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ORIGINAL CONTRIBUTIONS

# Impact of Preoperative Anemia on Postoperative Kidney Function Following Laparoscopic Bariatric Surgery

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**Abstract**

**Background** Preoperative anemia is a risk factor for acute kidney failure after high-risk surgeries. We assessed the impact of preoperative anemia on kidney function in an obese Asian population after laparoscopic bariatric surgery.

**Methods** Patient characteristics, comorbidities, type of surgery, perioperative profiles, eGFR, and micronutrition were retrospectively reviewed in 341 patients with obesity undergoing bariatric surgery. All patients, who had a preoperative estimated glomerular filtration rates (eGFR) ≥ 90 mL/min/1.73 $m^2$, were followed for 1 year and assigned to one of two groups: anemia or non-anemia group. Preoperative anemia was determined based on hemoglobin concentration.

**Results** The Pearson's correlation coefficient between preoperative body mass index (BMI) and preoperative eGFR of all patients was 0.169 ($p = 0.005$). Preoperatively, there were no significant differences in age, BMI, and eGFR between the anemia ($n = 38$) and non-anemia groups ($n = 303$). Patients in the anemia group had lower hemoglobin concentration at baseline, 1 month, and 12 months after surgery than those in the non-anemia group. Postoperative eGFR levels at 1 month ($p = 0.993$) and 1 year ($p = 0.118$) as well as hospital stay ($p = 0.941$) were comparable between the two groups. However, the percentage weight loss was significantly higher in the non-anemia group than that in the anemia group 1 year after bariatric surgery (30.0 ± 7.3% vs. 27.0 ± 8.1%; $p = 0.041$).

**Conclusions** Preoperative anemia did not negatively impact kidney function following laparoscopic bariatric surgery during the 12-month follow-up. Considering the potential adverse impact of anemia on postoperative weight loss, preoperative correction of anemia may be recommended.

**Keywords** Bariatric surgery · Glomerular filtration rate · Renal function

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## Introduction

Bariatric surgery is considered an efficacious treatment for morbid obesity not only because of its ability to achieve considerable weight loss but also because of the associated reduction in the risk of cardiovascular disease, certain cancers, and all-cause mortality [1]. In addition, obesity has been found to be an independent risk factor for the development and progression of chronic kidney disease [2, 3]. In patients undergoing general and orthopedic operations, the rate of acute kidney injury (AKI) has been reported to range from 0.55 to 1% [4, 5]. In contrast, the incidence of AKI reportedly ranges from 5.8 to 8.6% following bariatric surgery [6–9]. Therefore, the obese population appears to have an increased risk for postoperative kidney impairment. Moreover, postoperative AKI after bariatric surgery may prolong the duration of hospitalization [9] and was associated with worsening of renal function in long-term follow-up [10]. Accordingly, modifiable factors should be controlled preoperatively to reduce the incidence of preventable complications in this high-risk population.

Preoperative anemia is common among non-cardiac and non-neurological surgical patients (i.e., 25.3–39.9%) [11–15], and the prognostic value of anemia in surgery has been well studied. Several large-scale retrospective studies reported that preoperative anemia is an important risk factor that contributes to poor clinical outcomes (e.g., 30-day postoperative mortality and morbidity) [11–15] and increased consumption of healthcare resources [13]. Furthermore, this modifiable factor has been found to be independently associated with AKI after cardiac surgery [16]. In non-surgical patients, correcting anemia with human recombinant erythropoietin may retard the progression of renal dysfunction [17, 18]. Although anemia may play an important role in kidney dysfunction for some patient populations, the impact of preoperative anemia on kidney function has not been addressed in obese patients undergoing bariatric surgery. This study aimed at assessing the impact of preoperative anemia on kidney function as the primary end-point in an obese Asian population, while the influence of anemia on the length of hospital stay as well as the relationship between body mass index (BMI) and preoperative eGFR were the secondary outcomes.

## Methods

### Study Population and Variables

Between September 2014 and September 2017, medical records of adult patients having received any form of laparoscopic bariatric surgery (i.e., restrictive procedures and/or malabsorptive techniques) at a single tertiary referral center were retrospectively reviewed. All patients had failed previous attempts at weight loss through diet, exercise, life style modification, or medicine. All patients met the surgical criteria for bariatric surgery according to the Asian Consensus Meeting on Metabolic Surgery [19]. There is still no guideline regarding postoperative nutrition supplementation for patients after bariatric surgery in Taiwan. Postoperative nutrition supplement protocol at our institute consisted of two chewable multivitamin/mineral preparations (each containing vitamin B1 5 mg, vitamin B12 100 μg, folic acid 200 μg, vitamin D 7.5 μg, calcium 104 mg, vitamin A 488 μg, vitamin E 83 μg, zinc 7.5 mg). Iron status was monitored in all patients after surgery, and daily oral elemental iron 24 mg was given for a serum iron level < 60 μg/dL. Inclusion criteria included an age between 18 and 65 as well as postoperative follow-up at the outpatient clinic for at least 1 year. Patients with severe cardiovascular disease (e.g., heart failure), missing information on laboratory tests, preexisting renal insufficiency (i.e., eGFR < 90 mL/min/1.73 $m^2$), or an American Society of Anesthesiologists (ASA) Score ≥ 4 as well as those who underwent more than one relevant procedure and/or lost to follow-up during the study period were excluded from the present study. To eliminate the possible effects of blood transfusions on patient outcomes [20], patients who received preoperative or perioperative blood transfusions were also excluded.

Based on hemoglobin concentrations, patients were divided into the anemia and the non-anemia groups. Detailed perioperative data (e.g., demographics and laboratory tests) and postoperative data (e.g., eGFR and length of hospital stay) were collected from existing clinical databases. All data were entered into a computerized database with validity checks. The protocol of the whole study was reviewed and approved by the institutional research board (IRB) (Approval No. 20181119B). Informed patient consent was waived due to the retrospective nature of this study.

### Definitions and Outcomes

We defined preoperative hemoglobin concentration as the last hemoglobin measurement within 7 days before the index operation. Preoperative anemia was defined as a hemoglobin concentration < 12.0 g/dL for females and < 13.0 g/dL for males, according to WHO's sex-based criteria [13].

The primary study end point was change in eGFR, calculated based on the Chronic Kidney Disease Epidemiology Collaboration Equation [21], at 1 month and 1 year postoperatively. Glomerular hyperfiltration was defined as an eGFR ≥ 125 mL/min/1.73 $m^2$ [22]. The secondary outcomes were length of hospital stay and the relationship between body mass index (BMI) and preoperative eGFR.

### Statistical Analyses

Sample size was calculated based on a previous study which reported that the eGFR was 113 ± 13 mL/min per 1.73 $m^2$ in patients with obesity 1 year after bariatric surgery [23]. Twenty-two patients in each group were required to detect a between-group difference of 10% eGFR, with a $p = 0.05$ and a power of 80%. Categorical variables, which are expressed as frequencies and percentages, were compared by chi-square test. Continuous variables are reported as means and standard deviations. Continuous variables that were normally distributed were compared using Student's $t$ test, while non-normally distributed continuous variables were compared using the Mann–Whitney $U$ test. Pearson's correlation analysis was adopted for determining the significance of association between BMI and eGFR at baseline in the testing subjects as well as the changes in BMI and changes in eGFR during the study period in those with glomerular hyperfiltration. $p < 0.05$ was considered statistically significant. Statistical analyses were performed using the Statistical Program for Social Sciences, version 22.0 (SPSS, Chicago, IL).

## Results

### Demographic Characteristics, Comorbidities, Kidney Function, and Perioperative Parameters

From September 2014 to September 2017, a total of 419 patients who underwent laparoscopic bariatric surgery were retrospectively reviewed. The overall prevalence of preoperative anemia was 11.7% ($n = 49$). After excluding 78 cases, 341 patients were included in the final data analyses (Fig. 1). The Pearson's correlation coefficient between preoperative BMI and preoperative eGFR was 0.169 ($p = 0.005$), which demonstrated a significant but weak, positive correlation. The demographic characteristics, comorbidities, kidney function, and perioperative parameters of patients who underwent laparoscopic bariatric surgery are summarized in Table 1. The anemia group was more likely to be female (81.6% vs. 63.7%, $p = 0.029$), but there were no significant between-group differences in age, BMI, baseline eGFR, the presence of glomerular hyperfiltration, and baseline serum creatinine concentration (Table 1). Sleeve gastrectomy was the most common procedure performed (89.5% vs. 93.7% for anemia and non-anemia group, respectively, $p = 0.308$).

### Preoperative Micronutrition, Inflammatory, and Metabolic Profiles

Preoperative micronutrition, inflammatory (i.e., C-reactive protein), and metabolic profiles of the two groups of patients are shown in Table 2. Patients in the anemia group were more likely to present with lower iron (64.0 ± 44.9 vs. 93.6 ± 37.4 μg/dL, $p < 0.001$) and serum calcium (9.1 ± 0.4 vs. 9.3 ± 0.3 mg/dL, $p = 0.013$) levels than those in the non-anemia group.

### Length of Hospital Stay and Kidney Function 1 Month After Laparoscopic Bariatric Surgery

Length of hospital stay and kidney function 1 month after laparoscopic bariatric surgery are presented in Table 3. For

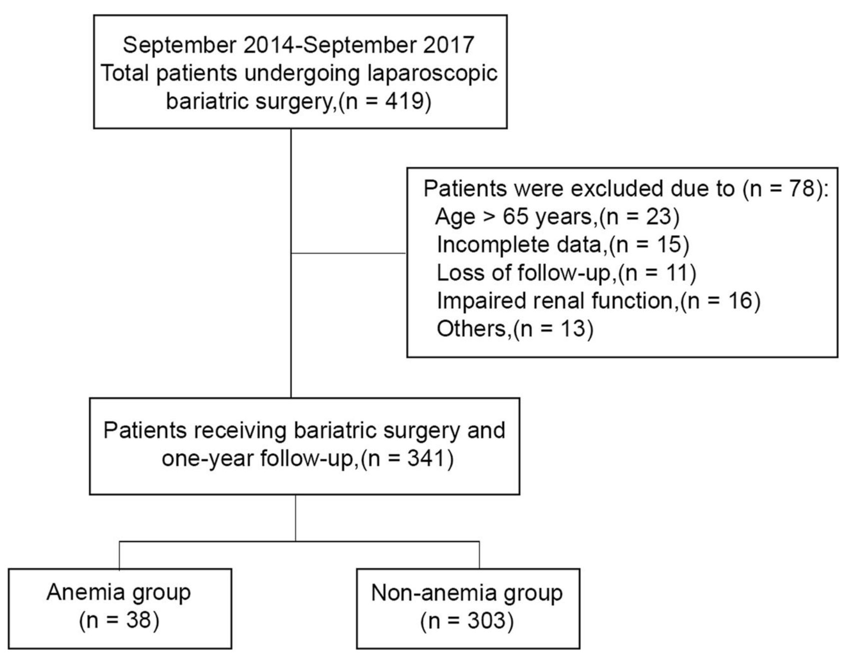


**Fig. 1** Flowchart of recruitment process in the retrospective study

**Table 1** Demographic characteristics, comorbidities, kidney function, and perioperative parameters of patients who underwent laparoscopic bariatric surgery

| | Anemia group ($n = 38$) | Non-anemia group ($n = 303$) | $p$ value |
|---|---|---|---|
| Age (year) | 37.5 ± 8.7 | 36.6 ± 11.1 | 0.571 |
| Sex (female) | 31 (81.6) | 193 (63.7) | 0.029 |
| Height (cm) | 161.4 ± 6.3 | 165.5 ± 8.7 | 0.001 |
| Weight (kg) | 100.2 ± 18.1 | 110.0 ± 22.8 | 0.011 |
| Body mass index (kg/m$^2$) | 38.3 ± 6.2 | 40.0 ± 6.6 | 0.149 |
| Hemoglobin (g/dL) | 11.1 ± 1.0 | 14.2 ± 1.3 | < 0.001 |
| Hematocrit (%) | 34.9 ± 2.5 | 42.9 ± 3.8 | < 0.001 |
| Baseline eGFR (mL/min per 1.73 m$^2$)† | 117.1 ± 18.7 | 117.6 ± 19.3 | 0.891 |
| Glomerular hyperfiltration* | 13 (34.2) | 86 (28.4) | 0.456 |
| Baseline serum creatinine (mg/dL) | 0.61 ± 0.1 | 0.65 ± 0.1 | 0.054 |
| Comorbidities | | | |
| Diabetes mellitus | 9 (27.3) | 63 (24.7) | 0.831 |
| Hypertension | 14 (36.8) | 146 (48.2) | 0.187 |
| Hyperlipidemia | 9 (23.7) | 56 (18.5) | 0.442 |
| Sleeve gastrectomy | 34 (89.5) | 282 (93.7) | 0.308 |
| Surgical time (min) | 103.0 ± 28.3 | 99.8 ± 25.4 | 0.45 |
| Perioperative fluid administration (mL) | 480.3 ± 169.9 | 513.7 ± 153.0 | 0.211 |
| Episode of hypotension | 5 (13.2) | 49 (16.2) | 0.631 |

*eGFR* estimated glomerular filtration rate

†Calculated using the Chronic Kidney Disease Epidemiology Collaboration Equation

*eGFR ≥ 125 mL/min per 1.73 m$^2$

both groups, the eGFR levels declined significantly (all $p < 0.001$) in postoperative 1 month compared with those at baseline. No notable difference was observed in the incidence of glomerular hyperfiltration 1 month after surgery between the anemia ($n = 5/38$) and non-anemia ($n = 38/303$) groups (13.2% and 12.5%, respectively, $p = 1$). There were no significant between-group differences in eGFR, serum creatinine concentration, and length of hospital stay in patients with or without preoperative anemia. The proportion of patients with glomerular filtration < 60 mL/min/1.73m$^2$ at 1 month was 0% and 1% in the anemia group and non-anemia ($n = 3/303$) group, respectively ($p = 1$).

### Hemoglobin, Body Mass Index, and Kidney Function at 12-Month Follow-up After Bariatric Surgery

The 12-month outcome after bariatric surgery is shown in Table 4. For both groups, the eGFR levels decreased significantly (all $p < 0.001$) 12 months after operation compared with those at baseline. No significant difference was noted in the incidence of glomerular hyperfiltration at 12-month follow-up between the anemia ($n = 3/38$) and non-anemia ($n = 36/303$) groups (7.9% and 11.9%, respectively, $p = 0.596$). In subgroup analysis for patients with preoperative glomerular hyperfiltration, no significant relationship was found between changes in BMI and changes in eGFR ($r = -0.201$, $p = 0.157$) by using Pearson's correlation test. Although patients in the anemia group generally had a significantly lower hemoglobin levels than those in the non-anemia group 1 year after surgery ($p < 0.001$), there were no significant between-group differences in BMI or eGFR. However, the percentage weight loss was significantly higher in the non-anemia group than that in the anemia group 1 year after bariatric surgery (30.0 ± 7.3% vs. 27.0 ± 8.1%; $p = 0.041$).

## Discussion

Patients with obesity are at risk for kidney injury after bariatric surgery [6–9]. To the best of our knowledge, this is the first study to assess the impact of preoperative anemia on postoperative kidney function and length of hospital stay in obese patients undergoing laparoscopic bariatric surgery. In the current study, hemoglobin levels were lower preoperatively and throughout the follow-up period in the anemia group compared with those in non-anemia group. In the 12-month follow-up, neither preoperative anemia nor subsequent low hemoglobin levels negatively influenced eGFR and length of hospital stay in obese patients following bariatric surgery. On the other hand, the percentage weight loss was significantly higher in subjects without preoperative anemia than that in the anemia group 1 year after bariatric surgery (30.0 ± 7.3% vs. 27.0 ± 8.1%; $p = 0.041$). This finding raised the issue regarding the necessity of preoperative correction of anemia and

**Table 2** Preoperative micronutrition, inflammatory, and metabolic profiles

| Variables | Anemia group (*n* = 38) | Non-anemia group (*n* = 303) | *p* value |
|---|---|---|---|
| C-reactive protein (mg/dL) | 3.2 ± 1.5 | 3.9 ± 2.2 | 0.115 |
| Albumin (g/dL) | 4.1 ± 0.3 | 4.4 ± 2.3 | 0.451 |
| Parathyroid hormone (pg/mL) | 42.8 ± 18.6 | 41.5 ± 18.5 | 0.725 |
| Glycated hemoglobin (HbA1c) (%) | 6.6 ± 1.7 | 6.7 ± 1.7 | 0.716 |
| GOT (U/L) | 28.6 ± 26.8 | 30.4 ± 22.7 | 0.661 |
| GPT (U/L) | 38.1 ± 40.5 | 46.6 ± 38.0 | 0.203 |
| Total cholesterol (mg/dL) | 185.5 ± 25.0 | 192.6 ± 36.0 | 0.278 |
| Triglycerides (mg/dL) | 203.7 ± 433.0 | 171.3 ± 116.3 | 0.671 |
| High-density lipoprotein (mg/dL) | 47.1 ± 11.2 | 45.9 ± 10.8 | 0.551 |
| Low-density lipoprotein (mg/dL) | 107.3 ± 22.3 | 113.7 ± 29.6 | 0.227 |
| Insulin (IU/mL) | 19.4 ± 18.1 | 28.6 ± 36.6 | 0.19 |
| Serum calcium level (mg/dL) | 9.1 ± 0.4 | 9.3 ± 0.3 | 0.013 |
| Serum iron level (μg/dL) | 64.0 ± 44.9 | 93.6 ± 37.4 | < 0.001 |
| Vitamin B12 level (pg/mL) | 538.7 ± 224.9 | 533.8 ± 264.5 | 0.923 |
| Serum Folate level (pg/mL) | 8.0 ± 5.2 | 7.1 ± 4.5 | 0.294 |
| Serum zinc level (μg/L) | 978.9 ± 201.9 | 1015.2 ± 229.0 | 0.467 |

*GOT* glutamate oxaloacetate transaminase, *GPT* glutamate pyruvate transaminase

optimization of nutritional deficiencies in obese patients undergoing laparoscopic bariatric surgery to achieve favorable weight loss.

Nutritional deficiencies (e.g., iron deficiency) in our patients were assessed at 1, 2, 3, 6, 9, and 12 months postoperatively and were corrected via nutritional supplementation. Despite supplementation, hemoglobin and iron levels in the anemia group were still lower than those in the non-anemia group. In addition, the prevalence of anemia reportedly ranges from 25.3 to 39.9% in surgical patients [11–15]. However, in the present study, the prevalence of preoperative anemia was only 11.7%, which is consistent with the reported prevalence of 12.2% in a previous meta-analysis on obese patients undergoing bariatric surgery [24]. Since it has been shown that obesity may predispose to iron deficiency [25], the reasons for the relatively low prevalence of preoperative anemia in obese patients receiving bariatric surgery remain unknown.

Obesity is known to be associated with the development and progression of chronic kidney disease [2, 3]. The pathophysiological mechanisms for obesity-associated kidney dysfunction have been found to involve systemic inflammation, metabolic changes, systemic and glomerular hypertension, hyperactivation of the renin-angiotensin-aldosterone axis and/or sympathetic nervous system, or increase in intra-abdominal pressure [3, 26–29]. Although the mechanisms for kidney dysfunction after bariatric surgery remain unclear, several risk factors such as a high BMI, diabetes, hyperlipidemia, and use of angiotensin-converting enzyme inhibitors were also implicated [6, 9]. Nevertheless, we observed no between-group differences

**Table 3** Length of hospital stay and kidney function 1 month after laparoscopic bariatric surgery

| Variables | Anemia group (*n* = 38) | Non-anemia group (*n* = 303) | *p* value |
|---|---|---|---|
| Hemoglobin (g/dL) | 11.7 ± 1.2 | 13.8 ± 1.2 | < 0.001 |
| Hematocrit (%) | 36.8 ± 3.0 | 42.0 ± 3.4 | < 0.001 |
| Serum iron level (μg/dL) | 58.7 ± 33.9 | 84.2 ± 28.4 | < 0.001 |
| eGFR (mL/min/1.73 m$^2$) | 104.6 ± 22.5[a] | 104.7 ± 22.0[a] | 0.993 |
| Glomerular hyperfiltration* | 5 (13.2%) | 38 (12.5%) | 1 |
| eGFR < 60 (mL/min/1.73 m$^2$) | 0 (0) | 3 (1%) | 1 |
| Serum creatinine (mg/dL) | 0.7 ± 0.2 | 0.8 ± 0.3 | 0.191 |
| Percentage weight loss (%) | 9.7 ± 2.4 | 10.6 ± 2.6 | 0.101 |
| Length of stay (days) | 1.5 ± 1.1 | 1.5 ± 0.8 | 0.941 |

*eGFR* estimated glomerular filtration rate

*eGFR ≥ 125 mL/min per 1.73 m$^2$

[a] $P < 0.001$ compared to baseline value determined by paired *t* test

**Table 4** Hemoglobin, body mass index, and kidney function at12-month follow-up after bariatric surgery

| | Anemia group ($n = 38$) | Non-anemia group ($n = 303$) | $p$ value |
|---|---|---|---|
| Hemoglobin (g/dL) | 10.9 ± 2.4 | 13.2 ± 1.7 | < 0.001 |
| Hematocrit (%) | 34.2 ± 6.3 | 40.2 ± 4.9 | < 0.001 |
| Serum iron (μg/dL) | 69.7 ± 49.6 | 104.9 ± 46.3 | 0.002 |
| eGFR (mL/min per 1.73 $m^2$) | 100.0 ± 32.9[a] | 109.4 ± 24.8[a] | 0.118 |
| Glomerular hyperfiltration* | 3 (7.9%) | 36 (11.9%) | 0.596 |
| eGFR < 60 (mL/min/1.73 $m^2$) | 1 (2.6%) | 1 (0.2%) | 0.211 |
| Serum creatinine (mg/dL) | 0.7 ± 0.1 | 0.7 ± 0.2 | 0.808 |
| C-reactive protein (mg/dL) | 1.2 ± 0.5 | 1.8 ± 0.9 | 0.203 |
| Excessive weight loss (%) | 91.0 ± 28.3 | 93.9 ± 22.9 | 0.533 |
| BMI (kg/$m^2$) | 27.8 ± 4.8 | 27.6 ± 4.4 | 0.886 |
| Percentage weight loss (%) | 27.0 ± 8.1 | 30.0 ± 7.3 | 0.041 |

*eGFR* estimated glomerular filtration rate; *BMI* body mass index

*eGFR ≥ 125 mL/min per 1.73 $m^2$

[a] $P < 0.001$ compared to baseline value using paired $t$ test

in patient characteristics, BMI, comorbidities (e.g., diabetes), inflammatory parameters, metabolic profiles, and baseline eGFR before surgery (Tables 1 and 2). Although the preoperative drug information was not available, most confounding factors in our study appear to be well controlled.

n patients with obesity, kidney dysfunction is initially characterized by glomerular hyperfiltration, followed by proteinuria, and, eventually, glomerular hypofiltration [30, 31]. Glomerular hyperfiltration may lead to long-term glomerular damage and deterioration in kidney function. In our study population, the prevalence of glomerular hyperfiltration in the anemia group was 34.2%, whereas it was 28.4% in the non-anemia group. Our results were comparable to those reported by Hou et al. who reported a prevalence of glomerular hyperfiltration in 26.2% of their Asian study population [32]. In contrast, the prevalence of glomerular hyperfiltration was previously reported to be 5.2% in non-Asian obese patients [22]. The conflicting results may be attributable to racial and ethnic disparities in the rate of kidney function decline before the onset of chronic kidney disease [33].

Many observational studies have established that weight loss after bariatric surgery may improve renal parameters or retard the progression of chronic kidney disease in patients with obesity [34–36]. To the best of our knowledge, only two studies which focused on the Asian population assessed changes in kidney function after bariatric surgery [23, 32]. The results of both studies demonstrated the effectiveness of bariatric surgery for improving glomerular hyperfiltration in patients with obesity [23, 32]. Our study further demonstrated that the eGFR improved at 1-month and 1-year follow-ups after bariatric surgery (Tables 3 and 4). Subsequent declines in eGFR could thus reflect the overall improvements in glomerular hyperfiltration in our patients.

The lack of significant positive correlation between changes in BMI and eGFR may be explained, at least partly, by the previous finding that consumption of hypocaloric diet for only 1 month could result in a reduction of proteinuria by up to 26% when the decrease in body weight was no more than 3% [37]. The finding was consistent with that of the present study in which the number of patients with preoperative glomerular hyperfiltration plummeted by over 50% with a percentage body weight loss of only about 10% in both groups 1 month after surgery (Table 3). Besides, a previous study has shown that even 1 week of high protein consumption could significantly increase the glomerular filtration rate by 5 mL/min in obese patients [38]. Together with the reported reduction in protein intake after bariatric surgery in the obese population [39], it is rational to speculate a notable postoperative decrease in eGFR. Therefore, beside weight reduction, dietary factors may have a role to play in the observed postoperative drops in eGFR in both groups in the current study).

Interestingly, the percentage weight loss in the non-anemia group was significantly higher than that in those with preoperative anemia 1 year after bariatric surgery (30.0 ± 7.3% vs. 27.0 ± 8.1%, respectively; $p = 0.041$). Although the underlying mechanisms for this finding remain unclear, blood hemoglobin concentration has been found to be positively correlated with maximal aerobic power and endurance performance [40]. Because exercise following bariatric surgery has been reported to be associated with a greater weight loss (i.e., over 4% BMI) compared to those without exercise [41], better exercise tolerance in those without preoperative anemia in the present study may partly account for the more significant weight loss compared to that in their anemic counterparts.

There are several limitations to be considered when interpreting our findings. First, the nature of the present investigation, which is a small-scale retrospective study at a single tertiary referral center, may have biased our results toward the null. Second, eGFR was used as a surrogate marker for postoperative kidney function, while the effects of unmeasured confounders (e.g., blood pressure) on the kidney function were not assessed and data on urinary albumin excretion or other measures of kidney function were not available. Third, there is no consensus on the optimal methods for measuring kidney function in patients with obesity. eGFR, calculated based on the Chronic Kidney Disease Epidemiology Collaboration Equation, may underestimate kidney function in patients with morbid obesity [42]. Fourth, because postoperative AKI was reported to occur at the median interval of 10 days following bariatric surgery [10], we were unable to determine the incidence of postoperative AKI in our patients who had relatively short hospitalization stays of only about 1.5 days. However, patients with eGFR < 60 mL/min/1.73 $m^2$ were observed in both groups during the study period (Tables 3 and 4), raising the possibility that postoperative development of AKI may contribute to worsening of renal function in subsequent follow-ups as previously reported [10]. Fifth, since our study included only Asian patients with eGFR ≥ 90 mL/min/1.73 $m^2$ who underwent laparoscopic bariatric surgery, the data may not be extrapolated to non-Asians. Finally, because eGFR may decrease in obese patients with preoperative glomerular hyperfiltration but increase in those with preoperative glomerular hypofiltration in response to renal function improvement, those with preoperative renal dysfunction were excluded to prevent conflicting interpretation of study results. Besides, elderly patients were also excluded to avoid the confounding effect of age on the present study [43]. Therefore, the findings of the present study could not be extrapolated to the above patient populations or patients undergoing open bariatric surgery. Further studies should be conducted to investigate whether preoperative anemia further negatively impact renal function in subgroup patients (e.g., elderly patients or patients with preexisting renal dysfunction).

## Conclusion

The results of the present study showed that preoperative anemia was not associated with increased risk of renal impairment or prolonged hospital stay during 1-year follow-up. However, to attain favorable weight loss, preoperative correction of anemia and optimization of nutritional deficiencies should be considered.

**Compliance with Ethical Standards** The protocol of the whole study was reviewed and approved by the institutional research board (IRB) (Approval No. 20181119B). Informed patient consent was waived due to the retrospective nature of this study.

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

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed Consent** This article does not contain any studies with human participants or animal performed by any of the authors. For this type of study, formal consent is not required. Informed consent does not apply to the submission.

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