Effect of bariatric surgery on cardiovascular risk factors

Dr. Manish Kumar Sharma, DNB; Dr. P.K. Chowbey, MS; Dr. J.P.S. Sawhney, DM

Department of Cardiology, Sir Ganga Ram Hospital, Rajinder Nagar, New Delhi

Abstract:

The objective of this paper is to find out the effects of weight loss on cardiovascular risk factors, C-reactive protein (CRP), and homocysteine in obese subjects treated with bariatric surgery. Bariatric surgery is increasingly being used as a therapeutic option for morbid obesity, which is linked with cardiovascular disease. However, it remains unclear whether surgically induced weight loss reduces cardiovascular risk factors. This prospective observational study enrolled 64 morbidly obese patients (BMI \( \geq 40 \text{ kg/m}^2 \) or \( \geq 35 \text{ kg/m}^2 \) with co-morbidities) and evaluated them for hypertension, glycated hemoglobin (HbA1c), CRP, homocysteine, and lipid profile before and 3, 6, and 12 months after a bariatric surgery. The significant improvement in BMI \( (p < 0.001) \), HbA1c \( (p < 0.001) \), blood pressure (BP) \( (p < 0.001) \), CRP \( (p < 0.001) \), and low-density lipoprotein (LDL) \( (p < 0.001) \) was observed at 12-month follow-up. Even at 3 months, significant improvement was seen in BMI \( (p < 0.001) \), HbA1c \( (p < 0.001) \), BP \( (p < 0.001) \), LDL \( (p = 0.011) \), and triglycerides \( (p = 0.048) \). In our study, at 12 months, there was a 54% and 51% reduction in diabetic and hypertensive population, respectively. Considerable weight loss following bariatric surgery leads to improvement in cardiovascular risk factors. However, whether reduction of these cardiovascular risk factors will decrease cardiovascular events is still unknown.

Key Words

- Bariatric surgery
- Weight loss
- Cardiovascular risk factors
- Body mass index
- Blood pressure
- Glycated hemoglobin

Introduction

The prevalence of obesity continues to rise in many parts of the world. Average annual increase in prevalence range from 0.2% to 18.5% in developed countries and 0.1% to 35.3% in developing countries. The rise in the prevalence of obesity is associated with increases in the prevalence of co-morbidities (e.g., type 2 diabetes, hyperlipidemia, hypertension, obstructive sleep apnea, heart failure, stroke, back and lower extremity weight-bearing degenerative problems, several forms of cancer, depression, etc.). These co-morbidities are responsible for more than 2.5 million deaths per year worldwide. The basis of the relation between obesity and the development of above co-morbidities is still unclear. Recent data show enhanced circulating levels of inflammatory mediators in obese individuals. These observations are interesting in the context of a suggested patho-physiological role of inflammatory mediators in the development of the obesity-related morbidity such as insulin resistance and cardiovascular disease. However, increased plasma levels of inflammatory markers and...
It is well-known that weight reduction improves obesity-related cardiovascular risk factors. Even limited weight loss (5–10%) has positive consequences. Thus, the greatly increased mortality and morbidity associated with morbid obesity (BMI ≥ 40 kg/m²) necessitates greater weight loss.

Unfortunately, diet therapy, with and without support organizations, is relatively ineffective in treating obesity in the long term. Currently there are no truly effective pharmaceutical agents to treat obesity, especially morbid obesity. In 1991, the National Institutes of Health established guidelines for the surgical therapy of morbid obesity (BMI ≥ 40 kg/m² or BMI ≥ 35 kg/m² in the presence of significant co-morbidities), now referred to as bariatric surgery.

Considering the above-mentioned facts, we hypothesized that weight loss after bariatric surgery, resulting in a reduction of the metabolic stress, leads to a decrease in inflammatory markers (C-reactive protein [CRP] and homocysteine) and cardiovascular risk factors in obese subjects.

Materials and methods

This study was conducted in the Department of Cardiology, in collaboration with the Department of Minimal Access and Bariatric Surgery, Sir Ganga Ram Hospital, New Delhi. All patients admitted within the period of September 2008 and August 2009 in the Department of Minimal Access and Bariatric Surgery, Sir Ganga Ram Hospital, New Delhi, and fulfilling the eligibility (BMI ≥40 kg/m² or ≥35 kg/m² with co-morbidities) for surgical treatment of obesity were included in this study.

The study protocol included an evaluation of baseline characteristics and risk factors for cardiovascular disease including lipid profile, glycated hemoglobin (HbA1c), CRP, and homocysteine at the time of admission. After evaluation, patients underwent one of the following surgical options (Figure 1): adjustable gastric banding; vertical (sleeve) gastrectomy; Roux-en-Y gastric bypass; biliopancreatic diversion procedures with a duodenal switch. Study subjects were followed up to 12 months at regular intervals after the bariatric surgery for assessment of the waist–hip ratio, BMI, hypertension, HbA1c, CRP, homocysteine, and lipid profile.

Data analysis

The analysis was carried out using Statistical Package for Social Sciences version 17.00 for Windows (SPSS 17.0). Statistical techniques included quantitative and qualitative analysis. Continuous variables are presented as mean ± SD. Categorical variables are expressed as frequencies. Unpaired t tests were used for comparison of continuous variables between two groups. Differences between groups were assessed with chi-square or Fisher’s exact test for categorical variables as appropriate. A p value of <0.05 was considered statistically significant.
Results

The study population had a mean age of 38.06 ± 11.16 years with 39 women (61%) and 25 men (39%). Preoperatively diabetes mellitus, hypertension, dyslipidemia, obstructive sleep apnea, physical inactivity, inadequate daily intake of fruit and vegetables, and family history of premature coronary heart disease were present in 57.81%, 82.81%, 92.19% 46.88%, 79.69%, 87.5%, and 7.8% patients, respectively. In the study population, prevalence of smoker and alcohol intake was 26.56% and 25%, respectively. Preoperative mean weight of the study population was 131.17 ± 23.02 kg.

Mean preoperative BMI, waist–hip ratio, SBP and DBP were 51.45 ± 8.20 kg/m², 0.96 ± 0.08, 143.45 ± 5.25 mmHg, and 89.18 ± 4.93 mmHg, respectively. On laboratory evaluation, mean preoperative HbA1c, CRP, and homocysteine were 7.07 ± 1.30%, 15.8 ± 7.86 μg/ml, and 18.79 ± 8.38 μmol/L, respectively. At baseline, mean total cholesterol (TC), low-density lipoprotein (LDL), very low-density lipoprotein (VLDL), high-density lipoprotein (HDL), and triglycerides (TG) were 181.56 ± 25.032 mg/dl, 116 ± 23.98 mg/dl, 33.96 ± 7.64 mg/dl, 160.34 ± 33.05 mg/dl, and 18.79 ± 8.38 μmol/L, respectively. There was no significant difference in mean preoperative weight loss between gastric bypass and sleeve gastrectomy groups at 3, 6, and 12 months of follow-up.

Thirty-eight patients (59.37%) underwent Roux-en-Y gastric bypass, whereas 26 (40.63%) underwent vertical (sleeve) gastrectomy. Significantly more patients underwent Roux-en-Y gastric bypass as compared with vertical (sleeve) gastrectomy (p = 0.034). The patients were followed at 3, 6, and 12 months after bariatric surgery for evaluation of clinical and laboratory parameters. Total excess weight loss was 29.01 ± 7.94% at 3 months, 46.4 ± 8.31% at 6 months, and 57.32 ± 8.69% at 12 months. There was significantly more excess weight loss at 6 months (p < 0.001) and 12 months (p < 0.001) as compared with excess weight loss at 3 months. There was no significant difference in excess weight loss between gastric bypass and sleeve gastrectomy groups at 3, 6, and 12 months of follow-up.

Table 1. Effect of weight loss on clinical parameters

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline</th>
<th>3 months</th>
<th>p value</th>
<th>6 months</th>
<th>p value</th>
<th>12 months</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist–hip ratio (mean ± SD)</td>
<td>0.96 ± 0.08</td>
<td>0.912 ± 0.05</td>
<td>&lt;0.001</td>
<td>0.883 ± 0.053</td>
<td>&lt;0.001</td>
<td>0.87 ± 0.053</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight (kg) (mean ± SD)</td>
<td>131.17 ± 23.02</td>
<td>110.01 ± 17.91</td>
<td>&lt;0.001</td>
<td>97.26 ± 13.93</td>
<td>&lt;0.001</td>
<td>89.01 ± 10.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg/m²) (mean ± SD)</td>
<td>51.45 ± 8.20</td>
<td>43.51 ± 6.99</td>
<td>&lt;0.001</td>
<td>38.3 ± 5.72</td>
<td>&lt;0.001</td>
<td>35.01 ± 4.66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBP (mmHg) (mean ± SD)</td>
<td>143.45 ± 5.25</td>
<td>138.03 ± 5.69</td>
<td>&lt;0.001</td>
<td>132.37 ± 6.19</td>
<td>&lt;0.001</td>
<td>127.3 ± 6.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP (mmHg) (mean ± SD)</td>
<td>89.18 ± 4.93</td>
<td>86.18 ± 4.76</td>
<td>&lt;0.001</td>
<td>83.62 ± 4.94</td>
<td>&lt;0.001</td>
<td>81.25 ± 4.01</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 2. Effect of weight loss on laboratory parameters

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline</th>
<th>3 months</th>
<th>p value</th>
<th>6 months</th>
<th>p value</th>
<th>12 months</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1c (%) (mean ± SD)</td>
<td>7.07 ± 1.30</td>
<td>6.97 ± 1.27</td>
<td>0.0012</td>
<td>6.41 ± 1.12</td>
<td>&lt;0.001</td>
<td>6.20 ± 0.974</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CRP (µg/ml) (mean ± SD)</td>
<td>15.81 ± 7.86</td>
<td>15.24 ± 7.39</td>
<td>0.058</td>
<td>11.05 ± 6.20</td>
<td>&lt;0.001</td>
<td>8.24 ± 5.36</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Homocysteine (µmol/L) (mean ± SD)</td>
<td>18.79 ± 8.38</td>
<td>18.50 ± 7.73</td>
<td>0.5043</td>
<td>17.95 ± 8.79</td>
<td>&lt;0.001</td>
<td>17.85 ± 7.43</td>
<td>0.068</td>
</tr>
</tbody>
</table>

Table 3. Prevalence of diabetes mellitus and hypertension before and after bariatric surgery

<table>
<thead>
<tr>
<th>Time period</th>
<th>All (n = 64)</th>
<th>Female (n = 39)</th>
<th>Male (n = 25)</th>
<th>p value</th>
<th>All (n = 64)</th>
<th>Female (n = 39)</th>
<th>Male (n = 25)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before surgery</td>
<td>37 (57.81%)</td>
<td>20 (51.28%)</td>
<td>17 (68%)</td>
<td>0.187</td>
<td>53 (82.81%)</td>
<td>31 (88%)</td>
<td>22 (64.06%)</td>
<td>0.379</td>
</tr>
<tr>
<td>Follow-up</td>
<td>37 (57.81%)</td>
<td>20 (51.28%)</td>
<td>17 (68%)</td>
<td>0.187</td>
<td>53 (82.81%)</td>
<td>31 (88%)</td>
<td>22 (64.06%)</td>
<td>0.379</td>
</tr>
<tr>
<td>At 3 months</td>
<td>28 (43.75%)</td>
<td>13 (33.33%)</td>
<td>15 (60%)</td>
<td>0.036</td>
<td>41 (64.00%)</td>
<td>24 (61.54%)</td>
<td>17 (68%)</td>
<td>0.599</td>
</tr>
<tr>
<td>p value</td>
<td>0.112</td>
<td>0.055</td>
<td>0.046</td>
<td>0.082</td>
<td>0.088</td>
<td>0.088</td>
<td>0.088</td>
<td>0.088</td>
</tr>
<tr>
<td>At 6 months</td>
<td>24 (37.5%)</td>
<td>11 (28.20%)</td>
<td>13 (52%)</td>
<td>0.055</td>
<td>32 (49.0%)</td>
<td>19 (50%)</td>
<td>13 (52%)</td>
<td>0.798</td>
</tr>
<tr>
<td>p value</td>
<td>0.021</td>
<td>0.037</td>
<td>0.029</td>
<td>&lt;0.001</td>
<td>0.005</td>
<td>0.006</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td>At 12 months</td>
<td>17 (26.50%)</td>
<td>8 (20.51%)</td>
<td>9 (36%)</td>
<td>0.171</td>
<td>26 (40.63%)</td>
<td>9 (25.64%)</td>
<td>11 (44%)</td>
<td>0.660</td>
</tr>
<tr>
<td>p value</td>
<td>&lt;0.001</td>
<td>0.005</td>
<td>0.024</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
After 3, 6, and 12 months of surgery, the waist–hip ratio was 0.912 ± 0.05 (p < 0.001), 0.883 ± 0.053 (p < 0.001), and 0.87 ± 0.053 (p < 0.001); weight was 110.01 ± 17.91 kg (p < 0.001), 97.26 ± 13.93 kg (p < 0.001), and 89.01 ± 10.06 kg (p < 0.001); BMI was 43.51 ± 6.99 kg/m² (p < 0.001), 38.3 ± 5.72 kg/m² (p < 0.001), and 35.01 ± 4.66 kg/m² (p < 0.001); SBP was 138.03 ± 5.69 mmHg (p < 0.001), 132.37 ± 6.19 mmHg (p < 0.001), and 127.3 ± 6.34 mmHg (p < 0.001); and DBP was 86.18 ± 4.76 mmHg (p < 0.001), 83.62 ± 4.94 mmHg (p < 0.001), and 81.25 ± 4.01 mmHg (p < 0.001), respectively.

HbA1c reduced from 7.07 ± 1.30 % to 6.97 ± 1.27 % at 3 months (p = 0.0012), 6.41 ± 1.12% at 6 months (p < 0.001), and 6.20 ± 0.974 % at 12 months (p < 0.001). CRP reduced from 15.81 ± 7.86 μg/ml to 15.24 ± 7.39 μg/ml at 3 months (p = 0.0581), 11.05 ± 6.20 μg/ml at 6 months (p < 0.001), and 8.24 ± 5.36 μg/ml (p < 0.001) at 12 months. Homocysteine reduced from 18.79 ± 8.38 μmol/L to 18.50 ± 7.73 μmol/L at 3 months (p = 0.5043), 17.95 ± 7.89 μmol/L at 6 months (p = 0.094), and 17.85 ± 7.43 μmol/L (p = 0.068) at 12 months.

Total cholesterol reduced from 181.56 ± 25.032 mg/dl to 180.84 ± 24.81 mg/dl at 3 months (p = 0.075), 173.99 ± 23.82 mg/dl at 6 months (p < 0.001), and 166.27 ± 23.15 mg/dl (p < 0.001) at 12 months. LDL reduced from 116 ± 23.98 mg/dl to 114.75 ± 23.35 mg/dl at 3 months (p = 0.011), 107.40 ± 23.07 mg/dl at 6 months (p < 0.001), and 97.1 ± 22.44 mg/dl (p < 0.001) at 12 months. VLDL reduced from 31.95 ± 6.63 mg/dl to 31.58 ± 6.44 mg/dl at 3 months (p = 0.07), 29.81 ± 5.63 mg/dl at 6 months (p < 0.001), and 28.02 ± 5.66 mg/dl (p < 0.001) at 12 months. HDL increased from 33.96 ± 7.64 mg/dl to 34.22 ± 7.67 mg/dl at 3 months (p = 0.2836), 36.69 ± 7.53 mg/dl at 6 months (p < 0.001), and 41.05 ± 6.28 mg/dl at 12 months (p < 0.001). TG reduced from 160.34 ± 33.05 mg/dl to 158.39 ± 31.6 mg/dl at 3 months (p = 0.0488), 149.54 ± 28.01 mg/dl at 6 months (p < 0.001), and 141.3 ± 26.41 mg/dl (p < 0.001) at 12 months.

Prevalence of diabetes mellitus decreased from 57.81% (preoperative) to 43.75% at 3 months (p = 0.112), 37.5% at 6 months (p = 0.021), and 26.56% at 12 months (p < 0.001) after surgery (Figure 2). Prevalence of hypertension decreased from 82.81% (preoperative) to 64.06% at 3 months (p = 0.016), 50% at 6 months (p < 0.0001), and 40.63% at 12 months (p < 0.0001) after surgery (Figure 2). The results of two different types of bariatric surgery (Roux-en-Y gastric bypass and sleeve gastrectomy) were compared after 12 months of surgery. There was no significant difference in the results of the two different types of surgery in terms of clinical (i.e., waist–hip ratio, BMI, SBP, and DBP) and laboratory parameters (i.e., HbA1c, CRP, homocysteine, and lipid profile).

![Figure 2: Prevalence of diabetes mellitus and hypertension](image)

## Discussion

This is a prospective observational study that aimed to demonstrate the effect of weight loss (after bariatric procedures) on cardiovascular risk factors, CRP, and homocysteine. Our study enrolled 64 morbidly obese subjects (as per NIH criteria) admitted for bariatric surgery in the Department of Metabolic and Minimal Access Surgery, Sir Ganga Ram Hospital, New Delhi.

After surgery, rapid weight loss was observed during first 6 months but weight loss after 6 months of surgery was slow. Such rapid weight loss resulted in decrease in BMI from 51.45 ± 8.20 kg/m² at baseline to 43.51 ± 6.99 kg/m² at 3 months, 38.3 ± 5.72 kg/m² at 6 months, and 35.01 ± 4.66 kg/m² at 12 months. BMI decreased most strikingly in the first 3 months postoperatively. These data are in line with that of Dielen et al. showing that BMI significantly decreased after surgery from 46.7 ± 5.8 kg/m² preoperatively to 33.0 ± 4.8 kg/m² at 12 months postoperatively. Several mechanisms have been suggested in various studies for the more substantial weight loss after bariatric procedures. These can be divided into three groups: caloric restriction, alterations in gastrointestinal hormones and nutrient absorption, and changes in energy metabolism.

Weight loss after bariatric surgery resulted in significant reduction in HbA1c. This significant reduction was observed as early as 3 months after the procedure. There was a 54% reduction of diabetic population after 12 months of follow-up. Such amount of reduction in HbA1c (from 7.5 to 6.0) was also observed in a meta-analysis by Heneghan et al. But the...
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Reduction of diabetic population was more in above-mentioned meta-analysis (75% vs. 54%), which can be explained on the basis of longer duration of follow-up in the meta-analysis (34 months vs. 12 months).

Rubino outlined three possible mechanisms of the effect of bariatric surgery on glucose homeostasis: the effect of weight loss, intestinal malabsorption, and hormonal changes.

Weight loss, as a mechanism, may play a role in the resolution of diabetes in obese patients who undergo gastric banding. Indeed, Ponce et al. demonstrated that after gastric banding, the rate of diabetes resolution was greater 2 years postoperatively than after the first year, and improvement correlated with the degree of weight loss. However, several studies have demonstrated a return to euglycemia and normal insulin levels within days of RYGB or BPD, changes that occur well before any significant loss in weight.

Interestingly, restrictive techniques result in lower rates of diabetes remission than mixed procedures, suggesting that gastrointestinal tract changes after malabsorptive procedures are involved in diabetes control (48% for gastric banding vs. 84% for RYGB and 98% for BPD). Therefore, diabetes resolution is not a result of weight loss alone. The rationale for intestinal malabsorption as a mechanism for diabetes control is derived from the fact that both hyperglycemia and free fatty acids induce insulin resistance and β-cell dysfunction by stimulating mitochondrial production of reactive oxygen species (ROS). Therefore, in theory, by limiting the area over which nutrients are absorbed, there is less absorption of both glucose and fat, leading to a reduction in the production of ROS and improved β-cell function and insulin sensitivity. While malabsorption is clinically evident after BPD, it does not occur after standard RYGB, suggesting that additional factors may play a role in glucose regulation. It has been hypothesized that rerouting food through the gastrointestinal tract leads to changes in gut hormone secretion, which in turn may mediate the antidiabetic effect of a bariatric surgery.

Several studies have demonstrated changes in gut hormone levels after RYGB, including increased anorectic hormones that induce satiety (e.g., GLP-1 and PPy) and decreased levels of orexigens like ghrelin, an appetite-stimulating hormone. Of note is the fact that GLP-1 increases the insulin response to nutrients and, in animal models, induces β-cell proliferation. Therefore, perhaps, it is the postsurgical endocrine effects that mediate the antidiabetic effect of RYGB.

Alternatively, surgical resolution of T2DM may be related to the anatomic changes associated with RYGB.

To this end, Rubino proposed the hindgut and foregut hypotheses. The hindgut theory postulates that diabetes control is due to accelerated delivery of nutrients to the distal intestine, which boosts a “physiologic” signal (e.g., GLP-1) that improves glucose metabolism. The foregut hypothesis states that excluding nutrients from the duodenum and proximal jejunum may inhibit the secretion of a signal that normally would induce insulin resistance and T2DM.

In our study, there was non-significant reduction in CRP level at 3 months, but 6 months onward, reduction in the CRP level was significant. This result was similar to data published by Dielen et al., in which CRP decreased from 35 mg/ml to 25 mg/ml after 12 months and 10 mg/ml after 24 months. Different explanations can be proposed for the initially sustained elevation of inflammatory mediators. First, the effect of the operation and the subsequent healing process might be a possible explanation for the enhanced inflammatory state during the first 6 months postoperatively. However, various studies demonstrate that the highest CRP levels occur 12–48 hours after surgery and will remain elevated only for a period of maximum 12 days postoperatively.

Second, a non-alcoholic steatohepatitis might be an explanation for the sustained elevation of inflammatory mediators. Rapid weight loss can result in a mild increase in inflammatory lesions (hepatitis). Increased concentration of intracellular fatty acids, as has been observed during rapid weight loss, could explain these inflammatory lesions in the liver after weight loss. Such elevated levels of free fatty acids may be directly toxic for the liver or lead to oxidative stress. However, severe non-alcoholic steatohepatitis and hepatic failure are seldom described after gastroplasty or gastric bypass. A third possible explanation for the prolonged elevation of inflammatory mediators might be an enhanced metabolic stress response due to relative starvation. It was demonstrated in very malnourished anorexia nervosa patients that TNFα and IL-1α were elevated compared with healthy controls. After refeeding, these inflammatory mediators returned to normal levels. If we assume that extensive weight loss after gastric restrictive surgery is comparable with starvation, this could be an explanation for the prolonged elevation of inflammatory mediators.

In our study, there was significant reduction in both SBP and DBP during follow-up. This significant reduction was seen as early as 3 months after surgery. The similar effects of bariatric surgery on SBP and DBP have been demonstrated by He and Stubbs. In their series of 310 patients at 1-year follow-up, SBP decreased from 144...
mmHg to 125 mmHg and DBP reduced from 85 mmHg to 82 mmHg. Overall, there was a 51% reduction in hypertensive population as compared with data shown by Heneghan et al.\textsuperscript{17} in which there was a 68% reduction in the hypertensive population. This difference can be explained on the basis of longer duration of follow-up in meta-analysis (34 months vs. 12 months). Although the pathophysiological mechanisms explaining the lowering of blood pressure with weight loss are not clear, numerous factors are probably involved. In obese patients, both body mass and heightened sympathetic activation contribute to the blood pressure elevation,\textsuperscript{46} and, furthermore, sympathetic hyperactivity might account for the resistance to weight loss of some hypertensive patients.\textsuperscript{47} The hyperinsulinemia secondary to insulin resistance activates multiple mechanisms leading to systemic hypertension (increased sodium absorption, stimulation of Na\textsuperscript{+}–H\textsuperscript{+} pump activity, and reduction of Na\textsuperscript{+}–H\textsuperscript{+} ATPase activity with increased sensitivity for angiotensin II). Furthermore, insulin activates angiotensinogen secretion from adipose tissue,\textsuperscript{48} which leads to a higher plasma renin activity and exerts important cardiovascular effects through the sympathetic nervous system. It has been shown that plasma renin activity is significantly increased in obese individuals.\textsuperscript{49,50} This increase is associated with higher levels of angiotensin II, which increase tubular absorption of sodium and contribute to systemic hypertension.\textsuperscript{51,52} The reduction in blood pressure after bariatric surgery could also be attributable to reductions in total circulating and cardiopulmonary blood volume and in sympathetic nervous system activity.\textsuperscript{53} The reductions in plasma catecholamines and plasma renin activity, which are associated with decreased sympathetic activity, also probably play a role.\textsuperscript{54}

In this study, there was significant improvement in lipid parameters. The significant reduction in TG and LDL were seen as early as at 3 months, but HDL level only significantly improved after 6 months. Similar pattern of improvement in lipid profile was also observed in the meta-analysis by Heneghan et al.,\textsuperscript{17} in which after the mean follow-up of 34 months, total cholesterol decreased from 205 to 169 mg/dl, LDL decreased from 118 to 94, TG decreased from 169 to 103, and HDL increased from 49 to 52. Weight loss and resultant improvements in hepatic insulin sensitivity likely explain these findings; however, the exact mechanisms for the benefits seen in dyslipidemia after weight loss surgery are not clear.\textsuperscript{55}

There was a non-significant reduction in the homocysteine level at 12 months. Borson-Chazot et al.\textsuperscript{56} and Dixon JB et al.\textsuperscript{57} noted significantly raised plasma homocysteine concentrations 1 year after bariatric procedures. They attributed this to a small fall in folate levels and recommended folate supplementation. Three micronutrients are important cofactors in homocysteine metabolism: folate and vitamin B12 are co-factors for the methylation of homocysteine to methionine, and vitamin B6 is involved in its catabolism. The decreasing trend in homocysteine in our series can be explained as we routinely prescribe folate and vitamin B12 supplementation as a part of standard care.

In the current study, there was no significant difference in various outcomes (both clinical and laboratory parameters) between two different types of bariatric surgery (Roux-en-Y gastric bypass and sleeve gastrectomy). In the meta-analysis by Buchwald et al.\textsuperscript{23} the laparoscopic Roux-en-Y gastric bypass group showed more resolution of type 2 diabetes mellitus and hypertension as compared with restrictive surgery. Roux-en-Y gastric bypass, being a combination restriction–malabsorption procedure, causes more weight loss as compared with sleeve gastrectomy. This explains the result of the above meta-analysis.

However, recent studies\textsuperscript{58,59} show no differences in the percentage of excess weight loss or the resolution of type 2 diabetes mellitus and hypertension between two groups. Their results may be explained on the basis of the short follow-up and limited population size as compared with meta-analysis by Buchwald et al. ($n = 22,094$).\textsuperscript{23}

**Conclusions**

This study concluded that bariatric surgery results in significant weight loss that is sustainable. The beneficial effects of weight reduction were expressed in the form of reduction in diabetic and hypertensive population and further better control of glycaemia and hypertension in remaining population. Lipid profile and CRP levels were improved similarly to as shown in previous studies. However, a trend in the non-significant reduction of homocysteine was a new finding in our study.

**Limitations**

This study has the limitations of control population (non-operative group) and limited period of follow-up. Furthermore, evaluation of cardiovascular events, cardiovascular mortality, and all-cause mortality were not the end-points of our study and we recognize that this study was underpowered to make any significant conclusions with respect to these outcomes.
References


Address for correspondence:
Dr. J.P.S. Sawhney: E-mail: jpssawhney@yahoo.com