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Short-term outcomes of laparoscopic D2 lymphadenectomy versus D2 lymphadenectomy plus complete mesogastric excision in distal gastric cancer patients with high body mass index

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Abstract

Background The technical challenges and safety issues involving laparoscopic D2 lymphadenectomy plus complete mesogastric excision (D2 + CME) for high body mass index (BMI) patients are still unknown. This study was conducted to compare the short-term outcomes of laparoscopic D2 + CME and D2 lymphadenectomy in distal gastric cancer patients of different BMI status.

Methods We retrospectively analyzed the data of patients with gastric cancer who underwent laparoscopic-assisted distal gastrectomy (LADG) at our center between 2019 June and 2023 September. Patients who underwent traditional laparoscopic D2 lymphadenectomy were divided into the D2 group, while patients undergoing laparoscopic D2 + CME were divided into the D2 + CME group. In each group, patients were further subdivided based on their BMI into the high BMI group (H-BMI, BMI ≥ 25) and normal BMI (N-BMI, BMI<25) group. A comparison was made between the characteristics of patients and their short-term outcomes in the two subgroups, respectively. Propensity score matching (PSM) at 1:1 ratio was performed to further assess the short-term outcomes of patients with high BMI in two groups.

Results All the qualified patients were divided into the D2 group ($n = 329$) and D2 + CME group ($n = 261$). In the subgroup analysis of early surgical outcomes of the D2 group, the high BMI subgroup had longer surgery time ($p = 0.007$), more blood loss ($p = 0.006$) and longer time to first flatus ($p = 0.001$), compared to the normal BMI subgroup. Conversely, in the D2 + CME group, significant differences were not observed in early surgical outcomes between the two subgroups($p > 0.05$). PSM yielded 44 high BMI patients with comparable baseline characteristics into the A group and the B group. Compared to the A group, patients with high BMI in the B group who received laparoscopic D2 + CME had shorter surgery time($p < 0.001$), less blood loss($p = 0.004$), more retrieved lymph nodes

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(LNs) ($p = 0.016$). No statistical differences were observed in terms of the first flatus time, pT stage, pN stage, pathological stage(pStage), vascular invasion, postoperative complications, or postoperative hospital stay($p > 0.05$).

Conclusion Our findings suggest the high BMI status had a significant impact on the early surgical results of laparoscopic conventional D2 lymphadenectomy. However, laparoscopic D2 + CME was unaffected by a high BMI. In addition, patients with high BMI benefit more from laparoscopic D2 + CME in terms of short-term outcomes. Laparoscopic D2 + CME is a recommended technique for distal gastric cancer patients with high BMI, which deserves further study and promotion.

Keywords Laparoscopic D2 gastrectomy, Complete mesogastric excision, High body mass index, Short-term outcomes

Introduction

Globally, gastric cancer is the fifth most common cancer and ranks fourth in terms of causes of death [1]. With over 40% of all new cases of stomach cancer diagnosed worldwide, China has the highest incidence rate of the disease [2]. In China, more than 80% of patients with gastric cancer are diagnosed with advanced gastric cancer. D2 lymphadenectomy has become the best recommended curative treatment for gastric cancer currently [3]. Despite the fact that the current guidelines for the treatment of gastric cancer explicitly specify the distribution of regional lymph nodes and the extent of lymph node dissection during standard D2 lymphadenectomy, the anatomical boundary of lymph node dissection remains undefined. As a result, the surgeon's experience plays a significant role in lymph node dissection for stomach cancer.

Laparoscopic D2 + CME was proposed as an optimal procedure in the surgical treatment of gastric cancer recently, focusing on en bloc excision of the mesogastrium [4]. D2 + CME was initially put forth by Gong as a mesentery concept-based procedure in the surgical treatment of gastric cancer [5]. Multiple studies showed that D2 + CME was safe and feasible, with better perioperative outcomes [5–8], as well as could decrease the amount of free intra-peritoneal cancer cells [9]. Recent results from a prospective, randomized clinical trial have demonstrated that D2 + CME is associated with better short-term outcomes and surgical safety [10]. Additionally, several studies revealed that D2 + CME not only reduced the local recurrence rate but also improved long-term efficacy [8, 11].

In Asian countries, including China, obesity rates have been rising rapidly, which has become one of the most important health issues in the world nowadays [12–14]. As a result, there is an increasing need among surgeons to treat overweight or obese patients with high BMI [15–19]. D2 + CME primarily focuses on accurate identification of the landmark structures and the anatomical boundary of mesogastrium, meticulously tracing the dissectible layer of loose connective tissue based on membrane anatomy [4]. For high BMI patients, it is difficult to identify mesogastrium's boundary concealed in the thick adipose tissue due to a large amount of visceral fat in abdominal cavity, which makes it more challenging to perform D2 + CME. While there are a few reports on the safety and feasibility of laparoscopic D2 lymphadenectomy for gastric cancer patients with high BMI [20, 21], there lack studies that report clinical outcomes in high BMI patients with gastric cancer who underwent D2 + CME. Therefore, there are still concerns about the technical difficulty of the procedure, particularly in high BMI patients. Thus, we tried to assess the effect of laparoscopic D2 + CME on surgical outcomes in comparison with laparoscopic D2 lymphadenectomy among distal gastric patients of different BMI status.

Patients and methods

Setting

Our institution, Affiliated Hospital of Chengde Medical University, is located in Chengde City, Hebei Province. Our hospital is a high-volume facility for the treatment of stomach cancer in the Chengde area. High-volume hospitals have better outcomes than low-volume hospitals for complex surgical procedures, therefore centralization is essential for surgeons to acquire the experience and competency they need to advance their skills and perform high-quality surgery [22].

Inclusion and exclusion criteria

720 consecutive patients who had laparoscopic radical distal gastrectomy between June 2019 and September 2023 were retrospectively screened. Histologically confirmed gastric cancer and laparoscopically assisted distal gastrectomy with curative resection (R0) were the prerequisites for inclusion. Patients with (1) open gastrectomy, (2) distant metastases, (3) additional malignancies, (4) preoperative chemoradiation therapy, or (5) combined resection of other organs were excluded from participating in the study. The flowchart of the patients' selection is shown in Fig. 1. Finally, there were 261 D2 + CME patients and 329 D2 cases in our patient cohort. All patients were operated on by the same surgeon (Enhong Zhao) who owned more than 20 years of clinical practice

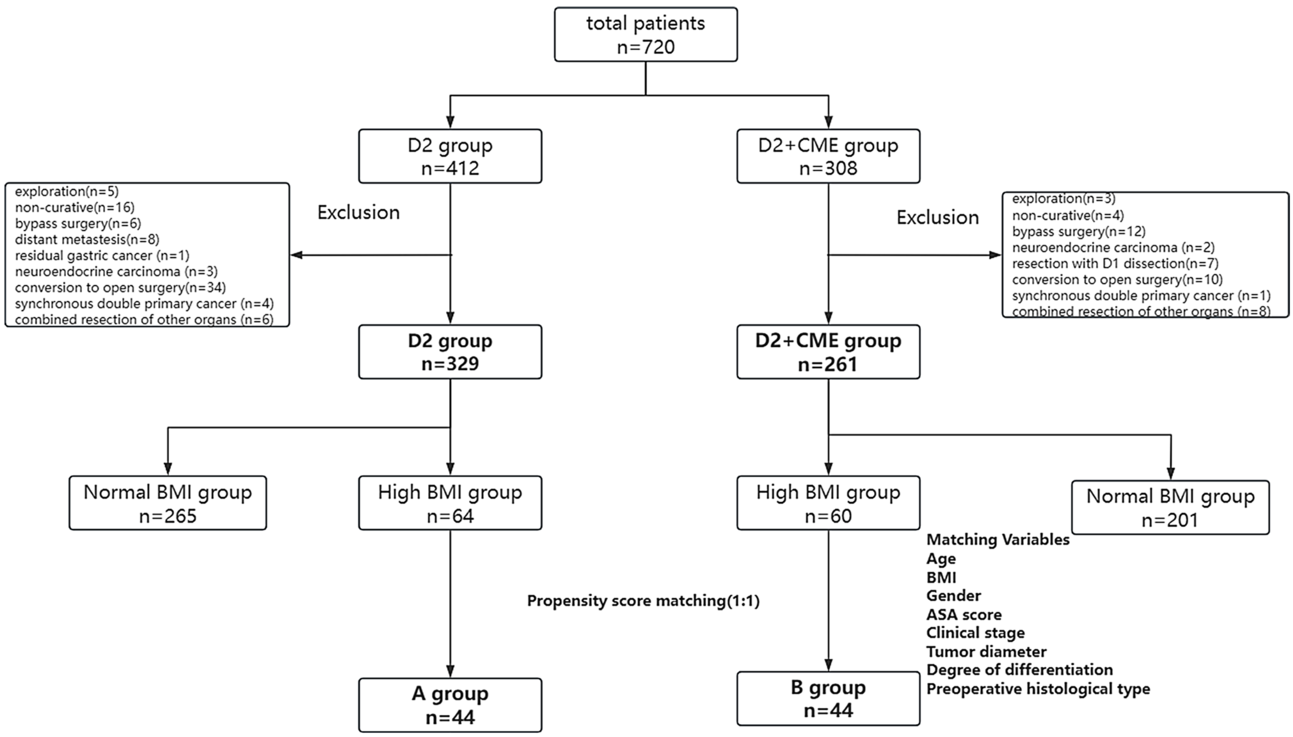

Fig. 1 Flowchart showing patients enrollment and PSM matching process

and experience of over 1000 cases of gastrectomies, including both open and laparoscopic procedures.

Surgical procedure

With the patient in the supine position, mobilization of the stomach and systematic lymph node dissection was performed via five trocars under a pneumoperitoneum. The surgeon stands on the patients' left side, one assistant on the right side, another assistant for camera stands between the patients' legs. D2 lymphadenectomy was undertaken complying with the rules of the latest Japanese Gastric Cancer Association treatment guideline [23], focusing on the extent of lymph node dissection (No. 1, 3, 4sb, 4d, 5, 6, 7, 8a, 9, 11p, and 12a). Anastomosis was completed extracorporeally. Initially, an epigastrium auxiliary incision was made to facilitate the excision of the specimen and the reconstruction of the digestive tract. The type of anastomosis depended on the clinical situation and surgeon's preference. The main reconstruction methods included Roux-en-Y and standard Billroth I or Billroth II gastrojejunal anastomosis with Braun's anastomosis.

In contrast to conventional D2 lymphadenectomy, the D2 + CME placed more emphasis on the mesogastrium's en bloc resection. the stomach's mesentery can be divided into several relatively independent regions, including right gastroepiploic mesentery (RGEM), left gastroepiploic mesentery (LGEM), right gastric mesentery (RGM) and left gastric mesentery (LGM). In short, the following standards were followed when performing the D2 + CME procedure: (a) the anatomical boundary of stomach's mesenteries[LGEM, RGEM, LGM, RGM] are clearly exposed; (b) the root of stomach's mesenteries are identified and adjacent mesentery are separated; (c) the fusion fascia spaces are dissected, and the embryological planes are extended; (d) the target mesenteries are completely dissociated from the mesangial bed; (e) the supplying blood vessels are ligated at the root of D2 level [4, 10].

RGEM

First, the transverse mesocolon was detached from mesogastium to expose the anatomical boundary of RGEM (Fig. 2A). Second, open the boundary to identify the root of RGEM at the point of superior mesenteric vein (SMV) (Fig. 2B). Finally, the right gastroepiploic vein (RGEV) and right gastroepiploic artery (RGEA) was ligated at their roots. When this process completed correctly, the RGEM including No. 6 LNs was resected en bloc.

RGM

Taking the proper hepatic artery (PHA) as the right boundary and the portal vein as the left border, the entire mesentery was dissected (Fig. 3A, B). Following the detachment from the gastroduodenal artery (GDA) and PHA, the RGM which included Nos. 5 and 12a as well as partial No. 8a LNs was en bloc excised.

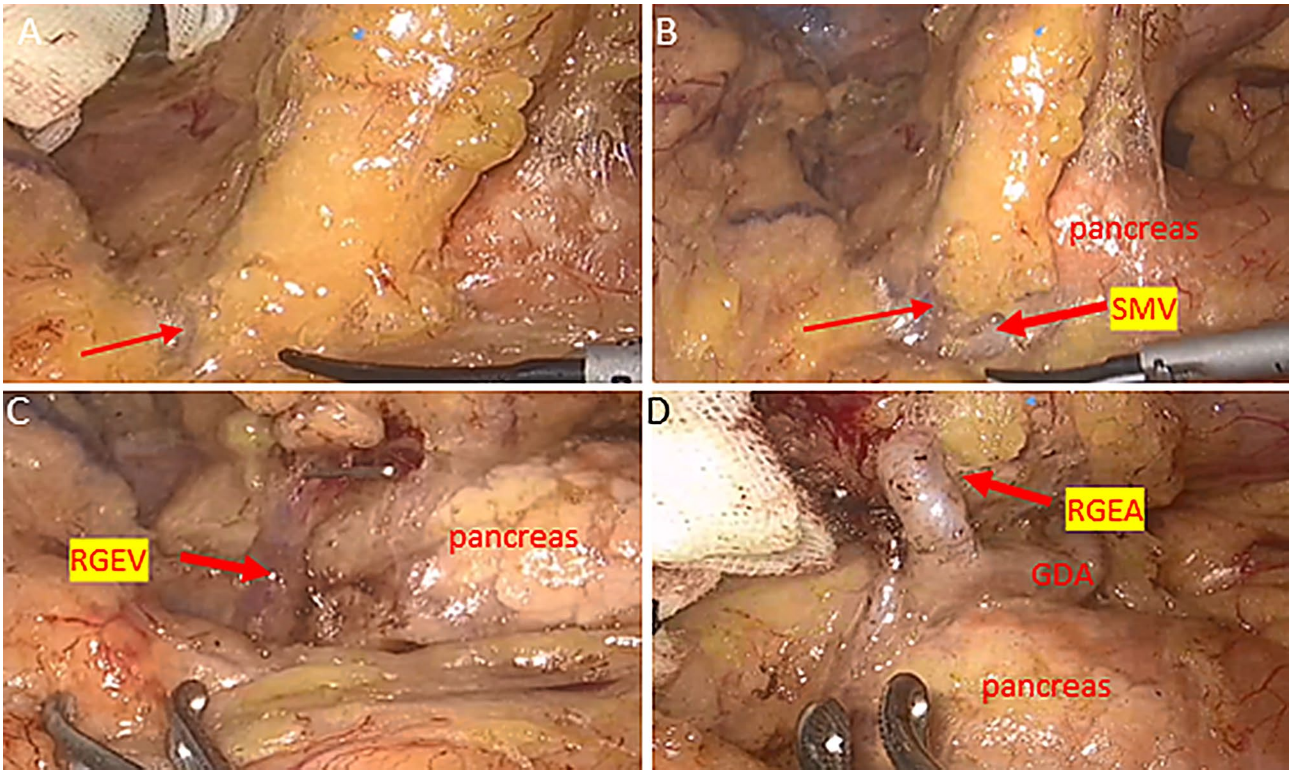

Fig. 2 **A** The anatomical boundary of RGEM (arrow). **B** The root of RGEM (thin arrow). **C** The RGEV was ligated at the root. **D** The RGEA was ligated at the root

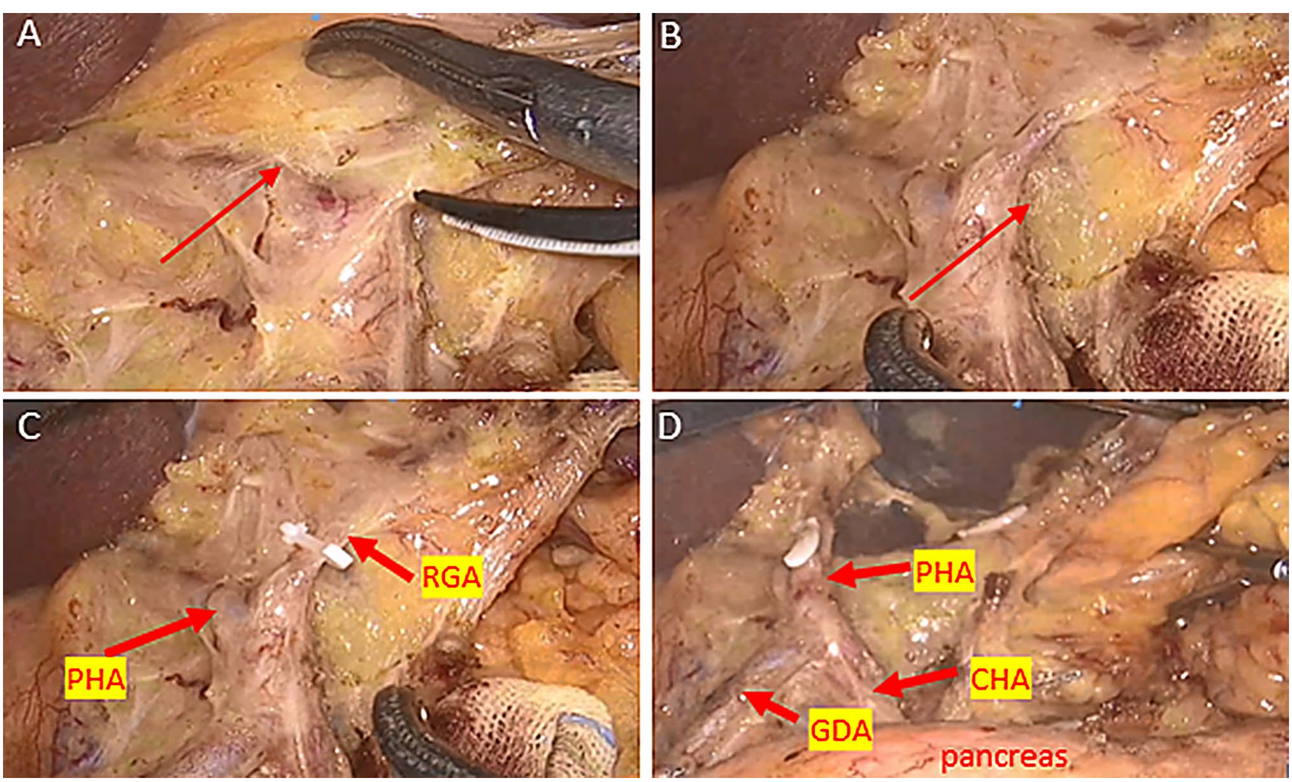

Fig. 3 **A** The anatomical boundary of RGM (arrow). **B** The root of RGM (arrow). **C** The RGV and RGA was ligated at the root. **D** The RGM was en bloc excised

LGM
Firstly, open the boundary of LGM along the superior border of the pancreas, and then continue to expose the root of LGM at the point of splenic vein (SV). The dissection proceeded till the left gastric vein (LGV), left gastric artery (LGA) were visible and ligated at the root in turn (Fig. 4C, D). By this step, the LGM including No. 7, No. 8a, No. 9, and No. 11p LNs were en bloc resected.

LGEM
The boundary was opened along the inferior border of the pancreas firstly, the left gastroepiploic vessels (LGEA&LGEV) and inferior splenic vessels (ISV) were visible in turn by dissection tracing this plane. Finally, the left gastroepiploic vein (LGEV) and left gastroepiploic artery (LGEA) was ligated at their roots. By this step, the LGEM including No. 4sb LNs was resected (Fig. 5).

Evaluation of patients' data
Based on the global standards established by the World Health Organization [24], we chose 25 kg/m^2 as our cut-off value distinguishing normal weight from overweight and obesity. Asians may be more likely to develop abdominal obesity and comorbidities when their BMI exceeds 25 kg/m^2 [25]. According to preoperative BMI, in each group, patients were sorted into two subgroups by BMI cutoff, the high BMI group (H-BMI, BMI ≥ 25 kg/m^2) and the normal BMI (N-BMI, BMI<25 kg/m^2) group.

Statistics about the demographics including age, gender, BMI, physical status according to the American Society of Anesthesiology (ASA), tumor size, clinical stage and pathological characteristics were gathered. Clinical and pathological stage was reported base on the 8th version of the International Union Against Cancer (UICC) TNM classification [26]. Surgery-related parameters and the surgical procedure were collected, operation duration, blood loss volume, number of retrieved LNs, first flatus time, and postoperative hospital stay, postoperative pathology data and outcomes included. Postoperative complications were defined as conditions that occurred during the hospital stay after surgery, including pulmonary infection, anastomotic leakage, fever, gastric emptying disorder etc. The Clavien-Dindo classification system was used to group these issues [27].

Subgroup analysis
To evaluate the impact of the two distinct approaches in patients with different BMI status, a comparison was made between the clinical characteristics and pathological features of patients in the two subgroups, respectively. In addition, the short-term outcomes, including intraoperative and postoperative results, were compared between patients with high BMI and those with normal BMI in order to verify whether or not the potential advantages are linked to different techniques.

PSM
PSM was conducted to further assess the short-term outcomes of high BMI patients within the two groups. All of the high BMI cases were matched using Propensity Score

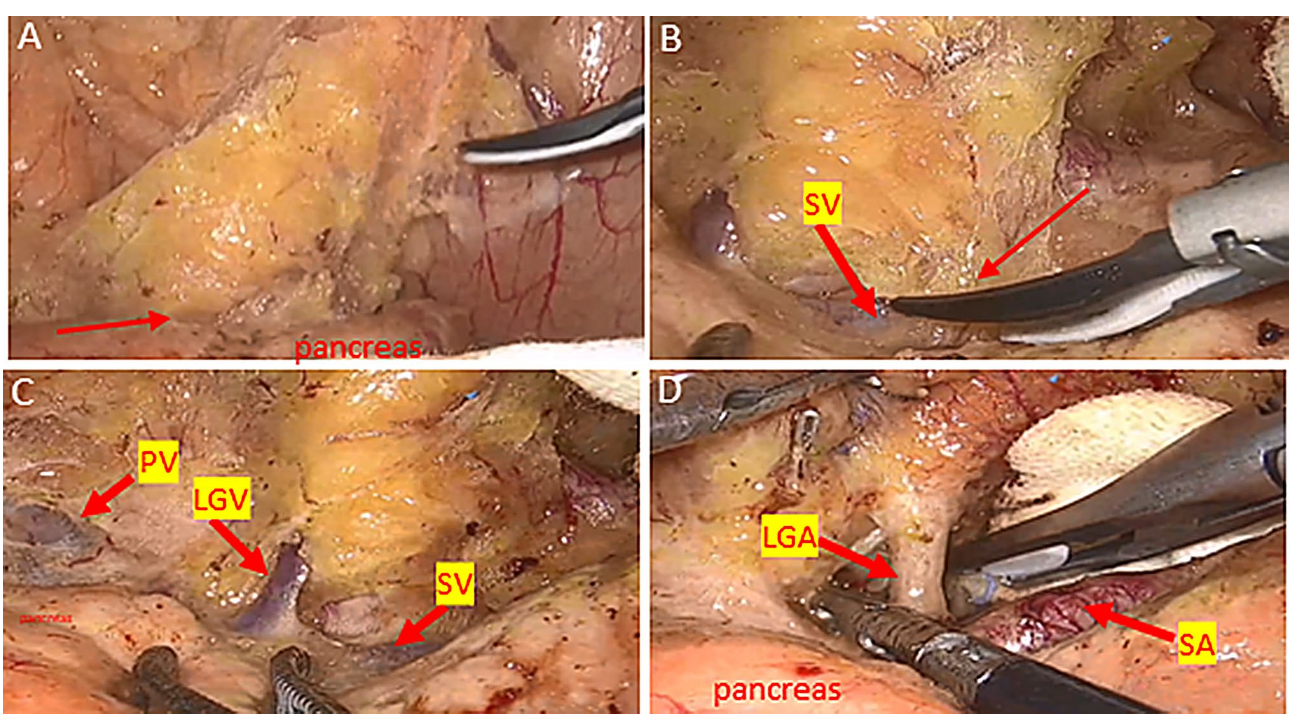

Fig. 4 **A** The anatomical boundary of LGM (arrow). **B** The root of LGM (thin arrow). **C** The LGV was ligated at the root. **D** The LGA was ligated at the root

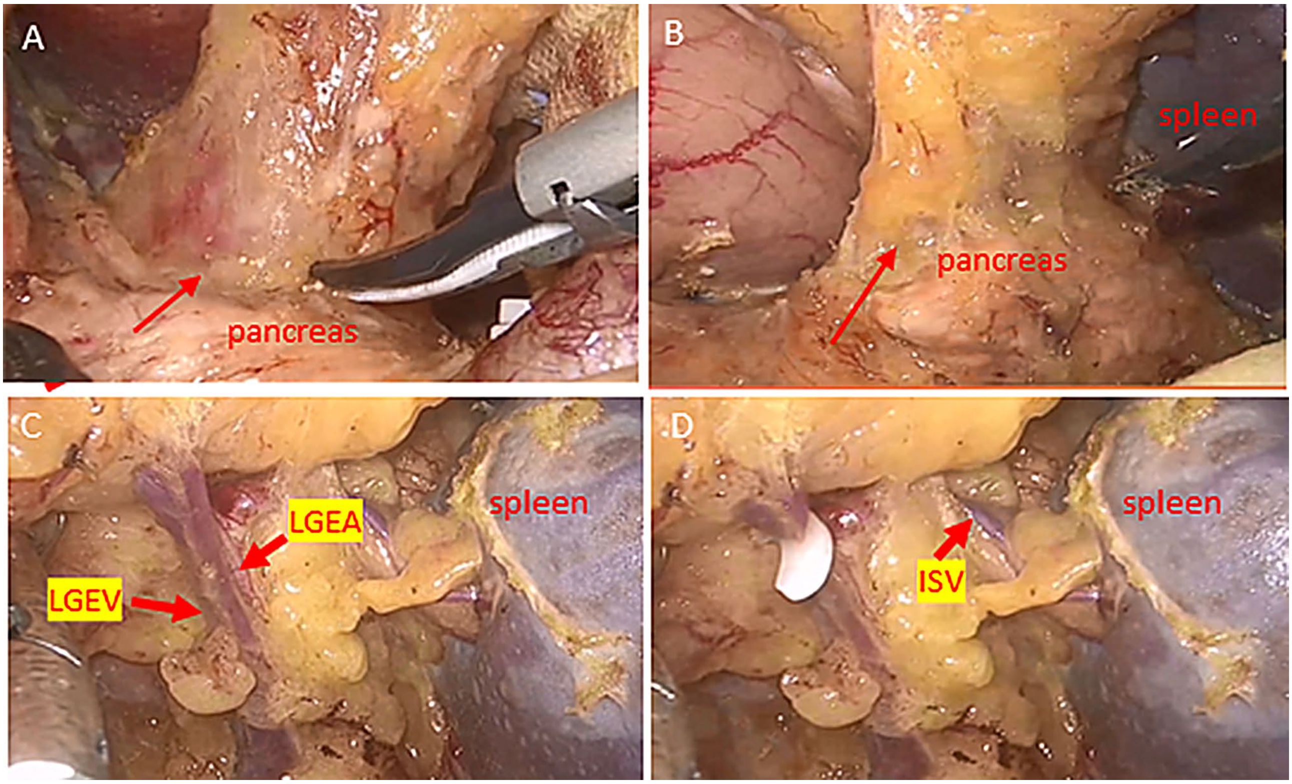

Fig. 5 **A** The anatomical boundary of LGEM (arrow). **B** The root of LGEM (arrow). **C** The RGEV and RGEA was ligated at the root. **D** The ISV was preserved to ensure the blood supply to the lower pole of the spleen

Matching at 1:1 ratio, leading to similar baseline characteristics for each group.

To lessen the impact of any possible selection bias, we performed 1:1 matching between the two groups based on the propensity score using a 0.02 caliper width. We used a multivariate logistic regression model to compute propensity scores for each patient in the two groups. Selected covariates, including gender, age, ASA score, preoperative histological type, degree of differentiation, tumor size and clinical stage. In each group, PSM generated 44 cases with comparable baseline features.

Statistical analysis

Continuous variables were presented as mean ± standard deviations (SD), and the Student's t test or Mann-Whitney U test were used to compare them. Every categorical variable was shown as frequency and percentage, and χ2 test or Fisher's exact test were used to compare them. Statistical significance was considered when the p-value is less than 0.05. All statistical analyses were performed with SPSS Statistics 25(IBM, Armonk, NY, USA).

Results

There was a total of 590 qualified cases, which were assigned into D2 group ($n=329$) and D2 + CME group ($n=261$). In each group, patients were further subdivided into the high BMI and normal BMI group, respectively. Subsequent PSM yielded 44 high BMI cases into the A group and the B group (Fig. 1).

Subgroup analysis

The clinical characteristics of these patients are summarized in Table 1. In comparing the high BMI and normal BMI patients in both of the D2 and D2 + CME groups, mean age, gender, ASA scores, tumor size, degree of differentiation, cT and cN were similar. However, in both of the two groups, there were significant differences in mean BMI between the two subgroups ($P=0.001$).

Table 2 presents the early surgical outcomes between the D2 and D2 + CME groups. In the D2 group, subgroup analysis showed that there were significant differences in surgery time ($p=0.007$), blood loss ($p=0.006$), time to first flatus($P=0.001$) between the high BMI and normal BMI group. No significant difference was observed in postoperative hospital stay, the number of retrieved lymph node, pT, pN, and pStage. On the other hand, the subgroup analysis of the D2 + CME group revealed that there were no differences statistically between the high BMI and normal BMI group.

The analysis of the subgroups showed that there were no differences statistically between the high BMI and normal BMI group in terms of overall complications,

Table 1 Demographic and clinical characteristics between the D2 and D2 + CME group

Variables	D2			D2+CME		
	***N*-BMI (*n* = 265)**	**H-BMI (*n* = 64)**	***P* value**	***N*-BMI (*n* = 201)**	**H-BMI (*n* = 60)**	***P* value**
Age	61.63±9.073	60.84±8.525	0.529	61.69±8.710	59.32±7.740	0.051
Gender			0.288			0.183
Male	207(78.1%)	46(71.9%)		155(77.1%)	37(61.7%)	
Female	58(21.9%)	18(28.1%)		46(22.9%)	23(38.3%)	
ASA-PS			0.963			0.647
I	4(1.5%)	11(1.6%)		3(1.5%)	1(1.7%)	
II	190(72.0%)	47(73.4%)		158(78.6%)	51(85.0%)	
III	69(26.1%)	16(25.0%)		38(18.9%)	8(13.3%)	
IV	1(0.4%)	0(0.0%)		2(1.0%)	0(0.0%)	
BMI	21.051±2.187	26.980±1.465	0.001	21.269±2.325	27.117±1.915	0.001
Long axis of tumor	3.895±2.166	3.997±2.404	0.742	4.170±2.262	4.063±2.159	0.747
Short axis of tumor	3.149±1.850	3.208±2.042	0.824	3.338±1.870	3.188±1.160	
Histological type			0.974			0.051
Well	12(4.8%)	3(4.7%)		22(10.9%)	1(1.7%)	
Moderate	145(54.7%)	34(53.1%)		107(53.2%)	31(51.7%)	
Poor	108(40.8%)	27(42.2%)		72(35.8%)	28(46.7%)	
cT stage			0.071			0.944
T1	50(18.9%)	19(29.7%)		41(20.9%)	10(16.7%)	
T2	29(10.9%)	11(17.2%)		25(12.4%)	8(13.3%)	
T3	62(23.4%)	13(20.3%)		40(19.9)	12(20.0%)	
T4	124(46.8%)	21(32.8%)		94(46.8%)	30(50.0%)	
cN stage			0.338			0.676
N0	119(44.9%)	33(51.6%)		91(45.3%)	29(48.3%)	
N+	146(55.1%)	31(48.4%)		110(54.7%)	31(51.7%)	

ASA-PS The American Society of Anesthesiology Physical Status Classification

TNM staging was based on the recent 8th edition of the AJCC Cancer Staging Manual

Table 2 Perioperative outcomes between the D2 and D2 + CME group

Variables	D2			D2 + CME		
	***N*-BMI (*n* = 265)**	**H-BMI (*n* = 64)**	***P* value**	***N*-BMI (*n* = 201)**	**H-BMI (*n* = 60)**	***P* value**
Surgery time(min)	162.4±32.041	174.73±34.802	0.007*	143.62±38.135	146.15±43.814	0.663
Blood loss(mL)	84.7±50.639	120.16±96.502	0.006*	72.37±77.597	75.50±55.584	0.772
Time to first flatus(d)	3.04±0.904	3.45±1.022	0.001*	3.14±0.749	3.18±0.624	0.679
pT stage			0.129			0.895
pT1	34(12.8%)	14(21.9%)		42(20.9%)	10(16.7%)	
pT2	43(16.2%)	13(20.3%)		24(11.9%)	8(13.3%)	
pT3	74(27.9%)	18(28.1%)		38(18.9%)	11(8.3%)	
pT4	114(43.1%)	19(29.7%)		97(48.3%)	31(51.7%)	
pN stage			0.764			0.813
pN0	118(44.5%)	33(51.6%)		92(45.8%)	29(48.3%)	
pN1	32(12.1%)	6(9.4%)		18(9.0%)	7(11.7%)	
pN2	57(21.5%)	13(20.3%)		47(23.4%)	11(18.3%)	
pN3	58(21.9%)	12(18.8%)		44(21.9%)	13(21.7%)	
pStage			0.172			0.763
I	59(22.3%)	21(32.8%)		54(26.9%)	16(26.7%)	
II	88(33.2%)	16(25.0%)		48(23.9%)	17(28.3%)	
III	118(44.5%)	27(42.2%)		99(49.3%)	27(45.0%)	
Postoperative hospital stay(d)	13.93±5.170	14.78±5.980	0.254	12.85±6.292	13.07±6.512	0.813
Number of retrieved LNs	20.35±2.828	19.75±1.234	0.100	25.44±2.588	25.68±1.836	0.503

*$p<0.05$

Table 3 Postoperative complications between D2 and D2 + CME group

Variables	D2			D2 + CME		
	N-BMI (*n* = 265)	H-BMI (*n* = 64)	*P* value	*N*-BMI (*n* = 201)	H-BMI (*n* = 60)	*P* value
Overall (n,%)[a]	42(15.8%)	16(25.0%)	0.085	18(9.0%)	9(15.0%)	0.177
Grade I or II (n,%)[a]	31(11.7%)	12(18.8%)	0.133	16(8.0%)	8(13.3%)	0.206
Fever	12(4.5%)	3(4.7%)		6(3.0%)	2(3.3%)	
Pulmonary infection	9(3.4%)	4(6.3%)		6(3.0%)	2(3.3%)	
Urinary tract infection	1(0.4%)	1(1.6%)		0	1(1.7%)	
Delayed gastric emptying	7(2.6%)	0		3(1.5%)	2(3.3%)	
Leakage of lymphic	1(0.4%)	1(1.6%)		0	0	
Wound infection	1(0.4%)	2(3.1%)		0	1(1.7%)	
Intraluminal bleeding	0	0		1(0.5%)	0	
Grade III or IV (n,%) [a]	11(4.2%)	4(6.3%)	0.470	2(1.0%)	1(1.7%)	0.668
Anastomic leakage	7(2.6%)	2(3.1%)		2(1.0%)	1(1.7%)	
Duodenal stump leakage	2(0.8%)	1(1.6%)		0	0	
Bowel obstruction	2(0.8%)	0		0	0	
Severe pulmonary infection	0	1(1.6%)		0	0	

[a] Clavien-Dindo's classification of surgical complication

Table 4 Clinical characteristics of high BMI patients in the A and B group after PSM

variable	A group	B group	*P* value
	n = 44	*n* = 44	
Age	60.93±8.239	59.73±7.666	0.521
Gender			0.823
Male	29(65.9%)	28(63.6%)	
Female	15(34.1%) 15(34.1%)	16(36.4%)	
BMI			0.279
25～28	37(84.1%)	35(79.5%)	
28～30	5(11.4%)	3(6.8%)	
≥ 30	2(4.5%)	6(13.6%)	
ASA			0.572
I	1(2.3%)	0	
II	34(77.3%)	36(81.8%)	
III	9(20.5%)	8(18.2%)	
Long axis of tumor	4.182±2.552	4.030±2.397	0.774
Short axis of tumor	3.352±2.225	3.155±1.787	0.647
Histological type			0.518
Well	1(2.3%)	1(2.3%)	
Moderate	26(59.1%)	22(50.0%)	
Poor	17(38.4%)	21(47.7%)	
cT stage			0.923
cT1	10(22.7%)	11(25.0%)	
cT2	7(15.9%)	6(13.6%)	
cT3	7(15.9%)	9(20.5%)	
cT4	20(45.5%)	18(40.9%)	
cN stage			0.831
cN0	21(47.7%)	22(50.0%)	
cN+	23(52.3%)	22(50.0%)	

mild (grades I and II) or severe (grades III and IV) complications, respectively. The high BMI patients' rates of overall complications were 25.0% in D2 ($n = 16$) and 15.0% in D2 + CME ($n = 9$) groups, respectively. In the D2 group, there were 4 patients experienced III or IV grade of complications: one patient was for severe pulmonary infection with respiratory failure that required management in intensive care unit (ICU). Two were for anastomotic leakages that lead to severe peritonitis, which needed surgical intervention and management in ICU. The other one experienced mild-to-moderate duodenal stump leakage. However, only one postoperative complication of mild-to-moderate anastomotic leakage occurred in the high BMI patients of the D2 + CME group. The incidence of different types of complications are shown in Table 3.

PSM analysis

There was no statistical difference of baseline characteristics between high BMI patients in the A group and the B group (Table 4). The early surgical outcomes of high BMI patients between the A group and B group are listed in Table 5. There were significant differences in surgery time ($p < 0.001$), blood loss ($p = 0.004$), the number of retrieved lymph node($p = 0.016$). No significant difference was observed in vascular invasion, postoperative hospital stay, pT, pN, or pStage.

As displayed in Table 6, there were 11 cases of complications in the A group, including 2 anastomosis leakages, 1 duodenal stump leakage, 3 fever, and 3 pulmonary infections, 1 urinary tract infection,1 severe pulmonary infection that required management in ICU. In the B group, there were 4 cases comprising 1 fever, 1 pulmonary infection, 1 wound infection, and 1 delayed gastric emptying. The incidence of short-term complication was 25.0% and 9.1%, respectively ($P = 0.092$). Also, no significant difference was observed regarding mild (grades I and II) and severe (grades III and IV) complications between the two groups.

Table 5 Perioperative outcomes of high BMI patients between the A and B group

Variable	A group $n=44$	B group $n=44$	P value
Surgery time(min)	179.70±35.883	149.34±38.877	˂0.001*
Blood loss(mL)	123.86±103.592	74.32±56.954	0.004*
The first flatus time(d)	3.43±1.065	3.18±0.620	0.175
pT stage			0.510
pT1	10(22.7%)	11(25.0%)	
pT2	11(25.0%)	6(13.6%)	
pT3	11(25.0%)	5(11.4%)	
pT4	12(27.3%)	22(50.0%)	
Number of retrieved LNs	24.11±4.42	26.00±2.343	0.016*
pN stage			0.051
pN0	21(47.7%)	22(50.0%)	
pN1	2(4.5%)	8(18.2%)	
pN2	11(25.0%)	6(13.6%)	
pN3	10(22.7%)	8(18.2%)	
pStage			0.607
I+II	25(56.8%)	28(63.6%)	
III	19(43.2%)	16(36.4%)	
Vascular invasion			0.999
Positive	14(31.8%)	15(34.1%)	
Negative	30(31.8%)	29(65.9%)	
Postoperative hospital stay (d)	15.23±6.668	13.57±8.799	0.250

*$p<0.05$

Table 6 Postoperative complications of high BMI patients between the A and B group

Variable	A group $n=44$	B group $n=44$	P value
Overall (n, %)[a]	11(25.0%)	4(9.1%)	0.092
Grade I or II (n, %)[a]	7(15.9%)	4(9.1%)	0.508
Fever	3(6.8%)	1(2.3%)	
Pulmonary infection	3(6.8%)	0	
Urinary tract infection	1(2.3%)	1(2.3%)	
Wound infection	0	1(2.3%)	
Delayed gastric emptying	0	1(2.3%)	
Grade III or IV (n, %)[a]	4(9.1%)	0	
Anastomosis leakage	2(4.5%)	0	
Duodenal stump leakage	1(2.3%)	0	
Severe pulmonary infection	1(2.3%)	0	

[a] Clavien-Dindo's classification of surgical complication

Discussion

The present study suggests that the status of high BMI in the traditional D2 lymphadenectomy have a significant impact on surgery time ($p=0.007$), blood loss ($p=0.006$), and time to first flatus ($p=0.001$). Based on our finding, it is presumed that D2 procedures in high BMI patients yielded worse surgical outcomes, including longer operation duration, more blood loss volume and slower recovery, compared to normal BMI patients. Clearly, surgery in high BMI patients is more demanding technically [28–30]. The thick abdominal wall creates a deep operation field, surgeons have less room for surgical manipulation, poorer vision of the operating field, and more difficulty identifying blood vessels concealed in the thick adipose tissue of the mesenterium and omentum due to the greater quantity of abdominal fat. Moreover, instead of en bloc mesogastrium excision, traditional D2 lymphadenectomy focuses on the concept of vascular-oriented lymph node dissection and emphasizes blood vessel architecture, relying largely on the surgeon's personal experience, which often creates an artificial opening in the mesogastrium during the procedure. Bleeding may occur after the mesogastrium is artificially opened. Stopping the bleeding requires additional time and effort from the surgeon. We therefore assumed that these challenges were the reason for the longer operating time, more blood loss volume, and slower recovery.

On the other hand, compared to normal BMI patients, the results of the D2 + CME group showed that the early surgical outcomes were not influenced by the status of high BMI. In contrast, D2 + CME focuses on correct surgical approach, accurate identification of the mesogastrial boundary and dissection tracing the space based on membrane anatomy instead of the vessels [4]. The region of connective tissue between the fusion fascia in high BMI patients is loose because of the huge quantity of adipose tissue filling in the mesogastrium, which facilitates identification of the correct anatomical plane. While regarding normal BMI patients, particularly those who lack adipose tissue between the fusion fascia, it can be challenging to precisely access the anatomical space because the fusion fascia space is dense and the anterior and posterior fascias of the mesogastrium fit firmly due to the lack of adipose tissue filling. When an incorrect anatomical space is penetrated, result in bleeding, interfere with the surgical procedure, and prolong the operation duration. Consequently, the surgical results of the high BMI and normal BMI groups did not differ significantly.

Based on comparable baseline characteristics using PSM at a 1:1 ratio, we assigned 44 patients into two groups, A and B, to further assess the short-term outcomes of D2 versus D2 + CME in high BMI patients. Compared to the A group, high BMI individuals in the B group did not differ significantly in terms of histological type or pathologic stage, but they did have more lymph nodes ($P=0.041$), less blood loss ($P=0.004$), and a shorter surgery time ($P=0.001$). In comparison to conventional D2 lymphadenectomy, our findings demonstrated that the D2 + CME could decrease blood loss and enhance the number of LNs obtained in high BMI patients, which are in accordance with previous research [7, 8, 10, 31]. However, contrary to earlier results, the D2 + CME could decrease the operation duration in our study. The shorter surgical time observed in the D2 + CME group may be due to the following factors. As mentioned previously, following the correct anatomically space helps prevent vascular damage and reduce intraoperative hemorrhage, which could lessen blood loss and shorten the length of the surgery. Additionally, our experience with D2 + CME has grown substantially. Although the D2 + CME approach is more complicated than the D2 technique, it does not significantly lengthen the whole surgical duration.

The number of retrieved LNs is now considered as an independent prognostic factor in patients with gastric cancer [32–34]. All patients in our study underwent R0 resection. The median number of LNs was 26.0 in the B group, which was higher than that in the A group (26.0 vs. 24.1, $p<0.05$). The quality of LN dissection can be guaranteed because the mean number of LNs obtained in both groups was greater than the 15 LNs recommended by the guidelines. The intrinsic number of LNs, the extent of the surgery, the retrieval technique, the fat volume of the specimens, and the nodal status are some of the parameters that Li et al. compiled as influencing the number of retrieved LNs [35]. In this study, the specimens and LNs were meticulously examined by experienced pathologists who were blinded to surgical interventions.

The incidence of postoperative complications is a crucial element in assessing the safety of surgery. In this investigation, there were no fatalities during the perioperative period. The overall complication rates of the A group and the B group were 25.0% and 9.1%, respectively, which were reasonable compared to previous reports [36–39]. Despite the fact that the A group's rate was 15.9% higher than the B group's, the two groups' rates of complications did not differ significantly ($p = 0.092$), which may be attributed to the relatively low number of patients. Regarding severe (grades III or IV) complications, particularly anastomotic leakage or duodenal stump leakage, did not occur in the B group in the current study. However, in the A group, there were 2 anastomotic leakage and 1 duodenal stump leakage. Possible reason for this could be that the small sample size was insufficient to identify differences between the two groups.

During the postoperative recovery course, multiple studies have demonstrated that the D2 + CME can reduce the duration of the postoperative first flatus and hospital stay [7, 8, 10]. However, in the present study, the first flatus time ($p = 0.175$) and postoperative hospital stay ($p = 0.250$) were not significant. The advantage of faster recovery was not observed as well, which may be attributed to a relatively low number of cases.

There were several limitations in our study. Firstly, this is a retrospective single-center study, prospective multicenter studies are required to further validate our findings because there may be limitations in extrapolating them to larger populations. Secondly, the sample size of the current study was insufficient, which would have jeopardized the validity of its conclusions. To further validate our study's findings, more research is required, particularly large-scale clinical studies. Thirdly, the percentage of obesity (BMI ≥ 30 kg/m^2) in the current study was low. We were unable to thoroughly assess D2 + CME's effects in patients with obesity, which was because the populations in the East and the West differed demographically. Thus, before our results are further applied, a similar analysis of patients (BMI ≥ 30 kg/m^2) in the West is required. Finally, the present study substantially focused on the short-term outcomes, long-term oncological outcomes or postoperative quality of life(QoL)were not involved. It remains unclear whether D2 + CME has a beneficial effect on a high BMI patients' QoL and prognosis, A lengthy follow-up period is necessary to accurately reflect the differences in long-term outcomes between the two groups.

In summary, our findings indicate that traditional laparoscopic D2 lymphadenectomy is less effective for early surgical outcomes in high BMI patients compared with those of normal BMI patients. Laparoscopic D2 + CME is more clearly beneficial for high BMI patients with the advantages of less blood loss volume, shorter operation duration and a greater number of lymph nodes harvested, which deserves further study and promotion. Accordingly, laparoscopic D2 + CME is a recommended treatment option for distal gastric cancer patients with high BMI.

Abbreviations

LADG	Laparoscopic-assisted distal gastrectomy
D2	D2 lymphadenectomy
D2 + CME	D2 lymphadenectomy plus complete mesogastric excision
PSM	Propensity score matching
ASA	American Society of Anesthesiology
BMI	Body mass index
LNs	Lymph nodes
pStage	Pathological stage
ICU	Intensive care unit
RGEM	Right gastroepiploic mesentery
RGM	Right gastric mesentery
LGM	Left gastric mesentery
LGEM	Left gastroepiploic mesentery
ISV	Inferior splenic vessels
QoL	Quality of life

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions
E Zhao contributed to the study design. Y Sun contributed to the data collection and extraction. L Hou contributed to the data analysis. Y Sun drafted the manuscript. E Zhao revised the manuscript. All authors have read and approved the final manuscript.

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Data availability
The data that support the findings of this study are available on request from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Affiliated Hospital of Chengde Medical University (CYFYLL2023544) and informed consent was taken from all the patients.

Consent for publication
Not applicable.

Disclosures
Yong Sun, Lei Hou, and Enhong Zhao have no conflicts of interest or financial ties to disclose.

Competing interests
The authors declare no competing interests.

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