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ORIGINAL CONTRIBUTIONS

Revisional One-Anastomosis Gastric Bypass After Restrictive Index Surgery—a Metaanalysis and Comparison with Revisional Roux-en-Y Gastric Bypass

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Abstract

Background One-anastomosis gastric bypass (OAGB) was established as a recognized bariatric procedure in the 2018 International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) position statement. This study evaluates the outcomes of revisional OAGB (rOAGB) after a restrictive index procedure, and to compare it to revisional RYGB (rRYGB).
Methods A literature search was performed according to the PRISMA guidelines on papers published from inception till February 2020. Original studies involving patients who underwent rOAGB after a primary failed restrictive procedure were included. The primary outcome measured was postrOAGB weight loss. Secondary outcome measures include comorbidity resolution, operative duration, length of stay, morbidity, and mortality.
Results A total of 21 studies with 1377 patients were included. Five studies compared rOAGB versus rRYGB. Majority of the patients (76%) were female, with mean age of 43.5 years old. Mean body mass index (BMI) before revisional surgery was 41.6 kg/m^2. The most common biliopancreatic limb length was 200 cm. Percentage of excess weight loss after rOAGB increases to a maximum of 76.0% at 48 months postsurgery. rOAGB resulted in a pooled prevalence of diabetes, hypertension, hyperlipidemia, and obstructive sleep apnea resolution of 74.9%, 48.4%, 63.2%, and 75.7% respectively. When compared to rRYGB, rOAGB demonstrated greater weight loss, comparable metabolic syndrome resolution, but with a shorter operating time. Morbidity and mortality rates were low across all studies.
Conclusions rOAGB has potential as an alternative revisional surgery, with weight loss profiles and rates of metabolic syndrome resolution that are comparable to rRYGB.

Keywords Revisional bariatric surgery · One-anastomosis gastric bypass · Roux-en-Y gastric bypass · OAGB · RYGB

Introduction

The incidence of morbid obesity has been on an upward trend in developed nations and remains a priority public health issue for many countries globally. Bariatric surgery is currently the most effective therapy for significant and sustainable weight loss, as well as improvement of metabolic profile [1–3]. Bariatric surgical techniques have evolved across the years, in a bid to find the most effective procedure that can achieve maximal weight loss and comorbidity resolution, while minimizing side-effects and complications.

Bariatric surgeries are broadly classified into restrictive versus malabsorptive procedures. After restrictive procedures such as sleeve gastrectomy, gastric banding, and gastric plication, some patients may require revision bariatric surgery due to insufficient weight loss, weight regain, or intractable gastroesophageal reflux disease (GERD) [4–6]. The most commonly performed revision bariatric surgery procedures are a re-sleeve or Roux-en-Y gastric bypass [6–8].

Roux-en-Y gastric bypass (RYGB) is considered the gold standard for bariatric procedures [9] and remains the most widely accepted procedure for patients with morbid obesity

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and metabolic syndrome, or those requiring revisional bariatric surgery [1]. However, RYGB is a technically demanding surgery with a steep learning curve [10]. The one anastomosis gastric bypass (OAGB), also known as "mini gastric bypass" or "omega-loop gastric bypass", was first proposed by Rutledge et al. in 1997 [11] as an alternative to the classic RYGB. OAGB is considered as a technically less demanding malabsorptive bariatric procedure, as it involves a single anastomosis. It consists of a lesser-curvature based long-sleeved gastric pouch, followed by a gastro-jejunal anastomosis between the gastric pouch and the jejunum, with a biliopancreatic limb that can range from 150 to 250 cm.

To date, there have been multiple randomized controlled trials and metaanalyses demonstrating effective weight loss postOAGB that is durable up to 5 years, as well as a favourable effect on glycemic control [12–17]. OAGB was also recently established as a recognized bariatric/metabolic procedure in the 2018 International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) position statement [18]. While primary OAGB is an established bariatric procedure, the evidence on revisional OAGB (rOAGB) as a secondary procedure is ambiguous. Studies have shown a significant weight loss and comorbidity resolution after rOAGB, however there still remain concerns of biliary reflux and malnutrition, as mentioned in the most recent IFSO consensus statement [19].

This is the first systematic review and metaanalysis that aims to evaluate the outcomes of rOAGB in comparison to revisional RYGB (rRYGB) after an initial failed restrictive procedure.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were adhered to in performing and reporting of this metaanalysis [20]. This study was registered online under PROSPERO (Registration number CRD42020205718) and in accordance with the PRISMA-P-2015 protocol [20].

Data Sources

A comprehensive literature search was conducted using PubMed/MEDLINE, Embase and the Cochrane Database of Systematic Reviews on papers published from inception up till February 2020 (Fig. 1). The search was performed using medical subject headings (MeSH) and a combination of keywords from the following two groups: (a) "bariatric surgery", "metabolic surgery", "one-anastomosis", "OAGB", "mini gastric bypass", "single anastomosis gastric bypass", and "omega loop gastric bypass", and (b) "revision surgery", "conversion", "failed procedure", and "second step".

All titles and abstracts that were identified through the search were screened against our study selection criteria as elaborated below. The full texts of all potentially relevant articles were extracted and assessed. A reference search list search was also performed based on relevant extracted full-text articles. Three reviewers, C.Y., G.H., and M.M. independently conducted title and abstract screening. Any disagreement over study selection was resolved by the two authors (C.Y. and D.Y.) in face-to-face discussions.

Inclusion/Exclusion Criteria

The following studies were included in this systematic review and metaanalysis: randomized controlled trials, case-matched studies, prospective longitudinal studies, and retrospective cross-sectional studies. Only studies involving patients who underwent rOAGB after a primary failed restrictive procedure were included. Restrictive bariatric procedures were defined as gastric plication, gastric banding, sleeve gastrectomy, and vertical banded gastroplasty. The primary outcome assessed is postrOAGB weight loss, either in terms of percentage of excess weight loss (%EWL), percentage of excess BMI loss (%EBMIL), or change in BMI (ΔBMI). Secondary outcome measures include comorbidity resolution, operative duration, length of stay, morbidity, and mortality.

Studies that met any of the following criteria were excluded: (i) abstracts, review articles, and clinical practice guidelines; (ii) nonhuman studies; (iii) nonEnglish papers; and (iv) articles with no full text (posters and/or conference abstracts).

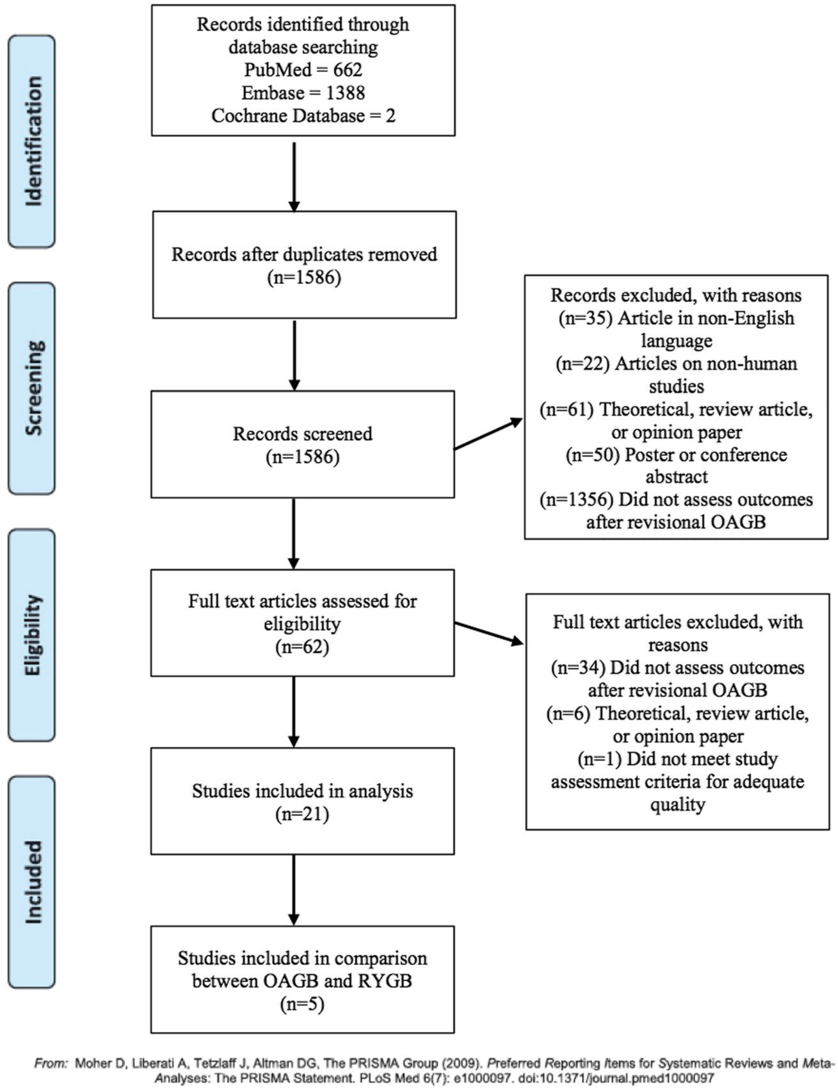
Assessment of Study Quality

All articles that met the above study selection criteria were analyzed. Given that there are no available tools to assess the methodological quality of retrospective case series, we utilized a modified Newcastle Ottawa Scale [21, 22] previously applied in other systematic reviews with good interrater agreement. The modified Newcastle Ottawa Scale has been adapted for the evaluation of non-comparative studies by removing items that relate to comparability and adjustment. Each study is judged on five items focusing on selection, representativeness of cases, and ascertainment of outcome and exposure. Only studies with a score of at least 3 out of 5 were deemed of adequate quality and included in this review.

Data Extraction

Data were extracted from each study individually. Patient demographics including age, gender, weight, and/or body mass index (BMI) were recorded where applicable. Details about the primary restrictive procedure and indication for revisional surgery were also recorded. Postrevisional surgery outcomes

Fig. 1 PRISMA diagram



were also extracted, which included weight loss (either %EWL, %EBMIL, or ΔBMI), operative time, length of stay, morbidity, mortality, and comorbidity resolution where applicable.

Statistical Analysis

All metaanalyses were done using inverse variance-weighted random-effects model to account for statistical and qualitative heterogeneity across studies. %EWL were metaanalyzed using the metan package in Stata (version 16.0, StataCorp), while pooled prevalence of comorbidity resolution were computed using the metaprop package which applies the variance-stabilizing Freeman-Tukey double-arcsine transformation to achieve approximate normality prior to pooling, followed by a back-transformation of the pooled estimate to the original scale [23].

Imputation of Missing Data

For imputation of missing mean %EWL and/or its standard deviation (SD), we used the following set of rules:

(i) If the within-study median and range of %EWL was provided, we used the formulas of Hozo et al. [24].
(ii) If the mean %EWL was reported but SD was missing and cannot be obtained using (i), we imputed missing SDs as the square root of the weighted mean variance of all other included studies in the metaanalysis [25]
(iii) If %EBMIL was reported and summary statistics for %EWL could not be imputed from (i) or (ii), we used %EBMIL in place of %EWL on the basis that they are interchangeable under certain assumptions.
(iv) Finally, if initial BMI and either ΔBMI or postop BMI was reported, we calculated the %EBMIL by plugging the values into the following equations: %EBMIL =

$\frac{\Delta BMI \times 100\%}{\text{Initial BMI}-25}$ or (Initial BMI−Postop BMI) $\frac{\times 100\%}{\text{Initial BMI}-25}$. Next, the mean %EBMIL and its SD were empirically estimated from 10,000 Monte Carlo simulations because no widely accepted approximations or closed form expressions exist for estimating the ratio distribution of two normally distributed variables [26, 27].

Results

Study Selection

Figure 1 shows the study selection flowchart. Using the above keywords, 662 articles were obtained from PubMed/

Table 1 Demographic data

Study ID (year)	Country	Time period	Type	Patients, *n*	Females, *n* (%)	Mean age, years	Index surgery	Initial BMI, kgm^{-2}	NOS
Debs (2020)	France	May 2010–May 2018	R	77	63 (82)	45.3 ± 14.8	LSG	46.9 (30–70)	5
Jamal (2020)	Kuwait	Jan 2015 – Dec 2018	P	56	50 (89)	37.6 ± 10.3	LSG	NA	5
Bhandari (2019)	India	Jan 2010 - Dec 2016	P	32	19 (59)	42.6 ± 11.0	LSG	44.0 ± 8.6	5
Chiappetta (2019)	Germany	Oct 2014 - Dec 2016	P	34	23 (68)	46.8 ± 11.5	LSG	56.5 ± 8.8	5
Heidari (2019)	Iran	2000–2016	P	38	NA	NA	LGP	NA	4
Musella (2019)	Italy	2007–2018	R	300	242 (80)	46.1 ± 10.5	196 LGB 104 LSG	45.1 ± 7	5
Poghosyan (2019)	France	Jan 2007 - Dec 2017	P	72	52 (72)	47 ± 10	LSG	49.1 ± 8	5
Almalki (2018)	Taiwan	May 2001 - Dec 2015	R	81	21 (26)	38.7 ± 9.8	55 VBG 26 LGB	NA	5
AlSabah (2018)	Kuwait	2008–2017	R	29	26 (90)	41.4 ± 10.2	LSG	49.1 ± 7.3	5
Noun (2018)	Lebanon	Jan 2016 - Feb 2017	P	21	11 (52)	39 ± 12	10 LGB 7 LSG 5 LGP	45 ± 4.8	4
Rafols (2018)	Multicenter	Mar 2002 - Jan 2017	R	191	171 (90)	40.6 ± 11.2	LGB	44.3 ± 6.8	4
Chansaenroj (2017)	Taiwan	May 2002 - Apr 2011	R	26	16 (62)	35.9 ± 8.8	LGB	39.9 ± 10.5	5
Ghosh (2017)	Australia	July 2012 - Dec 2015	R	74	67 (91)	48.3 ± 10.3	LGB	48.9 ± 11.2	5
Lessing (2017)	Israel	Mar 2015 - Mar 2016	R	98	70 (71)	43.5 ± 9.7	56 LGB 27 LSG 9 VBG 6 LGB + L-SG	NA	5
Meydan (2017)	Israel	Jun 2015 - Feb 2016	R	48	33 (69)	47.1 (19–70)	31 LGB 15 LSG 2 VBG	NA	4
Bruzzi (2016)	France	Oct 2006 - Oct 2008	R	30	26 (87)	53 ± 9	22 LGB 4 LSG 4 VBG	NA	5
Salama (2016)	Egypt	Dec 2013 - Dec 2015	P	39	NA	38.7	VBG	NA	4
Piazza (2015)	Italy	Jun 2007 - Nov 2012	P	48	39 (82)	38 (20–59)	LGB	NA	4
Moszkowicz (2013)	France	Oct 2006 - Feb 2012	R	23	13 (62)	49.5 ± 11.2	LSG	51.4 ± 11	5
Noun (2007)	France	Jun 2005 - Sept 2006	R	31	20 (65)	41.3 ± 10.3	16 LGB 15 VBG	NA	5
Wang (2004)	Taiwan	May 2001–March 2003	R	29	24 (83)	39.7	LSG	NA	4

All data expressed in mean ± SD unless otherwise specified

P prospective; *R* retrospective; *RCT* randomized controlled trial; *OAGB* one anastomosis gastric bypass; *LSG* laparoscopic sleeve gastrectomy; *LGB* laparoscopic gastric banding; *VBG* vertical banded gastroplasty; *LGP* laparoscopic gastric plication; *BMI* body mass index, *NOS* Newcastle Ottawa Scale (modified)

Table 2 Details of revisional OAGB

Study ID (year)	Reason for revisional OAGB (%)	Surgery type (%)	Bougie size, Fr	BP limb length, centimeters	Time to OAGB, months	BMI at rOAGB, kgm^{-2}	Operating time, minutes	Blood loss, milliliters	Length of stay, days
Debs (2020)	Weight loss failure/regain (100)	L (100)	36	150	NA	40.1 (29–57)	42.0 ± 8	56.8 ± 56.7	3
Jamal (2020)	Weight regain (100)	L (100)	36	175	82 ± 30.7	41.9 ± 7.9	NA	NA	NA
Bhandari (2019)	Weight loss failure/regain (100)	L (100)	36	250	NA	38.5 ± 6.3	NA	NA	NA
Chiappetta (2019)	Weight loss failure/regain (85) Intractable GERD (15)	L (100)	42	200	33.3 ± 22.8	45.7 ± 8.0	78.7 ± 35.7	<10	5
Heidari (2019)	Weight regain (54) Weight regain prone (45) Weight loss failure (2)	L (100)	NA	200	27.5 ± 19.2	42.0 ± 3.9	101.2 ± 21.2	NA	4.6 ± 5.1
Musella (2019)	Weight loss failure/regain (77) Intractable GERD (15) Band or pouch complications (8)	L (100)	32–38	180–200	21.8 ± 23.6	41.8 ± 6.3	95.5 ± 3.5	NA	NA
Poghosyan (2019)	Weight loss failure/regain (100)	L (94) OC (6)	32	150 or 200	28 ± 10	43.6 ± 7	80	NA	3.1
Almalki (2018)	Weight loss failure/regain (82) Intractable GERD (13) Achalasia (5)	L (100)	38	200	58.5 (14–180)*	37.8 ± 9.6	167.7 ± 55.8	108.6 ± 48.9	NA
AlSabah (2018)	Weight loss failure/regain (97) Intractable GERD (3)	L (100)	38	175–200	61.1 ± 19	42.6 ± 5.8	118.2 ± 53.1	NA	NA
Noun (2018)	Weight loss failure/regain (100)	L (100)	40	150 or 200	NA	42.9 ± 6.5	96.4 ± 20.9	NA	2.0 ± 0.3
Rafols (2018)	Weight loss failure/regain (41) Band complications (59)	L (97) OC (3)	32–36	150–250	NA	39.8 ± 6.9	NA	NA	NA
Chansaenroj (2017)	Weight loss failure/regain (77) Achalasia (11) GERD (8) Unknown (4)	L (100)	NA	NA	NA	39.3 ± 8.9	180.2 ± 58.7	160.9 ± 368.5	5.7 ± 11.4
Ghosh (2017)	Weight loss failure/regain (59) GERD or food intolerance (24) Band complications (16)	L (100)	36	150	NA	46.0 ± 8.9	72.7 ± 15.7	NA	2.6 ± 1.2
Lessing (2017)	Weight loss failure (88) Dysphagia (7) Abdominal pain or dyspepsia (5)	L (100)	34	200	105.6 ± 67.2	42.2 ± 8.3	NA	NA	2.4 (2–8)
Meydan (2017)	Weight loss failure/regain (94) GERD or dysphagia (6)	L (100)	34	150–200	107.2 (24–264)	41.8 (27.7–60.7)	157 ± 49	NA	2.6
Bruzzi (2016)	Weight loss failure (66) GERD (13) Dysphagia (10) Gastric prolapse (10)	L (100)	32	200	34	45.5 ± 7	140 ± 45	NA	NA
Salama (2016)	Weight loss failure/regain (70) GERD/band complications (30)	L (100)	36	180	NA	39.8 ± 8.2*	145.4 ± 29.2	NA	4.8 ± 2.2
Piazza (2015)	Band complications (43) GERD (31) Weight loss failure (15) Food intolerance/patient request (11)	L (100)	36	180–240	28.6	43.4 ± 4.2	NA	NA	3.3

Table 2 (continued)

Study ID (year)	Reason for revisional OAGB (%)	Surgery type (%)	Bougie size, Fr	BP limb length, centimeters	Time to OAGB, months	BMI at rOAGB, kgm^{-2}	Operating time, minutes	Blood loss, milliliters	Length of stay, days
Moszkowicz (2013)	Weight loss failure (81) Weight regain (19)	L (81) OC (19)	34	200	26.3 (8.2–63.7)	44 ± 7.7	NA	NA	NA
Noun (2007)	Weight loss failure/regain (58) GERD (18) Food intolerance (15) VBG staple line disruption (9)	O (100)	36	200	36.3 ± 18	39.5 ± 10.4	169.5	NA	4.7 (3–17)
Wang (2004)	Weight loss failure/regain (80) GERD (10) Staple line disruption (24) Stomal stenosis (10) Pouch dilation (35)	L (100)	60–80 ml	200	58.5 ± 18.3	41.7 (35.0–70.8)	171.4 ± 15.3	NA	6.4 ± 3.2

All data expressed in mean ± SD unless otherwise specified

OAGB one anastomosis gastric bypass; *BP* biliopancreatic; *BMI* body mass index; *GERD* gastro-esophageal reflux disease; *L* laparoscopic; *OC* open conversion; *O* open

*Data for time to revisional surgery inclusive of both revisional OAGB and revisional RYGB

MEDLINE, 1388 articles from Embase, and 2 from Cochrane Database of Systematic Reviews. After removal of duplicate articles, a total of 1586 articles were obtained and reviewed. A total of 1524 articles were excluded after title and abstract screening, and the full texts for the remaining 62 articles were extracted and reviewed. Out of these 62 full texts reviewed, 41 were excluded for the following reasons: (i) did not assess outcomes after rOAGB; (ii) theoretical analysis, review article, or opinion paper; and (iii) deemed to be of inadequate quality as determined by the modified Newcastle Ottawa Scale.

Overview of Studies (Table 1)

Twenty-one studies [28–48] with a total of 1377 patients were included in this systematic review (Table 1). Out of these 21 studies, five studies [29, 30, 33, 34, 37] compared rOAGB versus rRYGB outcomes. Majority of the studies ($n = 13$) were retrospective in nature, with the remaining eight studies being prospective. The time period studied ranged from 2000 to 2020. Majority of the patients were female, with 986/1300 (76%) patients. The mean age was 43.5 years old.

With regard to the index surgery performed, the majority were 696 laparoscopic gastric banding (LGB), followed by 509 laparoscopic sleeve gastrectomy (LSG), 124 vertical banded gastroplasty (VBG), 43 laparoscopic gastric plications (LGP), and 6 combined laparoscopic sleeve gastrectomy with banding (LGB + LSG). The initial BMI prior to index surgery was reported in 11 papers, with a mean of 46.3 kg/m^2.

Details of Revisional OAGB (Table 2)

The mean BMI prior to revisional surgery was 41.6 kg/m^2. Main indications for revisional surgery were either weight loss failure or weight regain, followed by gastro-esophageal reflux disease, and other band or procedure related complications. Time to revision surgery was reported in 14 articles, and ranged from 21.8 to 107.2 months. Majority of the revisional surgeries were performed laparoscopically, with only three studies [31, 33, 39] reporting a need for conversion to open in a small minority of patients (ranging from 3 to 19%), and one study [47] in which all patients underwent open revisional surgery. Description of the rOAGB procedure was described in majority of the studies—resizing of the gastric pouch was performed using bougie sizes ranging from 32 to 42 French, followed by the creation of a gastrojejunal stapled anastomosis. The biliopancreatic limb length was reported in 20 studies, and ranged from 150 to 250 cm measured from the ligament of Treitz. Operating time was reported in 15 studies, and ranged from 42 to 180 min. Blood loss was reported in only 4 studies, and ranged from < 10 to 160 ml. Length of stay was reported in 13 studies, and ranged from 2 to 6.4 days.

Table 3 Outcomes of revisional OAGB

Study ID (year)	Follow-up, months (N)	%EWL/%EBMIL/ΔBMI*, mean ± SD	Comorbidity resolution, *n* (%)				GERD, *n* (pre > post)	Bile reflux, *n* (%)	Morbidity, *n* (%)	Morbidity details	Mortality, *n* (%)
			DM	HTN	HLD	OSA					
Debs (2020)	12 (70) 24 (56) 60 (32)	74 (3–180) 79 (32–160) 77 (7–130)	8/13 (62)	15/23 (65)	NA	27/33 (82)	0 > 7 (2 converted to RYGB)	0	2 (3)	1 GJ anastomotic fistula, 1 pneumonia	0
Jamal (2020)	3 (33) 6 (32) 12 (27)	37.1 ± 6.9 35.7 ± 8.3 30.5 ± 9.4	2/5 (40)	8/19 (42)	NA	NA	NA	0	2 (3.5)	2 marginal ulcers	0
Bhandari (2019)	12 (28) 24 (25) 36 (22)	54.9 ± 9.2 52.1 ± 25.3 35.6 ± 22.9	1/2 (50)	3/3 (100)	NA	0	NA	NA	0	NA	0
Chiappetta (2019)	3 (34) 12 (34)	15 ± 10 29 ± 13	7/7 (100)	6/9 (67)	8/13 (62)	4/5 (80)	5 > 4	2 (5.9)	12 (35)	6 anastomotic ulcers, 4 GERD, 2 biliary reflux	0
Heidari (2019)	3 (36) 6 (33) 12 (31) 24 (21) 36 (8) 48 (7)	32.4 ± 9.8 51.6 ± 9.4 68.2 ± 8.1 76.0 ± 8.1 82.8 ± 12.9 80.1 ± 18.2	NA	NA	NA	NA	NA	NA	NA	NA	0
Musella (2019)	 6 (120) 12 (67) 24 (61) 36 (52)	%EBMIL 50.2 76.3 80.8 78.9	20/32 (63)	31/76 (41)	14/25 (56)	NA	46 > 19	NA	23 (7.7)	1 abdominal wall hernia, 5 anastomotic ulcer, 1 anastomotic leak, 2 gastric pouch leak, 1 small bowel perforation, 2 anastomotic stenosis, 9 intraabdominal bleeding	0
Poghosyan (2019)	6 (63) 12 (51) 24 (39) 36 (39) 48 (34) 60 (27)	55 ± 17 60 ± 20 64.8 ± 23 64.9 ± 25 67.7 ± 26 66.2 ± 28	12/16 (75)	6/29 (21)	NA	16/23 (70)	0 > 6	NA	14 (19.4)	1 bile leak, 2 marginal ulcers, 2 chronic diarrhea, 1 trocar port site herniation, 1 bleeding, 3 incisional hernia	0
Almalki (2018)	12 (53) 60 (19)	76.8 ± 57.1 73 ± 68.3	Metabolic syndrome = 28/31 (90)			NA	NA	NA	9 (11.1)	5 anastomotic leak, 2 intestinal obstruction, 1 major bleeding, 1 respiratory failure	1(1)
AlSabah (2018)	3 (27) 6 (20) 12 (17)	31.9 ± 14.1 48.0 ± 20.2 58.9 ± 23.7	NA	3/6 (50)	0/1 (0)	NA	1 > 0	NA	3 (10.3)	2 anastomotic leak, 1 anastomotic stenosis	0
Noun (2018)	 3 (21)	For %EBMIL, 41.7 ± 0.1#	3	2	NA	NA	0	0	NA	NA	NA

Table 3 (continued)

Study ID (year)	Follow-up, months (N)	%EWL/%EBMIL/ ΔBMI*, mean ± SD	Comorbidity resolution, n (%)				GERD, n (pre > post)	Bile reflux, n (%)	Morbidity, n (%)	Morbidity details	Mortality, n (%)
			DM	HTN	HLD	OSA					
	6 (21) 12 (21)	73.7 ± 0.1[#] 81.6 ± 0.2									
Rafols (2018)	12 (191)	%EBMIL = 74.4 (28.9)	NA	NA	NA	NA	NA	NA	9 (4.7)	5 anastomotic leaks, 1 major bleeding, 3 not mentioned	1 (0.5)
Chansaenroj (2017)	12 (19) 24 (16)	73.6 ± 25.2 76.7 ± 24.1	Metabolic syndrome = 15/16 (93.8)			NA	NA	NA	5 (19.2)	2 anastomotic leaks, 2 small bowel ileus, 1 major bleeding	0
Ghosh (2017)	3 (63) 6 (51) 12 (24)	37.8 ± 12.5 55.1 ± 15.8 67.0 ± 19.6	NA	NA	NA	NA	NA	4 (5.4) *converted RYGB	10 (13.5)	4 anastomotic strictures, 2 anastomotic ulceration, 1 anastomotic leak, 2 bowel obstruction, 1 respiratory failure	0
Lessing (2017)	3 (98) 6 (98) 12 (98)	42.3 ± 25.4 59.4 ± 19.6 72.8 ± 43.5	NA	NA	NA	NA	NA	0	9 (9)	6 anastomotic leak, 2 major bleeding, 1 bowel obstruction	0
Meydan (2017)	3 (32) 6 (11)	38.6 51.0	NA	NA	NA	NA	NA	NA	2 (4.2)	1 bleeding marginal ulcer, 1 acute myocardial infarction	0
Bruzzi (2016)	 12 24 60	For %EBMIL 61 ± 15 75 ± 17 66 ± 22	6/7 (85)	7/12 (58)	6/8 (75)	3/6 (50)	0 > 2	2 (6.7) *converted RYGB	3 (10)	2 biliary reflux, 1 marginal ulcer	0
Salama (2016)	12	ΔBMI = 9.7	NA	NA	NA	NA	NA	NA	1 (2)	1 iatrogenic bowel perforation	0
Piazza (2015)	6	ΔBMI = 9.3 ± 3.8	8/9 (88)	8/12 (66)	6/8 (75)	4/6 (66)	4 > 0	NA	NA	NA	NA
Moszkowicz (2013)	 3 6 12 24	For %EBMIL, 26.8 ± 12 37.2 ± 12.4 49.3 ± 19.8 51.6 ± 14.8	NA	NA	NA	NA	0	0	2 (9.5)	1 bile leak after cholecystectomy, 1 incisional hernia after midline laparotomy	0
Noun (2007)	6 (21)	ΔBMI = 8.9 ± 4.8	NA	NA	NA	NA	6 > 0	0	2 (6.4)	1 intra-abdominal abscess, 1 incisional hernia	0
Wang (2004)	12	ΔBMI = 9.6	NA	NA	NA	NA	NA	2 (6.9)	3 (10.3)	1 trocar port site herniation, 1 anastomotic leak, 1 staple line bleed	1 (3.4)

*%EWL at 1-year follow-up after revisional OAGB unless otherwise specified

[#] Assumption made of a typographical error during imputation of SD 0.1 by authors Noun et al., hence new SD calculated based on formulae in Methods section and imputed into statistical analysis accordingly

%EWL percentage excess body weight loss; *%EBMIL* percentage excess BMI loss; *ΔBMI* change in body mass index; *DM* diabetes mellitus; *HTN* hypertension; *HLD* hyperlipidemia; *GERD* gastro-esophageal reflux disease

Outcomes after Revisional OAGB (Table 3)

Follow-up duration for the studies ranged from 6 to 60 months. Weight loss after rOAGB is sustained up to 60 months postsurgery, as demonstrated by the metaanalyses performed in Fig. 2. %EWL after rOAGB increases steadily to a maximum of 76.0% (95% CI 46.8–105.3) at 48 months postsurgery. %EWL then decreases to 68.9% (95% CI 40.0–97.8) at the 60-month interval, suggesting some weight regain between the 4th and 5th postoperative year.

Comorbidity resolution was broadly classified into type 2 diabetes mellitus (DM), hypertension (HTN), hyperlipidemia (HLD), and obstructive sleep apnea (OSA). Only 12 [28–32, 34, 36, 38, 40, 41, 43, 46] out of 21 studies included in this

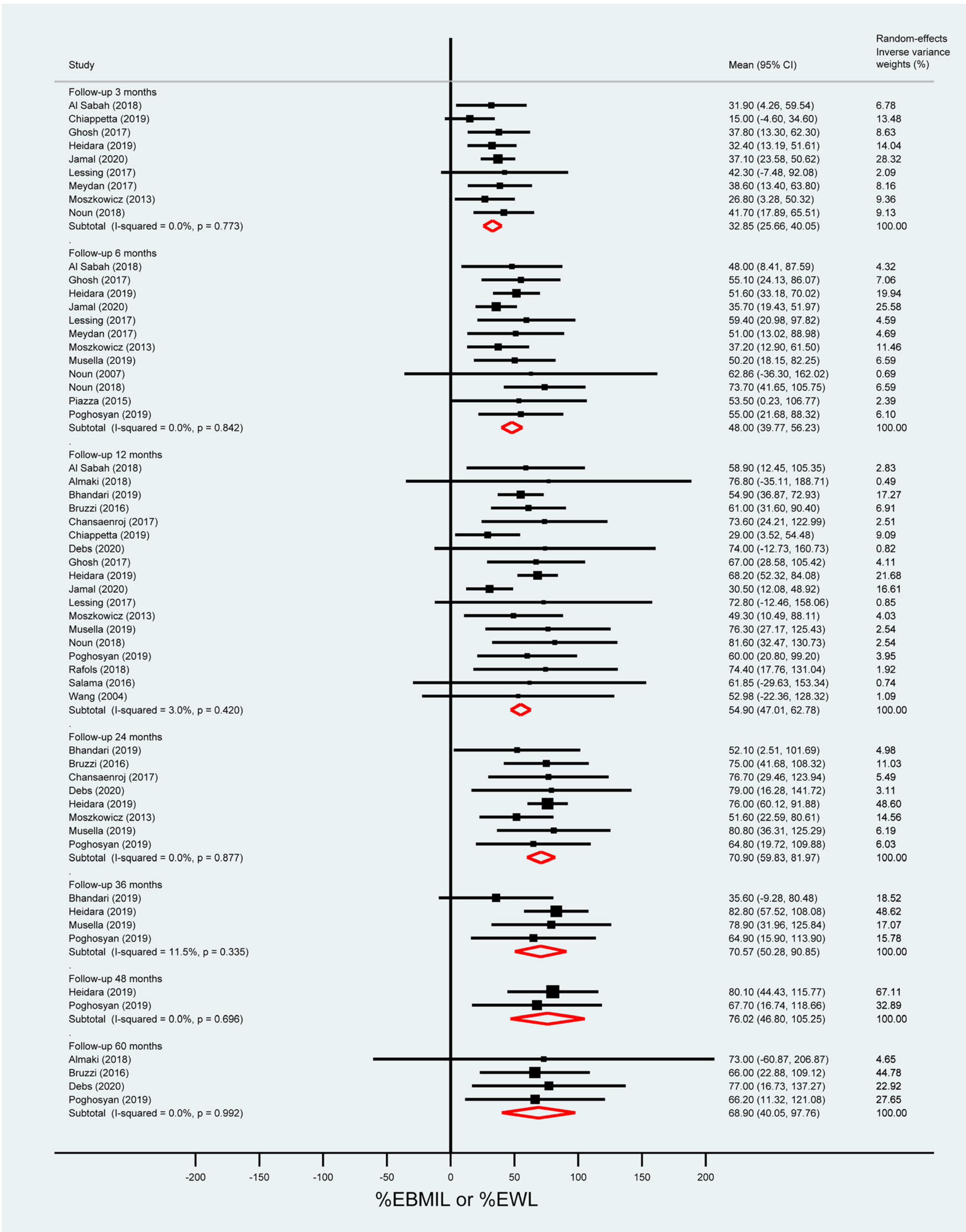


Fig. 2 Percentage of excess weight/BMI loss after revisional OAGB with time

review reported on comorbidity resolution, of which 2 [30, 34] reported it under the umbrella term of "metabolic syndrome" without further classification (Table 3). Only those studies reporting the prevalence of comorbidity resolution as per the above classification were included in the metaanalyses (Fig. 3). As demonstrated in Fig. 3, rOAGB resulted in a pooled prevalence of DM, HTN, HLD, and OSA resolution of 74.9%, 48.4%, 63.2%, and 75.7% respectively.

The morbidity after rOAGB was reported in 18 studies, and ranged from 0 to 19.2%. Table 3 details the type of complications after rOAGB as reported in the original studies. The reported mortality was low across all studies, with only 3 studies [30, 33, 48] reporting one mortality, and the rest having a mortality rate of 0%. The cause of mortality was reported in only two studies—one due to colonic necrosis [33], and one due to anastomotic leak [48].

Table 3 also demonstrates the impact of rOAGB on both gastroesophageal reflux disease (GERD) and biliary reflux. Five studies [29, 38, 40, 46, 47] reported a decrease in the incidence of GERD after rOAGB, whereas three studies [31, 36, 41] reported the emergence of de novo GERD after rOAGB (incidence ranging from 6.0 to 9.5%). The incidence of bile reflux after rOAGB was reported in ten studies—six studies [32, 39, 41, 43, 44, 47] reported a zero incidence of biliary reflux after rOAGB. In contrast, four studies [29, 35, 36, 48] described a bile reflux incidence ranging from 5.4 to

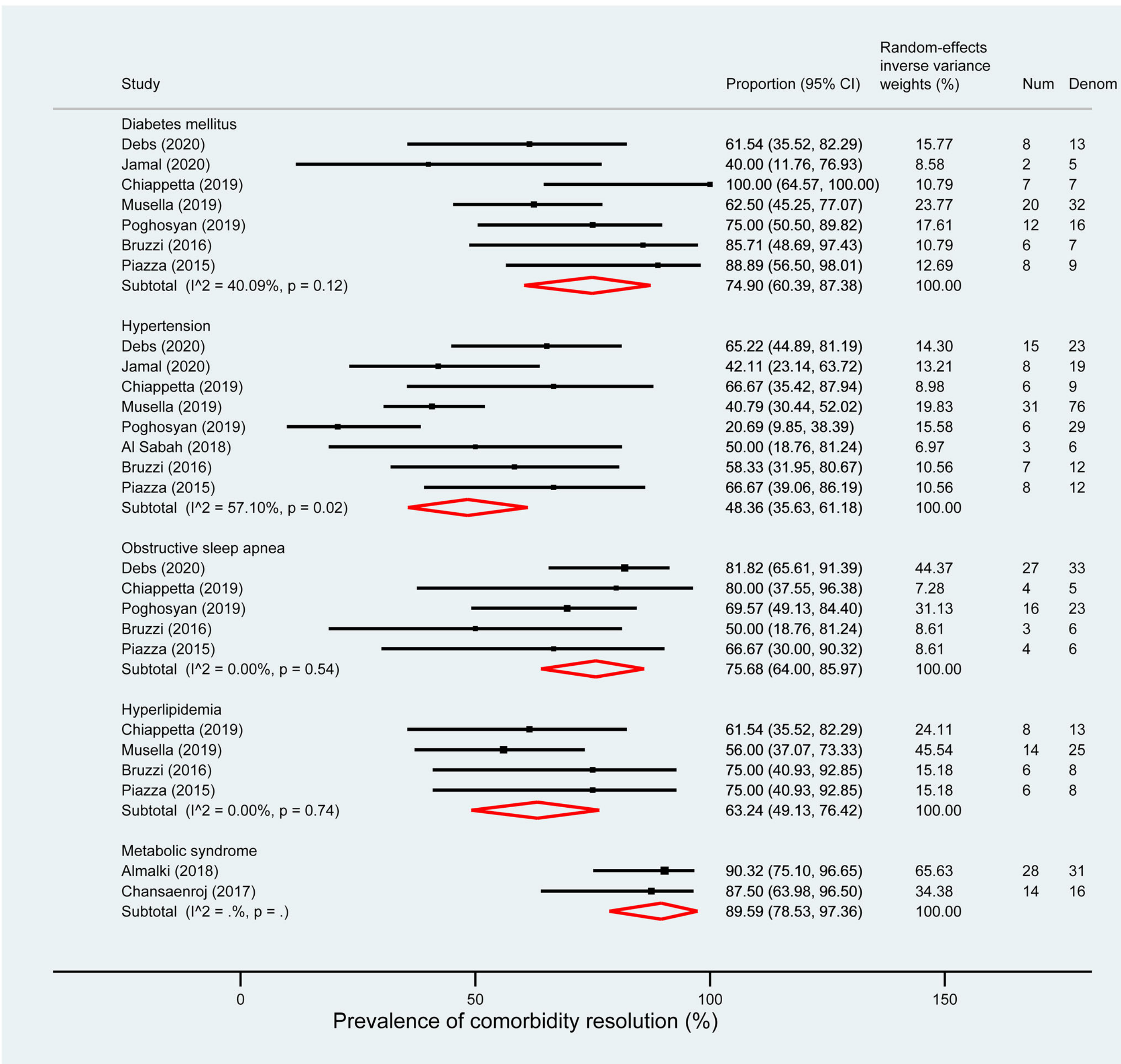


Fig. 3 Prevalence of comorbidity resolution after revisional OAGB

6.9%. Out of these four studies, two studies by Ghosh et al. [35] and Bruzzi et al. [36] described the conversion of rOAGB to subsequent RYGB due to intolerable biliary reflux—with an incidence of 5.4% and 6.7% respectively.

Revisional OAGB Versus Revisional RYGB (Tables 4 and 5)

Five studies [29, 30, 33, 34, 37] performed a comparative analysis between rOAGB and rRYGB. Table 4 describes the demographic data of the patients before revisional surgery. The BMI before revisional surgery was comparable in four studies, with one study [29] having a significantly higher BMI before rOAGB as compared to rRYGB.

Table 5 illustrates the outcomes after rRYGB versus rOAGB. The operating time was reported in four studies, with all four studies reporting a longer operating time in the rRYGB group (range 98.2–218.9 min) as compared to rOAGB (range 78.8–180.2 min). The length of stay was comparable in both groups. The morbidity for rRYGB ranged from 8.6 to 23.8%, whereas that for rOAGB ranged from 2.0 to 35.2%. Mortality was low across all studies. The %EWL/%EBMIL was more significant in the rOAGB group as compared to rRYGB group in the majority of the studies (Fig. 4). Metabolic syndrome resolution was comparable. In terms of postoperative reflux disease, only the paper by Chiapetta et al. [29] compared the incidence between the 2 groups. They demonstrated that the rOAGB group had a higher incidence of both anastomotic ulcers (17.6% versus 9.5%) and symptomatic bile reflux (5.9% versus 0%) as compared to the rRYGB group.

Discussion

Laparoscopic gastric banding (LGB) used to be one of the most popular bariatric surgeries until long-term studies started demonstrating a high incidence of weight regain and band complications [49, 50]. Laparoscopic sleeve gastrectomy (LSG), another type of restrictive surgery, has recently become the most frequently performed bariatric operation worldwide due to its effectiveness and simplicity [51]. However, there are conflicting data with regard to LSG patients in terms of long-term sustained weight loss and the development of reflux symptoms [52, 53]. The demand for revisional bariatric surgery is slowly increasing, especially after a failed index restrictive surgery. Options for revisional surgery in such patients include a resleeve, or conversion to a malabsorptive procedure, e.g., RYGB, OAGB, biliopancreatic diversion, and duodenal switch [54–56].

OAGB was recently established as a recognized bariatric/metabolic procedure in the 2018 International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO)

Table 4 Studies comparing revisional RYGB versus OAGB—prerevisional surgery demographic data

Study ID (year)	Country	Time period	Study type	Patients, *n*		Female, *n* (%)		Mean age, years		Initial BMI, kg m^{-2}		BMI prerevision surgery, kg m^{-2}	
				RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB
Chiappetta (2019)	Germany	Oct 2014–Dec 2016	P	21	34	19 (90)	23 (68)	46.1 ± 10.8	46.8 ± 11.5	49.8 ± 9.3	56.5 ± 8.8	36.6 ± 6.9	45.7 ± 8.0
Rafols (2018)	Multicenter	Mar 2002–Jan 2017	R	905	191	741 (82)	171 (90)	37.2 ± 10.1	40.6 ± 11.2	44.3 ± 6.7	44.3 ± 6.8	40.3 ± 6.9	39.8 ± 6.9
Almalki (2018)	Taiwan	May 2001–Dec 2015	R	35	81	12 (34)	21 (26)	39.7 ± 10.8	38.7 ± 9.8	NA	NA	37.1 ± 8.4	37.8 ± 9.6
Chansaenroj (2017)	Taiwan	May 2002–Apr 2011	R	9	26	7 (78)	16 (62)	40.6 ± 11.5	35.9 ± 8.8	38.8 ± 10.0	39.9 ± 10.5	36.9 ± 6.8	39.3 ± 8.9
Salama (2016)	Egypt	Dec 2013–Dec 2015	P	21	39	48 (80)		38.7		NA	NA	39.8 ± 8.2	

All data expressed in mean ± SD unless otherwise specified

P prospective; *R* retrospective; *RCT* randomized controlled trial; *RYGB* Roux-en-Y gastric bypass; *OAGB* one anastomosis gastric bypass; *BMI* body mass index

Table 5 Studies comparing revisional RYGB versus OAGB—outcomes after revisional surgery

Study ID (year)	Operating time, minutes		Length of stay, days		Morbidity, n (%)		Mortality, n (%)		%EWL/%EBMIL/ΔBMI at 1 year		Metabolic syndrome resolution, n (%)	
	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB	RYGB	OAGB
Chiappetta (2019)	98.2 ± 24.3	78.7 ± 35.7	5	5	5 (23.8) 2 anastomotic ulcer 1 anastomotic stenosis 1 pancreatitis 1 GERD	12 (35.2) 6 anastomotic ulcers 4 GERD 2 biliary reflux	0	0	22 ± 18	29 ± 13	5/16 (31)	21/29 (72)
Rafols (2018)	NA	NA	NA	NA	117 (12.9) 35 anastomotic leaks 36 major bleeding 46 not mentioned	9 (4.7) 5 anastomotic leaks 1 major bleeding 3 not mentioned	5 (0.5)	1 (0.5)	%EBMIL 66.6 (30.4)	74.7 (28.9)	NA	NA
Almalki (2018)	218.3 ± 44.5	167.7 ± 55.8	2.9 ± 0.8	4.0 ± 1.9	3 (8.6) 1 anastomotic leak 1 bowel obstruction 1 respiratory failure	9 (11.1) 5 anastomotic leaks 2 bowel obstruction 1 major bleeding 1 respiratory failure	0	1 (1)	32.9 ± 35.1	76.8 ± 57.1	13/14 (93)	28/31 (90)
Chansaenroj (2017)	218.9 ± 48.1	180.2 ± 58.7	7.1 ± 5.6	5.7 ± 11.4	1 (11.1) 1 small bowel ileus	5 (19.2) 2 anastomotic leaks 2 small bowel ileus 1 major bleeding	0	0	54.5 ± 23.5	73.6 ± 25.2	2/2 (100)	15/16 (94)
Salama (2016)	185.2 ± 57.8	145.4 ± 29.2	6.3 ± 0.7	4.8 ± 2.2	2 (9.5) 1 anastomotic stenosis 1 internal herniation	1 (2.0) 1 small bowel perforation	0	0	ΔBMI = 9.9	ΔBMI = 9.7	NA	NA

All data expressed in mean ± SD unless otherwise specified

%EWL percentage excess body weight loss; *%EBMIL* percentage excess BMI loss; *ΔBMI* change in body mass index

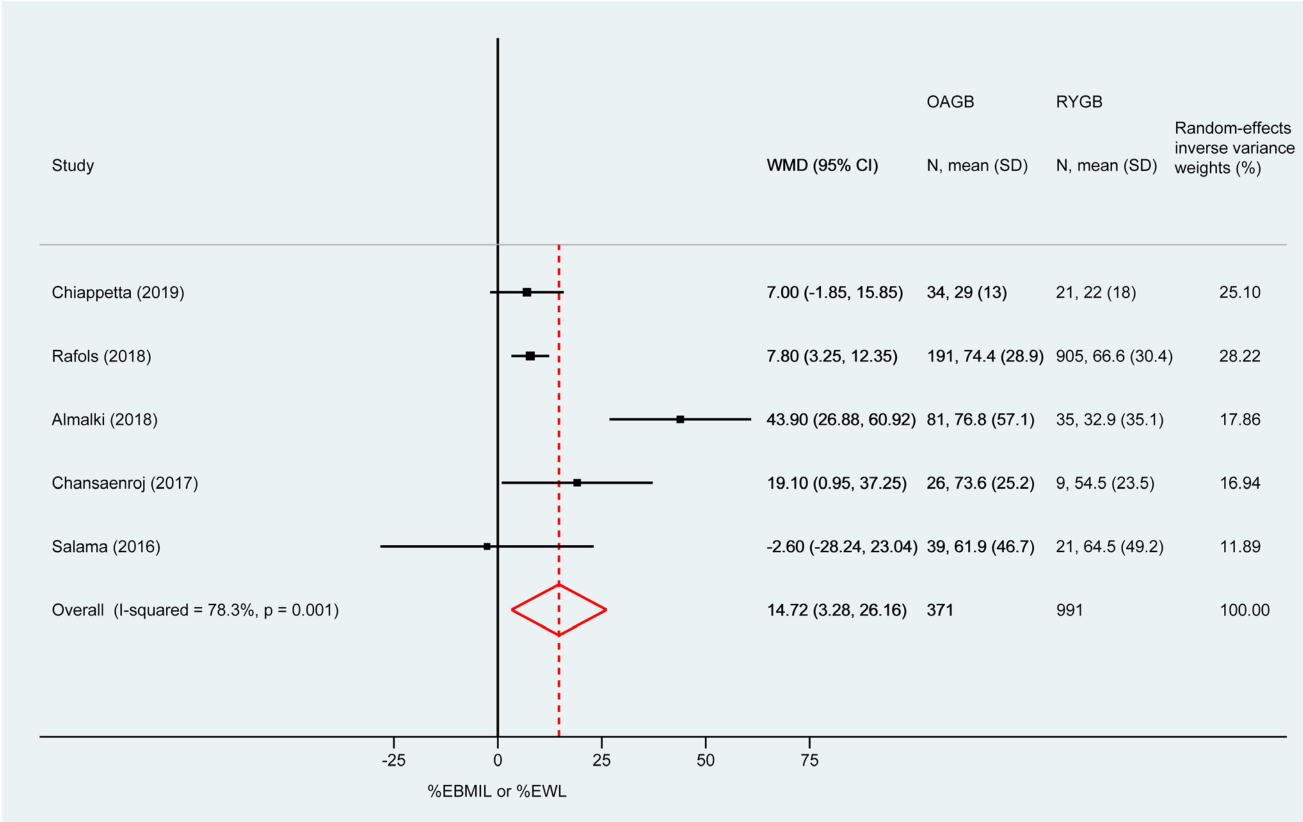


Fig. 4 Comparison of percentage excess weight/BMI loss after revisional OAGB versus revisional RYGB

position statement [18]. Several metaanalyses and randomized controlled trials have demonstrated higher %EWL and increased incidence of comorbidity resolution in patients who underwent OAGB when compared to RYGB [13–15, 17, 57]. However, the data on OAGB as a revisional procedure remains scarce. Recent evidence has shown that rOAGB achieves outcomes comparable to rRYGB with a comparatively more straightforward operative technique [29, 30]. To the authors' knowledge, this is the first metaanalysis evaluating the effects of rOAGB in comparison to rRYGB.

Our study demonstrates that rOAGB results in sustained weight loss up to 60 months postsurgery, with peak %EWL at the 48-month mark. When comparing rOAGB versus rRYGB, the former also demonstrated a higher percentage of excess weight loss. This is comparable to other metaanalyses evaluating primary OAGB versus RYGB, which have also shown better weight loss in the OAGB group [13, 15]. However, the YOMEGA trial by Robert et al. [17] comparing primary OAGB versus RYGB did not reveal any significant differences in weight loss. The biliopancreatic limb length in our included studies ranged from 150 to 250 cm, with 200 cm being the most commonly used length (which was also the length utilized in the YOMEGA trial). Prior studies comparing different biliopancreatic limb lengths in OAGB did not show any difference in weight loss between the standard 200 cm versus a longer limb length [58, 59].

In terms of comorbidity resolution, we demonstrate that rOAGB can result in DM, HTN, HLD, and OSA resolution of 74.9%, 48.4%, 63.2%, and 75.7% respectively. These results are also comparable to rRYGB. Previous metaanalyses by Jia et al. [13] and Magouliotis et al. [29] demonstrate that the incidence of DM resolution is higher in primary RYGB as compared to OAGB. This has been postulated to be secondary to the significant malabsorptive effects of OAGB.

Operating time was shorter in rOAGB than rRYGB in all comparative studies. The length of stay was comparable to rRYGB. The main significant complications after any bariatric surgery procedure include bleeding and leaks, and the incidences of these morbidities were shown to be acceptable for rOAGB in this present study, and also comparable to that of rRYGB. Incidence of mortality was also low.

The current controversies existing around the OAGB procedure are the risks of postoperative malnutrition and biliary reflux, of which the latter subsequently increases the risk of dysplastic modification of esophageal and gastric mucosa potentially leading to malignant transformation [17]. The metaanalyses by Magouliotis et al. [15] demonstrated a higher incidence of postoperative malnutrition after OAGB compared to RYGB, but this was mainly observed in cases where the biliopancreatic limb length was > 230 cm. The study by Robert et al. [17] published in The Lancet also showed that 16% of patients in the OAGB group had bile exposure in the stomach after 2 years. In this study, the data regarding biliary reflux postrOAGB is varied. Some studies describe the resolution of reflux disease after conversion of a restrictive index surgery to OAGB, whereas others describe de novo emergence of reflux disease. However, the incidence of severe biliary reflux requiring conversion to RYGB was also low, and only reported in 2 studies [35, 36]. There were also no reported esophageal or gastric malignancies. With regard to postoperative nutritional deficiencies, the majority of the included studies did not state the incidence of malnutrition after rOAGB, and hence was not included in this review. Future long-term studies will need to be conducted to evaluate the consequences of biliary exposure, and further characterize the extent of nutritional deficiency.

Some limitations of this metaanalysis include the heterogeneity of the studies included with respect to surgical technique. The different bougie sizes used and wide variation in biliopancreatic limb lengths may affect the weight loss postsurgery. Additionally, the number of direct comparative studies between rOAGB and rRYGB are few. Thus, we propose that more randomized controlled trials comparing rOAGB and rRYGB be conducted so that the choice between the two malabsorptive procedures is more certain. These trials should also have longer follow-up durations to determine the long-term outcomes of rOAGB as compared to rRYGB, in terms of the evaluation of weight regain, biliary reflux, and nutritional deficiencies.

Conclusion

This is the first metaanalysis evaluating the outcomes of rOAGB in comparison to rRYGB, and demonstrates that OAGB has potential as an alternative revisional surgery, with weight loss profiles and rates of metabolic syndrome resolution that are comparable to rRYGB. These are also achieved while having shorter operative times, due to a less technically demanding surgical technique. However, further long-term studies are still required to evaluate the incidence of weight regain, nutritional deficiencies, as well as the impact of biliary reflux.

Authors' Contributions All authors have contributed to this study.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was not required for this study.

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