Systematic Review and Meta-Analysis

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Effectiveness of bariatric surgical procedures

A systematic review and network meta-analysis of randomized controlled trials

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Abstract

Background: Bariatric surgery has proved to be an effective strategy in treating obesity. However, randomized controlled trials (RCTs) of 3 most common bariatric surgery procedures, Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), and laparoscopic adjustable gastric band (LAGB), reported inconsistent results. We performed a systematic review and network meta-analysis to synthesize evidence of effectiveness of the 3 common bariatric procedures from relevant RCTs.

Methods: The present study was a systematic review and network meta-analysis of RCTs. All RCTs must meet the following criteria to be included in the analysis: patients with body mass index (BMI) ≥30 kg/m^2, reported at least 1 outcome of interest, compared at least 2 of the 3 bariatric procedures, and had follow-ups of at least 1 year. Primary outcome was weight loss, expressed as differences in mean BMI reduction and percentage excess weight loss (%EWL) following 1 year after the surgery. Network meta-analysis was based on Bayesian framework with Markov Chain Monte Carlo simulation approach.

Results: Eleven RCTs that met the criteria were included in the review. Of 9 trials (n = 765), the differences in mean BMI reduction were −0.76 (95% CI: −3.1 to 1.6) for RYGB versus SG, −5.8 (95% CI: −9.2 to −2.4) for RYGB versus LAGB, and −5.0 (95% CI: −9.0 to −1.0) for SG versus LAGB. Eight RCTs (n = 656) reported percentage excess weight-loss (%EWL), the mean differences between RYGB and SG, RYGB and LAGB, and SG and LAGB were 3.8% (95% CI: −8.5% to 13.8%), −22.2% (95% CI: −34.7% to −6.5%), and −26.0% (95% CI: −40.6% to −6.4%), respectively. The meta-analysis indicated low heterogeneity between studies, and the node splitting analysis showed that the studies were consistent between direct and indirect comparisons ($P > .05$).

Conclusion: The RYGB and SG yielded similar in weight-loss effect and both were superior to LAGB. Other factors such as complications and patient preference should be considered during surgical consultations.

Abbreviations: %EWL = percentage excess weight loss, ASMBS = American Society for Metabolic and Bariatric Surgery, BMI = body mass index, CI = confidence interval, GERD = gastroesophageal reflux disease, GLM = generalized linear model, ITT = intent-to-treat, LAGB = laparoscopic adjustable gastric band, MeSH = Medical Subject Headings, NHANES = National Health and Nutrition Examination Surveys, NNT = number needed to treat, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analysis, RCT = randomized controlled trial, RYGB = Roux-en-Y gastric bypass, SG = sleeve gastrectomy, US = United States of America.

Keywords: bariatric surgical procedures, laparoscopic adjustable gastric band, meta-analysis, network meta-analysis, Roux-en-Y gastric bypass, sleeve gastrectomy, systematic review

1. Introduction

The prevalence of obesity is rising in both developed and developing countries.[1] According to the National Health and Nutrition Examination Surveys (NHANES), more than 2 out of 3 adults are considered overweight or obese, and 1 out of 3 adults are clinically obese in the United States (US).[2] Obesity is associated with metabolic conditions, such as type 2 diabetes and cardiovascular disease, certain types of cancer, and higher mortality.[3–5] In addition, the annual medical cost of obesity in the US was estimated to be $147 billion.[6]

Bariatric surgery is a well-established treatment strategy for obesity after failure of behavioral and pharmacologic weight loss therapies[7] and associated with improved comorbidities, quality of life, and survival in severe obesity.[8] According to the American Society for Metabolic and Bariatric Surgery (ASMBS), 196,000 bariatric surgeries were performed in 2015 in the US.[9] The 3 most commonly performed bariatric surgery procedures include Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), and laparoscopic adjustable gastric band (LAGB).[9,10]

Currently, there are no clear ranking of these 3 surgical procedures in terms of their effectiveness. The evidence examining the weight loss effect of SG in relation to RYGB is controversial.[11–13] Several meta-analyses have been performed to compare the effectiveness of bariatric surgery procedures; however, their results were based on older evidence.[7,12–14] With technological advances in surgical procedures, especially with newer procedures like SG and improved bariatric patient-care

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management,[13] an updated quantitative comparative effectiveness research was needed to aid in healthcare decision making.

Network meta-analysis is a statistical method of quantifying evidence from a network of multiple randomized controlled trials (RCTs) involving treatments compared directly, indirectly, or both.[15] This approach has advantages over the conventional pairwise meta-analysis such that it is able to assess the results of indirect as well as direct evidence and makes inferences on comparative effectiveness of interventions that have no head-to-head trials available.[16]

With increasing popularity of bariatric surgery procedures coupled with inconsistent reports of their effectiveness, an up-to-date comprehensive review with synthesis of more recent evidence is in need. The aims of our study are to perform a systematic review and meta-analysis of RCTs to comprehensively assess the short-term effectiveness and safety of the 3 common bariatric procedures.

2. Methods

This was a systematic review and network meta-analysis of RCTs conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and PRISMA Extension Statement for Network Meta-Analysis.[17,18] Our study used data and information from previously published clinical trials; thus, in Ethics Committee and Institutional Review Board were not required. In addition, all clinical trials used in our systematic review and meta-analysis received ethical and IRB approval from their respective institutions.

2.1. Search strategy and selection criteria

The literature review was conducted using PubMed and EMBASE online databases by 2 independent authors (JHK and QAL). The literature search was conducted until July 2016, and all published randomized clinical trials were included in the review. The following key terms were used under Medical Subject Headings (MeSH) for the search: "bariatric," "bariatric surgery," "Roux-en-Y," "gastric bypass," "sleeve gastrectomy," "gastrectomy," "lap band," and "gastric banding." A manual search using the references of selected retrieved articles was also performed.

Two independent investigators (JHK and QAL) reviewed the study titles and abstracts, and the studies that satisfied the inclusion criteria were retrieved for assessments. Disagreements between the reviewers were resolved by consensus. Studies were considered for inclusion if they included patients 17 years or older with body mass index (BMI) $\geq 30\,kg/m^2$; reported at least 1 outcome of interest; compared 2 of the 3 bariatric procedures, and had follow-up of at least 1 year.

Quality of each randomized trial was assessed using the Jadad scale, which is a 3-item, 5-point scale that is commonly used to rate the methodological quality of clinical trial. The maximum score possible was 5, in which maximum of 2 points are allocated for the description of randomization, 2 points for the descriptions of double-blinding, and 1 point for the description of patient withdrawals.[19] In addition, study's reporting of allocation concealment, intention-to-treat (ITT) analysis, and power calculation, as well as funding information were noted.

2.2. Bariatric surgery procedures

RYGB is a surgical procedure that constructs a small pouch from the proximal portion of the stomach, attaching directly to the small intestine and bypassing part of the stomach and duodenum. RYGB includes any RYGB in both open and laparoscopic procedures. SG is the newest surgical technique that involves removing a large portion of the stomach without removing or bypassing any part of the intestines. SG can be both open and laparoscopic and includes isolated SG but not vertical banded gastroplasty. LAGB is laparoscopically performed reversible procedure in which an inflatable band is placed around the proximal part of the stomach to create a small pouch. The band can be adjusted to increase or decrease restriction according to patients' needs.[20]

2.3. Data extraction

Full-text versions of potentially relevant papers identified in the initial screening were retrieved. Baseline characteristics of the population such as age, gender, and baseline BMI were extracted. Primary outcome was changes in weight loss, expressed as the mean difference in BMI reduction and in percentage excess weight loss (%EWL) following 1 year after the surgery. Secondary outcomes were early and late complications resulting from the surgical procedures. Early complications were defined as complications occurring <30 days after surgery while late complications were those occurring after 30 days of surgery.

2.4. Statistical analysis

Mixed-treatment comparison (also referred as network meta-analysis) using Bayesian-network approach was applied to synthesize evidence for the primary outcome. This method estimated relative effects of multiple treatments by fitting generalized linear model (GLM) under Bayesian framework.[21] Early and late complications were reported using descriptive statistics. Heterogeneity (I^2) was evaluated to determine variability between the included studies. I^2 value of 25% was defined as low heterogeneity, 50% as moderate heterogeneity, and 75% as high heterogeneity.[22] Consistency of results from direct and indirect evidence was analyzed using the node-splitting analysis of inconsistency.[23] All statistical analyses were conducted using R statistical program version 3.3.2.

3. Results

3.1. Search results

Initial search with keywords in electronic databases yielded a total of 5313 studies. Of these, 77 trials were included based on the titles and abstract and after restricting to human, English, and RCT studies. More studies were excluded due to irrelevant research questions and clinical outcomes (43 publications), duplicate study or study protocol only (12 publications), and not meeting inclusion criteria (11 publications). A flow diagram outlining the systematic review process is provided in Figure 1. A total of 11 unique trials satisfied the inclusion criteria and were included in the analysis (8 RYGB vs SG; 2 RYGB vs LAGB; 1 SG vs LAGB).[24–34] Figure 2 shows the patterns of comparisons among the different bariatric procedures with width of the lines proportional to the number of RCT studies for that comparison.

3.2. Study and patients characteristics

Study characteristics of the 11 included trials are shown in Table 1. All studies were published between 2006 and 2014, of which 1 clinical trial[33] was conducted in the US, 9

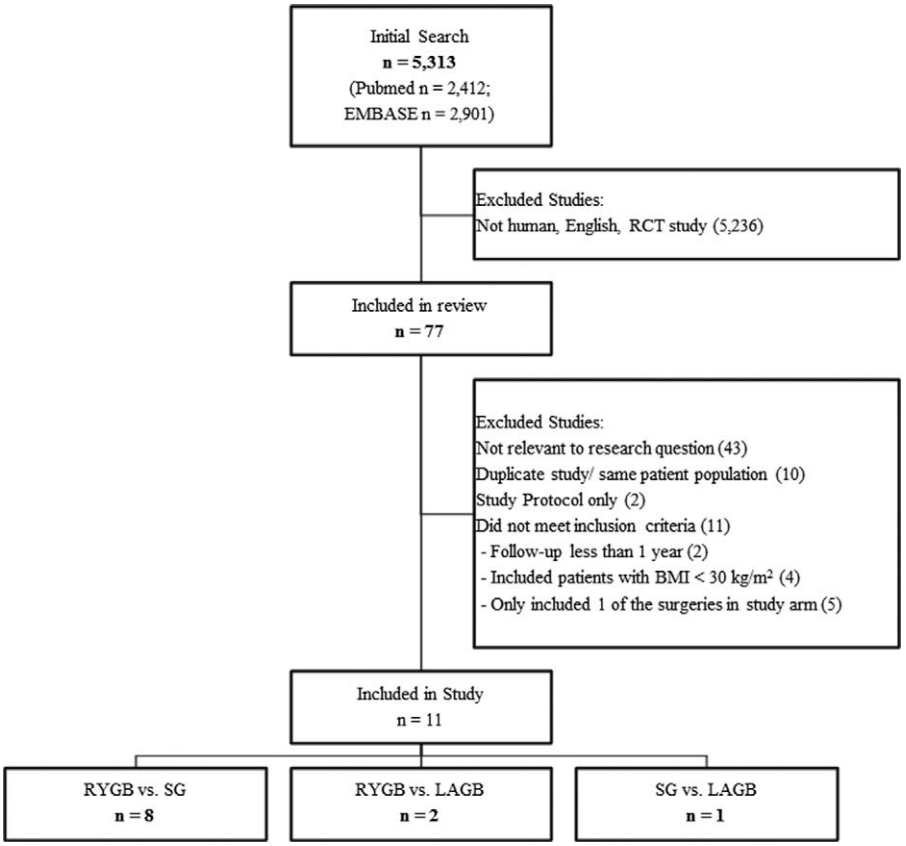

Figure 1. The search result. LAGB = laparoscopic adjustable gastric banding, RCT = randomized controlled trial, RYGB = Roux-en-Y gastric bypass, SG = sleeve gastrectomy.

trials[24–30,32,34] in Europe, and 1 study[31] in Asia. Follow-up time periods ranged from 1 to 5 years. Nine clinical trials reported weight loss as the primary outcome while 2 studies listed it as their secondary endpoint. Seven trials presented data on surgical complications and 4 trials reported obesity-related comorbidity information. Two trials explored patients' quality of life after the bariatric surgery procedures. The study quality assessment is reported in Table 2. The Jadad score ranged from 1 to 5 with the average score of 2.7. Only 2 of the 11 clinical trials used blinding technique.

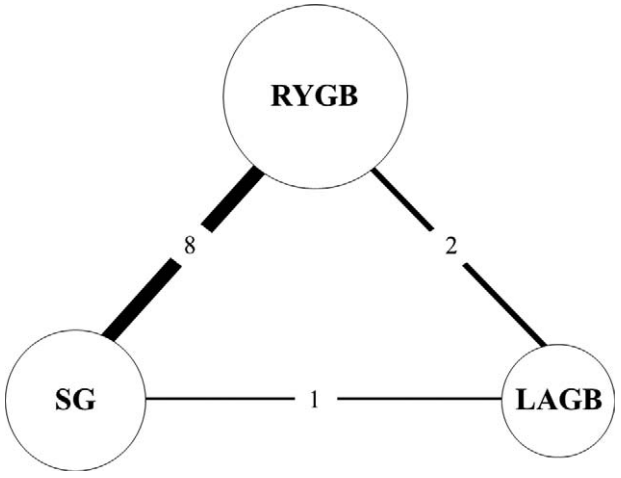

Figure 2. The network of included studies. The circles represent pooled number of studies and the width of bridging bar reflects the number of comparison. LAGB = laparoscopic adjustable gastric banding, RYGB = Roux-en-Y gastric bypass, SD = standard deviation, SG = sleeve gastrectomy.

The pooled sample size of all included clinical trials were 925 (n = 430 patients for RYGB, n = 342 patients for SG, and n = 153 patients for LAGB). Of the pooled study sample size, 26.1% were male with mean age of 39.7 ± 6.4 years and mean BMI of 43.9 ± 2.9 kg/m^2. Pooled patient baseline characteristics in terms of age, gender, and BMI were similar across all bariatric procedures (Supplementary Content 1, http://links.lww.com/MD/B953).

3.3. Weight loss

All clinical trials showed significant weight reduction when compared with their baseline weight after receiving bariatric surgery in all 3 procedures ($P < .05$). Among the 3 surgical procedures, smallest treatment effect in terms of weight loss was observed in LAGB, while conflicting results were seen between RYGB and SG.

Of 9 trials (n = 765)[24,26–29,31–34] that reported BMI as 1 of their outcomes at 1 year, 6 trials compared between RYGB and SG, 2 trials examined between RYGB and LAGB, and 1 trial compared LAGB with SG. The highest BMI reduction was observed in SG, followed by RYGB and LAGB. The mean BMI reduction was 13.5 kg/m^2 for RYGB (n = 355), 14.4 kg/m^2 for SG (n = 257), and 10.6 kg/m^2 for LAGB (n = 153). The mean difference of BMI reduction for SG relative to RYGB was −0.76 kg/m^2 (95% CI: −3.1 to 1.5), LAGB versus RYGB was

Table 1

Summary of included studies.

Author and year	Country	Follow-up, y	Procedure	Number of patients	Age, mean ± SD	Male/ female	Inclusion criteria	Exclusion criteria	Outcome(s)
Karamanakos, 2008	Greece	1	LRYGB	16	37 ± 8.25	4/12	NA	History of GI surgery; chronic medical or psychiatric illness; substance abuse	Weight loss; appetite; fasting and postprandial ghrelin and peptide-YY
			LSG	16	30.6 ± 7.8	1/15			
Kehagias, 2011	Greece	3	LRYGB	30	36 ± 8.4	8/22	BMI < 50	History of GI surgery; chronic medical or psychiatric illness	Weight loss; early and late complications; improvement of comorbidities; nutritional deficiencies
			LSG	30	33.7 ± 9.9	8/22			
Keidar, 2013	Israel	1	RYGB	19	51.45 ± 8.3	12/8*	Age 18 to 65; BMI >35; T2DM with OGTT at baseline with medication discontinued	History of GI surgery	HbA1C; body composition; glucose tolerance
			SG	18	47.7 ± 11.7	9/9			
Paluszkiewicz, 2012	Poland	1	RYGB	36	43.9 ± 10.8	13/23	Age 18 to 60; BMI ≥40, ≥35 with comorbidity	BMI >60; history of major GI surgery; poorly controlled medical or psychiatric illness; active alcohol or substance abuse; active duodenal/gastric ulcer; difficult to treat GERD with a large hiatal hernia; diagnosed or suspected malignancy	Weight loss; morbidity and mortality; remission or improvement of comorbidities; nutritional reoperations; deficiencies
			SG	36	44.9 ± 10.9	10/26			
Peterli, 2013	Switzerland	3	LRYGB	110	42.1 ± 11.2	31/79	Age 18 to 65; BMI >40, >35 with comorbidity; failure of conservative treatment over 2 y	Severe symptomatic GERD despite medications; large hiatal hernia; expected dense adhesions at the level of the small bowel; need for endoscopic follow-up of the duodenum; IBD	Weight loss; perioperative morbidity and mortality; remission rates of comorbidities; quality of life
			LSG	107	43.0 ± 11.1	30/77			
Ramon, 2012	Spain	1	LRYGB	7	46.1 ± 18.0	0/7	Age 18 to 60; BMI >40, >35 with comorbidity; female	BMI >50; undergoing revisional surgery	Weight loss; comorbidities; neurogastrointestinal hormones
			LSG	8	49.8 ± 9.0	0/8			
Vix, 2013	France	1	RYGB	45	35.2 ± 9.4	6/39	Age 18 to 60; BMI 40 to 60	History of upper and lower GI surgery; patient's preference for a specific procedure; hiatal hernia >2 cm	Weight loss; glycolipid profile change
			SG	55	35.1 ± 9.8	12/43			
Zhang, 2014	China	5	LRYGB	32	32.2 ± 9.2	14/18	Age 17 to 59; BMI 33 to 49	History of GI surgery; chronic medical or psychiatric illness; substance abuse	Morbidity rate, weight loss, quality of life; resolution or improvement of comorbidities
			LSG	32	29.3 ± 9.8	12/20			
Angrisani, 2007	Italy	5	LRYGB	24	34.1 ± 8.9	4/20	Age 17 to 49; BMI 36 to 49	History of GI surgery; hiatal hernia	Mortality; conversion to an open procedure; postoperative complications leading to reoperation; hospital stay; weight loss; improvement in comorbidities
			LAGB	27	33.8 ± 9.1	5/22			
Nguyen, 2009	United States	2	LRYGB	111	41.4 ± 11.0	25/86	Age 18 to 60; BMI ≥35 with comorbidity, 40 to 60	History of GI or bariatric surgery; large ventral hernia; hiatal hernia	Perioperative and late outcomes; weight loss, quality of life; costs
			LAGB	86	45.8 ± 9.8	21/65			
Himpens, 2006†	Belgium	3	Isolated LSG	40	41.8 ± 57.0	9/31	Candidate for laparoscopic restrictive surgery	NA	Relative weight loss; feeling of hunger; craving for eating sweets; GERD; complications and reoperations
			LAGB	40	38.3 ± 52.0	7/33			

%EWL = percent excess weight loss, BMI = body mass index, GERD = gastroesophageal reflux disease, GI = gastrointestinal, HbA1C = hemoglobin A1C, IBD = inflammatory bowel disease, LAGB = laparoscopic adjustable gastric band, LRYGB = laparoscopic Roux-en-Y gastric bypass, LSG = laparoscopic sleeve gastrectomy, NA = not available, OGTT = oral glucose tolerance test, RYGB = Roux-en-Y gastric bypass, SD = standard deviation, SG = sleeve gastrectomy, T2DM = type 2 diabetes mellitus.

* The combined number of male and female exceeds the total sample size.

† Mean age is calculated from the range and sample size.[35]

Table 2

Risk of bias.

Study	Jadad score*	Allocation concealment	Blinding	ITT analysis	Power calculation	Funding
Karamanakos, 2008	4	Adequate	Yes	Yes	Yes	NR
Kehagias, 2011	5	Adequate	Yes	Yes	NR	NR
Keidar, 2013	3	No	No	No	Yes	Disclosed
Paluszkiewicz, 2012	1	NR	No	Unclear	NR	Disclosed
Peterli, 2013	2	Adequate	No	Yes	NR	NR
Ramon, 2012	3	Adequate	No	Yes	Yes	Disclosed
Vix, 2013	3	Adequate	No	No	NR	Disclosed
Zhang, 2014	3	Adequate	No	Yes	NR	NR
Angrisani, 2007	3	Adequate	No	No	NR	NR
Nguyen, 2009	2	Adequate	No	No	Yes	Disclosed
Himpens, 2006	1	NR	No	Unclear	NR	NR

NR = not reported,

* Jadad score ranges from 1 to 5. Maximum of 2 points are given for description of randomization, 2 points for description of blinding, and 1 point for description of withdrawal of patients.[19]

$-5.8\,kg/m^2$ (95% CI: −9.1 to −2.3) with number needed to treat (NNT) of 3, and LAGB versus SG was $-5.1\,kg/m^2$ (95% CI: −8.9 to −0.9) with NNT of 10 (Fig. 3A).

Eight trials (n = 656)[24,25,27,30–34] reported %EWL at 1 year; of these studies, 5 examined the differences between RYGB and SG, 2 between RYGB and LAGB, and 1 between LAGB and SG. The %EWL showed similar trend as the BMI reduction in which SG resulted in the largest degree of weight loss followed by RYGB and LAGB. The mean %EWL for RYGB, SG, and LAGB were 67.3% (n = 294), 71.2% (n = 209), and 40.6% (n = 153), respectively. The differences in mean %EWL between SG and RYGB, LAGB and RYGB, and LAGB and SG were 3.9% (95% CI: −8.4 to 14.0), −22.0% (95% CI −35.0 to −6.5) with NNT of 3, and −26.0% (95% CI −41.0 to −6.4) with NNT of 5, respectively (Fig. 3B).

3.4. Weight loss results of individual studies (Supplementary Content 2, http://links.lww.com/MD/B953)

Karamanakos et al (2008)[24]: Sixteen patients were assigned to RYGB and 16 patients to SG (total n = 32). The BMI at 1 year declined to $31.5 \pm 3.4\,kg/m^2$ after RYGB and to $29.0 \pm 3.6\,kg/m^2$ after SG ($P = .41$). The %EWL was marginally greater in the SG group compared with RYGB at 69.7 ± 14.6% versus 60.5 ± 10.7%, respectively ($P = .05$).

Kehagias et al (2011)[25]: The study included 60 patients with BMI $\leq 50\,kg/m^2$. After randomization, 30 patients were assigned to RYGB and 30 to SG. Weight loss (%EWL) was significantly better after SG (72.9%) than RYGB (65.6%) in the first year of the study ($P = .05$). The study did not report BMI.

Keidar et al (2013)[26]: Forty-one patients with type 2 diabetes were randomly assigned to bariatric surgical procedures: 19 patients in RYGB or 18 patients in SG. A slightly greater weight loss in terms of BMI was observed in SG group ($30.4 \pm 3.8\,kg/m^2$ at year 1) than in RYGB group ($31.4 \pm 4.2\,kg/m^2$). %EWL was not reported in the study.

Paluszkiewicz et al (2012)[27]: The study included 72 morbidly obese patients who were randomized to RYGB (n = 36) or SG (n = 36). Significant weight loss was observed after the surgical procedures, but there was no difference between both groups at 1 year follow-up. %EWL in RYGB and SG groups reached 64.2% and 67.6%, respectively ($P > .05$).

Peterli et al (2013)[28]: Two hundred seventeen patients who were eligible for bariatric surgery were randomized into RYGB (n = 110) and SG (n = 100). There was a significant weight loss at 1 year in both groups. The study reported BMI results graphically which were extrapolated as mean BMI reduction from baseline as $14.3 \pm 10.7\,kg/m^2$ for RYGB and $12.9 \pm 9.6\,kg/m^2$ for SG at year 1. The study did not report %EWL.

Ramon et al (2012)[29]: Fifteen female patients with BMI over $40\,kg/m^2$ or $35\,kg/m^2$ with at least 1 severe comorbidity but $<50\,kg/m^2$ were included in the study. Seven patients underwent RYGB and 8 SG. A significant reduction in BMI was observed in both groups after the surgery, and the mean BMI at 1 year was significantly lower in RYGB as compared with SG ($P = .016$). % EWL was not assessed.

Vix et al (2013)[30]: One hundred patients who had BMI between 40 and $60\,kg/m^2$ were randomly assigned to RYGB (n = 45) and SG (n = 55). Mean postoperative 1-year %EWL was 80.38% after RYGB and 92.97% after SG. Vix et al did not assess change in BMI.

Zhang et al (2014)[31]: This study included 64 patients with BMI between 33 and $49\,kg/m^2$. Thirty-two patients were randomized to RYGB while another 32 patients were randomized to SG. Mean BMI at year 1 was $27.1\,kg/m^2$ for RYGB and $28.8\,kg/m^2$ for SG ($P > .05$). Mean %EWL at year 1 was 84.5% for RYGB and 73.9% for SG ($P > .05$).

Angrisani et al (2007)[32]: This study included 51 patients with BMI between 35 and $50\,kg/m^2$ of which 24 and 27 patients were randomly allocated to RYGB and LAGB, respectively. At 1 year, RYGB resulted in greater weight loss compared with LAGB for both BMI ($35.4\,kg/m^2$ in RYGB vs $38.7\,kg/m^2$ in LAGB) and % EWL (51.3% in RYGB vs 34.7% in LAGB).

Nguyen et al (2009)[33]: Two hundred fifty patients with BMI between 35 and $60\,kg/m^2$ were randomly assigned to RYGB (n = 111) or LAGB (n = 86). The mean %EWL was higher in the RYGB group than LAGB group (64.3 vs 36.5%, respectively; $P < .05$). The mean BMI was higher in the LAGB group than RYGB group (37.3 vs $31.6\,kg/m^2$, respectively; $P < .05$).

Himpens et al (2006)[34]: Eighty patients who were candidates for laparoscopic restrictive surgery were included in the study. Treatment with SG in 40 patients was compared with LAGB in 40 patients. The results showed that the median BMI reduction and %EWL after 1 year were significantly greater in SG group than in LAGB group with BMI of $25\,kg/m^2$ (0 to 48) versus 15.5 kg/m^2 (5 to 39) ($P < .001$) and %EWL of 57.7% (0 to 125.5) versus 41.1% (−11.8 to 130.5) ($P < .001$).

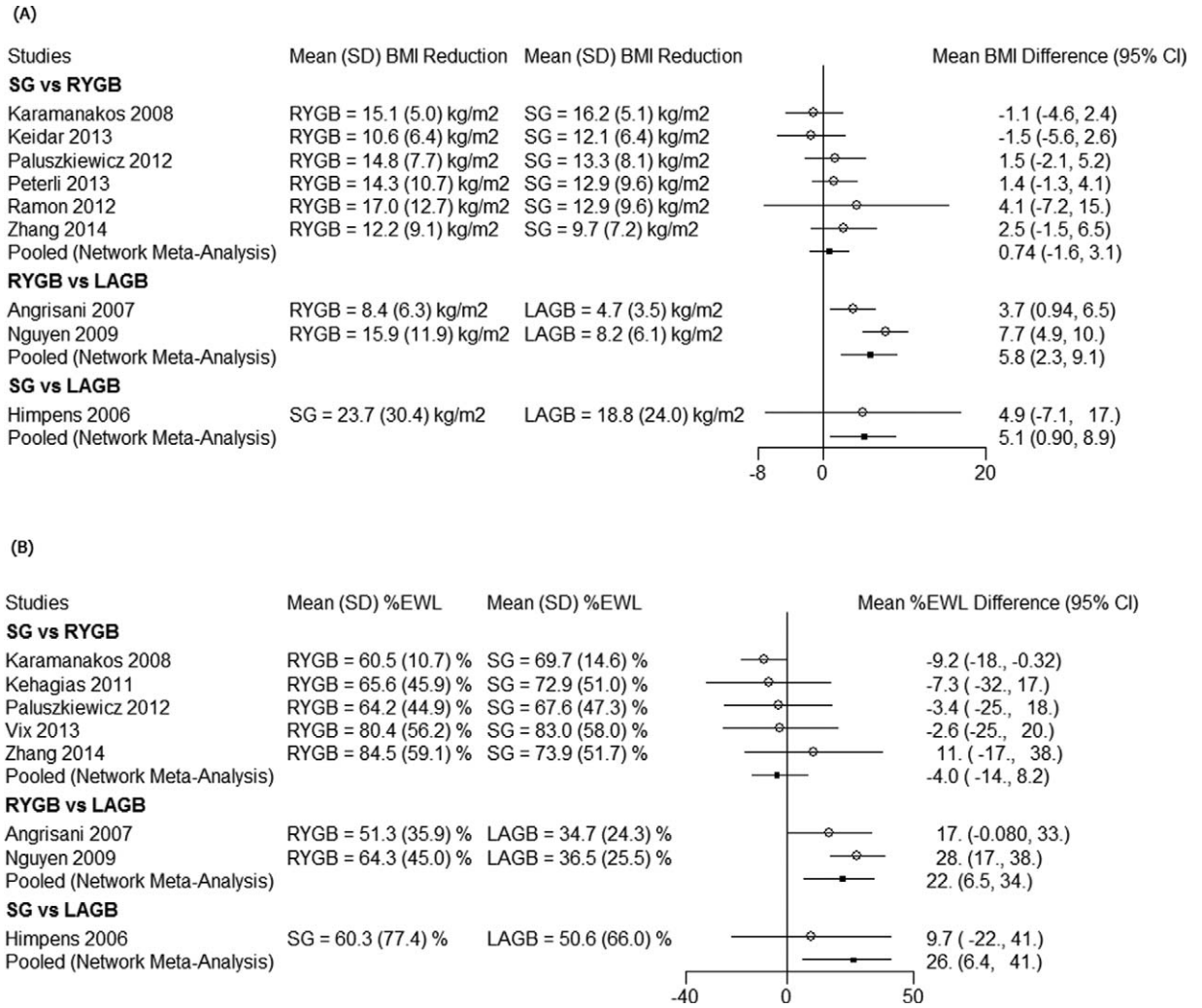

Figure 3. Forest plots of network meta-analysis results for (A) BMI reduction and (B) %EWL. Open circles indicate mean BMI difference of individual study while closed squares indicate results from the pooled network meta-analysis. The global I^2 value for the mean BMI reduction analysis was 10.9% (A) and mean %EWL was 0.0% (B). %EWL = percent excess weight loss, BMI = body mass index, CI = confidence interval, LAGB = laparoscopic adjustable gastric banding, RYGB = Roux-en-Y gastric bypass, SD = standard deviation, SG = sleeve gastrectomy.

3.5. Complications

Seven trials[25,27,28,31–34] reported surgery-related complications. Overall, LAGB was associated with fewer complications when compared with RYGB and SG. Surgery-site infection, obstruction, and bleeding were the most common early complications for RYGB, while gastroesophageal reflux disease (GERD) was often observed in SG. For late complications, nutritional deficiencies occurred most frequently, followed by obstruction and ulcer/GERD for both RYGB and SG (Supplementary Content 3, http://links.lww.com/MD/B953).

3.6. Heterogeneity

Heterogeneity, measured by I^2 value, is the consistency between studies that were included in a meta-analysis.[22] For BMI reduction, it was not statistically significant for heterogeneity: RYGB versus SG was $P = .921$, RYGB versus LAGB $P = .957$, and SG versus LAGB $P = .941$. For %EWL, heterogeneity P values were .388, .453, and .306 for RYGB versus SG, RYGB versus LAGB, and SG versus LAGB, respectively. The global I^2 value for the mean BMI reduction analysis was 10.9% and for mean % EWL was 0.0% (Fig. 3).

3.7. Inconsistency

Inconsistency in network meta-analysis denotes the consistency between direct and indirect evidence for each intervention.[23] The node splitting analysis showed all clinical trials were consistent between direct and indirect comparisons between RYGB and SG ($P = .977$ for BMI reduction and .327 for %EWL), RYGB and LAGB ($P = .980$ and .341), and SG and LAGB ($P = .975$ and .327).

4. Discussion

With the increased prevalence of obesity and its associated comorbid conditions, the number of bariatric surgeries performed in the US was up to >50% within 2 years between 2011 and 2013.[36] Despite the rise in bariatric surgery procedures, there are only few available meta-analyses that review the effectiveness of all 3 commonly performed bariatric surgical

procedures.[7,12–14] In addition, the 2 previously published meta-analysis studies explored the effectiveness of SG procedure, the newest bariatric surgery procedure, but only evaluated published data up to 2012.[12,13] An updated comparative effectiveness of the surgical interventions was in need as there has been a substantial increase in the SG procedure performed in comparison with RYGB and LAGB as well as improvement in surgical techniques over the recent years.[13]

4.1. Summary of the main results

The current systematic review and meta-analysis investigated the effectiveness and safety of the 3 most commonly performed bariatric surgical procedures: RYGB, SG, and LAGB. The results showed a significant difference in BMI reduction and %EWL between RYGB and LAGB, but not clear between RYGB and SG. There was no significant difference in effect of weight loss between RYGB and SG, although they were both superior to LAGB. Although less effective in terms of weight loss, LAGB resulted in less complications compared with other 2 surgical methods.

4.2. Agreements and disagreements with other studies

Our results were generally consistent with previous studies that examined comprehensive evidence of bariatric surgical procedures, that is, RYGB was superior to LAGB in terms of weight loss, but with greater number of complications, and SG was positioned between RYGB and LAGB in complication rates, but had conflicting evidence in terms of its weight loss effect compared with RYGB.[11–13] When using only RCTs, our study indicated that even though the differences in weight loss from RYGB and SG were not statistically significant, SG showed a tendency of better weight reduction. Similar trend was seen when comparing the effectiveness of RYGB and SG in other meta-analyses. In both meta-analysis studies, the pooled BMI reduction at 1 year after for SG and RYGB procedures were 10.1 kg/m^2 and 9.0 kg/m^2 in Padwal et al (2011), and 14.53 kg/m^2 and 16.2 kg/m^2 in Chang et al (2014), respectively. Both studies showed LAGB achieved the least amount of weight loss when compared with RYGB and SG. For %EWL, Chang et al study reported the pooled results of 72.32%, 69.70%, and 33.39% for RYGB, SG, and LAGB, respectively.[13] However, it was based on only 1 RCT that had evaluated SG. With more recent trials included, our analysis showed similar trend with the mean %EWL of 67.3%, 71.2%, and 40.6% for RYGB, SG, and LAGB, respectively.

4.3. Strengths and limitations

There were several important strengths in the current meta-analysis study. In our study, we attempted to reduce any potential bias by conducting the comprehensive literature search and study quality assessments with 2 independent reviewers. We performed the analysis using a robust statistical methodology, a network meta-analysis method, which allowed for the assessment of results from both direct comparison and mixed-treatment comparisons. Our network model consisted of a closed loop, which allowed for the assessment of inconsistency for both direct and indirect evidence for all 3 bariatric surgical procedures. More importantly, the current analysis included RCTs, which were the highest level of evidence, thus our pooled results should reflect closely the true effectiveness of the 3 most commonly performed bariatric surgical procedures. In addition, excluding non-RCT studies also allowed for inclusion of studies with homogenous methodology. This was supported by our results from the heterogeneity test, of which I^2 for both primary outcomes were of a value <25%, confirming only a small chance of heterogeneity among included studies. Our results from the network meta-analysis were also consistent among direct and indirect evidence. The fact that we evaluated both heterogeneity and inconsistency is a big strength in our analysis because homogenous studies and consistent evidence are the 2 most important assumptions made in a network meta-analysis.[37,38]

Nevertheless, certain limitations should be considered when interpreting the study findings. First, there were especially a limited number of clinical trials that evaluated LAGB as one of the study arms. However, this is inevitable as more evidence showed less achieved weight loss outcomes in LAGB compared with the other procedures, RYGB and SG. It is also important to mention that the majority of included trials did not blind the patient and clinicians as the interventions were surgical procedures in nature and different surgical procedures had different requirements in terms of pre-procedural preparations and patient follow-up (such as adjustment of patients' medications). Finally, the English restriction during the search is one of the limitations that can possibly affect the comprehensiveness of the search strategy.

In summary, the current meta-analysis study provided a synthesis of evidence on the comparative effectiveness of the 3 most commonly performed bariatric surgical procedures based on an updated and comprehensive RCT studies. The study utilized an advanced quantitative method for comparative research, network meta-analysis, to synthesize the relative effectiveness among all 3 surgical interventions. The results of our study were consistent with previous meta-analysis studies that examined these bariatric surgical procedures.

5. Conclusion

There was no still clear difference in effect of weight loss between the RYGB and SG procedures, though they were both superior to LAGB. Between RYGB and SG, other factors such as complications should be the primary focus during surgical consultations.

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