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Original article

Long-term and midterm outcomes of laparoscopic sleeve gastrectomy versus Roux-en-Y gastric bypass: a systematic review and meta-analysis of comparative studies

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Abstract

Objective: This study aimed to compare midterm and long-term weight loss and resolution of co-morbidity with laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG).

Summary: LRYGB and LSG are the most common procedures performed in bariatric surgery. However, their weight loss efficacy in the midterm and long-term has not been well compared.

Methods: A meta-analysis was performed by systematically identifying comparative studies conducted until the end of June 2016 that investigated weight loss outcome and resolution of co-morbidities (type 2 diabetes mellitus, hypertension, hyperlipidemia, hypertriglyceridemia, and obstructive sleep apnea) with LRYGB and LSG in the midterm (3–5 years) and long term ($\geq$5 years). The primary endpoint was weight loss after LRYGB versus LSG. The secondary endpoint was resolution of co-morbidities after these procedures.

Results: Fourteen studies comprising 5264 patients were eligible. Follow-up ranged from 36 months to 75.8 $\pm$ 8.4 months. The pooled result for weight loss outcomes did not show any significant difference in midterm weight loss (standardized mean difference = -0.03; 95% confidence interval (CI), -0.38–.33; P = .88) but a significant difference in the long-term weight loss outcome favoring LRYGB (standardized mean difference = .17; 95% CI, .05–.28; P= .005). The pooled results demonstrated no significant difference for resolution of type 2 diabetes mellitus, hypertension, hyperlipidemia, and hypertriglyceridemia.

Conclusion: Despite the insignificant difference between LRYGB and LSG in midterm weight loss, LRYGB produced better weight loss in the long-term. There was no significant difference between the 2 procedures for co-morbidity resolution. (Surg Obes Relat Dis 2016;▮:00–00.)

Keywords: Bariatric surgery; Laparoscopic Roux-en-Y gastric bypass; LRYGB; Laparoscopic sleeve gastrectomy; LSG; Weight loss; Meta-analysis

Bariatric surgery has been established as the stand-alone treatment for morbid obesity [1]. Currently, it is the only therapeutic option that results in substantial and durable weight loss [1–3]. Laparoscopic Roux-en-Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG) are the 2 most popular bariatric procedures performed in the United States [1,4,5]. However, their long-term effectiveness for weight loss and co-morbidity resolution has not been sufficiently compared [6].

Documentation of long-term weight loss is a hassle in bariatric surgery, since a substantial proportion of patients are lost to follow-up several years after enrollment into the

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weight loss program. Additionally, some LSG patients later undergo revisional surgery due to inadequate weight loss or weight regain [7–9]. For this reason, it has not been adequately determined which bariatric procedure, LRYGB or LSG, results in more weight loss or better co-morbidity resolution.

There has been no meta-analysis to pool available data on midterm (3–5 years) and long-term (≥5 years) outcomes of LRYGB and LSG. The aim of this systematic review is to compare midterm and long-term weight loss outcomes (primary endpoint) and co-morbidity resolution (secondary endpoint) of LRYGB and LSG through a meta-analysis of comparative studies.

Methods

This study was designed using *Cochrane handbook for systematic reviews of interventions* [10] and was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [11]. The protocol of this systematic review has been registered (CRD42016037669) and is available on the PROSPERO international prospective register of systematic reviews website (www.crd.york.ac.uk/PROSPERO/).

Search strategy

A comprehensive literature search was performed in the PubMed, ISI Web of Science, Scopus, Embase, and ClinicalTrials.gov databases as well as major journals in the fields of obesity, metabolic and bariatric surgery, and gastroenterology until the end of June 2016. A combination of the following search terms was applied: (sleeve gastrectomy, LSG, or SG) and (gastric bypass, RYGB, Roux-en-Y gastric bypass, or LRYGB). A manual screening of the reference lists of relevant studies and systematic reviews was also performed to supplement our literature search. Two independent reviewers performed the literature review, screening, and retrieval of the full texts of eligible papers and extracted data on study endpoints. Any conflict was resolved by a third researcher.

Eligibility and study selection

We screened the identified records for studies comparing weight loss outcomes or co-morbidity resolution of primary LSG versus laparoscopic LRYGB at least 3 years after weight loss surgery. Inclusion criteria were comparative human study in English language reporting weight loss outcomes or co-morbidity resolution after primary LRYGB versus primary LSG with at least 3 years of follow-up. The minimum follow-up point was determined according to the American Society for Metabolic and Bariatric Surgery position statements on bariatric procedures [12]. Studies with unobtainable outcomes of interest as mean ± standard deviation (SD) (for continuous outcome) or number/% (for dichotomous outcome) or an average follow-up <3 years; studies that recruited patients with a body mass index (BMI) <27 kg/m^2 or aged <18 or >65 years old; studies that combined data of revision or conversion surgeries; and review articles, editorial comments, or case reports were excluded (Table 1).

Definition of endpoints

The primary endpoint was weight loss outcome after bariatric surgery at the end of follow-up. The secondary outcome was co-morbidity resolution at the last follow-up.

Table 1
Inclusion/exclusion criteria for identified studies.

	Inclusion criteria	Exclusion criteria
Population	• BMI >27 kg/m^2 • Age >18 years • Undergoing bariatric surgery for weight loss or co-morbidity resolution	• None
Intervention	• Primary LRYGB and LSG	• Other bariatric procedures • Revision or conversion procedures
Outcome	• Weight loss, or • Co-morbidity resolution rate	• Unobtainable outcome as mean ± SD • Unobtainable outcome as number (%)
Study design	• Comparative cohorts comparing LRYGB versus LSG	• Noncomparative • Review articles, protocol descriptions, case report, or commentaries
Study sample size	• Any	• None
Follow-up	• Postoperative follow-up ≥3 years	• Follow-up <3years
Language	• English language	• Non-English full text

BMI = body mass index; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; SD = standard deviation.

The included studies were divided into 2 groups according to the average postoperative length of follow-up: midterm (3-5 years) and long term (≥5 years). The endpoints were separately analyzed for each group.

Data extraction

Extracted data included study characteristics (author, publication year, country of study, study type, sample size, and maximum follow-up), patient characteristics (average age and preoperative BMI and gender distribution in each group), and postsurgery outcome, including weight loss results (expressed as BMI loss, percent of excess weight loss (%EWL), weight loss, or excess weight loss) or comorbidity resolution (hypertension [HTN], type 2 diabetes mellitus [T2D], hyperlipidemia [HLP], hypertriglyceridemia [HTG], and obstructive sleep apnea [OSA]).

Quality assessment

Methodological quality assessment of included studies was performed by 2 authors (S.S. and A.A.S.) independently according to the Newcastle–Ottawa Scale (NOS) on nonrandomized comparative studies [13]. Included studies were assessed on 7 items, including representativeness, patient selection, ascertainment, mention of conflict of interest, comparability, outcome assessment, follow-up length, and follow-up adequacy, with a maximum score of 9. Comparative studies with a score ≥6 were considered of high quality (low risk of bias) while studies with a score <6 were considered of moderate or low quality (high risk of bias).

Data analysis

Data was analyzed using Review Manager for Windows version 5.3 (The Nordic Cochrane Centre, Copenhagen, Denmark). Continuous data were presented as mean ± SD and analyzed using the inverse variance. Categorical data were presented as frequency (percentages) and analyzed using the Mantel-Haenszel method. To quantify heterogeneity between studies, I^2 was calculated and considered representative of low heterogeneity at values <30%, of moderate heterogeneity at values between 30% and <50%, and of considerable heterogeneity at values >50%. The random-effects model was used for analysis of studies with considerable heterogeneity, and the fixed-effects model was used for studies with low or moderate heterogeneity. Because weight loss was reported variably by studies, data was synthesized using standardized mean difference (SMD). For categorical data, odds ratio (OR) was used as the presentation method. All values are reported with their corresponding 95% confidence intervals (CIs). A subgroup analysis was performed to identify the difference between midterm (Fig. 2) and long-term (Fig. 3) pooled outcomes. Publication bias was assessed by visual inspection of the funnel plot obtained from all included studies. A P value < .05 was considered statistically significant for both the pooled data and heterogeneity estimation.

Results

The PRISMA flow diagram for our database search and study selection is shown in Fig. 1. Following identification of a total of 1887 records by database search, title and abstract of 1397 records were screened after removal of duplicates. Of these, full text of 37 articles was retrieved, of which 14 papers comprising 5264 patients were eligible for inclusion in our meta-analysis [6,14–26]. Characteristics of included studies and their patient populations are presented in Table 2. Publication time frame ranged from 2010 to 2016. Six studies were prospective cohorts [18,20–24], 3 randomized controlled trials (RCTs) [6], 3 retrospective

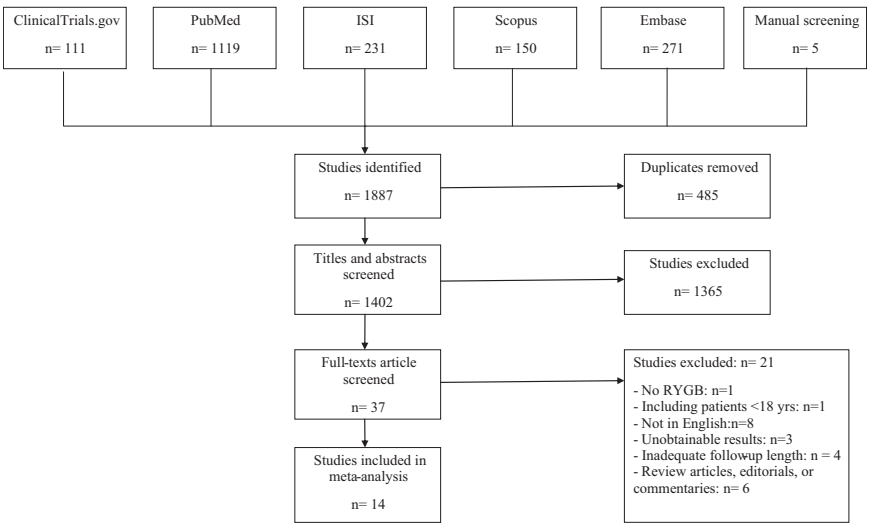


Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram for literature search and study selection.

Table 2
Characteristics of included studies.

	Author	Study type	Sample size		Average age		Gender (M/F)		Average preop BMI		Maximum follow-up
			LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	
1	Pekkarinen (2016) [26]	Retrospective cohort	163	94	47 (24–63)	49 (24–67)	61/102	31/63	49.2 (38.7–68.21)	47.4 (36.8–77.1)	6.85 yr
2	Perrone (2016) [23]	Prospective cohort	142	162	43.8 ± 4.6	41.8 ± 4.6	30/112	64/98	46.8 ± 3.6	47.4 ± 4.2	75.8 ± 8.4 mo
3	Lee (2015) [20]	Prospective cohort	519	519	36.1 ± 9.3	36 ± 9.1	140/379	132/387	37.5 ± 6	37.5 ± 6.1	60 mo
4	Dogan (2015) [17]	Retrospective cohort	245	245	41.2 ± 9.7	39.7 ± 10.0	44/201	44/201	47.2 ± 5.8	45.8 ± 6.0	3.1 ± 1.2 yr
5	Jammu (2015) [24]	Prospective cohort	295	339	38	23	85/210	185/154	42.5	35	53.5 mo
6	Yang (2015) [25]	RCT	32	32	41.4 ± 9.3	40.4 ± 9.4	13/19	9/23	32.3 ± 2.4	31.8 ± 3	36 mo
7	Leyba (2014) [21]	Prospective cohort	75	42	38 ± 9.9	34.6 ± 9.2	15/60	7/35	42.1 ± 4.7	41.1 ± 4.9	60 mo
8	Zhang (2014) [6]	RCT	32	32	32.2 ± 9.2	29.3 ± 9.8	14/18	12/20	39.3 ± 3.8	38.5 ± 4.2	60 mo
9	Alexandrou (2014) [15]	Cross-sectional pilot	55	40	44.8 ± 9.9	43.4 ± 11.2	15/40	4/36	49.1 ± 6.1	51.5 ± 7.2	48 mo
10	Moize (2013) [22]	Prospective cohort	294	61	45.2 ± 10.6	46.4 ± 11.6	20/41	68/226	47.4 ± 6	51.6 ± 6.7	60 mo
11	Boza (2012) [16]	Case-control	786	811	37 ± 10.3	36.4 ± 11.7	184/ 602	193/618	38 ± 3.4	37.9 ± 4.6	36 mo
12	Jimenez (2012) [18]	Nonrandomized cohort	98	55	49.6 ± 8.2	52.4 ± 9.1	31/67	29/26	44.8 ± 4.6	49.8 ± 7.2	35.4 ± 13.5 mo
13	Kehagias (2011) [19]	RCT	30	30	33.7 ± 9.9	36 ± 8.4	8/22	8/22	45.8 ± 3.7	44.9 ± 3.4	36 mo
14	Abbatini (2010) [14]	Retrospective cohort	16	20	53 ± 8.3	46.6 ± 4.2	3/13	8/12	47.4 ± 8	51.6 ± 15.9	36 mo

BMI = body mass index; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; RCT = randomized controlled trial.

cohorts [14,17,26], 1 a cross-sectional pilot [15], and a 1 case-control study [16].

Patient characteristics

Patient characteristics were inserted in the meta-analysis. Patients undergoing LRYGB and LSG did not significantly differ in age (weighted mean difference = .90 years; 95% CI, -0.10–1.91), male sex (OR = .82; 95% CI, 0.57–1.17), and BMI (weighted mean difference = -0.5 kg/m^2; 95% CI, -1.33–.33). Patient follow-up ranged from 36 months [14,16,19,25] and 75.8 ± 8.4 months [23]. Studies were divided, based on the reported average of follow-up, into midterm (3–5 years) and long-term (≥5 years) categories. Eight studies (3129 patients) followed their patients for an average of 3 to 5 years [14–19,24,25] and 6 studies (2135 patients) followed their patients ≥5 years [6,20–23,26]. Table 3 and 4

Methodological quality assessment (Table 3)

With the exception of 3 studies [14,22,24], all the included studies were of high quality (NOS score ≥6). Complete outcome assessment was satisfactory in 5 studies [6,16,24–26]. No studies reported conflict of interest. Follow-up length was satisfactory in 9 studies [6,15,17,20–24,26]. Follow-up adequacy (percent of patients present at the last follow-up) was met in 6 studies [6,15,18,19,23,25,26].

Weight loss outcome

Of 14 studies with an obtainable mean ± SD on weight loss outcome [6,14–23,25,26], 7 studies (2486 patients) compared weight loss between LRYGB and LSG after 3 to 5 years [14–19,25], while 6 studies (1642 patients) compared the outcome between the 2 procedures after 5 years (Table 4) [6,20–23,26]. The pooled result for weight loss outcome did not show any significant difference between LRYGB and LSG in midterm weight loss (SMD = -0.03; 95% CI, -0.38–.33; P = .88) but revealed a significant difference in long-term weight loss between LRYGB and LSG favoring LRYGB (SMD = .17; 95% CI, 0.05, –.28; P = .005). There was a high heterogeneity between studies in the midterm subgroup (I^2 = 91%, P < .0001) and a moderate heterogeneity between studies in the long-term subgroup (I^2 = 48%, P = .09).

T2D resolution

Five studies (355 patients) reported resolution rates for T2D after 3 to 5 years [16,18,19,24,25] and 2 studies (21 patients) reported T2D resolution rates after 5 years [6,21]. The pooled results demonstrated no significant difference in the odds ratio of T2D resolution between LRYGB and LSG in the midterm (OR = 1.62; 95% CI, .95–2.75; P = .08) or

long-term (OR = .73; 95% CI, 0.07–7.39; $P = .79$). There was a nonsignificant low heterogeneity between studies of both subgroups ($I^2 < 30\%$, $P > .05$).

HTN resolution

Five studies (533 patients) reported resolution rates for HTN after 3 to 5 years [14,16,19,24,25] and 2 studies (19 patients) reported HTN resolution rates after 5 years [6,21]. The pooled results demonstrated no significant difference in the odds ratio of HTN resolution between LRYGB and LSG in the midterm (OR = 1.24; 95% CI, 0.87–1.75; $P = .23$) and long-term (OR = 1.54; 95% CI, 0.22–10.99; $P = .67$). There was a nonsignificant low heterogeneity between studies of both sub-groups ($I^2 < 30\%$, $P > .05$).

HLP resolution

Five studies (798 patients) reported resolution rates for HLP after 3 to 5 years [14,16,19,24,25] and 2 studies (67 patients) reported HLP resolution rates after 5 years [6,23]. The pooled results yielded no significant difference in the odds ratio of HLP resolution between LRYGB and LSG in the midterm (OR = 1.21; 95% CI, 0.90–1.61; $P = .2$) and long-term (OR = 1.49; 95% CI, 0.33–6.69; $P = .79$). There was an insignificant low heterogeneity within studies of both subgroups ($I^2 = 0\%$, $P > .05$).

HTG resolution

Only 2 studies reported (409 patients) resolution rates for HTG after 3 to 5 years. The pooled results demonstrated no significant difference in the odds ratio of HTG resolution between LRYGB and LSG in the midterm (OR = 1.03; 95% CI, 0.69–1.52; p = .89). There was an insignificant low heterogeneity within studies of this group ($I^2 = 0\%$, $P > .05$).

OSA resolution

Only 2 studies, 1 midterm (7 patients) [19] and 1 long-term (12 patients) [6], reported OSA resolution rates. Since there was only 1 study in each subgroup, no pooled result could be obtained for resolution of this co-morbidity.

Sensitivity analysis

Excluding low-to-moderate studies with a NOS <6 [14,22,24] yielded similar results concerning weight loss

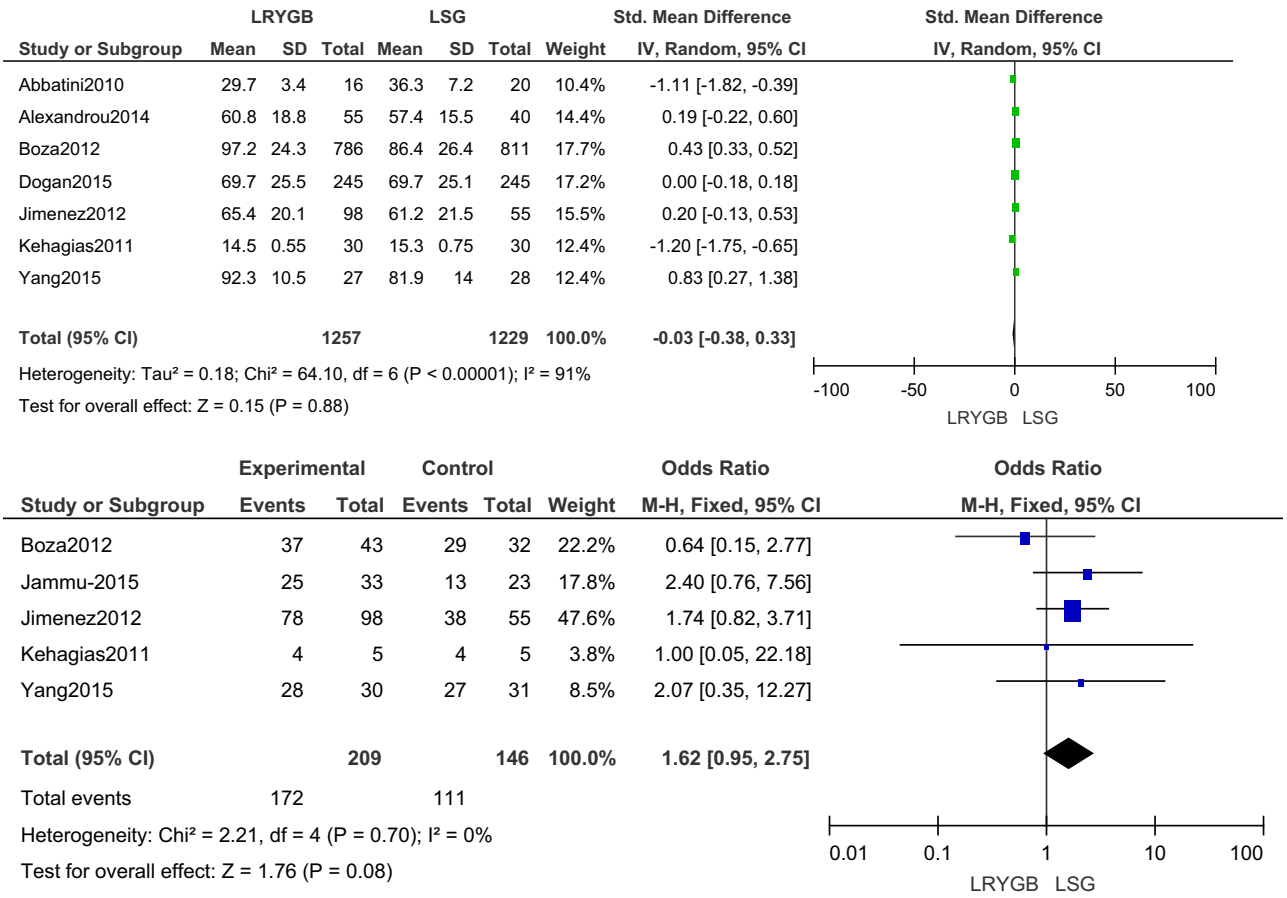


Fig. 2. Comparison of pooled midterm outcomes between laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy patients (from above to below: weight loss outcome, resolution of type 2 diabetes mellitus, hyperlipidemia, hypertension, and hyper triglycerides).

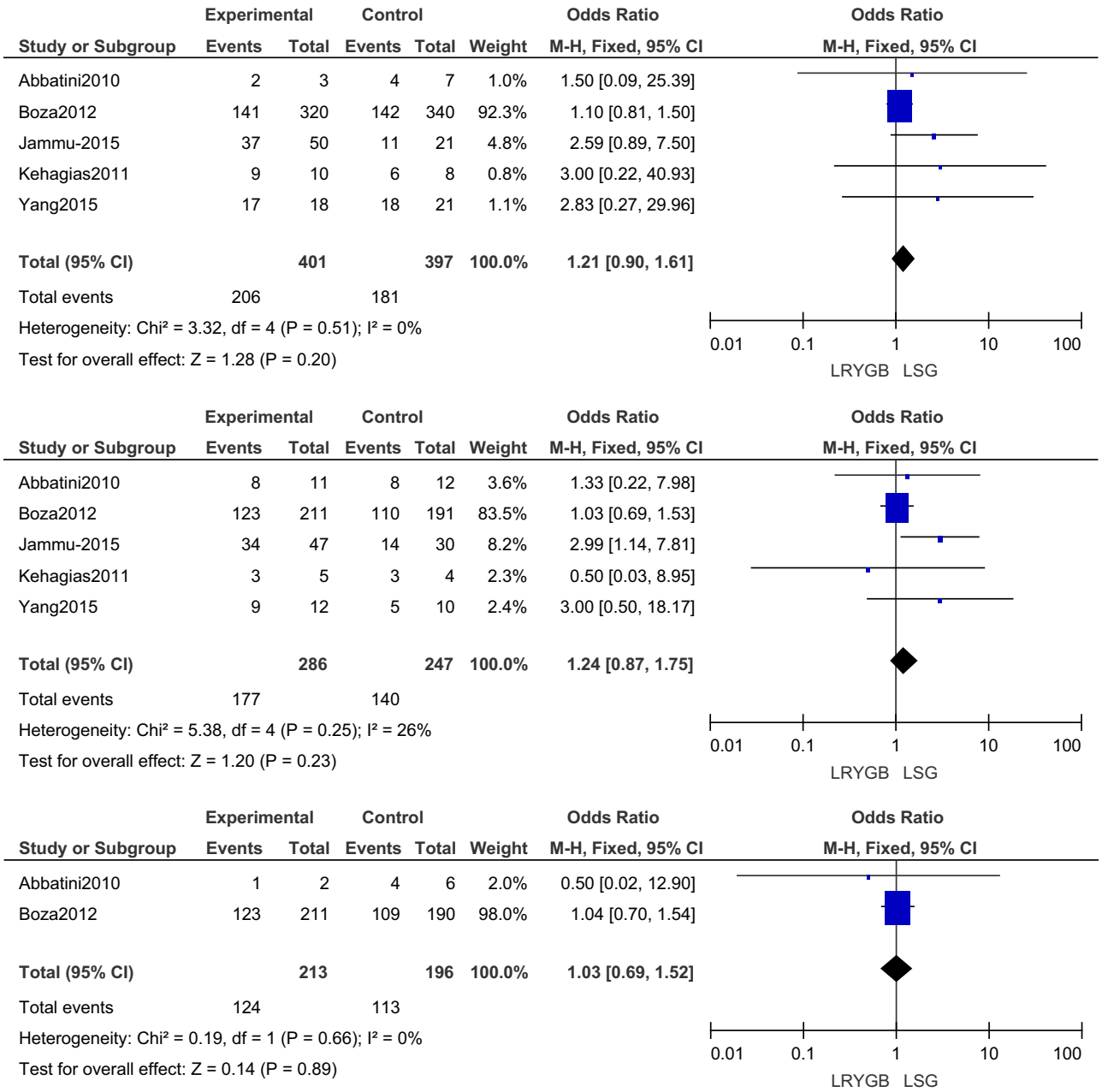


Fig. 2. Continued.

outcome at 3 to 5 years (SMD) = .10; 95% CI, -0.23–.44; $P = .55$) and ≥5 years (SMD = .17; 95% CI, 0.07–.32; $P = .002$). Due to small number of studies within each co-morbidity subgroup, sensitivity analysis was not performed.

Publication bias

Visual inspection of the funnel plot did not reveal any asymmetry of studies reporting weight loss outcomes difference between LRYGB and LSG patients (Fig. 4). However, this does not exclude publication bias, and, as mentioned above, interstudies heterogeneity was calculated for each subgroup meta-analysis.

Discussion

This systematic review and meta-analysis of comparative studies found similar weight loss and co-morbidity resolution in the midterm (3–5 years) and similar co-morbidity resolution in the long-term (≥5 years). However, this meta-analysis found a significantly better long-term weight loss outcome with LRYGB than with LSG. Fourteen studies were eligible, according to the systematic review quality

Table 3
Methodological quality assessment of included studies.

Study	Representativeness	Selection	Ascertainment	Conflicted results mentioned	Comparability[‡]	Outcome assessment	F/u length	F/u adequacy	Total score
Pekkarinen (2016) [26]	*	*	*	○	*	*	*	*	7
Perrone (2016) [23]	*	*	*	○	*	○	*	*	6
Lee (2015) [20]	*	*	*	○	**	○	*	○	6
Dogan (2015) [17]	*	*	*	○	**	○	*	○	6
Jammu (2015) [24]	*	*	*	○	○	*	*	○	5
Yang (2015) [25]	*	*	*	○	*	*	○	*	6
Leyba (2014) [21]	*	*	*	○	**	○	*	○	6
Zhang (2014) [6]	*	*	*	○	**	*	*	*	6
Alexandrou (2014) [15]	*	*	*	○	**	○	*	*	6
Moize (2013) [22]	*	*	*	○	○	○	*	○	4
Boza (2012) [16]	*	*	*	○	**	*	○	○	6
Jimenez (2012) [18]	*	*	*	○	**	○	○	*	6
Kehagias (2011) [19]	*	*	*	○	**	○	○	*	6
Abbatini (2010) [14]	*	*	*	○	○	○	○	○	3

F/u = follow-up.
[‡]A maximum of 2 points can be devoted to this criterion.
*Consistent with criteria (low risk of bias).
○Not consistent with criteria (high risk of bias).

requirements. Although 1 midterm study concluded superiority of the gastric bypass over sleeve gastrectomy in weight reduction and co-morbidity resolution [24] and 2 long-term studies demonstrated higher weight loss outcome for LRYGB compared with LSG [6,26], the remaining 11 studies found no significant difference in the efficacy of the 2 procedures in the midterm or long-term [14–23,25]. Meta-analyses were performed for all the mentioned outcomes except for OSA. A meta-analysis by Li et al. reported a better resolution rate for obesity-related co-morbidities with LRYGB compared to LSG, but also a higher complication and reoperation rate [27]. However, the main limitation of this meta-analysis is its inclusion of studies with short-term follow-up and combination of their data with midterm studies. Moreover, the meta-analysis of Li et al. disregarded the average follow-up of their included studies, as the midterm studies included in their analysis have followed their patients for an average of <3 years.

Publication bias and heterogeneity

Due to the strict inclusion criteria of our systematic review in terms of study design and follow-up length, there were few studies available in each subgroup. Hence, a low heterogeneity was observed between studies included in most of the subgroups. The exception was the weight loss subgroup, in which a high heterogeneity was detected, probably due to the larger number of included studies. Moreover, as determine by visual inspection, a low risk of publication bias was observed among all the included studies. However, this does not exclude other risks of bias among the studies in this systematic review.

Weight loss outcome

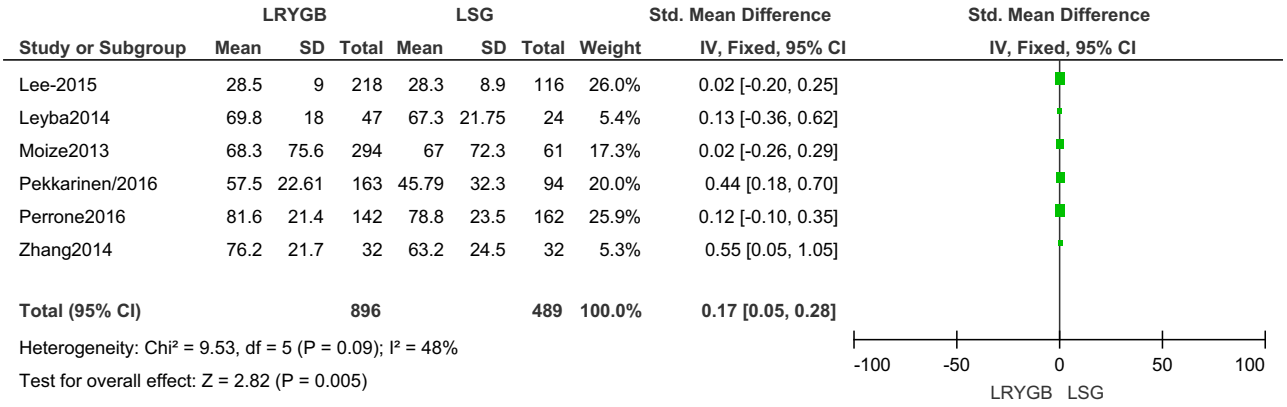
LRYGB has shown a good long-term outcome in weight loss and co-morbidity resolution, with 64.9% of patients achieving a %EWL of at least 50% after 7 years [28]. Similarly for LSG, it has been shown that 78% of patients sustained a %EWL of at least 50% after 7 years [29]. In the longest follow-up found in the literature, an average percent excess BMI loss of 52.2% and 62.5% was shown for LRYGB after 12 years [30] and LSG after 11 years [31], respectively. No meta-analysis has pooled the comparative data on LRYGB and LSG in the long-term. The only available meta-analysis of long-term comparisons of LRYGB versus LSG revealed an insignificantly greater weight loss and a superior co-morbidity resolution rate for LRYGB compared with LSG [27]. However, this study suffers a major limitation, which is that it the included short-term studies in the pooled analysis of midterm studies but claimed to be a long-term meta-analysis. In contrast with the study of Li et al. [27], our meta-analysis showed an insignificant weight loss difference in the midterm, but a significantly better weight loss outcome in the long-term with LRYGB than with LSG. Although these

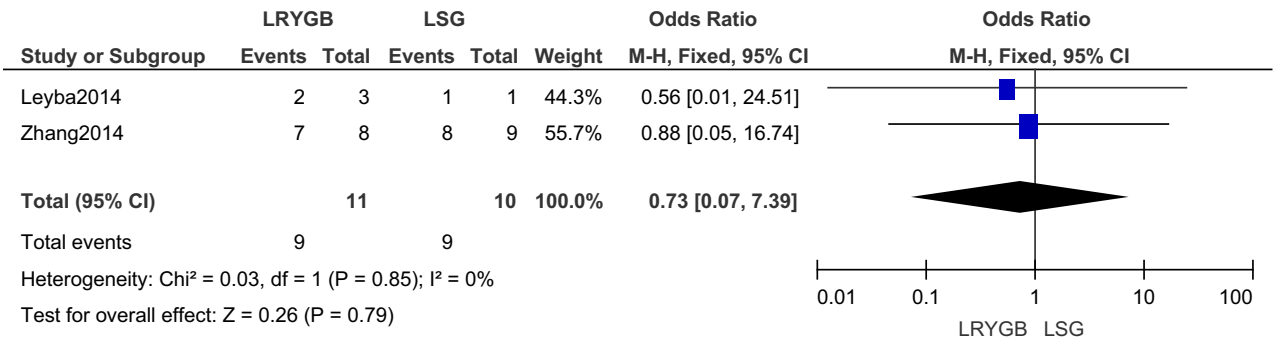
Table 4
Outcomes reported by studies at end of follow-up.

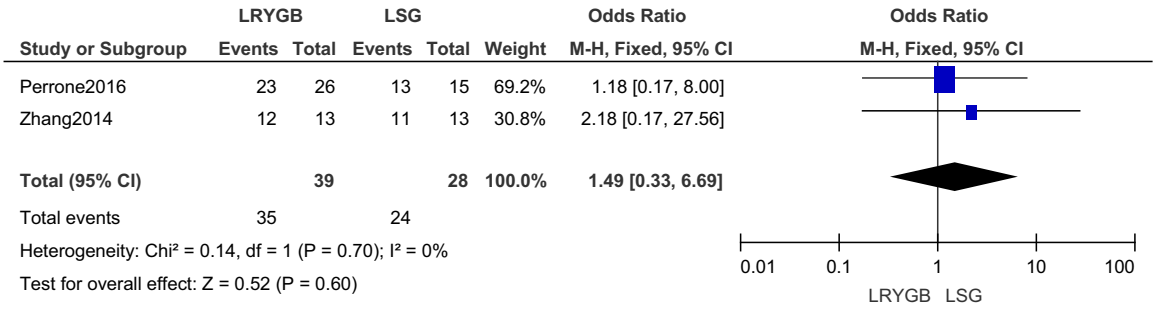
	Study	%Weight/BMI loss		T2D resolution		HTN resolution		HLP resolution		HTG		OSA resolution	
		LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG	LRYGB	LSG
						3-5 years							
1	Dogan (2015) [17]	69.7 ± 25.5	69.7 ± 25.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Jammu (2015) [24]	72.3	53.6	25/33	13/23	34/47	14/30	37/50	11/21	N/A	N/A	N/A	N/A
3	Yang (2015) [25]	92.3 ± 10.5	81.9 ± 14	28/30	27/31	9/12	5/10	17/18	18/21	N/A	N/A	N/A	N/A
4	Alexandrou (2014) [15]	60.8 ± 18.8	57.4 ± 15.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	Jimenez (2012) [18]	65.4 ± 20.1	61.2 ± 21.5	78/98	38/55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	Boza (2012) [16]	97.2 ± 24.3	86.4 ± 26.4	37/43	29/32	123/211	110/191	141/320	142/340	123/211	109/190	N/A	N/A
7	Kehagias (2011) [19]	14.5 ± 0.55	15.3 ± 0.75	4/5	4/5	3/5	3/4	9/10	6/8	N/A	N/A	2/3	4/6
8	Abbatini (2010) [14]	29.7 ± 3.4	36.3 ± 7.2	N/A	N/A	8/11	8/12	2/3	4/7	1/2	4/6	N/A	N/A
	Pooled outcome*	-.3 (-.38–.33) $P = .88$; $I^2 = 91\%$		1.62 (.95–2.75) $P = .08$; $I^2 = 0\%$		1.21 (.90–1.61) $P = .2$; $I^2 = 26\%$		1.24 (.87–1.75) $P = .2$; $I^2 = 0\%$		1.03 (.69–1.52) $P = .89$; $I^2 = 0\%$		NA	
						≥ 5 years							
9	Pekkarinen (2016) [26]	57.5 ± 22.61	45.79 ± 32.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	Perrone (2016) [23]	81.6 ± 21.4	78.8 ± 23.5	N/A	N/A	N/A	N/A	23/26	13/15	N/A	N/A	N/A	N/A
11	Lee (2015) [20]	28.5 ± 9	28.3 ± 8.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	Leyba (2014) [21]	69.8 ± 18	67.3 ± 21.75	2/3	1/1	4/6	1/2	N/A	N/A	N/A	N/A	N/A	N/A
13	Zhang (2014) [6]	76.2 ± 21.7	63.2 ± 24.5	7/8	8/9	4/6	3/5	12/13	11/13	N/A	N/A	5/5	7/7
14	Moize (2013) [22]	68.3 ± 75.6	67 ± 72.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pooled outcome*	.17 (.05–.28) $P = .005$; $I^2 = 48\%$		.73 (.07–7.39) $P = .79$; $I^2 = 0\%$		1.49 (.33–6.69) $P = .6$; $I^2 = 0\%$		1.54 (.22–10.99) $P = .67$; $I^2 = 0\%$		NA		NA	

BMI = body mass index; HLP = hyperlipidemia; HTG = hypertriglyceridemia; HTN = hypertension; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; N/A = not available; OSA = obstructive sleep apnea; T2D = type 2 diabetes mellitus.

*Pooled outcome is estimated as standardized mean difference for continuous variables and as odds ratio for categorical variables and expressed with the corresponding 95% confidence interval; I^2 = Heterogeneity.







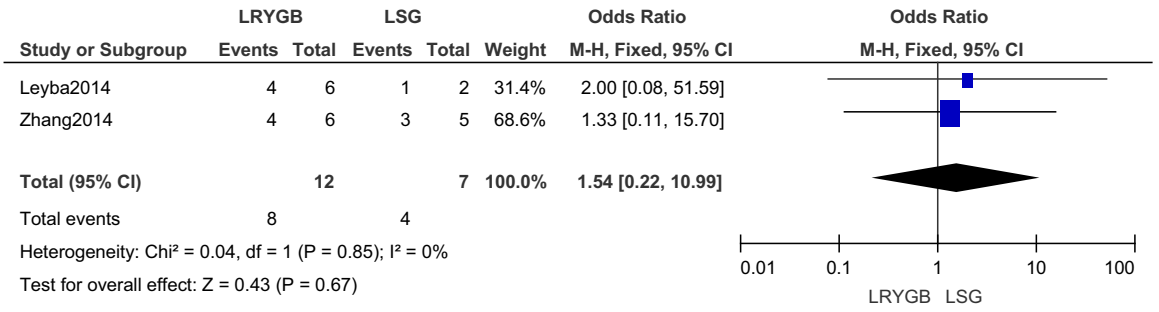


Fig. 3. Comparison of pooled long-term outcomes between laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy patients (from above to below: weight loss outcome, resolution of type 2 diabetes mellitus, hyperlipidemia, hypertension).

findings could result from the separate subgroup analyses of midterm and long-term studies, the large weight granted to the Pekkarinen study could affect the result of the meta-analysis in the long-term group [26]. Excluding the Pekkarinen study from the meta-analysis led to an insignificant difference in long-term weight loss between LRYGB and LSG. Moreover, this largely weighted study did not report long-term resolution of co-morbidities and hence did not impose such an effect on long-term subgroup of this meta-analysis.

Co-morbidity resolution

Both LRYGB and LSG have proven efficacy in terms of substantial resolution of obesity-related co-morbidities

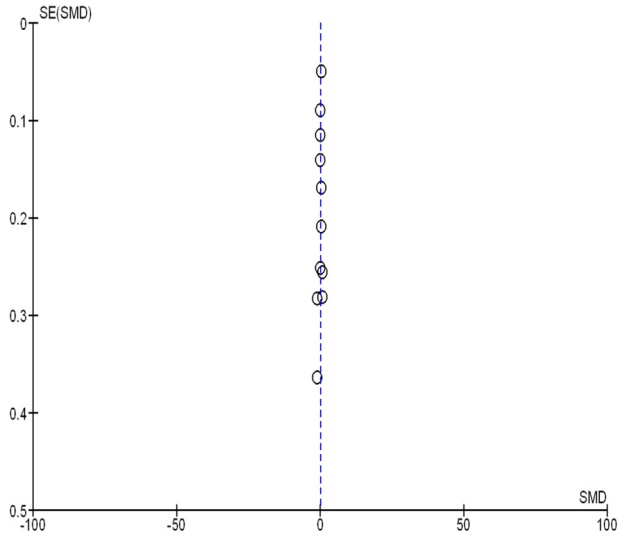


Fig. 4. Funnel plot of all studies reporting on weight loss outcome after laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy.

[29,32,33]. Additionally, it has been shown that co-morbidity resolution is sustained to some extent despite weight regain in some patients in the long term [32]. Our systematic review did not reveal any significant difference between the 2 procedures in terms of co-morbidity resolution, though subgroup analysis for each co-morbidity included few studies in the midterm and long-term arms of the meta-analysis. Moreover, there were not sufficient studies to perform a pooled analysis for HTG in the long term and OSA in both the midterm and the long term. Unlike our findings, the meta-analysis of Li et al. showed LRYGB to be more effective than LSG in co-morbidities resolution [27]. However, their results could be related to the fact that data from short-term and midterm studies were combined with long-term studies. Although it has been stated that metabolic benefits of LRYGB are seen before a substantial weight loss occurs [34,35], co-morbidity resolution in mainly restrictive procedures such as LSG may occur after a significant weight loss has been achieved [35]. This may explain the dilution of the difference in co-morbidity resolution between LRYGB and LSG after 3 years, when a significant weight loss has been achieved with both procedures [36].

Strength of this systematic review

This is the first meta-analysis of comparative studies on the long-term weight loss outcome and co-morbidity resolution of LRYGB and LSG. Our restrictive eligibility requirement of exclusively selecting studies with sufficient length of follow-up is another strength of this study, assuring the inclusion in the pooled analysis of comparative studies with the highest possible quality. Moreover, our systematic review focused on the most clinically relevant outcomes in metabolic and bariatric surgery, weight loss and resolution of the 5 most common obesity-related co-morbidities.

Limitation of this study

The main limitation of this study is related to a lack of data in available studies on co-morbidity resolution (the secondary endpoint) and inconsistencies in reporting weight loss outcomes. There is a substantial lack of RCTs in the literature investigating long-term outcomes of LRYGB versus LSG. Due to the restrictive inclusion criteria set for this systematic review, the number of included studies in each subgroup was relatively low. Although this led to the inclusion of high-quality comparative studies (with NOS score ≥ 6, low heterogeneity, and acceptable publication bias), a large body of literature was excluded from pooled analysis. Although we acknowledge the difficulty of designing and performing a RCT with long-term patient follow-up, our systematic review revealed the need for future comparative analysis of the available registry database on long-term outcomes after LRYGB and LSG.

Conclusion

This systematic review and meta-analysis demonstrated that despite the insignificant difference between LRYGB and LSG in midterm weight loss, LRYGB produces better weight loss in the long term. However, no significant difference was observed between LRYGB and LSG regarding the resolution of co-morbidities. Considering its more demanding technique and higher complication rate, LRYGB indications should be reconsidered in morbidly obese patients with co-morbidity.

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