1. Introduction

More and more people suffer from morbid obesity because of the increased living standard and decreased physical exercise in the past several decades. According to a recent report based on USA population, the incidence of obese among adults even reaches up to 34.9%.[1] Between 1980 and 2008, the mean global body mass index (BMI) was increasing by 0.4–0.5 kg/m² per decade for both men and women.[2] Obesity and related comorbidities reduce life expectancy[3] and add economic burden,[4] which highlights the significance of bariatrics. The most effective therapy to treat obese and related comorbidities is bariatric surgery, in which Roux-en-Y gastric bypass (RYGBP) and sleeve gastrectomy (SG) are two most popular procedures[5,6]. Introduced by D.W. Hess et al in 1988 as part of the bilipancreatic diversion,[7,8] SG is one of the most popular procedures (37%) in the world.[9] SG is a technically less complex procedure with short learning curve and effective weight loss,[9,10] but it suffers from two outstanding disadvantages including high risk of weight regain and gastro-esophageal reflux disease (GERD).[10,11] Mini-gastric bypass (MGB), also known as single anastomosis gastric bypass or omega gastric bypass, is a newly emerged procedure originated from Rutledge.[12] Due to safe and simple process as well as effective outcomes, MGB has quickly become one of the most popular procedures in many countries.[11,13] Despite of popular status, the extension of MGB is still limited by some concerns such as gastric and oesophageal bile reflux, marginal ulcer, poor

Abstract

Background: The laparoscopic mini-gastric bypass is a newly emerged surgical procedure in recent years. Owing to safe and simple process and effective outcomes, laparoscopic mini-gastric bypass has quickly become one of the most popular procedures in some countries. The safety and effectiveness of laparoscopic mini-gastric bypass versus laparoscopic sleeve gastrectomy remain unclear.

Methods: A systematic literature search was performed in PubMed, Embase, Cochrane library from inception to May 20, 2017. The methodological quality of Randomized Controlled Trials and non-Randomized Controlled Trials were, respectively, assessed by Cochrane Collaboration’s tool for assessing risk of bias and Newcastle–Ottawa scale. The meta-analysis was performed by RevMan 5.3 software.

Results: Patients receiving mini-gastric bypass had a lot of advantageous indexes than patients receiving sleeve gastrectomy, such as higher 1-year EWL% (excess weight loss), higher 5-year EWL%, higher T2DM remission rate, higher hypertension remission rate, higher obstructive sleep apnea (OSA) remission rate, lower osteoarthritis remission rate, lower leakage rate, lower overall late complications rate, higher ulcer rate, lower gastroesophageal reflux disease (GERD) rate, shorter hospital stay and lower revision rate. No significant statistical difference was observed on overall early complications rate, bleed rate, vomiting rate, anemia rate, and operation time between mini-gastric bypass and sleeve gastrectomy.

Conclusion: Mini-gastric bypass is a simpler, safer, and more effective bariatric procedure than laparoscopic sleeve gastrectomy. Due to the biased data, small sample size and short follow-up time, our results may be unreliable. Large sample and multicenter RCT is needed to compare the effectiveness and safety between mini-gastric bypass and sleeve gastrectomy. Future study should also focus on bile reflux, remnant gastric cancer, and long term effectiveness of mini-gastric bypass.

Abbreviations: CS = cohort study, EWL = excess weight loss, GERD = gastroesophageal reflux disease, MGB = mini-gastric bypass, NOS = Newcastle–Ottawa Scale, OSA = obstructive sleep apnea, RCT = randomized control trial, RR = risk ratio, SG = sleeve gastrectomy, T2DM = type 2 diabetes mellitus.

Keywords: bariatric, mini-gastric bypass, obesity, omega gastric bypass, single anastomosis gastric bypass, sleeve gastrectomy
follow-up, and remnant gastric cancer. During the past decade, many observational studies have proved the considerable short-term and long-term outcomes of MGB, but comparative studies between MGB and SG are still scarce. For this reason, we conducted a meta-analysis to help the surgeon make a better selection between MGB and SG.

2. Material and methods

2.1. Search strategy

A systematic literature search was conducted in PubMed, Embase, and Cochrane library from inception to May 20, 2017. The search strategy for Medline is as follows which was applied to other databases: (mason’s loop OR mini-gastric bypass OR single anastomosis gastric bypass OR one-anastomosis gastric bypass OR omega loop bypass OR omega gastric bypass OR omega-loop bypass OR single anastomosis gastric bypass OR omega omega loop bypass OR one-anastomosis gastric bypass OR two-anastomosis gastric bypass OR one-anastomosis gastric bypass) OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR OR O
3.1. Primary endpoints

3.1.1. One-year EWL%. A total of 7 studies\(^{[13,18,21,22,25,27,28]}\) reported the 1-year EWL% in our meta-analysis (Table 3). \(I^2 = 81\)%, so the random effects model was used to pool the 7 studies. The result indicated MGB group had a higher 1-year %EWL than SG group (\(P = .005\)) (Fig. 3A).

3.1.2. 5-year EWL%. A total of 3 studies\(^{[22,23,29]}\) reported the 5-year EWL% in our meta-analysis (Table 3). Since there were 2 studies involving overlap of data sets\(^{[23,29]}\), the most recent study was used. \(I^2 = 76\)%, so the random effects model was used to pool the 2 studies. The result indicated MGB group had a higher 5-year %EWL than SG group (\(P < .001\)) (Fig. 3B).

3.2. Remission rate of T2DM

A total of 10 studies\(^{[8,11,13,20-22,24,25,28,29]}\) reported the remission rate of T2DM in our meta-analysis (Table 3). There were 4 studies with overlap of data sets\(^{[8,13,24,29]}\), the 2 most recent studies were used. \(I^2 = 59\)%, so the random effects model was used to pool the 8 studies\(^{[11,13,20-22,24,28,29]}\). The result indicated MGB group had a higher remission rate of T2DM than SG group (\(P = .002\)) (Fig. 3C).

3.3. Remission rate of hypertension

A total of 7 studies\(^{[11,21,22,25,26,28,29]}\) reported the remission rate of hypertension in our meta-analysis (Table 3). \(I^2 = 48\)%, so the random effects model was used to pool the 6 studies. The result indicated MGB group had a higher remission rate of hypertension than SG group (\(P = .02\)) (Fig. 3D).

3.4. Remission rate of OSA

A total of 3 studies\(^{[21,22,25]}\) reported the remission rate of OSA in our meta-analysis (Table 3). \(I^2 = 0\)%, so the fixed effects model was used to pool the 3 studies. The result indicated MGB group had a higher remission rate of OSA than SG group (\(P = .03\)) (Fig. 3E).

3.5. Remission rate of osteoarthritis

A total of 2 studies\(^{[8,21]}\) reported the remission rate of osteoarthritis in our meta-analysis (Table 3). \(I^2 = 26\)%, so the fixed effects model was used to pool the 2 studies. The result indicated MGB group had a lower remission rate of osteoarthritis than SG group (\(P = .008\)) (Fig. 3F).

3.6. Secondary endpoints

3.6.1. Overall early complications rate. A total of 7 studies\(^{[8,13,18,21,22,25,27,28]}\) reported overall early complications rate in our meta-analysis (Table 4). Since there were 2 studies with overlap of data sets\(^{[8,13]}\), the most recent study was used. \(I^2 = 51\)%, so the random effects model was used to pool the 6 studies. No difference of overall early complications rate was found between MGB and SG (\(P = .28\)) (Fig. 4A).

3.6.2. Leakage rate. A total of 5 studies\(^{[11,13,21,27,28]}\) reported leakage rate in our meta-analysis (Table 4). \(I^2 = 41\)%, so the fixed effects model was used to pool the 5 studies. The result indicated MGB group had a lower leakage rate than SG group (\(P = .02\)) (Fig. 4B).

3.6.3. Bleed rate. A total of 6 studies\(^{[11,13,21,22,27,28]}\) reported bleed rate in our meta-analysis (Table 4). \(I^2 = 0\)%, so the fixed effects model was used to pool the 6 studies. No difference of bleed rate was found between MGB and SG (\(P = .95\)) (Fig. 4C).

3.6.4. Overall late complications rate. A total of 3 studies\(^{[8,22,23]}\) reported overall late complications rate in our meta-analysis (Table 4). \(I^2 = 0\)%, so the fixed effects model was used to pool the 3 studies. The result indicated MGB group had a lower overall late complications rate than SG group (\(P = .02\)) (Fig. 4D).

3.6.5. Ulcer rate. A total of 6 studies\(^{[11,21,22,23,26,28,29]}\) reported ulcer rate in our meta-analysis (Table 4). \(I^2 = 0\)%, so the fixed effects model was used to pool the 6 studies. The result indicated MGB group had a higher ulcer rate than SG group (\(P = .001\)) (Fig. 4E).

3.6.6. Vomiting rate. A total of 3 studies\(^{[11,25,28]}\) reported vomiting rate in our meta-analysis (Table 4). \(I^2 = 0\)%, so the fixed effects model was used to pool the 3 studies. No difference of vomiting rate was found between MGB and SG (\(P = .36\)) (Fig. 4F).

3.6.7. Anemia rate. A total of 2 studies\(^{[11,22]}\) reported anemia rate in our meta-analysis (Table 4). \(I^2 = 0\)%, so the fixed effects model was used to pool the 2 studies. The result indicated MGB group had a lower anemia rate than SG group (\(P = .02\)) (Fig. 4G).
model was used to pool the 3 studies. No difference of anemia rate was found between MGB and SG ($P=0.17$ (Fig. 4G).

3.6.8. GERD rate. A total of 4 studies$^{[11,22,25,28]}$ reported GERD rate in our meta-analysis (Table 4). $I^2=52\%$, so the random
Table 3

Resolution of comorbidities, %EWL and weight regain of included studies (mini-gastric bypass/sleeve gastrectomy).

| Author                        | Sample size | T2DM (%) | Hypertension (%) | OSA (%) | Ostearthritis (%) | %EWL (1 year) ± | %EWL (5 year) ± | Weight regain |
|-------------------------------|-------------|----------|------------------|---------|------------------|----------------|----------------|---------------|
| Kansou et al[21]             | 136/136     | 25       | 19               | 9       | 37               | 3             | 22             | 43            |
| Jammu et al[11]              | 473/339     | 59       | 13               | 10      | 41               | 7             | 14             | 16            |
| Kular et al[22]              | 104/118     | 58       | 6                | 49      | 12               | 4             | 27             | 46            |
| Lee et al[29]                | 30/30       | 12       | 9                | 3       | 12               | 7             | 14             | 16            |
| Musella et al[13]            | 96/110      | 82       | 14               | 67      | 46               | 14            | 41             | 15            |
| Lee et al[23]                | 519/519     | 58       | 5                | 49      | 12               | 4             | 30             | 12            |
| Seetharamanish et al[30]     | 101/100     | 44       | 6                | 36      | 13               | 4             | 59             | 137           |
| Plamper et al[27]            | 78/80       | 12       | 9                | 3       | 12               | 7             | 14             | 55            |
| Yang et al[28]               | 98/120      | 82       | 14               | 67      | 46               | 14            | 41             | 15            |
| Ding et al[20]               | 12/5        | 7        | 3                | 1       | 2                | 2             | 1              | 2             |
| Mione et al[21]              | 74/86       | 21       | 7                | 16      | 8                | 5             | 10             | 3             |

EWL = excess weight loss, N0 = Remission in LSG, N1 = Remission in LMGB, OSA = obstructive sleep apnea, R0 = Remission in LGB, R1 = Remission in LMGB, T2DM = type 2 diabetes mellitus.

4.1. EWL %

In the 13 included studies, the lowest EWL % for MGB and SG was 9.3% and 17%, respectively. We examined the effect of sample size and found a significant EWL % difference between MGB and SG (MGB > SG, p < 0.05). Our result indicated MGB had a superior EWL % for MGB (15-17.8%) compared to SG (10-12.5%). It is worth noting that after a larger sample size (N > 50), the difference between MGB and SG became more pronounced.

3.8. Operation time

A total of 8 studies reported operation time in our meta-analysis (Table 4, 5-98). The meta-analysis of MGB versus SG resulted in a significantly shorter operation time for MGB compared to SG (MGB: 123 ± 42 min, SG: 147 ± 50 min, p < 0.05). The difference between MGB and SG was found to be significant in the comparison of operation time.

3.7. Hospital stay

A total of 4 studies reported hospital stay in our meta-analysis (Table 4, 5-98). The meta-analysis of MGB versus SG showed that MGB had a shorter hospital stay than SG (MGB: 3 days, SG: 5 days, p < 0.05). This difference was significant after a larger sample size (N > 50).

3.7.1. Revision rate

A total of 5 studies reported revision rate in our meta-analysis (Table 4, 5-98). The meta-analysis of MGB versus SG showed that MGB had a lower revision rate than SG (MGB: 3%, SG: 7%, p < 0.05). This difference was significant after a larger sample size (N > 50).

4. Discussion

A meta-analysis of 6 studies (11-13,33) showed that MGB had a superior EWL % and better weight regain than SG (MGB: 17.8% ± 71.4%, SG: 10.3% ± 71.4%, p < 0.05). Our result indicated MGB had a lower revision rate than SG (MGB: 3%, SG: 7%, p < 0.05). The meta-analysis of MGB versus SG showed that MGB had a shorter hospital stay than SG (MGB: 3 days, SG: 5 days, p < 0.05). This difference was significant after a larger sample size (N > 50).
according to previous studies,[33,46] in view of which, future studies should compare MGB and SG in terms of 2-year or longer EWL%. Although we pooled the 5-year EWL%, minor sample size may influence the stability of the result. The higher EWL% of MGB may be due to different mechanisms between MGB and SG.

4.2. Remission rate of comorbidities

The most common comorbidities of morbid obesity are T2DM, hypertension, OSA and osteoarthritis, among which, T2DM is the most harmful one. Remission of T2DM was defined as HbA1C level < 6.5% in 3 studies,[13,20,28] < 6% in 1 study,[22] untold in 4 studies.[11,21,25,29] Remission of hypertension, OSA, and osteoarthritis was defined as normalization of baseline characteristics without using drugs or continuous positive-pressure airway machine.[8,21,22,25] The overall remission rate of T2DM, hypertension, OSA, and osteoarthritis was 86%, 75%, 93%, 68% for MGB and 65%, 60%, 76%, 88% for SG, respectively.

Previous large sample size and observational studies on MGB showed a remission rate of 84.1% to 94%,[16,33,34,37] 52.1% to 94%,[16,33,34] 50% to 90%,[33,34] and 18% to 36.5%[33,34] for T2DM, hypertension, OSA, and osteoarthritis, respectively.

Table 4

| Author            | Mortality | Overall early complications | Specific early complications | Overall late complications | Specific late complications | Hospital stay | Revision |
|-------------------|-----------|-----------------------------|------------------------------|---------------------------|----------------------------|--------------|---------|
| Kansou et al[21]  | 136/136   | 0/0                         | 6/8                          | –                         | Ulcer:10/0; stenosis:23/0  | –            | 0/0     |
| Jammu and Sharma[31] | 473/23 | 0/7                         | –                            | –                         | Vomiting:0/1; anemia:23/12 | –            | –       |
| Kular et al[22]   | 104/118   | 0/0                         | 5/14                         | 14/26                     | Ulcer:1/0; GERD:2/16; anemia:5/2; malnutrition:1/0; cholelithiasis:6/8 | 2.5 ± 1.3/3.4 ± 2.4 | 1/16    |
| Lee et al[29]     | 30/90     | 0/0                         | –                            | –                         | –                          | –            | 1/4     |
| Musella et al[31] | 175/138   | 8/5                         | Leakage:0/1; bleed:5/3       | –                         | –                          | –            | –       |
| Lee et al[29]     | 519/519   | 49/38                       | –                            | –                         | –                          | –            | –       |
| Seetharamaiah et al[28] | 101/100 | 0/0                         | Wound infection:4/6; leakage:0/1; bleed:3/4 | –                         | Vomiting:3/4; ulcer:2/1; GERD:2/3 | –            | –       |
| Plamper et al[27] | 169/118   | 1/3                         | 5/11                         | 2/5                       | –                          | 4.5 ± 2.6/7.2 ± 5.5 | 2/3     |
| Mochok et al[29]  | 19/56     | 0/0                         | 0/3                          | 2/5                       | –                          | 1/10         | –       |
| Musella et al[31] | 80/175    | 0/1                         | –                            | –                         | 3/20                       | –            | –       |

Figure 3. (A) 1 year EWL% of MGB versus SG. (B) 5 years EWL% of MGB versus SG. (C) T2DM remission rate of MGB versus SG. (D) Hypertension remission rate of MGB versus SG. (E) OSA remission rate of MGB versus SG. (F) Osteoarthritis remission rate of MGB versus SG. EWL = excess weight loss, MGB = mini-gastric bypass, OSA = obstructive sleep apnea, SG = sleeve gastrectomy, T2DM = type 2 diabetes mellitus.
T2DM, hypertension, OSA and osteoarthritis, respectively. Our results indicated MGB had a higher remission rate of T2DM, hypertension, OSA and a lower remission rate of osteoarthritis than SG. The higher remission rate of comorbidities of MGB may be explained by foregut and hindgut hypothesis.\[47,48] Due to the small sample size, the results on remission rate of OSA and osteoarthritis may be unreliable. Future studies should include the endpoints of OSA and osteoarthritis.

4.3. Early complications

The most common early complications include leakage, intraperitoneal bleed, wound infection, intraperitoneal abscess, and bowel obstruction. According to the results of our meta-analysis, the overall rate of early complications, leakage, and bleed of MGB were 6.5%, 0.76%, 1.3% versus 7.3%, 2.3%, 1.4% of SG. Rutledge et al\[35] performed a retrospective and observational study on 2410 patients having MGB, results showed that the rate of early complications was 5.9% and rate of leakage was 1.08%. Noun et al\[38] performed a similar study in 1000 consecutive patients, and results showed that the rate of early complications was 2.7% the rate of leakage was 0.43%, and the rate of bleeding was 1.6%. Most recently, Taha et al\[16] reported 1520 cases receiving MGB for consecutive 6 years, and results showed that the rate of early complications was 3.2% leakage rate was 0.1% and bleed rate was 1.7%. All the 3 large sample size observational studies presented the favorable rate early complications, which seemed superior than our results. Our results indicated MGB group had a similar overall rate early complications, similar bleed rate and lower leakage rate compared with SG group. The lower leakage rate in MGB group may be explained by the decreased intragastric pressures caused by pylorus exclusion.\[42]
4.4. Late complications

The most common late complications include ulcer, stenosis, vomiting, anemia, bile reflux, GERD, and malnutrition. The overall rate of complications, ulcer, vomiting, anemia, and GERD were 9.4%, 2.1%, 0.51%, 4.9%, 1.1% for MGB versus 14.6%, 0%, 1.6%, 3.1%, 9.1% for SG. Previous large sample size and observational studies have reported the overall rate complications of 2% to 7.9%,\textsuperscript{16,33,46} ulcer rate of 0.2% to 4%,\textsuperscript{16,33,33,33,46} stenosis rate of 0.1% to 0.8%,\textsuperscript{13,34,46} vomiting rate of\textsuperscript{144} anemia rate of 1.5% to 4.9%,\textsuperscript{13,34,35} bile reflux rate of 0% to 1.6%,\textsuperscript{16,46} GERD rate of 2%,\textsuperscript{134} and malnutrition rate of 2%\textsuperscript{134} for patients receiving MGB. Ulcer and stenosis generally happened at anastomosis area,\textsuperscript{11,21,22,25,28,29} which may account for the higher ulcer rate in MGB patients, whereas no anastomosis existed in SG patients. The lower GERD rate may be due to decreased intragastric pressure in MGB patients, which has been proven by Tolone et al.\textsuperscript{49} The authors hypothesized that the long narrow sleeve gastric tube could have caused an increase in intragastric pressure, triggering a rise in GERD. Bile reflux is the most concerned factor that limits the extension of MGB. Although previous observational studies reported a considerable rate of bile reflux (0%–1.6%),\textsuperscript{16,33,46} comparative studies on bile reflux between MGB and SG are rare. Tolone et al\textsuperscript{49} performed a small sample size comparative study between MGB and SG, and concluded patients receiving MGB had significantly diminished total number of reflux episodes, including acidic, weakly acidic, and weakly alkaline reflux. The reason why bile reflux symptom was rarely described in previous reports on MGB was that the bile can be neutralized by gastric acid secreted by remnant gastric before flowing to the gastrointestinal anastomosis, and the neutralized bile had less stimulation on gastric mucosa. Our results showed MGB group had a lower vomiting rate and higher anemia rate than SG group, and there was no significant statistical difference between two groups. Only one study reported stenosis rate, bile reflux rate, and malnutrition rate in MGB and SG patients, so we did not pool these endpoints. Future comparative studies between MGB and SG should include the endpoints of bile reflux and malnutrition.

4.5. Hospital stay, operation time, and revision rate

Our results shown MGB patients had a shorter hospital stay, lower revision rate, and similar operation time compared to SG patients. The shorter hospital stay may be explained by less trauma in MGB. The major causes of revision were malnutrition,\textsuperscript{22,25} bile reflux,\textsuperscript{27,29} and GERD\textsuperscript{2,25} for MGB patients, whereas weight regain,\textsuperscript{22} severe GERD\textsuperscript{2,25,27} for SG patients.

4.6. Previous meta-analysis

To our knowledge, there were 2 meta-analyses comparing MGB with SG published online. Quan et al\textsuperscript{50} performed a meta-analysis of MGB versus SG, and concluded MGB group had the same %EWL (P = .51) and 1-year postoperative BMI (P = .38), lower revision rate (P = .004) and higher remission rate of T2DM (P = .004) than SG group. Only 6 studies were included in Quan, Y’s meta-analysis, so the results were unreliable. Most recently, Magouliotis et al\textsuperscript{51} performed a simple meta-analysis of MGB versus SG, wherein 10 English studies were included and most results (one-year EWL %, remission rate of T2DM, remission rate of hypertension, bleed rate, anemia rate, GERD rate, hospital stay, operation time, and revision rate) were similar to our meta-analysis. In our meta-analysis, MGB group had a higher remission rate of OSA and lower leakage rate than SG group (P = .03), which was different from the Magouliotis meta-analysis results. There were 3 main differences between our meta-analysis and the Magouliotis meta-analysis. First, there were more eligible studies and more patients included in our meta-analysis, which made our meta-analysis more reliable. Second, we pooled the additional endpoints of 5-year %EWL, remission rate of osteoarthritis, overall rate of early complications, overall rate of late complications, ulcer rate, vomiting rate. Third, unlike the Magouliotis meta-analysis, the overlapped data were excluded from our meta-analysis. For example, data from the Milone\textsuperscript{26} and Musella\textsuperscript{13} study shared overlapped research time and their data were from the same hospital, and the data of the two studies were used by Magouliotis\textsuperscript{26} to pool T2DM remission rate, while we excluded the earlier one.

4.7. Limitations

Our meta-analysis still had some limitations. First, only 2 eligible studies were RCTs, the others were cohort studies with inherent selection bias. Second, small sample size and short follow-up time may influence the stability of result. Third, due to few eligible studies were included in our meta-analysis, so we did not perform an analysis of publication bias. Fourth, heterogeneity between studies was high in our meta-analysis, which may be explained by different basic patients’ characteristics of included studies and different surgical level of different hospital.

5. Conclusions

MGB is a simple, safe, and effective bariatric procedure. Due to the biased data, small sample size and short follow-up time, our results may be unreliable. Large sample and multicenter RCT is needed to compare the effectiveness and safety between mini-gastric bypass and sleeve gastrectomy. Future study should also focus on the endpoints of bile reflux, remnant gastric cancer and long term effectiveness in MGB patients.

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