Subclinical left ventricular dysfunction in severe obesity and reverse cardiac remodeling after bariatric surgery.

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# Abstract

## Aim

Obesity is associated with an increased cardiovascular risk. This study aimed to assess the role of echocardiography in the early detection of subclinical cardiac abnormalities in a cohort of obese patients with a preserved ejection fraction (EF) undergoing bariatric surgery.

## Methods and results

Forty consecutive obese patients referring to our centre for bariatric surgery were enrolled. Despite a baseline EF of 61±3%, almost half patients (43%) had a systolic dysfunction (SD) defined as GLS>-18%, and most of them (60%) had LV hypertrophy (LVH) or concentric remodeling (CR).

At 10-months after surgery, body weight decreased from 120±15kg to 83±12kg, BMI from 44±5kg/sqm to 31±5kg/sqm (both p<0.001). Septal and LV posterior wall thickness decreased respectively from 10±1mm to 9±1mm (p=0.004) and from 10±1mm to 9±1mm (p=0.007). All systolic parameters improved: EF from 61±3% to 64±3% (p=0.002) and GLS from -17±2% to -20±1% (p<0.001). Epicardial fat thickness reduction (from 4.7±1mm to 3.5±0.7mm, p<0.001) correlated with the reduction of left atrial area (p<0.001 R=0.35) and volume (p=0.02 R=0.25). Following bariatric surgery, we observed a reduced prevalence of LVH/CR (before 60%, after 22%, p=0.001) and a complete resolution of preclinical SD (before 43%, after 0%, p<0.001). Moreover, a post-operative reduction of at least 30kg correlated with regression of septal hypertrophy (p<0.001).

## Conclusion

Obese patients candidate to bariatric surgery have an high prevalence of preclinical SD and LVH/CR, early detectable with echocardiography. Bariatric surgery is associated with reverse cardiac remodeling; it might also have a preventive effect on atrial fibrillation occurrence by reducing its substrate.

## Keywords

Obesity, left ventricular remodelling, strain, systolic function, diastolic function, atrial fibrillation.

# INTRODUCTION

Obesity is associated with an almost doubled risk of coronary artery disease, heart failure and sudden death regardless of age, cholesterol, systolic blood pressure, smoke, glucose intolerance and left ventricular hypertrophy, as previously known from literature (1) (2) (3). The excess of adipose tissue affects the cardiovascular system through hemodynamic, inflammatory and metabolic modifications leading to a slow and subtle accumulation of epicardial fat, left ventricular hypertrophy, progressive diastolic and systolic dysfunction (4). Furthermore, an increased volume of epicardial fat is associated with a greater risk of atrial arrhythmias such as paroxysmal and persistent atrial fibrillation (AF) (5).

Significant weight loss obtained with bariatric surgery may lead to reverse cardiac remodeling, associated with beneficial effects on myocardial structure and systo-diastolic function (6).

In these high-risk patients preventive treatments are more effective when started before the onset of overt diastolic and systolic dysfunction. Novel diagnostic tools such as speckle-tracking echocardiography may detect subtle changes in myocardial systolic function even in asymptomatic patients with preserved ejection fraction (7).

This study was aimed to assess the role of echocardiography in the early detection of subclinical cardiac abnormalities in a cohort of obese patients undergoing bariatric surgery.

# METHODS

## Study design

This prospective cohort study assessed forty consecutive patients undergoing bariatric surgery from January to October 2017 within our centre. Oral and written informed consent was obtained from all patients before enrolment. Patients were included in the study if they were severely obese (body mass index ≥ 35 kg/sqm) and eligible for bariatric surgery. Exclusion criteria were past medical history of coronary artery disease, previously known hypertension or on treatment with any antihypertensive drug, a reduced ejection fraction (EF < 52% in males, EF < 54% in females), or echocardiographic images of insufficient quality for GLS analysis.

## End-points of the study

The primary end-point was the prevalence of morpho-functional cardiac abnormalities. The variation of morpho-functional parameters after bariatric surgery was the secondary end-point.

## Study protocol

All patients underwent a complete clinical and echocardiography assessment before surgery and ten months later, including laboratory tests with assessment of serum N-terminal pro-brain natriuretic peptide (NT-proBNP).

## Echocardiographic evaluation

Echocardiography was performed using Philips IE 33 with phased-array at frequency of 1.9-3.8 MHz. Standard apical, parasternal, subxiphoid, M-mode, color Doppler, pulse Doppler and tissue Doppler views were acquired. Philips QLAB was used for post-acquisition GLS analysis; volumes and ejection fraction (EF) were measured with the biplane Simpson’s method. All the echocardiograms were performed and examined according to the standards of the European Association of Cardiovascular Imaging (EACVI) guidelines. (8)

All images were acquired and off-line anonimously analysed by a single cardiologist with broad experience in cardiovascular imaging (C.R.). Twenty examinations were then randomly and blinded re-assessed by C.R and a secondexpert echocardiographer (S.F.).

Both morphology and function of left ventricle were analysed. End-diastolic diameter, end-diastolic volume (EDV) and end-systolic volume, septal and posterior wall thickness, mass and relative wall thickness along with atrial and ventricular volumes were measured. Left ventricular (LV) ejection fraction (EF), lateral S2, global longitudinal strain (GLS) using speckle tracking technique along with right ventricle contractility (TAPSE) were examined. E wave, A wave, E wave deceleration time (DT), septal and lateral e’ velocity , were analysed and E/A, septal E/e', lateral E/e' and average E/e' ratios were calculated. Grading of diastolic function was performed according to ASE guidelines(8b). Epicardial fat thickness was also measured by subcostal view. According to afore mentioned guidelines, increased LV end diastolic volume was defined as > 150 ml in males, > 106 ml in females. Increased septal thickness was defined as > 10 mm in males, > 9 mm in females. LV hypertrophy was defined in the presence of an LV mass/BSA ratio > 115 in males, > 95 in females. Relative wall thickness was used to discriminate patients with normal LV geometry, concentric hypertrophy, eccentric hypertrophy, concentric remodeling. Increased LA area was defined as > 20 sqcm. Abnormal GLS was defined as > -18%.

Reproducibility

Reproducibility of echo-Doppler and tissue Doppler measurements in our laboratory was previously reported (8c) (8d). For this study, variability was assessed in arandomly selected subset of 20 patients. Intraobserver coefficients of variation were 4.04% (p=0.94), 4.56% (p=0.90) and 9.07% (p=0.88) for LV septal and posterior wall thickness and epicardial fat thickness, respectively and 2.15% (p=0.95) for GLS. Corresponding intraclass correlation coefficients were all included between 0.88 and 0.95. Interobserver coefficients of variation were 4.83% (p=0.90), 5.01% (p=0.88) and 10.64% (p=0.84) for septal and posterior wall thickness and epicardial fat thickness, respectively and 3.12% for GLS, with corresponding intraclass correlation coeffcients of 0.82, 0.79, 0.70 and 0.81 respectively.

## Statistical analysis

Continuous variables, presented as means and standard deviations, were compared by non-parametric tests: Mann-Whitney’s test was used for independent data and Wilcoxon’s signed-rank test for paired data (pre-post evaluations). Categorical variables, presented as counts and percentages, were compared using the chi-square test with Yates’ correction or Fisher’s exact test. All analyses were performed using the SPSS for Windows version 18.0 (SPSS, Inc., Chicago, Illinois) and a two-sided significance level of ≤ 0.05 was considered statistically significant. Univariate logistic analysis was used to determine the association between risk factors and cardiac remodeling. The relative risk (RR) was computed with its 95% confidence interval (CI).

# RESULTS

This study enrolled 40 patients (male: female ratio of 11:29), with a mean age of 42 ± 11 years and a body mass index (BMI) of 44 ± 5 kg/sqm at the time of surgery. 35 patients (88%) underwent sleeve gastrectomy while 5 patients (13%) had gastric bypass. No one had hypertension, there were 15 (38%) current smokers, 7 (18%) with dyslipidaemia, 4 (10%) with diabetes and 7 (18%) with a family medical history of heart disease. All demographics are reported in *Table 1.*

Baseline systolic and diastolic blood pressures during pre-operative outpatient visit were respectively 144±17 mmHg and 84±14 mmHg.

## Prevalence of morpho-functional cardiac abnormalities

Baseline echocardiography (*Table 2, Table 3*) revealed LV hypertrophy or concentric remodeling in 24 patients (60%), an abnormally increased septal thickness in 24 patients (60%), an abnormally increased LV end diastolic volume in 23 patients (58%), an abnormally increased LA area in 30 patients (75%).

Four patients (10%) had a grade-I diastolic dysfunction, while other patients had a normal diastolic function. Average E/A ratio was 1.28 ± 0.34, while lateral E’ was 13.49 ± 3.65 cm/s and lateral E/e’ ratio was 6.31 ± 1.17. According to inclusion criteria, no patients had a reduced ejection fraction, although speckle tracking imaging analysis showed an abnormal GLS (> -18%) in 17 patients (43%). Mean epicardial fat thickness was 4.7 ± 1 mm.

## Follow-up evaluation

After bariatric surgery it was observed a body weight decrease of 34 ± 12 kg (mean 29% ± 9 reduction, from 120 ± 15 kg to 83 ± 12 kg, p<0.001). 24 patients (61%) lost at least 30 kg. BMI decreased from 44 ± 5 kg/sqm to 31 ± 5 kg/sqm (p<0.001), as described in *Figure 1*.

At 10-months echocardiographic assessment, LV, RV, LA and RA dimensions appeared all to be reduced; in particular, septal and LV posterior wall thickness decreased respectively from 10 ± 1 mm to 9 ± 1 mm (p=0.004) and from 10 ± 1 mm to 9 ± 1 (p=0.007). Compared with baseline assessment, no patient showed any degree of diastolic dysfunction at 10-month evaluation. Lateral E’ improved (from 13.49 ± 3.65 cm/s to 14.59 ± 3.25 cm/s, p=0.029) as long as septal E’ (from 9.05 ± 1.95 cm/s to 10.19 ± 2.01 cm/s, p=0.022), lateral E/e’ ratio (from 6.31 ± 1.17 to 5.82 ± 1.06, p=0.012) and septal E/e’ ratio (from 9.24 ± 1.68 to 8.32 ± 1.80, p=0.023).

Systolic parameters were also improved at 10-month evaluation: EF varied from 61 ± 3 % to 64 ± 3 % (p=0.002) and GLS varied from -17 ± 2 % to -20 ± 1 % (p<0.001). Lastly, epicardial fat thickness decreased from 4.7 ± 1 mm to 3.5 ± 0.7 (p<0.001) and NTproBNP level increased from 29 ± 29 pg/ml to 52 ± 32 pg/ml (p=0.002). All echocardiographic measurements are described in *Table 3*.

## Reverse cardiac remodeling

As shown in *Figure 2 and Table 2*, at 10-months after bariatric surgery, the prevalence of LV hypertrophy or concentric remodeling was reduced from 60% to 22% (p=0.001), abnormally increased septal thickness was reduced from 60% to 25% (p=0.003), abnormally increased LV end diastolic volume was reduced from 58% to 22% (p=0.003), LV hypertrophy was reduced from 25% to 5% (0.028), abnormally increased LA area was reduced from 75% to 35% (p=0.001).

Besides, follow-up echocardiographies showed a complete resolution of subclinical systolic dysfunction with GLS>-18%: previously observed in 43% patients, afterwards in none, p<0.01.

Furthermore, losing at least 30 kg through bariatric surgery was associated with regression of septal hypertrophy (p<0.01).

Weight loss correlated with septal thickness reduction (p=0.02 R=0.125) and with RV diameter decrease (p=0.03 R=0.19). Furthermore, the reduction of epicardial fat thickness correlated with LA area decrease (p<0.01 R=0.35) and with LA volume reduction (p=0.02 R=0.25). All correlations on *Figure 3*.

# DISCUSSION

According to the well-known pathophysiological cascade in obese subjects, as explained by *Alpert MA*, haemodynamic alterations produced by obesity induce LV dilatation, leading to LV hypertrophy (LVH) because of elevated LV wall stress. Therefore, the presence of LVH predisposes to LV diastolic dysfunction; eventually, if LV wall stress remain chronically elevated because of inadequate LVH, LV systolic dysfunction may ensue. (9) According to these previous findings, in our study we observed a high prevalence of LV dilatation and LV remodeling (LVR) or LVH (respectively 58% and 60%), a smaller prevalence of diastolic dysfunction (10%) and an even lower prevalence of systolic dysfunction (no patient had a compromised ejection fraction), despite a high proportion (43%) of patients with an abnormal GLS.

Actually, the documentation of a preserved EF by echocardiography does not exclude the possible presence of subtle alterations in LV myocardial composition and/or geometry. Speckle tracking echocardiography, assessing myocardial strain, provides more detailed information on global and regional active LV deformation, allowing to detect the presence of a subclinical systolic dysfunction (10). In our study we found a reduced GLS (>-18%) in 43% of patients, with a mean value of -17±2%. This is in line with the study of *Koshino et al*, where 28 obese patients undergoing bariatric surgery, with a mean BMI of 51, presented -11±4% as GLS value at baseline assessment (11). These data support the hypothesis that even in obesity cardiomyopathy the apparently isolated diastolic dysfunction (with preserved EF), may be associated with subclinical systolic dysfunction, as already demonstrated for other cardiomyopathies by *Pacileo et al.* (12). Therefore, the assessment of obese patients with speckle tracking echocardiography may help to identify patients with higher cardiovascular risk by detecting subclinical systolic dysfunction earlier than clinical overt manifestations, allowing them to receive more intensive controls and earlier interventions. According to the *American Society for Metabolic and Bariatric Surgery*, bariatric surgery is recommended for obese people with BMI≥40 kg/m², with BMI≥35 kg/m² and obesity-related comorbidities and for patients unable to achieve weight loss in other ways; thus, subclinical systolic dysfunction may be considered an obesity-related comorbidity and allow obese patient to receive earlier bariatric surgery.

As described by *Cuspidi et al*, bariatric surgery exerts important cardioprotective effects in morbidly obese patients through LV hypertrophy regression, improvement in LV geometry and diastolic function, reduction of left atrial size (13). According to this explanation and in line with data from similar studies such as *Shin et al*, *Mostfa et al* and *Kurnicka et al*, in our study many structural and functional parameters improved significantly after bariatric surgery (as shown in *Table 2* and *Table 3*) and 10-months echocardiography showed a significant reduction of LV dilatation, septal hypertrophy, a normalization of LVR/LVH along with a resolution of subclinical systolic dysfunction. (14) (15) (16) Diastolic dysfunction was no longer evident after bariatric surgery. Most diastolic parameters significantly improved at 10-month assessment, especially lateral and septal E/e’ ratios which are surrogate indexes of left ventricular filling pressures.

Furthermore, an interesting outcome of this study is that losing at least 30 kg leads to regression of septal hypertrophy (p<0.001).

The association between LA dilatation and AF has been known in literature for years and many studies proved it; actually, in the population of the Framingham Heart Study it appeared that there was a 39% increase in AF risk every 5 mm increment of LA diameter (17).

Less is known about the association between epicardial fat and AF. Epicardial fat is a unique fat compartment located between the myocardial surface and the visceral layer of the pericardium; among its physiological functions there are myocardial protection against hypothermia, mechanical protection for coronary circulation and energy source in the homeostasis of the myocardium; but epicardial fat is also considered a source of inflammatory mediators that might directly influence myocardium and coronary arteries (18). Recently, it also appears that this tissue, when abundant, penetrates deeply into the heart and invades spaces such as the interatrial septum. (19)

Its thickness is highly associated with paroxysmal and persistent AF, independently of traditional risk factors (5). In this study, 10-months echocardiography following bariatric surgery showed not only a significant decrease in epicardial fat thickness, but also a decrease in LA size (diameter, area, volume). Furthermore, epicardial fat reduction was linearly correlated with LA area decrease and LA volume reduction.

These data support the hypothesis that in obese patients both epicardial fat deposition and LA dilatation are the results of a negative cardiac remodeling. Abundant epicardial fat and significant LA dilatation can be ideal substrates for atrial arrhythmias such as AF. In this context, weight loss obtained with bariatric surgery was associated with a 10-months reverse remodeling able to reduce both substrates and then potentially able to act as a protective factor on AF.

Obese patients also have considerably lower plasma natriuretic peptide levels than individuals with a normal BMI, resulting in an even more complicated diagnosis and management of heart failure. (20) The present study shows a significant increase of serum NT-proBNP after bariatric surgery in line with many articles, such as *Chen-Tournoux A et al* one where 132 obese subjects present 5 times increased level of serum NT-proBNP 6 months after weight loss surgery, which isn’t attributable to clinical situations that usually upregulate its secretion because of well demonstrated cardiac improvements after bariatric surgery. (21)

## Limitations

This study has some limitations: it did not evaluate major adverse cardiac events; it was a monocentric study; follow-up was limited to 10 months. Furthermore, atrial fibrillation was not evaluated as an end-point. Blood pressure values were not recorded throughout the follow-up. Further studies could be helpful to assess the incidence of clinical events.

## CONCLUSIONS

This study shows that speckle tracking echocardiography may detect subclinical systolic dysfunction in obese patients with a normal ejection fraction, allowing early detection of those at higher risk of overt clinical events.

Bariatric surgery is associated with significant 10-months reverse cardiac remodeling and might exert a possible protective effect on AF occurrence by reducing its substrate.

# Notes

## Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures were performed 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.

Informed consent

Informed consent was obtained from all individual participants included in the study.

References

1. Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. *Circulation.* May 1983, Vol. 67(5), pp. 968-977.

2. Romero-Corral A, Montori VM, Somers VK, Korinek J, Thomas RJ, Allison TG et al. Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: a systematic review of cohort studies. *Lancet.* Aug 2006, Vol. 368 (9536), pp. 666-678.

3. Antonini-Canterin F, Di Nora C, Poli S, Sparacino L, Cosei I, Ravasel A et al. Obesity, Cardiac Remodelling, and Metabolic Profile: Validation of a New Simple Index beyond Body Mass Index. *Journal of Cardiovascular Echography.* Jan-Mar 2018, Vol. 28(1), pp. 18-25.

4. Poirier P, Giles TD, Bray GA, Hong Y, Stern JS, Pi-Sunyer FX et al. Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss. *Circulation.* Feb 2006, Vol. 113(6), pp. 898-918.

5. Wong CX, Ganesan AN, Selvanayagam JB. Epicardial fat and atrial fibrillation: current evidence, potential mechanisms, clinical implications, and future directions. *European Heart Journal.* May 2017, Vol. 38 (17), pp. 1294-1302.

6. Aggarwal R, Harling L, Efthimiou E, Darzi A, Athanasiou T, Ashrafian H. The Effects of Bariatric Surgery on Cardiac Structure and Function: a Systematic Review of Cardiac Imaging Outcomes. *Obesity surgery.* May 2016, Vol. 26(5), pp. 1030-1040.

7. Gong HP, Tan HW, Fang NN, Song T, Li SH, Zhong M et al. Impaired left ventricular systolic and diastolic function in patients with metabolic syndrome as assessed by strain and strain rate imaging. *Diabetes research and clinical practice.* Mar 2009, Vol. 83(3), pp. 300-7.

8. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *Journal of the American Society of Echocardiography.* Jan 2015, Vol. 28(1), pp. 1-39.

8b. Nagueh SF, Smiseth OA, Appleton CP, Byrd BF 3rd, Dokainish H, Edvardsen T, Flachskampf FA, Gillebert TC, Klein AL, Lancellotti P, Marino P, Oh JK, Popescu BA, Waggoner AD. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2016;29:277-314.

8c. Frea S, Bovolo V, Bergerone S, D’Ascenzo F, Antolini M, Capriolo M et al. Echocardiographic evaluation of right ventricular stroke work index in advanced heart failure: a new index? J Card Fail 2012;18:886–93

8d. Fornengo C, Antolini M, Frea S, Gallo C, Grosso Marra W, Morello M, Gaita F. Prediction of atrial fibrillation recurrence after cardioversion in patients with left-atrial dilation. Eur Heart J Cardiovasc Imaging 2015;16:335-41.

9. MA, Alpert. Obesity cardiomyopathy: pathophysiology and evolution of the clinical syndrome. *The American journal of the medical sciences.* Apr 2001, Vol. 321(4), pp. 225-236.

10. Tops LF, Delgado V, Marsan NA, Bax JJ. Myocardial strain to detect subtle left ventricular systolic dysfunction. *European journal of heart fail.* Mar 2017, Vol. 19(3), pp. 307-313.

11. Koshino Y, Villarraga HR, Somers VK, Miranda WR, Garza CA, Hsiao JF et al. Changes in myocardial mechanics in patients with obesity following major weight loss after bariatric surgery. *Obesity (Silver Spring, Md.).* Jun 2013, Vol. 21(6), pp. 1111-1118.

12. Pacileo G, Baldini L, Limongelli G, Di Salvo G, Iacomino M, Capogrosso C et al. Prolonged left ventricular twist in cardiomyopathies: a potential link between systolic and diastolic dysfunction. *European journal of echocardiography.* Nov 2011, Vol. 12(11), pp. 841-849.

13. Cuspidi C, Rescaldani M, Tadic M, Sala C, Grassi G. Effects of Bariatric Surgery on Cardiac Structure and Function: A Systematic Review and Meta-Analysis. *American Journal of Hypertension.* Feb 2014, Vol. 27(2), pp. 146-156.

14. Sung-Hee Shin, Yeon Ji Lee, Yoon-Seok Heo, Sang-Don Park, Sung-Woo Kwon, Seong-Ill Woo et al. Beneficial Effects of Bariatric Surgery on Cardiac Structure and Function in Obesity. *Obesity surgery.* Mar 2017, Vol. 27(3), pp. 620-625.

15. SA, Mostfa. Impact of obesity and surgical weight reduction on cardiac remodeling. *Indian Heart Journal.* Dec 2018, Vol. 70(3), pp. S224-S228.

16. Kurnicka K, Domienik-Karłowicz J, Lichodziejewska B, Bielecki M, Kozłowska M, Goliszek S et al. Improvement of left ventricular diastolic function and left heart morphology in young women with morbid obesity six months after bariatric surgery. *Cardiology journal.* 2018, Vol. 25(1), pp. 97-105.

17. Vaziri SM, Larson MG, Benjamin EJ, Levy D. Echocardiographic predictors of nonrheumatic atrial fibrillation. The Framingham Heart Study. *Circulation.* Feb 1994, Vol. 89(2), pp. 724-730.

18. Nagy E, Jermendy AL, Merkely B, Maurovich-Horvat P. Clinical importance of epicardial adipose tissue. *Archives of Medical Science.* Jun 2017, Vol. 13(4), pp. 864-874.

19. Leo LA, Paiocchi VL, Schlossbauer SA, Ho SY, Faletra FF. The Intrusive Nature of Epicardial Adipose Tissue as Revealed by Cardiac Magnetic Resonance. *Journal of Cardiovascular Echography.* Apr-Jun 2019, Vol. 29(2), pp. 45-51.

20. Chaitanya Madamanchi, Hassan Alhosaini, Arihiro Sumida, Marschall S. Runge. Obesity and Natriuretic Peptides, BNP and NT-proBNP: Mechanisms and Diagnostic Implications for Heart Failure. *International Journal of cardiology.* Oct 2014, Vol. 176(3), pp. 611-617.

21. Chen-Tournoux A, May Khan A, Baggish AL, Castro VM, Semigran MJ, McCabe EL et al. Impact of Weight Loss Following Weight Loss Surgery on Levels of Plasma N-Terminal Pro-B-Type Natriuretic Peptide. *American Journal of Cardiology.* Nov 2010, Vol. 106(10), pp. 1450-1455

## Table legends

Table 1: Demographics at baseline

Table 2: Morpho-functional cardiac abnormalities

Table 3: 10-months echocardiography

## Figure legends

Figure 1: Classification of obesity before and after bariatric surgery

Figure 2: Reverse cardiac remodeling

Figure 3: Correlations