%), Type II (9/125, 7.2%), Type III (6/125, 4.8%), Type IV (2/125, 1.6%), Type V (3/125, 2.4%), Type VI (0, 0%), Others (3/125, 2.4%). And this study combined vascular anatomy and clinical surgical risk to establish a new splenic artery classification model. It was found that the operation time and estimated blood loss in the CTA group were significantly lower than those in the non-CTA group. In addition, the blood loss in the CTA group combined with ICG (Indocyanine Green) labeled fluorescence laparoscopy was significantly less than that in the group without ICG labeled.

Conclusion: Preoperative CTA can objectively evaluate the vascular course and variation of patients, and then avoid the risk of operation, especially in combination with ICG labeled fluorescence laparoscopy, can further improve the quality of operation.

Introduction

In recent years, although the incidence of gastric cancer has decreased, its high incidence and mortality are still high, and it is still one of the main malignant tumors threatening human health¹. Although chemotherapy, immunotherapy, and targeted therapy have achieved good results in the treatment of gastric cancer, surgery-based comprehensive treatment is still the most effective treatment for gastric cancer². Since 1994, Kitano et al.³ first reported laparoscopic-assisted radical gastrectomy for gastric cancer, which has made laparoscopic gastric cancer surgery widely used. Subsequently, Goh et al.⁴ applied laparoscopic D2 radical gastrectomy for advanced gastric cancer for the first time in 1997 and achieved good short-term efficacy. In recent years, with the rapid development of laparoscopic equipment, the continuous improvement of surgeons' technical level, minimally invasive concept, and the promotion of accelerated rehabilitation surgery⁵, laparoscopic surgery has the advantages of small incision, good surgical field, less tumor extrusion, and rapid postoperative recovery, and has gradually become the first choice for surgeons and patients.

Lymph node dissection has an extremely important impact on the pathological staging of patients after surgery. The American Joint Committee on Cancer Staging manual recommends that at least 16 lymph

nodes be checked,collecting 16 nodes can prevent patients from being classified as N3b [6]. The lymph nodes mainly distributed along blood vessels determine the importance of dealing with blood vessels for laparoscopic radical gastric cancer surgery, so the precise positioning of blood vessels is particularly critical. However, compared with traditional open surgery, the surgeon cannot directly sense the blood vessels in the abdominal cavity with his hands during laparoscopic surgery, which makes the positioning of the blood vessels in the operation not precise enough. In addition, there are many variations in the blood vessels around the stomach, and the risk of accidental injury is high. This has always been an urgent problem in laparoscopic radical gastric cancer surgery. The traditional CT scan, gastroscopy, and upper gastrointestinal angiography before surgery cannot completely show the course of important blood vessels in the stomach. The discovery of vascular variation makes preoperative assessment and surgical risk prediction have certain limitations. However, multi-slice spiral CT angiography (CT angiography, CTA) can effectively make up for the shortcomings of the above-mentioned inspection methods. CTA is a comprehensive use of CT scanning and three-dimensional reconstruction technology, which can identify the course of blood vessels more clearly. Some studies have shown that CTA is superior to traditional angiography in diagnostic accuracy, safety, patient compliance, and examination time⁶. Based on CT, 3D images constructed with the help of CTA can simulate the three-dimensional state of perigastric blood vessels. That can be helpful for surgeons to make surgical plans and guide intraoperative operations, to reduce collateral injuries and avoid operation-related complications⁷. We analyzed the preoperative CTA results of texperimental group to understand the perigastric vascular course and variation, and compared the short-term clinical outcomes with the non-CTA group, aimed to evaluate the clinical application value of preoperative CTA in laparoscopic radical gastrectomy for gastric cancer.

Materials And Methods

Clinical data

This study retrospectively analyzed the clinical data of 214 patients who underwent laparoscopic D2 radical resection of gastric cancer in the Department of Gastroenterology, Qilu Hospital of Shandong University from August 2018 to April 2021. There were 125 patients in the CTA group underwent CTA examination of the celiac trunk artery before operation. And 89 patients in the same period before operation only examined by traditional enhanced CT were grouped in the non-CTA group. Inclusion criteria were (1) gastric cancer was diagnosed by gastroscopy and pathology;(2)The clinical data were intact;(3) Laparoscopic D2 radical gastrectomy for gastric cancer. Exclusion criteria included (1) The clinical data were incomplete;(2) The preoperative enhanced CT imaging data of the subjects could not be obtained;(3) The CTA 3D image cannot be recognized. All subjects were forbidden to eat for 8h before examination. Iopromide 300 was the contrast agent. During the enhancement scan, a high-pressure syringe was used to inject through the cubital vein at a rate of 5ml/s. In the CTA group, the volume data during the arterial enhanced CT phase of patients was transmitted to syngo.via workstation. Then we used volume rendering technology to prepare 3d images of the arteries by selecting CT values

suitable for specific target areas and color processing of the images⁸. The above images were fused to obtain the CTA image.

Anatomical study

Two senior radiologists and one gastroenterologist reviewed the preoperative CTA results of 125 patients, to distinguish the origin and course of perigastric artery: abdominal aorta (AA), celiac trunk, common hepatic artery (CHA), splenic artery (SA), left gastric artery (LGA), proper hepatic artery (PHA), right hepatic artery (RHA), left hepatic artery (LHA), accessory left hepatic artery (ALHA), accessory right hepatic artery (ARHA), right gastric artery (RGA). The perigastric artery was subtyped according to the specific classification method below.

The classification of the celiac trunk and its branches was according to Adachi classification⁹: Type I: LGA, CHA, and SA all originated from the celiac trunk, Type II: LGA originated from AA, CHA and SA originated from the celiac trunk, Type III: LGA from AA, CHA, SA and superior mesenteric artery (SMA) from the celiac trunk, Type IV: CHA, SA, SMA, and LGA all originated from celiac trunk. Type V: LGA and SA originated from CT, CHA originated from SMA, Type VI: Same as type V, but CHA was behind portal vein (PV). The classification of hepatic artery was according to the classification standard of Hiatt¹⁰: Type I, normal, Type II, LHA from LGA, Type III, RHA from SMA, Type IV, RHA from SMA, LHA from LGA coexist, Type V, CHA originated from SMA, Type VI, CHA originated from the AA. In this study, we established a new classification method of SA combining vascular anatomy and clinical practice. We classified according to whether there is a serious tortuosity or even helix in trunk of the SA, the number of SA branches, and the origin of SA upper pole branches.

Surgical study

All patients underwent laparoscopic radical gastrectomy (D2 lymph node dissection). In the CTA group, preoperative 3D CT angiography was used to guide the lymph node dissection of perigastric vessels during surgery. In the non-CTA group, routine dissection was performed.

Clinical Outcomes and statistical methods

(1) Baseline characteristics: age, sex, and body mass index (BMI); (2) Observed and recorded indicators during surgery: operative time, intraoperative blood loss, and incidence of vascular injury; (3) Postoperative short-term indicators: postoperative first exhaust time, first drinking time, first liquid diet time, postoperative first exhaust time, postoperative gastric tube and abdominal drainage tube extraction time, postoperative liver function (ALT, AST) and postoperative hospital stay time; (4) Postoperative complications: only grade $\geq$ II postoperative complications were counted according to Clavien-Dindo

grading¹¹; (5) Postoperative pathological results: tumor stage (AJCC), tumor differentiation, number of dissected lymph nodes, and number of positive lymph nodes.

SPSS23.0 statistical software was used to analyze the data. All quantitative data were expressed as mean ± standard deviation. Independent sample T-test was used for analysis, and chi-square test was used for all counting data. A *P* value < 0.05 was considered significant.

Conflicts

The authors declare no competing financial interests. The study was approved by the Medical ethics committee of Qilu Hospital of Shandong University (no. 2018-223), and was performed in accordance with relevant guidelines and regulations. All participants provided written informed consent.

Results

Branching classification of perigastric arteries

The celiac trunk branches classification according to Adachi criteria⁹ were Type I (118/125, 94.4%), Type II (3/125, 2.4%), Type IV (1/125, 0.8%), Type V (2/125, 1.6%), Type VI (1/125, 0.8%) (Table 1). The hepatic artery according to Hiatt classification standard¹⁰ was Type I (102/125, 81.6%), Type II (9/125, 7.2%), Type III (6/125, 4.8%), Type IV (2/125, 1.6%), Type V (3/125, 2.4%), Type VI (0, 0%), Others: 3 cases (3/125, 1.6%). In one case, the RHA originated from the AA and the PHA originated from the celiac trunk artery. In two cases, RHA from AA. (Figure.1) (Table 2) The splenic artery is classified into 10 types (Table 3) according to several high-risk factors for surgery based on the splenic artery, such as the course of the trunk of the SA, the origin of the superior pole branch and the number of SA branches. (Figure.2) The purpose of establishing the arterial classification is to avoid accidental injury to important blood vessels in surgery, especially when we found important perigastric blood vessels have changed. (Figure.3) In this study, the most common risk factor for surgery is tortuosity of the splenic artery, which accounts for 54.4% (68/125). In addition, there was 1 case of splenic aneurysm found in CTA examination, which was removed after the preoperative evaluation of CTA. Additionally, we pay attention to the preoperative CTA detection rate of the right gastric artery, and found it reached 65.6% in this study.

Table 1 Branch classification of celiac trunk (Adachi standard)

Adachi classification	Adachi classification		This study	
I	221/252	87.7%	117/125	94.4%
II	16/252	6.4%	3/125	2.4%
III	3/252	1.2%	0/125	0%
IV	6/252	2.4%	1/125	0.8%
V	1/252	0.4%	2/125	1.6%
VI	5/252	2.0%	1/125	0.8%

Table 2 Hepatic artery classification (Hiatt standard)

Hiatt classification	Hiatt classification		This study	
I	757/1000	75.70%	102/125	81.6%
II	97/1000	9.70%	9/125	7.2%
III	106/1000	10.60%	6/125	4.8%
IV	23/1000	2.30%	2/125	1.6%
V	15/1000	1.50%	3/125	2.4%
VI	2/1000	0.20%	0/125	0%
Others	0/1000	0.00%	3/125	2.4%

Table 3 splenic artery classification

The course of the trunk of the SA	Our study	Proportion (n%)	Number of branches	The origin of the superior pole branch	Our study	Proportion (n%)	Type
Spiral twists or turns	68	54.4%	One branch	-	2	1.6%	I
			Two branches	The middle segment of the SA	2	1.6%	IIa
				No	44	35.2%	IIb
			Three branches	The middle segment of the SA	7	5.6%	IIIa
				No	13	10.4%	IIIb
No spiral twists or turns	58	46.4%	One branch	-	1	0.8%	IV
			Two branches	The middle segment of the SA	1	0.8%	Va
				No	35	28.0%	Vb
			Three branches	The middle segment of the SA	9	7.2%	VIa
				No	11	8.8%	VIb

Baseline characteristics

There was no significant difference in age, sex, BMI, operation site, tumor stage, and tumor differentiation between the CTA group and non-CTA group in preoperative basic data. $P \geq 0.05$ (Table 4)

Table 4 Baseline data of patients

Project	CTA group n=125	non-CTA group n=89	P Value
Sex			0.558
male	97	72	
female	28	17	
Age (years)	59.34±10.23	60.92±9.34	0.243
BMI Kg/cm ²	24.15±3.28	24.41±3.63	0.587
Tumor stage			0.924
I	52	34	
II	35	30	
III	38	25	
Tumor* differentiation			0.339
Low differentiation	93	60	
Middle differentiation	26	24	
Highly differentiated	6	5	

* tumor staging was carried out according to AJCC grading criteria¹².

Intraoperative situation

The operation time and estimated blood loss in the experimental group were significantly lower than those in the non-CTA group (251.88 ±55.91 vs 268; 37.44±21.50 vs 50.47±24.49 P<0.05). But there was no significant difference in the rate of vascular injury. (P>0.05) (Table 5)

Table 5 Intraoperative condition of the patient

Project	CTA group n=125	non-CTA group n=89	P-Value
Duration of operation (min)	251.88±55.91	268.34±30.78	0.023
estimated blood loss (ml)	37.44±21.50	50.47±24.49	0.010
total lymph nodes	28.93±11.55	30.24±14.30	0.477
positive lymph nodes	3.55±5.48	5.06±10.22	0.208
Vascular injury	1 (0.80%)	2 (2.25%)	0.766

Short-term recovery situation after operation

There was no significant difference in postoperative liver function, postoperative hospital stay, postoperative first exhaust time, postoperative drinking time, postoperative first fluid diet time, postoperative removal of drainage tube time, postoperative and complication incidence. $P \geq 0.05$ (Table 6)

Table 6 Postoperative short-term recovery

	CTA group n=125	non-CTA group n=89	P Value
Postoperative complications ($\geq$ II grade)	21/12.0%	12/10.11%	0.508
postoperative hospital stay	11.97 $\pm$ 5.62	11.34 $\pm$ 2.75	0.279
first drinking water	5.43 $\pm$ 4.41	5.08 $\pm$ 3.26	0.501
first fluid diet	6.69 $\pm$ 4.46	5.98 $\pm$ 4.12	0.229
postoperative first exhaust	5.46 $\pm$ 2.17	6.06 $\pm$ 2.54	0.076
gastric tube extubation	5.22 $\pm$ 3.55	4.49 $\pm$ 2.25	0.068
left abdominal drainage time	7.82 $\pm$ 3.30	7.28 $\pm$ 2.66	0.192
right abdominal drainage time	9.30 $\pm$ 4.08	8.94 $\pm$ 2.16	0.414
postoperative liver function (AST)	61.61 $\pm$ 158.68	59.05 $\pm$ 60.59	0.869
postoperative liver function (ALT)	65.17 $\pm$ 149.83	56.78 $\pm$ 57.35	0.569

Complications

Complications were classified according to the complication classification criteria proposed by Clavien-Dindo¹¹. Complications were defined as adverse events occurring within 30 days after surgery, and only the most severe complications were considered when multiple complications occurred in the same patient. In this study, a total of 24 patients developed postoperative complications, including 21 in the CTA group and 12 in the non-CTA group. Vascular damage is a serious complications during surgery. There was 2 cases occurred in the non-CTA group, 1 case in the CTA group. In the non-CTA group, In this patient, intraoperative bleeding was caused by accidental injury during lymph node dissection, because of the splenic artery is severely spiral. Finally vascular slip suture was performed to repair and hemostasis. In the other patient with total gastrectomy, the upper pole branch of the SA was sent out from the middle part of the SA, which was thought to be severed of the posterior gastric artery. In The CTA group, the trunk of SA was damaged and bleeding due to electrical coagulation leakage, and the patient was transferred to laparotomy for vascular repair and hemostasis.

ICG labeled

For the preoperative CTA group, we also divided groups to study the influence of laparoscopy combined with ICG labeled on the recent clinical results. We can see that under different modes of fluorescence laparoscopy, the lymph nodes are presented in normal state, green stained state, and enhanced white state.(Figure.4) Our study, the estimated blood loss of the CTA group was significantly less than the non-CTA group (29.00 ± 11.65 ml vs 44.78 ± 25.38 ml, $P < 0.05$). The operation time, total number of lymph nodes dissected, total number of positive lymph nodes were not significantly different between the two groups(247.76 ± 52.82 min vs 258.27 ± 60.40 min, 27.32 ± 10.40 vs 31.43 ± 12.84 , 3.14 ± 5.35 vs 4.18 ± 5.72 , $P \geq 0.05$)(Table 7)

Table 7 Comparison between ICG and non-ICG groups

	ICG group	non-ICG group	p-value
estimated blood loss (ml)	29.00 ± 11.65	44.78 ± 25.38	0.012
Operation time (min)	247.76 ± 52.82	258.27 ± 60.40	0.322
Total number of lymph nodes dissected	27.32 ± 10.40	31.43 ± 12.84	0.064
Total number of positive lymph nodes	3.14 ± 5.35	4.18 ± 5.72	0.311

Discussion

Gastric cancer is one of the most common malignant tumors of the digestive system. Surgery is currently considered the only radical cure¹³. With the development of minimally invasive surgery, laparoscopic radical gastrectomy has been widely used in the treatment of gastric cancer and achieved good therapeutic effects¹⁴. However, preoperative enhanced CT cannot accurately judge the anatomy of important vessels, thus affecting lymph node dissection, which has always been an urgent problem to be solved in laparoscopic surgery. In this study, preoperative CTA was used to guide the operation by understanding perigastric arteries. The results showed that the operative time and estimated blood loss in The CTA group were significantly lower than those in the non-CTA group (251.88 ± 55.91 min vs 268.34 ± 30.78 min, 37.44 ± 21.50 ml vs 50.47 ± 24.49 ml, $P < 0.05$). There were no significant differences in the total number of lymph nodes, the number of positive lymph nodes, the incidence of complications, vascular injury, and other recent clinical outcomes between the two groups ($P > 0.05$)(Table 6). For decades, the classification of perigastric arteries has been a concern by gastrointestinal surgeons. Many studies^{9,10,15}reported the classification of gastric peripheral arteries and carried out detailed classification. Among them, Adachi classification and Hiatt classification are more classical. We conducted vascular classification according to Adachi classification and Hiatt classification and discussed vascular variation to avoid accidental injury caused by vascular variation, designed to make surgery safer

Some studies have divided the anatomical types of gastric peripheral arteries into 7 categories, among which LGA directly derived from AA accounted for 2.3%¹⁶. In this study, there were 3 cases of type II variation (2.4%): LGA was directly derived from AA, while CHA and SA were still derived from celiac trunk. Understanding the origin and course of LGA before surgery is helpful to ligation of LGA and dissection of No.7 lymph node. In addition, in one case of total gastrectomy, the trunk of the SA was mistakenly regarded as the LGA was severed because the LGA was thin and originated from the AA, while the SA from the celiac trunk was in an upward direction. The spleen turned black, and the SA was created to restore the spleen blood supply. If we anticipate the variation of the LGA with the help of preoperative CTA, the risk of dissevered vessels during surgery will be greatly reduced. In Marco's study¹⁷, a complete tetrafurcated trunk was detected in 4/596 CTs (0.7 %). Our study, there was one case of type IV variation (0.8%): CHA, SA, SMA, and LGA were all originated from CT. Since the dissection scope of D2 lymph node dissection does not include the SMA scope, it will not affect the dissection of lymph nodes. In this variation, attention should be paid to avoid misjudgment of blood vessels.

Keishi¹⁸ et al. research statistics showed that 28 of 714 cases (3.9%) CHA originated from SMA, and portal vein was directly exposed under 8a lymph node, without being covered by marker vessels. In our study, CHA originated from SMA in 3 patients (2.4%). If the CHA is damaged due to excessive separation without knowing vascular variation during intraoperative dissociation of the region, acute hepatic ischemia may be caused. Open abdomen to stop bleeding will not only prolong the operation time but also affect the recovery of patients after surgery, especially those patients with poor liver function. In addition, the portal vein is not covered by the CHA, which is a marker vessel, and will be directly exposed to the lymph nodes of Group 8a¹⁸. If it is not foreseen before surgery, the risk of lymph node dissection of Group 8a will be increased to some extent. In this study, CTA suggested this in the preoperative evaluation process, which helped the surgeon to remove lymph nodes without damaging the portal vein and hepatic artery. Hiatt typing: In this study, the total variation rate of the hepatic artery was 17.6%, which was similar to Hiatt's study. However, the variation of the hepatic artery is complex and diverse, and the Hiatt classification cannot cover all variations¹⁹. In this study, we found 2 types not described in Hiatt classification: in 1 case, the RHA originated from the celiac trunk; in 2 cases, RHA originated from AA.

According to relevant reports²⁰, 15-20% ALHA may originate from The LGA and reach the liver together with the hepatic branch of the left vagus nerve, which is sometimes the only arterial blood flow in the left hepatic lobe. ALHA can be divided into alternative LHA or accessory LHA. In 200 anatomical reports, the former accounted for 55% and the latter accounted for 45%²¹. In this study, there were 9 cases of type II variation: abnormal LHA from the LGA. It is uncertain whether the LHA is absent. To determine the blood supply source of the liver, the surgeon needs to carefully separate the blood vessels during the operation, continuing to separate tissue bare vessels from the root of the LGA upward until the LHA is exposed. If the accessory LHA is large or the LHA is lack, the LGA should be ligated from the root of the accessory LHA, otherwise the blood supply of the left liver will be cut off directly. The ischemia of the accessory left hepatic artery may cause transient liver dysfunction in the early postoperative period, which will

undoubtedly have a serious impact on patients with poor liver function. In addition, studies have shown that the estimated amount of blood loss in patients with abnormal LHA variation is significantly higher than that in patients without such variation²¹.

According to reports, the incidence of ARHA ranged from 0.42% to 10.6%, and ARHA was mainly from SMA(546 cases, 5.6%)²². In this study, 6 type II variants (4.8%) of RHA were derived from SMA. In D2 lymph node dissection of gastric cancer, although the region of the RHA was not involved, Eshuis et al. believed that accidental injury or ligation of aRHA during pancreaticoduodenectomy might increase the risk of complications²³. In this study, the detection rate of the RGA was (82/125, 65.6%). We considered the RGA was thinner than other gastric peripheral arteries, and due to technical limitations, CTA could not display or could not display the specific RGA out of shape²¹, so the detection rate was not high. But there is no denying the importance of identifying the RGA. In one case of total gastrectomy, we cut the RGA and the liver turned black at this time. The surgeon continued to separate the tissue along the RGA and found the PHA was also be clipped by mistake, which narrowed the RGA. Then we opened the vascular clip, and re-clipped the RGA without PHA, to make the blood flow to the liver again. We consider that due to the abnormal course of the PHA, the course moves upward and closely adheres to the RGA. Therefore, it is necessary for the surgeon to have predictive protection or avoidance of blood vessels, especially when dealing with blood vessels close to the blood supply of the liver such as RGA, try to avoid clamping the right RGA close to the root. And preoperative CTA provides clues to identify the special course of blood vessels.

In this study, the abnormal SA was classified according to three factors that affect the risk of surgery: the number of SA branches, whether there were spiral tortuous arteries and whether the upper splenic pole branches were generated in the middle part of the artery. Preoperative understanding of the bending degree of SA would be beneficial to complete intraoperative dissection of No.11 lymph node and reduce the risk of SA injury. In a case of distal radical gastrectomy, we found that the middle part of the splenic artery branched upward, mistakenly thinking that the branch is short gastric artery and cut this blood vessel. When we continue to separate tissues around the stomach, that branch was found to be the superior splenic branch, which not only affected the blood supply of the spleen, but also the blood supply of the remnant stomach, because the upper pole branch of the spleen sends out a small posterior gastric artery. In addition, we found that tortuous SA also bring a high risk of surgery. If the patient's SA is curved, if these arteries are not paid attention to before surgery and not completely exposed during surgery, it is easy to mistake them for lymph nodes, injury the SA, and lead to hemorrhage and even splenectomy. Therefore, preoperative evaluation of the tortuousness and bifurcation of the SA is a necessary part of the operation. In addition, 1 patient was found to have a giant splenic aneurysm by preoperative CTA examination, which was of high surgical risk. It has been reported that laparoscopic treatment of splenic aneurysms is a safe, effective, and minimally invasive option²⁴. We made reasonable surgical strategies, ligation of lymph nodes in the region before dissection and excision of upper splenic branch vessels, avoiding the impact of emergencies and minimizing the damage to patients, thus safely and quickly performing surgery and giving patients the maximum benefit.

A large number of studies have shown^{5,16,25,26} that preoperative CTA examination can reduce the amount of blood loss, shorten the operation time and even improve the detection rate of lymph nodes in laparoscopic radical gastrectomy. In our study, there was no significant difference in the total number of lymph nodes and the number of positive lymph nodes between the CTA group and the non-CTA group ($P > 0.05$), which was believed to be related to the veteran experience of the surgeon and the result of careful dissection. Although in this study, postoperative liver function, three days of abdominal drainage after operation, postoperative hospital stay, postoperative exhaust time, postoperative try drinking time, first liquid diet time, postoperative first time to remove the drainage tube, postoperative complications, such as the recent clinical outcomes were no obvious difference ($P > 0.05$), but the estimated blood loss and operation time was lower than that in the group of CTA. Although the amount of blood loss and operation time are not direct indicators of clinical efficacy, we believe that they can be used to evaluate surgical quality to some extent. The lack of intraoperative bleeding may be related to the shortened time of intraoperative blood vessel identification and treatment by preoperative CTA assessment. We think the reason for the shorter operation time is that we can identify the blood vessels through CTA and perform the operation accurately. Literature on the LADG learning curve suggests that surgeons become proficient after 40 operations²⁷. Based on this study, we further believe that preoperative CTA will play a significant role in safely and efficiently completing surgery for surgeons who are still overcoming the learning curve.

Notably, in the CTA group, the preoperative ICG staining group had less blood loss than the group without ICG staining ($P < 0.05$), but there was no significant statistical difference in the number of lymph node dissection and the injuries of large vessels. We found that preoperative CTA combined with ICG labeled was more effective in reducing blood loss, although it did not reduce large vessel injury incidence rate. We considered that preoperative CTA and ICG labeled could effectively distinguish lymphatic vessels from small blood vessels by fluorescence mode, effectively avoiding bleeding caused by small blood vessel injury and thus reducing the amount of blood loss. In this study, we considered that the time required to start the fluorescence pattern recognition process would prolong the total operation time. Even so, there was no significant difference in the operation time between the two groups, indicating that the combination of ICG markers did not prolong the operation time. There was no significant difference in the injury of important vessels in this study, and our data showed that there was only 1 case of SA injury caused by coagulation hook damage in the CTA group—not the wrong surgical procedure.

The sample size of this study is small, and this research is a retrospective analysis, not enough to explain the problem. So, It is necessary to conduct prospective studies and expand the sample size based on this study. Since the inferior pyloric artery, LGA and RGA are thin, 3d-CT reconstruction technology has a limited ability to develop them, so this study did not analyze them. In the future, more fine angiography technology can be used to develop them, and their moving characteristics and proportion can be analyzed. This study sample size is lesser, and this study is a retrospective analysis. In the future, we will further verify randomized controlled trials based on this research.

Studies have shown that preoperative CTA is helpful in other laparoscopic surgery fields such as liver transplantation²⁸. With the development of functional laparoscopy, CTA may be widely used clinically as

a reliable method for perigastric vessels identifying before surgery. Preoperative 3D angiography of the gastric peripheral artery can not only shorten the operation time but also make intraoperative blood loss lower. Moreover, ICG labeled fluorescent laparoscopic technology's precise positioning of lymph nodes can make our surgery safer. Finally, we believe that preoperative CTA can objectively evaluate the vascular course and variation of patients, shorten the operation time and reduce the amount of intraoperative blood loss to a certain extent, and can improve the perioperative recovery of patients. And through subgroup analysis, ICG labeled can further reduce the amount of blood loss and improve the quality of surgery without increasing the operation time.

Conclusion

Preoperative CTA can objectively evaluate the vascular course and variation of patients, and then avoid the risk of operation, especially in combination with ICG labeled fluorescence laparoscopy can further improve the quality of operation. In the future, further randomized controlled trials will be set up based on this research.

Declarations

Conflicts of interest

The authors disclose no conflicts.

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Authorship

Peng Liu analyzed the clinical data and drafted the article, Wenbin Yu critically revised and gave final approval for the publication. Meng Wei, Danping sun, Xin Zhong, Jun Ouyang, Yize Liang collected the clinical data.

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Figures

Figure 1

Classification of celiac trunk

(a)LGA, CHA, and SA all originated from the celiac trunk. (b)LGA originated from AA , CHA and SA originated from the celiac trunk. (c) CHA, SA, SMA, and LGA all originated from celiac trunk.(d)CHA originated from SMA. (e)ALHA from LGA. (f)the ARHA originated from SMA. (g)ARHA from SMA, ALHA from LGA coexist. (h)In this case,ARHA from AA.(i)In this case,ARHA from celiac trunk.

Figure 2

Several conditions of splenic artery

(a)A straight SA. (b)A spiral SA,as a risk factor for surgery which could extend the lymph node dissection time.(c)The splenic artery is of three-branched type. The middle branch and the lower branch originate from the end of the splenic artery, but the upper pole branch originates from the middle part of the splenic artery.(d)In this case, a huge splenic aneurysm was found in the superior branch of the splenic artery

Figure 3

Several typical vascular variations during surgery

LGA originated from AA , CHA and SA originated from the celiac trunk. (b)CHA originated from SMA. So the portal vein is directly exposed in the surgical field without occlusion of the common hepatic artery(c)ALHA from LGA.(d)A spiral SA.

Figure 4

Lymph node images under different modes of laparoscopy with fluorescent labeled of indocyanine green

(a)Lymph nodes in normal mode. (b)Lymph nodes in contrast mode,that can more easily identify deep stained lymph nodes.(c-d)Green-stained lymph nodes under ICG-labeled fluorescence mode.