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REVIEW

Does One-Anastomosis Gastric Bypass Expose Patients to Gastroesophageal Reflux: a Systematic Review and Meta-analysis

Ali Esparham[1] · Soheil Ahmadyar[1] · Tooraj Zandbaf[2] · Amin Dalili[3] · Alireza Rezapanah[3] · Robert Rutledge[4] · Zhamak Khorgami[5,6]

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Abstract

This systematic review and meta-analysis aimed to investigate the incidence of new-onset gastroesophageal reflux, reflux change, esophagitis, Barrett's esophagus, and revision due to reflux, gastritis, and marginal ulcer after one-anastomosis gastric bypass (OAGB). We performed subgroup analyses based on primary and revisional OAGB and time of follow-up. Meta-analysis of 87 studies with 27,775 patients showed a 6% rate of new-onset reflux after OAGB. Preoperative reflux status did not change significantly after OAGB. The rate of esophagitis and Barrett's esophagus was 15% and 1%, respectively. The new-onset reflux rate after OAGB was significantly higher than gastric bypass but not different with sleeve gastrectomy. The current study showed a relatively low rate of reflux and its complications after OAGB, but it was significantly higher than Roux-en-Y gastric bypass.

Keywords Esophagitis · Gastroesophageal reflux · Reflux · One-anastomosis gastric bypass · Mini gastric bypass · GERD · Barrett's esophagus · Marginal ulcer

Key Points
- The current study showed a relatively low rate of gastroesophageal reflux and its complications after OAGB.
- OAGB had a significantly higher rate of new-onset reflux than Roux-en-Y gastric bypass.
- Studies with sample sizes > 500 had a 3% rate of new-onset reflux versus 7% for studies with lower sample sizes.

✉ Zhamak Khorgami
zhamak-khorgami@ouhsc.edu

1 Student Research Committee, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

2 Department of General Surgery, Faculty of Medicine, Mashhad Medical Sciences, Islamic Azad University, Mashhad, Iran

3 Department of General Surgery, School of Medicine, Surgical Oncology Research Center, Imam Reza Hospital, Mashhad University of Medical Sciences, Mashhad, Iran

4 Center for Laparoscopic Obesity Surgery, 6240 N Durango Dr STE 120, Las Vegas, NV 89149, USA

5 Department of Surgery, University of Oklahoma School of Community Medicine, 1919 S. Wheeling Avenue, Suite 600, Tulsa, OK 74104-5638, USA

6 Harold Hamm Diabetes Center, University of Oklahoma Health Sciences Center, Oklahoma City, OK, USA

Introduction

One-anastomosis gastric bypass (OAGB) is the third most common bariatric procedure globally after sleeve gastrectomy and Roux-en-Y gastric bypass (RYGB) [1]. OAGB was first mentioned by Rutledge et al. in 1997 as a modified type of standard RYGB [2]. OAGB has several advantages leading to advocacy for its wider adoption including a shorter learning curve, technical simplicity, the possibility of conversion to another bariatric type, and good weight loss and resolution rate of obesity-related comorbidities [3]. Due to promising results and low risk of complications, the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) and the American Society for Metabolic & Bariatric Surgery (ASMBS) have endorsed OAGB as a bariatric/metabolic procedure [4].

However, there is still some concern about post-OAGB reflux and other complications such as esophagitis, Barrett's esophagus, and its association with adenocarcinoma, gastritis, and marginal ulcer after OAGB [5–9]. In addition, the incidence of reflux and its complications were reported in a wide range after OAGB. One group of studies reported a high rate of reflux up to 28% [10–12]. On the other hand, some studies showed a low rate of reflux and its consequences after OAGB [13–15]. Also, the effect of primary

or revisional surgery on the incidence of reflux and its complications is not clear yet. The current systematic review and meta-analysis aimed to investigate the incidence of new-onset gastroesophageal reflux, reflux change after OAGB, marginal ulcer, esophagitis, Barrett's esophagus, gastritis, and revision due to reflux after OAGB. Furthermore, the incidence of new-onset reflux was compared between OAGB and two other weight loss surgeries, sleeve gastrectomy and RYGB.

Methods

Search Strategy

Relevant studies were identified by conducting a comprehensive search by using Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines until Jan 15, 2023. PubMed, Embase, Web of Science, and Scopus databases were searched by using the following keywords: ("One anastomosis gastric bypass" OR "OAGB" OR "Single-anastomosis gastric bypass" OR "Single anastomosis gastric bypass" OR "Mini gastric bypass" OR "MGB" OR "omega loop gastric bypass" OR "loop gastric bypass") AND ("bile reflux" OR "Reflux" OR "gastroesophageal reflux" OR "GERD" OR "Barrett" OR "Barrett's" OR "Barretts"). Also, a manual search was done by assessing the references of related articles. There was no published year or language limit for the search process.

Inclusion and Exclusion Criteria

For initial inclusion, we included all the observational (retrospective and prospective) and randomized controlled trial (RCT) studies reporting the incidence of new-onset reflux, reflux change, marginal ulcer, esophagitis, Barrett's esophagus, gastritis, or revision due to reflux after OAGB. Exclusion criteria were non-English studies, abstracts, conference abstracts, editorial letters, case studies, reviews, and meta-analyses. Studies with patients under 18 years of age were also excluded.

Study Selection

Literature search and study selection have been evaluated independently by two authors (AE and TZ) which were blinded to each other's evaluation. After removing the duplicated studies, titles and abstracts were fully screened if they met the eligibility criteria. In addition, a third reviewer (ZK) resolved any kind of disagreement by discussion and consensus.

Quality Assessment

The quality assessment process was performed by two independent reviewers (AE and SA), and any discrepancies were solved by further discussion with the third reviewer (ZK). For the assessment of the quality of studies, the Joanna Briggs Institute (JBI) quality score (maximum score of 13) was used for the RCT studies. Also, the National Institutes of Health quality assessment tool for before-after studies (maximum score of 12) was used for the quality assessment of observational studies [16]. The quality scores are reported in Table 1.

Data Extraction and Subgroup Analysis

Two independent reviewers (AE and TZ) extracted the related data. The extracted data included author, year, country, study design, age, gender, sample size, time of follow-up, preoperative body mass index (BMI), type of surgery (primary or revision), previous bariatric surgery (in case of revisional surgery), surgery technique (size of bougie, length of biliopancreatic (BP) limb, pouch size, and concurrent anti-reflux procedures), postoperative PPI prescription, method of reflux detection, the incidence of new-onset reflux, reflux change, marginal ulcer, esophagitis (Los Angeles (LA) grade of esophagitis), Barrett's esophagus, gastritis, and revision due to reflux. In addition, subgroup analyses were performed based on time of follow-up (shorter or longer than 5 years), design of the study (observational or RCT), and type of OAGB (as primary or revisional surgery).

Statistical Analysis

Stata Software version 17 (Stata Corp LCC, TX) was used for statistical analysis. The heterogeneity was calculated with I^2, in which I^2 lower than 50% shows non-severe heterogeneous variables and I^2 more than 50% presents severe heterogeneous variables. Fixed and random effect analyses were used for the meta-analysis of non-severe and severe heterogeneous variables, respectively. The incidence rate was presented with a 95% confidence interval (CI). A *P*-value lower than 0.05 is considered significant. A random effects meta-regression model was performed to find any association between sample size, age, preoperative BMI, size of bougie, and length of the BP limb with the main variables.

Publication Bias

To minimize the impact of publication bias on the results of our meta-analyses, we conducted a comprehensive assessment using a range of established statistical methods. Specifically,

Table 1 General characteristics of included studies

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Zarshenas et al. [17]	Australia	Retrospective	45	24	29 R, 16 P	AGB	52.7 ± 11.3	47.1 ± 8	De novo reflux	Clinical symptoms	5
Wilczyński et al. [18]	Poland	Retrospective	47	60	R	SG	45 ± 10.7	40.4 ± 5.8	De novo reflux, pre- and postoperative reflux, esophagitis, marginal ulcer	Endoscopy, clinical	8
Tolone et al. [19]	Italy	Prospective	22	12 and 60	P	NA	39.2 ± 7.5	47.8	De novo reflux, esophagitis	Endoscopy, clinical symptoms, reflux questionnaire score, high-resolution impedance manometry, and impedance-pH monitoring	7
Tasdighi et al. [20]	Iran	Retrospective	154 and 55	36	P	NA	41.42 ± 11.0 and 37.7 ± 10.2	54.9 ± 4.8 and 55.1 ± 4.3	De novo reflux, marginal ulcer	NR	6
Szymańskiet al. [21]	Poland	Retrospective	50	24	P	NA	47.9 ± 8.19	43.7 ± 5.5	Esophagitis, Barrett's esophagus	Endoscopy, biopsy, and questionnaire	7
Soprani e al. [22]	France	Retrospective	2046	60	P	NA	39.7 ± 66.7	42.6 ± 6.9	De novo reflux, marginal ulcer, esophagitis, Barrett's esophagus, revision	Endoscopy, clinical symptoms	5

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Soprani et al. [22]	France	Retrospective	1000	60	R	AGB	40.3 ± 66.3	41.3 ± 7	De novo reflux, marginal ulcer, esophagitis, Barrett's esophagus, revision	Endoscopy, clinical symptoms	5
Sohrabi Maralani et al. [23]	Iran	Retrospective	805	60	P	NA	39.73 ± 11.50	44.79 ± 6.07	De novo reflux, pre- and postoperative reflux, marginal ulcer, revision, gastritis	Clinical symptoms	6
Slagter et al. [24]	The Netherlands	Retrospective	289	36	P	NA	48 ± 11	42	De novo reflux, pre- and postoperative reflux, marginal ulcer, esophagitis, Barrett's esophagus, revision	Endoscopy, clinical symptoms	8
Slagter et al., anti-reflux technique [24]	The Netherlands	Retrospective	289	36	P	NA	48 ± 11	43	De novo reflux, pre- and postoperative reflux, marginal ulcer, esophagitis, Barrett's esophagus, revision	Endoscopy, clinical symptoms	8
Shivakumar et al. [25]	India	RCT	101	36	P	NA	42.89 ± 14.02	44.32 ± 7.88	De novo reflux, marginal ulcer, revision	Not reported	9 *

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Shenouda et al. [26]	Egypt	Prospective	20	6	P	NA	34 ± 1.5	47	Gastritis, esophagitis, Barrett's esophagus	Clinical symptoms, endoscopy, questionnaire	7
Schmitz et al. [27]	Germany	Retrospective	150	36	P	NA	39.11 ± 0.9	64.14 ± 0.3	De novo reflux, marginal ulcer, revision	Not reported	4
Salama and Hassan [28]	Egypt	Prospective	50	12	P	NA	35.5	NA	Gastritis, esophagitis, Barrett's esophagus	Endoscopy, pH-metry	6
Maurice et al. [29]	Australia	Retrospective	254	48	R	AGB, SG	47.6	43.6	Revision	Questionnaire	7
Almuhanna et al. [30]	Taiwan	Retrospective	2223	1–18 years	P	NA	35.3 ± 11.4	40.2 ± 11.9	Marginal ulcer, revision	NR	5
Robert et al. [31]	France	RCT	117	24	P	NA	44.4 ± 11.4	43.8 ± 6.1	De novo reflux, marginal ulcer, gastritis, esophagitis, Barrett's esophagus	Clinical symptoms, questionnaire	9*
Rheinwalt et al. [32]	Germany	Retrospective	55	24	R	SG	42 ± 1.3	45.5 ± 1.0	De novo reflux, pre- and postoperative reflux	Clinical symptoms	7
Rayman et al. [33]	Israel	Retrospective	144	Median: 29 (range 7–78)	R	SG	42.4 ± 10.5	47.2 ± 6.6	Pre- and postoperative reflux	Clinical symptoms and endoscopic or fluoroscopic	8
Plamper et al. [34]	Germany	Retrospective	911	25	P	NA	42 ± 11	50.97 ± 7.31	De novo reflux, marginal ulcer, revision	Clinical symptoms	5

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Pizza et al. [35]	Italy	Retrospective	60	24	P	NA	35.2 ± 9	44 ± 6	Marginal ulcer, gastritis, esophagitis, Barrett's esophagus, revision	Endoscopy	8
Pizza et al. [35]	Italy	Retrospective	60	24	P	NA	34.2 ± 9	43 ± 5	Marginal ulcer, gastritis, esophagitis, Barrett's esophagus, revision	Endoscopy	8
Pizza et al. [35]	Italy	Retrospective	60	24	P	NA	34.2 ± 9	44 ± 5	Marginal ulcer, gastritis, esophagitis, Barrett's esophagus, revision	Endoscopy	8
Petrucciani et al. [12]	Italy, France	Retrospective	215	84	R	AGB	43.2 ± 10.5	44.4 ± 6.4	De novo reflux, marginal ulcer, revision	Clinical symptoms	5
Parmar et al. [36]	UK	Retrospective	125	11.4	P and R	1 SG, 13 balloon insertions	45	48.1	De novo reflux, pre- and postoperative reflux, marginal ulcer, revision	Clinical symptoms	6
Ospanov et al. [37]	Kazakhstan	RCT	40	24	P	NA	NA	41.18 ± 6.36	De novo reflux, marginal ulcer, gastritis, revision	Clinical symptoms, endoscopy	10*
Noun et al. [38]	Lebanon	Retrospective	923	60	P	NA	32.77±10	42.50±6.39	De novo reflux, marginal ulcer	Clinical symptoms, endoscopy	6
Noun et al. [38]	Lebanon	Retrospective	77	60	R	VBG (n = 32) and gastric banding (n = 45)	37.55 ± 10	41.25 ± 8.34	De novo reflux, marginal ulcer	Clinical symptoms, endoscopy	6

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Mustafa et al. [39]	UK	Retrospective	198	24	P	NA	44.5 ± 11.8	48.8 ± 7.8	De novo reflux, marginal ulcer, revision	Clinical symptoms	7
Musella et al. [40]	Italy	Retrospective	300	20.8	R	104 SG and 196 AGB	46.1 ± 10.5	41.8 ± 6.3	De novo reflux, pre- and postoperative reflux	Clinical symptoms	7
Musella et al. [41]	Italy	Retrospective	2678	5 and 10 years	2251 P, 427 R	NR	42.2 ± 3.8	45.39 ± 3.63	De novo reflux, pre- and postoperative reflux, marginal ulcer, revision	Clinical symptoms, questionnaire, endoscopy, high-resolution impedance manometry	8
Mahdy et al. [42]	United Arab Emirates	Retrospective	91	12	P	NA	38.4 ± 11.6	44.8 ± 7.7	Pre- and postoperative reflux	Clinical symptoms, endoscopy	7
Liagre et al. [43]	France	Retrospective	245	80	P	NA	39.7 ± 13.2	54 ± 4.9	Marginal ulcer, gastritis, esophagitis, Barrett's esophagus, revision, hiatus hernia, pre- and postoperative reflux	Clinical symptoms	6
Level et al. [44]	Venezuela	RCT	9	60	P	NA	37.5 ± 6.6	42.9 ± 5.5	De novo reflux, pre- and postoperative reflux	Clinical symptoms, endoscopy	8*
Kular et al. [13]	India	Retrospective	1054	72	P	NA	38.4 ± 9.6	43.2 ± 7.4	De novo reflux, pre- and postoperative reflux	Clinical symptoms	6

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Kermansaravi et al. [45]	Iran	Prospective	192	12	P	NA	41.0	NR	De novo reflux, pre- and postoperative reflux, revision	Clinical symptoms, questionnaire	10
Kermansaravi et al. [46]	Iran	Retrospective	23	60	R	SG	42.4 ± 9.4	46.3 ± 10.4	De novo reflux, pre- and postoperative reflux	Clinical symptoms, questionnaire, endoscopy	8
Katayama et al. [47]	Brazil	RCT	10	6	P	NA	39.5 ± 7.0	43.2 ± 3.7	Quality of life (which questionnaire), esophagitis	Clinical symptoms, endoscopy, biopsy	10*
Kassir et al. [48]	France	Prospective	23	36	P and R	NR	35	44.84	De novo reflux, revision	Not reported	5
Kansou et al. [49]	France	Retrospective	136	12	P	NA	41.2 ± 11.3	42.8 + 5	Marginal ulcer	Not reported	6
Jammu and Sharma [50]	India	Retrospective	473	53.5	P	NA	46.5	56.5 (range 40–73)	Marginal ulcer, de novo reflux	Not reported	5
Doulami et al. [51]	Greece	Prospective	11	12	P	NA	39.2	46.04	De novo reflux, pre- and postoperative reflux, Barrett's esophagitis, pH-metry	Clinical symptoms, pH-metry	9
Hussain et al. [52]	UK	Retrospective	527	36	519 P and 7 R	SG	44	48 + 8.01	Marginal ulcer, revision, de novo reflux	NR	6
Hany et al. [15]	Egypt	RCT	80	12	R	SG	42.6 ± 7.1	45.1 ± 8.3	De novo reflux, pre- and postoperative reflux, marginal ulcer, manometry	Clinical symptoms, endoscopy	10*

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Haggag et al. [53]	Egypt	Retrospective	40	36	P	NA	44.5	54.1	Quality of life esophagitis, de novo reflux	Clinical symptoms, duodenogastric biliary reflux monitoring, pH monitoring, endoscopy	7
Gricks et al. [54]	Australia	Retrospective	325	12	304 P, 21 R	SG, AGB	44	42	Marginal ulcer, revision	Endoscopy	7
Gholizadeh et al. [55]	Iran	Retrospective	61	60	P	NA	67.6 ± 2.03	46.42 ± 5.46	De novo reflux, pre- and postoperative reflux, margin ulcer	Clinical symptoms	5
Genco et al. [56]	Italy	Prospective	48	39	P	NA	NR	45.2 ± 6.9	Esophagitis, pre- and postoperative reflux, revision	Clinical symptoms, endoscopy, questionnaire	8
Felsenreich et al. [11]	Austria	Retrospective	50	44	P	NA	43.1	43.7 ± 4.8	De novo reflux, pre- and postoperative reflux	Clinical symptoms, questionnaire, 3D-CT volumetry	8
Fahmy et al. [57]	Egypt	Prospective	30	12	P	NA	31.3	45.5	De novo reflux, pre- and postoperative reflux, gastritis, esophagitis	Endoscopy, clinical symptoms	8
Felsenreich et al. [58]	Austria	Retrospective	13	64	R	SG	43.1 ± 8.9	45.0 ± 7.3	Esophagitis, Barrett's esophagus, revision	Endoscopy, esophageal manometry, pH-metry, questionnaires	6

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Eskandaros [59]	Egypt	Retrospective	214	24	P	NA	38.6 + 10.1	55.5 + 2.9	De novo reflux, pre- and postoperative reflux, marginal ulcer	pH monitoring	8
Elmahdy et al. [60]	Egypt	Prospective	40	24	R	SG	28.2 ± 7.2	NR	Gastritis	NR	5
Eldredge et al. [61]	Australia	Prospective	20	6	P	NA	41.8	45.7	Gastritis, esophagitis	Endoscopy, gastric fluid aspiration for bilirubin analysis, biliary scintigraphy, questionnaires	7
Debs et al. [62]	France	Retrospective	77	60	R	SG	45.3 ± 14.8	40.1	De novo reflux, pre- and postoperative reflux, revision	Clinical symptoms	6
de la Cruz et al. [10]	Germany	Retrospective	42	36	R	SG	47.2 ± 10.8	43.4 ± 9.2	De novo reflux, pre- and postoperative reflux, marginal ulcer	Clinical symptoms	6
Chiappetta et al. [63]	Germany	Retrospective	34	12	R	SG	46.8 ± 11.5	45.7 ± 8	De novo reflux, pre- and postoperative reflux, marginal ulcer,	Clinical symptoms, questionnaire	7
Chevallier et al. [64]	France	Retrospective	1000	26.3	P and 177R	11 VBG, 125 AGB, 41 SG	41.8	45.7	Revision, de novo reflux	Clinical symptoms	5

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Charalampos et al. [65]	Greece	Retrospective	94	36	P	NA	41.5 ± 10.7	49.2 ± 7.3	De novo reflux, pre- and postoperative reflux, marginal ulcer	Clinical symptoms	7
Chakhtoura et al. [66]	France	Retrospective	100	12	P and R	20 AGB, 4 VBG	40.9 ± 11.5	46.9 ± 7.4	De novo reflux	NR	5
Carbajo et al. [14]	Spain	Retrospective	1200	6–12 years	P and 27 R	13 AGB, 14VBG	43	46	De novo reflux, gastritis, pre- and postoperative reflux, marginal ulcer	Clinical symptoms, endoscopy, questionnaire	8
Carandina et al. [67]	France	Retrospective	385	10 and 15 years	P and R	185 AGB, 5 SG	43.2 ± 9.7	44.3 ± 6.7	Marginal ulcer, de novo reflux revision	Clinical symptoms	6
Di Capua et al. [68]	Italy	Retrospective	98	27	R	SG, AGB, laparoscopic gastric plication	48 ± 8	36 ± 8	Pre- and postoperative reflux, marginal ulcer, esophagitis, revision	Clinical symptoms, endoscopy	7
Cantay et al. [69]	Turkey	Retrospective	96	12	P and 56 R	NR	42.7 ± 10.9	45.2 ± 5.5	De novo reflux	NR	5
Bruzzi et al. [70]	France	Retrospective	126	60	P and R	22AGB, 4 VBG, 4 SG	50 ± 10	47 ± 8	De novo reflux, marginal ulcer, revision	NR	7
Bertrand et al. [71]	France	Retrospective	392	44.87	P and R	67 AGB, 2 Mason gastroplasty, 18 SG	44 ± 11.2	43 ± 3.6	De novo reflux, marginal ulcer, revision	NR	6
Apers et al. [72]	Netherlands	Retrospective	287	36	P	NA	44	42.7	De novo reflux, revision	Clinical symptoms	7

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Abdallah et al. [73]	Egypt	Retrospective	40	12	P	NA	43.8± 10.6	52.2± 11.9	De novo reflux	Clinical symptoms	5
Sneineh et al. [74]	Belgium	Retrospective	264	24	NR	NR	48 ± 19	NA	De novo reflux, pre- and postoperative reflux	Clinical symptoms	5
Keleidari et al. [75]	Iran	Prospective	64	12	P	NA	34.1 ± 11.3	41.73 ± 2.65	De novo reflux	Endoscopy, biopsy	8
Poghosyan et al. [76]	France	Retrospective	72	63	R	SG	47 ± 10	43.6 ± 7	De novo reflux, marginal ulcer, revision	Clinical symptoms	4
Rheinwalt et al. [77]	Germany	Retrospective	324	36	P	NA	42.5 ± 11.4	53.75 ± 6.51	Marginal ulcer, de novo reflux	NR	6
Neuberg et al. [78]	France	Retrospective	63	8 years	P	NA	41 ± 11.4	43.56	De novo reflux, revision	NR	6
Saarinen et al. [79]	Finland	RCT	40	6	P	NA	44.4	45.2	Marginal ulcer, gastritis, esophagitis, de novo reflux, pre- and postoperative reflux	Clinical symptoms, endoscopy, scintigraphy	8*
Jamal et al. [80]	Kuwait	Retrospective	56	12	R	SG	37.6	41.9 ± 7.9	Marginal ulcer	Clinical symptoms	4
Poublon et al. [81]	Netherlands	Retrospective	185	36	R	65 SG and 120 AGB	46 ± 9.0	40.9	Marginal ulcer, de novo reflux, pre- and postoperative reflux	NR	6
Kraljević et al. [82]	Switzerland	Retrospective	12	36	R	SG	45.2 ± 10.1	40.2	Revision	Endoscopy	6
Bashah et al. 2020 [83]	Qatar	Retrospective	49	3.8 ± 1.4	R	SG	37.8 ± 9.4	43.6 ± 7.4	De novo reflux, marginal ulcer, revision	Clinical symptoms	5

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Hussain et al. [84]	UK	Retrospective	925	30	913 P and 12 R	AGB and SG	44 + 11.2	48 + 7.37	De novo reflux, revision	NR	7
Olmi et al. 2019 [85]	Italy	Retrospective	50	24	50 R	SG	40	41	De novo reflux, marginal ulcer, esophagitis	Questionnaire, endoscopy, clinical symptoms	8
Acar et al. [86]	Turkey	Retrospective	120	24	P	NA	48.5 ± 15	47 ± 7	Marginal ulcer, de novo reflux revision	NR	7
ElAbd et al. [87]	Kuwait	Retrospective	40	31 ± 12.3	P	NA	40 ± 10.4	43.7 + 7.7	De novo reflux	Endoscopy, clinical symptoms	7
Fetouh et al. [88]	Egypt	Retrospective	60	36	P	NA	33.5 ± 8.14	53.29 ± 6.91	Gastritis	Endoscopy, clinical symptoms	5
Goel et al. [89]	India	Retrospective	3187	NA	3143 P, 44 R	NR	43.3 ± 12.2	44.85 ± 7.87	De novo reflux, marginal ulcer	NR	4
Mahfouz et al. [90]	Egypt	Prospective	25	12	R	SG	32.4 ± 3.4	34.1 ± 3.7	Pre- and postoperative reflux	Clinical symptoms	7
Zakaria and Elhoofy [91]	Egypt	Retrospective	310	24	P	NA	NA	49.3 ± 9.9	De novo reflux, revision	NR	5
Soong et al. [92]	Taiwan	Retrospective	246	60	P	NA	31.9	56.2	De novo reflux, revision, marginal ulcer, esophagitis	Clinical symptoms, endoscopy	7
Nevo et al. [93]	Israel	Retrospective	31	21	R	VBG	43.2 ± 12.1	39.7 ± 5.9	De novo reflux	NR	4
Winstanley et al. [94]	UK	Retrospective	89	25	P	NA	46 ± 12.1	47.89 ± 8.10	Marginal ulcer, pre- and postoperative reflux, revision,	Clinical symptoms	7
Lee et al. [95]	China	RCT	40	24	P	NA	30.7	44.8	Marginal ulcer	Questionnaire	9*

Table 1 (continued)

Author	Country	Study design	Sample size	Follow-up (months)	Type of surgery	Previous surgery	Age (year)	BMI (kg/m^2)	Reported variables	Method of detection	Quality score
Taha et al. [96]	Egypt	Prospective	243	24	R	AGB, VBG, SG	38.7	37.8	De novo reflux, revision	Questionnaire, clinical symptoms	8
ElGohary et al. [97]	Egypt	Prospective	31	12	P	NA	39.1 ± 10.9	45.88 ± 6.26	Revision, de novo reflux	Clinical symptoms, endoscopy	8

Age and BMI reported as mean ± standard deviation

NA not applicable, *P* primary, *R* revision, *NR* not reported, *AGB* laparoscopic adjustable gastric banding, *VBG* vertical banded gastroplasty, *SG* sleeve gastrectomy, *RCT* randomized controlled trial

*JBI quality score was used for RCT studies (maximum score of 13). Also, the National Institutes of Health quality assessment tool for before-after studies was used for observational studies (maximum score of 12)

we employed funnel plots, Egger's linear regression test, and trim and fill analysis for each of the outcomes examined, including new-onset reflux, reflux change, marginal ulcer, esophagitis, Barrett's esophagus, gastritis, and revision due to reflux. Funnel plots were used for detecting any asymmetry in the plot suggesting potential publication bias. Also, Egger's linear regression test estimates the degree of funnel plot asymmetry using a regression model. In the case of identified funnel plot asymmetry, we employed trim and fill analysis. This method identifies potentially missing studies and imputes their effect sizes, enabling us to estimate the impact of these studies on the overall meta-analysis results.

Results

Study Characteristics

The systematic search of PubMed, Scopus, Embase, and Web of Science databases results in 1330 articles. After removing 616 duplicated articles, 718 remaining articles were assessed by title and abstract, and 568 articles were excluded per study protocol. The remaining 150 articles were reviewed in full text, and 87 articles met the inclusion criteria and were included in the final analysis. A total of 64, 15, and 8 studies were retrospective, prospective, and RCT, respectively. A total of 27,775 patients who underwent OAGB were included in this study. Figure 1 shows the PRISMA flowchart. The general characteristics and surgical techniques of the included studies are summarized in Table 1 and supplementary table 1, respectively. In addition, Table 2 presents the results of the pooled analysis in total and subgroups after OAGB.

New-Onset Reflux (De Novo Reflux)

Pooled random effects analysis of 70 articles showed a 6% rate of new-onset reflux after OAGB (95% CI 4–8%, I^2 = 94.9%, $P < 0.001$) (Fig. 2) [10, 12–15, 17–20, 22–25, 27, 31, 34, 36–41, 44–46, 48, 50, 52, 53, 55, 58, 59, 62–67, 69–74, 76–79, 81, 83, 85–87, 89, 91–93, 96–98]. In addition, subgroup analysis of studies based on types of surgery showed OAGB as primary and revisional surgery resulted in 4% (95% CI 3–6%, I^2 = 91.1%, and $P < 0.001$) and 10% (95% CI 8–13%, I^2 = 75%, $P < 0.001$) rate of new-onset reflux, respectively (Supplementary Figure 1 and 2).

Change in Reflux Before and After Surgery

Twenty-nine articles reported pre- and postoperative reflux [10, 11, 13–15, 18, 23, 24, 32, 33, 36, 41–46, 51, 55–57, 62, 63, 74, 79, 81, 90]. The results showed that reflux change was insignificant in patients who underwent OAGB (OR = 0.59, 95% CI 0.28–1.26, I^2 = 96.6%, $P = 0.17$)

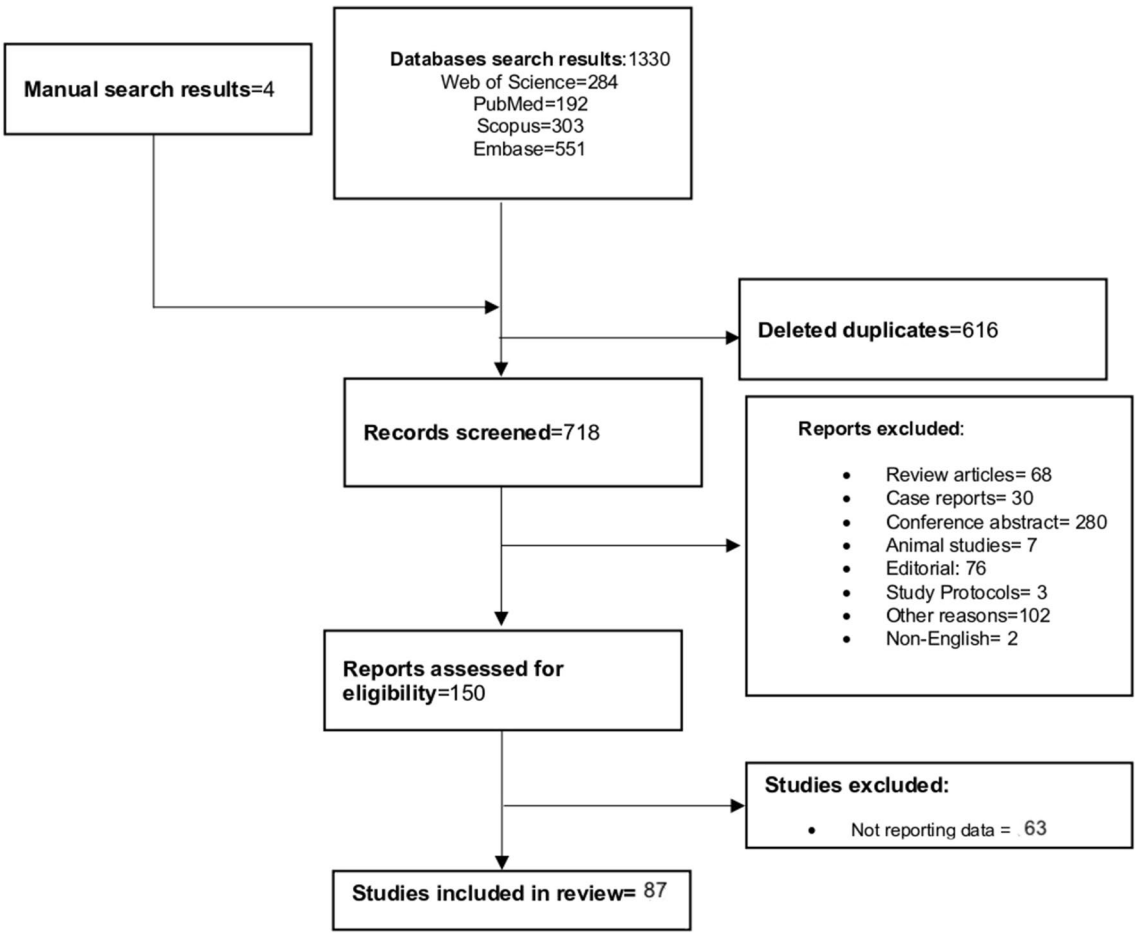

Fig. 1 PRISMA diagram for study selection

Table 2 The results of the pooled analysis in total and subgroups after one-anastomosis gastric bypass

Complication	Total	Type of surgery		Time of follow-up		Type of study	
		Primary	Revision	Short time (< 5 years)	Long time (> 5 years)	Observational	RCT
Change in reflux, odds ratio	0.59	1.21	0.26*	0.51	0.69	0.48	0.61
New-onset reflux (%)	6%	4%	10%	6%	6%	6%	8%
Marginal ulcer (%)	3%	3%	2%	3%	2%	3%	3%
Esophagitis (%)	15%	16%	19%	13%	19%	14%	16%
Barrett's esophagus (%)	1%	1%	NR	1%	1%	1%	1%
Gastritis (%)	15%	17%	NR	16%	14%	15%	15%
Revision for reflux (%)	2%	1%	6%	2%	2%	2%	0%

RCT randomized controlled trial, *NR* not reported

*Significant

(Supplementary Figure 3). However, subgroup analysis based on types of surgery demonstrated that reflux did not change significantly after primary OAGB (OR = 1.21, 95% CI 0.39–3.79, $P = 0.74$), while it reduced significantly after OAGB as revisional surgery (OR = 0.26, 95% CI 0.1–0.7, $P = 0.01$) (Supplementary Figures 4 and 5).

Gastritis

Sixteen studies reported the rate of postoperative gastritis after OAGB [14, 24, 26, 28, 31, 35, 37, 43, 56, 57, 60, 61, 79, 88] which was 15% in pooled analysis (95% CI 8–23%, $I^2 = 87.6\%$, $P < 0.001$) (Supplementary Figure 6). In subgroup

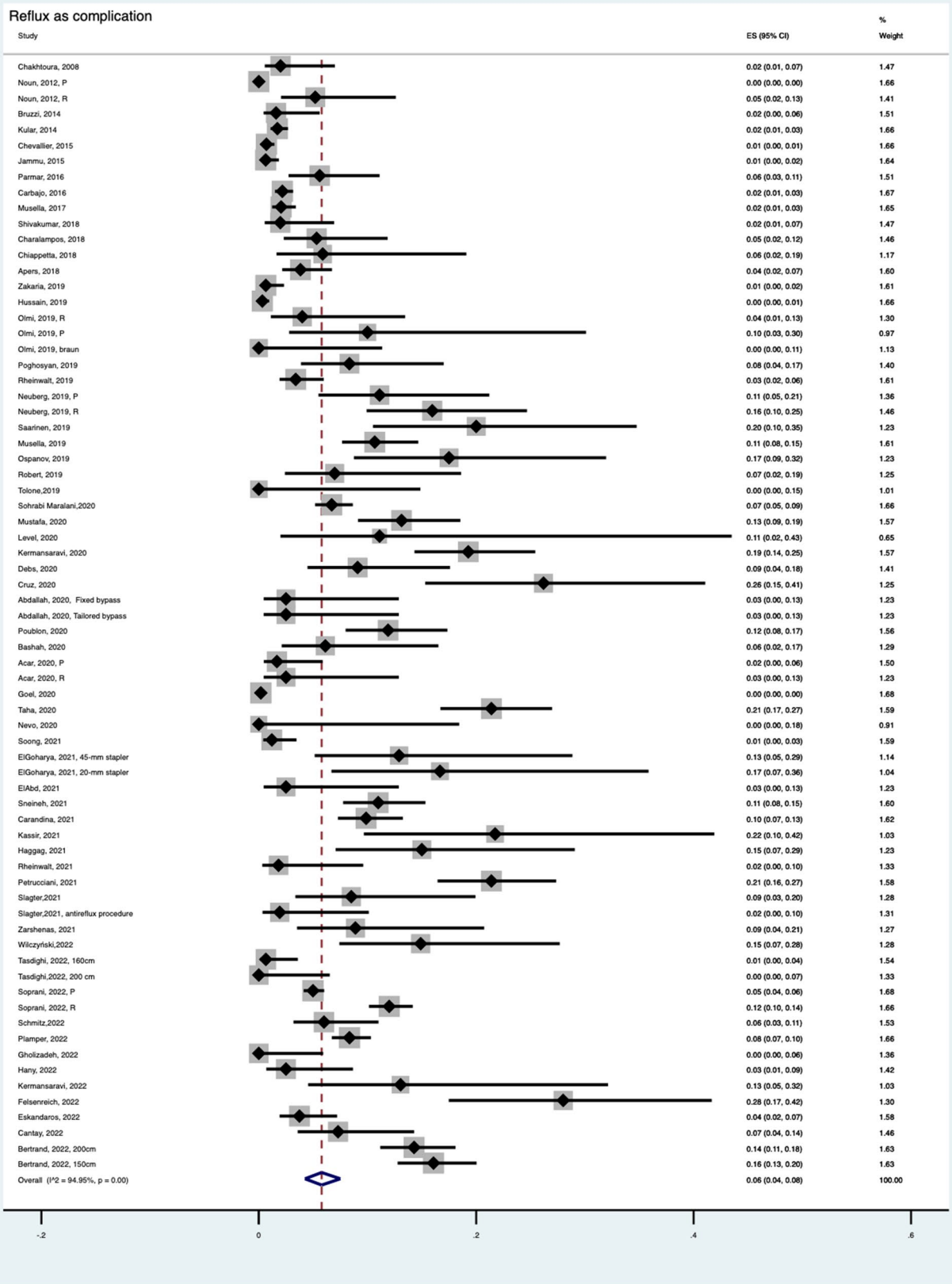

Fig. 2 The pooled analysis of the incidence of new-onset reflux after one-anastomosis gastric bypass using a random effects model

analysis, gastritis was found in 17% of patients who underwent OAGB as primary surgery (95% CI 8–27%, $I^2 = 88.3\%$, $P < 0.001$) (Supplementary Figure 7).

Esophagitis

Postoperative esophagitis was reported in 23 studies [11, 18, 19, 21, 22, 24, 26, 28, 31, 35, 43, 47, 52, 56–58, 79, 84, 85, 92]. The pooled random effects analysis revealed that esophagitis was diagnosed in 15% of patients with OAGB (95% CI 5–28%, $I^2 = 97.4\%$, $P < 0.001$) (Supplementary Figure 8). Subgroup analysis based on the grade of esophagitis showed that mild (Los Angeles (LA) grade A and B) and severe (LA grade C and D) esophagitis were diagnosed in 13% and 1% of patients after OAGB (Supplementary Figures 9 and 10). Additionally, patients who underwent OAGB as primary and revisional surgery presented with 16% (95% CI 5–31%, $I^2 = 95.8\%$, $P < 0.001$) and 19% (95% CI 0–69%, $I^2 = 98.1\%$, $P < 0.001$) esophagitis, respectively (Supplementary Figures 11 and 12).

Barrett's Esophagus

The pooled fixed effects analysis of 15 studies showed that the rate of Barrett's esophagus was 1% after OAGB (95% CI 0–2%, $I^2 = 0\%$, $P = 0.63$) (Supplementary Figure 13) [11, 21, 22, 24, 28, 31, 35, 53, 56, 61, 79].

Marginal Ulcer

The pooled random effects analysis of 57 studies revealed that 3% of patients experienced marginal ulcers after OAGB (95% CI 2–4%, $I^2 = 87.2\%$, $P < 0.01$) (Supplementary Figure 14) [10, 12, 13, 15, 18, 20, 22–25, 27, 31, 34–38, 40, 41, 43, 49, 50, 52–56, 59, 63, 65, 67, 70, 71, 76, 77, 79–87, 89, 92, 94, 95]. Furthermore, marginal ulcers occurred in 3% of patients with primary OAGB (95% CI 2–4%, $I^2 = 87.7\%$, $P < 0.01$) and 2% of patients with revisional OAGB (95% CI 1–4%, $I^2 = 60.8\%$, $P < 0.01$) (Supplementary Figures 15 and 16).

Revisional Surgery Due to Severe Reflux

The pooled random effects analysis of 44 studies showed that 2% of patients with OAGB were converted to RYGB due to severe reflux (95% CI 1–3%, $I^2 = 89.7\%$, $P < 0.01$) (Supplementary Figures 17) [22–25, 27, 29, 30, 34–37, 39, 41, 43, 45, 48, 49, 52, 54, 56, 62–64, 67, 68, 70–72, 76, 78, 82–84, 86, 91, 92, 95, 96]. In addition, subgroup analysis demonstrated that 1% and 6% of patients who underwent OAGB as primary and revisional surgery were converted to RYGB due to severe reflux (95% CI 1–3%, $I^2 = 88.9\%$, $P < 0.01$) (95% CI 3–8%, $I^2 = 73.7\%$, $P < 0.01$), respectively (Supplementary Figures 18 and 19).

Comparison of OAGB with RYGB and Sleeve gastrectomy

The pooled fixed effect analysis of 22 studies showed that OAGB had a significantly higher incidence of new-onset reflux compared to RYGB (OR = 2.64, 95% CI 2.01–3.49, $I^2 = 42.8\%$, $P < 0.01$) [11, 15, 17, 18, 31, 33, 39, 44, 50, 57, 61, 63, 69, 74, 75, 77, 81, 89, 92, 93, 96]. In addition, the pooled random effects analysis of 13 studies showed that the incidence of postoperative new-onset reflux was not significantly different between OAGB and sleeve gastrectomy ($P = 0.31$) (Supplementary Figures 20 and 21).

Effect of Surgical Volume on New-Onset Reflux

Since meta-regression showed an inverse correlation between the rate of new-onset reflux and the sample size of studies, a subgroup analysis was performed based on the sample size of included studies. The rate of new-onset reflux was 7%, 7%, and 3% in studies with sample sizes of less than 100, 100–500, and more than 500 patients, respectively (Supplementary Figures 22, 23, and 24).

Meta-regression Analysis

To find potential cofounders (sample size, length of BP limb, bougie size, preoperative BMI, and age) for the aforementioned variables, the random effects meta-regression was used. The results showed that sample size, length of BP limb, and preoperative BMI were significantly inversely correlated with the incidence of new-onset reflux after OAGB ($Z = -2.74$, $P = 0.006$), ($Z = -1.99$, $P = 0.047$), and ($Z = -2.31$, $P = 0.021$) respectively. However, there was no significant correlation between other variables and these potential cofounders.

Sensitivity Analysis

The results of the sensitivity analysis showed that new-onset reflux, change in reflux, marginal ulcer, Barrett's esophagus, and revisional surgery due to severe reflux were not influenced significantly by a single study. However, the gastritis rate reduced to 11% and 12% after removing Fahmy et al.'s and Genco et al.'s study respectively (Supplementary Figure 25) [56, 57]. In addition, sensitivity analysis showed that the esophagitis rate was influenced significantly by several studies (Supplementary Figure 26).

Publication Bias

The funnel plot of new-onset reflux is presented in Supplementary Figure 27. As shown, there is an asymmetry in studies with smaller sample sizes. In line with this result,

the Egger test showed a significant effect of small sample size studies ($P = 0.037$). In addition, trim-and-fill analysis demonstrated that new-onset reflux incidence decreased to 4% (95% CI 3–5%). However, the Egger test did not show a significant effect of small sample size studies for other variables. Also, the results of the trim-and-fill analysis did not demonstrate missing studies for other variables.

Discussion

Obesity has a strong correlation with the incidence of reflux. In fact, 61% of patients with obesity suffer from reflux, and it was indicated that increasing BMI can result in erosive esophagitis which is strongly linked with Barrett's esophagus and gastro-esophageal junction malignancy [99, 100]. Weight loss, especially after bariatric surgery, can improve reflux and patients' quality of life [101, 102]. Nevertheless, some bariatric procedures may worsen reflux or cause new-onset reflux [103]. OAGB has advantages like a short learning curve and technical simplicity as mentioned, as well as improvement of comorbidities which lead to the popularity of this type of surgery [3]. However, reflux and its subsequent complications are the main concerns about OAGB. According to a recent survey, a considerable percentage of surgeons who do not conduct OAGB still maintain the belief that this particular procedure carries a heightened risk of developing gastric and/or esophageal cancers [104]. Hence, we conduct this systematic review and meta-analysis on 87 studies and 27,775 patients to investigate the rate of reflux and its complications in patients who underwent OAGB.

The pooled results of the current study showed that OAGB was associated with 6% of new-onset reflux. This result is constant in the pooled analysis of studies with short- and long-term (more than 5 years) follow-ups. OAGB as primary surgery for patients with obesity leads to 4% of new-onset reflux. On the other hand, OAGB as revisional surgery was followed by a 2.5 times higher (10%) incidence of new-onset reflux. Previous studies showed that preoperative reflux and revisional OAGB are risk factors for postoperative reflux after OAGB [41]. Therefore, patients who underwent revisional OAGB should be counseled before the surgery and monitored closely afterward.

Our study showed that OAGB had a significantly higher incidence of postoperative new-onset reflux compared to RYGB (OR = 2.64). Furthermore, although our analysis was unable to show a significant difference between OAGB and sleeve gastrectomy with regard to postoperative new-onset reflux, the 6% rate of new-onset reflux was lower than the 23% rate after sleeve gastrectomy reported in a meta-analysis by Yeung et al. [105]. The mechanism of reflux after OAGB is unclear. It was indicated that the sleeved shape of the gastric conduit can cause increased intra-gastric pressure according to Laplace's law in which the pressure is inversely correlated with diameter in a poorly dilatable cylinder [19, 106]. Meantime, it has been stated that a long gastric pouch can decrease reflux [41, 50, 107].

One of the potential benefits of bariatric surgery is its ability to alleviate reflux symptoms in patients with obesity. Some studies showed the anti-reflux effect of OAGB in patients with preoperative reflux [13, 14]. Nevertheless, in the current study, the pooled results did not show a significant reduction in reflux incidence after OAGB in patients with preoperative reflux. In fact, in the previous experts' consensus, 75% of experts disagree that the OAGB is a suitable option for patients with severe reflux [108]. Our study showed that in patients with preoperative reflux, revisional OAGB (after a failed restrictive bariatric surgery) is associated with a significantly reduced incidence of reflux postoperatively (OR = 0.26). Nevertheless, most of the failed restrictive bariatric surgery were sleeve gastrectomy in which the rate of postoperative reflux was high, and this result can be due to the better anti-reflux properties of OAGB compared to sleeve gastrectomy.

The most common complication of reflux is esophagitis. Reflux can also cause Barrett's esophagus which is a precursor lesion to esophageal adenocarcinoma and is one of the main concerns about OAGB [109]. The results of our study showed that the incidence of postoperative esophagitis was 15% after OAGB. However, most of these cases were LA grade A and B esophagitis (13%). This result is almost half of what was previously reported for sleeve gastrectomy [105]. In a systematic review and meta-analysis of sleeve gastrectomy, the incidence of postoperative esophagitis was 30%, and in the subgroup analysis of long-term results, this rate was 28% [105]. However, in the current study, the rate of postoperative esophagitis was 19% in a subgroup analysis of studies with long-term follow-up (> 5 years). In addition, the rate of Barrett's esophagus after OAGB was 1% in the current study which was lower than the 6% rate which was reported after sleeve gastrectomy [105]. The incidence of Barrett's esophagus was 1% in pooled results of studies with long-term follow-up which is lower than the 8% rate of Barrett's esophagus after sleeve gastrectomy in pooled results of studies with long-term follow-up [105]. However, in most of the included studies, esophagoduodenoscopy was performed only in patients with reflux symptoms. Therefore, esophagitis incidence and Barrett's esophagus rate could be underestimated. In addition, gastritis as a potential complication of bile reflux was presented in 15% of patients with OAGB in the current study. These results imply the importance of the IFSO recommendation for sleeve gastrectomy regarding upper endoscopy at 1-year post-operation for all patients, followed by repeat surveillance every 2–3 years, regardless of reflux symptoms which may be also considered for OAGB [110].

Marginal ulcers are one the most important complications of bariatric surgery that can even lead to perforation and revisional surgery. Marginal ulcer seems to be the result of a combination of tissue ischemia, foreign body, and gastric acid. In fact, previous studies showed that cigarette smoking, small gastric pouch, NSAIDs, alcohol, and learning curve < 50 operations are the risk factors for developing marginal ulcers after OAGB [64, 98, 111–114]. The current study showed that the incidence rate of marginal ulcers was 3%. This result is also constant in the subgroup analysis of long-term follow-up (> 5 years) and RCT studies. This result is in accordance with the 2.8% marginal ulcer rate reported in a systematic review done by Mahawar et al. after OAGB and similar to RYGB [115]. In addition, in the current study, most of these marginal ulcers were treated by PPI, and there were a small number of patients who needed surgical intervention due to perforated marginal ulcers.

One of the important advantages of OAGB is its simplicity of reversal and revision [3, 116]. In fact, patients with irritable reflux who do not respond to high-dose PPI and lifestyle management may need revision surgery. RYGB is the surgical option of choice in patients with severe reflux. Previous studies showed that RYGB can significantly improve reflux and even its complications such as Barrett's esophagus [117, 118]. In this study, the rate of revisional surgery due to reflux after OAGB was 2%. This rate did not change in the pooled analysis of long-term follow-up studies. However, this number is half of what was previously reported in the meta-analysis of sleeve gastrectomy [105].

However, most of the pooled analyses in the current study had heterogeneous results. In fact, the study's sample size is a cofounder for heterogeneity of new-onset reflux. The results of the subgroup analysis based on the study sample size showed that studies with sample sizes of more than 500 have a 3% rate of new-onset reflux, while this result was about 7% for studies with lower sample sizes. Also, some studies reported an abnormally high rate of reflux after OAGB. In addition, as can be seen in supplementary Table 1, surgical technique and postoperative PPI use are quite different between included studies. With regards to these results and the varying correlation between OAGB and reflux, it can be suggested that surgeon experience and expertise, peri-operative management of patients such as PPI use, patient lifestyle, diet, and patient selection for OAGB can be potentially important factors for this variable reflux rate.

This is the largest meta-analysis with 27,775 patients with OAGB to assess the incidence of new-onset reflux, changes in reflux, esophagitis, Barrett's esophagus, revision due to reflux, marginal ulcer, and gastritis. These findings can help current practices and guidelines. In addition, subgroup analyses based on the type of surgery, time of follow-up (less and more than 5 years), and design of studies (observational and RCT) were done to reduce heterogeneity and improve the reliability of the results.

This study has multiple limitations. The method of detection for reflux was different between the included studies (clinical symptoms, questionnaire, and upper endoscopy). Acid versus bile reflux was not differentiated in most studies. Additionally, most of the reported pooled analyses had heterogeneous results. We performed meta-regression and subgroup analysis to detect the source of heterogenicity and reduce it. Also, there was a lack of data regarding the standardization of perioperative management, surgical technique, and threshold for revisional surgery. Furthermore, the follow-up time was in a wide range between the included studies, and we had to perform a subgroup analysis based on the time of follow-up to solve this problem. It is highly recommended for future studies to investigate the potential factors that make patients with OAGB susceptible to reflux and its complications. Also, studies with long-term follow-up with upper endoscopy and pH-impedance testing are recommended.

Conclusion

The current study showed that the rate of new-onset reflux after OAGB is approximately 6%. Two percent of patients with OAGB needed revision due to severe reflux. However, patients who underwent OAGB as revisional surgery after failed restrictive bariatric surgery experience a higher rate of reflux (10%). Further research is needed on the mechanism of reflux after OAGB and how to prevent it.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11695-023-06866-y.

Data availability Interested researchers may request access to the data by contacting the corresponding author.

Declarations

Ethics statement This meta-analysis paper is based on previously published studies and does not involve any direct participation of human or animal subjects.

Conflict of interest The authors declare no competing interests.

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