Early Improvement in Left Ventricular Mechanics After Laparoscopic Sleeve Gastrectomy Detected by Global Longitudinal Strain

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Abstract

Aim: Obesity is associated with structural and functional cardiac abnormalities, including left ventricular hypertrophy, diastolic dysfunction, and subclinical myocardial impairment. Global longitudinal strain (GLS) is a sensitive marker for detecting early myocardial impairment before changes in left ventricular ejection fraction (LVEF) occur. This study aimed to evaluate the early effects of laparoscopic sleeve gastrectomy (LSG) on cardiac remodeling and myocardial mechanics using conventional and speckle-tracking echocardiography. **Methods:** This retrospective single-center study included 66 patients with severe obesity who underwent LSG. Clinical, metabolic, and echocardiographic parameters were evaluated before surgery and at a mean follow-up of approximately 3–6 months. Conventional and speckle-tracking echocardiography were used to assess left ventricular structure and myocardial mechanics. Preoperative and postoperative parameters were compared using paired-samples t-test. **Results:** The mean age was 36.9 ± 11.7 years, and 75.8% of patients were female. Following LSG, significant reductions were observed in body weight, body mass index, and blood pressure (all $p<0.001$), accompanied by improvements in glucose and lipid metabolism. Echocardiographic evaluation revealed significant reductions in left atrial volume, left ventricular dimensions and mass, as well as improved diastolic function parameters, including E/A and E/e′ ratios (both $p<0.001$). Despite no significant change in LVEF, GLS improved significantly after surgery (20.0 ± 2.7% vs. 21.8 ± 2.4%, $p<0.001$), indicating early recovery of subclinical myocardial dysfunction. **Conclusion:** LSG is associated with significant early reverse cardiac remodeling and improvement in subclinical myocardial dysfunction. GLS appears to be more sensitive than conventional echocardiographic systolic indices for detecting early myocardial recovery following bariatric surgery.

Keywords: Obesity; laparoscopic sleeve gastrectomy; global longitudinal strain; reverse cardiac remodeling; speckle-tracking echocardiography; myocardial dysfunction

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1. Introduction

Obesity is a major global health problem associated with increased cardiovascular morbidity and mortality through complex hemodynamic, metabolic, and inflammatory mechanisms[1,2]. Chronic excess adiposity contributes to increased circulating blood volume, elevated cardiac output, insulin resistance, neurohormonal activation, oxidative stress, and endothelial dysfunction, ultimately promoting adverse cardiac remodeling and obesity-related cardiomyopathy[3]. Structural and functional cardiac alterations associated with obesity include left ventricular (LV) hypertrophy, impaired ventricular relaxation, increased myocardial stiffness, left atrial enlargement, and progressive deterioration in myocardial performance[4].

Conventional echocardiographic parameters such as left ventricular ejection fraction (LVEF) may remain within normal limits during the early stages of obesity-related myocardial dysfunction, limiting their sensitivity for detecting subclinical myocardial impairment[1,5]. In recent years, speckle-tracking echocardiography and global longitudinal strain (GLS) analysis have emerged as reliable and reproducible imaging techniques capable of identifying subtle abnormalities in myocardial mechanics before overt systolic dysfunction becomes clinically apparent[5]. Reduced GLS values may therefore reflect early impairment in longitudinal myocardial fiber function despite preserved LVEF.

Bariatric surgery is currently considered the most effective long-term therapeutic strategy for severe obesity and has been associated with substantial improvements in metabolic profile and cardiovascular risk factors[2,6]. Previous studies demonstrated favorable effects of bariatric surgery on LV geometry, myocardial hypertrophy, diastolic function, and cardiac remodeling[3,4,6]. Among bariatric procedures, laparoscopic sleeve gastrectomy (LSG) has gained widespread acceptance because of its technical feasibility, efficacy, and favorable safety profile.

More recently, several investigations suggested that GLS may detect early myocardial recovery after bariatric surgery even in the absence of significant changes in conventional systolic function[1,5,7]. Despite increasing evidence regarding the cardiovascular benefits of bariatric surgery, data specifically evaluating early subclinical myocardial recovery after LSG using speckle-tracking echocardiography remain limited. Furthermore, the relationship between postoperative weight reduction and early reverse cardiac remodeling has not been fully clarified. Therefore, the present study aimed to evaluate the early effects of laparoscopic sleeve gastrectomy on cardiac structure, diastolic function, and myocardial deformation parameters using conventional echocardiography and speckle-tracking strain imaging in patients with severe obesity.

2. Methods

2.1.Study Design and Population

This single-center retrospective observational study included a total of 66 patients with severe obesity who underwent laparoscopic sleeve gastrectomy between February 2023 and December 2023. Postoperative clinical, laboratory, and echocardiographic evaluations were performed during the early follow-up period between 3 and 6 months after surgery.

Patients with heart failure, chronic liver failure, chronic kidney disease, chronic obstructive pulmonary disease, active infection, or inadequate image quality for strain analysis were excluded from the study.

2.2.Clinical and Laboratory Assessment

Baseline demographic characteristics, cardiovascular risk factors, anthropometric measurements, and laboratory parameters were recorded before surgery and at follow-up evaluation. Body mass index (BMI) was calculated as weight divided by height squared (kg/m²). Blood pressure measurements were obtained under standardized resting conditions.

Biochemical analyses included fasting glucose, HbA1c, triglycerides, total cholesterol, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol.

2.3.Echocardiographic Assessment

All echocardiographic examinations were performed using a GE Vivid E95 ultrasound system (GE Healthcare, Chicago, IL, USA). Standard transthoracic echocardiographic examinations were performed in accordance with the current recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging[8,9].

Left ventricular dimensions, interventricular septal thickness, posterior wall thickness, left atrial diameter, left atrial area, left atrial volume, left atrial volume index, LV mass, and LV mass index were assessed. Left ventricular ejection fraction (LVEF) was measured using the modified Simpson biplane method.

Diastolic function was evaluated using transmitral Doppler and tissue Doppler imaging parameters, including mitral E velocity, mitral A velocity, E/A ratio, septal e′ velocity, lateral e′ velocity, and average E/e′ ratio.

2.4.Speckle-Tracking Echocardiography

Global longitudinal strain analysis was performed offline using EchoPAC software (GE Healthcare). Standard apical 2-chamber, 3-chamber, and 4-chamber views were analyzed, and GLS values were automatically generated after manual adjustment of the region of interest when necessary (Figure 1). All strain analyses were performed by experienced echocardiographers blinded to clinical data.

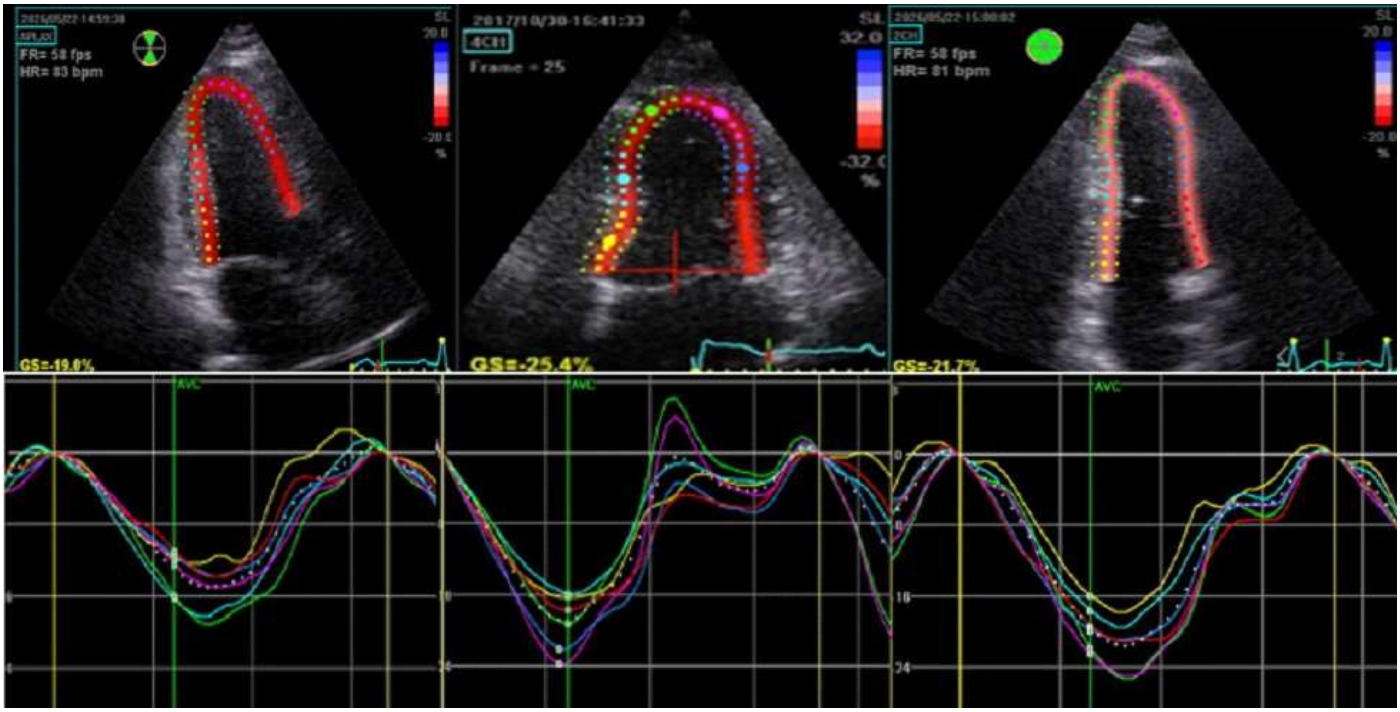

Figure 1. GLS measurements by 2D speckle tracking. The strain is calculated in each one of the apical views (APLAX, 2C, 4C).

2.5.Study Endpoints

The primary endpoint of the study was the change in GLS values following laparoscopic sleeve gastrectomy during the early postoperative period despite preserved LVEF.

Secondary endpoints included changes in LV diastolic function parameters and structural cardiac remodeling indices.

2.6.Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

Normality distribution was assessed using visual methods (histograms and probability plots) and analytical methods. Paired-samples t-test was used to compare preoperative and postoperative continuous variables. A p-value <0.05 was considered statistically significant.

2.7.Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee (decision no. 130/45, approval date: 04 February 2023). All participants provided written informed consent prior to enrollment, and the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

3. Results

3.1.Baseline Characteristics

A total of 66 patients with severe obesity were included in the study. The mean age was 36.9 ± 11.7 years, and 75.8% of the study population were female. Hypertension was present in 25.8% of patients, diabetes mellitus in 21.2%, obstructive sleep apnea syndrome in 9.1%, smoking in 15.2%, and alcohol consumption in 22.7% (Table 1).

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population

Clinical Parameters	Value
Number of patients	66
Age, years	36.9 ± 11.7
Female sex, n (%)	50 (75.8)
Male sex, n (%)	16 (24.2)
Hypertension, n (%)	17 (25.8)
Diabetes mellitus, n (%)	14 (21.2)
Obstructive sleep apnea syndrome, n (%)	6 (9.1)
Smoking, n (%)	10 (15.2)
Alcohol consumption, n (%)	15 (22.7)
Coronary artery disease, n (%)	1 (1.5)

Values are presented as mean ± standard deviation or number (%).

3.2.Metabolic and Hemodynamic Changes

At a mean follow-up of approximately 6 months after surgery, significant reductions in body weight and BMI were observed. Mean body weight decreased from 121.5 ± 15.2 kg to 80.5 ± 12.2 kg ($p<0.001$), while BMI decreased from 44.1 ± 4.4 kg/m² to 29.4 ± 3.4 kg/m² ($p<0.001$).

Significant improvements were also observed in metabolic parameters. Fasting glucose levels decreased from 106.4 ± 35.9 mg/dL to 93.5 ± 24.4 mg/dL ($p=0.006$), whereas HbA1c decreased from 6.09 ± 1.84% to 5.48 ± 1.02% ($p<0.001$). Triglyceride levels significantly decreased and HDL cholesterol significantly increased following surgery, while total cholesterol and LDL cholesterol levels remained unchanged. Systolic blood pressure significantly decreased from 125.1 ± 13.5 mmHg to 114.1 ± 11.6 mmHg ($p<0.001$), and diastolic blood pressure decreased from 78.1 ± 9.5 mmHg to 70.4 ± 7.2 mmHg (p<0.001) (Table 2).

Table 2. Changes in metabolic and hemodynamic parameters before and after laparoscopic sleeve gastrectomy

Parameter	Preoperative	Postoperative	p-value
Weight (kg)	121.5 ± 15.2	80.5 ± 12.2	<0.001
Height (m)	1.66 ± 0.09	1.66 ± 0.09	0.858
BMI (kg/m²)	44.1 ± 4.4	29.4 ± 3.4	<0.001
Fasting glucose (mg/dL)	106.4 ± 35.9	93.5 ± 24.4	0.006
HbA1c (%)	6.09 ± 1.84	5.48 ± 1.02	<0.001
SBP (mmHg)	125.1 ± 13.5	114.1 ± 11.6	<0.001
DBP (mmHg)	78.1 ± 9.5	70.4 ± 7.2	<0.001
LDL-C (mg/dL)	122.5 ± 38.7	121.3 ± 36.0	0.775
HDL-C (mg/dL)	45.0 ± 10.2	49.9 ± 10.6	0.001
TG (mg/dL)	144.8 ± 83.3	110.5 ± 47.4	<0.001
Total cholesterol (mg/dL)	196.5 ± 45.9	193.6 ± 44.9	0.562

Values are presented as mean ± standard deviation. BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, LDL-C: low-density lipoprotein, HDL-C: high-density lipoprotein, TG: triglycerides.

3.3.Echocardiographic Findings

Significant reverse remodeling was observed in left atrial and left ventricular structural parameters following LSG. Left atrial diameter, left atrial area, left atrial volume, and left atrial volume index all significantly decreased after surgery. Left atrial volume demonstrated a marked reduction from 50.3 ± 5.4 mL to 38.5 ± 4.5 mL (p<0.001). Left ventricular end-diastolic diameter (LVEDD) and left ventricular end-systolic diameter (LVESD) significantly decreased during follow-up. LV mass significantly regressed from 218.0 ± 42.0 g to 191.9 ± 49.1 g (p<0.001), and height-indexed LV mass values similarly showed significant improvement. Although LV mass index calculated according to body surface area increased after surgery, this finding was likely related to the substantial postoperative reduction in body surface area. LVEF remained preserved and did not significantly change following surgery (70.1 ± 3.9% vs. 70.5 ± 3.3%, p=0.068) (Table 3).

Table 3. Changes in Structural Echocardiographic Parameters Following Laparoscopic Sleeve Gastrectomy

Parameter	Preoperative	Postoperative	p-value
BSA (m²)	2.35 ± 0.17	1.92 ± 0.18	<0.001
IVS thickness (mm)	10.10 ± 1.18	10.08 ± 2.50	0.933
PW thickness (mm)	9.64 ± 1.03	9.45 ± 1.03	0.017
LVEDD (mm)	46.7 ± 4.1	45.9 ± 3.5	0.020
LVESD (mm)	28.0 ± 3.0	27.3 ± 2.6	0.004
LAD (mm)	37.4 ± 4.1	35.8 ± 3.2	0.006
LAA (cm²)	20.8 ± 3.4	19.7 ± 3.2	0.025
LAV (mL)	50.3 ± 5.4	38.5 ± 4.5	<0.001
LAVI (mL/m²)	21.4 ± 1.7	20.2 ± 3.2	0.002
LV mass (g)	218.0 ± 42.0	191.9 ± 49.1	<0.001
LV mass index (g/m²)	92.9 ± 16.8	100.5 ± 26.9	0.015
Height-indexed LV mass	131.3 ± 23.3	115.9 ± 30.4	<0.001

Values are presented as mean ± standard deviation. BSA: body surface area, IVS: interventricular septum, PW: posterior wall, LAD: left atrial diameter, LAA: left atrial area, LAV: left atrial volume, LAVI: left atrial volume index, LVEDD: left ventricular end-diastolic diameter, LVESD: left ventricular end-systolic diameter, LV: left ventricular.

Table 4. Changes in Left Ventricular Systolic, Diastolic, and Myocardial Deformation Parameters

Parameter	Preoperative	Postoperative	p-value
LVEF (%)	70.1 ± 3.9	70.5 ± 3.3	0.068
Global longitudinal strain (%)	20.0 ± 2.7	21.8 ± 2.4	<0.001
Mitral E velocity (cm/s)	72.2 ± 7.8	77.1 ± 6.0	<0.001
Mitral A velocity (cm/s)	56.9 ± 10.4	48.7 ± 4.7	<0.001
E/A ratio	1.30 ± 0.20	1.59 ± 0.14	<0.001
Septal e′ velocity (cm/s)	9.09 ± 1.58	9.39 ± 0.94	0.179
Lateral e′ velocity (cm/s)	11.98 ± 1.70	12.29 ± 1.08	0.173
Average E/e′ ratio	6.94 ± 1.06	3.57 ± 0.33	<0.001

Values are presented as mean ± standard deviation. LVEF: left ventricular ejection fraction.

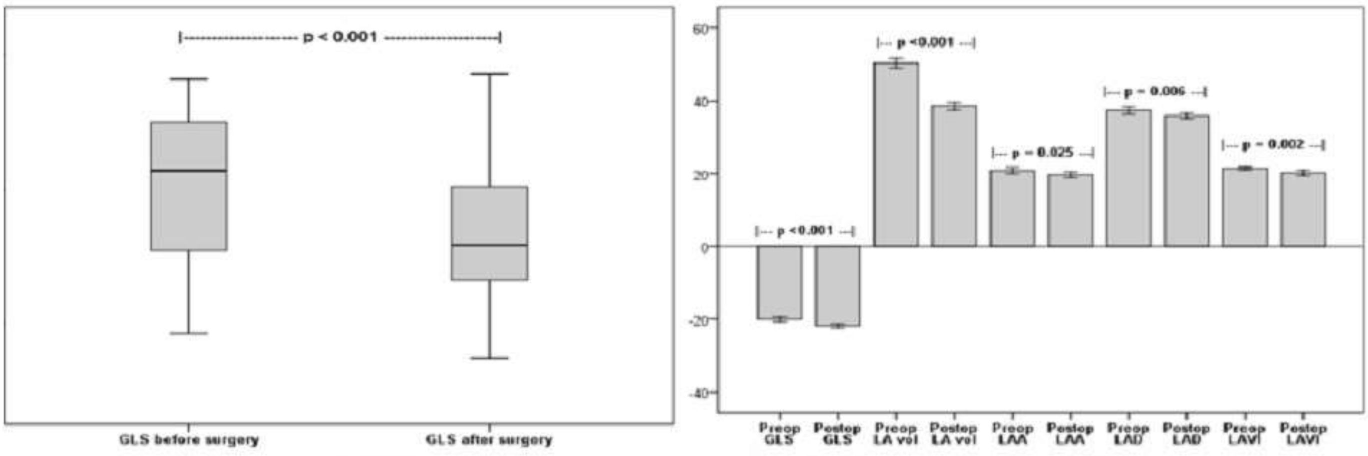

Figure 2A. Changes in GLS and left atrial parameters before and after LSG.

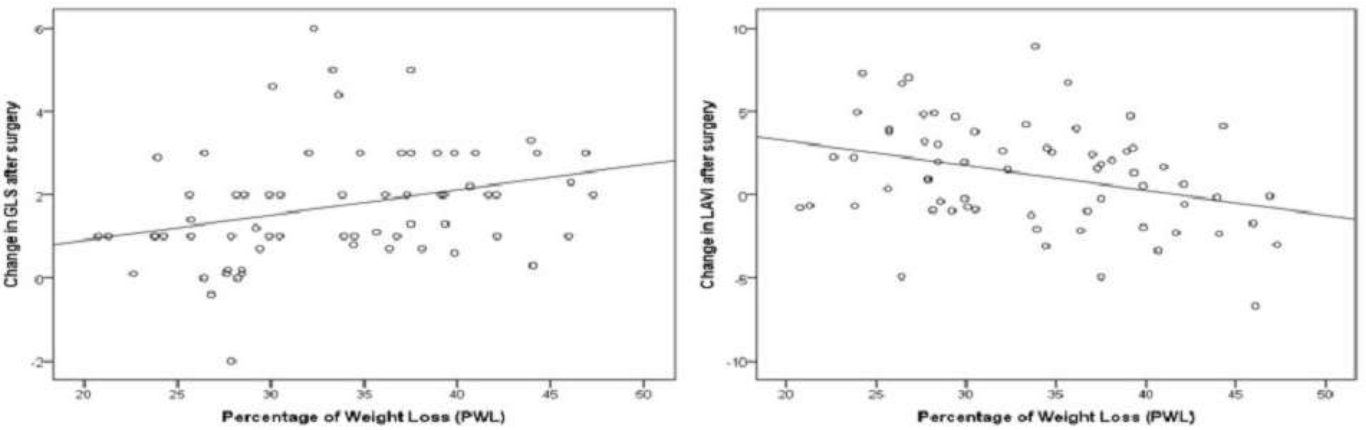

Figure 2B. The relationship between percentage weight loss and changes in GLS and LAVI after surgery.

3.4.Diastolic Function and Myocardial Deformation Analysis

Significant improvement was observed in LV diastolic function parameters following LSG. The E/A ratio significantly increased from 1.30 ± 0.20 to 1.59 ± 0.14 (p<0.001), whereas the average E/e′ ratio significantly decreased from 6.94 ± 1.06 to 3.57 ± 0.33 (p<0.001), indicating improved LV relaxation and lower filling pressures.

Global longitudinal strain significantly improved from −20.0 ± 2.7% preoperatively to −21.8 ± 2.4% postoperatively ($p<0.001$) (Figure 2), despite preserved LVEF. These findings suggest early recovery of subclinical myocardial dysfunction after LSG (Table 4). Furthermore, greater percentage weight loss was associated with more pronounced reductions in left atrial volume index, suggesting a weight-loss-dependent reverse remodeling process. The changes in GLS and left atrial parameters before and after LSG are presented in Figure 2A, whereas the associations between percentage weight loss and both GLS and LAVI are illustrated in Figure 2B.

4. Discussion

The present study demonstrated that laparoscopic sleeve gastrectomy is associated with significant early reverse cardiac remodeling and improvement in myocardial mechanics in patients with severe obesity. The principal findings of the current study were: (1) significant improvement in GLS despite preserved LVEF, indicating recovery of subclinical myocardial dysfunction; (2) marked improvement in LV diastolic function; (3) regression of left atrial enlargement and LV hypertrophy; and (4) substantial metabolic and hemodynamic improvement accompanying structural and functional cardiac recovery.

Obesity-related cardiac dysfunction is characterized by progressive alterations in myocardial structure and ventricular mechanics resulting from chronic hemodynamic overload, metabolic dysregulation, systemic inflammation, and neurohormonal activation[6,10,11]. These pathophysiological processes contribute to myocardial hypertrophy, impaired ventricular relaxation, increased filling pressures, and ultimately obesity-related cardiomyopathy[12]. Importantly, conventional systolic function may remain preserved during the early stages of myocardial involvement, making the identification of subclinical dysfunction particularly challenging.

One of the most important findings of our study was the significant improvement in GLS despite unchanged LVEF. This observation supports the growing evidence that strain imaging is more sensitive than conventional systolic indices for identifying subtle myocardial dysfunction and detecting early myocardial recovery after bariatric surgery[1,13]. Longitudinal myocardial fibers located predominantly within the subendocardial layer are especially vulnerable to metabolic stress and increased wall tension associated with obesity. Therefore, GLS may detect myocardial impairment before abnormalities become apparent in conventional systolic measurements.

Our findings are consistent with previous studies evaluating myocardial deformation after bariatric surgery. Santos et al. reported significant improvement in LV mechanics after sleeve gastrectomy using speckle-tracking echocardiography[1]. Similarly, Inci et al. demonstrated favorable short- and mid-term changes in myocardial deformation parameters following bariatric surgery[13]. More recently, Ding et al. showed that postoperative weight loss improved myocardial work indices and myocardial efficiency after sleeve gastrectomy, further supporting the reversibility of obesity-related myocardial dysfunction following substantial surgical weight reduction[14]. In another study, Öz et al. also showed that sleeve gastrectomy improves left ventricular systolic function (LV longitudinal and circumferential global strains, as well as three-dimensional LV ejection fraction) and seems to contribute to reversing left ventricular remodeling in both genders[15]. Collectively, these findings suggest that myocardial recovery may occur early after bariatric surgery and can be sensitively detected using advanced myocardial deformation imaging techniques.

Another important observation in our cohort was the marked improvement in LV diastolic function. Significant increases in E/A ratio together with substantial reductions in E/e′ ratio indicate improved ventricular relaxation and reduced LV filling pressures during the early postoperative period. Previous investigations similarly demonstrated favorable effects of bariatric surgery on diastolic function[16-18]. Diastolic dysfunction is considered one of the earliest manifestations of obesity-related myocardial involvement and frequently precedes overt systolic impairment[16]. Therefore, the observed improvement in diastolic indices likely reflects early reversal of myocardial stiffness and intracardiac pressure overload after substantial postoperative weight loss.

Kaya et al. reported significant improvement in LV relaxation parameters following sleeve gastrectomy, while Şimşek et al. demonstrated early postoperative improvement in transmitral Doppler indices[16]. In addition, Büber et al. showed beneficial effects of LSG on diastolic function and atrial electromechanical properties, emphasizing the broad cardiovascular impact of surgical weight reduction[17]. Our findings further strengthen the evidence that early postoperative metabolic improvement is associated with favorable recovery in ventricular filling dynamics.

Left atrial remodeling represents another clinically important component of obesity-related cardiac disease. Chronic elevation in LV filling pressures contributes to progressive atrial enlargement and increased atrial wall stress[19]. In the present study, significant reductions were observed in left atrial diameter, left atrial volume, and left atrial volume index following surgery, indicating early reverse atrial remodeling. Furthermore, greater postoperative weight loss was associated with greater reduction in left atrial remodeling parameters, suggesting a weight-loss-dependent cardiac recovery process. These findings support the concept that the magnitude of reverse remodeling may parallel the degree of metabolic and hemodynamic improvement achieved after bariatric surgery.

Regression of LV hypertrophy was another notable finding of our study. Significant reductions in LV mass and height-indexed LV mass support the presence of early reverse structural remodeling after substantial postoperative weight loss. Interestingly, BSA-indexed LV mass values demonstrated relative variability following surgery. This phenomenon has previously been described in bariatric populations and is likely related to rapid postoperative reductions in body surface area, which may influence indexed calculations despite true regression in myocardial mass. Therefore, height-indexed LV mass measurements may provide a more physiologically reliable assessment of residual hypertrophy after bariatric surgery.

The marked improvement in glucose metabolism, lipid profile, and blood pressure observed in our cohort likely contributed substantially to myocardial recovery. Reduction in metabolic stress, systemic inflammation, sympathetic activation, and ventricular afterload may collectively facilitate reverse remodeling processes and improvement in myocardial mechanics during the early postoperative period[2,4,10,11]. These findings further support the concept that the cardiovascular benefits of bariatric surgery extend beyond weight reduction alone.

Laparoscopic sleeve gastrectomy is associated with significant early reverse cardiac remodeling, characterized by improvements in left ventricular structure, diastolic function, and myocardial mechanics in patients with severe obesity. Although conventional systolic function remained preserved, global longitudinal strain detected early recovery of subclinical myocardial dysfunction, highlighting its greater sensitivity compared with traditional systolic indices in the early postoperative period. The simultaneous improvement in left atrial remodeling, left ventricular hypertrophy, metabolic profile, and myocardial deformation parameters further supports the concept of weight loss–dependent cardiovascular recovery following bariatric surgery.

Importantly, our findings highlight the clinical value of speckle-tracking echocardiography for the early detection and monitoring of obesity-related myocardial impairment, even in the absence of overt systolic dysfunction. Clinically, GLS assessed by speckle-tracking echocardiography may serve as a sensitive imaging biomarker for detecting and monitoring subclinical myocardial dysfunction and early cardiac recovery following bariatric surgery. These results further reinforce the role of bariatric surgery not only as an effective metabolic intervention but also as a potential strategy for reducing long-term cardiovascular risk and preventing progression toward heart failure. Future large-scale prospective studies with longer follow-up are warranted to clarify the durability of these improvements and to determine whether early GLS recovery translates into better long-term cardiovascular outcomes.

Limitations

Several limitations should be acknowledged. First, this was a single-center retrospective observational study with a relatively modest sample size. Second, follow-up duration was limited to the early postoperative period (3–6 months), and therefore the long-term sustainability of reverse remodeling could not be evaluated. Third, the absence of a non-surgical control group limits definitive causal interpretation. Fourth, patients with overt heart failure and major systemic comorbidities were excluded, which may limit generalizability to broader obesity populations. Finally, advanced myocardial tissue characterization techniques, including cardiac magnetic resonance imaging, were not available in the present study.

genAI: No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by all authors.

Statement of Ethics: This study is approved by the Ethical Committee of Çukurova University Faculty of Medicine (Approval No. 130/45, date: 04 February 2023). All participants provided written informed consent prior to enrollment, and the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Data Availability: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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Author Contributions: Rabia Eker Akıllı: Literature review and data collection, drafting the article, analysis and interpretation of echocardiographic and clinical data, final approval.

Ömer Tepe: Interpretation of echocardiographic and clinical data, participated in manuscript drafting, final approval.

Onur Sinan Deveci: Conception and design, revising the article, supervision, final approval.

Ali Deniz: Data analysis, revising the article, final approval.

Orçun Yalav: Design, revising the article, final approval.

Haydar Ali Candan: Participated in manuscript drafting, final approval.

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