

# Bariatric Surgery for the Treatment of Morbid Obesity: A Meta-analysis of Weight Loss Outcomes for Laparoscopic Adjustable Gastric Banding and Laparoscopic Gastric Bypass

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Received: 14 April 2009 / Accepted: 10 July 2009  
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**Abstract** Bariatric surgery has emerged as an important tool in the fight against morbid obesity. However, reviewers have noted that there is a scarcity of long-term clinical surveillance data for bariatric surgery beyond 1-year follow-up and that a high percentage of patients are lost to follow-up, raising questions regarding the accuracy of current outcomes estimates. A meta-analysis of clinical reports providing bariatric surgery weight loss outcomes for morbidly obese patients was conducted over the period 2003–2007. Studies included were randomized controlled trials, nonrandomized controlled trials, and consecutive case series involving patients receiving either laparoscopic adjustable gastric banding (LAGB) or laparoscopic gastric bypass (LGB) surgery. Included studies involved  $n=7,383$  patients and were largely academic hospital-based (78.6%) and retrospective in design (71.4%). Weight loss outcome was defined by percent excess weight loss (%EWL). Composite estimates showed a significantly greater % EWL for LGB surgery (62.6%) compared to LAGB (49.4%). The superiority of LGB persisted at all three

postsurgical time points examined (1, 2, and >3 years). Problems were identified regarding incomplete or suboptimal data reporting in many studies reviewed, and high patient attrition was evident at 2-year (49.8% LAGB, 75.2% LGB) and >3-year (82.6% LAGB, 89% LGB) end points. This meta-analysis confirms the superiority of LGB to LAGB in %EWL found in earlier studies. Although problems in study quality raised significant concerns regarding the validity of current weight loss estimates in this area, there was no evidence of publication bias.

**Keywords** Laparoscopic gastric bypass · LGB · Laparoscopic adjustable gastric banding · LAGB · Bariatric surgery · Outcomes · %EWL · Laparoscopic adjustable gastric banding · LAGB laparoscopic gastric bypass · LGB · Weight loss

## Introduction

Morbid obesity (MO), defined as a Body Mass Index (BMI) above 40, is estimated to afflict six million of the US population while another 9.6 million have a BMI of 35–40 [1]. A number of serious comorbidities are associated with MO, including type 2 diabetes, hypertension, obstructive sleep apnea, osteoarthritis, gastroesophageal reflux disease, nonalcoholic fatty liver disease, and breast, ovarian, gallbladder, and prostate cancers [2]. Bariatric surgery has emerged as a critical tool in the fight against MO given the poor weight loss maintenance associated with nonsurgical approaches for obesity treatment, including dietetic, behavioral, and pharmaceutical interventions [3]. There has been a dramatic increase in recent years in the number of bariatric surgery procedures performed in

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response to the MO epidemic with around 220,000 bariatric surgeries estimated for 2008 [4]. The most common forms of bariatric surgery performed for MO are laparoscopic adjustable gastric banding (LAGB), a purely restrictive approach, and laparoscopic gastric bypass (LGB), an approach that involves restriction, malabsorption, and changes to gut hormones that impact hunger and satiety [5].

Buchwald et al. [6] conducted a systematic review and meta-analysis of open and laparoscopic bariatric surgery outcomes reported in the clinical literature over the period 1990–2003 focusing on weight loss, operative mortality, and comorbidity outcomes that included LAGB and LGB surgery trials. The results showed an overall percent excess weight loss (%EWL) of 47.5% for LAGB based on 12 studies and 61.6% for LGB based on 22 studies. These estimates have been widely used as clinical benchmarks in the field.

Several reviewers have noted that there is a scarcity of long-term clinical surveillance data for bariatric surgery beyond 1-year follow-up and that a high percentage of patients are lost to follow-up, raising questions regarding the accuracy of our outcome estimates [7, 8]. Also, the recent rapid increase in number of surgeries being carried out may impact weight loss outcomes as increased surgeon experience has been linked to improved clinical outcomes [9]. In response to these issues, we conducted a meta-analysis of the recent bariatric surgery clinical literature to examine reported weight loss outcomes for LAGB and LGB procedures. We also explored the quality of the salient published clinical trials, including patient follow-up rates and reporting of surgical variables for LAGB and LGB that may be associated with bariatric surgery weight loss outcomes. These include reporting of pouch size and postsurgical gastric band adjustment for LAGB and pouch size, limb length, anastomosis size, and preservation of the vagal nerve for LGB [8].

## Methods

We conducted an electronic search of English language articles for bariatric surgery using selected Medical Subject Headings (MeSH) terms to identify studies reporting weight loss outcomes for LAGB or LGB procedures (Table 1). Databases used for the search included Medline, SCOPUS, Proquest, and the Cochrane Library Database of Systematic Reviews for the period 2003–2007. Criteria for exclusion included nonhuman studies, nonsurgical interventions, studies of open bariatric surgery procedures, case reports, letters and comments, and studies with patient follow-up of less than 1 year. Criteria for inclusion included one-group or two-group prospective or retrospective cohort designs,

**Table 1** MeSH terms used for literature search

Bariatric surgery/methods, standards, statistics, and numerical data
Bariatric surgery/trends/follow-up studies/outcomes
Obesity, morbid/surgery
Laparoscopic
Laparoscopy/gastric bypass
Laparoscopy/gastroplasty
Laparoscopic bariatric surgery

surgical treatment with LAGB or LGB, adult populations only (>18 years old), BMI $\geq$ 35, and consecutive patient series.

Electronic copies of all papers identified in the online search were reviewed against the exclusion and inclusion criteria. All qualifying articles were then reviewed to determine if they had sufficient data for analysis, including weight loss reported as a mean with standard deviation and sample size. Selected papers were then abstracted and entered into a data abstraction form that contained all salient information for the analyses. Three reviewers independently reviewed the studies, abstracted the data, and resolved any differences in interpretation by consensus with the final decision made by the statistician. For all studies, weight loss was reported as mean %EWL, defined as: ((weight loss/excess weight)  $\times$  100) [8]. Meta-analyses were performed to examine mean %EWL outcomes separately for LAGB and LGB. Several studies reported results for separate mutually exclusive surgical subgroups rather than all patients combined, and these were treated as separate studies in the meta-analysis. When there was more than one follow-up period for the study, the longest follow-up period for which complete %EWL data were available was used for calculating effect size.

Composite estimates of effect size and their 95% confidence intervals were computed separately for each type of surgery using a random-effects model [10]. The Q-test [11, 12] was used to test for significant heterogeneity of effect size among studies [13] within each surgery type and for significant differences between surgery types. A funnel plot of effect size versus sample size was calculated to assess publication bias (file drawer effect) [14]. The percentage of patients lost to follow-up was documented for each study at 1, 2, or >3 year end points. We also documented reporting of several key operative details that potentially impact weight loss outcomes [9]. Specifically, for LAGB, we documented the reporting of gastric pouch size and number of times the band was adjusted by the surgeon postsurgery. For LGB, we documented the reporting of Roux-en-Y limb length, gastric pouch size, gastrojejunostomy anastomosis size, and preservation of the vagal nerve.

## Results

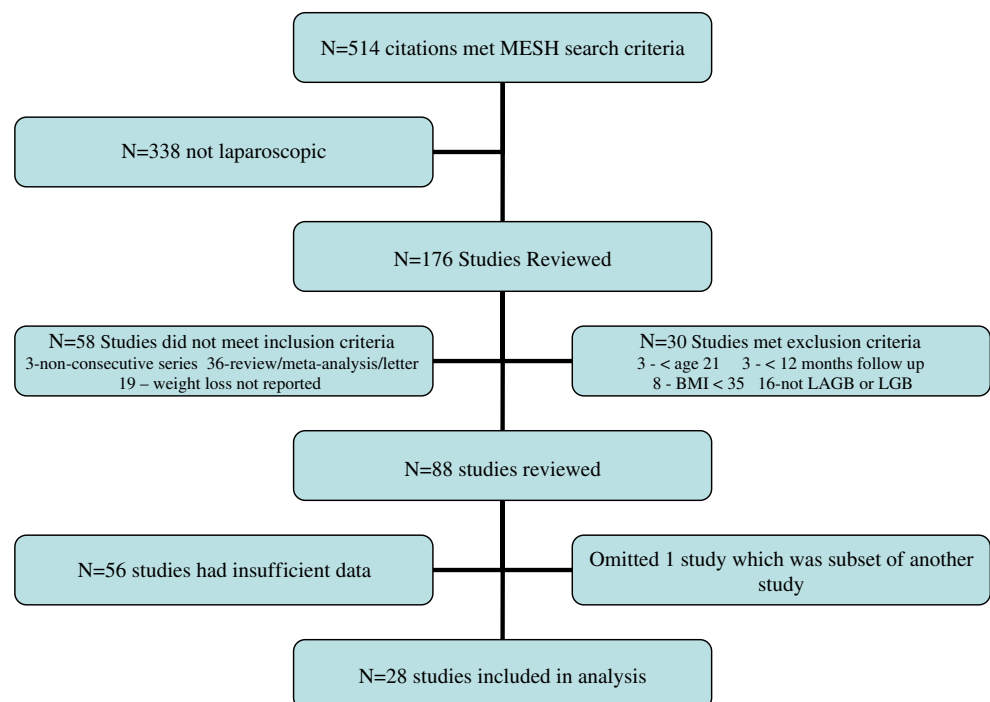
Figure 1 shows the study attrition diagram and the number of publications included at each step of the literature search. An initial search identified 514 publications of which 426 were excluded, resulting in 88 eligible publications, 29 of which had sufficient data on %EWL for inclusion in the analysis [15–43]. One study [33] which was a reanalysis of a subgroup of another study [32] was excluded. Of the remaining 28 studies, 18 included LAGB surgery alone or in combination with LGB, and 13 included LGB alone or in combination with LAGB (Table 2). Mean follow-up was 34 months postsurgery for LAGB studies (range 12–60 months) and 28 months for LGB studies (range 12–87 months). Of 28 studies included in the analyses, 20 were retrospective in design (71.4%) and 8/28 were prospective. The setting for the studies was mostly academic hospital (22/28, 78.6%), with the remainder community hospital and private practice (each 3/28, 10.7%).

Figures 2 and 3 show the effect sizes (%EWL) with 95% confidence intervals by surgery type and involving a total of 7,383 patients. Results showed significant heterogeneity in effect sizes within surgery type ( $p < 0.001$ ), validating the choice of a random-effects model for the meta-analysis. The composite estimate for %EWL was 49.4% (95% CI 44.9 to 54.0) for LAGB and 62.6 (95% CI 58.6 to 66.6) for LGB. The difference in effect sizes between the two types of surgery was statistically significant ( $Q = 30.7$ ,  $df = 1$ ,  $p < 0.001$ ).

Composite %EWL broken down by time since surgery for LAGB showed an improving degree of excess weight loss over time for both LAGB and LGB. Specifically, for LAGB, this was 42.6% at 1 year, 50.3% at 2 years, and 55.2% at >3 years since surgery (Table 3). For LGB, this was 61.5% at 1 year, 69.7% at 2 years, and 71.2% at >3 years since surgery. Median attrition rates for LAGB studies and LGB studies at 1-year follow-up were 17.0% (range 0–77.7%) for LAGB and 0.0% (0–65.9%) for LGB patients. There was a marked loss of bariatric surgery patients to follow-up for both surgery types beyond the 1-year follow-up point. Specifically, the 24-month attrition rate was 49.8% (range 0–92.3%) for LAGB and 75.2% (0–95.8%) for LGB, and >3 year follow-up attrition rate was 82.6% (25.9–93.3%) for LAGB and 89.0% (49.2–90.4%) for LGB.

Seventeen trials of LGB were examined for their reporting of salient postsurgical management operative details that may impact weight loss outcomes (Table 4). Results showed that 12/17 (70.5%) of LGB studies reported limb length but only as a range (75–150 cm). Eleven reported pouch size (64.7%) but only as a range (15 to 30 cm); none reported anastomosis size, and none reported whether preservation of the vagal nerve had occurred. For LAGB, three of 20 studies (15%) reported pouch size with a range from 10 to 20 ml, and 1/20 (5%) described frequency of postsurgical gastric band tightening (range two to five times). Mean patient age was reported in 26/29 (89.6%) of studies and gender by 27/29 (93.1%).

**Fig. 1** Study attrition diagram for meta-analysis of bariatric surgery studies



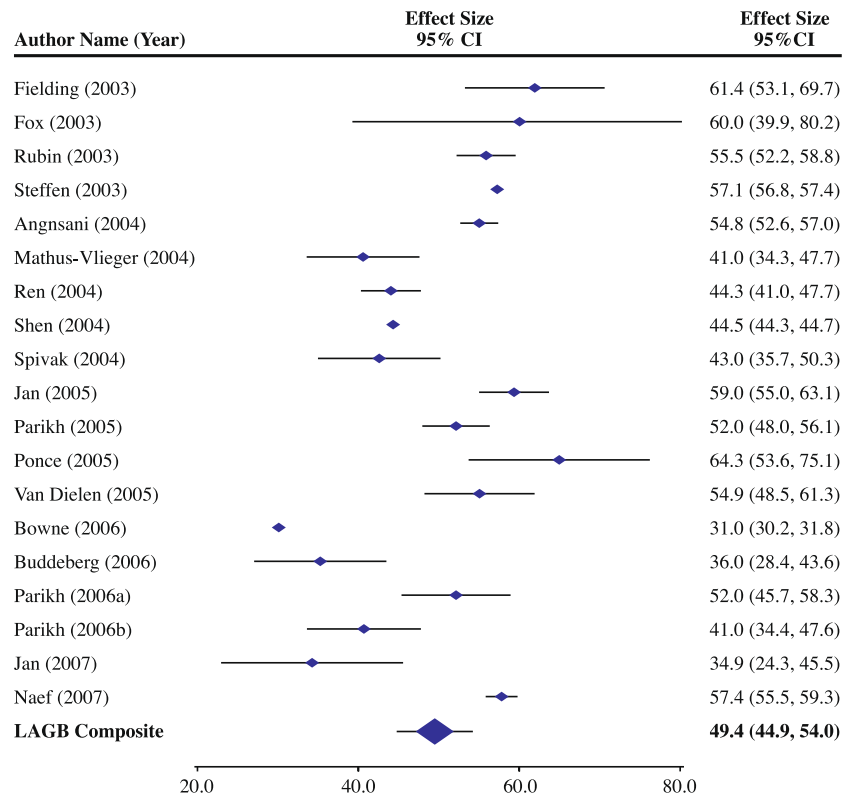
**Table 2** Characteristics of bariatric surgery studies included in meta-analyses

Author	Year	Surgery	Duration (months)	Setting	Randomization	Time frame	Total			LAGB			LGB			
							N	N	N	N	N	N	N	N	N	Mean age
Angnsani	2004	LAGB	23	Hospital/academic	Nonrandomized	Retrospective	573	573	38.3	122	NR	NR	NA	NA	NA	NA
Bowne	2006	LAGB	41	Community hospital	Nonrandomized	Retrospective	106	60	41.9	10	NR	NR	NA	NA	NA	NA
Buddeberg	2006	BOTH	24	Hospital/academic	Nonrandomized	Prospective	63	40	43.5	23	NR	NR	23	43.5	23	NR
Dallal	2004	LGB	78	Hospital/academic	Nonrandomized	Retrospective	30	NA	NA	NA	NA	NA	30	50	10	NR
Farkas	2005	LGB	NR	Hospital/academic	Nonrandomized	Retrospective	213	NA	NA	NA	NA	NA	213	37.9	27	NR
Fielding	2003	LAGB	72	Private practice	Nonrandomized	Retrospective	76	76	NR	27	NR	NR	NA	NA	NA	NA
Fox	2003	LAGB	65	Private practice	Nonrandomized	Retrospective	105	105	44.8	18	NR	NR	NA	NA	NA	NA
Gould	2004	LGB	11	Hospital/academic	Nonrandomized	Retrospective	100	NA	NA	NA	NA	NA	100	44.4	12	NR
Jan	2005	LAGB	38	Hospital/academic	Nonrandomized	Retrospective	373	154	46	32	145	396	NA	NA	NA	NA
Jan	2007	BOTH	61	Hospital/academic	Nonrandomized	Retrospective	898	406	47	88	NA	NA	492	44	62	479
Lee	2004	LGB	14	Hospital/academic	Randomized	Prospective	90	NA	NA	NA	NA	NA	90	31.6	13	NR
Lee	2005	LGB	25	Hospital/academic	Randomized	Prospective	80	40	NA	NA	NA	NA	40	31.1	12	NR
Mathus-Vlieger	2004	LAGB	NR	Hospital/academic	Randomized	Prospective	50	25	35	8	NR	NR	NA	NA	NA	NA
Moose	2003	LGB	21	Community hospital	Nonrandomized	Retrospective	67	NA	NA	NA	NA	NA	67	42	8	NR
Naef	2007	LAGB	91	Hospital/academic	Nonrandomized	Prospective	128	128	40.2	41	NR	NR	NA	NA	NA	NA
Olbbers	2005	LGB	18	Hospital/academic	Randomized	Prospective	83	NA	NA	NA	NA	NA	37	NR	12	NR
Pajechi	2007	LGB	51	Hospital/academic	Nonrandomized	Retrospective	75	NA	NA	NA	NA	NA	75	NR	18	NR
Parikh	2005	LAGB	37	Hospital/academic	Nonrandomized	Retrospective	749	749	42.3	218	630	630	NA	NA	NA	NA
Parikh	2006	LAGB	39	Hospital/academic	Nonrandomized	Retrospective	123	123	37	NR	65	65	NA	NA	NA	NA
Perugini	2003	LGB	31	Hospital/academic	Nonrandomized	Retrospective	188	NA	NA	NA	NA	NA	188	44	31	NR
Ponce	2005	LAGB	50	Private practice	Nonrandomized	Retrospective	1,014	1014	42.3	185	999	999	NA	NA	NA	NA
Puzziferri	2006	LGB	22	Hospital/academic	Randomized	Prospective	59	NA	NA	NA	NA	NA	59	47	3	NR
Ren	2004	LAGB	20	Hospital/academic	Nonrandomized	Retrospective	444	444	42.1	103	NR	NR	NA	NA	NA	NA
Rubin	2003	LAGB	41	Hospital/academic	Nonrandomized	Prospective	250	250	37	43	NR	NR	NA	NA	NA	NA
Shen	2004	BOTH	14	Hospital/academic	Nonrandomized	Retrospective	301	186	40.4	56	NR	NR	115	41.3	23	NR
Spivak	2004	LAGB	22	Community hospital	Nonrandomized	Retrospective	271	271	40	35	NR	NR	NA	NA	NA	NA
Steffen	2003	LAGB	51	Hospital/academic	Nonrandomized	Retrospective	824	824	43	188	NR	NR	NA	NA	NA	NA
Van Dielen	2005	LAGB	32	Hospital/academic	Randomized	Prospective	50	50	37.2	10	NR	NR	NA	NA	NA	NA

7,383

NR not reported, NA not applicable, LAGB laparoscopic adjustable gastric banding, LGB laparoscopic gastric bypass

**Fig. 2** Effect sizes for laparoscopic adjustable gastric banding studies

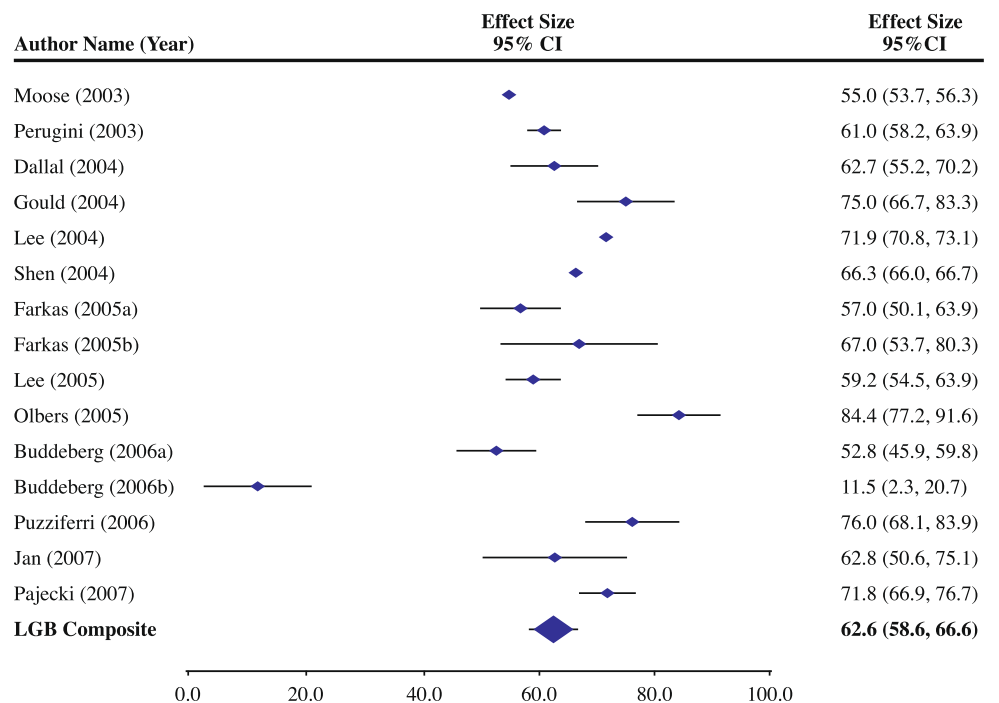


A funnel plot of all studies showed no evidence of publication bias (Fig. 4). The plot showed a classic funnel shape, with a large spread of points at the bottom of the graph in studies with small sample sizes, and a symmetric distribution about the mean of all studies.

**Discussion**

This meta-analysis of bariatric surgery weight loss outcomes for 28 studies reported in the literature from 2003 to 2007 involved 7,383 LAGB and LGB patients. The studies

**Fig. 3** Effect sizes for laparoscopic gastric bypass studies



**Table 3** Weight loss outcomes reported for LAGB and LGB by follow-up end point

Surgery type	Follow-up period (year)	Effect size Mean %EWL	95% CI		# Studies
			LL	UL	
LAGB	1	42.6	37.3	47.9	15
	2	50.3	46.5	54.0	12
	3	55.2	50.7	59.7	9
LGB	1	61.5	57.4	65.5	10
	2	69.7	63.7	75.7	5
	3	71.2	60.5	82.0	2

LAGB laparoscopic adjustable gastric banding, LGB laparoscopic gastric bypass

reviewed were observational or interventional trials that were predominantly retrospective in design (72.4%) and carried out at academic hospital centers (79.4%) with the remainder carried out at community hospitals or in private practice (20.6%).

We found similar effect sizes in terms of %EWL to those reported by Buchwald et al. [4] for laparoscopic and open LAGB and LGB studies published from 1995 to 2003. Specifically, we found a composite %EWL of 49.4% for LAGB versus the estimate of 47.5% by Buchwald et al. and found a composite %EWL of 62.6% for LGB versus 61.6% for Buchwald et al. We found %EWL outcomes for LGB significantly superior to those for LAGB at all three time points examined (1, 2, and >3 years). The improvement in

%EWL for LGB over LAGB was approximately 19% at 1 year and 16% at >3 years.

Our examination of selected aspects of study quality highlighted a number of concerns regarding data quality, reporting of patient characteristics, documentation of key surgical techniques and postsurgical management issues, and patient follow-up rates. For example, 64% of 88 studies that met our study exclusion and inclusion criteria were omitted for insufficient reporting of %EWL data needed for the analyses. Also, while documentation of pouch size and limb length for LGB were generally well reported, these data were typically provided as a range of values but not mean and standard deviations that would provide a clearer picture of central tendency and dispersal [7]. It is

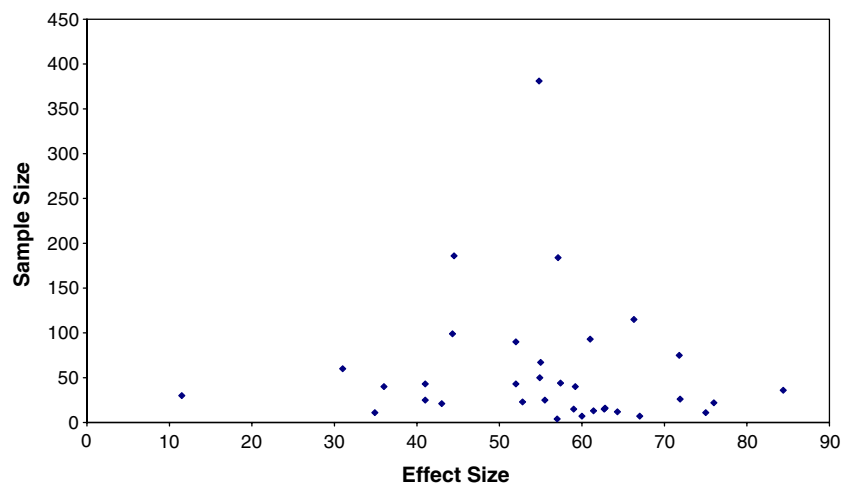
**Table 4** Operative details reported for LGB and LAGB bariatric surgery studies

Surgery type	Author	Year	Limb length (cm)			Pouch size (ml)			# Times band tightened post surgery		
			Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
LAGB	Jan	2005	–	–	–	NR	15	20	–	–	–
	Mathus-Vlieger	2004	–	–	–	15	NR	NR	NR	NR	NR
	Olbers	2005	–	–	–	NR	10	20	NR	NR	NR
	Steffen	2003	–	–	–	NR	10	15	NR	NR	NR
	Van Dielen	2005	–	–	–	NR	NR	NR	NR	3	5
LGB	Bowne	2006	NR	150	NR	NR	30	NR	–	–	–
	Dallal	2004	NR	75	150	NR	15	NR	–	–	–
	Farkas	2005	NR	100	150	NR	30	NR	–	–	–
	Farkas	2005	NR	100	150	NR	30	NR	–	–	–
	Gould	2004	NR	100	150	NR	30	NR	–	–	–
	Jan	2005	NR	100	NR	NR	15	20	–	–	–
	Lee	2004	NR	100	150	NR	15	20	–	–	–
	Lee	2005	NR	100	150	NR	15	20	–	–	–
	Moose	2003	NR	150	NR	NR	20	NR	–	–	–
	Olbers	2005	NR	75	NR	NR	10	20	–	–	–
	Perugini	2003	NR	120	NR	NR	NR	NR	–	–	–
	Puzziferri	2006	NR	75	150	NR	15	20	–	–	–

This table represents the subset of studies where salient data were reported. Neither anastomosis size nor vagal nerve preservation status was reported for any LGB studies included in the meta-analysis and was not included

LGB laparoscopic gastric bypass, LAGB laparoscopic adjustable gastric banding, NR not reported, – not applicable

**Fig. 4** Funnel plot examining publication bias for bariatric surgery studies



recognized that surgeons face practical challenges in obtaining accurate measurement of these parameters and this may have led to the practice of reporting ranges. For example, achieving accurate anastomosis measurement may prove challenging as it will vary by stapler type or whether hand-sewn. Similarly, contraction and dilation of the bowel segment may result in variability in reported limb length across surgeons. Documentation of vagal nerve preservation and size of anastomosis was omitted in all LGB studies and may be in part due to a lack of consensus regarding its clinical significance. For LAGB studies, pouch size was reported for only 15% of studies, and postsurgical gastric band tightening was documented in only 5% of studies which is disconcerting given its potential significance in supporting sustained weight loss through stoma adjustment [44]. While patient retention in the clinical reports is high at 1 year for studies involving both surgeries, 49.8% of LAGB and 75.2% of LGB patients were lost to follow-up at 2 years, and 82.6% of LAGB and 89% of LGB were lost at >3 years. Despite these concerns, it was encouraging that our analysis showed that there was no evidence of a publication bias or “file drawer effect” among studies included in the analyses.

A number of research initiatives have recently emerged that could significantly improve the rigor of clinical trials in bariatric surgery published since the 2003–2007 period reviewed. For example, the National Institutes of Health Longitudinal Assessment of Bariatric Surgery (LABS) Consortium launched in 2003 has standardized and disseminated information on patient characteristics, surgical procedures, medical and psychosocial outcomes, and economic factors to promote evidence-based information collection regarding the risks and benefits of bariatric surgery [45]. Another significant development is the increasing influence of the Consolidated Standards of Reporting Trials (CONSORT, second version, 2007) guidelines which

provide an evidence-based minimum set of recommendations for reporting clinical trials [46]. CONSORT offers a standard checklist for authors to prepare reports of trial findings, facilitating their complete and transparent reporting and aiding their critical appraisal and interpretation. Additionally, the Bariatric Surgery Center of Excellence<sup>®</sup> certification by the American Society for Metabolic and Bariatric Surgery and its associated Research Consortium are focusing on the systematic collection, tracking, and measurement of surgery outcome data, developing clinical practice guidelines, and conducting clinical trials that may increasingly benefit clinical trial quality in bariatric surgery. The American College of Surgeons has developed the Bariatric Surgery Center Network Accreditation Program that similarly assesses the quality of surgical care and systematic measurement of clinical outcomes [47]. In combination, these advances in standards of research and professional audit and certification are expected to positively impact the quality of clinical trials in bariatric surgery and improve the accuracy of our estimates of weight loss trajectories for LAGB and LGB.

Finally, while not a focus of this review, it is notable that postsurgical assessments of diet and physical activity were absent from the clinical trials reviewed. While surgeons in particular may view anatomic changes created through bariatric surgery as the primary causative agents to weight loss outcomes, postsurgical dietary and physical activity behaviors are also likely to impact weight loss although our knowledge in this area is minimal. Careful documentation of patient diet and fluid intake as well as physical activity patterns may advance our understanding of weight loss outcomes in bariatric surgery.

In conclusion, the results of this meta-analysis identified a composite %EWL of 49.4% for LAGB and 62.6% for LGB surgery. Problems were identified regarding data quality and patient follow-up rates. Recent developments

in national standards for surgical programs and clinical outcomes trials are expected to improve our understanding of weight loss outcomes over time for LAGB and LGB procedures.

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