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ORIGINAL ARTICLE

Impact of Bariatric Surgery on Cardiovascular Risk Reduction in Korean Obese Patients

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Purpose: Morbid obesity is a well-known risk factor for cardiovascular disease (CVD). This study aimed to quantitatively evaluate the effects of bariatric surgery on CVD risk reduction in Korean obese patients by using three CVD risk prediction models (Framingham General Cardiovascular Risk Score [FRS], Pooled Cohort Equation [PCE], and Korean Risk Prediction Model [KRPM]), and to investigate which procedure between laparoscopic Roux-en Y gastric bypass (LRYGB) and laparoscopic sleeve gastrectomy (LSG) is a better option for CVD risk reduction. **Materials and Methods:** We retrospectively reviewed all obese patients who underwent bariatric surgery at a single institution from October 2009 to May 2016. Of the 1034 patients reviewed, 83 patients (6.5%) who met the criteria for calculating the FRS, PCE, and KRPM scores and had a follow-up of at least 1 year were included in this study. **Results:** The FRS, PCE, and KRPM scores were significantly decreased at postoperative 1 year (10.47±7.30% to 6.33±4.59%, P=0.000; 5.45±6.25% to 2.75±2.75%, P=0.000; and 4.53±2.96% to 3.49±2.13%, P=0.000, respectively) in LRYGB. The PCE and KRPM scores were significantly decreased (4.13±3.63% to 2.42±2.45%, P=0.004 and 4.14±1.95% to 3.22±1.94%, P=0.000, respectively) in LSG, but not the FRS (9.43±3.58% to 5.63±3.24%, P=0.118). There was no difference in absolute risk reduction in FRS, PCE, and KRPM between LRYGB and LSG (4.13±5.08% and 3.80±3.50%, P=0.788; 2.70±0.52% and 1.72±0.49%, P=0.799; and 1.03±1.85% and 0.92±0.97%, P=0.776, respectively). **Conclusion:** LRYGB and LSG can equally significantly decrease the CVD risk in the Korean population, based on FRS, PCE, and KRPM.

Key Words: Cardiovascular diseases, Risk assessment, Bariatric surgery, Roux-en-Y gastric bypass, Morbid obesity

INTRODUCTION

Morbid obesity and its associated comorbidities are important public health problems worldwide. Over the past several decades, the prevalence of obesity has been dramatically increasing in all populations. According to the updated data of the World Health Organization in 2017, the number of overweight and obese adults globally was >1.9 billion (39%) and >650 million (13%), respectively, in 2016, and the worldwide prevalence of obesity nearly tripled between 1975 and 2016 [1]. In Korea, the prevalence of obesity with a body mass index (BMI) of ≥30 kg/m^2 has rapidly increased, with the prevalence in 2013 (4.2%) being almost double that in 2002 (2.5%) [2]. As the obese population increases in number, the incidence of type 2 diabetes mellitus (T2DM), hypertension, dyslipidemia,

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cardiovascular disease (CVD), stroke, reproductive disorders, cancer, and other obesity-related comorbidities is also increasing, and the management of these conditions has enormous social costs [3].

Bariatric surgery has emerged as the best option for treating obesity and its related comorbidities, showing better effects than nonsurgical therapy such as diet and lifestyle modification or pharmaceutical therapy [4,5]. Many studies have already shown that bariatric surgery has significant benefits against T2DM, hypertension, and dyslipidemia, which are risk factors for CVD, thus suggesting that bariatric surgery may also improve CVD risk [6-9].

The Framingham General Cardiovascular Risk Score (FRS), revised in 2008 by the Framingham Heart Study, and the Pooled Cohort Equation (PCE), developed in 2013 by the American College of Cardiology and the American Heart Association (ACC/AHA), are generally used to quantitatively assess the 10-year CVD risk [10,11]. Several studies have addressed the efficacy of bariatric surgery in reducing the CVD risk based on either the FRS or PCE, or both [12-15]. However, some investigators demonstrated that FRS and PCE can overestimate the risk in populations in Europe and Asia including Korea [16-21]. To adjust these interpopulation differences, the Korean Heart Study introduced the Korean Risk Prediction Model (KRPM), which showed better discrimination and calibration than FRS and PCE in the Korean population [20,22,23]. To our knowledge, there has been no study on Asian populations about the effect of bariatric surgery on the CVD risk based on these prediction models.

In addition, studies on which kind of bariatric surgery would be more beneficial in improving the CVD score are rare. Several studies reported that laparoscopic Roux-en Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), and laparoscopic adjustable gastric banding reduced the CVD risk score; however, most of them were noncomparative studies [12,24-26] and only few studies directly compared LSG and LRYGB [13-15,27].

The aim of this study was to quantitatively evaluate the effects of bariatric surgery on CVD risk reduction in Korean obese patients by using three different CVD risk prediction models (FRS, PCE, and KRPM), and to investigate which procedure between LRYGB and LSG is the better option for CVD risk reduction based on differences in CVD risk scores.

MATERIALS AND METHODS

We retrospectively reviewed the prospectively collected medical records of Korean patients who underwent either of the two types of bariatric surgery (LRYGB or LSG) at Soonchunhyang University Hospital Obesity Surgery Center from October 2009 to July 2017. The data of patients aged between 40 and 74 years without CVD at the baseline examination were collected, and patients who met the criteria for calculating the risk scores were finally included.

Clinical parameters including age, sex, BMI, lipid profiles, systolic blood pressure (SBP), medical history including hypertension and T2DM, tobacco use, and types of surgery were collected before surgery and 1 year after surgery.

The CVD risk was assessed using FRS, PCE, and KRPM [10,11,20]. All three risk prediction models calculate the 10-year risk of CVD. Age, sex, SBP, total and high-density lipoprotein (HDL) cholesterol, smoking status, and treatment for hypertension and T2DM are considered in the FRS and KRPM calculations. In PCE, the risk is estimated using the same variables with additional racial consideration (either Caucasian or African American). In this study, we adopted the Caucasian model of PCE considering the recommendation of the ACC/AHA. PCE for Caucasians may be considered for risk estimation in Hispanics and Asians, although the risk may be overestimated in these populations [10]. FRS estimates the risk for coronary heart disease (coronary death, myocardial infarction, coronary insufficiency, and angina), cerebrovascular events (ischemic stroke, hemorrhagic stroke, and transient ischemic attack), peripheral artery disease (intermittent claudication), and heart failure. PCE and KRPM only calculate the risk of coronary heart disease mortality, nonfatal myocardial infarction, and stroke. We used Excel spreadsheets for calculating the FRS according to the Framingham Heart Study and the PCE score according to the AHA. They are available at https://

www.framinghamheartstudy.org/fhs-risk-functions/cardiovascular-disease-10-year-risk/ and https://professional.heart.org/professional/GuidelinesStatements/PreventionGuidelines/UCM_457698_ASCVD-Risk-Calculator.jsp. The KRPM score was calculated using Excel spreadsheets with the coefficients provided by the Korean Heart Study [20]. The heart/vascular age was also calculated using the FRS and previously mentioned variables. This calculation provides the estimated heart or vascular age of the patient in comparison with the real chronologic age. The maximum heart age that this tool can calculate is 86 years [11]. The ideal cardiovascular risk is obtained by calculating the PCE score with the mean age of the patient, BMI ≤25 kg/m^2, and no comorbidities [10]. Remission of T2DM was defined as normal measurements of glucose metabolism (glycated hemoglobin <6.5%, fasting blood glucose <126 mg/dL) in the absence of antidiabetic medications. Remission of hypertension was defined as a blood pressure of <140/90 mmHg without antihypertensive medications [28].

Table 1. Baseline characteristics of the patients who underwent between LRYGB and LSG

Variables	LRYGB (n=55)	LSG (n=12)	P value
Age (years)	48.40±6.18	47.33±5.77	0.586
Females	43 (78.18)	9 (75.00)	1.000
BMI (kg/m^2)	37.30±6.52	37.21±8.71	0.624
Total cholesterol (mg/dL)	210.20±36.76	203.00±35.96	0.540
HDL (mg/dL)	51.02±12.10	46.42±11.07	0.217
SBP (mmHg)	123.36±10.78	125.83±10.84	0.475
Hypertension	32 (58.18)	8 (66.67)	0.749
T2DM	27 (49.09)	7 (58.33)	0.562
Tobacco use	13 (23.64)	1 (8.33)	0.435
FRS (%)	10.47±7.30	9.43±3.58	0.474
PCE (%)	5.45±6.25	4.13±3.63	0.787
KRPM (%)	4.53±2.96	4.14±1.95	0.974
Heart/Vascular age (years)	63.44±14.89	64.75±10.63	0.521

Variables = number (%); HDL = high-density lipoprotein cholesterol; SBP = systolic blood pressure; FRS = Framingham CVD risk score; PCE = ACC/AHA pooled cohort equation; KRPM = Korean prediction model for ASCVD.

1. Statistical analysis

Categorical variables were described as counts and percentages, and continuous variables were presented as means and standard deviations after confirming that they follow a normal distribution based on the Shapiro-Wilk test. When comparing variables between groups, the t-test and Mann-Whitney test for continuous variables and the chi-square test and Fisher's exact test for categorical variables were used according to the test for normal distribution. For paired data comparison, paired t-test and Wilcoxon signed rank test for continuous variables and McNemar's test for categorical variables were used. All analyses and data summaries were generated using IBM SPSS Statistics SPSS version 21.0. Two-tailed P<0.05 was considered statistically significant.

Table 2. Changes in parameters related to CVD risk after bariatric surgery

Variables	Baseline	POD 1 year	ARR/AAR	RRR	P value
BMI (kg/m^2)	37.28±6.89	27.89±5.72			0.000
Total cholesterol (mg/dL)	208.91±36.45	171.61±33.35			0.000
HDL (mg/dL)	50.19±11.98	58.76±14.58			0.000
SBP (mmHg)	123.81±10.75	118.96±15.60			0.051
Hypertension	40 (59.70)	31 (46.27)			0.022
T2DM	34 (50.75)	26 (38.81)			0.021
Tobacco use	14 (20.90)	17 (25.37)			0.250
Ideal CVD risk (%)	1.14±0.92				
FRS (%)	10.28±6.78	6.21±4.36	4.07	40	0.000
PCE (%)	5.22±5.86	2.69±2.69	2.53	48	0.000
KRPM (%)	4.46±2.80	3.44±2.08	1.01	23	0.000
Heart/Vascular age (years)	63.67±14.16	52.40±14.39	11.27		0.000

Variables = number (%); HDL = high-density lipoprotein cholesterol; SBP = systolic blood pressure; FRS = Framingham CVD risk score; PCE = ACC/AHA pooled cohort equation; KRPM = Korean prediction model for ASCVD; ARR = Absolute risk reduction; AAR = Absolute age reduction; RRR = Relative risk reduction.

RESULTS

Of the 1034 patients who underwent bariatric surgery, a total of 67 patients (6.5%) who met the criteria for calculating preoperative and postoperative CVD risks were included. There was a female predominance, with women accounting for 77.61%. The mean patient age was 48.21±6.08 years, and the preoperative BMI was 37.28±6.89 kg/m^2. The proportions of patients with T2DM, hypertension, and cigarette smoking were 50.75%, 59.70%, and 20.90%, respectively. LRYGB was much more often performed (82.09%, n=55) than LSG (17.91%, n=12) in our study population. There was no statistically significant difference between the two groups in all characteristics described. The demographic characteristics of the two groups are shown in Table 1. Table 2 shows the changes in parameters related to CVD risk after bariatric surgery. The mean BMI decreased from 37.28±6.89 to 27.89±5.72 kg/m^2 at 1 year after surgery, and the resolution of hypertension and T2DM was achieved in 13% (P=0.022) and 12% (P=0.021) of patients, respectively. SBP also decreased from 123.81±10.75 to 118.96±15.60 mmHg (P=0.051) after bariatric surgery.

Table 3 shows the changes in parameters related to CVD risk between baseline and 1 year after LRYGB. The BMI, total cholesterol, HDL, hypertension, and all CVD risk

Table 3. Changes in parameters related to CVD risk after LRYGB

Variables	Baseline	POD 1 year	ARR/AAR	RRR	P value
BMI (kg/m^2)	37.30±6.52	27.86±5.31			0.000
Total cholesterol (mg/dL)	210.20±36.76	169.25±32.39			0.000
HDL (mg/dL)	51.02±12.10	59.93±15.15			0.000
SBP (mmHg)	123.36±10.78	119.09±16.57			0.132
Hypertension	32 (58.18)	24 (43.64)			0.021
T2DM	27 (49.09)	22 (40.00)			0.125
Tobacco use	13 (23.64)	16 (29.09)			0.250
Ideal CVD risk	1.18±0.98				
FRS (%)	10.47±7.30	6.33±4.59	4.13	39	0.000
PCE (%)	5.45±6.25	2.75±2.75	2.70	50	0.000
KRPM (%)	4.53±2.96	3.49±2.13	1.03	23	0.000
Heart/Vascular age (years)	63.44±14.89	52.58±14.79	10.86		0.000

Variables = number (%); HDL = high-density lipoprotein cholesterol; SBP = systolic blood pressure; FRS = Framingham CVD risk score; PCE = ACC/AHA pooled cohort equation; KRPM = Korean prediction model for ASCVD; ARR = Absolute risk reduction; AAR = Absolute age reduction; RRR = Relative risk reduction.

Table 4. Changes in parameters related to CVD risk after LSG

Variables	Baseline	POD 1 year	ARR/AAR	RRR	P value
BMI (kg/m^2)	37.21±8.71	28.04±7.63			0.000
Total cholesterol (mg/dL)	203.00±35.96	182.42±36.96			0.080
HDL (mg/dL)	46.42±11.07	53.42±10.55			0.091
SBP (mmHg)	125.83±10.84	118.33±10.52			0.142
Hypertension	8 (66.67)	7 (58.33)			1.000
T2DM	7 (8.33)	4 (33.33)			0.250
Tobacco use	1 (8.33)	1 (8.33)			1.000
Ideal CVD risk	0.98±0.58				
FRS (%)	9.43±3.58	5.63±3.24	3.80	40	0.118
PCE (%)	4.13±3.63	2.42±2.45	1.72	42	0.004
KRPM (%)	4.14±1.95	3.22±1.94	0.92	22	0.000
Heart/Vascular age (years)	64.75±10.63	51.58±12.98	13.17		0.003

Variables = number (%); HDL = high-density lipoprotein cholesterol; SBP = systolic blood pressure; FRS = Framingham CVD risk score; PCE = ACC/AHA pooled cohort equation; KRPM = Korean prediction model for ASCVD; ARR = Absolute risk reduction; AAR = Absolute age reduction; RRR = Relative risk reduction.

scores and heart/vascular age were improved significantly after LRYGB; however, SBP and the status of T2DM were not meaningfully changed after surgery.

Table 4 shows the changes in parameters related to CVD risk between baseline and 1 year after LSG. The BMI, PCE score, KRPM score, and heart/vascular age were significantly decreased after LSG, and total cholesterol and HDL were marginally improved; however, SBP, hypertension and T2DM status, and FRS showed no significant differences between before and after surgery.

Table 5 compares the parameters related to CVD risk between LRYGB and LSG at 1-year follow-up. There was no significant difference in all parameters related to CVD risk scores between the two groups.

DISCUSSION

To the best of our knowledge, this paper has significance in that it is the first study to be conducted on an Asian population about the effect of bariatric surgery on CVD risk reduction by using quantitative CVD risk prediction models. The results of this study may provide important evidence supporting the concept that bariatric surgery can significantly reduce the CVD risk in Asian patients. Moreover, our results might indicate the appropriate risk prediction model for Asian populations.

Table 5. Comparison of parameters related to CVD risk between LRYGB and LSG at 1 year follow-up

Variables	LRYGB (n=55)	LSG (n=12)	P value
BMI (kg/m^2)	27.86±5.31	28.04±7.63	0.567
Total cholesterol (mg/dL)	169.25±32.39	182.42±36.96	0.218
HDL (mg/dL)	59.93±15.15	53.42±10.55	0.163
SBP (mmHg)	119.09±16.57	118.33±10.52	0.880
Hypertension	24 (43.64)	7 (58.33)	0.355
T2DM	22 (40.00)	4 (33.33)	0.753
Tobacco use	16 (29.09)	1 (8.33)	0.270
FRS ARR (%)	4.13±5.08	3.80±3.50	0.788
PCE ARR (%)	2.70±0.52	1.72±0.49	0.799
KRPM ARR (%)	1.03±1.85	0.92±0.97	0.776
Heart/Vascular age AAR	10.86±13.32	13.17±12.10	0.582

Variables = number (%); HDL = high-density lipoprotein cholesterol; SBP = systolic blood pressure; FRS = Framingham CVD risk score; PCE = ACC/AHA pooled cohort equation; KRPM = Korean prediction model for ASCVD; ARR = Absolute risk reduction; AAR = Absolute age reduction; RRR=Relative risk reduction.

This study demonstrated that bariatric surgery reduces the CVD risk, as significant improvement of all CVD risk scores were observed after surgery. This result is concordant with that of other studies that used FRS or PCE [13-15]. However, the FRS or PCE scores at baseline and after surgery in this study seemed to be lower than those in previous studies. The FRS at baseline and 1 year after surgery in our study showed a mean value of 10.3% and 4.1% respectively, whereas the FRS was 26.6% and 16.7%, respectively, in one study [15] and 34.5% and 15.5%, respectively, in another study [13]. With respect to PCE, our data (5.2% and 2.7% at baseline and 1 year after surgery, respectively) were lower than those of a previous study (11.6 and 7.8, respectively) [14]. We speculated on the reasons for these large differences between our study and other studies. First, there were differences in the factors involved in the calculation of scores among the studies. When compared with the study population of Blanco et al. [14], our patients had younger age, included more women, had lower SBP, and had lower rates of hypertension and smoking. Further, the BMI in our population (mean 37.2 kg/m^2) was lower than that in other studies (42.8 kg/m^2 in Blanco et al. [14] and 45.7 kg/m^2 in Major et al. [13]), and BMI affects the factors involved in the calculations. Our data were supported by another study on an Asian population with a relatively low BMI (40.5 kg/m^2), in which low FRS at baseline (5.2%) and at 1 year after LSG (2.0%) was reported [26]. Second, there were differences in the calculation methods of the risk scores. We used the lipid-based FRS for the prediction of CVD; however, other studies used the BMI-based FRS, which could produce higher estimates than the lipid-based FRS in obese patients [13,15]. However, a similar relative risk reduction was observed between this study (39.6% in FRS and 48.5% in PCE) and other studies (37.2%, 37.5%, 55.1% in FRS [13-15] and 32.8% in PCE [14]), although the absolute risk reduction in this study was lower than that in other studies. Moreover, the heart/vascular age was also reduced by an amount similar to that reported in other studies (absolute age reduction: 11.3 years in this study; 10.8 years in Blanco et al. [14] and 8.4 years in Gutierrez-Blanco et al. [15]). This means that bariatric surgery significantly reduces the CVD risk regardless of racial disparity.

The CVD risk varies as a function of diet, lifestyle, and ethnic origin. The KRPM score was estimated lower than the FRS at baseline and 1 year after surgery in this study. Some investigators reported that the FRS has a tendency of overestimating the risk of CVD when applied to the Korean population, in which the CVD incidence is low; therefore, this makes it difficult to apply the risk prediction models as they were developed [18,29]. Jung et al. [20] reported that the Caucasian model of PCE overestimates the CVD risk in male patients and underestimates the CVD risk in female patients. The same trend was found when comparing PCE and KRPM in this study. The PCE score was higher in men at both baseline and 1 year after surgery than the KRPM score (PCE: 9.33 ± 8.22 at baseline, 4.19 ± 3.35 at 1 year after surgery; KRPM: 4.93 ± 3.24 at baseline, 3.06 ± 1.74 at 1 year after surgery). On the other hand, the PCE score was lower in women in the same periods (PCE: 4.03 ± 4.42 at baseline, 2.26 ± 2.33 at 1 year after surgery; KRPM: 4.32 ± 2.67 at baseline, 3.55 ± 2.17 at 1 year after surgery; data not shown). In the preoperative evaluation for selecting candidates for bariatric surgery, the application of PCE in male patients has the risk of overestimating the CVD risk. Thus, KRPM can be considered a possible alternative for the risk calculation.

We observed no significant difference in the CVD risk scores between LRYGB and LSG in Korean patients. Studies comparing the CVD risk score between two surgical procedures are scarce [13-15]. All studies were retrospective studies that concluded that both procedures have good effects in terms of CVD risk reduction, with no significant difference. Two randomized controlled trials published in 2018 compared the long-term outcomes over a 5-year follow-up period in patients who underwent LSG and LRYGB [8,9]. Although these studies did not directly compare the CVD risk scores, the CVD risk scores can be indirectly inferred by comparing the factors that determine the scores. In the study by Peterli et al. [8], there was no significant difference in total cholesterol, HDL, and remission of hypertension and T2DM between the LSG and LRYGB groups. On the other hand, in the study by Salminen et al. [9], there was no difference in total cholesterol, HDL, and remission of T2DM between the LSG and LRYGB groups, but 51% of the patients in the LRYGB group discontinued hypertension medications and showed significantly better results than those in the LSG group (29%). These results suggest that the CVD risk score in the LRYGB group may be better than that in the LSG group. However, this is only an indirect comparison. To obtain more evidence, well-designed studies with a CVD score as the primary endpoint should be conducted.

This study has several limitations associated with its retrospective nature, lack of randomization, small sample size, and short-term follow-up period. There is also a chance of selection bias because only patients with complete data at follow-up were included. Despite these shortcomings, this is, to our best knowledge, the first study on an Asian population to compare and analyze LRYGB and LSG in terms of cardiovascular risk outcomes based on various CVD risk score models. Continued efforts to revise the risk prediction models by using newer and ethnic-specific cohorts will provide more insight in the future.

CONCLUSION

LRYGB and LSG can equally decrease the CVD risk in the Korean population based on FRS, PCE, and KRPM.

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