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Review Article

Laparoscopic versus open splenectomy and esophagogastric devascularization for portal hypertension: a meta-analysis

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Abstract: Objective: The goal of this study was to determine whether laparoscopic splenectomy and esophagogastric devascularization (LSD) are superior to open splenectomy and esophagogastric devascularization (OSD) for portal hypertension. Methods: Articles comparing LSD and OSD for portal hypertension were searched in databases. Evaluated endpoints were operation outcomes, postoperation recovery, and postoperation complications. Results: Ten studies that recruited a total of 629 patients were identified for inclusion. Longer operation time [mean difference (MD), 43.15; 95% confidence interval (CI), 29.65 to 56.66; $P < 0.00001$], less intra-operation blood loss (MD, -149.31; 95% CI, -210.26 to -88.36; $P < 0.00001$), earlier time of passing flatus (MD, -1.13; 95% CI, -1.55 to -0.71; $P < 0.00001$), earlier time of oral intake (MD, -1.68; 95% CI, -2.03 to -1.33; $P < 0.00001$), less overall morbidity [odds ratio (OR), 0.58; 95% CI, 0.35-0.97; $P = 0.04$] and shorter hospital stay (MD, -4.30; 95% CI, -6.44 to -2.16; $P < 0.0001$) in the LSD group. There was no significant difference between the two groups in transfusion rate, hospital mortality, hospitalization cost, and bleeding recurrence rates. Conclusions: Laparoscopic splenectomy and esophagogastric devascularization is a feasible, effective, and safe surgical procedure, and is advantageous over open surgery for the treatment of portal hypertension.

Keywords: Liver cirrhosis, portal hypertension, laparoscopy, splenectomy, esophagogastric devascularization

Introduction

Portal hypertension (PH) is a common major complication of liver cirrhosis and is highly prevalent in China, which generally results in two severe complications--esophagogastric variceal bleeding and hypersplenism. Variceal bleeding is the most common cause of death in patients with PH, occurring in approximately 30% of cases, with a 30-day mortality of 20% when the portal venous pressure reaches above 12 mmHg [1]. Complications of hypersplenism, including decreased platelets and/or white blood cells (WBC), can lead to bleeding and infection [2]. Liver transplantation has been regarded as the most effective means of treatment for patients with cirrhosis and PH. However, organ shortages and high medical costs greatly limit the clinical application. Although esophageal varices can be treated with endoscopic methods, endoscopic treatment for gastric varices is still controversial [3, 4]. Several studies recommend surgical interventions to treat cirrhosis and PH, such as distal splenorenal shunt, transjugular intrahepatic portosystemic stent shunt, balloon-occluded retrograde transvenous obliteration, or splenectomy with esophagogastric devascularization.

Open splenectomy and esophagogastric devascularization (OSD), developed first by Sugiura in the 1960s, has been the main treatment for PH with esophagogastric variceal bleeding and/or hypersplenism for a long time, because it can simultaneously solve bleeding, thrombocytopenia, and/or leucopenia. However, liver function of patients with cirrhosis and PH is usually poor, and OSD is associated with a high morbidity and mortality [5]. Owing to the cumulative experiences of laparoscopic surgeries and recent development in endoscopic instruments, lapa-

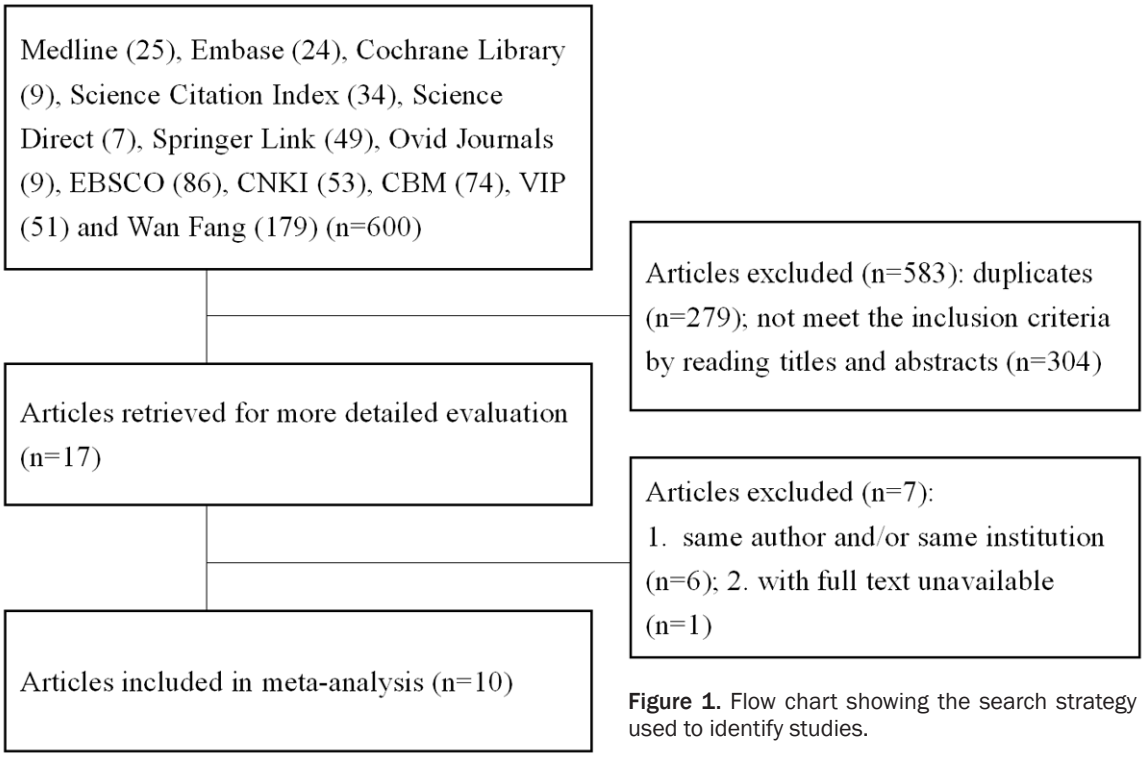

Figure 1. Flow chart showing the search strategy used to identify studies.

roscopic approaches have been increasingly used in various fields, including laparoscopic splenectomy and esophagogastric devascularization (LSD) for patients with liver cirrhosis and PH [6]. However, to date, there are only a few reports with small simple size about the experiences of LSD from a single center. Although little research has indicated that the outcomes of LSD are better than those for OSD, the safety and feasibility of LSD are still uncertain. Therefore, it is appropriate to make a systematic review and comprehensive analysis of the existing evidence regarding the LSD and OSD to determine whether LSD is superior to OSD for portal hypertension secondary to liver cirrhosis.

Methods

Selection of studies

A systematic literature search (Medline, Embase, Cochrane Library, Science Citation Index, Science Direct, Springer Link, Ovid Journals, EBSCO, CNKI, CBM, VIP and Wan Fang) was performed to identify all eligible articles. Randomized controlled trials (RCTs) and non-RCTs (N-RCTs) published until 31th, October, 2015 comparing LSD and OSD for PH were eligible for inclusion. The following medical search headings (MeSH) were used: "laparoscopy", "minimal invasive surgery", "open approach", "portal hypertension", "splenectomy", "esophagogastric devascularization", "azygoportal disconnection", "Hassab's operation" and "comparative study". Their combinations or similar headings were also searched such as "laparoscopic approach", "minimally invasive treatment", and "laparoscopic treatment". A personal search was also performed with reference lists of the retrieved relevant articles and reviews, to identify additional trials to make sure that all the potential studies were included.

Inclusion and exclusion criteria

All included trials were required to fulfill the following criteria: (a) being published on humans in English or Chinese; (b) providing clear documentation of the operation approaches as "laparoscopic" or "open"; (c) reporting the outcomes after surgery; and (d) when two or multiple studies were published by the same institution and/or authors, either the higher-quality study or the most recent trail was included in the meta-analysis. Studies were excluded if (a) it was impossible to extract the appropriate

Table 1. Study characteristics-demographics of laparoscopic and open splenectomy and esophagogastric devascularization

Author	Study period	Design	Group	Patients (n)	M/F (n)	Age (yr)	Etiology (P/S/A/O, n)	Child-Pugh (A/B/C, n)	Quality score
Hong et al. [11]	2004-2006	N-RCT	LSD	20	16/4	48 (29-78)[1]	19B/1/0/0	7/12/1	2
			OSD	20	17/3	48 (32-62)	18B/1/1/0	6/13/1	
Sun [12]	2005-2008	N-RCT	LSD	36	21/15	52.4 ±12.1	28B/4/3/1	29/7/0	2
			OSD	36	23/13	56.8 ± 9.4	30B/3/1/2	25/11/0	
Wu [13]	2004-2010	N-RCT	LSD	32	23/9	39.9 ± 11.2	30B/1/1/0	21/11/0	1
			OSD	30	21/9	42.5 ± 12.3	26B, 1C/1/2/0	19/11/0	
Wang [14]	2005-2007	N-RCT	LSD	20	15/5	43.8 ± 13.85	20/0/0	13/7/0	1
			OSD	25	18/7	46.16 ± 10.28	25/0/0	15/10/0	
Jiang [15]	2006-2010	N-RCT	LSD	34	30/4	47.3 ± 13.5	27B/0/4/3	29/5/0	1
			OSD	34	28/6	46 ± 9.4	26B/0/5/3	31/3/0	
Ma et al. [16]	2008-2010	N-RCT	LSD	19	37/6	44 (29-58)	34B, 5C/0/4/0	11/32/0	2
			OSD	24					
Huang et al. [17]	2009-2012	N-RCT	LSD	20	11/9	50.8[2]	20B/0/0	16/4/0	1
			OSD	20	14/6	49.4	20B/0/0	15/5/0	
Jiang et al. [18]	2006-2009	N-RCT	LSD	26	19/7	41.5 ± 21.8	23B/0/1/2	17/8/1	3
			OSD	26	21/5	44.6 ± 19.6	21B/0/2/3	20/5/1	
Zheng et al. [19]	2007-2010	N-RCT	LSD	24	7/17	43 (20-56)	18B, 6C/0/0/0	15/9/0	4
			OSD	30	13/17	47 (18-68)	23B, 7C/0/0/0	16/14/0	
Zhe et al. [20]	2008-2011	N-RCT	LSD	80	63/17	48.5 ± 12.2	69B, 2C/0/6/3	34/46/0	4
			OSD	73	51/22	43.6 ± 12.4	64B, 3C/0/4/2	25/48/0	

[1]Medians with ranges in parentheses; [2]Medians; LSD: Laparoscopic splenectomy and esophagogastric devascularization; OSD: Open splenectomy and esophagogastric devascularization; N-RCT: Non-randomized controlled trials; M/F: Male/Female; P/S/A/O: Posthepatitis/Schistosomal/Alcoholic/Other; A/B/C: Grade of Child-Pugh; B, Hepatitis B; C, hepatitis C; NM: Not mentioned.

data, such as case reports, letters, reviews and commentary; (b) there was no control group; (c) hand-assisted LSD was included in the laparoscopic group; (d) laparoscopic and open surgery were performed for hepatocellular carcinomas which were companied with PH; (e) other treatments, such as endoscopic sclerotherapy, endoscopic ligation, transjugular intrahepatic portosystemic shunt were applied for PH before surgery; and (f) the number of cases was < 40.

Study eligibility assessment

Two authors (Su A and Zhao Y) independently scanned the title and abstract of each publication for potentially eligible studies. Full articles were then obtained for detailed evaluation. Any disagreement in the selection process was resolved through discussion. If this failed, a third person (Zhang G) adjudicated.

Outcome evaluation

The following outcomes were used to compare LSD and OSD. Operation outcomes included operation time, intra-operation blood loss and transfusion rate. Post operation outcomes included hospital mortality, overall morbidity, post operation hemorrhage, pancreatic fistula, gastric leakage, pulmonary infection, pleural effusion, ascites, incisional infection, portal vein system thrombosis, post operation time of passing flatus, post operation time of oral intake, length of hospital stay, hospitalization cost and bleeding recurrence.

Data extraction

Two authors (Su A and Zhao Y) independently extracted data from all eligible studies using standardized forms. Data extracted from each study included: first author, study period, study design, participant characteristics, and operation and post operation outcomes. Any disagreements were resolved using the same method as mentioned above. The authors of all eligible studies were also contacted if there were missing data or inaccurate information.

Quality assessment

The Jadad scoring system was used to assess the quality of RCTs [7]. The N-RCTs were scored on the following basis: prospective *vs.* retro-

Table 2. Study characteristics pre-operation laboratory examination of laparoscopic and open splenectomy and esophagogastric devascularization

Author	Group	Patients (n)	Bleeding (n)	Hg (g/L)	WBC (×10^9/L)	Platelet (×10^9/L)	Diameter of spleen (cm)	Conversion (n)	Follow-up (month)
Hong et al. [11]	LSD	20	19	108 (56-124)[1]	3 (0.7-5.9)	49.7 (5-95)	NM	0	6-24
	OSD	20	17	97 (66-131)	2.7 (1.5-3.6)	61.9 (21-92)			
Sun [12]	LSD	36	36	NM	NM	NM	25.4	0	3-36
	OSD	36	36				26.9		
Wu [13]	LSD	32	19	102.75 ± 16.19	3.08 ± 1.04	62.17 ± 23.09	18.97 ± 4.93	3	NM
	OSD	30	18	93.12 ± 26.19	3.59 ± 2.15	59.22 ± 23.64	17.43 ± 3.89		
Wang [14]	LSD	20	20	NM	3.31 ± 1.22	NM	NM	0	NM
	OSD	25	25		2.75 ± 1.56				
Jiang [15]	LSD	34	34	NM	NM	NM	17.97 ± 4.18	2	NM
	OSD	34	34				18.88 ± 5.43		
Ma et al. [16]	LSD	19	19	75-108	1.9-3.8	50-84	NM	0	6
	OSD	24	24						
Huang et al. [17]	LSD	20	20	NM	NM	NM	20.6 ± 3.8	0	NM
	OSD	20	20				21.1 ± 4.2		
Jiang et al. [18]	LSD	26	26	NM	NM	NM	NM	2	1-34
	OSD	26	26						
Zheng et al. [19]	LSD	24	NM	69 (32-92)	2.4 (1.3-5)	48 (32-83)	18.5 (15-24)	0	3-36
	OSD	30		73 (32-94)	3 (1.2-4.7)	53 (29-76)	19 (15-25)		
Zhe et al. [20]	LSD	80	63	NM	2.0 ± 0.8	16.8 ± 6.6	21.1 ± 5.8	9	2-50
	OSD	73	57		2.2 ± 0.9	17.3 ± 7.1	22.4 ± 6.9		

[1]Medians with ranges in parentheses; LSD: Laparoscopic splenectomy and esophagogastric devascularization; OSD: Open splenectomy and esophagogastric devascularization; Hg: Hemoglobin; WBC: White blood cell; NM: Not mentioned.

spective data collection; assignment to LSD or OSD by means other than surgeon preference; an explicit description of surgical procedure; and long-term follow-up (studies were given a score of 1 for each of these areas; score 1-4) [8]. The study was considered to be of high quality if the quality score is ≥ 3.

Statistical analysis

Meta-analysis was performed in line with the recommendations of the Cochrane Collaboration and the Quality of Reporting of Meta-analyses (QUORUM) guidelines [9, 10]. Statistical analysis of dichotomous variables was carried out by using odds ratio (OR) as the summary statistic, while continuous variables were analyzed using the mean difference (MD), and both were reported with 95% confidence intervals (CI). OR represented the odds of an adverse event occurring in the LSD group *vs.* the OSD group and it was considered statistically significant at $P < 0.05$ if the 95% CI did not include the value 1, while WMD summarized the difference between the two groups in the continuous variables and it was considered statistically significant at $P < 0.05$ if the 95% CI did not cross the value 0. Heterogeneity between studies was measured using X^2 and I^2, and $I^2 > 50\%$ was considered statistically significant. Either a fixed effects model or random effects model was applied to calculate the pooled effect based on the heterogeneity. But the random effects model was used first to assess the heterogeneity. Subgroups were used for sensitivity analysis and a funnel plot was used to identify publication bias based on the overall morbidity. Analysis was conducted by using the statistical software Review Manager (version 5.0).

Results

Eligible studies

Ten N-RCTs, involving a total of 629 cases that compared the outcomes of LSD with OSD in patients with PH secondary to liver cirrhosis, were identified for pooled analysis, including seven studies [11-17] published in Chinese and three [18-20] in English (**Figure 1**). The details of the included studies are summarized in **Tables 1** and **2**. The sample size ranged from 40 to 153 patients. The mean age of the patients varied between 40 and 57 years. The mean proportion of males varied between 37%

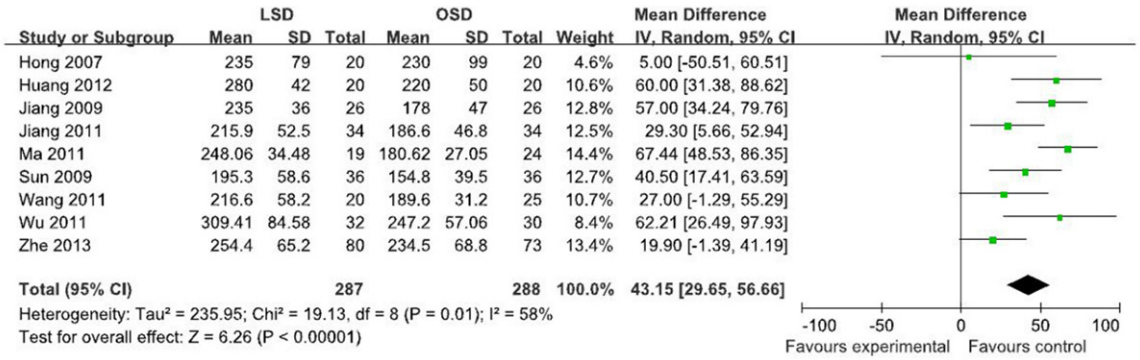

Figure 2. Meta-analysis of all available data in operation time with random effect model.

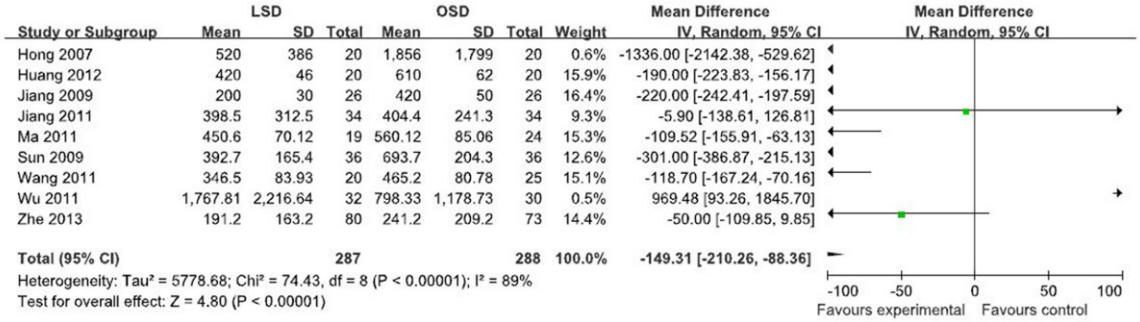

Figure 3. Meta-analysis of all available data in intra-operation blood loss with random effect model.

and 86%. The mean proportion of patients with history of upper gastrointestinal bleeding varied between 60% and 100%. Rates of conversion varied between 0% and 11%. The main cause of conversion was intra-operation bleeding. Of the ten studies, five [11, 12, 18-20] reported the results of long-term follow-up and three [18-20] were high-quality studies. There were no significant differences between the two groups in age (MD, -0.49; 95% CI, -4.00 to 3.03; P = 0.79), sex (OR, 0.97; 95% CI, 0.67-1.40; P = 0.87), etiology (OR, 1.09; 95% CI, 0.67-1.76; P = 0.74), WBC (MD, -0.16; 95% CI, -0.40 to 0.09; P = 0.21), platelet (MD, -0.38; 95% CI, -2.52 to 1.76; P = 0.73), Child-Pugh Grade A (OR, 1.21; 95% CI, 0.85-1.73; P = 0.29) and longest diameter of spleen (MD, -0.31; 95% CI, -1.43 to 0.80; P = 0.58).

Meta-analysis of operation outcomes

Operation time (min): All the studies reported on operation time, but one [19] of them did not provide sufficient information (210 *vs.* 190, P = 0.105). Meta-analysis of the remaining nine studies with random effects model (I^2 = 58%) showed that it was significantly longer in patients undergoing LSD than in those undergoing OSD (MD, 43.15; 95% CI, 29.65 to 56.66; P < 0.00001) (**Figure 2**).

Intra-operation blood loss (mL): Intra-operation blood loss was reported in nine studies, and eight reported the data using mean and standard deviation (SD). No SD was reported by Zheng et al. [19] (90 *vs.* 350, P < 0.0001). The random effects model was used due to significant heterogeneity (I^2 = 89%) between studies, and the overall effect indicated it was significantly lower in the LSD group than in the OSD group (MD, -149.31; 95% CI, -210.26 to -88.36; P < 0.00001) (**Figure 3**).

Transfusion rate: Three studies [13, 18, 20] reported the number of patients who received transfusions during or after the operation. The result of pooled analysis showed no statistically significant difference between the two groups (OR, 0.80; 95% CI, 0.45-1.41; P = 0.44) (**Figure 4**).

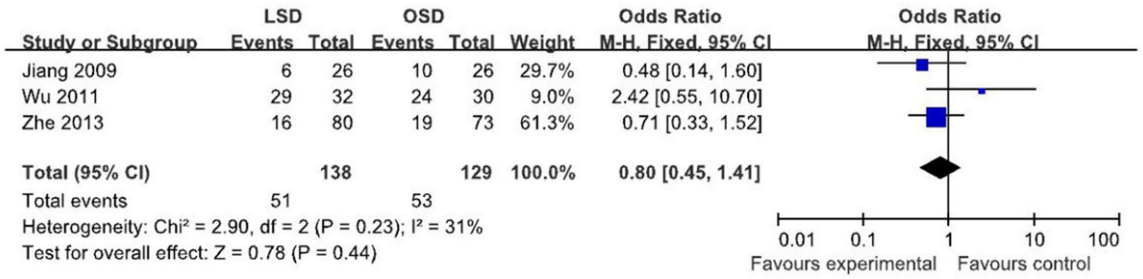

Figure 4. Meta-analysis of all available data in transfusion rate with fixed effect model.

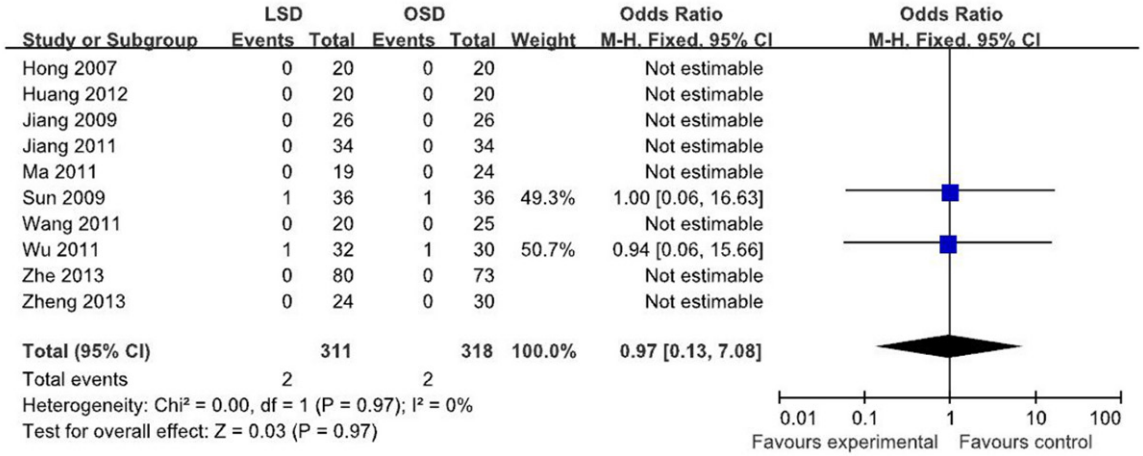

Figure 5. Meta-analysis of all available data in mortality with fixed effect model.

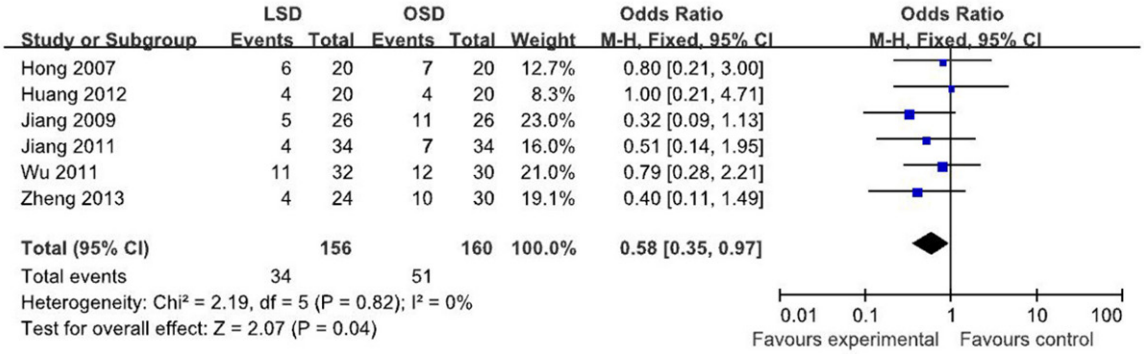

Figure 6. Meta-analysis of all available data in morbidity with fixed effect model.

Meta-analysis of postoperation outcomes

Mortality: All the ten studies [11-20] reported on hospital mortality. Among the 629 patients involved, four patients (two in the LSD group and two in the OSD group) died from intra-operation (25%) and post operation (75%) massive hemorrhage. The summarized effect revealed no significant difference between the two groups (OR, 0.97; 95% CI, 0.13-7.08; $P = 0.97$) (**Figure 5**).

Morbidity: Six studies [11, 13, 15, 17-19], including 316 patients, were analyzed for the overall post operation morbidity. It was described in 21.8% of patients in the LSD group and in 31.9% of those in the OSD group. The result of pooled analysis indicated LSD was

Table 3. Post operation complications of laparoscopic versus open splenectomy and esophagogastric devascularization

Complications	Number of studies	Number of patients		OR	95% CI	*P* value	Heterogeneity (I^2)
		LSD	OSD				
Post operation hemorrhage	5 [18-21, 24]	8/208	9/199	0.86	0.34, 2.17	0.75	0%
Pancreatic fistula	3 [18, 20, 24]	3/142	5/135	0.61	0.16, 2.37	0.47	0%
Gastric leakage	3 [18, 20, 25]	2/140	1/139	1.46	0.29, 7.36	0.65	0%
Pleural effusion	4 [17, 19, 20, 24]	11/158	20/149	0.49	0.23, 1.05	0.07	25%
Pulmonary infection	5 [18-20, 24, 25]	4/198	17/195	0.25	0.09, 0.70	0.008	0%
Ascites	5 [17-20, 25]	19/192	23/189	0.79	0.41, 1.54	0.50	0%
Incisional infection	6 [17-20, 24, 25]	1/218	17/215	0.17	0.05, 0.53	0.002	0%
Portal vein system thrombosis	7 [17, 18, 20, 21, 24]	42/196	28/189	1.59	0.90, 2.81	0.11	35%

LSD: laparoscopic splenectomy and esophagogastric devascularization; OSD: open splenectomy and esophagogastric devascularization; OR: Odds ratio; CI: Confidence interval.

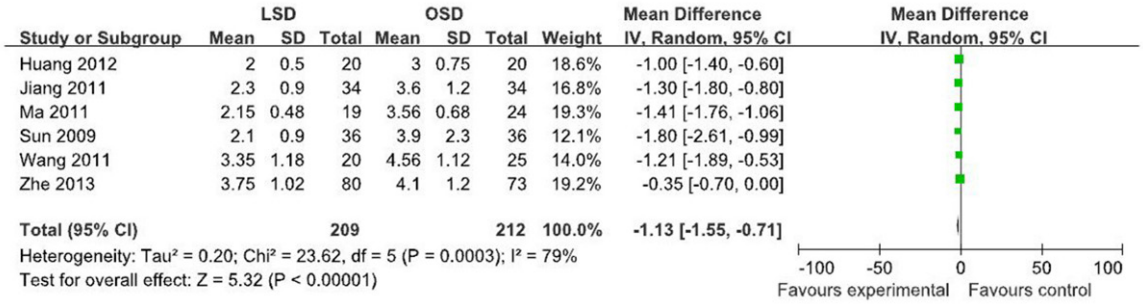

Figure 7. Meta-analysis of all available data in post operation time of passing flatus with random effect model.

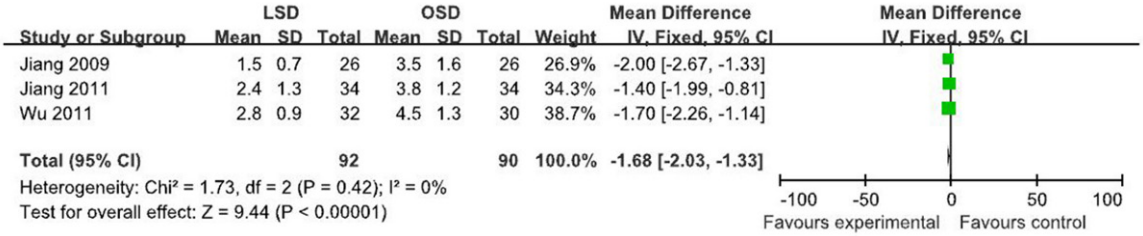

Figure 8. Meta-analysis of all available data in post operation time of oral intake with fixed effect model.

associated with significantly fewer post operation complications in comparison with OSD (OR, 0.58; 95% CI, 0.35-0.97; *P* = 0.04) (**Figure 6**). The results of pooled analysis with each post operation complication are shown in **Table 3**. The summarized effects of pulmonary infection and incisional infection revealed statistically significant results favoring LSD. There was no significant difference between LSD and OSD in post operation hemorrhage, pancreatic fistula, gastric leakage, pleural effusion, ascites and portal vein system thrombosis.

Post operation time of passing flatus (d): Seven studies [12, 14-17, 19, 20] evaluated post operation time of passing flatus, but one [19] of them did not provide sufficient information (3.00 *vs.* 4.88, *P* < 0.0001). Meta-analysis of the other six studies with random effects model (I^2 = 79%) showed that significantly less time was required to pass flatus and achieve recovery of gastrointestinal function in the LSD group than in the OSD group (MD, -1.13; 95% CI, -1.55 to -0.71; *P* < 0.00001) (**Figure 7**).

Post operation time of oral intake (d): Post operation time of oral intake was reported in three studies [13, 15, 18]. Pooling of the individual results revealed that the post operation time of oral intake is significantly earlier in the

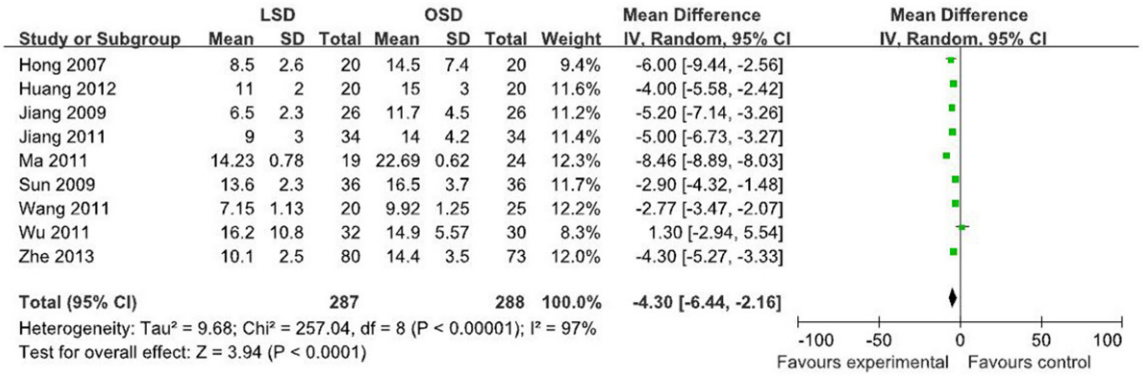

Figure 9. Meta-analysis of all available data in length of post operation hospital stay with random effect model.

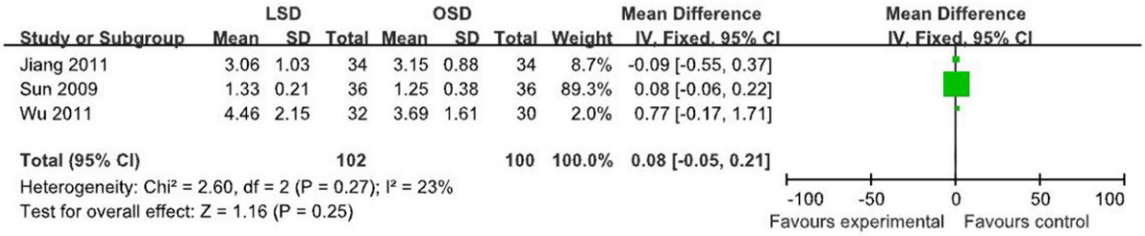

Figure 10. Meta-analysis of all available data in hospitalization cost with fixed effect model.

LSD group (MD, -1.68; 95% CI, -2.03 to -1.33; $P < 0.00001$) (**Figure 8**).

Post operation analgesia: Two studies [13, 18] reported the results of post operation analgesia. One study [13] provided the times of post operation analgesia between the two groups and showed that patients in the LSD group had significantly less times of post operation analgesia (0.94 ± 0.95 *vs.* 2.83 ± 1.02, $P < 0.001$). The other study [18] reported the number of patients who required analgesic drugs. The result indicated that significantly less patients in the LSD group required analgesic drugs after surgery (7.69 *vs.* 73.08%, $P < 0.001$).

Length of post operation hospital stay (d): Data of length of post operation hospital stay was available in nine studies [11-18, 20]. The studies showed that patients in the LSD group had a shorter length of post operation hospital stay (MD, -4.30; 95% CI, -6.44 to -2.16; $P < 0.0001$), which was associated with significant heterogeneity between the groups in all available studies for pooled analysis ($I^2 = 97\%$) (**Figure 9**).

Hospitalization cost (RMB, ×10^4 yuan): Three studies [12, 13, 15] reported on the hospitalization costs. The result of pooled analysis suggested that there was no significant difference between the two groups (MD, 0.08; 95% CI, -0.05 to 0.21; $P = 0.25$) (**Figure 10**).

Bleeding recurrence: Results of long-term follow-up were reported in five studies [11, 12, 18-20]. The period of follow-up was 1 to 50 months. Bleeding recurrence was noted in two studies [12, 20]. However, Sun [12] did not provide the number of patients with bleeding recurrence in the two groups, and reported that one patient in the OSD group died from bleeding recurrence during the follow-up period of 3 to 36 months. Zhe et al. [20] reported that variceal re-bleeding occurred in five laparoscopy patients (6.3%) and in six (8.2%) patients with open surgery ($P = 0.638$).

Sensitivity analysis

Sensitivity analyses were carried out by excluding each study from the analysis of each outcome measure. Subgroup with high-quality studies was used for the sensitivity analysis. The results of the analysis were the same as those when all studies were selected, except for the portal vein system thrombosis (**Table 4**).

Table 4. Sensitivity analysis with high-quality studies

Complications	Number of studies	Number of patients		OR	95% CI	*P* value	Heterogeneity (I^2)
		LSD	OSD				
Morbidity	2 [18, 19]	9/50	21/56	0.36	0.15, 0.89	0.03	0%
Postoperation hemorrhage	2 [18, 20]	2/106	5/99	0.41	0.09, 1.88	0.25	0%
Pancreatic fistula	2 [18, 20]	2/106	2/99	0.95	0.16, 5.52	0.95	0%
Gastric leakage	2 [19, 20]	1/104	1/103	1.06	0.15, 7.40	0.95	17%
Pleural effusion	2 [18, 20]	6/106	13/99	0.55	0.08, 3.81	0.55	54%
Pulmonary infection	3 [18-20]	2/130	10/129	0.25	0.07, 0.93	0.04	0%
Ascites	2 [19, 20]	5/104	9/103	0.56	0.18, 1.76	0.32	0%
Incisional infection	3 [19, 20]	1/130	9/129	0.19	0.04, 0.90	0.04	0%
Portal vein system thrombosis	2 [18, 20]	41/106	22/99	2.35	1.23, 4.50	0.01	0%

LSD: laparoscopic splenectomy and esophagogastric devascularization; OSD: open splenectomy and esophagogastric devascularization; OR: Odds ratio; CI: Confidence interval.

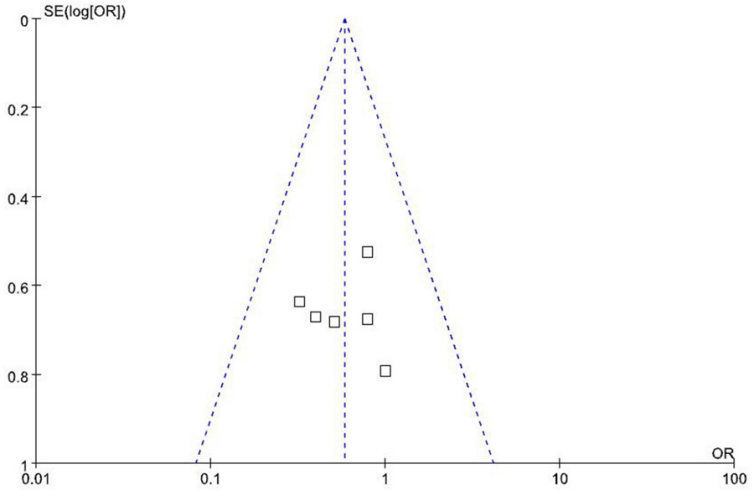

Figure 11. Funnel plot of comparison of laparoscopic *vs*. open splenectomy and esophagogastric devascularization in morbidity. SE: Standard error; OR: Odds ratio.

Publication bias

A funnel plot of the studies used in the meta-analysis reporting on morbidity is shown in **Figure 11**. None of the studies lies outside the limits of the 95% CI, and all studies are equally distributed around the vertical axis. Therefore, there is no evidence of publication bias in the present meta-analysis.

Discussion

Despite this meta-analysis found that LSD for PH was associated with a statistically significant increase in operation time, LSD was superior to OSD with respect to intra-operation blood loss, overall post operation morbidity, pulmonary infection and incisional infection, the time to return to normal gastrointestinal functions and length of post operation hospital stay.

Compared with OSD, LSD may have several theoretical advantages: (1) less surgical stress; (2) a smaller surgical incision which decreases post operation analgesia and the incidence of pulmonary infection and wound infection; (3) milder post operation abdominal adhesions that reduces the difficulty of the later liver transplant operation; (4) a clearer view and converted perspective to expose narrow spaces; and (5) more effective to occlude varicose blood vessels around the esophagus and gastric fundus with the harmonic shears or LigaSure vessel-sealing equipment, which avoids post operation bleeding in OSD as a result of ligature slipping [19].

In the current study, the operation time in the LSD group was longer than in the OSD group, which is consistent with the previous researches. There were three potential reasons for the longer operation time in the LSD group: (1) the narrow operation space due to splenomegaly; (2) special attention given to the prevention of intra-operation variceal bleeding and (3) LSD converted to OSD as the result of bleeding. However, Zhe et al. [20] found that the mean operation time in the LSD group was shorter

gradually. Operation time in the LSD group in the early stage was longer than in the OSD group but was equal to or even shorter than in the open procedure in the latter stage. According to the learning curve of laparoscopic surgery, the operation time was obviously different in different centers and mainly depended on the experience and skill of the surgeons [21].

Bleeding during LSD is very difficult to control and is the leading cause for conversion to OSD. Therefore, more attention should be paid to prevent intra-operation variceal bleeding. Less intra-operation blood loss in the patients with LSD may be attributed to a clearer operation vision and ingenious instruments used in the laparoscopic procedure. Although transfusion rate was similar in both groups, blood transfusion should be more in the OSD group than in the LSD group. In addition, intra-operation splenic blood salvage was advocated to avoid the risk associated with allogeneic transfusion during surgery, with an advantage of significantly increased post operation hemoglobin levels [22].

As shown in previous studies, because minimally invasive surgery had less influence on intra-abdominal organs compared with open operations, gastrointestinal functions may recover faster and the time of oral intake may be earlier. In this meta-analysis, the results also revealed that there was lower incidence of overall post operation complications, pulmonary infection and incisional infection, and shorter hospital stay in the LSD group, which was consistent with the outcomes of laparoscopic *vs.* open surgery for other major abdominal procedures, such as liver and colorectal surgery [23, 24]. A smaller incision, which leads to milder pain, less analgesia, easier expectoration and earlier mobilization, greatly decreases the rate of pulmonary infection and wound infection, and, therefore, shortens the length of hospital stay. Moreover, LSD did not increase the incidence of mortality, post operation hemorrhage, pancreatic fistula, gastric leakage, pleural effusion, ascites, portal vein system thrombosis, bleeding recurrence and hospital cost. The higher incidence of portal vein system thrombosis in the LSD group reported by Zhe et al. [20] was greatly attribute to the result of sensitivity analysis (50% *vs.* 30.1%, $P = 0.012$).

In spite of the obvious advantage of LSD, it is a complicated procedure which requires abundant experience in laparoscopic skills. Supermassive splenomegaly and perisplenitis are considered to be two relative contraindications to laparoscopic splenectomy [25]. Therefore, if surgeons meet the following conditions during LSD: (1) narrow operation space; (2) difficulty with retrieval; (3) severe adherence of adjacent organs; and (4) unable to control intra-operation bleeding, hand-assisted LSD or OSD should be taken into account [11].

The meta-analysis has some limitations and the results should be interpreted with caution. First, all the studies included in this meta-analysis were N-RCTs. Second, seven in ten studies were low-quality studies. Third, a significant heterogeneity between the two groups was observed in the operation time, intra-operation blood loss, post operation time of passing flatus and length of post operation hospital stay. Nevertheless, the results of sensitivity analysis with high-quality studies further confirmed the conclusion drawn above.

In conclusion, the current study suggests that LSD is a feasible, effective, and safe surgical procedure, and is advantageous over open surgery for the treatment of portal hypertension.

Disclosure of conflict of interest

None.

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