Surgical Endoscopy (2021) 35:2440–2456
https://doi.org/10.1007/s00464-020-08283-z

REVIEW ARTICLE

Robotic bariatric surgery for the obesity: a systematic review and meta-analysis

Zhengchao Zhang[1,2] · Lele Miao[1,2] · Zhijian Ren[1,2] · Yumin Li[1,2]

Received: 16 June 2020 / Accepted: 31 December 2020 / Published online: 21 April 2021

Abstract

Objective The aim of this meta-analysis is to evaluate the safety and efficacy of bariatric surgery (BS) in patients with obesity by robotic bariatric surgery (RBS) compared with laparoscopic bariatric surgery (LBS).

Methods The study was performed through searching in Pubmed, Web of Science, Embase database and Cochrane Library until March 31, 2020 comparing RBS with LBS. Data were calculated on the following endpoints: operative time, length of hospital stay, reoperation within 30 days, overall complications, leak, stricture, pulmonary embolisms, estimated blood loss and mortality. Data as relative risks (OR), or weighted mean difference (WMD) were summarized with 95% confidence interval (CI). Risk of publication bias was assessed through standard methods.

Results Thirty eligible trials including 7,239 robotic and 203,181 laparoscopic surgery cases showed that RBS was referred to attain longer operative time [WMD = 27.61 min; 95%CI (16.27–38.96); $P<0.01$] and lower mortality [OR 2.40; 95% CI (1.24–4.64); $P=0.009$] than LBS. Length of hospital stay [WMD = − 0.02; 95% CI (− 0.19–0.15); $P=0.819$], reoperation within 30 days [OR 1.36; 95% CI (0.65–2.82); $P=0.411$], overall complications [OR 0.88; 95% CI (0.68–1.15); $P=0.362$], leak [OR 1.04; 95% CI (0.43–2.51); $P=0.933$], stricture [OR 1.05; 95% CI (0.52–2.12); $P=0.895$], pulmonary embolisms [OR 1.97; 95% CI (0.93–4.17); $P=0.075$], estimated blood loss[WMD = − 1.93; 95% CI (− 4.61–0.75); $P=0.158$] were almost similar in both RBS group and LBS group. Three was no statistically significant difference between RRYGB and LRYGB in EWL%, no statistical significance between RSG and LSG after 1 year, 2 years and 3 years.

Conclusion RBS presented lower mortality within 90 days and longer operative time in this meta-analysis with similar safety and efficacy for the obesity compared with LBS in other outcomes. Additionally, RBS might be beneficial in the future if it would be evaluated in comprehensive and long-term endpoints.

Keywords Robotic · Laparoscopic · Bariatric surgery · Obesity · Meta-analysis

Obesity is a worldwide chronic disease among all the costly disorders [1]. Lots of therapies could be chosen for the patients with obesity, (e.g., drugs, dietary therapies physical exercise and bariatric surgery). In fact, the effect of drugs, physical exercise and dietary therapy was unobvious for the compliance was not optimistic all around the world [2]. Hence, some patients would like to choose bariatric surgery as an alternative option.

Bariatric surgery is commonly performed to help the obesity lose weight and has been proved valuable for its comorbidities [3]. There were four surgeries could be applied in clinical practice including RYGB(Roux-e-Y Gastric Bypass), SG(sleeve gastrectomy), AGB(adjusted gastric band) and BPD-DS(Biliopancreatic diversion with duodenal switch) [4–6]. Furthermore, all the four types of surgeries can be performed in either laparoscopic or robotic surgery in a minimally invasive way.

Except for the all the merits that laparoscopic bariatric surgery obtained, which includes minimally invasive techniques, high definition vision and precise operation [9], robotic bariatric surgery may acquire more advantages for both patients and surgeons in the long run. Although some meta-analyses [6–8] on this topic have been published, they did not conclude precise results between RBS and LBS; on

✉ Yumin Li
liym@lzu.edu.cn

1 Department of General Surgery, Lanzhou University Second Hospital, Lanzhou 730000, China

2 Key Laboratory of Digestive System Tumors of Gansu Province, Lanzhou 730000, China

the other hand, they did not include all the four surgeries and some new trials have been published recently [21, 27]. Therefore, we performed this meta-analysis to compare RBS and LBS so as to indicate a preferred surgical approach.

Materials and methods

Literature research

A comprehensive systematic literature research in the Pubmed, Web of Science, Embase database and Cochrane Library were performed to retrieve all the relevant articles following the recommendation of the Preferred Reporting Items for Systematic review and Meta-analyses(PRISMA) Statement. All the studies were searched before March 31, 2020 with the limit of "human" and papers in English. The initial search strategies included using random combination of following Medical Subject Heading (Mesh) search terms: "robotic surgery" and "laparoscopic surgery" and "bariatric surgery" and "obesity". The reference list of the identified articles were manual searched to additional studies(Supplementary Table S1).

Criteria for inclusion and exclusion

To be eligible for selection of this meta-analysis, studies were required to meet the following criteria: (1) compare the therapeutic effects of RBS and LBS for the treatment of obesity, (2) report at least one of the outcomes mentioned below, (3) patients were confirmed to have obesity, (4) articles were published as papers only in English. Abstracts, letters, and reviews without original data were excluded. Besides, the following studies were also excluded: (1) studies dealing with open surgery for patients with obesity, (2) case reports and studies lacking control groups, (3) studies with no clearly reported outcomes of interests, (4) patients with drug and dietary therapy.

The primary endpoints were EWL(excess weight loss)% and BMI loss, operative time, length of hospital stay, overall complications reoperations within 30 days. The second endpoints were leak, stricture, estimated blood loss and pulmonary embolisms.

Data extraction and outcome measure

The titles and abstracts of all identified articles were read independently by two reviewers (Lele Miao, Zhijian Ren), and irrelevant ones were excluded according to the PICO principles. Parameters extracted included first author, year of publication, the country in which the study was performed, study design, patient characters, and all available short-term and long-term outcomes. If any disagreement or discrepancy occurred in the studies, the two reviewers consulted a third reviewer (Zhengchao Zhang) until a consensus was reached.

Assessment of methodological quality

The methodological quality of the included studies was assessed by the two reviewers independently using the New castle-Ottawa Scale. Scores were assigned for patient selection, comparability of the study groups, and outcome assessment [10].

Statistical analysis

The effect measures estimated were OR and WMD with a 95% CI for dichotomous variables. Pooled OR and WMD were calculated using either the fixed effects model or random effects model. Heterogeneity was evaluated by X^2 and I^2. $I^2 < 25\%$ and $I^2 > 50\%$ reflect small and large inconsistency, respectively. A funnel plot based on the survival outcomes was conducted to explore the possibility of publication bias(Supplementary Fig. S1). Statistical analyses were performed with State SE 12 software (Stata Corp, College Station, Texas, 77845 USA). A value of $P < 0.05$ was considered statistically significant. Subgroup analysis was attempted because there were three types of surgeries in the meta-analysis. In order to draw publication bias, funnel plots and Egger's test were carried out to evaluate the bias according to the Cochrane Handbook. Sensitivity analysis was performed if more than 10 studies were included for one outcome.

Results

Study selection

A comprehensive and systematic research was performed in all the databases and 1092 articles were yielded. After excluding duplicates, 202 articles were reviewed. Finally, 26 studies were identified comparing RBS with LBS for the obesity through our reading titles, abstracts and full texts, while 2 studies were identified after our manual search. Hence, the 28 studies [11–38] compromising 30 trials were included in this meta-analysis (Fig. 1).

Characteristics and risk of bias

The studies compromised 210,962 patients with obesity, among whom 7547 patients underwent RBS and 203,415 patients underwent LBS. There were 1 RCT, 5 prospective studies and 22 retrospective studies among them. Additionally, 1 study from Brazil, 4 studies from Europe with 23 studies from America reported the outcomes comparing

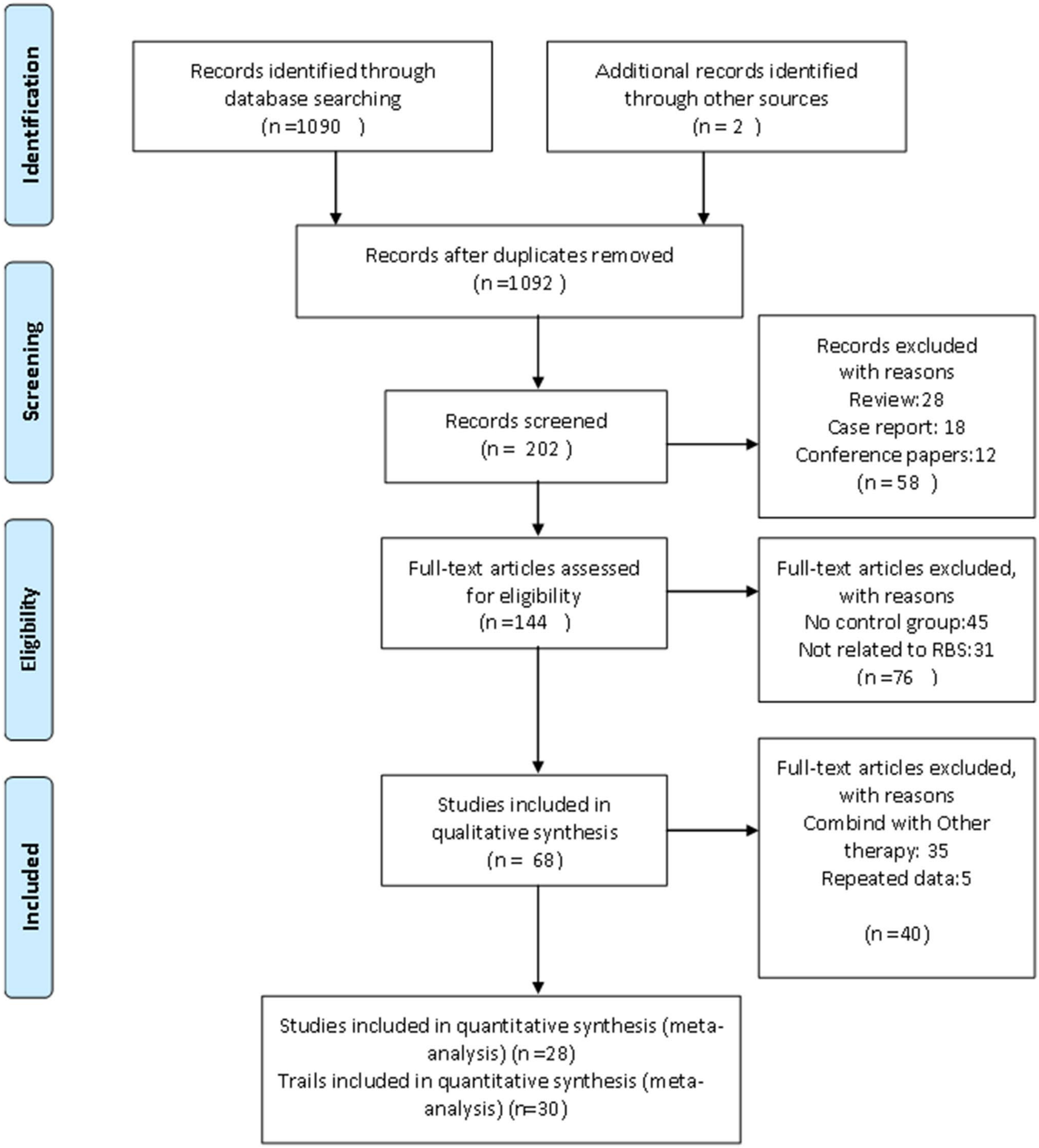

Fig. 1 Follow chart of studies identified, included, and excluded

RBS and LBS. 2 studies were from multi-centers and the rest were from single center. There was 1 study reported 3 trials comprising 3 surgical approaches. More detailed information of the characters is presented in Table 1.

The studies pooled in our meta-analysis of operative time, length of hospital stay, reoperation within 30 days and leak presented high heterogeneity. Therefore, we performed funnel plots and Egger's test. Finally, the funnel plots showed a symmetric distribution and the Egger' test confirmed no publication bias in the incidence of operative time, length of hospital stay, reoperation within 30 days.

Table 1 Characteristics of eligible studies

Study ID	Country	Time period	Type of study	Patients(n)		Female		Mean age(mean ± SD)		Mean preoperative BMI, kg/m^2 (mean ± SD)		NOS
				LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	
Ahmad. 2016 [11]	USA	2011.1–2014.12	R	173	172	127	144	45.8 ± 12.3	47.3 ± 11.3	46.2 ± 6.0	47.4 ± 7.1	7
Ayloo .2011(a) [12]	USA	2006.1–2009.12	R	45	90	42	78	43 ± 8	39 ± 9	46 ± 6	48 ± 6	5
Benizri. 2013 [13]	USA	2007.1–2011.12	P	100	100	N	N	N	N	N	N	7
Buchs. 2014 [14]	Switzerland	2003.1–2013.9	P	389	388	305	284	42 ± 10.4	43.8 ± 10.7	44.8 ± 6.2	44 ± 5.2	7
Celio. 2017 [15]	USA	2007–2012	R	135,040	2415	N	N	45.4 ± 11.7	45.1 ± 11.5	47.5 ± 8.3	47.6 ± 10.8	5
Curet. 2009 [16]	USA	2005.1.1–12.31	R	114	21	N	90.50%	N	46.5	N	45.6	7
Hubens. 2008 [17]	Netherlands	2004.10–2006.4	P	45	45	36	37	39(23–61)	42(21–62)	43.9(35.1–56.2)	44.2(35.1–55.4)	7
Lyn-Sue. 2016 [18]	USA	2012.1–2015.1	R	25	25	N	N	43.4	41.7	46.5	45.3	5
Mohr. 2005 [19]	USA	2002.7–2002.9 2004.3–2004.4	R	10	10	N	N	43.5(33–53)	38.5(34–52)	43.0(36.2–52.8)	45.6(36.6–59)	7
Moon. 2016(a) [20]	USA	2012.1–2014.4	R	206	64	159	46	45.0 ± 1.6	45.9 ± 10.0	48.4 ± 8.1	48.4 ± 7.9	6
Myers. 2013 [21]	USA	2009.10–2011.9	R	100	100	83	76	47 ± 10.83	45.9 ± 9.95	44.6 ± 5.69	45.7 ± 6.31	5
Park. 2011 [22]	USA	2007.1–2009.12	R	195	105	141	83	43.9 ± 10.86	42.2 ± 10.95	47.67 ± 9.42	46.77 ± 8.35	5
Sanchez. 2005 [23]	USA	2004.7–2005.4	P	25	25	22	23	44.4(20–59)	43.3(27–58)	43.4(37–55)	45.5(35–62)	6
Scozzari. 2011 [24]	Italy	2006.9–2009.6	R	423	110	318	83	41.1(19.0–64.0)	42.6(24.0–62.0)	47.3(23.4–70.3)	46.7(33.7–78.2)	7
Snyder. 2010 [25]	USA	2003-	R	356	320	N	N	N	45 ± 10	N	49.1 ± 10.5	5
Smeenk. 2016 [26]	Netherlands	2011.11–2015.1	R	100	100	80	92	42 (18–65/11.87)	39 (20–62/10.21)	42 (35–56/4.75)	40 (35–47/2.66)	6
Stefanidis. 2017 [27]	USA	2007–2015	P	121	125	103	103	42.2 ± 9.8	45.6 ± 11.1	46.7 ± 5.5	48.3 ± 6.7	7
Villamere. 2015(a) [28]	USA	N	R	34,667	1,217	27,288	962	N	N	N	N	5
Wood. 2014 [29]	USA	N	R	100	100	85	74	43.65 ± 9.71	44.25 ± 10.28	48.50 ± 8.35	50.08 ± 9.35	7
Wood. 2014 [29]	USA	N	R	100	100	85	74	43.65 ± 9.71	44.25 ± 10.28	48.50 ± 8.35	50.08 ± 9.35	7
Altieri. 2016 [30]	USA	2012	R	LSG	RSG	LSG	RSG	LSG	RSG	LSG	RSG	
				7690	118	6015	89	N	N	N	N	7
Ayloo. 2011(b) [31]	USA	9/2007–2/2010	P	39	30	35	29	38 ± 10	38 ± 9.1	56 ± 11.7	57 ± 10.7	7
Elli. 2015 [32]	USA	1/2008–12/2013	R	304	105	244	95	41 ± 0.96	41 ± 10.2	51.34 ± 8.95	49 ± 7.05	9
Kannan. 2016 [33]	USA	2/2010–0/2012	R	57	46	32	28	46	46	52.73 ± 11.17	48.69 ± 9.59	9

Table 1 (continued)

Study ID	Country	Time period	Type of study	Patients(n)		Female		Mean age(mean ± SD)		Mean preoperative BMI, kg/m^2 (mean ± SD)		NOS
				LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	
Moon. 2016(b) [34]	USA	6/2008–12/2014	R	378	267	293	189	44.1 ± 11.5	43.4 ± 11.9	45.2 ± 7.6	46.7 ± 7.7	8
Pepper. 2016 [35]	USA	6/2012–8/2014	R	14	14	10	12	18	17	48	43	5
Schraibman. 2014 [36]	Brazil	1/2011–3/2013	P	32	16	16	6	46 ± 13	43 ± 16	39.41(37.96–40.86)	41.44(39.33–43.56)	9
Vilallonga. 2013 [37]	Spain	9/2006–11/2012	P	100	100	64	79	43 ± 11	44 ± 11	47 ± 6	48 ± 8	9
Villamere. 2015(b) [28]	USA	10/2010–2/2014	R	18,694	957	14,400	738	N	N	N	N	5
				LAGB	RAGB	LAGB	RAGB	LAGB	RAGB	LAGB	RAGB	
Villamere. 2015(c) [28]	USA	10/2010–2/2014	R	3753	75	N	N	N	N	N	N	5
Edelson. 2010 [38]	USA	12/2006–6/2009	R	120	287	89	230	47 ± 11.2	45 ± 11.3	45.1 ± 6.7	45.4 ± 5.5	5

RRYGB robotic Roux-e-Y Gastric Bypass, *LRYGB* laparoscopic Roux-e-Y Gastric Bypass, *RSG* robotic sleeve gastrectomy, *LSG* laparoscopic sleeve gastrectomy, *RAGB* robotic adjusted gastric band, *LAGB* laparoscopic adjusted gastric band. *SD* standard deviation

Sensitivity analysis

We performed sensitivity analysis on outcomes with high heterogeneity to investigate their potential sources and assess the robustness of these outcomes by omitting each of the included studies one by one to each outcomes. Due to lacking enough eligible studies to meet 10 studies, other outcomes can not be assessed for the potential publication bias in fact. We conducted the sensitivity by excluding the lowest-quality study each time, and finally we found that there were not relevant studies influencing the results (Supplementary files).

Primary outcomes

EWL% and BMI loss

The assessment of weight lose is EWL%, which indicates that the effect of weight lose of the two comparable methods. Unfortunately, there were not enough eligible articles to draw a comparison between RBS and LBS in this meta-analysis (Table 2).

Park [22] and Stefanidis [27] reported EWL% after 1 year, which all presented no statistically significant difference between RRYGB and LRYGB in EWL%(RRYGB 61.9% versus LRYGB 61.3% in Park and RRYGB 84% versus LRYGB 77% in Stefanidis). Four studies reported EWL% in RSG group after 12 months and four studies reported EWL% in LSG group. Elli [32] showed no statistical significance between RSG and LSG after 1 year, 2 years and 3 years. Vilallonga [37] showed no statistical significance in RSG and LSG groups (66% in RSG versus 67% in LSG, $P=$ NS). Pepper [35] reported the EWL% after 1 month in RSG and LSG indicating an equivalent EWL% in both groups [RSG 18(range: 16.6 to 21.2) versus LSG 18(range:16 to 22), $P=1.000$]. Kannan [33] reported the EWL% after 1 year, indicating a favor in RSG group (57% in RSG versus 48% in LSG, $P=0.09$). As for the RAGB and LAGB, RBPD-DS AND LBPD-DS, there were few article reported the EWL% after surgery.

In addition, BMI loss can demonstrate the efficiency weight loss at the same time. Buchs [14] and Lyn-Sue reported BMI loss in the RRYGB and LRYGB groups. Interestingly, Buchs presented a lower BMI loss after 24 months in RRYGB group (RRYGB 15.3 ± 4.4 versus LRYGB 17.1 ± 5.5), while Lyn-Sue [18] offered a same BMI loss after 12 months in both RRYGB and LRYGB. Elli reported no statistical significance in BMI loss in RSG and LSG groups lacking standard deviation.

Operative time

15 trials [11–13, 15, 17, 19–21, 24, 25, 27, 29, 31, 32, 35] reported operation time comparing RBS and LBS including 141,009 participants [WMD = 27.61 min; 95% CI (16.27–38.96); $P<0.01$] with heterogeneity ($I^2=96.4\%$, $P<0.001$). There was slightly significantly difference in the operation time indicating LBS taking shorter time.

In RYGB group, RBS showed a longer operation time with 12 trials [11–13, 15, 17, 19–21, 24, 25, 27, 29] [WMD = 27.55 min; 95% CI (12.67–42.42); $P<0.001$] with heterogeneity ($I^2=97.1\%$, $P<0.001$). 1 trial [19] indicated no significant difference, 2 trials [12, 13] indicated shorter operative time in RBS and 9 studies [11, 15, 17, 20, 21, 24, 25, 27, 29] indicated longer operative time in RBS.

In SG group, RBS also showed a longer operative time with 3 trials [31, 32, 35] [WMD = 28.69 min; 95% CI (22.84–34.53); $P<0.001$] with heterogeneity ($I^2=28.9\%$, $P=0.245$) (Fig. 2).

Length of hospital stay

There was no significant difference in length of hospital stay for RBS [21 trials [11–14, 18–20, 24, 25, 28–35, 37], 189,685 participants, WMD = -0.02; 95% CI (−0.19–0.15); $P=0.819$] with heterogeneity ($I^2=83.2\%$, $P<0.001$).

In RYGB group, 2 trials [12, 14] reported shorter length of hospital stay in RBS, 1 trial [13] reported longer length of hospital stay in RBS and the rest [18–20, 24, 25, 28, 29] reported no statistical significance in RBS and LBS [WMD = −0.06; 95% CI (−0.29–0.17); $P=0.608$] with heterogeneity ($I^2=84.6\%$, $P<0.001$).

In SG group, 2 trials [32, 35] reported shorter length of hospital stay in RBS, 1 trial [34] reported longer length of hospital stay in RBS and the rest [30, 31, 33] reported no statistical significance in RBS and LBS [WMD = 0.00; (95% CI −0.38–0.38); $P=0.987$] with heterogeneity ($I^2=84.6\%$, $P<0.001$).

In AGB group, 1 trial [37] reported no statistical significance in RBS and LBS [WMD = 0.15; 95% CI (−0.08–0.38); $P=0.193$] (Fig. 3).

Reoperation within 30 days

There was no significant difference in reoperation within 30 days for RBS [9 trials [14, 18, 20, 21, 27, 33, 34, 37, 38], 140,303 participants, OR 1.36; 95% CI (0.65–2.82); $P=0.411$] with heterogeneity ($I^2=64.8\%$, $P=0.004$).

In RYGB group, pooled data reported no statistical significance in RBS and LBS [OR 1.24; 95% CI (0.37–4.18); $P=0.725$] with heterogeneity ($I^2=80.2\%$, $P=0.000$). Among them, 2 trials [14, 27] showed lower reoperation within 30 days in RBS, while 3 trials [18, 20, 21] showed

Table 2 EWL% of different periods in RBS and LBS

Study	(%EWL) 1 month		(%EWL) 3 months		(%EWL) 6 months		(%EWL) 12 months		(%EWL) 24 months		(%EWL) 36 months	
ID	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB	LRYGB	RRYGB
Ayloo, 2011(a) [12]	N	N	N	35.40% [I]	N	49.80%	N	60.30%	N	N	N	N
Buchs, 2014 [14]	26.3 ± 9.2 [II]	26.2 ± 2	N	N	N	N	83.9 ± 19	79.7 ± 23.1	87.4 ± 25	83.5 ± 21.1	83.6 ± 19.5	75.2 ± 22
Park, 2011 [22]	N	N	N	N	N	N	61.3 ± 15.1	61.9 ± 15.5	N	N	N	N
Scozzari, 2011 [24]	N	N	N	33.6 (10–76.2) [III]	N	50.9 (24.5–102.4)	N	62.1 (21.9–87.3)	N	64.5 (33.3–88.5)	N	64.4 (41.5–85.)
Stefanidis, 2017 [27]	N	N	N	N	N	N	84%	77%	N	N	N	N
	LSG	RSG	LSG	RSG	LSG	RSG	LSG	RSG	LSG	RSG	LSG	RSG
Elli, 2015 [32]	29	29.49	N	N	42.6	44.52	52.23	48.89	N	N	N	N
Kannan, 2016 [33]	N	N	N	N	34 ± 16.5	39 ± 12	48 ± 28.2	57 ± 20.4	N	N	N	N

I the percentage of extra weight loss, *II* The mean and standard deviation (SD) of extra weight loss. *III* the mean and range (minimum to maximum) of weight loss higher reoperation within 30 days in RBS, specifically in RYGB group.

In SG group, 3 trials [33, 34, 37] reported no statistical significance in RBS and LBS [OR 2.08; 95% CI (0.74–5.86); $P=0.168$] without heterogeneity ($I^2=0.0\%$, $P=0.419$).

In AGB group, 1 trial [38] reported no statistical significance in RBS and LBS [OR 1.26; 95% CI (0.34–4.75); $P=0.730$] (Fig. 4).

Overall complications

There was no significant difference in overall complications for RBS [16 trials [15, 17, 19–25, 28, 29, 31, 37, 38], 163,587 participants, OR 0.88; 95% CI (0.68–1.15); $P=0.362$] without heterogeneity ($I^2=29.0\%$, $P=0.133$).

In RYGB group, 12 trials [15, 17, 19–25, 28, 29] reported no statistical significance in RBS and LBS [OR 0.96; 95% CI (0.76–1.2); $P=0.712$] without heterogeneity ($I^2=22.0\%$, $P=0.228$).

In SG group, 3 trials [28, 31, 37] reported no statistical significance in RBS and LBS [OR 0.43; 95% CI (0.12–1.56); $P=0.195$] without heterogeneity ($I^2=0.0\%$, $P=0.783$).

In AGB group, 1 trial [38] reported less overall complications in RBS and LBS [OR 0.06; 95% CI (0.00–0.90); $P=0.042$] (Fig. 5).

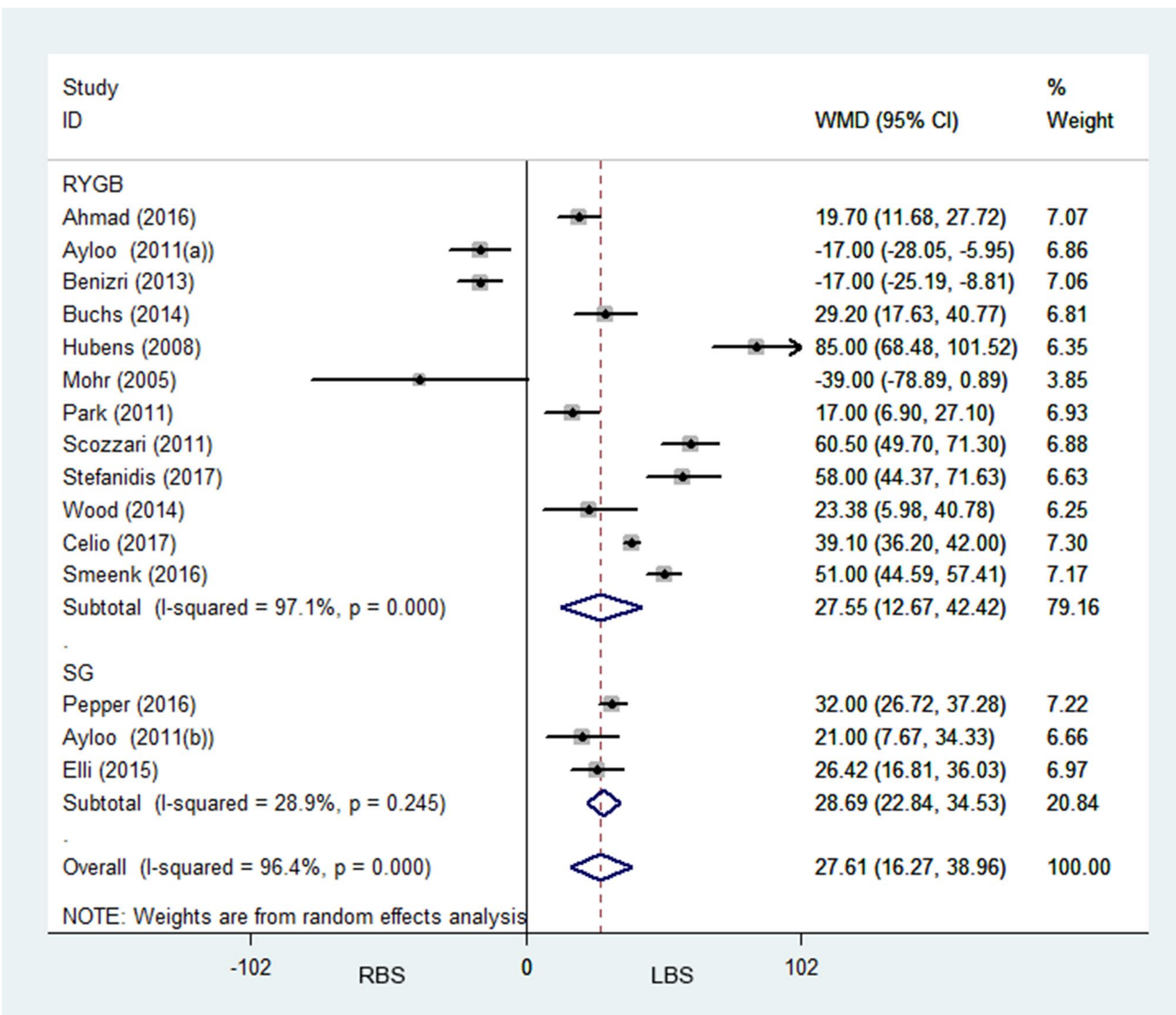

Fig. 2 A meta-analysis of operative time for RBS versus LBS

Secondary outcomes

Leak

There was no significant difference in leaks for RBS [14 trials [12–15, 17, 19–25, 34, 37], 141,551 participants, OR 1.04; 95% CI (0.43–2.51); $P = 0.933$]. Also, there were mild heterogeneity in the comparison ($I^2 = 69.7\%$, $P < 0.001$).

In RYGB group, 1 trial [14] presented lower leaks in RBS, while 2 trials [15, 20] presented higher leaks in RBS. Overall data indicated no significant difference in RBS and LBS [OR 1.20; 95% CI (0.44–3.22); $P = 0.723$] with heterogeneity ($I^2 = 69.8\%$, $P < 0.001$).

In SG group, 2 trials [34, 37] showed no significant difference in RBS and LBS [OR 0.54; 95% CI (0.15–1.86); $P = 0.326$] without heterogeneity ($I^2 = 0.0$, $P = 0.465$) (Fig. 6).

Pulmonary embolisms

There was no significant difference in pulmonary embolisms for RBS [4 trials [12, 14, 20, 25], 1,858 participants, OR 1.97; 95% CI (0.93–4.17); $P = 0.075$] without heterogeneity ($I^2 = 0\%$, $P = 0.891$) (Fig. 7).

Estimated blood loss

There was no significant difference in estimated blood loss for RBS [4 trials [11, 22, 27, 31], 960 participants, WMD = − 1.93; 95% CI (− 4.61–0.75); $P = 0.158$] without heterogeneity ($I^2 = 0\%$, $P = 0.652$).

In RYGB group, 3 trials [11, 22, 27], showed no statistical significance in RBS. [WMD = − 2.01; 95% CI (− 4.80–0.78); $P = 0.158$] without heterogeneity ($I^2 = 0\%$, $P = 0.450$).

In SG group, 1 trial [31], reported no statistical significance in RBS. [WMD = − 1.00; 95% CI (− 10.73–8.73); $P = 0.840$] (Fig. 8).

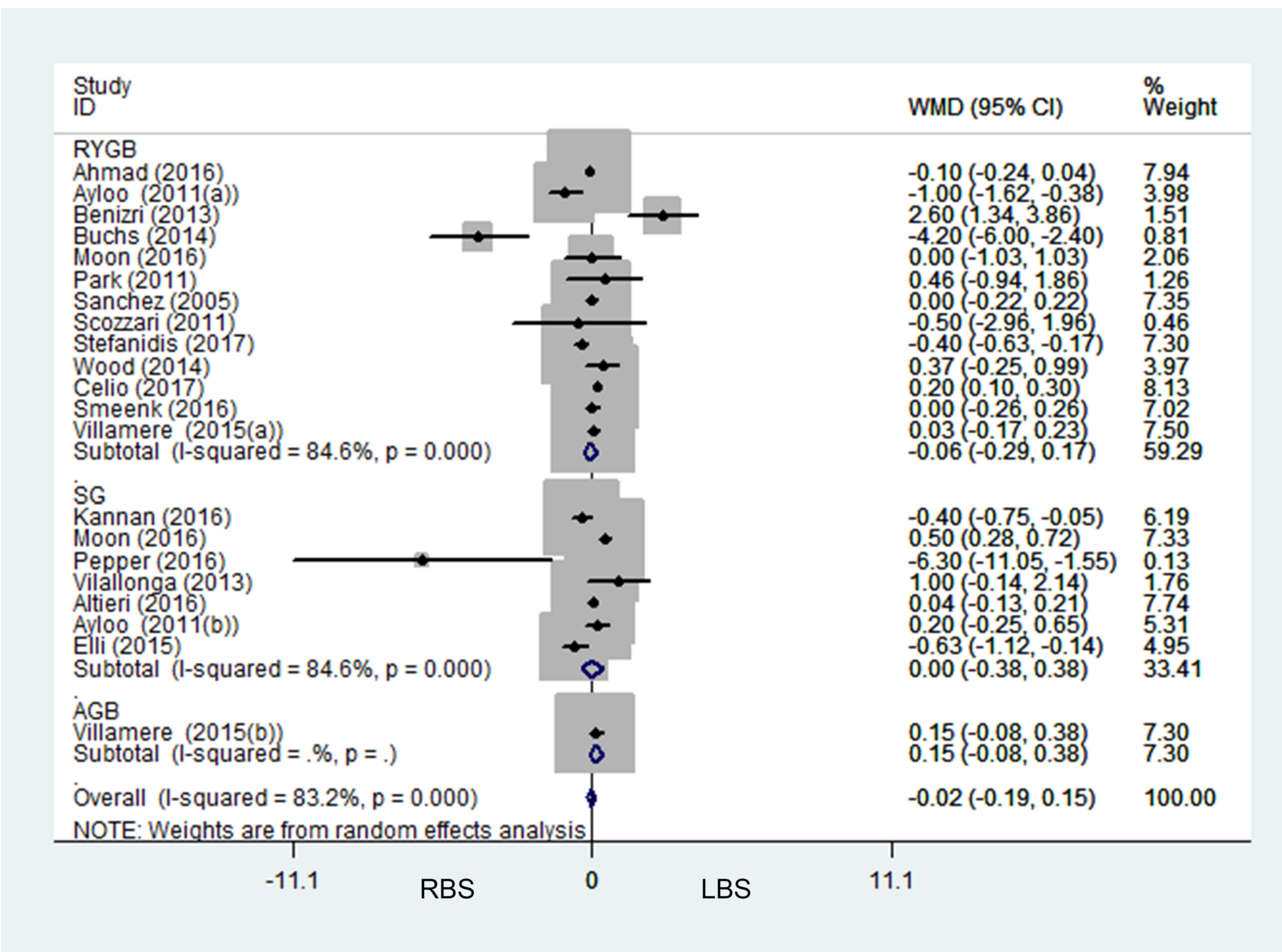

Fig. 3 A meta-analysis of length of hospital stay for RBS versus LBS

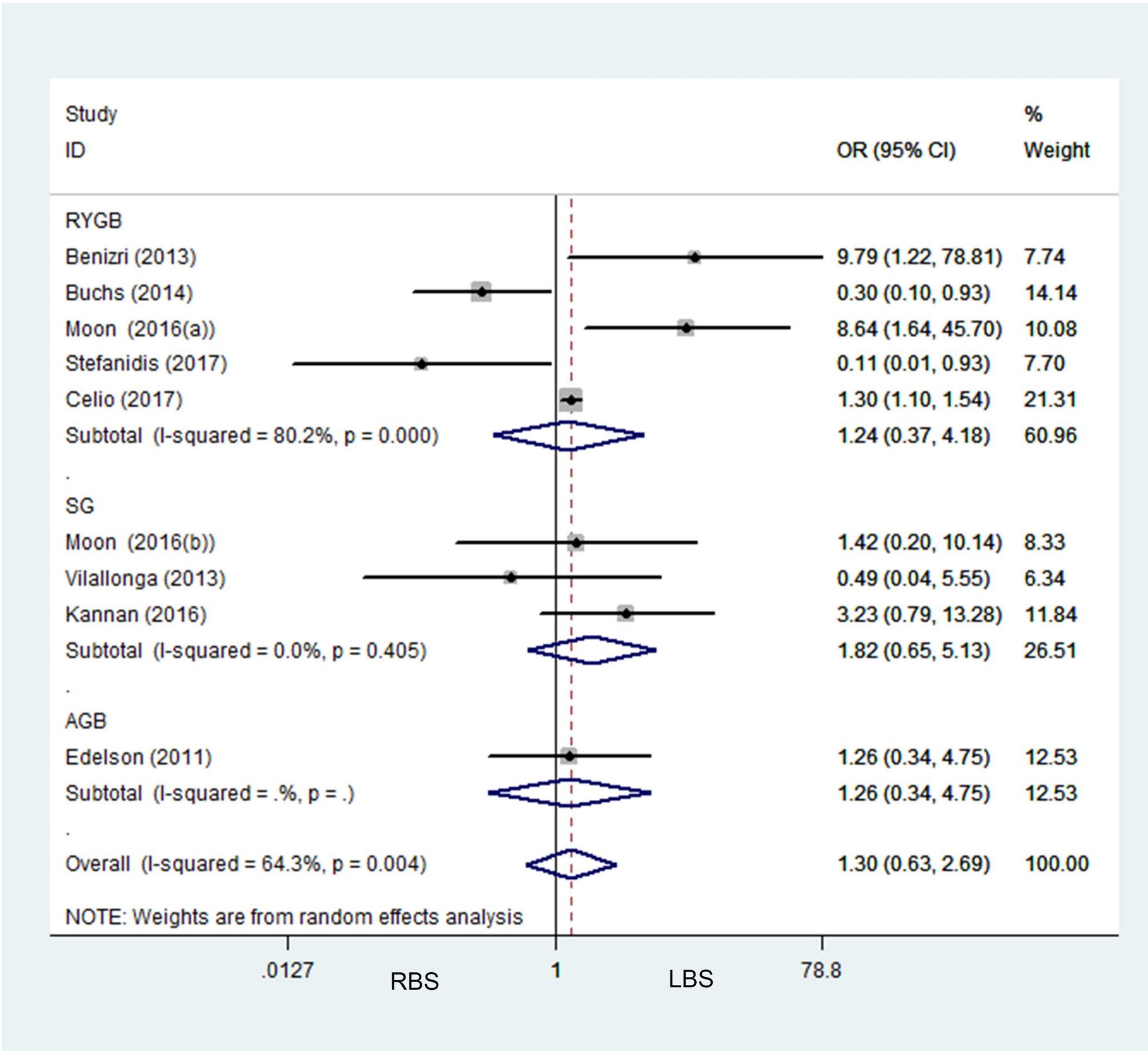

Fig. 4 A meta-analysis of reoperation within 30 days for RBS versus LBS

Stricture

11 trials [12, 13, 15, 17, 18, 21, 22, 24–27] reported no significant difference in stricture for RBS including 140,430 participants [OR 1.05; 95% CI (0.52–2.12); $P=0.895$] with heterogeneity ($I^2=55.2\%$, $P=0.014$). (Fig. 9).

Discussion

This meta-analysis compared RBS and LBS in perioperative outcomes and postoperative outcomes including 30 trials compromising 4 surgical approaches. Although there were only 1 RCT among the 30 trials, well-designed meta-analysis including non-RCTs could also provide moderate

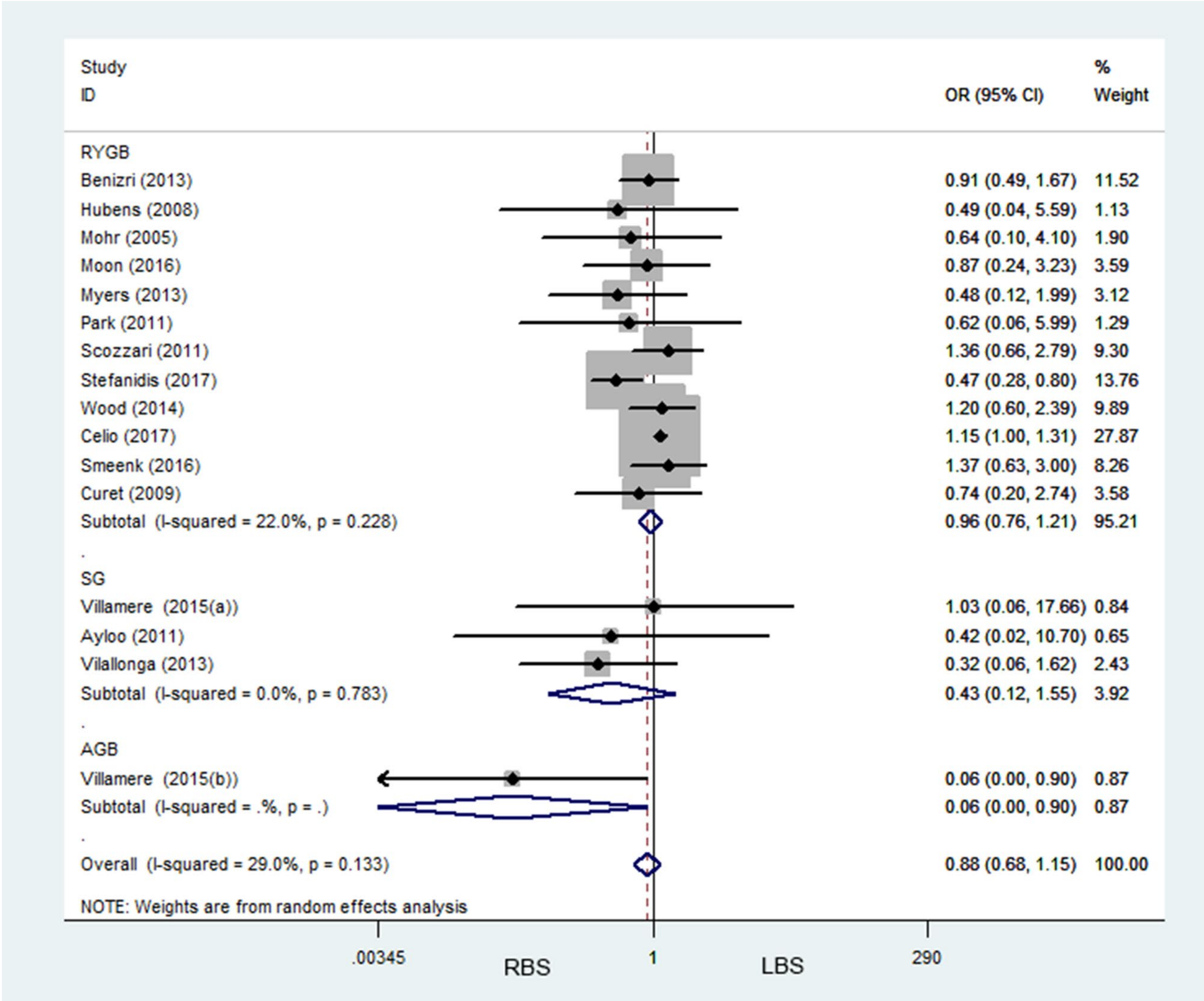

Fig. 5 A meta-analysis of overall complications for RBS versus LBS

or high-quality evidence from the results. Our meta-analysis examined all the outcomes with the latest studies published until now. We assessed the studies strictly and extracted data prudently to evaluate the safety and efficacy in RBS fairly. Weight loss was the necessary outcome for RBS no matter which type of surgery was performed but unfortunately, there was not enough data to extract to evaluate the true safety between RBS and LBS. Operative time was showed longer in RBS and length of hospital stay was not significantly different between RBS and LBS. Estimated blood loss was reported no significant difference in RBS. Reoperation within 30 days, leak, stricture, pulmonary embolism and overall complications were indicated no significant difference in RBS. Interestingly, mortality within 90 days was revealed in favor of RBS with lower percentage.

As for the effect of weight loss induced by RBS, it is an imperative factor to evaluate the efficiency of weight loss caused by the two surgical approaches between the RBS and LBS [39]. According to our results, RBS may be not inferior to LBS during different periods for weight loss assessed by EWL% and BMI loss. In different surgical approaches, there were not significant difference among the four types of surgeries in RBS, in other words, RBS did not show advantages in different surgeries. However, RYGB performed by RBS revealed a slight favor in weight loss compared to LBS especially after 12 months in Kannan's [33] study(EWL%:57% in RSG versus 48% in LSG, $P = 0.09$), while SG showed no significant difference in either RBS or LBS. Our meta-analysis presented no significant difference in weight loss that RBS can be beneficial according to our results. In fact, there also need more researches to compare the weight loss between RBS and LBS to provide more prudent evidence. As for cost, RBS showed more expense obviously for RBS need more

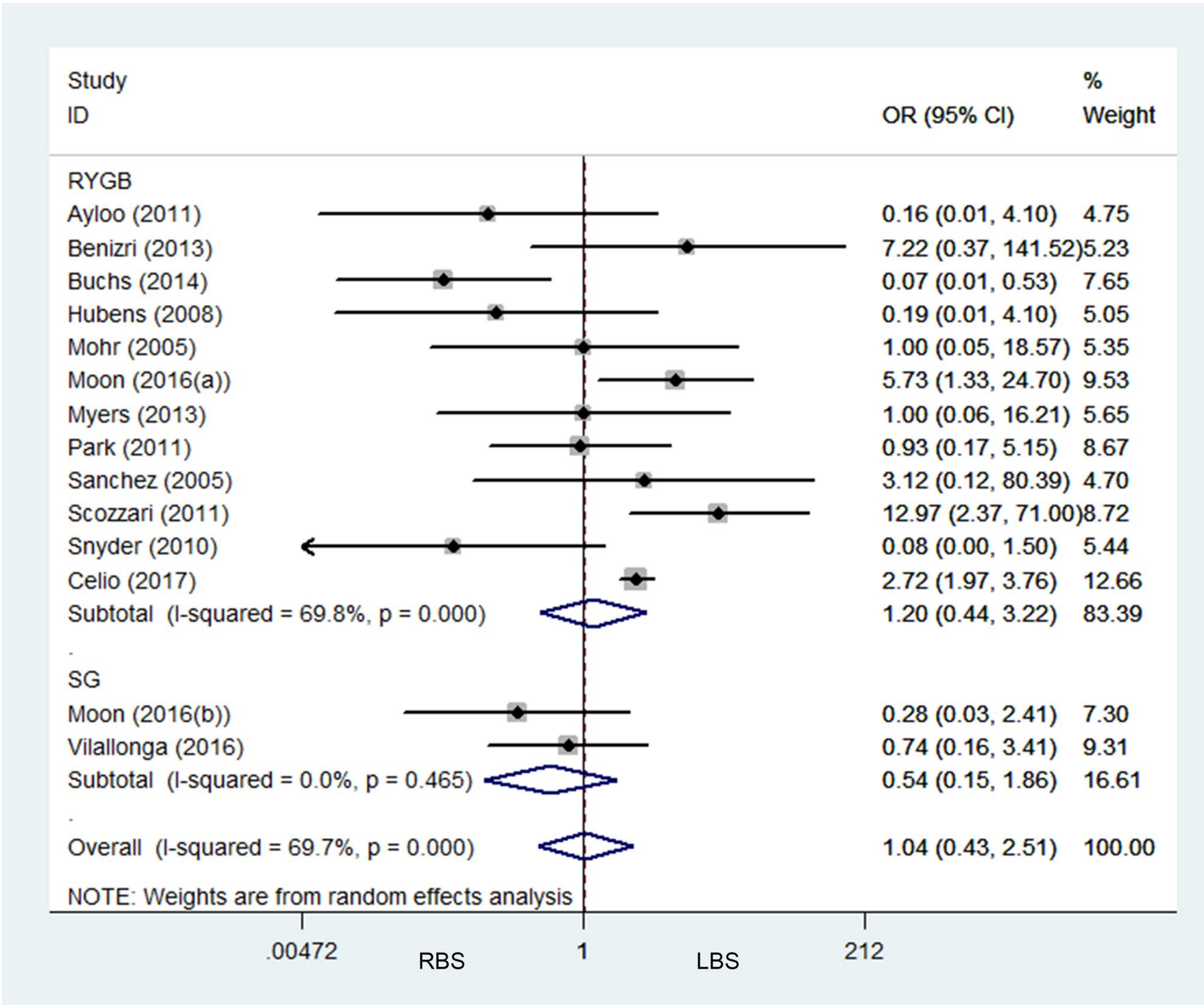

Fig. 6 A meta-analysis of leak for RBS versus LBS

advanced techniques, more auxiliary instruments and ICU fees probably [40, 41]. After the popularization of robotic surgery, cost of RBS may decrease partially in the future. To the best of our knowledge, there may be the first meta-analysis to compromise three surgical approaches in RBS comparing weight loss including all the efficient outcomes (e.g., EWL% and BMI loss). Besides, we found that lots of studies comparing RBS and LBS did not report weight loss induced by surgery normatively and detailedly resulting in lack of enough data. So we suggested that studies should pay more attention to weight loss in the future.

Operative time was showed longer in RBS including RYGB and SG with high heterogeneity in our meta-analysis ($I^2 = 96.4\%$, $P < 0.001$). RBS operations required an additional 27.61 min to perform. Recent meta-analysis [6] focusing on the RBS also showed longer operative time in RBS [SMD = 0.61, 95% (CI 0.25–0.96), $P < 0.0001$].Other studies focused on robotic surgery for abdominal operation revealed longer operative time [Francesco Paolo Prete [42], MD = 38.43; 95% CI (31.84–45.01):$P < 0.00001$, $I^2 = 4\%$, Hengrui Liang [43], SMD = 0.30, 95% CI (0.04–0.64), $P = 0.086$]. The mild difference between RBS and LBS were the operative time, while another study showed a shorter learning curve in RBS [44].Among all the studies reporting operative time, 2 studies indicated shorter operative time in RBS, while 12 studies indicated longer operative time in RBS. Besides, only five studies defined the operative time as the interval from incision to wound closure without docking time for the robotic surgery. Other studies did not define the operative time precisely, which may result in the high heterogeneity. The time spending on the instruments installation in robotic procedure may prolong operative time compared

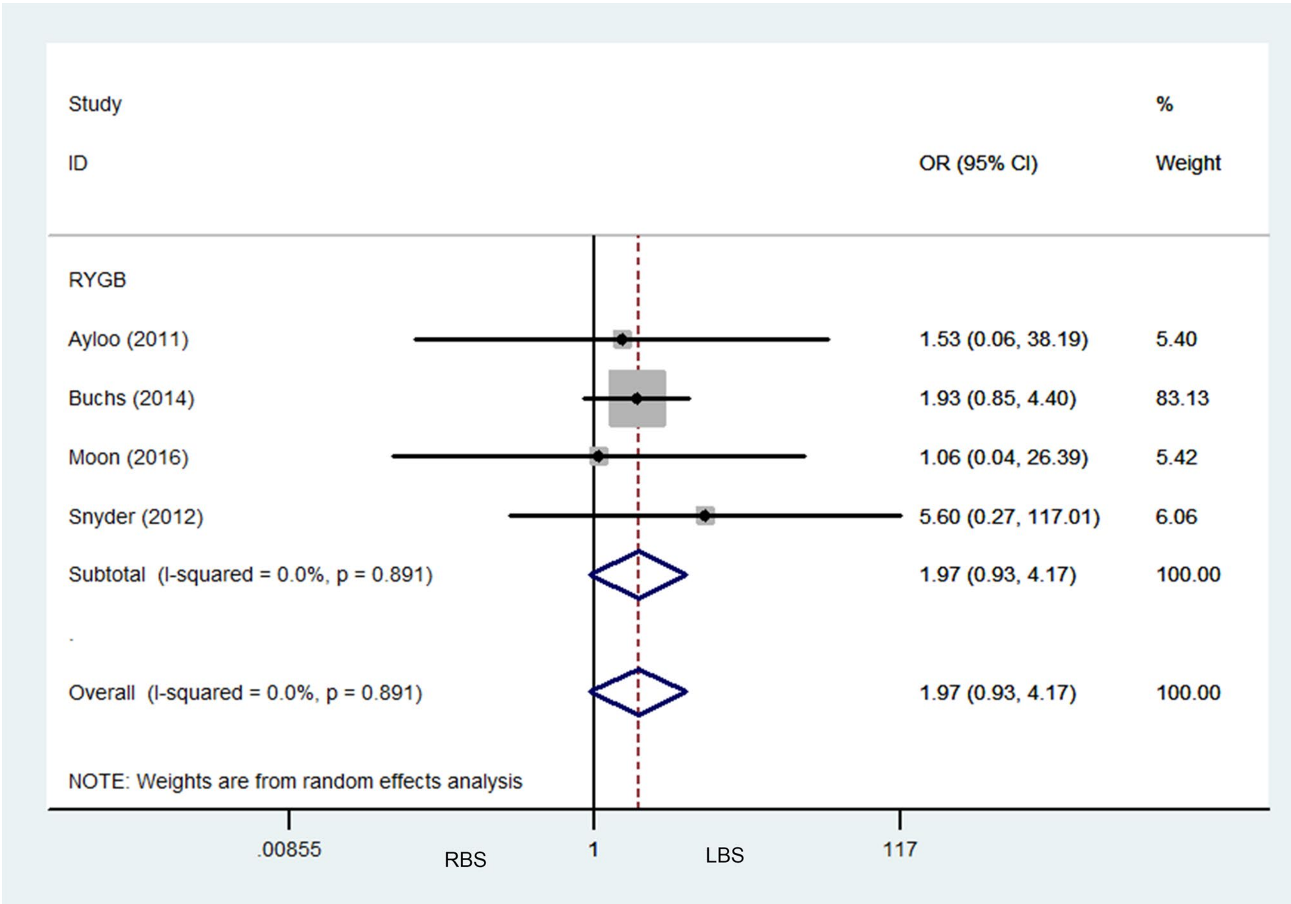

Fig. 7 A meta-analysis of pulmonary embolisms for RBS versus LBS

with LBS and most of hospitals included studies were teaching hospitals so during the surgery resident doctors or juniors need to learn professional knowledge from the surgeons. What is more, the definition of operative time should be clear and unified in the studies, otherwise the heterogeneity may be not avoided and the evidence cannot be reliable.

Likely, length of hospital stay was assessed to evaluate the efficacy of RBS in most studies and we reported no significant difference in RBS. The recent meta-analyses [6] showed similar outcomes in the length of hospital stay between robotic surgery and laparoscopic surgery either for bariatric surgery or robotic surgery of abdominal operation [Kun Li [6], SMD = −0.02, 95% CI (0.17–0.12), $P = 0.77$, Francesco Paolo Prete [42], MD = 0.61; 95% CI (2.23–1.02), Hengrui Liang [43], SMD = −0.08, 95% CI (0.23–0.07), $P = 0.292$]. Length of hospital stay was not defined precisely and consistently. Among all the studies reporting length of hospital stay, 5 studies reported shorter length of hospital stay in RBS, while 2 studies reported longer length of hospital stay in RBS. Additionally, Buchs reported the overall hospitalization time, while Moon and Mohr reported the prolong hospitalization time, which may lead to heterogeneity in the comparison. Owing to the lack of normative data, the heterogeneity was hard to be avoided and the evidence may be low. Therefore, we hope more and more studies will define length of hospital stay precisely in order to provide reliable results. Recent studies comparing robotic surgery and laparoscopic surgery almost conclude the same conclusion for the robotic surgery, indicating no significant difference in RBS.

During pooling a comparison between RBS and LBS, it is vital for surgeons to choose a preferred surgery to reduce mortality for patients with obesity. However, there is few meta-analysis comparing mortality between RBS and LBS. Mortality within was defined as death occurred in the operation or after operation, all the alive participants include in the studies all account for the whole mortality within 90 days. In our meta-analysis, we presented lower mortality in RBS. Actually, there were 9 deaths among 5187 participants in RBS, while 156 cases who were dead among 189,313 participants in LBS. According to the studies which presented mortality, we ascribe the mortality to these causes like circulatory and pulmonary comorbidities. Another study [43] focusing on robotic

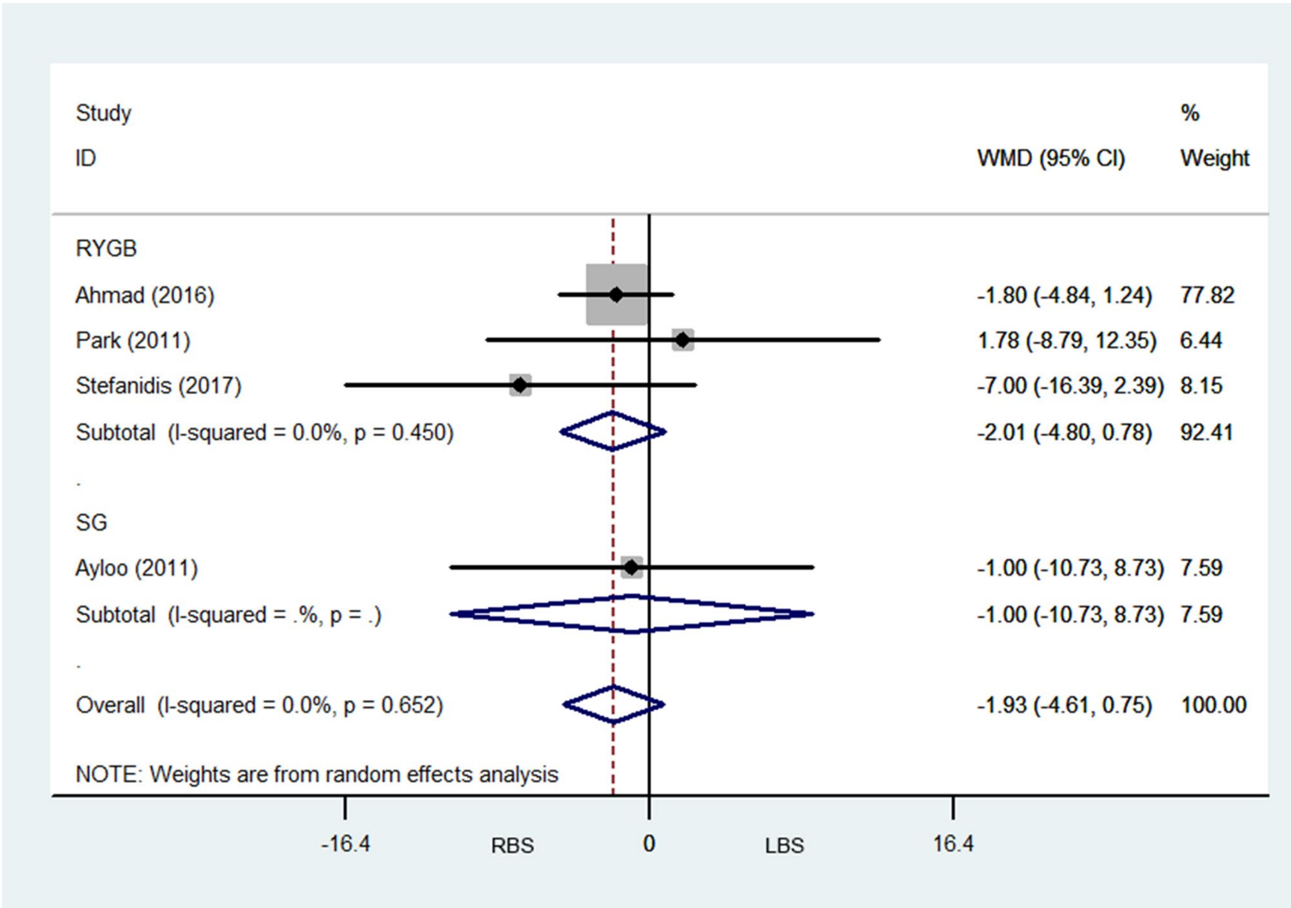

Fig. 8 A meta-analysis of estimated blood loss for RBS versus LBS

surgery for abdominal surgery indicated that robotic surgery can reduce mortality to some extent [OR 0.53, 95% CI (0.29–0.99), $P=0.045$]. As far as the mortality happened in the bariatric surgery, there may be caused by its comorbidities and postoperative complications. On the other hand, RBS may reduce postoperative complications partly for RBS can make the wound exposed less during operative and postoperative situations.

We found no significant difference in length of hospital stay, reoperation within 30 days, overall complications, leak, stricture, pulmonary embolisms and estimated blood loss. In contrast to other meta-analysis on RBS, our meta-analysis showed almost the similar trend in RBS for the common outcomes. Hence, these outcomes may manifest that RBS was not prior to LBS, while the hypothesis predicted that RBS is beneficial for clinical practice. Moreover, some studies discussed the rate of conversion to open surgery or laparoscopic surgery focusing on abdominal surgery but we found that learning curve and the proficiency of surgery influenced the rate in a large part.

Besides, there are four major types of surgeries for the obesity patients, such as RYGB, SG, AGB and BPD-DS. Until now, the choice of the four types of surgeries for the surgeons also needs scientific and prudent evidence. In RYGB group, pooled data showed no significant difference in EWL% and BMI loss, reoperation within 30 days, overall complications, leaks, pulmonary embolisms and intra-operation blood loss. Longer operative time and lower mortality within 90 days were presented in RBS. Furthermore, a slight trend was revealed in RBS with shorter length of hospital stay and higher stricture in RBS. In SG group, only longer operative time was presented in RBS with a slight trend of shorter length of hospital stay in RBS. Other outcomes indicated no significant difference in RBS. In AGB group, RBS revealed less overall complications [OR 0.06; 95% CI (0.00–0.90); $P=0.042$]. Due to lacking enough data, only length of hospital stay and reoperation within 30 days reported, while outcomes showed no significant difference. In BPD-DS group, there were not articles comparing RBS with LBS in BPD-DS, so we can not draw data analysis for the forest plots. Recent studies [45–49] have reported that robotic BPD-DS can be safe and efficient, especially for the high-BMI patients with lower complications and shorter length of hospital stay. Above all, this systematic review

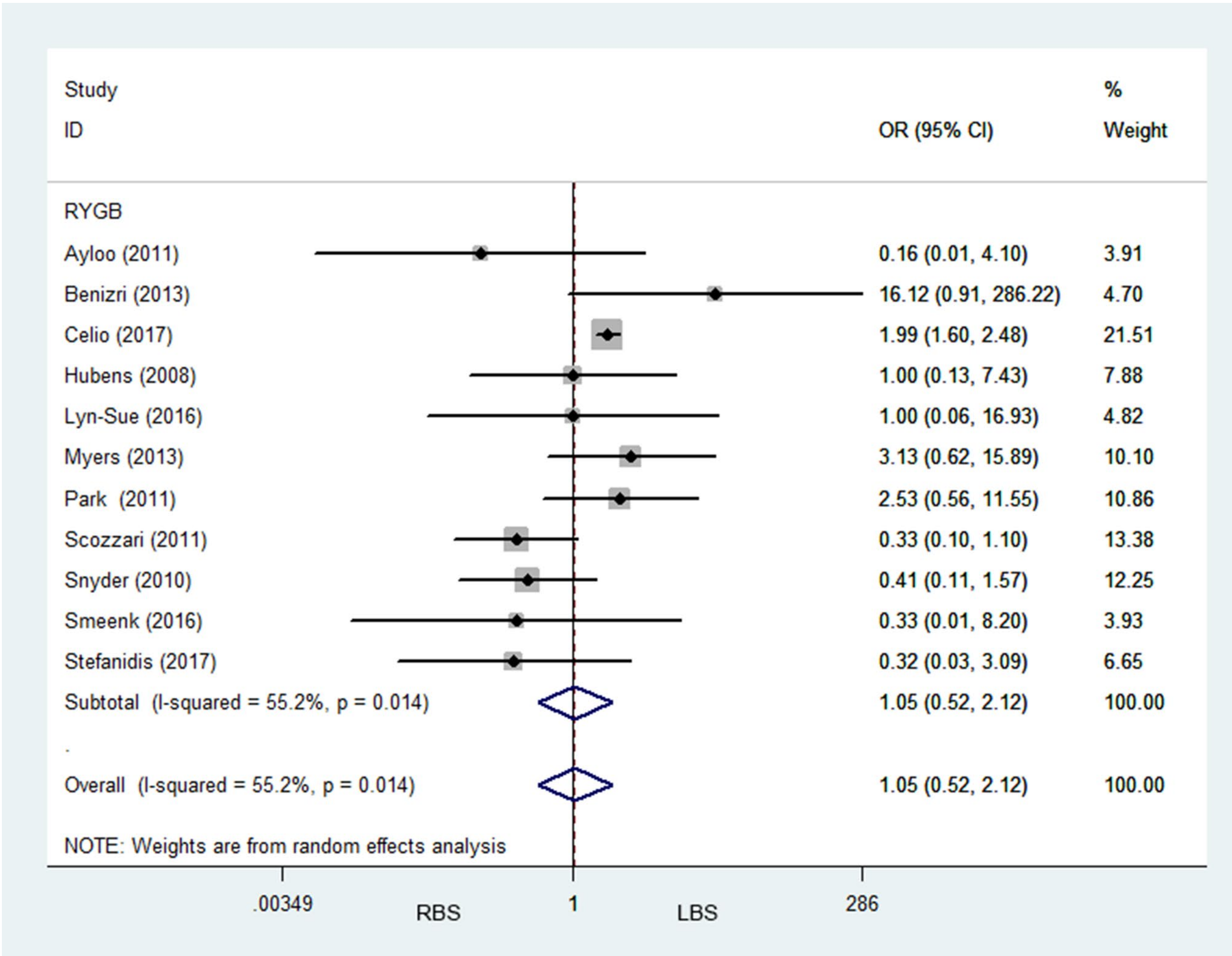

Fig. 9 A meta-analysis of stricture for RBS versus LBS

recommended weak suggestions in RBS for the surgeons with all the results.

The previous meta-analysis [6] compared the robotic bariatric surgery and laparoscopic bariatric surgery and revealed that RBS and LBS have no difference between length of hospital stay, overall complications, leak and stricture, while RBS have longer operative time and cost. Meanwhile, our meta-analysis showed slightly different results including 30 trials with longer operative time, higher cost and lower mortality within 90 days. However, our meta-analysis was not the same as the previous meta-analysis for this previous study may have some problems with the data extraction. Ayloo published the relevant articles in 2011 [12] and 2016 [50] which all discussed the RRYGB and LRYGB without providing the exact patients characters. In other words, the two articles included duplicated patients leading to a wrong method for data extraction. Besides, there were other articles having the same mistakes such as Scozzari 2011 [24] and Scozzari 2014 [51], Buchs 2014 [14] and Buchs 2015 [52]. In other words, duplicated data may provide low-quality evidence. During data extraction, we had better follow the principles of data extraction strictly and patiently to avoid drawing unreliable data.

As a novel minimally invasive technique, RBS may not give out strong priority according to statistical outcomes with its strong merits in theory including 3-dimensional vision, flexibility due to more operative arms and scientific ergonomics [53]. One reason may be that included studies did not report the outcomes focusing on the real advantages in the long run such as the uncomfortable events caused by standing all day in the operation room of surgeons and the possibilities of telemedicine. Another may be that robotic

Table 3 Results in RBS and LBS

Categorical outcomes	Number of studies (size)	Effect estimate	95%CI	I^2	P
Operative time	15 (141,009)	WMD = 27.61	16.27–38.96	$I^2 = 96.4\%$	$P < 0.01$
Length of hospital stay	21 (189,685)	WMD = − 0.02	− 0.19–0.15	$I^2 = 83.2\%$	$P = 0.819$
Reoperation within 30 days	9 (140,303)	OR = 1.36	0.65–2.82	$I^2 = 64.8\%$	$P = 0.411$
Overall complications	16 (163,587)	OR = 0.88	0.68–1.15	$I^2 = 29.0\%$	$P = 0.362$
Leak	19 (142,592)	OR = 0.84	0.37–1.95	$I^2 = 66.4\%$	$P = 0.691$
Stricture	11 (140,430)	OR = 1.05	0.52–2.12	$I^2 = 55.2\%$	$P = 0.895$
Pulmonary embolisms	4 (1858)	OR = 1.97	0.93–4.17	$I^2 = 0\%$	$P = 0.075$
Estimated blood loss	4 (960)	WMD = -1.93	− 4.61–0.75	$I^2 = 0\%$	$P = 0.158$

surgery was carried on just a few years ago so there were not numerous researches available to compare RBS and LBS. Therefore, there should be more high-quality trials to illustrate these diffusions (Table 3).

Last but not least, bariatric surgery is only one aspect of the robotic surgery and it is not robust that RBS can be much better than LBS. So we can not conclude that robotic surgery is super. Moreover, there are four common types of surgeries treating patients with obesity as mentioned above, while few evidence showed a prior approach in RBS comparing LBS. According to the recent guidelines of management for patients with obesity, there is not affirmative surgery until now, EASO (European Association for the Study of Obesity) [54] also reported that there was no difference on the postoperative complications among the four types of surgeries. Besides, ASMBS (American Society for Metabolic & Bariatric Surgery) [55] published a nutritional guideline for patients with obesity aiming to talk about the surgeon weight loss. All in all, the recent guidelines did not provide an accurate and recommended surgery to lose weight in a safe and efficient way. That is also a necessary reason to conduce this meta-analysis. However, we hope we can provide some authentic tips for evidence through this work.

There were some strengths in our study. With a comprehensive, systematic literature research, this meta-analysis probably avoided publication bias to some extent. Also, all the included studies were compliant to PRISMA criteria may add more accurate and precise data to our study. What is more, data extraction of our study followed the principle very strictly compared with the previous meta-analysis so we can provide more reliable evidence. Included studies comprised participants from America, Europe and Latin America affording a worldwide suggestion for the patients with obesity.

Unavoidably, this meta-analysis also has some limitations as follows: 1, All the included studies are not randomized control trials leading to a bias in the data extraction, although the cohort study, retrospective study and prospective study also give useful evidence for clinic. 2, In the process of statistical analysis, we did this meta-analysis for the influence of combined all the four surgeries resulting in some bias in the calculation. 3, The sample size of this study may be not big enough to produce more scientific and prudent evidence as designed before. Therefore, there may need more and more high-quality trials to compare the RBS and LBS in the long run.

Conclusion

Given all the results and discussions mentioned above, the effect of RBS and LBS may be similar in length of hospital stay, reoperation within 30 days, overall complications, leak, stricture, pulmonary embolisms and estimated blood loss. Operative time should be defined precisely and cost-effectiveness needs to be concerned in the future. More detailed information of primary outcomes of BS should be reported in the future trials. Virtually, RBS has been proved similar as LBS treating the obesity without increasing risks for operations and complications. As for the obesity, it is better to choose an experienced doctor with rapport. More high-quality perspective studies comparing RBS and LBS should be conducted to confirm the results.

Supplementary Information The online version of this article (https://doi.org/10.1007/s00464-020-08283-z) contains supplementary material, which is available to authorized users.

Acknowledgements Yumin Li and Zhengchao Zhang contributed to study concept and design; Zhengchao Zhang, Lele Miao and Zhijian Ren contributed to literature search, review of the studies, and data extractions. Zhengchao Zhang contributed to data analysis and data interpretation. Lele Miao and Zhijian Ren contributed to verify the statistical analysis and scrutinized data. Yumin Li provided expert insight. Yumin Li contributed to supervision throughout the whole study. All the authors contributed writing the manuscript. All authors approved the final version of the manuscript.

Funding This study is funded by the National Natural Science Foundation of China (Project Approval Number: 31770537) and Special Research Project of Lanzhou University Serving the Economic and Social Development of Gansu Province (054000282).

Compliance with ethical standards

Disclosure Zhengchao Zhang, Lele Miao, Zhijian Ren, and Yumin Li have declare that they have no competing interests.

References

1. Ng M, Fleming T, Robinson M et al (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013:a systematic analysis for the Global Burden of Disease Study 2013. Lancet 384:766–781
2. Courcoulas AP, Christian NJ, Belle SH et al (2013) Weight change and health outcomes at 3 years after bariatric surgery among individuals with severe obesity. JAMA 310(22):2416–2425
3. Mingrone G, Panunzi S, De Gaetano A et al (2015) Bariatric–metabolic surgery versus conventional medical treatment in obese patients with type 2 diabetes: 5 year follow-up of an open-label, single-centre, randomized controlled trial. Lancet 386:964–973
4. Puzziferri N, Roshek III TB, Mayo HG et al (2014) Long-term follow-up after bariatric surgery a systematic review. JAMA 312(9):934–942
5. Schauer PR, Bhatt DL, Kirwan JP et al (2014) Bariatric surgery versus intensive medical therapy for diabetes—3-year outcomes. N Engl J Med 370:2002–2013
6. Li K, Zou J, Tang J et al (2016) Robotic versus laparoscopic bariatric surgery: a systematic review and meta-analysis. Obes Surg 26(12):3031–3044
7. Economopoulos KP, Theocharidis V, McKenzie TJ et al (2015) Robotic vs laparoscopic Roux-En-y gastric bypass: a systematic review and meta-analysis. Obes Surg. 25(11):2180–2189
8. Magouliotis DE, Tasiopoulou VS, Sioka E et al (2017) Robotic versus laparoscopic sleeve gastrectomy for morbid obesity: a systematic review and meta-analysis. OBES SURG 27:245–253
9. Huang YM, Huang YJ, Wei PL (2017) Outcomes of robotic versus laparoscopic surgery for mid and low rectal cancer after neoadjuvant chemoradiation therapy and the effect of learning curve. Medicine 96:40
10. Li X, Wang T, Yao L et al (2017) The safety and effectiveness of robot-assisted versus laparoscopic TME in patients with rectal cancer A meta-analysis and systematic review. Medicine 96:29
11. Ahmad A, Carleton JD, Ahmad ZF et al (2016) Laparoscopic versus robotic-assisted Roux-en-Y gastric bypass:a retrospective, single-center study of early perioperative outcomes at a community hospital. Surg Endosc 30:3792–3796
12. Ayloo SM, Addeo P, Buchs NC et al (2011) Robot-assisted versus laparoscopic Roux-en-Y gastric bypass: is there a difference in outcomes? World J Surg 35:637–642
13. Benizri EI, Renaud M, Reibel N et al (2013) Perioperative outcomes after totally robotic gastric bypass: a prospective nonrandomized controlled study. Am J Surgery 206:145–151
14. Buchs NC, Morel P, Azagury DE et al (2014) Laparoscopic versus robotic Roux-En-Y gastric bypass: lessons and long-term follow-up learned from a large prospective monocentric study. OBES Surg 24:2031–2039
15. Celio AC, Kasten KR, Schwoerer A et al (2017) Perioperative safety of laparoscopic versus robotic gastric bypass: a propensity matched analysis of early experience. Surg Obes Relat Dis 13(11):1847–1852
16. Curet MJ, Curet M, Solomon H et al (2009) Comparison of hospital charges between robotic, laparoscopic stapled, and laparoscopic handsewn Roux-en-Y gastric bypass. J Robotic Surg 3:75–78
17. Hubens G, Balliu L, Ruppert M et al (2008) Roux-en-Y gastric bypass procedure performed with the da Vinci robot system: is it worth it? Surg Endosc 22:1690–1696
18. Lyn-Sue JR, Winder JS, Kotch S, et al. (2016) Laparoscopic gastric bypass to robotic gastric bypass: time and cost commitment involved in training and transitioning an academic surgical practice. J Robotic Surg 10:111–115
19. Mohr CJ, Nadzam GS, Curet MJ et al (2005) Totally robotic Roux-en-Y gastric bypass. Arch Surg 140:779–786
20. Moon RC, Gutierrez JC, Royall NA et al (2016) Robotic Roux-en-Y gastric bypass, is it safer than laparoscopic bypass? OBES Surg 26:1016–1020
21. Myers SR, McGuirl J, Wang J (2013) Robot-assisted versus laparoscopic gastric bypass: comparison of short-term outcomes. OBES Surg 23:467–473
22. Park CW, Lam ECF, Walsh TM et al (2011) Robotic-assisted Roux-en-Y gastric bypass performed in a community hospital setting: the future of bariatric surgery? Surg Endosc 25:3312–3321
23. Sanchez BR, Mohr CJ, Morton JM et al (2005) Comparison of totally robotic laparoscopic Roux-en-Y gastric bypass and traditional laparoscopic Roux-en-Y gastric bypass. Surg Obes Relat Dis 1(6):549–554
24. Scozzari G, Rebecchi F, Millo P et al (2011) Robot-assisted gastrojejunal anastomosis does not improve the results of the laparoscopic Roux-en-Y gastric bypass. Surg Endosc 25:597–603
25. Snyder BE, Wilson T, Leong BY et al (2010) Robotic-assisted Roux-en-Y gastric bypass: minimizing morbidity and mortality. OBES Surg 20:265–270
26. Smeenk M, van Hof G, Elsten E et al (2016) The results of 100 robotic versus 100 laparoscopic gastric bypass procedures: a single high volume centre experience. OBES Surg 26:1266–1273
27. Stefanidis D, Bailey SB, Kuwada T et al (2018) Robotic gastric bypass may lead to fewer complications compared with laparoscopy. Surg Endosc 32(2):610–616
28. Villamere J, Gebhart A, Stephen Vu et al (2015) Utilization and outcome of laparoscopic versus robotic general and bariatric surgical procedures at Academic Medical Centers. Surg Endosc 29:1729–1736
29. Wood MH, Kroll JJ, Garretson B (2016) A comparison of outcomes between the traditional laparoscopic and totally robotic Roux-en-Y gastric bypass procedures. J Robotic Surg 8:29–34
30. Altieri MS, Yang J, Telem DA et al (2016) Robotic approaches may offer benefit in colorectal procedures, more controversial in other areas: a review of 168,248 cases. Surg Endosc 30:925–933

31. Ayloo S, Buchs NC, Addeo P et al (2011) Robot-assisted sleeve gastrectomy for super-morbidly obese patients. J Laparoendosc Adv Surg Tech A 21(4):295–299
32. Elli E, Gonzalez-Heredia R, Sarvepalli S et al (2015) Laparoscopic and robotic sleeve gastrectomy: short- and long-term results. OBES SURG 25:967–974
33. Kannan U, Ecker BL, Choudhury R (2016) Laparoscopic hand-assisted versus robotic-assisted laparoscopic sleeve gastrectomy: experience of 103 consecutive cases. Surg Obes Relat Dis 12(1):94–99
34. Moon RC, Stephenson D, Royall NA et al (2016) Robot-assisted versus laparoscopic sleeve gastrectomy: learning curve, perioperative, and short-term outcomes. OBES Surg 26:2463–2468
35. Pepper VK, Rager TM, Diefenbach KA et al (2016) Robotic vs. laparoscopic sleeve gastrectomy in adolescents; reality or hype. OBES SURG 26:1912–1917
36. Schraibman V, Macedo ALV, Epstein MG et al (2014) Comparison of the morbidity weight loss, and relative costs between robotic and laparoscopic sleeve gastrectomy for the treatment of obesity in Brazil. OBES Surg 24:1420–1424
37. Vilallonga R, Fort JM, Caubet E et al (2013) robotic sleeve gastrectomy versus laparoscopic sleeve gastrectomy: a comparative study with 200 patients. OBES Surg 23:1501–1507
38. Edelson PK, Dumon KR, Sonnad SS et al (2011) Robotic vs. conventional laparoscopic gastric banding:a comparison of 407 cases. Surg Endosc 25:1402–1408
39. Kang JH, Le QA (2017) Effectiveness of bariatric surgical procedures a systematic review and network meta-analysis of randomized controlled trials. Medicine. 96:46
40. Lyn-Sue JR, Winder JS, Kotch S et al (2016) Robotic versus laparoscopic bariatric surgery: a systematic review and meta-analysis. J Robot Surg Jun 10(2):111–115
41. Alibhai MH, Shah SK, Walker PA et al (2015) A review of the role of robotics in bariatric surger. J Surg Oncol. 112(3):279–283
42. Prete FP, Pezzolla A, Prete F et al (2018) Robotic versus laparoscopic minimally invasive surgery for rectal cancer: a systematic review and meta-analysis of randomized controlled trials. Ann Surg 267(6):1034–1046
43. Liang H, Liang W, Zhao L et al (2018) Robotic versus video-assisted lobectomy/segmentectomy for lung cancer: a meta-analysis. Ann Surg 268(2):254–259
44. Acquafresca PA, Palermo M, Rogula T et al (2015) Most common robotic bariatric procedures: review and technical aspects. Ann Surg Innov Res. 28:9
45. Antanavicius G, Sucandy I (2013) Robotically-assisted laparoscopic biliopancreatic diversion with duodenal switch: the utility of the robotic system in bariatric surgery. J Robotic Surg 7:261–266
46. Antanavicius G, Rezvani M, Sucandy I (2015) One-stage robotically assisted laparoscopic biliopancreatic diversion with duodenal switch: analysis of 179 patients. Surgery Obes Relat Dis 11:367–371
47. Fantola G, Reibel N, Germain A et al (2015) Second-stage robot-assisted biliopancreatic diversion with duodenal switch after sleeve gastrectomy. OBES SURG 25:197–198
48. Sudan R, Bennett KM, Jacobs DO et al (2012) Multifactorial analysis of the learning curve for robot-assisted laparoscopic biliopancreatic diversion with duodenal switch. Ann Surg. 255:940–945
49. Sudan R, Podolsky E (2015) Totally robot-assisted biliary pancreatic diversion with duodenal switch: single dock technique and technical outcomes. Surg Endosc 29:55–60
50. Ayloo S, Roh Y, Choudhury N (2016) Laparoscopic, hybrid, and totally robotic Roux-en-Y gastric bypass. J Robot Surg 10:41–47
51. Scozzari G, ZaniniM CF et al (2014) High incidence of trocar site hernia after laparoscopic or robotic Roux-en-Y gastric bypass. Surg Endosc 28:2890–2898
52. Buchs NC, Azagury DE, Pugin F et al (2015) Roux-en-Y gastric bypass for super obese patients: what approach? Int J Med Robot Comput Assist Surg 12(2):276–282
53. Jeong IG, Khandwala YS, Kim JH et al (2017) Association of robotic-assisted vs laparoscopic radical nephrectomy with perioperative outcomes and health care costs, 2003 to 2015. JAMA 318(16):1561–1568
54. Busetto L, Dicker D, Azran C et al (2017) Practical recommendations of the obesity management task force of the european association for the study of obesity for the post-bariatric surgery medical management. Obes Facts 10:597–632
55. Parrott J, Frank L, Rabena R et al (2017) American Society for metabolic and bariatric surgery integrated health nutritional guidelines for the surgical weight loss patient 2016 update: micronutrients. Surg Obes Relat Dis 13(5):727–741