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Original Article

Protective effects of laparoscopic sleeve gastrectomy on atherosclerotic and hemocytic parameters in obese patients

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ABSTRACT

Objectives: The aim of this study was to evaluate the effects of the change in the body mass index following laparoscopic sleeve gastrectomy on the vascular morphology structure and biochemical and hemocytic parameters.

Material and Methods: A prospective evaluation of 60 patients who underwent sleeve gastrectomy was conducted. The relationship was evaluated between the vascular morphological parameters and biochemical and hemocytic inflammatory variables of the patients preoperatively and at 6, 12, and 18 months postoperatively.

Results: Compared to the baseline values, a significant decrease was determined in the carotid intima media thickness at 6, 12, and 18 months ($p<0.001$, $p<0.001$, $p<0.001$, respectively). The compliance and distensibility values were observed to increase over time ($p<0.05$, $p<0.001$, $p<0.001$, respectively). A statistically significant difference was determined in the carotid intima media thickness values according to gender, with males (n:7) measuring 0.618±0.123 mm and females (n:53) measuring 0.506±0.113 mm ($p<0.01$). When patients were grouped as neutrophil-to-lymphocyte ratio ≤2.54 (n:41) and neutrophil-to-lymphocyte ratio>2.55 (n:19), the increasing neutrophil-to-lymphocyte ratio values were observed to be in proportion to the carotid intima media thickness, and the difference was statistically significant ($p<0.001$). When factors affecting the vascular morphology parameters measured at baseline and throughout the study were evaluated with the correlation analysis, there was observed to be a positive correlation between the baseline carotid intima media thickness thickness and neutrophil percentage ($r=0.736$, $p<0.001$) and neutrophil-to-lymphocyte ratio ($r=0.676$, $p<0.001$), and between the negative correlation and lymphocyte percentage ($r=-0.628$, $p<0.001$).

Conclusion: Laparoscopic sleeve gastrectomy is not only a cosmetic procedure reducing the body mass index values, but it also has a beneficiary effect on vascular morphology, biochemical, and hemocytic parameters.

Keywords: Hemocytic inflammatory parameters, laparoscopic sleeve gastrectomy, vascular morphology

INTRODUCTION

The increasing global prevalence of obesity in the last 30 years has caused comorbidities such as Type 2 diabetes mellitus (DM), hypertension (HT), and dyslipidemia and serious health problems, primarily cardiovascular diseases (CVD) (1). Although it is not possible to explain the effect of obesity on cardiovascular functions by a single mechanism, previous studies have focused on the role of increasing arterial stiffness (AS) (2-5).

Similarly, the relationship between the increased systolic and diastolic blood pressures (SBP and DBP) and hyperglycemic status of obesity and CVD is also now known. In addition, inflammation has been suggested as a risk factor for coronary artery disease (CAD) as a result of the studies on the role it plays in the development of atherosclerosis and plaque instability (5-7).

Together with the use of diet, exercise, and various medications in the treatment of obesity, bariatric surgery, particularly sleeve gastrectomy (SG), has been increasingly used in recent years as it is easy to apply and has fewer complications compared to other surgical methods (8). Previous studies have shown that various surgical methods used in the treatment of obesity have improved several metabolic parameters and that with SG, besides the treatment of metabolic diseases such as Type 2 DM, the lipid profile has reduced the cardiovascular risks by showing positive effects on arterial elasticity, diastolic functions, and left ventricle mass (9-11). However, to the best of our knowledge, there has been no study on the change in hemocytic inflammatory markers such as the neutrophil percentage, lymphocyte percentage, neutrophil-to-lymphocyte ratio (NLR), the mean platelet volume (MPV), and vascular morphology parameters such as the carotid intima media thickness (cIMT), elastic modulus, distensibility, and elasticity in individuals who have lost weight as a result of SG.

The aim of this study was to evaluate the effects of a body mass index (BMI) change following laparoscopic sleeve gastrectomy (LSG) on the vascular morphological structure and biochemical and hemocytic inflammatory parameters.

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MATERIAL AND METHODS

Study Population

Approval for the study was granted by the local Ethics Committee. This prospective study was conducted on a total of 60 morbidly obese and super-obese patients who presented at the General Surgery Polyclinic for obesity surgery between October 2014 and July 2016. Informed consent was obtained from all the patients. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Clinical parameters, anthropometric measurements, biochemical and hematological parameters, and radiological variables such as cross-sectional compliance, cross-sectional distensibility, lumen cross-section area, wall cross-section area, and elastic modulus were analyzed at 0, 6, 12, and 18 months. The power of the study and the range of a sufficient number of patients were evaluated with power analyses and terminated when the sample size reached 60 according to the cIMT parameters with 91% power to detect the test hypothesis with a significance level of 0.05. To prevent the study bias, the radiological data and hematological and biochemical parameters were gathered separately (by Author 1 and Author 2, respectively) and were combined for statistical evaluation after the study was completed.

Initial Assessment

Before commencing the study, a detailed anamnesis was taken from all the patients, including cardiac and metabolic diseases, medications used, and information about cigarette smoking. Baseline anthropometric variables and the SBP and DBP values were recorded for each patient. Blood samples were taken from all the patients before the study for blood glucose, triglyceride, high-density lipoprotein (HDL), low-density lipoprotein (LDL), cholesterol, neutrophil percentage, lymphocyte percentage, platelet count, and MPV values. NLR was calculated from the obtained data.

Ultrasonographic Evaluation Before the Study

Measurements were taken using a high-resolution Doppler ultrasonography system (Aplio™ 400 Platinum, Toshiba Medical Systems Corporation, Tochigi, Japan) with a broadband linear probe (PLT-704SBT, Aplio™ 400 Platinum, Toshiba Medical Systems Corporation, Tochigi, Japan). First, the probe was placed in the right carotid artery bifurcation, and cIMT, diastolic, and systolic lumen diameters were measured. Pulse pressure measurements (SP, DP, ΔP) were taken with an automatic sphygmomanometer (Vitagnost 2015 OC, MARS, Taiwan). The vascular AS parameters were calculated as described in literature (12) using the following equations:

- Cross-sectional compliance=$(\pi.(SD^2-DD^2))/(4.(SP-DP))$
- Cross-sectional distensibility=$(SD^2-DD^2)/(DD^2.(SP-DP))$
- Diastolic wall stress=$(DD/(2.IMT)).((SP+SD)/2)$
- Cross-sectional area of lumen=$\pi.DD^2/4$
- Cross-sectional area of wall=$\pi.((DD/2)+IMT)^2-\pi.(DD/2)^2$
- Elastic modulus=(3/(1+(Cross-sectional area of lumen/Cross-sectional area of wall)))/ Cross-sectional distensibility

Anthropometric Measurements

Body mass index was calculated as weight (kg)/height squared (m^2).

Laboratory Tests

Before taking the blood samples, the patients were questioned in detail, and physical examination was made to evaluate the presence of infection. Patients with suspected infection in the physical examination and elevated white cell levels were called for a follow-up examination 1 month after treatment. If no infection was determined, blood samples were taken between 08^{00} 10^{00} after a 10-minute rest.

Surgical Procedure

The same surgical method was applied to all patients by the same surgical team (FMY, EB). The procedure was applied with the 5-trochar method to the patient lying in the French position, in the reverse Trendelenburg position. The abdomen was inflated with 14 mmHg carbon dioxide, then starting from approximately 3cm prepyloric, the gastrocolic and gastrosplenic ligaments were cut with a 5 mm LigaSure (Covidien, Dublin,

Table 1. Baseline characteristics of the studied participants

Characteristic	Male (n=7)	Female (n=53)	P
Age (years)	35.14±11.30	38.86±10.39	0.38
BMI (kg/m2)	47.76±5.16	47.52±5.48	0.91
SBP (mmHg)	135.71±9.75	136.98±11.02	0.77
DBP (mmHg)	76.54±5.81	77.28 ±5.81	0.72
Blood glucose concentration	98.71±16.67	104.37±28.79	0.61
Total cholesterol (mg/dL)	194.50±28.29	207.94±30.77	0.31
Triglycerides (mg/dL)	114.71±19.28	170.18±88.66	0.10
HDL-cholesterol (mg/dL)	38.50±5.98	39.52±7.14	0.73
LDL-cholesterol (mg/dL)	123.71±27.93	122.56±30.44	0.92
VLDL	23.66±3.93	32.51±16.06	0.18
HbA1C	5.17±0.49	5.96±1.02	0.13
Neu percentage	62.50±3.65	62.12±6.65	0.88
Lymp percentage	28.22±2.79	28.41±6.07	0.93
NLR	2.23±0.30	2.34±0.79	0.73
Plt (K/μL)	306.42±39.34	308.62±75.06	0.94
MPV (fL)	9.55±0.74	9.43±1.40	0.82
Intima-media thickness (mm)	0.618±0.123	0.506±0.113	0.01
Compliance	0.128±0.024	0.183±0.083	0.09
Elastic modulus (N/m^2)	212.63±60.54	157.57±103.23	0.17
Distensibility (mmHg 1×10^3)	0.0046±0.001	0.0071±0.004	0.13

Data are expressed as the mean±SD; unless otherwise noted.
Independent T-Test (Bootsrap)—Mann–Whitney U Test (Monte Carlo)—Fisher's Exact Test (Monte Carlo)
BMI: body mass index; DBP: diastolic blood pressure (mmHg); HbA1C: hemoglobin A1C; HDL: high-density lipoprotein (mg/dL); LDL: low-density lipoprotein (mg/dL); MPV: mean platelet volume (fL); NLR: neutrophil-to-lymphocyte ratio; Plt: platelet (K/μL); SBP: systolic blood pressure (mmHg); VLDL: very low-density lipoprotein

Ireland), and the stomach was mobilized. A 38Fr orogastric tube was placed in the prepyloric area. Then a laparoscopic 60 mm stapler (Echelon Flex Endopath Stapler; Ethicon Endo-Surgery, Cincinnati, OH, USA) was used, with the first two stapler cartridges 4.2 mm green, and the other cartridges 3.5 mm blue. After completion of the resection, the resected tissue was removed from the 12 mm trocar, and the procedure was terminated. Radiologically, cIMT, compliance, distensibility, and elastic modulus values were accepted, and NLR was accepted in the hematological parameters.

In the patients were evaluated with respect to their age, gender, comorbidities, BMI values, biochemical parameters such as blood glucose, HbA1C HDL-cholesterol, LDL-cholesterol, Triglycerides and hematological parameters such as neutrophil percentage, lymphocyte percentage, NLR, MPV, and platelet count and radiological variables such as cIMT, compliance, dıstensibilty, and elastic modulus.

Statistical Analysis

Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 22.0 (IBM Corp.; Armonk, NY, USA). Data were stated as mean±standard deviation (SD). Comparisons between groups were performed by one-way ANOVA test followed by Bonferroni correction. To evaluate factors related to cIMT, linear regression models were used, and data were stated as beta-coefficients at a 95% confidence interval (CI). A value of $p<0.05$ was accepted as statistically significant.

RESULTS

The patients included in the study comprised 53 (88.3%) females and 7 (11.7%) males (Table 1). The mean age of the patients was 38.43±10.47 years (range: 18–56 years), and the baseline mean BMI values were 47.55±5.40 (range: 39–61.73). At the 6, 12, and 18-month follow-up examinations, the mean BMI values were 35.19±4.56 kg/m^2, 30.84±4.00 kg/m^2, and 28.35±3.88 kg/m^2, respectively (Table 2). The reduction in the BMI values was more evident in the first 6 months, and the rate of decreased, although it continued. In the preoperative period, 29.5% of patients were using medication for high blood pressure, then together with the reducing the SBP and DBP values proportional to the weight lost, at the end of 18 months, only 3.3% continued to use medication for high blood pressure. The anthropometric changes of the patients are shown in Table 2.

Compared with the baseline biochemical values, the lipid profile and glycemic parameters of the patients were observed to have significantly improved (Table 2). Similar results were not seen in the anthropometric hemocytic parameters. At the end of 18 months, while a decrease was observed in NLR, MPV, and the platelet count, the lymphocyte percentage was seen to have increased compared to the preoperative values (Table 2).

A statistically significant decrease was determined in the cIMT values at 6, 12, and 18 months compared to the baseline values ($p<0.001$, $p<0.001$, $p<0.001$), and no difference was seen between the values at 6, 12, and 18 months

Table 2. Clinical, biological, biochemical, hematologic, and vascular morphologic parameters of the study group, preoperatively, and at 6, 12, and 18 months postoperatively

	Preoperatively	6 months postoperatively	12 months postoperatively	18 months postoperatively
Weight (kg)	124.66±15.24	92.20±12.28#	80.78±2.81#	74.35±9.14#
BMI (kg/m^2)	47.55±5.40	35.19±4.56#	30.84±4.00#	28.355±3.88#
SBP (mmHg)	136.83±10.81	127.17±12.78*	124.58±8.54*	117.50±4.73#
DBP (mmHg)	88.34±6.74	83.52±4.14	76.28±5.74*	73.57±5.18*
Blood Glucose (mg/dL)	103.71±27.61	83.52±10.30#	85.34±9.00#	84.97±9.99#
Total Cholesterol (mg/dL)	206.55±30.57	173.66±23.24#	189.33±33.17	179.50±34.15#
HDL-Cholesterol (mg/dL)	39.41±6.99	50.61±13.06#	45.11±10.82*	54.20±10.17#
LDL-Cholesterol (mg/dL)	122.69±29.92	105.71±27.24*	113.09±24.00	118.73±31.29
Triglycerides (mg/dL)	163.36±85.17	126.12±59.51*	116.67±70.14*	99.41±39.79#
Neu percentage	62.16±6.35	52.47±7.28#	50.68±7.11#	53.76±7.07#
Lymp percentage	28.39±5.77	36.92±6.74#	38.36±6.20#	36.34±6.59#
NLR ratio	2.33±0.75	1.50±0.45#	1.38±0.42#	1.55±0.46#
MPV (fL)	9.44±1.33	9.12±1.24	9.01±1.04	8.86±0.95*
Plt (K/µL)	308.36±71.58	256.55±61.67#	249.41±65.38#	249.84±48.51#
Intima-media thickness (mm)	0.519±0.11	0.384±0.06#	0.342±0.06#	0.353±0.06#
Compliance	0.177±0.08	0.213±0.07*	0.233±0.07#	0.232±0.07#
Distensibility (mmHg 1×10^3)	6.8±0.4	8.9±0.4*	10±0.5#	11±0.4#
Elastic modulus (N/m^2)	163.99±100.41	100.30±35.43#	85.20±27.00#	79.59±33.68#

Data are expressed as the mean±SD, unless otherwise noted. Analysis of variance post hoc Tukey honest significant difference with Bonferroni correction

BMI: body mass index; DBP: diastolic blood pressure (mmHg); HbA1C: hemoglobin A1C; HDL: high-density lipoprotein (mg/dL); LDL: low-density lipoprotein (mg/dL); MPV: mean platelet volume (fL); NLR: neutrophil-to-lymphocyte ratio; Plt: platelet (K/µL); SBP: systolic blood pressure (mmHg)

*$p<0.05$ vs. baseline, #$p<0.001$ vs. baseline

Table 3. Comparison of vascular morphology values according to different parameters

Groups		Intima-media Thickness (mm)	Compliance	Elastic Modulus (N/m²)	Distensibility (mmHg 1×103)
BMI	≤49.9 kg/m² (n:39)	0.501±0.122	0.177±0.077	157.168±105.26	7.08±0.4
	≥50 kg/m² (n:21)	0.548±0.109	0.180±0.088	171.79±91.36	6.6±0.4
P	0.15	0.87	0.60	0.72	
Gender	Male (n:7)	0.618±0.123	0.128±0.024	212.63±60.54	4.6±0.1
	Female (n:53)	0.506±0.113	0.183±0.083	157.57±103.23	7.1±0.4
P	0.01	0.09	0.17	0.13	
SBP	≤120 mmHg (n:39)	0.514±0.121	0.180±0.08	160.40±102.41	7.0±0.4
	≥121 mmHg (n:21)	0.514±0.104	0.154±0.07	187.33±88.57	5.7±0.3
P	0.42	0.40	0.48	0.42	
	≤106 mg/dL				
Glucose concentration (n:45)	0.517±0.12	0.175±0.07	157.19±81.40	0.0068±0.003	
	≥107 mg/dL (n:15)	0.542±0.11	0.182±0.08	184.42±145.15	0.0070±0.005
P	0.084	0.77	0.36	0.87	
Total cholesterol (mg/d) (n:38)	≤200 mg/dL				
	0.506±0.11	0.175±0.079	157.87±89.98	0.0068±0.004	
	≥201 mg/dL (n:22)	0.538±0.12	0.189±0.079	162.71±107.52	0.0072±0.004
P	0.33	0.53	0.86	0.68	
NLR	≤2.54 (n:41)	0.484±0.111	0.183±0.086	156.43±102.64	7.0±0.45
	>2.55 (n:19)	0.595±0.102	0.174±0.079	180.32±96.05	6.7±0.39
P	0.001	0.703	0.396	0.824	
MPV	≤10.4 (n:46)	0.492±0.119	0.185±0.082	153.32±85.04	7.2±0.42
	>10.5 (n:14)	0.527±0.118	0.150±0.071	199.06±137.83	5.4±0.36
P	0.335	0.163	0.137	0.151	

Data are expressed as the mean±SD, unless otherwise noted
Independent T-Test(Bootsrap)—Mann–Whitney U Test (Monte Carlo)—Fisher's Exact Test (Monte Carlo)—Pearson Chi-Squared Test (Monte Carlo)—One-Way Analysis of Variance
BMI: body mass index; MPV: mean platelet volume (fL); NLR: Neutrophil-to-lymphocyte ratio; SBP: Systolic blood pressure (mmHg)

(p>0.05). The compliance and distensibiity values were observed to increase over time (p<0.05, p<0.001, p<0.001) (Table 2).

The basal vascular morphology values of the patients included in the study were compared taking into consideration some different clinicopathological factors (Table 3). Accordingly, the patients were grouped as morbidly obese (Group 1, n=39, BMI≤49.9 kg/m²) and super obese (Group 2, n=21, BMI≥50 kg/m²), and when the relationship between the BMI values and the vascular morphology values was examined, there was no statistically significant difference observed between the groups (p=0.15, p=0.87, p=0.72, p=0.60). When the vascular morphology values were evaluated according to gender, the cIMT values were 0.618±0.123 mm for males (n:7) and 0.506±0.113 mm for females (n:53), with a statistically significant difference between the genders (p<0.01). A significant difference was determined between the genders in respect to compliance values (p<0.09), but although the distensibility and elastic modulus values of females were determined to be better than those in males, there was no significant difference (p=0.17, p=0.13). When the patients were grouped according to biochemical values such as hyperglycemia and hypercholesterolemia, no statistically significant difference was observed between the groups. The statistical evaluation results are shown in Table 3.

The patients were grouped as NLR≤2.54 (n:41) and NLR>2.55 (n:19) (13). The cIMT values increased in proportion to the increasing NLR values, and the difference was observed to be statistically significant (p<0.001). Although the compliance, distensibility, and the elastic modulus values deteriorated with an increased NLR, the results were not observed to be statistically significant (Table 3). Classification was made as MPV≤10.4 and MPV>10.5. The vascular morphology values at high MPV values were observed to have deteriorated, although not to a statistically significant degree (Table 3).

In the correlation analysis of the factors affecting the vascular morphology parameters measured at baseline and during the study, a positive correlation was determined between cIMT and male gender (r =–0.304, p<0.01), neutrophil percentage (r=0.736, p<0.001) and NLR (r=0.676, p<0.001), and a negative correlation with lymphocyte percentage (r=–0.628, p<0.001).

Table 4. Comparison of factors affecting the vascular morphology structure preoperatively and at 18 months postoperatively

	Intima-media thickness (mm)				Compliance				Distensibility (mmHg 1×10^3)				Elastic modulus (N/m^2)			
	Preoperative		Postoperative 18th month		Preoperative		Postoperative 18th month		preoperative		Postoperative 18th month		preoperative		Postoperative 18th month	
	r	P	r	P	r	P	r	P	r	P	r	P	r	P	r	P
Gender	-0.304*	0.01	-0.106	0.102	0.22	0.09	0.102	0.11	0.197	0.13	0.06	0.40	-0.178	0.17	-0.146	0.05
BMI	0.135	0.30	0.521**	0.001	0.036	0.78	-0.234**	0.001	0.018	0.88	-0.297**	0.001	-0.003	0.98	0.353**	0.001
SBP	0.057	0.66	0.531**	0.001	-0.059	0.65	-0.234	0.01	-0.031	0.81	-0.336**	0.001	0.070	0.59	0.356**	0.001
Glucose	0.65	0.62	0.348**	0.001	-0.066	0.61	-0.07	0.33	-0.009	0.94	-0.115	0.11	0.100	0.44	0.272**	0.001
HbA1C	0.075	0.63	0.197	0.08	-0.079	0.61	-0.090	0.42	-0.046	0.77	-0.134	0.23	0.083	0.59	0.095	0.401
T Chol	0.004	0.976	0.285**	0.001	-0.088	0.51	-0.120	0.13	-0.067	0.61	-0.008	0.92	0.031	0.81	0.188*	0.019
HDL	-0.132	0.326	-0.232**	0.002	0.129	0.33	0.072	0.34	0.129	0.33	0.72	0.35	0.095	0.48	-0.187*	0.014
LDL	0.068	0.060	0.156*	0.037	0.063	0.63	-0.011	0.88	0.154	0.24	0.084	0.26	0.029	0.82	0.105	0.162
Neu percentage	0.736**	0.001	0.610**	0.001	-0.073	0.57	-0.173**	0.008	-0.172	0.189	-0.123	0.06	0.377**	0.003	0.384**	0.001
Lymp %	-0.628**	0.001	-0.596**	0.001	0.020	0.876	0.194**	0.003	0.133	0.310	0.157*	0.017	-0.296*	0.022	-0.379**	0.001
NLR	0.676**	0.001	0.653**	0.001	-0.043	0.746	-0.181**	0.006	-0.161	0.218	-0.145*	0.028	0.341**	0.008	0.391**	0.001
MPV	-0.241	0.063	-0.008	0.902	0.034	0.797	-0.012	0.855	-0.004	0.976	-0.092	0.166	-0.078	0.55	0.118	0.073
Plt	0.253	0.051	0.384**	0.001	-0.064	0.628	-0.152*	0.021	-0.099	0.45	-0.112	0.09	0.147	0.262	0.270**	0.001

BMI: body mass index; DBP: diastolic blood pressure (mmHg); HbA1C: hemoglobin A1c HDL: high-density lipoprotein (mg/dL); LDL: low-density lipoprotein (mg/dL); MPV: mean platelet volume (fL); NLR: neutrophil-to-lymphocyte ratio; Plt: platelet (K/µL); SBP: systolic blood pressure (mmHg) *: p<0.05; **:p<0.001

The vascular, hematological, and biochemical parameters in the preoperative period decreased over time, and when the correlations between the vascular, hematological, and biochemical parameters were re-evaluated at the end of the study, taking the significant differences into account, there was seen to be a significant correlation between several parameters and cIMT, compliance, distensibility, and elastic modulus. The data are shown in Table 4 and Figures 1, 2, and 3.

In the linear regression analysis of the results seen as significant correlations in the postoperative period, the factor with the most effect on cIMT was observed to be a decrease in the BMI value. The crude model shows the association between cIMT and BMI: β=0.453 (95% CI), p<0.001. The most important interactions between cIMT and variables within the biochemical and hemocytic parameters were determined to be between Neupercentage: β=0.797 (95% CI) and NLR: β=0.111 (95% CI) (p<0.01).

DISCUSSION

To the best of our knowledge, this is the first study to evaluate the relationship between changes occurring in BMI following LSG and the vascular morphology structure and hemocytic inflammatory parameters.

It was observed that as the BMI values of the patients decreased, there was a parallel decrease in the cIMT values, which was seen to be statistically significant at 6, 12, and 18 months compared to the baseline values. When factors related to the change in the cIMT values were evaluated, a strong relationship was observed with BMI and SBP. Of the biochemical parameters, a strong positive relationship was seen with hyperglycemia and total cholesterol values in particular, and the increase in the HDL cholesterol levels was observed to negatively affect cIMT. The correlation between NLR from the inflammatory parameters and cIMT was extremely strong and the increase in lymphocyte percentage was observed to have a negative effect on cIMT. Although a reduction was seen in the MPV values with weight lost, the correlation was not significant.

At the end of the study period, there was a strong negative correlation observed between the decrease in BMI and compliance and distensibility. While no correlation was observed between biochemical parameters and compliance or distensibility, of the hemocytic inflammatory markers, the increase in the lymphocyte percentage and the decrease in the NLR values were seen to have positive effects on both compliance and distensibility.

There is a known relationship between CVD and age and gender. Although previous studies have shown changes in vascular morphology parameters in males and those older than 45 years in particular (14, 15), no correlation was seen in the current study between age and vascular morphology changes. This was thought to be due to the low mean age of the patients in the study. However, when the results were evaluated in respect of gender, the mean baseline cIMT of the male participants (0.618 mm) were seen to be higher than those of the females (0.506 mm) (p<0.001). In a study by Dengel et al. (16), the cIMT values of males were reported to be higher, but after correction taking the carotid diameter into consideration, the difference was eliminated.

A high blood pressure is a well-known risk factor for CDV and cerebrovascular diseases. There is not only a direct effect of high BP, but increasing vascular cIMT through possible indirect mechanisms also causes an increase in AS (17). In the

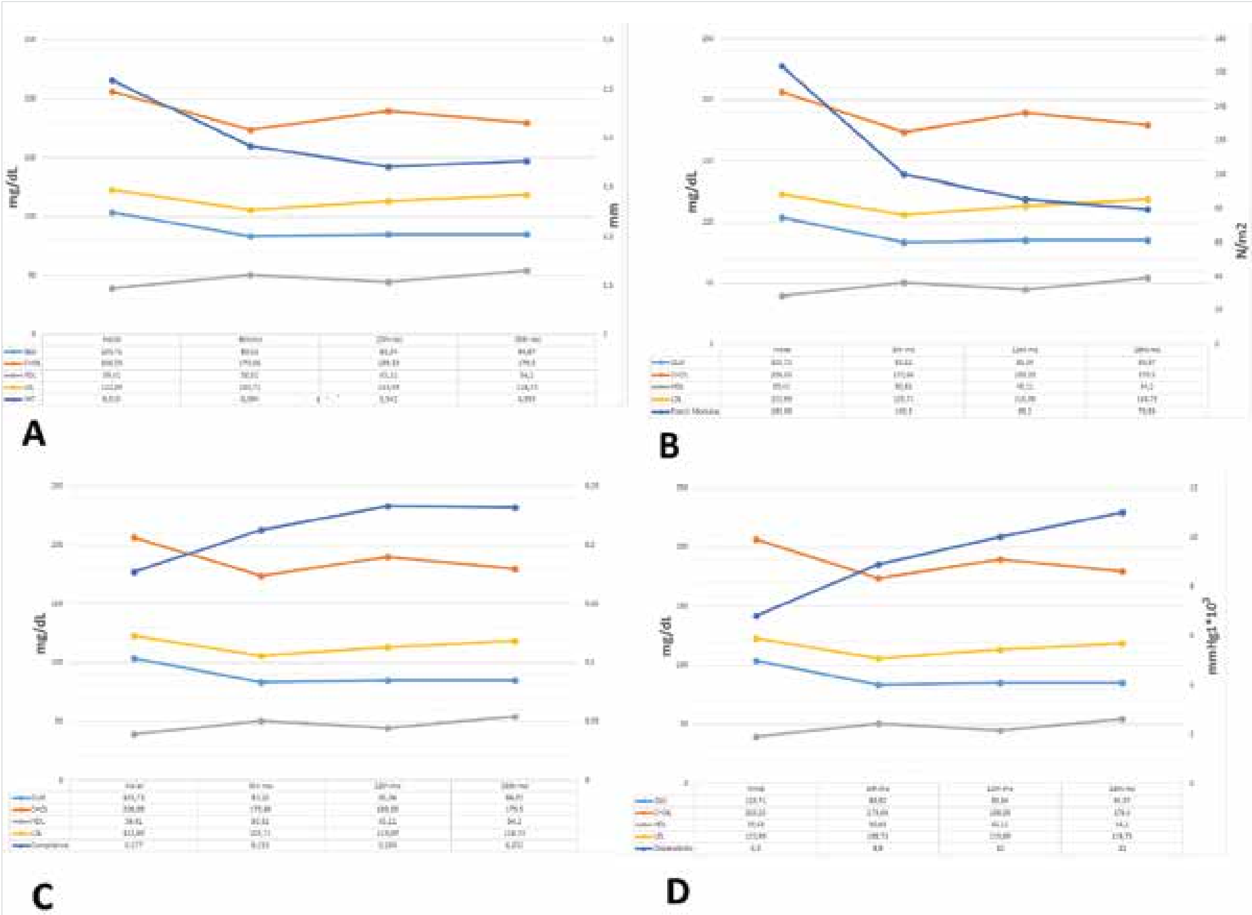

Figure 1. a-d. Temporal correlation of biochemical and vascular stiffness parameters. It is seen that IMT and biochemical parameters decrease with time (a). A positive correlation with elastic modulus and biochemical parameters (b). A negative correlation between compliance, distensibility, and biochemical parameters (c, d)

current study, while no correlation was observed between the traditional risk factor of SBP and baseline cIMT, a strong correlation was observed after treatment with the reduced cIMT values. At the beginning of the study, 29.5% of the patients had severe HT that required at least one medication, while at the end of the 18-month follow-up, only 3.3% of patients required medication. The improvement in hypertensive status was seen to have positive effects on distensibility although not as much as cIMT. Apart from the decrease in the SBP and BMI values, which were thought to have a direct effect on cIMT in the current study, an improvement was also observed in biochemical parameters and hemocytic parameters through indirect mechanisms.

When evaluation has been made in respect of biochemical parameters, several studies have shown a correlation between CVD and the hyperglycemic state and hyperlipidemia, and this has become a generally accepted status. Tropeano et al. (18) reported that hyperglycemia was one of the factors with an independent effect on cIMT. Sanches et al. (19) reported a relationship between an increased insulin resistance and cIMT. A recent study reported a significant decrease in the cIMT and insulin resistance in patients undergoing SG (20). In the current study, an extremely strong correlation was seen between the hyperglycemic status and both the cIMT and elastic modulus. However, similar results were not determined between distensibility and compliance. In the linear regression analyses of the current study, there was seen to be interaction between both the blood glucose level (10%) and the decrease in the HbA1C level (17%) with cIMT.

Dyslipidemia is an independent risk factor in the development of atherosclerosis, and the hyperlipidemic status has been shown to be related to an increase in cIMT (21). This relationship is known to be more evident based on familial hypercholesterolemia (22, 23). In studies that have evaluated the relationship between cIMT and cholesterol sub-types, the LDL cholesterol (LDL-C) concentrations have been reported to be related to an increase in cIMT (24, 25), and an increase in HDL cholesterol has been reported to have a positive effect (26). Similar to findings in the literature, in the current study, the HDL levels had a negative effect on cIMT, and no effect was seen with regard to compliance and distensibility. However, in contrast to literature reports, the LDL cholesterol levels, which showed a weak effect on cIMT in the current study, were not observed to be significantly correlated with any other parameters apart from cIMT.

Inflammation and lipid peroxidization are mechanisms held responsible for the development of atherosclerosis. However, there are different views related to whether immunological parameters, inflammatory cytokines, and lipid peroxidization products have an effect on cIMT. Previous studies have generally focused on the key role of inflammation in CAD (13, 27, 28). In contrast to the key role played by neutrophils in particular in coronary

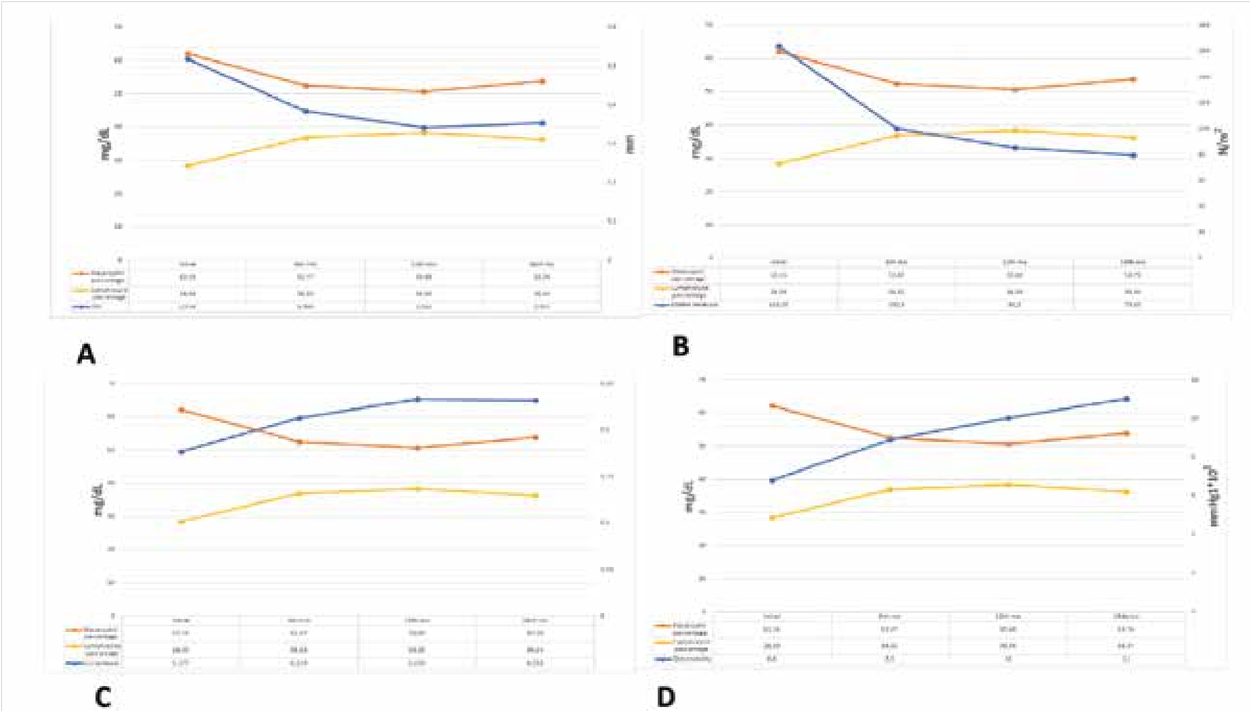

Figure 2. a-d. Temporal correlation of hemocytic and vascular stiffness parameters. Negative correlation with lymphocyte percentage and IMT, elastic modulus (a, b). Positive correlation between compliance, distensibility, and lymphocyte percentage (c, d)

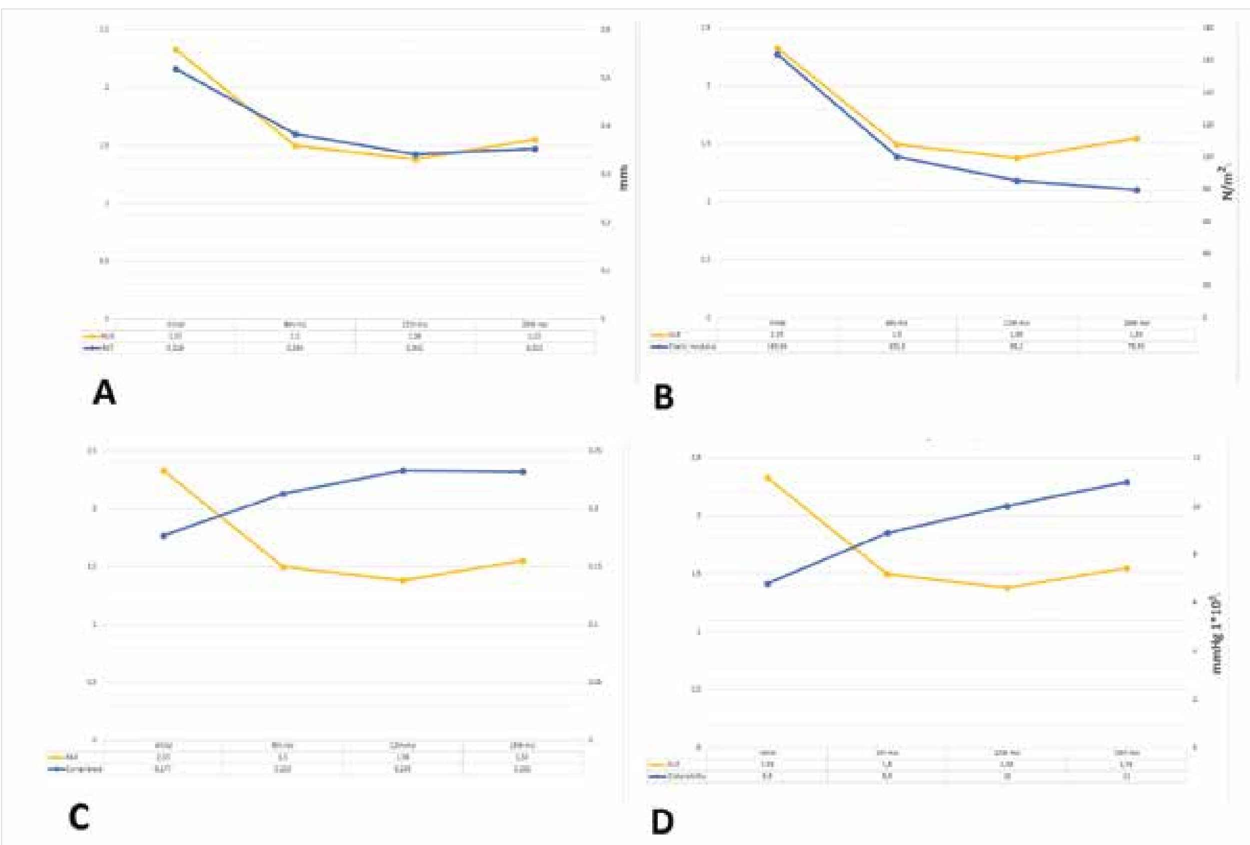

Figure 3. a-d. Temporal correlation of NLR and vascular stiffness parameters. Positive correlation between NLR and IMT (a). The elastic modulus decreases with the reduction in NLR (b). There is an opposite relationship between compliance, distensibility, and NLR (c, d)

events, it has been suggested that lymphocytes have a regulatory role in the inflammatory response and in atherosclerosis (13, 27, 28). It has also been emphasized that NLR is an indirect indicator of CAD and is an independent marker for adverse cardiac events and mortality in patients with stable CAD (29).

In a recent study, it was highlighted that NLR and MPV were independent markers of the presence of severe atherosclerosis (13). However, to the best of our knowledge, no previous study has examined the change in hemocyte inflammatory parameters in patients who have undergone bariatric surgery and evaluated the relationship of this change with vascular parameters. In this study, by focusing on this main idea, we aimed to evaluate the relationship between the weight loss and the vessel wall and inflammatory response. There was an extremely rapid decrease in NLR, especially during the first 6 months in the patients from the current study who were seen to rapidly lose weight, and this decrease was thought to be associated with the decrease in neutrophil percentage and increase in lymphocyte percentage.

Parameters such as NLR and neutrophil percentage that were objective criteria of this study were seen to be strongly correlated with all the vascular stiffness parameters. Uysal et al. (13) emphasized that a cutoff value of 2.54 was extremely effective in showing the atherosclerotic process on coronary angiography in patients with no previous findings. This value was taken into consideration in the current study when the baseline NLR values were grouped, and it was seen that values >2.54 had a significantly positive effect on cIMT.

Recent studies have suggested that MPV is a potential biomarker for CDV (13, 30). High-volume thrombocytes are metabolically and enzymatically more active than small-volume thrombocytes, and they are thought to have a higher hemostasis capacity. Studies conducted on this subject have reported that CDV are seen more in patients with high MPV, and there is a greater possibility of the development of CDV in healthy individuals with high MPV (13, 30). In a recent study, it was reported that patients with MPV values >10.4 were a risk group for the development of atherosclerosis even if there was no previous cardiovascular pathology on angiography (13). In the current study, MPV values decreased together with the BMI values, and a statistically significant difference was determined in the values at the end of 18 months compared with the baseline values. Although there was no statistically significant difference when the baseline MPV values were grouped as above and below 10.4, the vascular parameters of patients with MPV >10.4 were seen to be worse.

The main limitation of this study was that there was no control group. However, as seen in Table 3, the study participants were separated into objective sub-groups. As it was considered that individual differences such as BMI, HT, and diabetes could change the biochemical, vascular, morphologic, and anthropometric hemocytic parameters, it was planned to use the pre- and postoperative values of the same individuals. Thus, it was aimed to minimize individual variations. Although the number of patients included was limited, according to the power analyses applied, the number was sufficient so that the results could be interpreted.

CONCLUSION

The study results showed that bariatric surgical procedures such as SG are not only cosmetic procedures reducing the BMI values, but they also have a protective effect on vascular parameters and thereby on CVD by bringing the hyperglycemic state under control, regulating HT, and controlling various inflammatory parameters.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects"

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.B., F.M.Y.; Design - E.C., M.B.,.; Supervision - E.B., F.M.Y.; Resource - M.B., F.M.Y., E.C.; Materials - E.B., F.M.Y., M.B.; Data Collection and/or Processing - M.B., F.M.Y., E.C.; Analysis and/or Interpretation - F.M.Y., M.B.; Literature Search - E.B., E.C.; Writing Manuscript - M.B., E.C.; Critical Reviews - E.B.

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