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ORIGINAL PAPER

Short- and Long-Term Impact of Metabolic Surgery on Obesity Outcomes in Iranian Non-Diabetic Obese Patients

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ABSTRACT

Introduction: *Metabolic surgery (MS) has been demonstrated to achieve sustained weight loss with significant improvement of metabolic parameters, including reduced cardiovascular diseases and diabetes. This study aimed to evaluate the effect of MS on obesity outcomes and cardiovascular risk factors in Iranian non-diabetic obese patients.*

Methods: *This retrospective follow-up study included non-diabetic obese patients with a body mass index (BMI) of 30 kg/m² or higher who underwent MS (LSG or GB) in a single institution in Ahvaz, Iran, from April 2019 to March 2023. Of the 162 reviewed patients, 139 subjects (85.80%) who completed one-year follow-up visits were included in this study. Medical history, anthropometric, biochemical parameters, comorbidities and Framingham risk score (FRS) were evaluated at baseline and annual visits after MS.*

Results: *The mean weight and BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), FRS, lipid profile, liver enzymes and fasting blood glucose (FBS) were significantly improved 12 months postoperatively. The percentage of total weight loss (%TWL) and BMI loss (%BMI) was 30.32±8.14 and 30.32±8.14, respectively, at the one-year follow-up after surgery. At one-year follow-up, a significant resolution of hypertension and dyslipidemia was observed in 44.4% and 73.9% of patients, respectively, and this improvement was stable throughout the follow-up period, with no significant difference between procedures. The type of MS had no effect on changes in weight and BMI at one-year and long-term follow-up after surgery (P>0.05), except the mean weight loss was greater with RYGB than LSG at one-year follow-up*

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(P=0.043). Surgery-related side effects were observed in eight cases (5.8%), and there was no difference between the two types of MS (P=0.931).

Conclusion: *Our results indicate that MS is a safe and effective procedure for reducing obesity-related complications and improves cardiovascular risk profiles in non-diabetic patients with a BMI of ≥30 kg/m².*

Keywords: bariatric surgery, obesity comorbidities, cardiovascular risk factors.

INTRODUCTION

Obesity is a serious and costly chronic disease (1) that currently affects 13% of the global adult population (2). Despite recent advancements in medicine and public health, the prevalence of obesity continues to increase at an alarming rate (3, 4). Various degrees of obesity are associated with an increased risk of developing a wide range of diseases, including type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVDs), hypertension, stroke, various types of cancer and mental health disorders (3, 5, 6).

Currently, gastrointestinal surgeries are the most rapid and effective methods for achieving significant and sustainable weight loss in obese individuals. These procedures are collectively referred to as bariatric surgery (with the aim of weight loss) or metabolic surgery (for reducing cardiometabolic risk) (3, 4). Metabolic surgery (MS), in addition to being the most effective treatment for weight reduction, is also known for its beneficial effects in mitigating cardiovascular risk factors, including improvements in diabetes, hypertension and hyperlipidemia (5-8). Furthermore, a limited number of studies have evaluated the impact of MS on reducing the Framingham risk score (FRS), which predicts the risk heart attack, and have confirmed the reduction in cardiovascular risk following MS (5, 9, 10). However, related studies in Iran are limited.

In recent years, the indications for MS have evolved due to its potential benefits, and MS is now recommended as an appropriate option for all individuals with a body mass index (BMI) of 35 kg/m² or higher, regardless of the presence or absence of underlying diseases. Additionally, it is advised for patients with mild obesity (BMI 30–34.9 kg/m²) with metabolic disorders who have not achieved significant outcomes (sustained weight loss and improvement of obesity-related complications) through non-surgical approaches (11).

Despite the well-established benefits of MS in improving obesity-related complications, most studies have primarily focused on its impact on diabetes remission (12, 13) with fewer studies conducted on non-diabetic patients. On the other hand, a significant proportion of obese patients suffer from underlying conditions other than diabetes (10). Moreover, due to racial and ethnic variations, the findings of previous studies may not be generalizable to the Iranian population undergoing MS. Given that indications for MS vary widely from one country to another, a comprehensive evaluation of its outcomes across different regions is essential. Therefore, the present study aimed to assess the effects of common MSs, including laparoscopic sleeve gastrectomy (LSG) and gastric bypass (GB) (4, 14), on obesity-related outcomes (hypertension and hyperlipidemia) and the FRS in Iranian non-diabetic patients. ❑

METHODS

Study design

This retrospective follow-up study was conducted on non-diabetic obese patients with BMI ≥30 kg/m² who underwent MS at Naft Hospital in Ahvaz, Iran, between April 2019 and March 2023. The study protocol was approved by the research ethics committee of Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran (ethical code: IR.AJUMS.HGOLESTAN.REC.1403.087). This study was conducted according to the guidelines established by the Declaration of Helsinki.

Patients

The sample size was estimated using G*POWER software and based on the previous study by Alamro *et al* (5), with a 95% confidence interval (α=0.05), 90% power (β=0.1) and effect size of

0.27 to be 138 patients and considering a 5% dropout rate, 145 patients included the study. Participants were selected using a convenience sampling method based on the following eligibility criteria:

- *inclusion criteria* – age between 18–65 years, undergoing MS (LSG, or GB) for the first time and having a BMI ≥ 30 kg/m^2 with or without obesity-related comorbidities; patients were eligible to participate if they had completed one-year of follow-up visits.
- *exclusion criteria* – patients with type 1 or type 2 diabetes mellitus (DM), active substance use, history of organ transplant, history of cancer in the past two years, history of severe liver disease with ascites, pregnancy during follow-up and less than one-year follow-up or incomplete clinical data after surgery.

Of the 162 patients reviewed by us, 139 subjects who completed the one-year follow-up were included in this study, of whom 70 had a five-year follow-up.

Data collection

Data were collected from the patient's medical records. Demographic information, anthropometric measures, medical history including comorbidities and medications, smoking, blood pressure and biochemical parameters were obtained for all participants. All data were collected at baseline (preoperatively) and 12 months and annual visits until five-year postoperatively.

Laboratory parameter assessed included complete blood count (CBC); lipid profile, including HDL-cholesterol (HDL-C), LDL-cholesterol (LDL-C), triglycerides (TG) and total cholesterol (TC); liver function tests, including alanine aminotransferase (ALT), aspartate aminotransferase (AST); fasting blood glucose (FBS) and serum Vitamin D (25-OH Vitamin D). For all tests, venous blood samples were taken from patients after at least eight hours fasting.

Hypertension was diagnosed if either SBP was ≥140 mm Hg and/or DBP was ≥90 mm Hg or subjects consumed antihypertensive medications (15). Hyperlipidemia was defined as the presence of either following criteria: TC ≥ 200 mg/dL, TG≥ 150 mg/dL, LDL-C ≥ 130 mg/dL, and HDL-C< 40 mg/dL or being under treatment with lipid-lowering drugs (16).

The values of FRS for coronary heart disease were evaluated using the MedCalc online calculator (available at: https://www.mdcalc.com/calc/38/framingham-risk-score-hard-coronary-heart-diseas). The main components for estimated FRS were age, sex, smoking status, TC, HDL, SBP and use of medication for treating high blood pressure (BP).

The type of MS was selected for each patient according to standard protocols and indications and all procedures were performed by the same group of surgeons using the same standardized techniques and instruments. Any surgery-related adverse events, including gastrointestinal bleeding, anemia and mortality, were monitored and recorded. All patients received nutritional advice from a dietitian after surgery as well as physical activity counseling. In addition, they were treated for other comorbidities according to standard guidelines.

Outcome definitions

Patients weight was evaluated at annual visits after MS. The BMI was determined as weight (kg) divided by height squared (kg/m^2). Weight loss, BMI change, percentage BMI loss (% BMIL), percentage of total weight loss (%TWL) and percentage of excess weight loss (EWL%) were calculated as follows:

BMI change = post-op BMI – initial BMI
%BMIL = (pre-op BMI – post-op BMI) / (pre-op BMI) × 100
%TWL = (pre-op weight – post-op weight) / (pre-op weight) × 100
%EWL = (pre-op weight – post-op weight) / (pre-op weight – ideal body weight) × 100

The ideal weight was defined by the weight corresponding to a BMI of 25 kg/m^2 (17).

Comorbidities, including hypertension, dyslipidemia, cardiovascular diseases and FRS, were evaluated based on medical history, medications and laboratory results, and imaging findings during preoperative and postoperative visits. Two team members independently reviewed all patients' medical records to verify data accuracy. The status of postoperative comorbidities was defined according to the standards reported by the American Society for Metabolic and Bariatric Surgery (ASMBS). Based on these criteria, patients were classified into two categories: resolved (complete resolution or improvement of the comorbidity) and non-resolved (unchanged or worsening of the condition) (8).

Statistical analysis

Continuous variables were reported as mean ± standard deviation (SD) or median (Q1-Q3), and categorical variables were expressed as frequency (percentage). The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Independent t-test was used to compare quantitative variables and chi-square test was applied for qualitative variables. Spearman's correlation coefficient was used to assess associations between continuous variables. For intragroup comparisons over time, one-way ANOVA with repeated measures (or the Friedman test) was used. Wilcoxon signed-rank test with Bonferroni correction was used for pairwise comparisons between time points. Cochran's Q test was used to evaluate changes in comorbidity status over time. All statistical analyses were conducted using IBM® SPSS® version 22 (SPSS Inc., Chicago, IL, USA) for Windows and a P-value < 0.05 was considered statistically significant. ❑

RESULTS

A total of 139 patients (87.1% females) with the mean age of 40.04±11.70 years were included in the present study (Table 1). Among them, 106 subjects (76.26%) underwent LSG, eight (5.76%) Roux-en-Y gastric bypass (RYGB) and 25 patients (17.98%) mini-gastric bypass (MGB). The follow-up rates at one year and five years were 85.8% (n=139) and 50.4% (n=70), respectively.

TABLE 1. Baseline characteristics of patients

Variable		
Age (year), mean ± SD		40.04 ± 11.70
Gender, n (%)	Female	121 (87.1)
	Male	18 (12.9)
Weight (kg), mean±SD		114.29 ± 16.67
Height (cm), mean±SD		161.81 ± 7.89
BMI (kg/m^2), mean±SD		43.53 ± 4.43
Active smoker, n (%)		7 (5.0)
Hypertension		27 (19.4)
Hyperlipidemia		23 (16.5)
CAD		5 (3.6)
Stroke		1 (0.7)
Metabolic surgery, n (%)	LSG	106 (76.26)
	GB*	33 (23.74)

CAD=coronary artery disease; LSG=laparoscopic sleeve gastrectomy; GB=gastric bypass

*Patients who underwent Roux-en-Y gastric bypass and mini-gastric bypass procedures were assessed in one group as GB due to the small number of subjects.

Patients' mean weight decreased significantly from 114.29 ± 16.67 kg preoperatively to 80.21 ± 15.26 kg at the one-year follow-up (P<0.0001). Similarly, the mean BMI decreased from 43.53 ± 4.43 kg/m^2 preoperatively to 30.44 ± 4.74 kg/m^2 at the one-year follow-up (P<0.0001) (Figure 1 and Table 2). At the one-year follow-up, the mean %TWL was 30.32 ± 8.14, the mean %EWL 72.81 ± 21.03 and the mean %BMI loss 30.32 ± 8.14.

Repeated measures ANOVA showed that changes in weight and BMI over time were statistically significant (P<0.0001). However, %TWL, %EWL and %BMIL did not show significant differences in assessments at one year, 2–4 years and five years (P>0.05). Additionally, the Wilcoxon signed-rank test indicated that the mean weight and BMI at one-year, 2–4-year and five-year follow-ups were significantly lower than preoperative values (P<0.05) (Table 2).

At the one-year follow-up after surgery, 18 patients (12.95%) achieved their ideal weight, while 24 patients (17.27%) were within ≤5 kg of their ideal weight. Among the 70 patients who completed the five-year follow-up, four patients (5.71%) had achieved their ideal weight and 15 patients (21.43%) were within ≤5 kg of their ideal weight. At the five-year follow-up, 34 patients (48.57%) maintained their initial weight loss.

The results demonstrated a significant improvement in both systolic and diastolic BP at the one-year follow-up after MS compared to preoperative values (P<0.0001), and this improvement remained stable up to long follow-up (Table 3). Systolic and diastolic BP levels at the one-year and long (2–5 years) follow-ups were significantly lower than preoperative values (P<0.05). However, no significant difference was observed between the one-year and long-term follow-ups (P>0.05).

The changes in FRS over time were statistically significant (P<0.0001). Pairwise comparisons showed that FRS values at both the one-year and 2–4-year follow-ups were significantly lower than preoperative values. Additionally, there was a significant difference between the one-year and long-term follow-ups (P<0.05). However, no significant differences were found between the 2–4-year and five-year follow-ups or be-

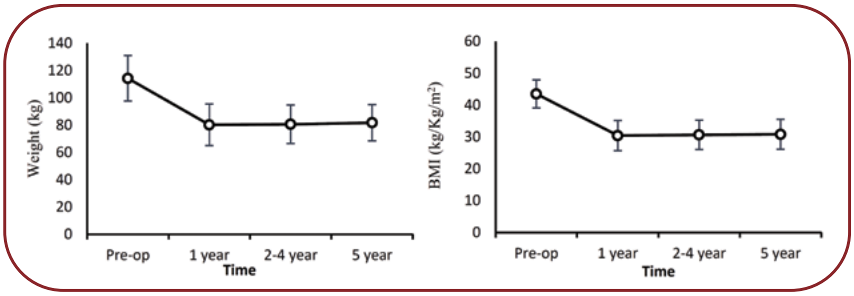

FIGURE 1. Weight and changes of body mass index (BMI) pre- and postoperatively

TABLE 2. Weight and changes of body mass index (BMI) pre- and postoperatively

Variable	Preoperatively	One year postoperatively	2-4 years postoperatively	Five years postoperatively	P-value*
Weight (kg), mean±SD	114.29±16.67	80.21±15.26#	80.6±14.08#	81.74±13.35#	<0.0001
BMI (kg/m^2), mean±SD	43.53±4.43	30.44±4.74#	30.67±4.63#	30.82±4.71#	<0.0001
TBWL (kg), mean±SD	-	34.90±10.66	34.48±13.56	34.99±12.27	0.924
%TWL, mean±SD	-	30.32±8.14	29.60±9.54	29.76±9.34	0.931
EWL, mean±SD	-	72.81±21.03	70.61±22.63	70.45±23.42	0.970
BMI change (kg/m^2), mean±SD	-	13.26±3.86	13.04±4.75	13.10±4.29	0.927
%BMI loss, mean±SD	-	30.32±8.14	29.60±9.54	29.76±9.34	0.931

BMI=body mass index; TBWL=total body weight loss; %TWL=percent total body weight loss;
% EWL=percent excess weight loss; % BMIL=percentage BMI loss
*P-values were determined by one-way ANOVA with repeated measures.
# indicates a significant change (P<0.05) compared to preoperative values.

TABLE 3. Comparison of cardio-metabolic and biochemical variables pre- and postoperatively

Variable	Preoperatively	One year postoperatively	2-4 years postoperatively	Five years postoperatively	P-value*
SBP (mm Hg), mean±SD	117.37±10.70	114.47±8.47#	113.89±8.84#		<0.0001
DBP (mm Hg), mean±SD	73.90±7.62	72.99±7.32#	72.45±7.21#		0.003
FRS (%), mean±SD	1.51±2.74	0.97±2.05#	1.27±2.52#	1.47±2.90$	<0.0001
HDL-C (mg/dL), mean±SD	44.87±12.01	52.59±10.71#	53.34±10.82#	52.61±10.93#	<0.0001
LDL-C (mg/dL), mean±SD	121.60±32.76	108.71±32.67#	107.93±30.51#	110.74±31.30#	<0.0001
TG (mg/dL), mean±SD	161.39±77.65	94.95±34.09#	100.26±43.25#	101.48±39.02#	<0.0001
TC (mg/dL), mean±SD	199.55±39.00	180.68±36.30#	180.66±35.54#	182.38±36.86#	<0.0001
AS (U/L), mean±SD	26.14±13.02	19.25±5.91#	20.27±9.75#	19.86±8.33#	<0.0001
ALT (IU/L), mean±SD	28.99±18.46	18.40±8.00#	19.23±11.41#	18.92±10.03#	<0.0001
ALP (IU/L), mean±SD	190.65±50.03	173.73±47.57#	173.25±44.02#	167.70±39.34#	<0.0001
FBS (mg/dL), mean±SD	100.65±11.44	89.94±8.67#	89.99±9.52#	91.08±9.46#	<0.0001
WBS ($\times 10^9$/L), median (Q1-Q3)	9100.00 (7600.00-10200.00)	7000.00 (6100.00-8100.00)#	7000.00 (6100.00-8000.00)#	7000.00 (6175.00-8050.00)#	<0.0001
Hb (g/dL), median (Q1-Q3)	12.40 (11.50-13.30)	12.30 (11.50-13.10)	12.30 (11.30-13.00)	12.20 (11.15-12.90)	0.671
PLT ($\times 10^3$ µL), median (Q1-Q3)	287000.00 (249000.00-338000.00)	260000.00 (214000.00-300000.00)#	252000.00 (211000.00-300000.00)#	264000.00 (222250.00-314250.00)#	<0.0001
MCV (fL), median (Q1-Q3)	85.00 (80.00-88.00)	85.00 (80.00-88.00)	85.00 (78.00-88.00)	83.00 (75.00-86.25)	0.099
25-OH VitD (ng/mL), median (Q1-Q3)	20 (15-30)	30 (20.75-38.50)#	28 (18.20-37.50)#		<0.0001

SBP=systolic blood pressure; DBP=diastolic blood pressure; FRS=Framingham risk score; HDL-C=high-density lipoprotein cholesterol; LDL-C=low density lipoprotein cholesterol; TG=triglyceride; TC=total cholesterol; AST=aspartate aminotransferase; ALT=alanine aminotransferase; ALP=alkaline phosphatase; FBS=fasting blood sugar; WBC=white blood cells; Hb=hemoglobin; PLT=platelet count; MCV=mean corpuscular volume.
*P-values were determined by Friedman's test.
#indicates a significant change (P<0.05) compared to preoperative values.
$Indicates a significant change (P<0.05) between one-year and long-term follow-up.

tween the one-year and 2–4-year follow-ups (P>0.05) (Figure 2, Table 3).

The results also indicated that all lipid profile parameters and liver function tests had a significant improvement at the one-year follow-up after MS compared to preoperative levels, and this improvement remained stable until the five-year follow-up. In contrast, changes in hemoglobin (Hb) and mean corpuscular volume (MCV) over time were not statistically significant (P=0.671

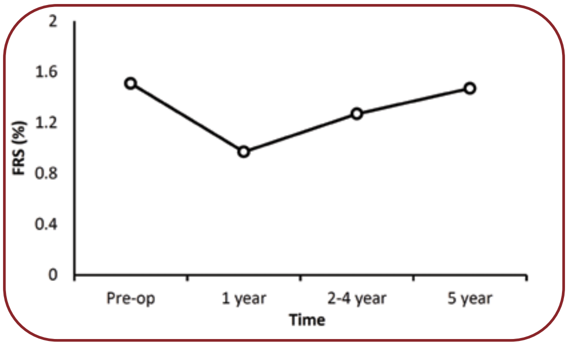

FIGURE 2. Framingham risk score (FRS) changes pre- and postoperatively

and P=0.099, respectively). On the other hand, significant changes were observed in FBS, white blood cell (WBC) count, platelet count (PLT) and serum 25-OH vitamin D levels over the follow-up period (P<0.0001) (Table 3).

At the one-year follow-up, a significant resolution of hypertension and hyperlipidemia was observed in 44.4% and 73.9% of patients, respectively and this improvement remained stable throughout the long-term follow-ups. There was no significant difference in the incidence of hypertension and hyperlipidemia between the MS procedures in one-year (P=0.212 and P=0.883, respectively) and long-term follow-up (P=0.638 and P=0.759, respectively). Moreover, no new cases of CVDs (including myocardial infarction [MI], coronary artery disease [CAD], stroke, atrial fibrillation [AF], or heart failure [HF]) were reported during the follow-up period.

Cochran's Q test results demonstrated a significant reduction in prevalence of hypertension and dyslipidemia at three time points: preoperatively, one year and long-term (2-5 years) postoperatively (P<0.0001 for both conditions). While the improvement was significant at the one-year follow-up (P<0.0001 for both conditions), there was no significant difference between the one-year and long-term follow-ups (P=0.988 and P=0.083, respectively) (Table 4).

Surgery-related adverse events were observed in eight patients (5.8%), including five cases (3.6%) of cholecystectomy, two cases (1.4%) of gastrointestinal bleeding and one case (0.7%) of anemia requiring iron infusion. There was no significant difference in the rate of complications between LSG and GB (5.7% *vs*. 6.1%; P=0.931).

The mean weight change at one year (P=0.016) and five-year (P=0.048) fallow-up after surgery was significantly greater in men than in women. The mean weight loss was greater with GB than LSG at one-year follow-up (P=0.043) (Table 5). The type of MS had no effect on changes in BMI, at one-year and long-term follow-up after surgery (P=0.127 and 0.413, respectively) (Table 6). No significant differences were found in weight and BMI changes at one-year and long-term follow-ups after MS based on the presence of different comorbidities (P>0.05) (Tables 5 and 6).

TABLE 4. Comparison of comorbidities occurring pre- and postoperatively

Comorbidities	Preoperatively	One-year follow-up		Long follow-up (2-5 years)		P-value*
		Resolved	Non-resolved	Resolved	Non-resolved	
Hypertension	27 (19.4)	12 (44.4)	15 (55.6)	13 (48.1)	14 (51.9)	<0.0001
Hyperlipidemia	23 (16.5)	17 (73.9)	6 (26.1)	20 (87.0)	3 (13.0)	<0.0001

* Cochran's Q test

TABLE 5. Comparison of weight changes based on patient gender and presence of underlying diseases

Variable		Weight changes (kg) in one-year	P-value*	Weight changes (kg) in long-term	P-value*
Gender	Female	34.02±10.57	0.016	33.79±12.44	0.048
	Male	41.07±9.38		41.88±9.03	
Hypertension	No	35.10±10.77	0.683	34.82±12.50	0.853
	Yes	34.10±10.35		35.58±11.96	
Hyperlipidemia	No	35.21±10.95	0.496	35.05±12.59	0.919
	Yes	33.45±9.25		34.50±10.30	
Metabolic surgery, n (%)	LSG	33.76±9.85	0.043	35.24±10.75	0.765
	GB	38.29±12.33		33.99±17.62	

LSG=laparoscopic sleeve gastrectomy; GB=gastric bypass.
*Independent t-test

TABLE 6. Comparison of body mass index (BMI) changes based on patient gender and presence of underlying diseases

Variable		BMI changes (kg/m^2) in one-year	P-value*	BMI changes (kg/m^2) in long-term	P-value*
Gender	Female	13.19±3.91	0.600	12.95±2.93	0.545
	Male	13.76±3.56		13.96±4.50	
Hypertension	No	13.34±3.98	0.655	13.18±4.54	0.814
	Yes	12.95±3.42		12.84±3.47	
Hyperlipidemia	No	13.38±4.01	0.461	13.23±4.45	0.526
	Yes	12.70±3.09		12.04±2.84	
Metabolic surgery, n (%)	LSG	12.95±3.59	0.127	13.34±3.94	0.413
	GB	14.19± 4.51		12.14±5.56	

BMI=body mass index; LSG=laparoscopic sleeve gastrectomy; GB=gastric bypass.
*Independent t-test

There was a significant and positive correlation between the amount of weight loss and the reduction in FBS one year after surgery (r=0.190, P=0.038). However, this correlation was not significant for BMI (r=0.159, P=0.083).

No significant correlation was found between changes in weight, BMI, lipid profile and liver enzymes and the patients' age (P>0.05). However, a significant and positive correlation between changes in the FRS one year after MS and patient age (r=0.037, P<0.0001) was observed, which indicated that older patients experienced greater improvements in FRS. ❑

DISCUSSION

The results of the present study demonstrated that MS lead to a significant and sustained reduction in weight and BMI in non-diabetic obese patients during the one-year follow-up, with this reduction being maintained up to the five-year follow-up. Our findings are consistent with previous studies reporting that commonly performed MSs such as LSG and GB have substantial effects on weight loss (8, 18, 19). In a study by Alamro *et al*, MS in obese patients (BMI ≥30 kg/m^2) led to significant reductions in weight and BMI regardless of comorbidities (5). Lee *et al* reported that 26.9% of patients achieved substantial weight loss one year after MS and maintained this reduction over two- and three-year follow-ups (20).

The present study also showed that weight loss in the GB group was greater than in the LSG group during the one-year follow-up. Similarly, Tabesh *et al* in Iran found that the mean weight, BMI and %TWL significantly decreased one year after MS, and these reductions were more pronounced in the GB and one anastomosis gastric bypass (OAGB) compared to LSG (21). Other studies have also reported greater weight loss following GB compared to LSG (18, 22). The latest data from the 10-year follow-up of the SLEEVEPASS randomized clinical trial revealed a 50.7% reduction in EWL after RYGB and a 43.3% reduction after LSG (23). However, in a study by Baldwin *et al* in the United States on patients with class I obesity (BMI 30–34.9 kg/m^2), both RYGB and LSG produced has comparable and successful weight loss outcomes (8).

Despite the increasing use of various bariatric and metabolic surgical procedures, the underlying mechanisms of their effectiveness have not been fully clarified. Metabolic surgery induces weight loss through mechanisms including malabsorption, caloric intake restriction, as well as changes in eating behaviors, appetite, taste and olfactory senses, food aversion, and hormonal changes (24, 25). However, based on the present findings, GB resulted in greater weight loss compared with LSG, which may be attributed to the malabsorption effects of this procedure (21).

The improvement of obesity-related comorbidities is one of the main goals of MS. According to previous reports, different types of MS are successful in resolving comorbidities such as DM, HTN and dyslipidemia (7, 18, 21). In the present study, MS at one-year follow-up showed significant results regarding the improvement of BP, lipid profile parameters and obesity-related diseases such as hypertension and dyslipidemia, and this improvement remained stable through the five-year follow-up.

In the study by Khalaj *et al*, both LSG and RYGB procedures showed considerable effects on the remission of hypertension (39.1% and 54.7%, respectively) and dyslipidemia (14.2% and 29.8%, respectively) at two years after surgery (18). Similarly, Tabesh *et al* revealed that MSs (LSG, GB and OAGB) significantly reduced cardiometabolic risk factors and obesity-related diseases; also, significant improvements were observed in FBS, lipid profile and obesity related comorbidities such as dyslipidemia at one-year follow-up, and these improvements did not differ by surgical technique (21).

In the study by Berry *et al*, significant improvement in comorbidities was observed during the three-year follow-up after LSG surgery, with dyslipidemia and hypertension improving in 52% and 75% of patients, respectively (1). Baldwin *et al* also reported that RYGB and LSG in patients with class I obesity had similar and successful outcomes in improving obesity-related comorbidities, and at one-year follow-up remission of hypertension and dyslipidemia was observed in 57.1% and 61.54% of patients, respectively (8). Likewise, Ali *et al* reported that LSG in morbidly obese patients led to significant reductions in BP, with 90% improvement in hypertension and 95% in dyslipidemia at one year post-operatively, which remained stable in long- time (26). In another study conducted by Alamro *et al* on obese patients (BMI ≥30 kg/m²) undergoing MS, there were significant reductions in systolic and diastolic BP at one-year follow-up, and the prevalence of hypertension decreased from 78.1% to 22.5% after surgery (5). A large meta-analysis also reported improvement in hypertension in 63.7% of patients following MS (27).

Since hypertension is one of the components of metabolic syndrome and is associated with obesity, and given that many studies have shown that weight loss can reduce blood pressure (28, 29), the results obtained by us support that MS is an effective strategy for controlling BP in obese individuals.

In agreement with our findings, Jiménez *et al*'s study of short- and long-term outcomes of GB performed found a significant improvement in TC, LDL-C and TG levels and increased HDL-C at 3, 6, 9, 12, 18 and 24 months after MS compared to preoperative values (30). The improvement in lipid profile might be attributed to reduction in gastric volume leading to decreased gastric lipase production (31) or the malabsorptive influence of MS (32). Similar enhancements in lipid metabolism and lipid profile parameters following MS have been reported in other studies as well (5, 10, 21, 33).

Our findings also indicated a significant reduction in the FRS one year following MS compared to preoperative levels, with greater reductions being observed in patients with hypertension and hyperlipidemia. Additionally, a direct and significant correlation between FRS changes and patient age was found. These results suggest that MS can help reduce the risk of CADs, particularly in older non-diabetic patients suffering from hypertension and hyperlipidemia, which are all known cardiovascular risk factors.

Consistent with these findings, Alamro *et al* reported a significant decrease in FRS one year after MS (5). Similarly, in a study by Schiavon *et al*, MS led to a notable reduction in FRS in obese patients with hypertension (10). Jeon *et al* also reported a significant decrease in FRS at one year after RYGB and LSG in obese patients without prior CVDs, with no significant difference in FRS reduction between the two surgical techniques (34). Reduction of cardiovascular risk following MS has also been documented in other studies (30, 34, 35).

These findings highlight the promising role of MS as an effective weight loss strategy in lowering FRS, which reflects the risk of CAD, and in improving other potential cardiovascular risk factors such as hypertension and hyperlipidemia. However, since the CVD risk varies depending on dietary patterns, lifestyle and ethnic-racial origin, it is difficult to generalize these results to other populations (34, 35).

In the present study, the type of MS had no effect on changes in lipid profile after surgery. In other studies, the type of MS had no effect on changes in lipid profile and improvement of dyslipidemia 12 months after surgery (36, 37). However, previous studies have indicated that various MS procedures have different effects on lipid profiles, where malabsorptive procedures like RYGB considerably affect LDL-C and TC more than restrictive procedures such as LGS (38). In malabsorptive surgery, cholesterol absorption decreases while cholesterol synthesis increases, which is associated with enhanced hepatic catabolism. Fat malabsorption leading to increased fecal fat excretion and elevated intestinal oxalate absorption have been implicated in the improvement of postprandial lipemia (*i.e.*, increased concentration of lipids in the blood) in patients undergoing this type of surgery. For restrictive procedures, a reduction in gastric volume and a decrease in the production of gastric lipase and cholecystokinin result in decreased hydrolysis of

TGs, leading to reduced absorption of free fatty acids (31).

The current study found that liver function tests including AST, ALT and ALP significantly improved at one-year follow-up after MS compared to before surgery, and this improvement remained stable up to five-year follow-up. This agrees with previous studies (39, 40). Moreover, Alamro *et al*, showed a significant improvement at 12 months postoperatively in AST and ALT serum levels (5).

In the present study, FBS significantly decreased in one-year follow-up after MS, and this reduction remained stable until long-term. There is substantial evidence to support the view that, MS is a valuable strategy not only for treating diabetes but also for glycemic control in nondiabetic patients with severe obesity (21, 33). Similarly, Saleh *et al* reported a significant improvement in blood glucose levels following MS in obese non-diabetic patients (41). Schiavon *et al* also found that FBS significantly decreased one year after MS in non-diabetic obese patients (10).

According to our results, the TWL was directly and significantly associated with the improvement in FBS, suggesting that weight loss has a potential effect on the improvement of glucose control. This finding is consistent with the results of Tabesh *et al*, who also reported a significant correlation between TWL and FBS improvement (21). Evidence suggests that weight loss may improve glucose control and insulin sensitivity, but other mechanisms are likely involved. Indeed, postoperative changes in the gastrointestinal tract anatomy may reduce blood glucose levels through the activation of multiple gastrointestinal-related mechanisms (42).

In our study, surgery-related complications were observed in only 5.8% of patients during the follow-up period, with no significant difference in adverse events across different surgical procedures and no mortality was reported, indicating that MS is a safe and effective metabolic intervention in non-diabetic obese patients. Postoperative complications have significantly declined with the advent of laparoscopic techniques. The intraoperative mortality rate ranges from 0.1% to 1.1%, while intraoperative complications widely vary from 2% to 20%, depending on the type of procedure and patient characteristics (1, 3, 33). A large comparative study on the complications of MS found no significant differences in mortality or complication rates between RYGB and LSG techniques (43).

Ultimately, this retrospective follow-up study evaluated various metabolic outcomes following MS. To our knowledge, it is the first comprehensive study on the effects of common MS in non-diabetic obese patients in Iran. However, this study had several limitations. Due to its retrospective nature, issues such as missing data and insufficient follow-up led to the exclusion of many patients from studywe and were unable to control confounding factors such as calorie intake, diet and physical activity. In addition, our findings representative of the one specialized surgical center for MS (Naft Hospital in Ahvaz city) and reflect current medical practice, limiting the generalizability of the results to other populations or regions. Furthermore, consecutive sampling led to inconsistency in the proportion of surgical types, with a predominance of LSG cases.

Therefore, larger multicenter prospective studies are warranted to achieve more reliable and generalizable results. Future studies should aim to provide more robust evidence for better patient selection for MS based on relevant clinical factors and personalized considerations, rather than solely on BMI and diabetes. ❑

CONCLUSIONS

Performing metabolic surgery (LSG or GB) in non-diabetic patients with obesity (BMI ≥ 30 kg/m^2) is a safe, effective and durable procedure for reducing obesity-related complications and improves cardiovascular risk profiles. Diabetes and BMI should not be considered the only indications for bariatric and metabolic surgery. However, randomized studies comparing different MS procedures with longer term follow-up are needed. ❑

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