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ORIGINAL CONTRIBUTIONS

The Effectiveness and Safety of Barbed Sutures in the Bariatric Surgery: a Systematic Review and Meta-analysis

Yifei Lin[1] · Youlin Long[2] · Sike Lai[3] · Yonggang Zhang[4] · Qiong Guo[2] · Jin Huang[1,2,4] · Liang Du[2,5]

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Abstract

Background Knotless barbed sutures can eliminate knot tying during the bariatric surgery (BS). Since effects reported on patients and surgeons are ambiguous, this study is determined to identify the effectiveness and safety of knotless barbed suture in BS.

Methods PubMed, EMBASE, Cochrane Register of Clinical Studies, and ClinicalTrials.gov were searched for randomized controlled trials (RCTs) and cohort studies comparing barbed sutures with conventional sutures in BS (until July 2, 2018). Quality assessment was conducted due to Cochrane's recommendations. Review Manager was applied to analyze the data, and we performed subgroup analyses based on study design type and surgery type.

Results A total of four cohort studies (25,505 patients, low to moderate risk of bias) and four RCTs (1480 patients, low to moderate risk of bias) proved eligible. BS includes laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy. Comparing to conventional suture, pooling data showed that suture time (MD = − 4.87, 95%CI − 8.82 to − 0.92, $P = 0.02$) and operative time (MD = − 7.88, 95%CI − 14.10 to − 1.67, $P = 0.01$) declined significantly in the barbed group. Although no significant change was in the overall postoperative complications and hospital stay, subgroup analysis of RCTs suggested that significantly, fewer bleeding conditions happened in barbed groups.

Conclusions Although quality of all the studies was relatively moderate and the number of the included studies was limited, the barbed suture may have the potentiality to be an effective and reliable technique and extend the application in other bariatric surgeries. More evidence with randomized design, larger sample sizes, and longer follow-up need to compel validations of this state-of-the-art in the future.

Keywords Barbed suture · Bariatric surgery · Surgical technique · Systematic review

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✉ Jin Huang
michael_huangjin@163.com

✉ Liang Du
125798620@qq.com

[1] Urology Department, Institute of Urology, Laboratory of Reconstructive Urology, West China Hospital, Sichuan University, Chengdu, Sichuan, People's Republic of China

[2] Chinese Evidence-Based Medicine Center, West China Hospital, Sichuan University, Chengdu 610041, People's Republic of China

[3] West China School of Medicine, Sichuan University, Guoxuexiang 37, Chengdu 610041, Sichuan, China

[4] West China Hospital, Sichuan University, Guoxuexiang 37, Chengdu 610041, Sichuan, China

[5] West China Medical Publishers, West China Hospital, Sichuan University, Chengdu 610041, People's Republic of China

Background

Obesity is now a global epidemic observed in more than 30 countries [1]. According to statistical forecasts, 51% of the US population will have obesity by 2030 [2]. Varieties of interventions were approved to reduce the problem, and accumulated evidence has suggested that bariatric procedures were more effective than medical or lifestyle interventions for both weight loss and remission of type 2 diabetes [3]. It is reported that the top two most popular bariatric procedures worldwide are laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG), which account for 45% and 37%, respectively in 2013 [4].

From the surgeons' perspectives, laparoscopic intracorporeal knot tying in both procedures is a complex technique, even for an expert, that can result in unpredictable consequences including leaks and fistulas [5, 6]. Recently, an innovation of absorbable, knotless barbed suture has been

used for bariatric surgery (BS). Initiated in 1964 [7], this technique has been first described to eliminate knot tying in plastic and gynecological surgery previously [8]. And then some systematic reviews, in terms of radical prostatectomy [9, 10], have confirmed the equivalence of biocompatibility and tensile strength of knotless barbed suture compared to conventional sutures in urological field and even in general surgical field [11, 12].

Since effects reported on patients and surgeons are ambiguous and no meta-analysis was reported about BS, thus we carried out this meta-analysis and systematic review to identify the effectiveness and safety of knotless barbed suture in BS comparing with the conventional sutures.

Material and Methods

Study Identification and Selection

The MEDLINE, EMBASE, and the Cochrane Library databases were searched using the following terms: ("gastric" OR "bariatric" OR "bypass") AND ("barbed" OR "knotless") AND ("suturing" OR "suture") (last updated in July 2018). In order to modify the results and to avoid the publication bias, we also searched clinical trials registered in Clinicaltrials.gov (last updated on July 2, 2018).

All studies had to meet the following inclusion criteria: (a) study design had to be a randomized controlled trial (RCT) or observational controlled studies based on human subjects; (b) patients underwent bariatric surgeries including LRYGB and LSG; (c) interventions had to be conventional suture versus barbed suture; and (d) the studies provided short- or long-term outcomes. The following exclusion criteria were also applied: (a) no control; (b) conventional sutures were other materials or approaches such as mesh or staple rather than smooth sutures; conventional sutures are traditional smooth knot-tying anastomosis sutures regardless of continuous Lemberts' or through-and-through suture [13]; (c) abstracts, reviews, and overlapped studies; and (d) studies published in languages other than English. The computer search was supplemented with a manual search for references of included studies.

Data Extraction and Outcome Measures

We imported the search results into bibliographic citation management software (EndNote X7). Two reviewers independently collected the data and reached a consensus on all items. The following items were extracted from each study if they were available: first author's family name, publication year, original country, journal, study design, sample size, and postoperative complications.

The main outcome measures chosen for the current meta-analysis were suture time, operative time, hospital stay, and postoperative complications (bleeding, stenosis, and leak). Heterogeneity of the outcomes was assessed to confirm the appropriateness of combining individual studies.

Definition

Operative time was defined as the total time of surgery. Suture time for LRYGB was time of gastrojejunal anastomosis, while for LSG was the time of reinforcement. After surgeries, postoperative complications (bleeding, stenosis, leak, and overall postoperative complications) of the suture and hospital stay were also recorded. We specially evaluated the postoperative complications based on the modified Clavien–Dindo classification [14]. Specifically, bleeding, stenosis, and leak of the anastomosis were the top three complications that occurred most frequently and related most to bariatric surgeries.

Methodological Quality Assessment

The risk of bias of included RCTs was assessed following Cochrane's recommendations, considering random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting [15]. Publication bias was evaluated by funnel plot. Newcastle-Ottawa Scale (NOS), a widely used and accepted instrument, was applied for assessing the risk of bias of observational controlled studies [16]. We included the following items for cohort studies: ascertainment of BS, representativeness of the barbed cohort, ascertainment of exposure to barbed suture, selection of the non-exposed cohort, demonstration that outcome of interest (i.e., suture time) was not presented at the start of study, comparability of study controls for important factors (e.g., adequate adjustment for confounders or matching for important confounding factors), assessment of outcome (e.g., blinding assessment and adjudication), and completeness of the follow-up.

Data Synthesis and Analysis

Separate meta-analysis was conducted within different subgroups according to bariatric surgery types (LRYGB and LSG) and study designs (RCT and cohort study). In all analyses, we estimated the pooled mean difference (MD) to assess continuous data, while pooled odds ratios (ORs) were calculated for the assessment of dichotomous data (postoperative complications).

The pooled estimations regarding outcomes expressed either as dichotomous or continuous variables were calculated with the use of a fixed-effects model (if high heterogeneity, then use random effects model). The existence of statistical heterogeneity between the included studies was assessed via the χ^2 test and I^2 test. For all analyses, $P < 0.05$ was

considered statistically significant. Statistical analyses were performed using the software programs Review Manager (Version 5.3).

Results

Study Selection Process and Characteristics

A total of four cohort studies [17–20] (25,505 patients, low to moderate risk of bias) and four RCTs [21–24] (1480 patients, moderate risk of bias) were eligible. A flow diagram of the detailed selection process is shown in Fig. 1. Table 1 demonstrates the baseline characteristics and the results of all the studies. All the outcomes of subgroup analyses are shown in Table 2 and Appendix Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14. Follow-up time ranged from 6 weeks to 36 months.

Of the four cohort studies, the patient population within a study, regardless of exposed patients (i.e., those using barbed suture) or unexposed patients (i.e., those not using barbed suture), were identified from a same clinical setting. Ascertainment of patients performed bariatric surgeries in all studies was based on surgical records. None of the studies adjusted important confounding factors by matching pairs or performing multivariate analysis of the outcomes to adjust the results. None of studies reported loss to follow-up (0%). In general, risk of bias in cohort studies was low to moderate.

Of the four trials, three conducted computer-generated randomization, one used the block randomization; three used sealed envelopes for allocation concealment; only one applied blinding to both surgeons and patients; no one stated that they applied blinding to outcome assessors. Only two studies claimed that no participants lost to follow-up. In general, risk of bias was low to moderate in RCTs (Appendix Table 1 and Appendix Table 2).

Suture Time

Of the eight cohort studies, five reported the suture time of BS (Fig. 2a). High heterogeneity was reported ($P < 0.00001$, $I^2 =$

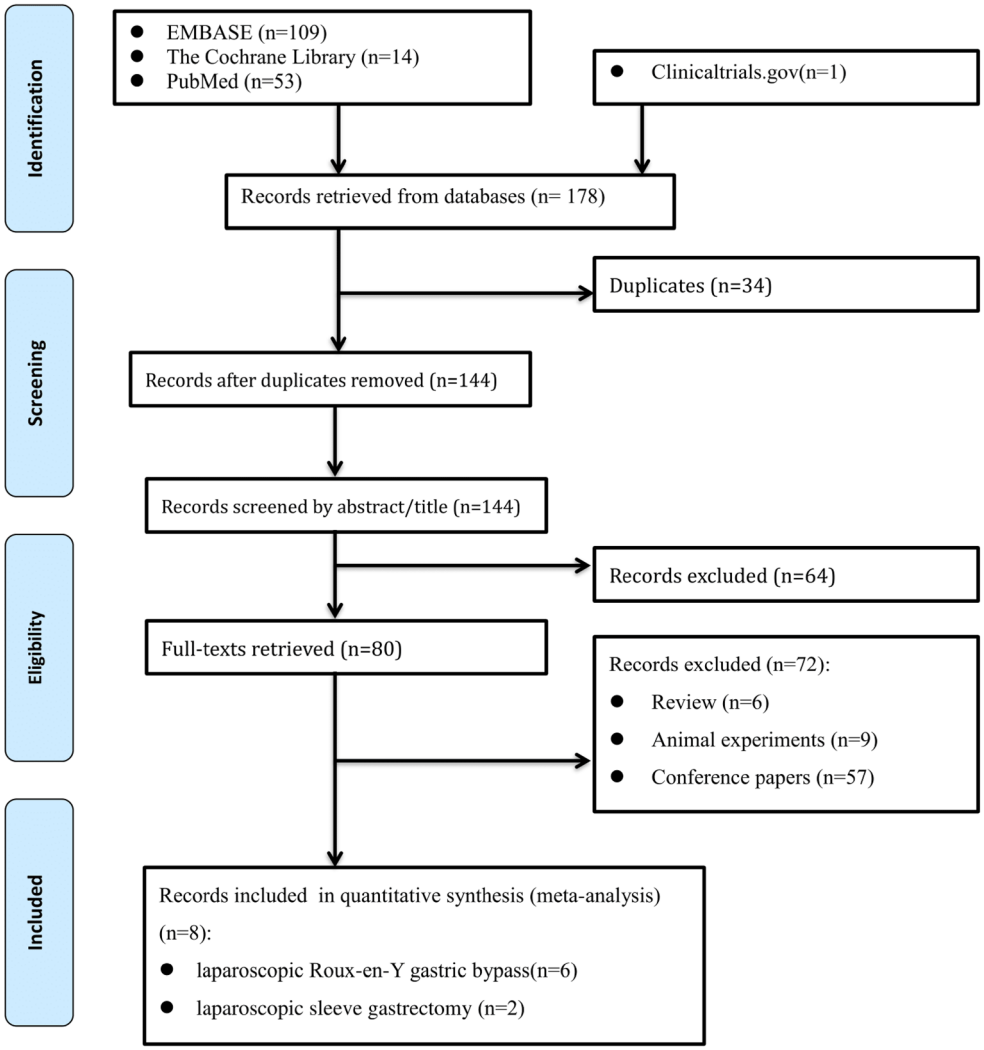

Fig. 1 Flow diagram of the detailed selection process

Table 1 Basic characteristics of all pooled studies in the meta-analysis

Author/year	Surgery type	Country	Barbed type/brand	Study design	Anastomosis type	Median follow-up	Sample size	Age
							B/C	B/C
Milone/2013	LRYGB	Italy	Uni/V-Loc 180 (Covidien, Mansfield, MA)	RCT	Gastrointestinal	6 months	30/30	36.5 ± 6.8/35.1 ± 9.3
Costantino/2013	LRYGB	France	Uni/V-Loc 180 (Covidien, Mansfield, MA)	Prospective cohort study	Gastrojejunal and antecolic jejunojejunal	NR	239/76	38 ± 10.8/40 ± 10.7
De Blasi/2013	LRYGB	Luxembourg	Uni/V-loc® 15 cm (Covidien, Mansfield, USA)	Prospective cohort study	Gastrojejunotomy	6 months	50/50	43.7 ± 12.1/42.4 ± 10.6
Tyner/2013	LRYGB	US	Uni/V-Loc 180 (Covidien, Mansfield, MA)	Retrospective cohort study	Gastrojejunostomy and jejunojejunostomy	3.8 months (B/C: 2.0 months/ 5.4 months)	46/38	48.3 ± 11.9/46.3 ± 9.8
Carandina/2016	LSG	France	Uni/V-Loc 90 (Covidien, Mansfield, MA)	RCT	Staple line reinforcement	36 months	150/150	37.1 ± 11.7/35.5 ± 11.2
Gys/2017	LRYGB	Belgium	Uni/Stratafix™ (ethicon endosurgery, Cincinnati, OH)	RCT	Gastrojejunal and jejunojejunal	6 months	100/100	40.4/38.9
Vidarsson/2017	LRYGB	Sweden	Uni/V-Locs (Medtronic, Mansfield, MA)	Retrospective cohort study	Gastrojejunostomy	NR	2211/22795	41.0 ± 11.6/40.9 ± 11.2
Hany/2018	LSG	Egypt	Uni/V-Loc 180 (Covidien, Mansfield, MA)	RCT	Staple line reinforcement	6 weeks	460/460	37.8 ± 11.8/38.04 ± 11.15

Author/year	SEX (M/F)	BMI	Suture time (min ± SD)	Operative time (min ± SD)	Hospital stay (days ± SD)	Cost (€ ± SD)	Postoperative complications
	B/C	B/C	B/C	B/C	B/C	B/C	B/C
Milone/2013	1.50/2.33	45.8 ± 3.5/46.4 ± 3.3	12.8 ± 1.4/24.1 ± 2.2	122.7 ± 31.1/134.4 ± 30.8	NR	26.0/39.9 ± 5.2	Clavien I: anastomotic leak (1/1), bleeding (0/1)
Costantino/2013	0.12/0.21	44.9 ± 6.9/44 ± 6.5	Gastrojejunal: 17.4 ± 5.1/21.3 ± 6.3 Jejunojejunal: 15.2 ± 5.5/21.4 ± 4.9	62.7 ± 15.5/74.3 ± 15.3	3.6 ± 1.2/3.3 ± 0.6	NR	Clavien II: intestinal injury (2/0), abdominal pain (5/0), pneumothorax (1/0) Clavien IIIb: intestinal occlusion (4/1), cholecystitis (6/1), intestinal bleeding (1/0)
De Blasi/2013	NR	44.0 ± 4.5/44.7 ± 7.6	8.22 ± 2.1/11 ± 1.55	119.28 ± 26.29/125.06 ± 20.32	3.2 ± 0.45/3.1 ± 0.3	18.326 ± 1.646/ 26.69 ± 2.722	0/0
Tyner/2013	0.12/0.12	41.9 ± 5.3/41.3 ± 4.7	NR	154.2 ± 74.7/178.9 ± 44.4	2.6 ± 1.4/2.3 ± 0.7	NR	Clavien I: bleeding (1/1), tachycardia (0/1) Clavien II: dehydration (2/3), esophagitis (1/0), subarachnoid hemorrhage (1/2) Clavien IIIb: bowel obstruction (1/0)
Carandina/2016	0.25/0.27	43.8 ± 10.7/44 ± 13	NR	124.6 ± 22.8/126.2 ± 18.9	6.1 ± 4/6 ± 4.6	NR	Clavien I: bleeding (1/1), leak (4/3) Clavien IIIb: stenosis (2/1)
Gys/2017	4.00/2.85	40.5/40.8	Gastrojejunal: 07:41 ± 01:11/08:13 ± 01:29	61:22 ± 17:28/60:44 ± 12:27	3.0 ± 0.2/3.0 ± 0.1	NR	Clavien I: bleeding (0/4), intestinal leakage (1/0)

Table 1 (continued)

Author/year	SEX (M/F)	BMI	Suture time (min ± SD)	Operative time (min ± SD)	Hospital stay (days ± SD)	Cost (€ ± SD)	Postoperative complications
			Jejunojejunal: 06:12 ± 00:59/06:10 ± 01:19				
Vidarsson/2017	0.30/0.33	41.3 ± 5.1/41.3 ± 5.1	NR	58 ± 22/69 ± 33	1.5 ± 2.8/1.9 ± 2.6	NR	Clavien I: leak or abscess (39/319) Clavien IIIb: small bowel obstruction (27/311), stricture (2/32)
Hany/2018	0.50/0.57	47.64 ± 7.29/47.07 ± 7.38	NR	69 ± 1.65/50.8 ± 1.58	1.92 ± 0.33/1.97 ± 0.42	NR	Clavien I: bleeding (2/3);Clavien IIIa: leak (0/8); Clavien IIIb: bleeding (0/4) (blood transfusion)

LRYGB, laparoscopic Roux-en-Y gastric bypass; *LSG*, laparoscopic sleeve gastrectomy; *RCT*, randomized controlled study; *B*, barbed suture; *C*, control; *NR*, not reported

99%) so that random effects model was performed rather than fixed effects model. The pooling of raw data of these 975 patients presented that barbed suture group had a shorter suture time than control group (MD = − 4.87, 95%CI − 8.82 to − 0.92, $P = 0.02$). Specifically, subgroup analysis on study designs showed that only in cohort studies, barbed suture groups had about 3.12-min shorter suture time than control (95%CI − 4.12 to − 2.11, $P = 0.02$, Appendix Fig. 1). Subgroup analysis on procedure types showed that both LRYGB and LSG had similar results with shorter suture time in barbed suture group (Table 2, Appendix Fig. 8).

Operative Time

Of the eight cohort studies, seven reported the operative time of BS (Fig. 2b). Due to the fact that the heterogeneity was high among the operative time ($P < 0.00001$, $I^2 = 92\%$), random effects model was performed instead of fixed effects model. The pooling of raw data of these 26,065 cases suggested that patients with barbed suture versus control had a significantly shorter operative time (MD = − 7.88, 95%CI − 14.10 to − 1.67, $P = 0.01$). Moreover, subgroup analysis on study designs showed that only in cohort studies barbed suture group had about 12.7-min shorter operative time than control (95%CI − 15.64 to − 9.75, $P < 0.00001$, Appendix Fig. 2). Subgroup analysis on procedure types showed that LRYGB using barbed suture could reduce 9.17 min compared to control (95%CI − 15.70 to − 2.64, $P = 0.006$, Appendix Fig. 9).

Hospital Stay

Seven studies reported outcomes of hospital stay (Fig 2c). The pooling outcomes of the 26,925 cases did not present significant benefits of barbed suture over conventional suture (MD = − 0.01, 95%CI − 0.13 to 0.12, $P = 0.91$). This finding was, however, highly limited due to a very high level of heterogeneity with random effect model ($I^2 = 89\%$, $P < 0.00001$). Moreover, subgroup analysis showed that no significant improvement of barbed suture in both procedures regardless of study designs (Appendix Figs. 3 and 10).

Postoperative Complications

Overall

All the eight studies presented about postoperative complications. The pooling outcomes of all the 26,985 patients did not show significant difference between two groups (OR = 0.83, 95%CI 0.42 to 1.65, $P = 0.60$, Fig. 2d). Subgroup analysis demonstrated consistent results in both procedures, regardless of RCTs or cohort studies. This finding was also limited due to a high level of heterogeneity with random effect model ($I^2 = 54\%$, $P = 0.04$, Appendix Figs. 4 and 11).

Table 2 Pooled outcomes of all the subgroups based on bariatric surgery types and study design types

Outcomes	Subgroups	No. of studies	No. of cases: barbed/control	MD/OR	95%CI	Heterogeneity	*P* value for effect size
Suture time	LRYGB	4	419/256	− 4.67	[− 9.16, − 0.17]	$P < 0.00001$; $I^2 = 99\%$	$Z = 2.03$ ($P = 0.04$)
	LSG	1	150/150	− 5.70	[− 7.61, − 3.79]	NA	$Z = 5.84$ ($P < 0.00001$)
	RCT	3	280/280	− 5.90	[− 13.66, 1.86]	$P < 0.00001$; $I^2 = 100\%$	$Z = 1.49$ ($P = 0.14$)
	Cohort	2	289/126	− 3.12	[− 4.13, − 2.11]	$P = 0.20$; $I^2 = 39\%$	$Z = 6.06$ ($P < 0.000001$)
Operative time	LRYGB	6	2676/23089	− 9.17	[− 15.70, − 2.64]	$P < 0.00001$; $I^2 = 90\%$	$Z = 2.75$ ($P = 0.006$)
	LSG	1	150/150	− 1.60	[− 6.34, 3.14]	NA	$Z = 0.66$ ($P = 0.51$)
	RCT	3	280/280	− 0.92	[− 4.61, 2.78]	$P = 0.28$; $I^2 = 21\%$	$Z = 0.49$ ($P = 0.63$)
	Cohort	4	2546/22959	− 12.70	[− 15.64, − 9.75]	$P = 0.18$; $I^2 = 39\%$	$Z = 8.46$ ($P < 0.00001$)
Hospital stay	LRYGB	5	2646/23059	0.03	[− 0.19, 0.25]	$P < 0.00001$; $I^2 = 92\%$	$Z = 0.24$ ($P = 0.81$)
	LSG	2	610/610	− 0.05	[− 0.10, − 0.00]	$P = 0.76$; $I^2 = 0\%$	$Z = 2.00$ ($P = 0.05$)
	RCT	3	710/710	− 0.02	[− 0.06, 0.01]	$P = 0.32$; $I^2 = 13\%$	$Z = 1.2$ ($P = 0.23$)
	Cohort	4	3256/22959	0.05	[− 0.32, 0.46]	$P < 0.00001$; $I^2 = 94\%$	$Z = 0.29$ ($P = 0.77$)
All complications	LRYGB	6	2676/23089	1.13	[0.70, 1.83]	$P = 0.33$; $I^2 = 14\%$	$Z = 0.49$ ($P = 0.63$)
	LSG	2	610/610	0.45	[0.04, 4.92]	$P = 0.01$; $I^2 = 85\%$	$Z = 0.66$ ($P = 0.51$)
	RCT	4	740/740	0.41	[0.11, 1.53]	$P = 0.08$; $I^2 = 56\%$	$Z = 1.32$ ($P = 0.19$)
	Cohort	4	2546/22959	1.25	[0.86, 1.78]	$P = 0.35$; $I^2 = 5\%$	$Z = 1.13$ ($P = 0.26$)
Bleeding	LRYGB	5	376/368	0.42	[0.11, 1.54]	$P = 0.51$; $I^2 = 0\%$	$Z = 1.31$ ($P = 0.19$)
	LSG	2	699/536	0.37	[0.10, 1.41]	$P = 0.44$; $I^2 = 0\%$	$Z = 1.46$ ($P = 0.15$)
	RCT	4	740/740	0.28	[0.09, 0.86]	$P = 0.75$; $I^2 = 0\%$	$Z = 2.23$ ($P = 0.03$)
	Cohort	3	335/164	1.61	[0.17, 15.67]	$P = 0.68$; $I^2 = 0\%$	$Z = 0.41$ ($P = 0.68$)
Stenosis	LRYGB	5	2437/23013	0.64	[0.15, 2.69]	NA	$Z = 0.60$ ($P = 0.55$)
	LSG	1	150/150	2.01	[0.18, 22.45]	NA	$Z = 0.57$ ($P = 0.57$)
	RCT	3	280/280	2.01	[0.18, 22.45]	NA	$Z = 0.57$ ($P = 0.57$)
	Cohort	3	2370/22883	0.64	[0.15, 2.69]	NA	$Z = 0.60$ ($P = 0.55$)
Leak	LRYGB	5	2437/23013	1.27	[0.91, 1.77]	$P = 0.86$; $I^2 = 0\%$	$Z = 1.43$ ($P = 0.15$)
	LSG	2	610/610	0.34	[0.01, 9.47]	P = 0.04; $I^2 = 77\%$	$Z = 0.63$ ($P = 0.53$)
	RCT	3	280/280	0.75	[0.15, 3.78]	$P = 0.17$; $I^2 = 41\%$	$Z = 0.34$ ($P = 0.73$)
	Cohort	3	2307/22883	1.27	[0.90, 1.77]	NA	$Z = 1.34$ ($P = 0.17$)

LRYGB, laparoscopic Roux-en-Y gastric bypass; *LSG*, laparoscopic sleeve gastrectomy; RCT, randomized controlled study; *NA*, not available

Bleeding

Six studies reported data of bleeding outcomes based on 1979 participants (Fig. 2e). Pooling of these studies demonstrated a slightly significant association between the suture types for bleeding (OR = 0.39, 95%CI 0.16 to 1.00, $P = 0.05$, $I^2 = 0\%$) with marginal magnitude. Interestingly, subgroup analysis in RCTs showed that barbed sutures could significantly reduce the conditions of bleeding (OR = 0.28, 95%CI 0.09 to 0.86, $P = 0.03$, $I^2 = 0\%$, Appendix Fig. 5).

Stenosis

Six studies showed data of stenosis based on 25,750 patients (Fig. 2f). Only two studies reported a total of 37 cases with stenosis and the results of the meta-analysis did not show significant difference between barbed suture and control (OR = 0.85, 95%CI 0.27 to 2.68, $P = 0.78$, $I^2 = 0\%$). Subgroup analysis reported consistent results both between bariatric procedures and between study designs (Appendix Figs. 6 and 13).

Leak

Pooling of all the seven studies did not suggest a statistically significant association between the suture types and postoperative leaks (OR = 1.09, 95%CI 0.53 to 2.26, $P = 0.81$, $I^2 = 21\%$, Fig. 2g). Moreover, subgroup analysis based on different study designs also suggested similar results, regardless of LRYGB or LSGC (Appendix Figs. 7 and 14).

Cost

No studies noted the cost-effectiveness of barbed suture in bariatric surgeries and the total cost of the surgery, but one RCT and one prospective cohort study, from Italy and

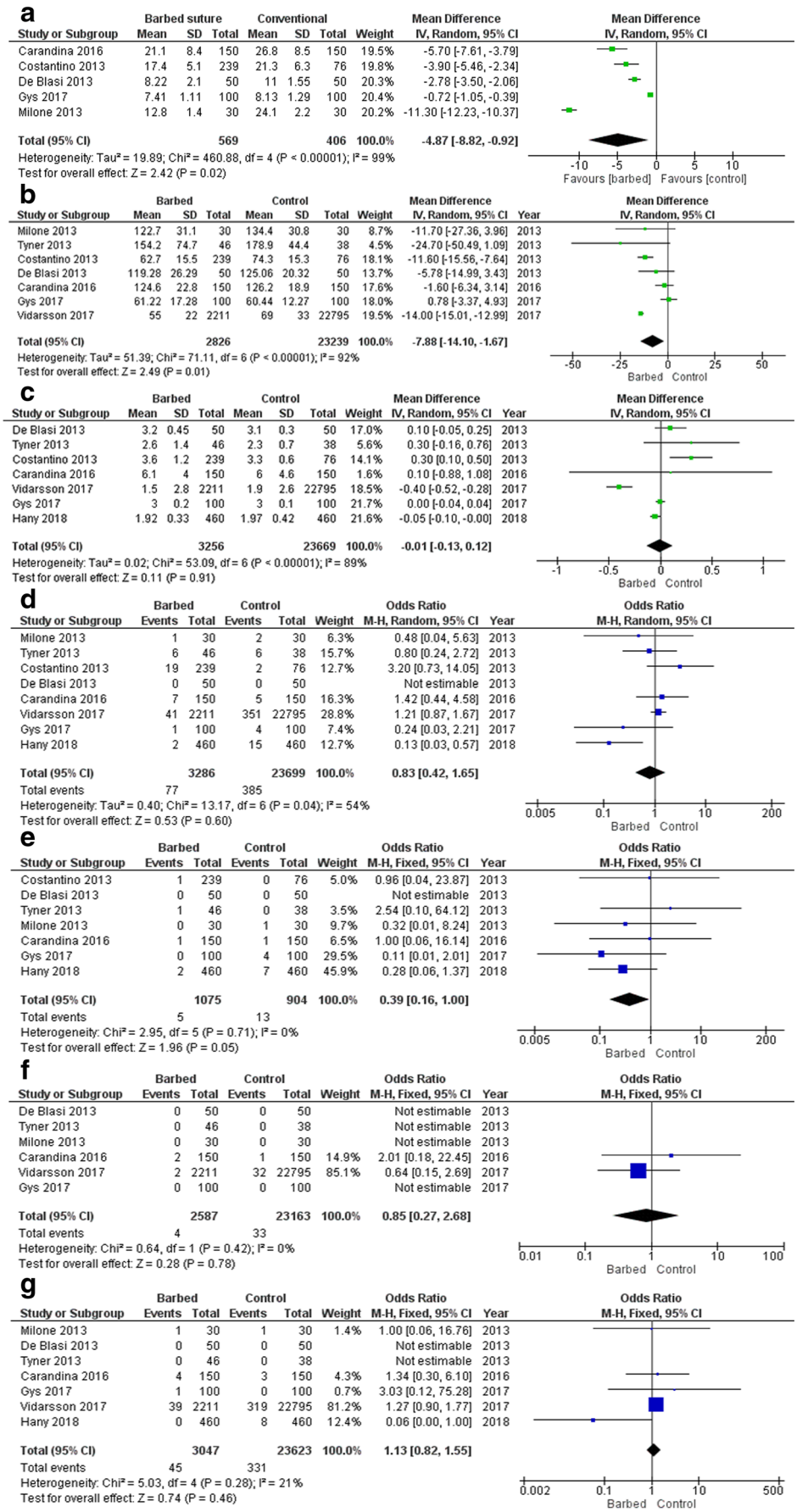

Fig. 2 Forest plots of all the results comparing barbed suture and conventional suture. **a** A forest plot of suture time with or without barbed suture. **b** A forest plot of operative time with or without barbed suture. **c** A forest plot of hospital stay with or without barbed suture. **d** A forest plot of postoperative complications with or without barbed suture. **e** A forest plot of bleeding with or without barbed suture. **f** A forest plot of stenosis with or without barbed suture. **g** A forest plot of leak with or without barbed suture

Luxemburg respectively, mentioned the suture cost for LRYGB (Table 1). Although the results from two studies were not eligible for meta-analysis, both showed that the barbed suture may be cheaper than control. The results need to be interpreted cautiously.

Discussion

In this systematic review, we have included all the controlled studies to test the effects of barbed suture on BS. The pooling of all the studies showed significant decreases of suture time and operative time in barbed suture group, while no significant increases in hospital stay and postoperative complications, including bleeding, stenosis, and leak; the quality of included cohort studies was high to moderate. Besides, the pooling of all the RCTs only showed a significant decline in bleeding conditions in barbed suture group. Specifically, subgroup analysis only suggested that using barbed suture in LRYGB could significantly decrease gastrojejunal anastomosis time and operative time and no significant increase of postoperative complications in barbed suture group.

As the most important factor after BS, both suture time and operative time indicated an overall significant reduction of outcomes in barbed suture groups, especially in LRYGB. This means barbed suture can effectively reduce the suture time, operative time, and even the anesthesia time during BS so as to better the recovery of patients. Different hospitals or surgeons from different countries may be the reason for the high heterogeneity of suture time and it is well-known that performing intracorporeal anastomosis requires specific training and a learning curve in every surgeon. But still, the most can reduce to approximately half of the control [21]. Therefore, this procedure could result in an easier and safer anastomosis, which might be valued by the vast majority of specialists.

People may be initially worried that the barbed suture may cause various side effects to gastrointestinal tract postoperatively. Interestingly, neither more postoperative complications nor longer hospital stay was reported in barbed suture generally comparing to traditional suture. Interestingly, significant reduction of postoperative bleeding of barbed groups was found compared to the traditional suture in our study, despite the fact that no studies claimed the exact estimated blood loss (volume) in each group, which may lead to some confounding factors. What is more, some hemostatic agents used during surgery that were not assessed may also affect the final results. In addition, both stenosis and fistula cases hardly occurred in barbed and traditional suture in our meta-analysis, although we initially supposed that the alien body reactions from any suture could cause surrounding inflammatory reaction which may cause infection, as well as other unexpected outcomes. The reason may be the follow-up not long enough, for only Carandina et al. [24] reported the longest median follow-up time to 36 months, other eligible studies all reported no more than a year (Table 1).

Besides, the severity of those complications, such as stenosis length and volume/length of fistula was not reported in all the studies. The evaluation tools including radiology approaches, for instance, contrast radiography, to figure out the anatomy or functional change should be also considered [25–27]. From a biomechanical point of view [28], reinforcement of staple line using either knotless or knotted sutures may help to prevent leakage. These results were consistent with our findings. Even though no difference was found, Vakil et al. [29] conducted a study regarding different surgeries with a barbed running suture compared to a non-barbed suture with loose stitches. The authors concluded that the ability to maintain the integrity of the suture was higher in the barbed suture.

Whether a new technique is cost-effective can be a main concern to many decision makers. Most cost-effectiveness studies [30, 31] support the use of barbed suture, but none of them were conducted in the bariatric surgery. Our included studies indicated that barbed suture may lower the price, but still lack cost-effectiveness data. Therefore, whether barbed suture was considered to be an inexpensive technique needs more studies to validate.

Our pooled outcome provides convincing evidence for the relationship between the barbed suture and some important surgical indicators for BS. However, there are limitations of this study. (1) The cases of postoperative complications, either the total analysis or subgroup analysis, were similarly low between two groups but the severity evaluation with longer follow-up was not taken into account. (2) Despite that our literature search was extensive, it did not cover conference publications, letters to the editor, and animal studies and (3) because only eight studies were recruited, the risk of publication bias could not be assessed by the Begg's funnel plots. Nevertheless, our result renews a latest meta-analysis on barbed suture in BS. To the best of our knowledge, this is the most comprehensive and the only meta-analysis to date investigating the association between barbed and traditional suture in BS.

Conclusion

Significant declines of suture time, operative time, and bleeding patients were found using barbed suture in BS, with no increases of hospital stay and other postoperative complications, although quality of all the studies was relatively moderate and the number of the included studies was limited. The barbed suture may have the potentiality to be an effective and reliable technique and needs cautious interpretation when extending the application in other bariatric surgeries. Future evidence with higher quality, more randomized-controlled, larger sample sizes, and longer follow-up will be needed to confirm the findings of the present studies.

Authors' Contribution Y Lin: project development, data analysis and management, manuscript writing, and editing

Y Long, S Lai, and Q Guo: data collection

L Du and Y Zhang: data analysis and management, manuscript writing, and editing

J Huang: data analysis and project development

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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