Systematic Review and Meta-Analysis

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Meta-analysis of the effectiveness of laparoscopic adjustable gastric banding versus laparoscopic sleeve gastrectomy for obesity

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Abstract

Background: Laparoscopic adjustable gastric banding (LAGB) and laparoscopic sleeve gastrectomy (LSG) are common weight loss procedures. Our meta-analysis compared these procedures for the treatment of morbid obesity and related diseases.

Methods: We systematically searched the PubMed, Embase, and the Cochrane Library through January 2018. The percentage of excess weight loss (%EWL), improvement or remission of type 2 diabetes mellitus (T2DM) and hypertension were analyzed and compared.

Results: Thirty-three studies with 4109 patients were included. Greater decreases in excess weight were found in patients who received LSG at 6 months (weighted mean difference (WMD) −9.29, 95% confidence interval (CI): −15.19 to −3.40, $P=.002$), 12 months (WMD −16.67 95% CI: −24.30 to −9.05, $P<.0001$), 24 months (WMD −19.63, 95% CI: −29.00 to −10.26, $P<.0001$), and 36 months (WMD −19.28, 95% CI: −27.09 to −11.47, $P<.0001$) than in patients who received LAGB. However, there were no significant differences in the 3-month outcomes between the 2 groups (WMD −1.61, 95% CI: −9.96 to 6.73, $P=.70$). T2DM patients after LSG experience more significant improvement or remission of diabetes (odds ratio (OR): 0.22, 95% CI: 0.06–0.87, $P=.03$). The 2 groups did not significantly differ regarding improvement or remission of hypertension (OR 0.80, 95% CI: 0.46–1.38, $P=.42$).

Conclusion: LSG is a more effective procedure than LAGB for morbidly obese patients, contributing to a higher %EWL and greater improvement in T2DM.

Abbreviations: %EWL = percentage of excess weight loss, BMI = body mass index, BP = blood pressure, BPD = biliopancreatic diversion, CIs = confidence intervals, LAGB = laparoscopic adjustable gastric banding, LRYGB = laparoscopic Roux-en-Y gastric bypass, LSG = laparoscopic sleeve gastrectomy, MeSH = medical subject heading, OR = odds ratio, RCTs = randomized controlled trials, T2DM = type 2 diabetes mellitus, WHO = World Health Organization, WMD = weighted mean difference.

Keywords: diabetes mellitus, hypertension, laparoscopic sleeve gastrectomy, laparoscopy adjustable gastric banding, obesity

1. Introduction

World Health Organization data indicate that there were 422 million diabetic patients in 2014, and 10% of them were obese. Bariatric surgery is the most effective available therapy for obese patients with type 2 diabetes mellitus (T2DM); in fact, diabetes remission often occurs before significant weight loss, and the effects are superior to those of conventional therapy in randomized controlled trials (RCTs).[1–4]

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Conventionally, 4 bariatric procedures are used for morbidly obese patients: laparoscopic adjustable gastric banding (LAGB), laparoscopic sleeve gastrectomy (LSG), laparoscopic Roux-en-Y gastric bypass (LRYGB), and biliopancreatic diversion (BPD).[5,6] LAGB initially accounted for most procedures and exerts a weight loss effect through a restrictive mechanism.[3] The band is placed 1 to 2 cm below the gastroesophageal junction and secured in place with a monofilament suture of the cardia and fundus below the band to the pouch above the band.[7] This operation is the least complex common procedure to perform and has the lowest early postoperative morbidity. However, the prevalence of this procedure has markedly declined in the past 10 years.[8] LSG is a bariatric procedure involving resection of most of the stomach along the greater curvature, leaving only a narrow tube between the gastroesophageal junction and the pylorus.[9] LSG has received increasing attention because of the relatively low rate of complications and the degree of percentage of excess weight loss (%EWL) and glucose reductions.[10] Given the increasing popularity of LSG over LAGB as a restrictive procedure, we performed a systematic review and meta-analysis of the available published literature to compare outcomes of the 2 approaches.

2. Methods

2.1. Literature search strategy

We searched PubMed, Embase, and the Cochrane Library for relevant articles (through January 2018). The following medical subject heading (MeSH) terms and their combinations were searched [in the Title/Abstract]: "body weight," "weight loss," "weight gain," "weight change," "body fat," "adipose tissue," "sleeve gastrectomy," "gastric banding," and "bariatric surgery." The search strategy also used several text terms to identify relevant information. Reference lists from relevant primary studies and review articles were also examined to find additional publications.

2.2. Study inclusion and exclusion criteria

The following inclusion criteria were applied: RCTs and nonrandomized studies that compared LAGB with LSG regardless of publication date, and studies reporting outcomes of % EWL and/or diabetes mellitus and hypertension. Remission of T2DM is defined as fasting plasma glucose levels less than 125 mg/dL with A1c < 6.5% maintained for at least 1 year.[11] Hypertension remission was defined as normal blood pressure (BP) levels without antihypertensive therapy at 1 year (systolic BP < 140 mm Hg and diastolic BP < 90 mm Hg) and hypertension improvement was considered when a decrease in dosage or number of antihypertensive medications was required or when a decrease in systolic or diastolic BP levels was observed with the same medication.[12] The major exclusion criteria were duplicate publications; studies using animal models; studies that did not report usable data; case reports, letters, or articles that were not full texts; and commentaries, reviews and non-English publications.

2.3. Data extraction and risk-of-bias assessment

Two investigators independently extracted and evaluated all eligible studies. The authors, publication year, number of patients, mean age, %male subjects, and mean body mass index (BMI) were recorded for each study. We captured the following outcome variables: %EWL and (or) improvement or remission of T2DM and (or) hypertension. %EWL was stratified according to different follow-up time points (3, 6, 12, 24, and 36 months). In addition, major obesity-related diseases, including T2DM and hypertension, were also pooled and compared. Discrepancies were resolved by discussion between the 2 authors. If the 2 authors could not reach a consensus, the third author was consulted, and a final decision was made by voting. Two authors independently assessed the risk of bias using the approach recommended by the Cochrane Handbook for Systematic Reviews of Interventions.[13] Efforts were made to obtain exact numerical data from authors via email if the data were not available in the article.

2.4. Statistical analysis

Analysis of outcomes was performed with STATA/SE version 12.0 and Review Manager Version 5.0. Continuous variables were pooled using the weighted mean difference (WMD) with 95% confidence intervals (CIs), while odds ratios (ORs) with 95% CIs were applied to perform the statistical analysis for dichotomous variables. A χ^2 test was performed to assess the heterogeneity of the included studies.[14] If $P > .1$ and/or $I^2 <$ 50%, the fixed effect model was used for data analysis; otherwise, the random-effect model was adopted. Publication bias of studies was estimated by Begg funnel plot with Egger test. If publication bias was present, we further evaluated the number of missing studies by the Duval and Tweedie trim and fill procedure and recalculated the pooled risk estimates with the addition of those missing studies. The statistical tests were 2-sided, and $P < .05$ was considered statistically significant. If data on continuous outcomes were reported as medians and ranges, we estimated the mean and standard deviation according to the Hozo method.[15]

2.5. Ethical review

This is a meta-analysis article, does not involve ethical review, and ethical approval is not necessary after inquiring the ethical review committee in our hospital.

3. Results

A flow chart of the literature search strategies is presented in Fig. 1. After exclusion of several studies for methodological reasons, our search yielded 33 eligible published studies for this meta-analysis.[16–48] All studies were published after 2005 and included a total of 4109 patients. Among these patients, 2126 (51.7%) underwent LAGB, and 1983 (48.3%) underwent LSG. The sample size of these trials ranged from 10 to 245 patients. Fourteen trials were nonrandomized, prospective observational studies,[16,19,22–25,27,28,33,37,39,41,45,47] 18 were retrospective cohort studies,[17,18,20,21,26,29–32,34–36,38,40,42–44,46] and 1 was a prospective RCT.[48] The improvement or remission of diabetes and hypertension is recorded in different follow-up periods, and all patients were followed for less than 4 years. The characteristics and the risk of bias in the included studies are shown in Table 1 and Fig. 2.

3.1. %EWL after LAGB versus LSG

The results indicated that patients receiving LSG had significantly higher scores at 6 months (WMD −9.56, 95% CI: −15.74 to −3.38, $P = .002$, $I^2 = 95\%$; Fig. 3B), 12 months (WMD −16.67

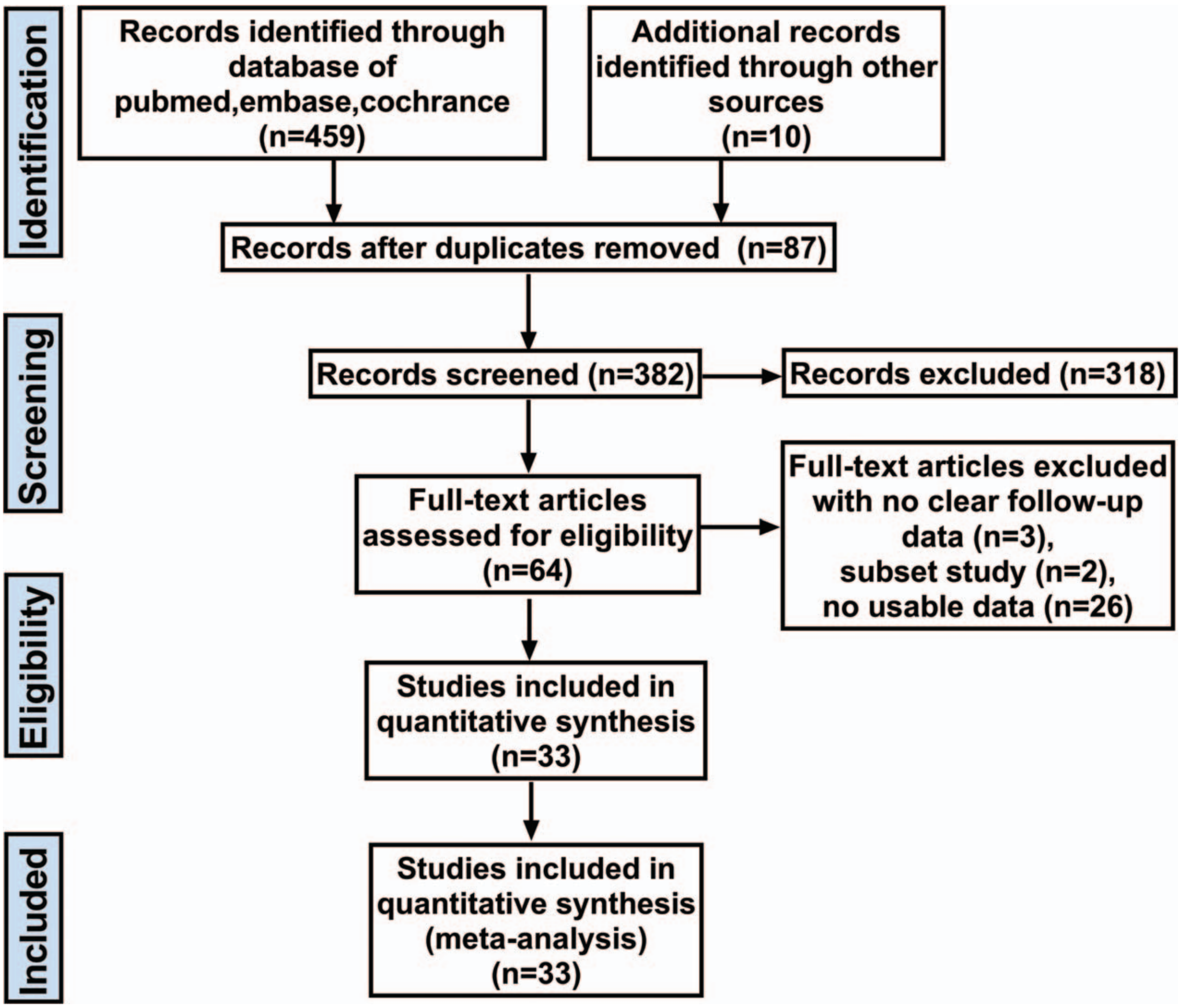

Figure 1. Study selection diagram for the meta-analysis of bariatric procedures.

95% CI: −24.30 to −9.05, $P<.0001$, $I^2=97\%$; Fig. 4A), 24 months (WMD −19.63, 95% CI: −29.00 to −10.26, $P<.0001$, $I^2=95\%$; Fig. 4B), and 36 months (WMD −19.28, 95% CI: −27.09 to −11.47, $P<.0001$, $I^2=82\%$; Fig. 4C) after surgery. However, there was no significant difference between the LSG group and the LAGB group at 3 months (WMD −1.61, 95% CI: −9.96 to 6.73, $P=.62$, $I^2=98\%$; Fig. 3A).

3.2. Improvement or remission of T2DM after LAGB versus LSG

Considering the significant heterogeneity between the 2 groups ($P<.00001$, $I^2=87\%$), the random-effect model was applied. LSG appeared to have a significant effect on improvement or remission of T2DM after the postoperative follow-up period (OR 0.22, 95% CI: 0.06–0.87, $P=.03$, Fig. 5A).

3.3. Improvement or remission of hypertension after LAGB versus LSG

According to the pooled data, 223 of 362 (61%) patients with hypertension experienced improvement of their hypertension after LAGB, and 330 of 497 (63%) patients with hypertension improved after LSG. As expected, LSG had the same impact on hypertension as LAGB (OR 0.80, 95% CI: 0.46–1.38, $P=.42$, Fig. 5B) according to the meta-analysis of the 7 eligible studies. Due to the existence of heterogeneity ($P=.03$, $I^2=55\%$), a random effects model was used.

3.4. Publication bias and heterogeneity

The funnel plots used to detect publication bias in the meta-analysis are presented in Fig. 6. No evidence of publication bias was detected for %EWL at 6 months (Egger test, $P=.458$, Fig. 6A), %EWL at 12 months (Egger test, $P=.622$, Fig. 6B) after surgery, or the improvement/remission of hypertension (Egger test, $P=.107$, Fig. 6D) after surgery. Publication bias was present only for improvement/remission of T2DM after surgery ($P=.044$). After using the trim and fill' method for improvement/remission of T2DM after surgery, there was no longer evidence of publication bias ($P=.057$, Fig. 6C). Publication bias was not calculated for the rest of the outcomes due to the small number of studies that were included. Substantial heterogeneity was present in the meta-analysis findings, with I^2 values ranging from 55.0%

Table 1

Characteristics of the studies included in the meta-analysis.

Author/year	Study type	LAGB vs LSG			
		Patient number	Mean age (year)	%Male	BMI (kg/m²)
Langer FB, 2005	Pro	10 vs 10	38.5±13.6 vs 39.3±11.7	90 vs 90	46.7±3.5 vs 48.3±5.7
Himpens J, 2006	RCT	40 vs 40	36 (20–61) vs 40 (22–65)*	18 vs 23	37(30–47) vs 39(30–53)*
Gan SS, 2007	Pro	12 vs 21	NA	17 vs 38	NA
Kasama K, 2008	Pro	13 vs 23	43±10 vs 38±10	38 vs 74	37.5±4 vs 49.1±12
Kueper MA, 2008	Pro	16 vs 16	NA	44 vs 44	NA
Breznikar B, 2009	Re	180 vs 30	NA	12 vs 67	NA
Wang Y, 2009	Re	15 vs 10	NA	33 vs 40	38.5±2.2 vs 39.4±3.8
Wong SK, 2009	Pro	57 vs 30	41±9 vs 33±7	42 vs 30	40±7 vs 45±8
Omana JJ, 2010	Re	74 vs 49	41±14 vs 45±12	22 vs 27	44±5 vs 52±11
O'Keefe KL, 2010	Re	34 vs 6	NA	NA	45.9±6.9 vs 50.0±12.0
Varela JE, 2011	Pro	20 vs 20	54.9±8 vs 51.7±8	80 vs 60	42.5±5 vs 44.8±5
Brunault P, 2011	Pro	102 vs 29	39.3±9.6 vs 41.0±10.6	17 vs 24	48.1±6.1vs 54.3±10.1
Alley JB, 2012	Re	39 vs 69	47.0±9.5 vs 49.6±10.7	18 vs 22	41.9±5.2 vs 42.7±5.0
Hady HR, 2012	Re	100 vs 100	NA	34 vs 48	45.21±3.96vs 52.15±8.5
Fenske WK, 2013	Pro	13 vs 11	NA	NA	NA
Musella M, 2014	Pro	120 vs 175	NA	60 vs 42	NA
Lehmann A, 2014	Re	130 vs 72	39.4±10.4 vs 38.8±11.9	24 vs 24	45.2±5.4 vs 44.1±5.3
Cheng IC, 2014	Re	68 vs 130	33.2±9.1 vs 33.3±7.4	51 vs 28	40.7±4.9 vs 41.6±6.1
Dogan K, 2015	Re	245 vs 245	39.6±10.0 vs 39.7±10.0	18 vs 18	44.8±5.0 vs 45.8±6.0
Chaudhry UI, 2015	Re	17 vs 17	44.0±12.0 vs 45.0±9.8	24 vs 24	45.0±6.2 vs 46.5±4.8
Lee WJ, 2015	Pro	42 vs 42	31.9±8.8 vs 32.1±8.6	57 vs 33	40.8±5.9 vs 40.7±6.1
Flint R, 2015	Pro	94 vs 134	45.1±11.9 vs 44.8±9.11	NA	42.2±7.1 vs 50.0±9.0
Pedroso FE, 2015	Re	137 vs 37	16.9±1.2 vs 17.3±1.82	31 vs 27	48.3±8.3 vs 50.1±9.4
Mizrahi I, 2015	Pro	11 vs 15	38.9±1.6 vs 36.5±3.1	36 vs 53	43±1.3 vs 42.7±1.1
Moon RC, 2016	Re	68 vs 73	62.7±2.2 vs 64.1±2.9	24 vs 33	42.7±5.6 vs 44.0±7.0
Cunha FM, 2016	Re	80 vs 55	NA	13 vs 11	43.4±4.5 vs 44.4±5.2
Kruljac I, 2016	Pro	21 vs 15	36 (31–44) vs 45 (34–51)*	23.8 vs 26.7	41.8±1.4 vs 47.4±1.8
Lee SK, 2016	Re	72 vs 116	33.6±10.3 vs 5.0±10.4	23.6 vs 25.9	38.9±5.4 vs 39.1±6.2
Clough A, 2016	Re	125 vs 62	43.2±10.6 vs 47.6±9.3	29.6 vs 41.9	46.3±7.3 vs 55.2±11.0
Castellani RL, 2017	Re	85 vs 26	NA	NA	NA
Aelfers SC, 2017	Pro	29 vs 53	38.4±10.7 vs 42.5±12.0	17.2 vs 26.0	44.8±6.8 vs 42.5±4.5
Haruta H, 2017	Re	46 vs 183	NA	NA	31 vs 31
Sierzantowicz R, 2017	Re	11 vs 69	NA	NA	43.41±3.4 vs 48.55±5.5

BMI=body mass index, LAGB=laparoscopic adjustable gastric banding, LSG=laparoscopic sleeve gastrectomy, NA=not available, Pro=prospective, RCT=randomized controlled trial, Re=retrospective.
* Reported as medians and range.

to 98.0%. After stratification of data, heterogeneity decreased in some categories. The pooled effectiveness of LAGB versus LSG for obesity findings significantly varied by study type, publication date, and revision surgery (Table S1, http://links.lww.com/MD/C855).

4. Discussion

Bariatric surgery is currently the most effective therapy for long-term weight loss in morbidly obese patients. In addition, it is effective for the treatment of obesity-related diseases, such as T2DM and hypertension. Currently available bariatric procedures include LAGB, LRYGB, LSG, and BPD.[5,6] In this meta-analysis, we compared the efficacy of LAGB and LSG on obesity and related diseases by analyzing published studies.

Although an informative systematic review has been published, no previous studies have quantitatively analyzed such a robust dataset of LAGB versus LSG for obesity and related diseases. Wang et al[49] showed that LSG was a more effective procedure for morbid obesity than LAGB in a small meta-analysis using a fixed effect model for data analysis, while heterogeneity was evident. Our study incorporates and extensively updates these results and clarifies the difference between the effects of LAGB and LSG on %EWL. However, improvement or remission of diabetes and hypertension cannot be clarified because of insufficient data. We extracted data from 33 valid independent studies of 4109 patients interviewed for LAGB and LSG using a standardized method and sampled data without selection bias. This evaluation reinforced the finding that LSG led to significantly greater %EWL than LAGB over long-term periods. These findings provide strong evidence for long-term %EWL benefit among patients who undergo LSG. Only 2 studies included 5-year outcomes and recruited adolescent or adult patients. It is very likely that publication bias exists; we did not include the analysis for 5-year outcomes. To the best of our knowledge, this is the first meta-analysis comparing the long-term outcomes of LSG and LAGB. Furthermore, LSG is a more effective approach than LAGB for treating morbid obesity comorbidities such as diabetes mellitus.

Altieri et al[50] reported that at least one-fifth of patients who received LAGB in the state of New York between 2004 and 2010 underwent device revision or removal. The revision rate may be as high as 34.17%. However, 20.36% underwent more than 1 subsequent intervention. Revisional procedures had a

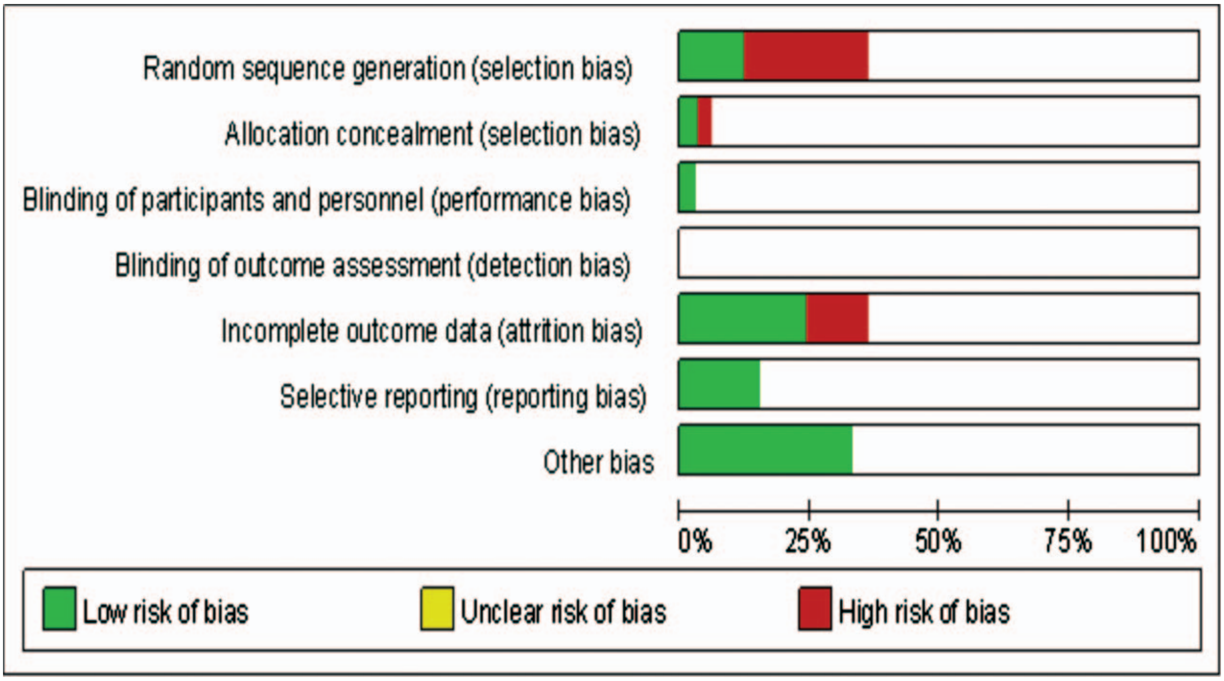

Figure 2. Risk of bias of included studies.

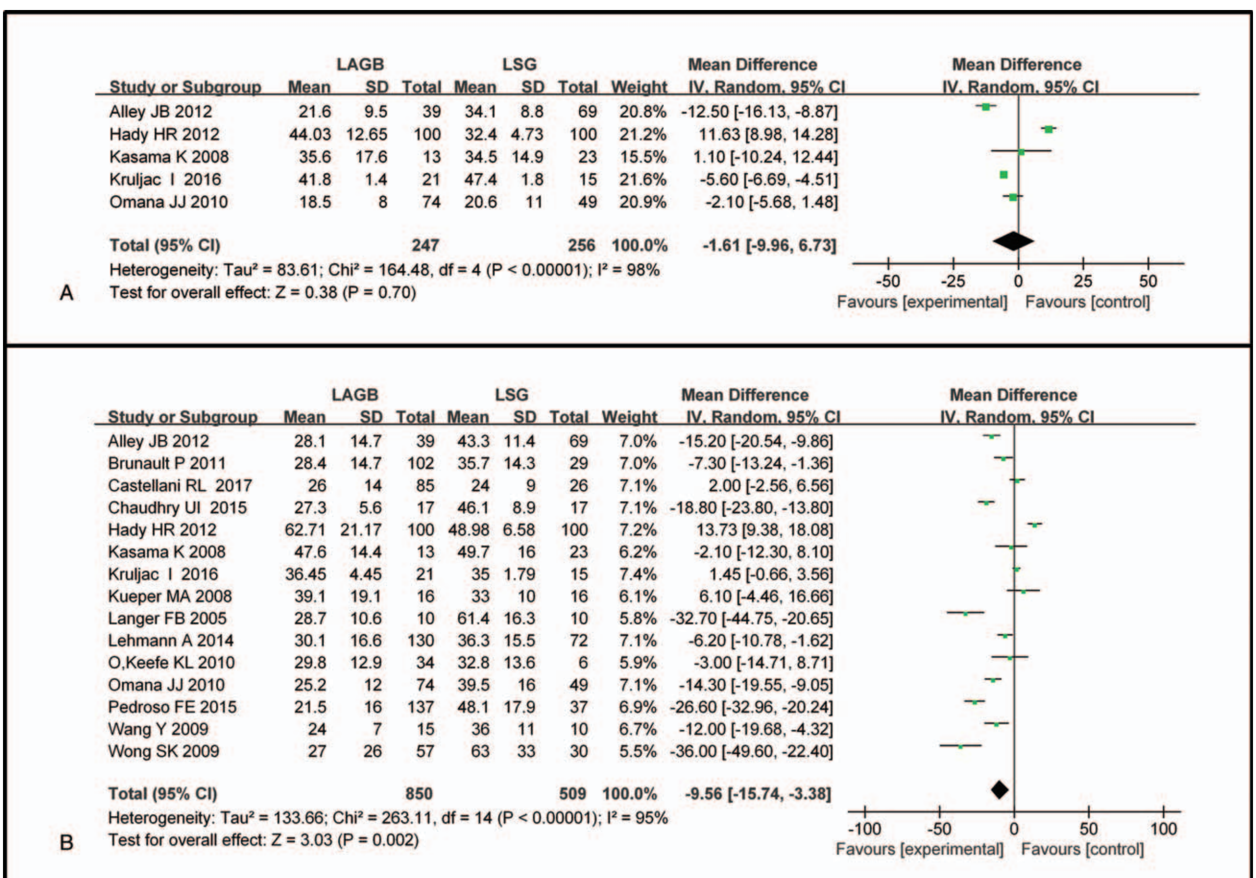

Figure 3. Forest plot of comparisons between LAGB and LSG for %EWL at (A) 3 months and (B) 6 months after surgery. Mean differences are shown with 95% CIs. LAGB = laparoscopic adjustable gastric banding, LSG = laparoscopic sleeve gastrectomy, CIs = confidence intervals, %EWL = percentage of excess weight loss.

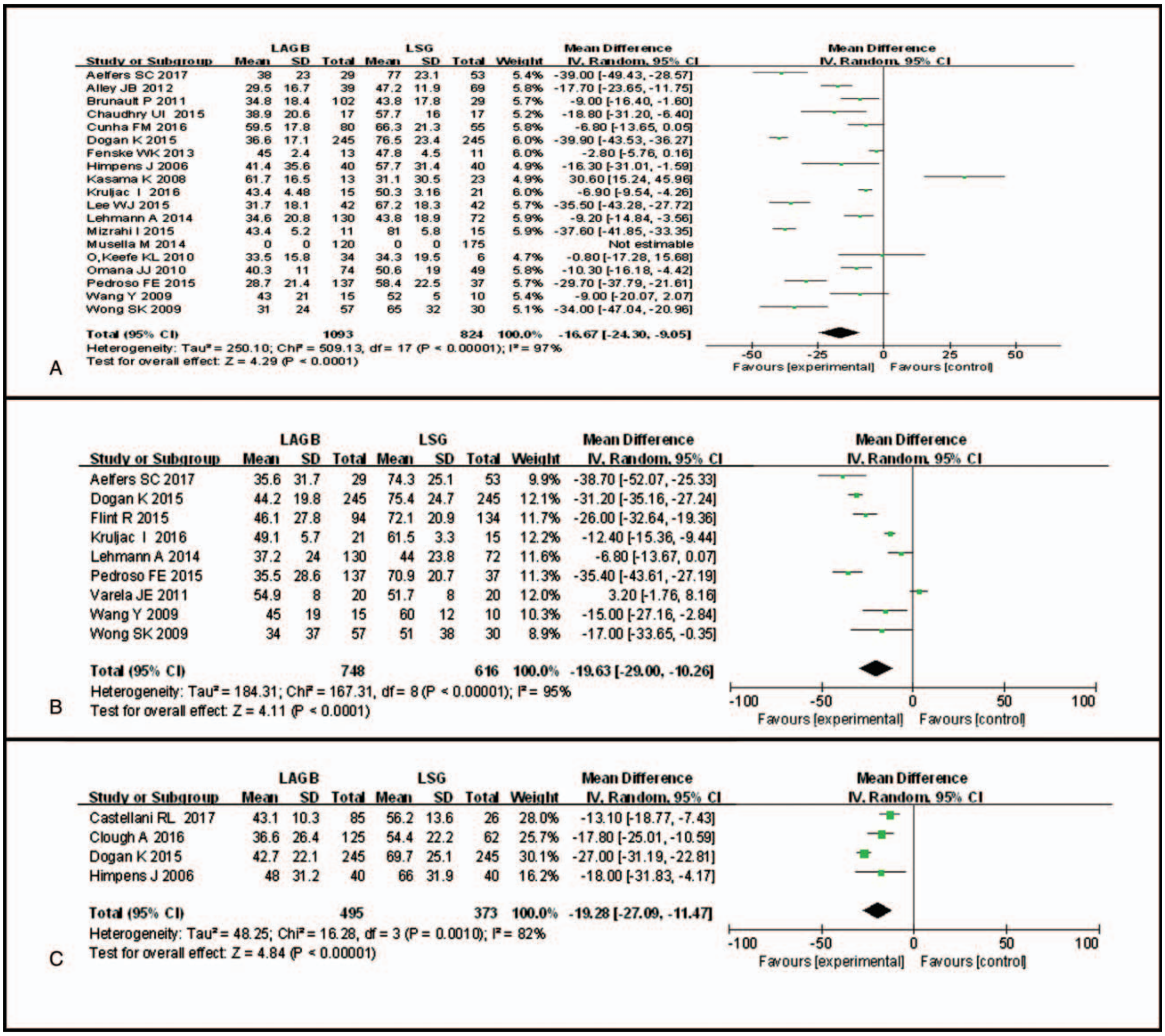

Figure 4. Forest plot of comparisons between LAGB and LSG for %EWL at (A) 12 months, (B) 24 months, and (C) 36 months after surgery. Mean differences are shown with 95% CIs. LAGB = laparoscopic adjustable gastric banding, LSG = laparoscopic sleeve gastrectomy, CIs = confidence intervals, %EWL = percentage of excess weight loss.

higher rate of complications, most commonly digestive/intestinal complications, surgical errors, or pneumonia.[50] In contrast, the total number of LSG cases is increasing due to the simplicity of the procedure, its low risk, and good outcomes.[51,52] According to a new survey, LSG has been the most frequently performed surgery in Asia in recent years. Our meta-analysis indicated that LAGB has a similar effect as LSG on %EWL in the 3-month postoperative period. The reason for this similar result may be that surgeons often prescribe a low carbohydrate diet after LAGB, which may account for greater %EWL at 3 months than at other time points, as adherence to the diet declines. One interesting study by Chakravarty et al[53] compared LAGB with other bariatric procedures. The authors concluded that LAGB was not the most effective bariatric procedure for reducing weight compared with other procedures; nevertheless, LAGB was associated with fewer early complications, a shorter operative time, and a shorter length of hospital stay. However, our meta-analysis also demonstrated that patients who underwent LSG lost more excess weight by 6, 12, 24, and 36 months than those who underwent LAGB. The highest concentrations of ghrelin are found in the gastric fundus, and production stops when this area is removed after LSG, which may result in greater %EWL after LSG.[5,23,54] Ghrelin is the only gastrointestinal hormone that stimulates food intake, and the serum ghrelin level is inversely proportional to body weight. Langer et al[23] reported that ghrelin levels remained unchanged immediately after LAGB and increased after 1 and 6 months, whereas ghrelin decreased both immediately and at 1 and 6 months after LSG.

Because the prevalence of comorbidities was different among groups, performing a direct comparison of the procedures is difficult to determine which procedure is superior; therefore, we only compared the comorbidities of T2DM and hypertension. LSG was observed to achieve better T2DM control than LAGB. In addition to improved glucose metabolism being associated with %EWL after surgery, gut hormones play a major role in

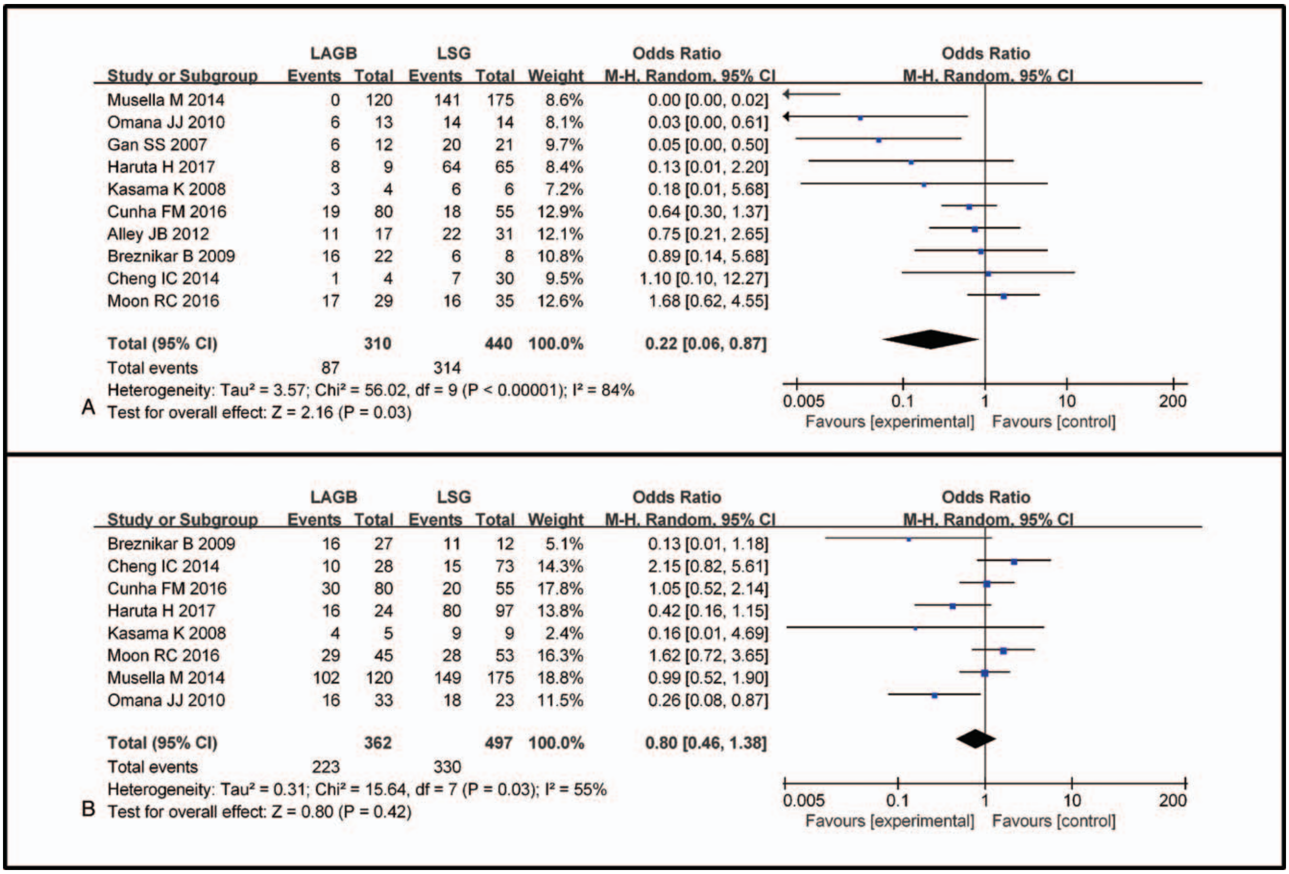

Figure 5. Forest plot of comparisons between LAGB and LSG in terms of the improvement or remission of T2DM and hypertension postoperatively. Odds ratios are shown with 95% CIs. LAGB = laparoscopic adjustable gastric banding, LSG = laparoscopic sleeve gastrectomy, CIs = confidence intervals, T2DM = type 2 diabetes mellitus.

diabetes improvement or remission and, most likely, in %EWL after LSG.[5,55] The hindgut hypothesis proposes that stimulation of the distal ileum with the early arrival of undigested nutrients is responsible for the improvement in glucose tolerance after bariatric surgery.[56] Remarkable changes in factors such as glucagon-like peptide 1 are the basis of this hypothesis.[57] Gastric banding operations do not cause obvious alterations in gut hormones and seem to depend exclusively on restriction-derived weight loss for the antidiabetic and weight loss effects. Himpens et al[58] reported long-term outcomes after LAGB; preoperatively, 6.4% of the patients had DM, which increased to 14.1% at 12 years. Other mechanisms of %EWL involve bile acid, gut microflora, the vagus nerve, and other gut hormones.[59–61] LSG may be a better choice than LAGB for patients with T2DM. Due to complications such as LSG-like leaks and gastro-bronchial fistulas, LAGB can still be considered for the surgical treatment of morbid obesity and appears to be safer, especially in patients without obesity-related diseases. However, both procedures were equivalent in hypertension control. The antihypertensive effect of bariatric surgery has been attributed to the reduction in plasma aldosterone levels, particularly in those with visceral adiposity.[62] BP might often increase back to preoperative levels during the weight regain or even during the weight maintenance phase.[63,64]

There are some limitations of our meta-analysis that should be considered. First, our article is limited by a lack of RCTs with large sample sizes. Second, some patients in the included studies converted to open surgery, which may introduce bias in the final result. Third, due to fasting blood glucose < 126 mg/dL was defined as diabetes remission, there were patients who were defined as being in remission of T2DM who had prediabetes. In addition, there may be patients with blood pressure < 130 mm Hg but ≥ 120 mm Hg, systolic, and < 85 mm Hg but ≥ 80 mm Hg, diastolic. These patients may fall into the elevated blood pressure category according to the 2017 updated blood pressure guidelines, although these clinical reports included in the meta-analysis were completed before 2017.

Well-designed studies with larger sample sizes and longer follow-up periods are merited for future studies. Nevertheless, this meta-analysis was conducted at an appropriate time, and we provide the most up-to-date information in this area.

In conclusion, our meta-analysis emphasizes that LSG can lead to significantly greater sustained %EWL and T2DM remission than LAGB, while these 2 procedures have similar effects on hypertension. However, these conclusions should be validated in further RCTs with appropriate sample sizes, and long-term follow-up outcomes should be confirmed.

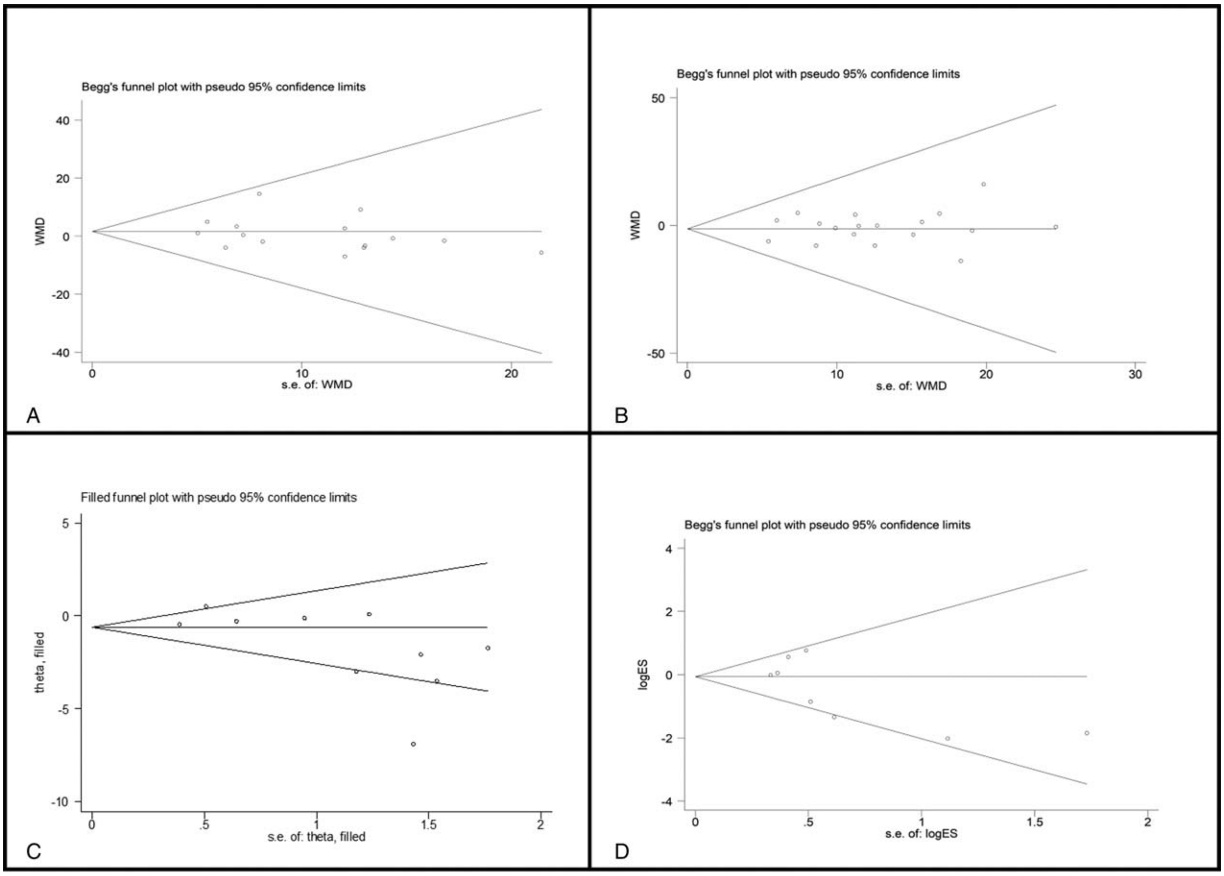

Figure 6. Funnel plot using Begg method for (A) %EWL at 6 months, (B) %EWL at 12 months, (D) improvement or remission of hypertension after surgery; Funnel plot using adjusted trim and fill method for (C) improvement or remission of diabetes.

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