

Review

Comparative analysis for the effect of Roux-en-Y gastric bypass vs sleeve gastrectomy in patients with morbid obesity: Evidence from 11 randomized clinical trials (meta-analysis)

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ABSTRACT

Background: Laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG) are the most common procedures performed during bariatric surgery and both of them have been demonstrated having significant efficacy for morbid obesity. However, the comparative analysis of the effect of them has not been well studied. Thus, this comparative analysis was conducted to determine whether LRYGB and LSG are equivalent for mid- and long-term weight loss, resolution of comorbidities and adverse events (AEs).

Methods: We searched the Cochrane Library, PubMed, Embase and Web of Science databases up to January 1, 2019 for studies that investigated LRYGB and LSG with respect to weight loss outcomes, resolution of comorbidities and AEs. Standardised mean differences (SMDs) and risk ratios (RR) with 95% confidence intervals (CIs) were calculated to compare the outcomes of the groups. Two reviewers assessed the quality of the trials and extracted the data independently. All statistical analyses were performed using the standard statistical procedures in Review Manager 5.2.

Results: We included 11 studies (N = 1,328 participants) in this meta-analysis. Our results showed no significant difference in excess weight loss between LRYGB and LSG, with a pooled SMD of -0.16 (95% CI: -0.52 – 0.19 ; $P = 0.36$). Further, the pooled results showed no significant difference in midterm and long-term weight loss between the comparative groups. Similarly, no significant difference was found in T2DM resolution. The pooled results indicate that patients receiving LSG experienced fewer postoperative complications and reoperation rate, with pooled RRs of 1.66 (95% CI: 1.33–2.07; $P < 0.00001$) and 1.73 (95% CI: 1.14–2.62; $P = 0.01$). LRYGB may be superior to LSG in dyslipidemia, hypertension and gastroesophageal reflux disease (GERD) remission. **Conclusions:** The present meta-analysis indicated that both LRYGB and LSG are equivalent for excess weight loss and T2DM resolution. However, patients receiving LSG experienced fewer postoperative complications and reoperation rate than those who underwent LRYGB. LRYGB may be superior in dyslipidemia, hypertension and gastroesophageal reflux disease (GERD) remission.

1. Introduction

Bariatric surgery has been established as a standalone treatment for morbid obesity, and has been widely adopted [1]. It is the only therapeutic option that results in substantial and long-lasting weight loss [2–4]. Laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG) are the two most popular bariatric procedures performed in the United States [5]. However, they have not been sufficiently compared in terms of long-term effectiveness for weight loss and resolution of comorbidities [6].

Documentation of long-term weight loss following bariatric surgery

is difficult, as a substantial proportion of patients are lost to follow-up over the years following enrolment in the weight loss program. Additionally, some patients who have undergone LSG later undergo revisional surgery due to inadequate weight loss or weight regain [7–9]. For this reason, it has not been determined whether LRYGB or LSG is superior for weight loss and resolution of comorbidities.

Though previous analysis have been conducted, there has been no consistency among reports of the efficacy of LRYGB and LSG for weight loss and resolution of comorbidities, such as type 2 diabetes mellitus (T2DM), reoperation, obstructive sleep apnea hypopnea syndrome (OSAHS), hypertension, gastroesophageal reflux disease (GERD), back

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or joint pain and depression. In addition, two updated RCTs [10,11] have been published recently which have not been included in previous analysis. Thus, this comparative analysis was conducted to determine whether LRYGB and LSG are equivalent for mid- and long-term weight loss, resolution of comorbidities and adverse events (AEs).

2. Methods and materials

2.1. Criteria for considering studies

2.1.1. Including criteria

The inclusion criteria were as follows: (1) randomised controlled trial (RCTs); (2) patients with body mass index (BMI) > 27.5 kg/m², aged > 18 years, and undergoing bariatric surgery for weight loss or comorbidities; (3) patients who underwent primary LRYGB or LSG; (4) a minimum follow-up of 12 months; (5) reportage of relevant outcomes, i.e. weight loss and/or comorbidity resolution rate; and (6) study published in English.

2.1.2. Excluding criteria

The exclusion criteria were as follows: (1) non-RCTs, experimental trial on animals or non-human study; (2) abstract, letter, editorial, expert opinion, review, or case report; (3) patients undergoing other bariatric procedures, revision or conversion procedures; (4) other diseases that may influence outcome; (5) insufficient data or not meeting our inclusion criteria; and (6) not published in English.

2.2. Definition of outcomes

- (1) Overall outcomes: including both mid and long term outcomes, or the follow-up time was not stated;
- (2) Midterm outcomes: events or outcomes happened within 12–36 months;
- (3) Long-term outcomes: events or outcomes happened after 36 months.

2.3. Search strategy

We searched the Cochrane Library, PubMed, EMBASE and Web of Science databases up to January 1, 2019. Our search terms were: “bariatric surgery”; “sleeve gastrectomy”; “LSG”; “SG”; “gastric bypass”; “RYGB”; “Roux-en-Y gastric bypass”; “LRYGB”; “obesity” and “diabetes”. The reference sections of some studies were also searched. Two assessors independently screened the titles and abstracts of each study. When a relevant study was identified, the full text was obtained for further evaluation.

2.4. Quality assessment

Two assessors, who underwent standardised training prior to this meta-analysis, independently evaluated the quality of all of the included studies using the Jadad score for RCT studies [12]. In addition, the risk of bias for each RCT, and across all RCTs, was evaluated, as illustrated by figures generated using RevMan 5.2 software [13].

2.5. Data extraction

Data for the comparative analysis of mid- and long-term weight loss outcomes and resolution of comorbidities, between LRYGB and LSG, were extracted independently by two reviewers; disagreement was resolved by discussion. The data extracted from each study, including year of publication, country of origin, study design, patient demographics such as gender, mean age, and BMI, follow-up time, and main outcomes were collated using a standardised form.

Data were inputted into RevMan 5.2 software for analysis [13].

2.6. Statistical analysis

Outcome data were compared between the LRYGB and LSG groups, combined across studies, using the standard statistical procedures provided in RevMan 5.2 [13]. Standardised mean differences (SMDs) and risk ratio (RR) and its associated 95% confidence interval (CI) were measured. Heterogeneity among studies was evaluated by the chi-square-based Q statistic test [14]; the P_h value and I^2 statistic, ranging from 0% to 100%, were used to quantify the effect of heterogeneity [15]. $P_h \leq 0.10$ was deemed to represent significant heterogeneity, and pooled risk ratios (RRs) were estimated using a random-effect model (DerSimonian and Laird method [16]). When no statistical heterogeneity was observed ($P_h > 0.10$), a fixed effects model (Mantel–Haenszel method [17]) was used. The outcome measures were considered significantly different between the treatment groups if pooled SMDs with 95% CIs did not overlap with zero, or pooled RRs with 95% CIs did not overlap with one.

This study strictly abided by the standards of the Preferred Reporting Items for Meta-analysis and Meta-Analyses (PRISMA) [18] and Assessing the Methodological Quality of Systematic Reviews (AMSTAR) guidelines [19].

3. Results

3.1. Included studies, study characteristics, and quality assessment

In total, 2,058 studies were initially identified; after duplicates were removed, the titles and abstracts of 1,069 studies were screened. Of these, 1011 studies were excluded, and the full texts of the remaining 58 studies were obtained for further evaluation. After reading the full texts, 46 studies were excluded for various reasons such that, ultimately, 11 RCTs [6,10,11,20–27] (N = 1,328 participants) were included in this meta-analysis (Fig. 1). One study was excluded because of the follow-up time failed to meet our inclusion criteria [28]. Among the studies, the sample size ranged from 15 to 238 patients. The follow-up time ranged from one month to 60 months (Table 1).

Graphs showing risk of bias were then generated. The overall risk of bias for each RCT is presented as a percentage relative to all included studies in Fig. 2, and the risk of individual types of bias is displayed in Fig. 3. The risk of bias graphs for the RCTs indicated generally good methodological quality, mainly in terms of selection and reporting biases. However, there was a high risk of performance bias in all studies. An unclear risk of bias was mainly seen in terms of detection and “other” biases.

3.2. Comparison of weight loss between LRYGB and LSG

As shown in Fig. 4, no significant difference in excess weight loss between LRYGB and LSG was found, with a pooled standardised mean difference (SMD) of -0.16 (95% CI: -0.52 – 0.19 ; $P = 0.36$). Similarly, the pooled results also showed no significant difference in midterm and long-term weight loss between LRYGB and LSG, with pooled SMDs of -0.19 (95% CI: -2.17 – 1.80 ; $P = 0.85$) and 0.15 (95% CI: -0.59 – 0.89 ; $P = 0.70$). The pooled analysis was performed using a random-effects model because significant heterogeneity ($P_h < 0.1$) was detected among the studies.

3.3. Comparison of T2DM resolution between LRYGB and LSG

This study also compared and analysed the effect of LRYGB and LSG for resolving T2DM. Our pooled analysis showed that LRYGB and LSG had equal efficacy for T2DM remission, with pooled RRs of 1.12 (95% CI: 0.95–1.33; $P = 0.16$) for overall remission (Fig. 5), 1.06 (95% CI: 0.90–1.25; $P = 0.47$) for midterm remission and 1.18 (95% CI: 0.94–1.47; $P = 0.16$) for long-term resolution. In addition, no significant difference was found in T2DM improved (RR 0.57; 95% CI:

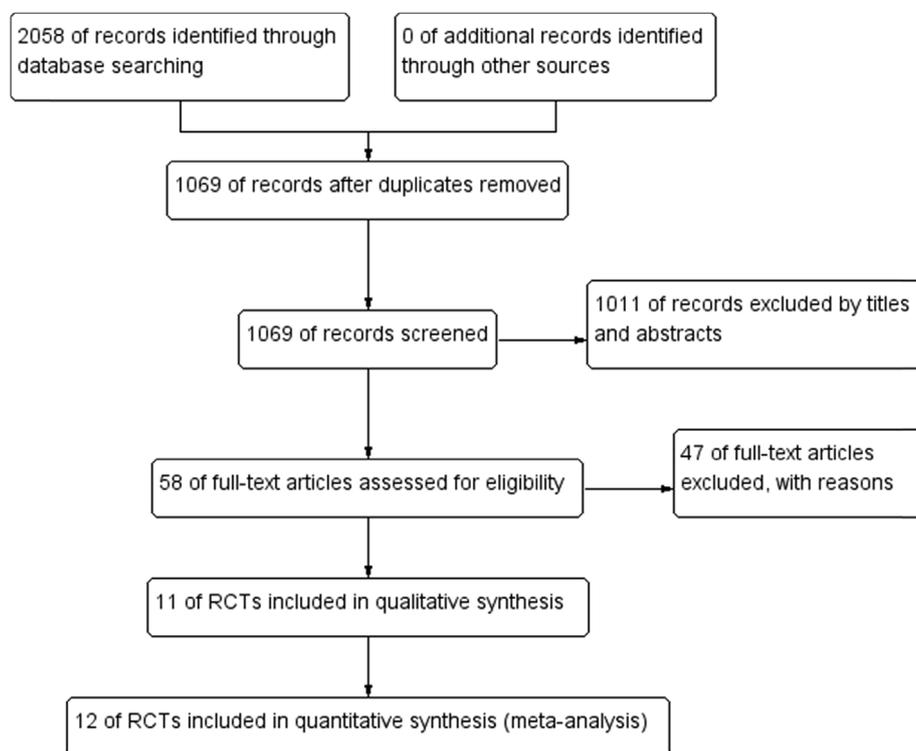


Fig. 1. Flow diagram of literature search and selection of included studies for meta-analysis.

0.26–1.24; $P = 0.16$), unchanged (RR 0.93; 95% CI: 0.21–4.20; $P = 0.92$), and worsened (RR 0.42; 95% CI: 0.03–6.62; $P = 0.54$) (Table 2). The analysis was performed using a fixed-effect model, as no significant heterogeneity among the studies was found, except the analysis of T2DM worsened.

3.4. Comparison of complication and reoperation between LRYGB and LSG

Our pooled analysis showed that LRYGB had more complications after operation, with pooled RR of 1.59 (95% CI: 1.25–2.02; $P = 0.0001$) for overall complications (Fig. 6). Our subgroup analysis further indicated significant difference in early complication, with pooled RR of 2.14 (95% CI: 1.26–3.64; $P = 0.005$). However, no significant difference was found in late complication (RR 1.29; 95% CI: 0.88–1.88; $P = 0.19$). In addition, we also compared the reoperation rate of both comparative groups and found that patients received LRYGB may experience higher rate of reoperation with a pooled RR of 1.73 (95% CI: 1.14–2.62; $P = 0.01$) (Table 3). The analysis was performed using a fixed-effect model, as no significant heterogeneity among the studies was found.

3.5. Resolution of co-morbidities with LRYGB and LSG

We also compared LRYGB and LSG in terms of the resolution of comorbidities. The pooled results indicated LRYGB may be superior to LSG in dyslipidemia remission, with pooled RRs of 1.36 (95% CI: 1.17–1.59; $P < 0.0001$) for overall remission and 1.43 (95% CI: 1.19–1.72; $P = 0.0001$) for long-term remission. However, no difference was found in midterm dyslipidemia remission (RR 1.13; 95% CI: 0.93–1.38; $P = 0.23$) and in dyslipidemia unchanged (RR 0.50; 95% CI: 0.16–1.59; $P = 0.24$). LRYGB may also have higher hypertension remission rate, with pooled RRs of 1.23 (95% CI: 1.05–1.44; $P = 0.01$) for overall remission and 1.23 (95% CI: 1.04–1.45; $P = 0.01$) for long-term remission. However, in dyslipidemia midterm remission, improved and unchanged, there was no difference. In addition, we found that LRYGB may be superior to LSG in GERD improvement with pooled RR of 1.48

(95% CI: 1.07–2.04; $P = 0.02$). In contrast, LSG may worsen GERD symptoms and may lead to de novo GERD, with pooled RRs of 0.16 (95% CI: 0.06–0.44; $P = 0.0004$) and 0.33 (95% CI: 0.15–0.68; $P = 0.003$) respectively. No significant difference was found in the analysis of remission of OSAHS, back or joint pain, hyperuricemia and depression (Table 4).

4. Discussion and conclusion

Bariatric surgery has many benefits, including promoting weight loss and the resolution of T2DM and other comorbidities of obesity [29,30]. Weight loss is associated with short-term amelioration and prevention of metabolic and cardiovascular disorders, but whether these benefits persist over time is unknown. In addition, Sjöström et al. reported that bariatric surgery appears to be a more viable option for treating severe obesity compared with conventional therapy, being associated with long-term weight loss, improved lifestyle and, except for hypercholesterolemia, amelioration of risk factors present at baseline. Furthermore, the 2- and 10-year rates of recovery from diabetes, hypertriglyceridaemia, low levels of high-density lipoprotein cholesterol, hypertension and hyperuricemia were more favourable in the surgery group than in the control group, whereas recovery from hypercholesterolemia did not differ between the groups. Moreover, the surgery group had lower 2- and 10-year incidence rates of diabetes, hypertriglyceridaemia and hyperuricemia than the control group; no differences between the groups in the incidence of hypercholesterolemia and hypertension were detected [3]. LRYGB and LSG are the most commonly performed procedures in bariatric surgery. However, their weight loss efficacy in the mid- and long-term has not been compared. Thus, this study compared LRYGB and LSG in terms of mid- and long-term weight loss, and the resolution of comorbidities.

Our analysis indicated that LRYGB and LSG had similar efficacy with respect to weight loss, including midterm and long-term weight loss. However, LSG showed a lower incidence of reoperation and postoperative complications, especially in early complications defined as 0–30 days after operation. These early complications included In the

Table 1
The characteristics of included studies for the analysis of LRYGB versus LSG for weight loss and resolution of co-morbidity.

| Study (author/year) | Country | Study design | Sample size | Gender (M/ F) | Mean age (range/SD) | | BMI(kg/m ²) | | Follow-up time (month) | Outcomes |
|-------------------------|-------------|-------------------------------------------|-------------|------------------|---------------------|-------------|-------------------------|--------------|---------------------------|--------------------------------------------------------------------------------------------|
| | | | | | LRYGB | LSG | LRYGB | LSG | | |
| Kehagias I et al., 2011 | Greece | RCT | 60 | 16/44 | 36.0 (8.4) | 33.7 (9.9) | 45.8 (3.7) | 44.9 (3.4) | 36.0 | BMI, T2DM, co-morbidities |
| Keidar A et al., 2013 | Israel | parallel un-blinded RCT | 37 | 21/16 | 51.45 (8.3) | 47.7 (11.7) | 42.0 (4.8) | 42.5 (5.2) | 12.0 | BMI, T2DM, FBG |
| Nogues X et al., 2010 | Spain | RCT | 15 | 0/15 | 45.86 (8.6) | 49.63 (9.6) | 43.1 (3.9) | 43.5 (3.2) | 12.0 | BMI, reoperation |
| Peterli R et al., 2013 | Switzerland | RCT | 217 | 61/156 | 42.1 (11.2) | 43.0 (11.1) | 44.2 (5.3) | 43.6 (5.3) | 12.0 | T2DM, co-morbidities, reoperation |
| Salminen P et al., 2018 | Finland | multicenter, multisurgeon, open-label RCT | 240 | 73/167 | 48.4 (9.3) | 48.5 (9.6) | 46.4 (5.9) | 45.5 (6.2) | 60.0 | Excessweight loss, resolution of comorbidities, improvement of QoL, all AEs and mortality. |
| Schauer PR et al., 2014 | US | RCT | 97 | 31/66 | 48.0 (8.45) | 47.8 (8.08) | 37.1 (3.39) | 36.1 (3.91) | 36.0 | BMI, T2DM, reoperation, LDL |
| Peterli R et al., 2017 | Switzerland | Multicenter RCT | 217 | 61/156 | 42.1 (11.2) | 43.0 (11.1) | 44.2 (5.3) | 43.6 (5.3) | 48.0 | weight loss, comorbidities, quality of life, and complications. |
| Vix M et al., 2013 | France | RCT | 100 | 18/82 | 35.23 (9.37) | 35.13 (9.7) | 47.09 (5.64) | 45.57 (4.79) | 12.0 | FBG, LDL |
| Yang J et al., 2015 | China | RCT | 64 | 22/42 | 41.4 (9.3) | 40.4 (9.4) | 32.3 (2.4) | 31.8 (3) | 36.0 | BMI, T2DM, HTN, HLP |
| Zhang Y et al., 2014 | China | RCT | 64 | 26/38 | 32.2 (9.2) | 29.3 (9.8) | 39.3 (3.8) | 38.5 (4.2) | 60.0 | BMI, T2DM, co-morbidities |
| Peterli R et al., 2018 | | Multicenter RCT | 217 | 61/156 | 42.1 (11.2) | 43.0 (11.1) | 44.2 (5.3) | 43.6 (5.3) | 60.0 | weight loss, changes in comorbidities, increase in QoL and AEs. |

LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; RCT, randomized control trial; BMI, body mass index; T2DM, type 2 diabetes mellitus; AEs, adverse events; QoL, quality of life; SD, standard deviation; HTN, hypertension; HLP, hyperlipidemia.

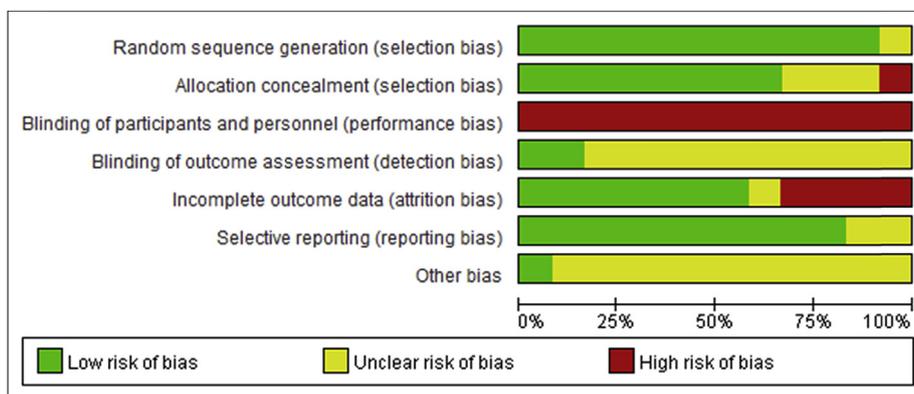


Fig. 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included RCT studies.

| | Random sequence generation (selection bias) | Allocation concealment (selection bias) | Blinding of participants and personnel (performance bias) | Blinding of outcome assessment (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Other bias |
|-------------------------|---------------------------------------------|-----------------------------------------|-----------------------------------------------------------|-------------------------------------------------|------------------------------------------|--------------------------------------|------------|
| Kehagias I, et al. 2011 | + | + | - | ? | - | + | ? |
| Keidar A, et al. 2013 | + | - | - | ? | - | + | ? |
| Nogues X, et al. 2010 | ? | ? | - | ? | ? | + | ? |
| Peterli R, et al. 2013 | + | ? | - | ? | - | + | ? |
| Peterli R, et al. 2017 | + | ? | - | + | + | + | + |
| Peterli R, et al. 2018 | + | + | - | ? | + | + | ? |
| Salminen P, et al. 2018 | + | + | - | + | + | + | ? |
| Schauer PR, et al. 2014 | + | + | - | ? | - | + | ? |
| Vix M, et al. 2013 | + | + | - | ? | + | ? | ? |
| Yang J, et al. 2015 | + | + | - | ? | + | ? | ? |
| Zhang Y, et al. 2014 | + | + | - | ? | + | + | ? |

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included RCT study.

sleeve gastrectomy obstruction, intra-abdominal abscess formation, pleural empyema, obstruction of the biliopancreatic limb and leakage at the gastrojejunostomy. In the study of Peterli R [10], one patient had a leakage at the gastrojejunostomy with a complicated course, which eventually led to multiorgan failure and death. In addition, LRYGB and

LSG had similar efficacy in terms of both mid- and long-term resolution of T2DM, as well other comorbidities. Yip et al. compared T2DM remission and weight loss rates between patients with T2DM undergoing gastric bypass versus sleeve gastrectomy. Their analysis included 21 prospective studies (3 RCTs) and 12 retrospective studies, involving 1,375 patients in total; no significant difference in either T2DM remission or weight loss was observed between gastric bypass and sleeve gastrectomy, which resulted in similar early T2DM remission rates at 3 months of 67% and 56%, respectively, with modest rates of additional T2DM remission thereafter; meanwhile, weight loss increased substantially between 3 and 12 months postoperatively, for both procedures [4]. LRYGB may be superior to LSG in dyslipidemia, hypertension and GERD remission. Our subgroup analysis further indicated that the superior effect of LRYGB in dyslipidemia, hypertension and GERD remission was only observed in long-term remission. No significance was found in midterm remission. Two RCTs were performed to compare the long-term efficacy of LRYGB and LSG with respect to BMI reduction and resolution of comorbidities in morbidly obese subjects, at least 5 years after surgery [10,11]. Peterli et al. performed an RCT that included 217 patients, and a 5-year follow-up, to determine any differences between SG and GBP in terms of weight loss, comorbidities, quality of life and adverse events [10]. There found no significant difference in the rate of BMI reduction at 5 years between SG and GBP (61.1% and 68.3%, respectively; absolute difference, -7.18%; 95% CI: -14.30% to -0.06%; $P = 0.22$ after adjusting for multiple comparisons). Gastric reflux remission was observed more frequently after GBP (60.4%) than after SG (25.0%). Gastric reflux worsened (more symptoms or therapy) more frequently after SG (31.8%) than after GBP (6.3%). There were 16 (of 101; 15.8%) and 23 (of 104; 22.1%) patients who underwent reoperations or interventions after SG and GBP, respectively [40]. In addition, a multicentre, multi-surgeon, open-label, randomised clinical equivalence trial enrolling 240 morbidly obese patients aged 18–60 years was conducted by Salminen et al., to determine whether LSG and LGB are equivalent in terms of weight loss outcomes at 5 years in patients with morbid obesity [10]. That study included 240 patients, and 80.4% completed the 5-year follow-up. Their results showed that although GBP was associated with a greater likelihood of weight loss at 5 years, the difference was not significant [11].

Our study had several limitations, the most serious of which was the variation in sample size among the included studies. Although we analysed 1,566 participants, the sample size ranged widely among the studies, from 15 to 238 patients, which may have constituted a bias. In addition, the ages and preoperative BMIs of the included patients also varied widely, which may have led to heterogeneity. Though significant difference was found in reoperation rate, limited by the number of studies, we failed to conduct subgroup analysis to explore midterm or long-term reoperation rate as well as different cause of reoperation. For the analysis of resolution of co-morbidities, the number of studies included was small and this may result in bias of the pooled results.

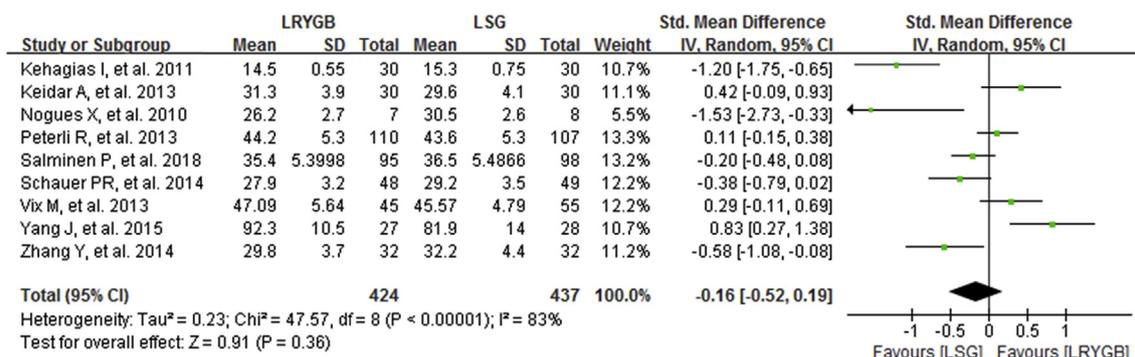


Fig. 4. Forest plot of comparison of excess weight loss between LRYGB and LSG.

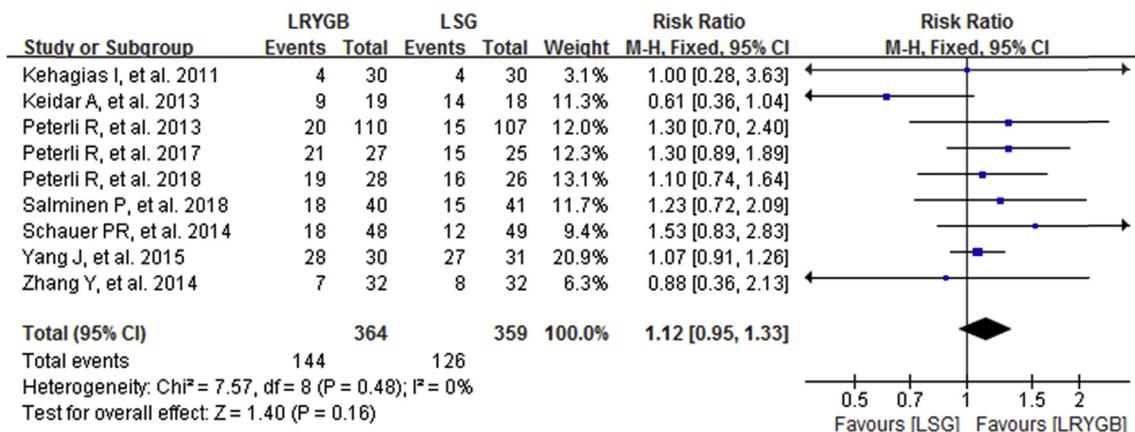


Fig. 5. Forest plot of comparison of T2DM remission between LRYGB and LSG.

Table 2

The pooled results of the comparison of weight loss and T2DM resolution between LRYGB and LSG.

| Groups/subgroups | Number of studies | Pooled results | | | Heterogeneity | | |
|---------------------|-------------------|----------------|------------|---------|----------------|----------------------|-------------------------|
| | | RR | 95% CI | P value | I ² | P _h value | Analytical effect model |
| T2DM remission | 9 | 1.12 | 0.95, 1.33 | 0.16 | 0% | 0.48 | Fixed-effect model |
| Midterm remission | 2 | 1.06 | 0.90, 1.25 | 0.47 | 0% | 0.83 | Fixed-effect model |
| Long-term remission | 4 | 1.18 | 0.94, 1.47 | 0.16 | 0% | 0.71 | Fixed-effect model |
| T2DM improved | 2 | 0.57 | 0.26, 1.24 | 0.16 | 0% | 0.76 | Fixed-effect model |
| T2DM unchanged | 2 | 0.93 | 0.21, 4.20 | 0.92 | N/A | N/A | Fixed-effect model |
| T2DM worsened | 2 | 0.42 | 0.03, 6.62 | 0.54 | 68% | 0.08 | Random-effect model |

RR, risk ratio; CI, confidence intervals; T2DM, type 2 diabetes mellitus; N/A, not available.

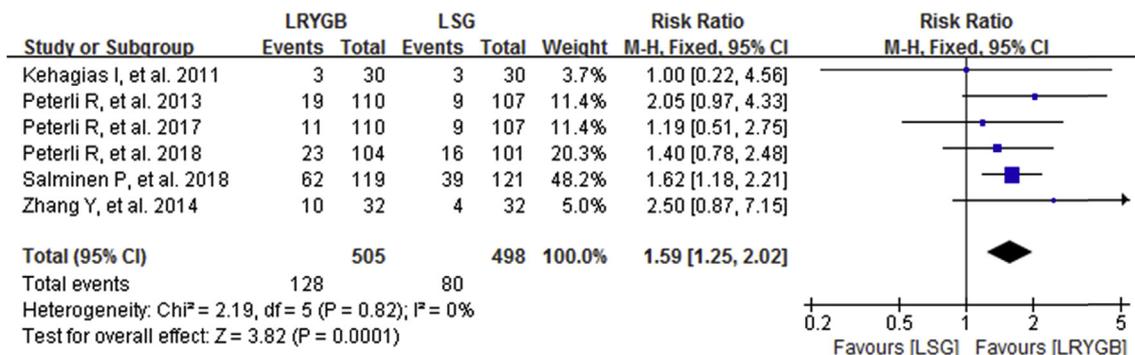


Fig. 6. Forest plot of comparison of complications between LRYGB and LSG.

Additional, more rigorous studies are needed to determine the relative long-term efficacy of different bariatric surgeries.

In conclusion, the present meta-analysis indicated that both LRYGB and LSG are equivalent for excess weight loss and T2DM resolution.

However, patients receiving LSG experienced fewer postoperative complications and reoperation rate than those who underwent LRYGB. In contrast, LRYGB may be superior in long-term remission of dyslipidemia and hypertension. LRYGB may be beneficial to GERD

Table 3
The pooled results of the complications after operation and reoperation between LRYGB and LSG.

| Groups/subgroups | Number of studies | Pooled results | | | Heterogeneity | | |
|-----------------------|-------------------|----------------|------------|-----------|----------------|----------------------|-------------------------|
| | | RR | 95% CI | P value | I ² | P _h value | Analytical effect model |
| Complications | | | | | | | |
| Early complications | 2 | 2.14 | 1.26, 3.64 | 0.005 | 0% | 0.42 | Fixed-effect model |
| Late complications | 2 | 1.29 | 0.88, 1.88 | 0.19 | 0% | 0.69 | Fixed-effect model |
| Overall complications | 7 | 1.66 | 1.33, 2.07 | < 0.00001 | 0% | 0.84 | Fixed-effect model |
| Reoperation | 6 | 1.73 | 1.14, 2.62 | 0.010 | 0% | 0.81 | Fixed-effect model |

RR, risk ratio; CI, confidence intervals.

Table 4
The pooled results of the resolution of co-morbidities with LRYGB and LSG.

| Characteristics | Number of studies | Pooled results | | | heterogeneity | | |
|-------------------------|-------------------|----------------|-------------|----------|----------------|----------------------|-------------------------|
| | | RR | 95% CI | P value | I ² | P _h value | Analytical effect model |
| Dyslipidemia | | | | | | | |
| Overall remission | 6 | 1.36 | 1.17, 1.59 | < 0.0001 | 40% | 0.14 | Fixed-effect model |
| Midterm remission | 2 | 1.13 | 0.93, 1.38 | 0.23 | 0% | 0.72 | Fixed-effect model |
| Long-term remission | 4 | 1.43 | 1.19, 1.72 | 0.0001 | 34% | 0.21 | Fixed-effect model |
| Improved | 3 | 0.67 | 0.47, 0.95 | 0.03 | 0% | 0.40 | Fixed-effect model |
| Unchanged | 3 | 0.50 | 0.16, 1.59 | 0.24 | 68% | 0.05 | Random-effect model |
| Hypertension | | | | | | | |
| Overall remission | 6 | 1.23 | 1.05, 1.44 | 0.01 | 1% | 0.41 | Fixed-effect model |
| Midterm remission | 2 | 1.23 | 0.71, 2.15 | 0.46 | 14% | 0.28 | Fixed-effect model |
| Long-term remission | 4 | 1.23 | 1.04, 1.45 | 0.01 | 22% | 0.28 | Fixed-effect model |
| Improved | 3 | 0.80 | 0.59, 1.10 | 0.17 | 0% | 0.82 | Fixed-effect model |
| Unchanged | 3 | 0.62 | 0.37, 1.04 | 0.07 | 9% | 0.33 | Fixed-effect model |
| OSAHS | | | | | | | |
| Remission | 2 | 0.93 | 0.78, 1.12 | 0.46 | 0% | 0.81 | Fixed-effect model |
| Improved | 2 | 1.15 | 0.78, 1.69 | 0.49 | 0% | 0.34 | Fixed-effect model |
| Back or Joint Pain | | | | | | | |
| Remission | 2 | 0.93 | 0.72, 1.19 | 0.57 | 0% | 0.68 | Fixed-effect model |
| Improved | 2 | 1.03 | 0.76, 1.40 | 0.85 | 52% | 0.15 | Fixed-effect model |
| Unchanged | 2 | 1.30 | 0.18, 9.27 | 0.79 | 84% | 0.01 | Random-effect model |
| Worsened | 2 | 0.87 | 0.22, 3.41 | 0.84 | 0% | 0.49 | Fixed-effect model |
| GERD | | | | | | | |
| GERD remission | 2 | 1.68 | 0.86, 3.29 | 0.13 | 79% | 0.03 | Random-effect model |
| GERD improved | 2 | 1.48 | 1.07, 2.04 | 0.02 | 7% | 0.34 | Fixed-effect model |
| GERD unchanged | 2 | 0.67 | 0.38, 1.17 | 0.16 | 0% | 0.35 | Fixed-effect model |
| GERD worsened | 2 | 0.16 | 0.06, 0.44 | 0.0004 | 0% | 0.59 | Fixed-effect model |
| de novo GERD | 2 | 0.33 | 0.15, 0.68 | 0.003 | 0% | 0.86 | Fixed-effect model |
| Hyperuricemia remission | 2 | 1.11 | 0.78, 1.59 | 0.55 | 80% | 0.02 | Random-effect model |
| Depression | | | | | | | |
| Remission | 2 | 0.98 | 0.52, 1.88 | 0.96 | 2% | 0.31 | Fixed-effect model |
| Improved | 2 | 2.07 | 0.24, 17.61 | 0.51 | 78% | 0.03 | Random-effect model |
| Unchanged | 2 | 0.76 | 0.32, 1.79 | 0.53 | 58% | 0.12 | Fixed-effect model |

RR, risk ratio; CI, confidence intervals; OSAHS, obstructive sleep apnea hypopnea syndrome; GERD, gastroesophageal reflux disease.

improvement but LSG may worsen GERD symptoms and may lead to de novo GERD. Base on this conclusion, when choose the type of operation, the main determinant should be the co-morbidities such as dyslipidemia, hypertension and GERD of patients, not the BMI or T2DM. Future studies should focus on the comparison of complication and co-morbidities.

Data statement

The material of this article is original research. All data in this manuscript is available and transparent for readers.

Ethical approval

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Author contribution

The authors on this paper all participated in study design. All authors have read and approved this version of the article, and due care has been taken to ensure the integrity of the work. The material of this article is original research and no part of this paper has been previously published. The material has also not been submitted for publication elsewhere while under consideration. No conflict of interest exists in the submission of this manuscript. All authors have the appropriate permissions and rights to the reported data.

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Appendix A. Supplementary data

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