Original article

One Anastomosis Gastric Bypass Surgery: Consequences Over Ascorbic Acid, Cobalamin, Calciferol, and Calcium.

Bariatric Surgery Series: Paper I

Arya Singh [1 a, b], Rahnuma Ahmad [2], Susmita Sinha [3], Md. Ahsanul Haq [4], Mahendra Narwaria [1 b], Mainul Haque [5 a, b], Santosh Kumar [6], Nandita Sanghani [7]

Abstract

Background: Nutrient deficiency after malabsorptive bariatric procedure is a common phenomenon. The study aims to determine the prevalence of nutritional insufficiencies (specific with Ascorbic acid, Cobalamin, calciferol and calcium) in obese population opting for One Ananstomosis Gastric Bypass surgery (OAGB), and also to understand the association of these nutrients with change in Body Mass Index (BMI) after the surgery. ***Methods:*** One hundred fifty subjects comprising males and females aged 20-60 years were randomly selected at a bariatric center in India. Subjects belonged to both grade III and grade II obesity. Plasma aa, serum $vitB_{12}$, serum $VitD_3$ and serum calcium concentrations were prospectively assessed at 0m, 3m, and 6m of surgery through high-performance liquid chromatography. ***Result:*** The values of nutrients beyond the standard levels are considered as deficiency. Both follow up values showed a significant increase in cobalamin, Calciferol, and ascorbic acid levels compared to baseline data. ***Conclusion:*** Nutrition depletion and deficiency are often seen in post bariatric cases. The contributing factors included high BMI, food intolerance, and non-adherence to supplements and correct dietary regimens. With the correction of weight and comorbidities, the levels also showed a stable and positive level.

Keywords*:* *Obesity, Obesity surgery, One Anastomosis Gastric bypass, Vitamin deficiency, Ascorbic Acid, Vitamin C, Calciferol, $vitD_3$, Calcium, obalamin*

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Introduction

There is no permanent treatment for the chronic metabolic condition called obesity. However, compared to conservative management, the efffectiveness of metabolic surgery appears to be more. The one-anastomosis gastric bypass has drawn interest due to its apparent efffectiveness and simplicity [1-6]. In the United States alone, by 2018, about 252000 bariatric surgeries were performed yearly [7]. Between the years 1993 and year 2016, there

1. [a]PhD Scholar, Karnavati School of Denistry, Karnavati University, Gandhinagar, Gujarat-382422. India. [b] Asian Bariatrics Plus Hospital, V Wing-Mondeal Business Park, S G Highways, Ahmedabad-380054, India.
2. Department of Physiology, Medical College for Women and Hospital, Dhaka, Bangladesh.
3. Department of Physiology, Khulna City Medical College and Hospital, 33 KDA Avenue, Hotel Royal Crossing, Khulna Sadar, Khulna 9100, Bangladesh.
4. Infectious Diseases Division, icddr, b, Mohakhali, Dhaka-1212, Bangladesh.
5. [a]Unit of Pharmacology, Faculty of Medicine and Defence Health, Universiti Pertahanan Nasional Malaysia (National Defence University of Malaysia), Kuala Lumpur, Malaysia. [b] Professor and Research Advisor, Department of Scientific Research Center (KSRC) Karnavati School of Dentistry, Karnavati University, Gandhinagar, Gujarat-382422. India.
6. Department of Periodontology, Karnavati School of Dentistry, Karnavati University, Gandhinagar, Gujarat-382422. India.
7. Department of Biochemistry, Karnavati School of Dentistry, Karnavati University, Gandhinagar, Gujarat-382422. India.

Correspondence Mainul Haque. The Unit of Pharmacology, Faculty of Medicine and Defence Health, Universiti Pertahanan Nasional Malaysia (National Defence University of Malaysia), Kem Perdana Sungai Besi, 57000 Kuala Lumpur, Malaysia. **Email**: runurono@gmail.com, mainul@upnm.edu.my. Cell Phone: +60109265543.

was an increase in bariatric surgeries among men from 15.3% to 20.4% [8].

Bariatric surgery leads to long-term weight loss. This weight loss is mainly due to decreased energy intake as the bypass leads to malabsorption to some extent of macronutrients that are energy dense [9,10]. However, there remains a risk of vitamin and other micronutrient deficiency development. Clinical complications due to deficiency of micronutrients following bypass include osteomalacia, anemia, pellagra, scurvy, and Wernicke encephalopathy [11-15]. Such risk of complications necessitates monitoring plasma vitamin levels in individuals who undergo gastric bypass. Such biomarkers monitoring can help early detection of changes in the concentration of vitamins. Thus, clinical complications can be prevented through intervention [16].

Obesity and Bariatric Surgery

An improper or excessive assemblage of fat that could harm one's health is called obesity. Body mass index (BMI) is a measure of weight relative to height frequently used to categorize persons as overweight or obese. According to WHO, adult obesity is defined as having a BMI of 30 or higher. However, for the Asian population, who are more likely to develop diabetes and obesity at earlier ages and lower BMIs, the cutoff criteria have been lowered to 22.5 and 27.5 [17]. In developed countries, obesity and its associated consequences are the primary cause of disabilities, premature mortality, and low quality of life [18]. Long-term weight loss is frequently challenging to attain, despite the fact the focus of obesity management is on dietetics, behavioral changes, and way of living [19]. The insufficient effectiveness, adverse reactions, and limited availability of medication in markets limit pharmacotherapy for obesity [20]. To manage obesity and its problems, bariatric surgeries have become the preferred option. It is possible to enhance weight loss, resolution of type 2 diabetes, and maybe lower ongoing medical expenses using a variety of surgical treatments [21]. The National Institute for Clinical Excellence (NICE) In the UK advises bariatric surgery as a first-line treatment option for patients with a BMI >35 kg/m^2 with other medical conditions or >40 kg/m, as well as for individuals with a BMI >50 kg/m^2 [22].

Ascorbic Acid Relation with Obesity and Bariatric Surgery

Several epidemiological studies have found a negative relationship between plasma ascorbate concentration and body weight. Vitamin C levels are inversely affected by an increase in body weight [23,24]. In obesity, certain factors lower plasma vitamin C levels. One such factor is the high distribution volume accompanying a rise in body weight resulting in decreased plasma ascorbate when intake is not raised while body weight rises [25,26]. Block *et al.*, carried out a study based on volume depletion and repletion which found that increasing body weight lowered plasma vitamin C levels in the subject's same dietary vitamin C intake [27]. Another factor is that dysregulation of adipocytes and systemic inflammation in obese individuals causes a rise in oxidative stress, resulting in high Vitamin C turnover [28,29]. Vitamin C concentration must be adequate in the plasma for the optimum functioning of vitamin C dependent enzymes [30,31]. Therefore a fall in the concentration of vitamin C in obese and overweight individuals may hamper the functioning of enzymes and further raise the risk of disease development [32].

Bariatric surgery leads to significant weight loss [33]. However, surgery complications like insufficient nutrient absorption, gastrointestinal complications, and inadequate supplementation of vitamins may result in vitamin deficiency, including ascorbic acid deficiency [33-37]. Deficiency of vitamin C prevalence after surgery ranges between 10%-50% [37,38]. Clinical signs resulting from defects like petechiae, gum bleeding, and poor wound healing are rare [39].

Cobalamin Relation with Obesity and Bariatric Surgery

Cobalamin or vitamin B_{12} and folate deficiency are the most observed vitamin deficiencies among bariatric surgery patients, putting them at risk for developing anemia [40]. Cobalamin deficiency symptoms include macrocytic anemia, leucopenia, glossitis, thrombocytopenia, paresthesia, and irreversible neuropathies [41]. The action of gastric acid and pepsin in the stomach causes cobalamin/vitamin B_{12} to be released from binding to protein in meals [42]. After that, it attaches to the intrinsic factor before entering the terminal ileum and being absorbed [43]. Multiple factors, such as intolerance to animal proteins, decreased gastric secretions that hinder the cleavage of the vitamin from the protein, and insufficient secretion and function of intrinsic factor that reduces absorption, lead to cobalamin deficiency in gastric bypass patients [44]. The absence of beneficial digestive secretions can lead to bacterial overgrowth in the defunctionalized ileal section leading to cobalamin insufficiency [45]. To normalize serum vitamin B_{12} levels, appropriate amounts of B_{12} are absorbed through passive diffusion in the ileum. Vitamin B_{12} can also be administered intravenously. An immediate course of antibiotic therapy may be given if a microbial overgrowth is thought to be present. In addition, concerns have been raised about proper nutrition during pregnancy and lactation as more women of reproductive age have bariatric surgery [46].

Relation of Calciferol with Obesity and Bariatric Surgery

Vitamin D_3 or Calciferol, along with its metabolites that are 25 $(OH)D_3$ or 25 hydroxycholecalciferols and $1,25(OH)_2D_3$ or 1,25 dihydroxycholecalciferol deposit in lipid droplets of fat cells [47]. 25 hydroxycholecalciferols, a fat-soluble vitamin) disseminates to the liver, fat, muscle, and other tissues in small amounts [48]. An inverse association between obesity and plasma 25(OH)D has been noted in some studies [49-51]. Another study has also observed an inverse correlation between waist circumference, total mass of fat, visceral and subcutaneous adiposity, and body mass index (BMI) [52]. Sequestration of vitamin D seems to be a possible mechanism at play. Extensive storage of vitamin D occurs within the excess adipose tissue resulting in a low concentration of 25(OH)D in plasma [53]. Drincic *et al.*, suggested another mechanism from the volumetric dilution hypothesis: dilution of 25(OH)D in high volume in obese individuals [54]. There may also be increased breakdown of vitamin D in adipose tissue and decreased 25-hydroxylation [55].

Vitamin D deficiency has been observed both before and after bariatric surgery, irrespective of the procedure type and dose of supplementation [56,57]. Fifty-one studies monitoring vitamin D levels in obese subjects who underwent bariatric surgery with a range of follow-ups between 3 months to 11 years after surgery were included in a systemic review. The review noted that the mean level of 25 (OH)D was below 30ng/ml after surgery [58].

Relation of Ca^{2+} with Obesity and Bariatric Surgery

Individuals with extreme obesity and other linked illnesses, such as type 2 diabetes, are now often and appropriately treated with bariatric surgery [59]. The main goal of bariatric surgery is to promote sustained weight loss, which still requires behavioral modifications [60]. One of the most significant susceptibility indicators for type 2 diabetes is being obese, which increases the body's incapacity to sustain normal glycemic conditions due to the gradual loss of insulin ability to produce and rising insulin resistance [61, 62]. The effectiveness of bariatric surgery in lowering significant amounts of weight and comorbidities has been demonstrated in numerous trials, and it is now being used more commonly as a recognized treatment [63]. Besides, intestinal absorption is severely compromised due to physiological and anatomical changes following surgery, which hamper the absorption of vitamin D and Ca^{2+}, the two essential components in bone formation. Patients undergoing bariatric surgery are at high risk for severe vitamin D insufficiency and osteomalacia due to several causes. Because the duodenum and proximal jejunum, where Ca^{2+} and vitamin D are usually absorbed, were bypassed during surgery, absorption of these nutrients is affected [64]. Another explanation for inadequate Ca^{2+} and vitamin D absorption involves mixing with biliopancreatic secretion in a shared channel and steatorrhea [65]. Therefore, these patients must take calcium and vitamin D supplements for the rest of their lives. The Obesity Society, American Society for Metabolic & Bariatric Surgery, and the American Association of Clinical Endocrinologists all advise a daily intake of 1200 to 1500 mg of elemental calcium and at least 3000 units of vitamin D [66].

Objectives of the Study

The change in the level of ascorbic acid, cobalamin, calciferol, and Ca^{2+} 6 months after weight loss surgery. Additionally, the relationship between BMI change and nutrient status after OAGB (One Anastomosis Gastric Bypass Surgery).

Materials and Methods

Study Details

Study Type: A longitudinal observational study was conducted, and the patients were selected randomly. *Study Period*: This study was conducted from January 2021 to January 2022. *Sampling Type:* Universal sampling was done in the institution, and only those who gave consent for the study were included. *Study Subject:* The subjects of this research were recruited from Asian Bariatrics Hospital, SG Highways, Ahmedabad, Gujarat, India. *Methods of Enrollment and Randomization:* Patients were enrolled between February 2021 and July 2021, and a 6-month follow-up was completed by January 2022. A written informed consent form was obtained from all the subjects, and they were informed about the possible benefits, side effects, and risks associated with the surgical interventions as well as the purpose of the study. *Sample Size:* Based on the records of previous years of the hospital, Asian Bariatrics, one of the wide-ranging and sizeable centers of obesity and metabolic surgery in India, has several approximately 20-25 patients every month. Thus, to meet the required sample size of 120-150, subjects will be enrolled for 6 months from the hospital and followed up for another 6 months, precisely at 3 and 6 months post-bariatric surgery, based on their informed consent before undergoing surgery to cooperate for this research.

Sample Size Estimation with Single Group Mean

N = (Zα/2)2 s2 / d2

Zα/2 = standard deviation for the two-tailed alternative hypothesis at a significance level.

S = the standard deviation obtained from the previous study or pilot.

D = the estimate's accuracy or how close to the true mean.

Zα/2=3.29; s=6; d=1.5.

The calculated sample size would be 130. If the allowance of 10% for missing, losses to follow-up, and withdrawals are assumed, then the corrected sample will be 143 subjects. The corrected sample size thus obtained is 130/ (1.0-0.10) □ 130/0.9 = 145; for 20% allowances, the corrected sample size will be 156. So, the estimated sample size proffered for this study would be 130-156. (Reference: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3409926/)

Inclusion Criteria: The subjects were aged 20–50 years and had failed to sustain weight loss by nonsurgical measures. Subjects were both genders, with a mean BMI of 45.63±6.54 (male) and 41.81± 5.93kg/m^2 (female). Exclusion criteria: The subjects possess a history of previous weight loss surgery, severe cardio-respiratory disease, cancer, oral steroid treatment, and psychiatric medications. These requirements are in pace with the recommendations indicated for bariatric surgery.

Anthropometric Evaluation

Weight, height, and BMI were used for anthropometric evaluation. The patients were weighed on a Bioelectrical Impedance Machine in Body 770. Height was measured with BSM 170 In Body measuring scale.

Surgical Intervention

Surgery was performed by laparoscopic technique. At first, Pneumoperitoneum was created using a 5 mm Endopath instrument at Palmer's point, the remaining 3 ports –11 mm supra-umbilical port, 12mm right of right Rectus muscle port, and 5 mm port on right hypochondrium. Gastroesophageal junction dissection was done by retracting the fundus and dividing the peritoneum overlying the GE junction using a Goldfinger instrument. Further, the greater omentum was divided vertically to the upper line of the transverse colon and later divided transversely. DJ flexure was identified, and a loop of small bowel was traced to 150 cm. The loop was then pulled up in ante colic fashion and anchored to the greater curvature opposite the incisura. Dissection for the gastric pouch was started by creating a window in the lesser curve near the incisura. Subsequent stapler firing (multiple purple and blue staplers) made the required stomach pouch of around 100ml. 36 Fr Gastric Calibration Tube was used. A blue stapler created a stoma of 5 cm, and enterotomy was closed with another blue stapler. Alimentary and biliopancreatic limb measurements were 150 cm. The patients were evaluated pre-operatively and at 3 and 6 months after surgery.

Nutritional Intervention

Vitamin status was examined at the baseline visit or at least 12 weeks before surgery and at 3 months and 6 months after surgery. Patients followed a very-low-calorie diet (1000 kcal) with protein and fiber supplements for 1 week immediately before surgery to reduce their liver floor. Post-surgery, all patients were put on a low-calorie progressive diet for 1 month, and later the diet was revised as per the weight loss observed over time. The diet plan consisted of three to four portions from the milk group, one portion from the eggs and meat group, and two portions of legumes, two to three from each vegetable, and fruit per day, with restriction of simple carbohydrates and stimulation of the intake of complex carbohydrates, for a total of 1200 kcal/d and protein 60-80 g/d, and guidelines for the practice of physical activity. All patients in the postoperative period received commercially available mineral and vitamin supplements, per American Society of Metabolic & Bariatric Surgery (ASMBS) guidelines, 2016, after a week of surgery. Ursodeoxycholic acid (600 mg/d) was provided until 6 months after surgery to reduce the risk of gallstone formation, except for patients who had previously undergone cholecystectomy [67]. At follow-up, the patients were asked about supplement intake frequency and compliance, dietary concerns, and complaints after surgery like gastric reflux, constipation, diarrhea, nausea, vomiting, etc.

Biochemical Assays

Biochemical assays of Serum aa, Ca^{2+}, Serum vitamin B_{12}, and Vitamin D_3 were done through high-performance liquid chromatography to evaluate the 3 consecutive follow-ups. As per World Health Organization (WHO), the expected level of plasma ascorbate is 0.6 to 2.0 mg/dL, and deficiency is below 0.2 mg/dL [68]. Other nutrients lie in the range stated as Serum Ca^{2+}: 8.5-10.5 mg/dl [69], Vitamin D_3: 25-80 ng/mL [70], and Vitamin B_{12}: 200-900 pg/mL) [71].

Statistical Methods

We utilized mean and standard deviation for continuous data and percentage for categorical data in our descriptive statistics. To determine the mean difference in Calcium, serum iron, Cobalamin, Calciferol, and Ascorbic Acid levels before and after follow-up, we utilized a paired sample t-test. We examined the effects of Anastomosis Gastric Bypass Surgery by treating time (pre- and postoperative follow-up) as the primary predictor variable in our regression model. To analyze the impact of time, we used a mixed effects model with time as a fixed effect and the within-subject difference as a random effect. Our regression model included age, sex, BMI, and comorbidities, but the comorbidities showed no effect. Therefore, we evaluated the final model by removing the comorbidities from the regression model. We considered p values <0.05 to be statistically significant. We conducted our analyses using STATA 15 (Stata Corp, LP, College Station, Texas, USA) and generated figures using GraphPad Prism-8·3·0·538.

Ethical Approval

This study was approved by the Institutional Review Board of Asian Bariatrics Hospital, SG Highways, Ahmedabad, Gujarat, India, with Reference number IECHR-AB/2021/11 dated 19/05/2021. All the study subjects verbally explained the study's intention, motive, and future scientific publication. The written informed consent was obtained before data collection commenced.

Results

In this observational study, 150 patients were included before undergoing one anastomis gastric bypass surgery. The patients had a mean age of (mean±SD) 41.7±14.7 years. Of the participants, 56 (37.3%) were male, and 94 (62.7%) were female. The most prevalent comorbidity identified among the enrolled patients was hypertension, which affected 49.3%, followed by OSAS at 32.7%, and a history of diabetes at 29.3% (Table 1).

Table 1: Demographic characteristics of the study participants.

Factors	Observation
Age	41.7±14.7
Sex	
Male	56(37.3%)
Female	94(62.7%)
H/O Diabetes	44(29.3%)
H/O Hypertension	74(49.3%)
H/O OSAS	49(32.7%)
H/O Dyslipidemia	31(20.7%)
H/O Hypothyroidism	25(16.7%)

Data were presented as mean±SD or number with percent in the parenthesis.

Furthermore, both follow-up measurements showed a significant increase in cobalamin, Calciferol, and ascorbic acid levels compared to baseline (Table 2 and Figure 1). Most of the patients enrolled in the study were initially classified as obese; however, after the surgery, most became overweight. Both follow-up measurements revealed a significant reduction in BMI compared to the baseline measurement (Table 2 and Figure 1).

One year of age increase significantly increased serum Ca^{2+} by 0.02 ng/dl (95% CI 0.01, 0.03; p=0.002), and the female participants showed significantly higher S. Ca^{2+} (p=0.033). Serum iron level increased by 10.1 µg/dl at the first follow-up after surgery (95% CI= 0.51, 19.6; p=0.039) compared to pre-surgery measurement, and 0.27 µg/dl was noted by increasing by every one year increased of age. After surgery, Cobalamin showed a significant increase of 333 ng/ml and 334 ng/ml at follow-ups 1 & 2, respectively. Furthermore, age also showed a significant increase in Cobalamin by 4.72 ng/ml (p=0.001) (Table 3).

Calciferol also significantly increased after Anastomosis Gastric Bypass Surgery by 0.25 pg/ml (95% CI=0.05, 0.45; p=0.015) and 0.32 pg/ml (95% CI= 0.05, 0.59; p=0.018), respectively compared to pre-surgical observation. Similarly, ascorbic acid had a higher acceleration after post-surgical follow-ups by 14.5 mg/dl (95% CI=10.4, 18.5; p<0.001) and 16.0 mg/dl (95% CI=11.0, 20.9; p<0.001) respectively, compared to pre-surgical measurement. In comparison, every one-year increase in age declined the ascorbic acid by 0.11 mg/dl (95% CI=-

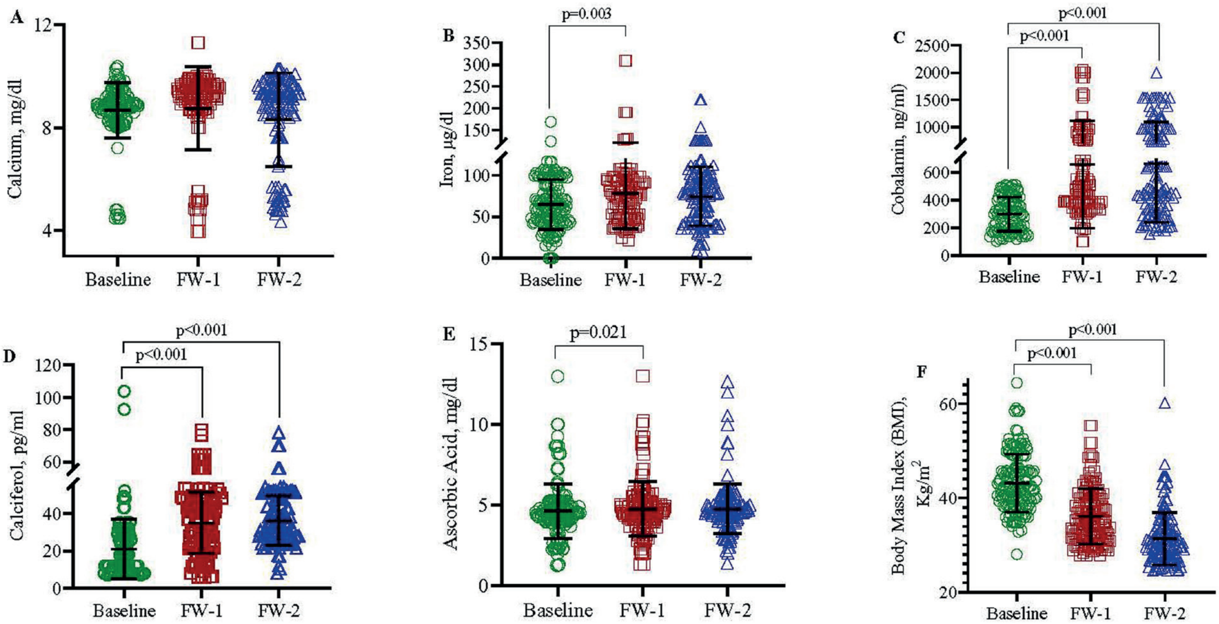

Figure 1: Difference in ascorbic acid, cobalamin, calciferol, calcium, serum iron level, and BMI before and after one Anastomosis Gastric Bypass Surgery. Paired sample t-test was applied to see the difference between baseline with follow-ups 1 & 2.

Table 2: Difference in Calcium, serum iron, Cobalamin, Calciferol, and Ascorbic Acid level before and after one Anastomosis Gastric Bypass Surgery.

	Baseline	Follow-up 1	P-value	Follow-up 2	p-value*
Calcium	8.66±1.14	8.69±1.68	0.826	8.34±1.70	0.071
Cobalamin	302.8±120.4	722.0±465.8	<0.001	745.3±472.4	<0.001
Calciferol	20.8±13.9	33.7±16.2	<0.001	35.2±13.2	<0.001
Ascorbic Acid	4.63±1.71	4.77±1.70	0.021	4.67±1.77	<0.001
BMI, Kg/m^2	43.1±6.12	36.1±5.88	<0.001	31.3±5.54	<0.001

0.21, -0.001; p=0.050) (Table 3). Additionally, no association was found between Ca^{2+} and Vitamin D at any follow-up.

Discussion

This study found plasma Iron levels after Bariatric surgery (Table 2, Figure 1). A similar finding was reported by Shipton *et al.*, they noticed increased serum iron levels after bariatric surgery, which peaked 12 months after the procedure [72]. Santos *et al.*, also found a significant rise in serum iron level postoperatively, and Tussing-Humphreys *et al.*, reported an improvement in iron status [73,74]. This improvement in serum iron level may be attributed to a reduction in hepcidin level following surgery [73]. Hepcidin is a hormone formed by the human liver that plays a central role in the absorption of iron and is found to be associated with the lowering of uptake of iron and iron release by macrophages [75, 76]. Inflammation results in hepcidin production, and since obesity is related to inflammation [77], these individuals are likely to have raised serum hepcidin levels with subsequent falls in serum iron levels. The increase in iron level observed in our study suggests an improvement in iron absorption likely due to reduced hepcidin levels resulting from the lowering of the inflammation process due to weight loss after bariatric surgery [Figure 2].

Table 3: The effect of one Anastomosis Gastric Bypass Surgery on Calcium, serum iron, Cobalamin, Calciferol, and Ascorbic Acid level between follow-up and pre-operation.

	Serum Calcium		Serum iron		Cobalamin		Calciferol		Ascorbic Acid	
	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value	β (95% CI)	p-value
Time										
Baseline	Ref.		Ref.		Ref.		Ref.		Ref.	
FW-1	0.21(-0.17, 0.58)	0.279	10.1(0.51, 19.6)	0.039	333(227, 439)	<0.001	0.25(0.05, 0.45)	0.015	14.5(10.4, 18.5)	<0.001
FW-2	-0.17(-0.61, 0.28)	0.465	3.96(-7.06, 15.0)	0.481	324(199, 448)	<0.001	0.32(0.05, 0.59)	0.018	16.0(11.0, 20.9)	<0.001
Age	0.02(0.01, 0.03)	0.002	0.27(0.04, 0.51)	0.022	4.72(2.01, 7.43)	0.001	0.004(-0.01, 0.02)	0.622	-0.11(-0.21, -0.001)	0.050
BMI	0.02(-0.01, 0.04)	0.190	-0.44(-1.01, 0.14)	0.139	-4.12(-10.7, 2.43)	0.218	0.02(-0.002, 0.03)	0.087	0.03(-0.23, 0.29)	0.842
Sex										
Male	Ref	Ref.			Ref.		Ref.		Ref.	
Female	0.38(0.03, 0.72)	0.033	-1.57(-8.88, 5.74)	0.674	-19.4(-100, 61.5)	0.638	0.44(-0.07, 0.94)	0.091	0.29(-2.91, 3.94)	0.859

Note: Both the estimates and significant differences were calculated using a subject-specific mixed effects model controlling for time, age, BMI, and sex.

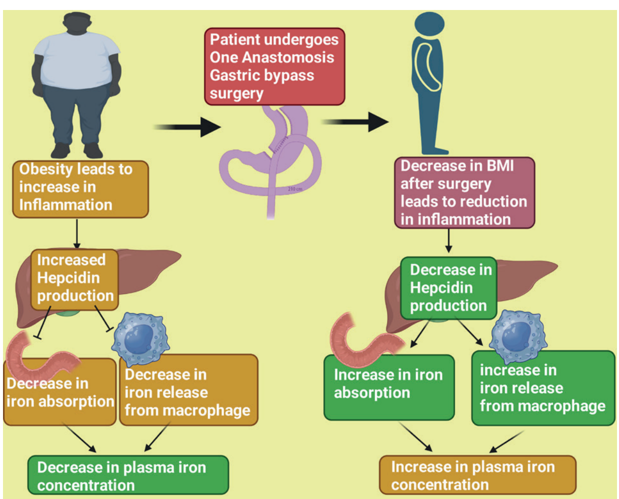

Figure 2: Illustration of the possible mechanism which connects obesity-related inflammation to a decrease in plasma iron levels. It also shows that after performing one anastomosis gastric bypass surgery, inflammation reduces, decreasing BMI, which leads to decreased hepcidin production from the liver and improvement in plasma iron levels. This figure has been drawn utilizing the premium version of BioRender with the License number MK25D66TMV. **Image Credit**: Rahnuma Ahmad.

The present study showed the mean (±SD) cobalamin was increased to 722.0±465.8 and 745.3±472.4 pg/mL on follow-up 1 and follow-up 2, respectively, which was statistically highly significant (p<0.001) (Table 2, Figure 1). In addition to this, after surgery, Cobalamin showed considerably raised to the level of 333 ng/ml and 334 ng/ml at follow-ups 1 & 2, respectively (Table 3, Figure 1). These findings were consistent with studies done by other researchers. They found significantly higher postoperative cobalamin levels than the control group, possibly due to vitamin B_{12} supplementation and probiotic administration [78,79]. Serum readings of cobalamin may reflect current consumption, particularly when not fasting or if the supplement was taken a few hours before the blood test. Therefore, if there is a concern for deficiency, physicians should treat it using extra supplements. The mean (±SD) serum calcium level increased from the baseline value of 8.66±1.14 to 8.69±1.68 and 8.34±1.70 mg/dl on follow-up 1 and 2, respectively (Table 2, Figure 1). One year of age increase significantly increased serum Ca^{2+} by 0.02 ng/dl (95% CI 0.01, 0.03; p=0.002), and the female participants showed significantly higher Serum Ca^{2+} (p=0.033) (Table 3). The duodenum and proximal gut are where normal calcium absorption primarily occurs. The food stream does not reach this section of the intestine due to gastric bypass, which results in calcium malabsorption after surgery. This consequence in Parathyroid hormone upregulation increases vitamin D synthesis, facilitating bone resorption and intestinal absorption of calcium [80] (Figure 3). In addition, after the procedure, most of the study participants who were earlier considered obese transformed into overweight patients. Referring to Table 2 and Figure 1, both follow-up measurements showed a significant decrease in BMI from the baseline measurement. Another study reported a similar finding. They showed that the mean BMI and mean weight was significantly ($p<0.001$) decreased in subjects with morbid obesity before and after one anastomosis gastric bypass (OAGB) achieved at a single center throughout a 2-year follow-up [81].

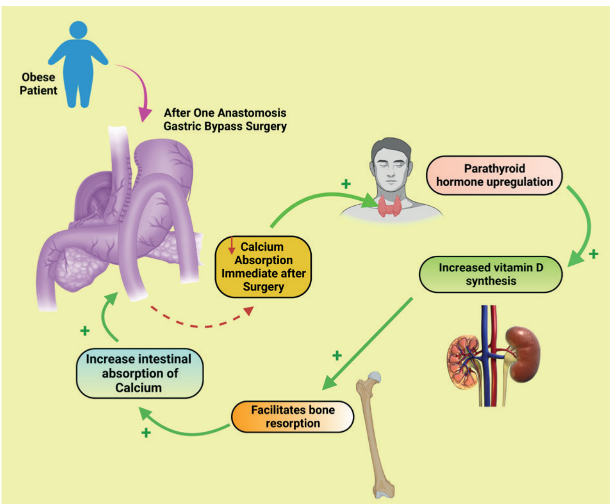

Figure 3: Diagram showing the mechanism of increased intestinal absorption of calcium after One Anastomosis Gastric Bypass Surgery. This figure has been drawn utilizing the premium version of BioRender with the License number ZA25D84HAL. **Image Credit**: Susmita Sinha.

In our study, a rise in the ascorbic acid level was observed 3 months and 6 months postoperatively when compared to the pre-operative value (Table 2, Figure 1). This finding follows the findings of Aesth *et al*., who found a gradual increase in Vitamin C levels in plasma during the first year following bariatric surgery [82]. The concentration of Vitamin C may have increased due to vitamin supplementation after surgery. Also, the gradual Vitamin C increase may be attributed to the reduction in obesity-associated inflammation [82,83]. Since multiple factors contribute to micronutrient deficiency, such as reduced nutrient absorption, overgrowth of small intestine bacteria, altered eating habits, and vomiting, it is necessary to promote vitamin supplementation and continue to monitor the micronutrient levels of these patients [84,85]. Vitamins and minerals supplementation recommended for these patients is modified and adapted from Clinical Practice Guidelines from the combined American Association of Clinical Endocrinologists (AACE), The Obesity Society (TOS) [86], The Endocrine Society Clinical Practice Guidelines [87] and the American Society for Metabolic and Bariatric Surgery (ASMBS) Integrated Health Nutrition Guidelines [88]. Our study also notes a decline in serum ascorbic acid levels with age, possibly due to the increased prevalence of chronic illnesses with age and lower compliance to Vitamin intake in the older population [89]. Calciferol's plasma level was significantly increased postoperatively compared to baseline at 3 months and 6 months after surgery. Beckman *et al*., study findings were similar of the current research results [90]. The possible mechanism for this change in Vitamin D plasma level may be a due reduction in body weight, fat mass, and inflammation related to obesity. A decrease in inflammatory cytokines was associated with weight loss in a previous study [91]. An inverse relationship has been observed between Interleukin-6 (an inflammatory cytokine) and 25(OH)D [92]. Thus, improving inflammation mediated by weight loss and reduced Vitamin D turnover may increase the circulating level of plasma vitamin D [90]. However, other studies found improved but low 25(OH)D levels after bariatric surgery [93-96]. Food intake drastically reduces after altering the gastrointestinal tract from 2300-2900 kcal/day [97,98] to about 1200-1400 kcal/day [98,99]. Since the number of vitamin D-rich foods is few, like milk and oily fish, adequate supplementation with Vitamin D is necessary to avoid deficiency [90]. The patients were given vitamin supplementation in our study.

Conclusion

This study contributes relevant knowledge for managing individuals who opt for gastric bypass surgery. Nutritionists and Physicians are likely to increase their involvement in performing follow-ups of patients who undergo bariatric surgery since the number of patients choosing to undergo this surgery is rising. The outcome of this study shows the increase in vitamin and mineral concentration following gastric bypass surgery. Such studies can help build guidelines that may be observed in primary health care levels. These guidelines must include the follow-up visit schedules, the biomarkers to be checked, to the supplements that must be prescribed acccoriding to the personlized needs of the patient, and signs that indicate the need for referral. The affordable, effective, and feasible regimen of follow-up for patients after bariatric surgery needs to be established for the health and safety of those hoping for a life free from obesity and related comorbidities without having to face the deteriorating effects of nutritional deficiencies.

Consent for Publication

The author reviewed and approved the final version and has agreed to be accountable for all aspects of the work, including any accuracy or integrityn issues.

Disclosure

The author declares that they do not have any financial involvement or affiliations with any organization, association, or entity directly or indirectly with the subject matter or materials presented in this editorial. This includes honoraria, expert testimony, employment, ownership of stocks or options, patents, or grants received or pending royalties.

Data Availability

The data is exclusively available from the principal author for research purposes only.

Authorship Contribution

All authors contributed significantly to the work, whether in the conception, design, utilization, collection, analysis, and interpretation of data or all these areas. They also participated in the paper's drafting, revision, or critical review, gave their final approval for the version that would be published, decided on the journal to which the article would be submitted, and made the responsible decision to be held accountable for all aspects of the work.

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