

Analysis of Right Atrial Function in Obese Pediatric Patients

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Abstract

Background : Left atrial enlargement and right and left ventricular dysfunction have been described in obese Patients. A number of studies have also described atrial dysfunction in obese children and adolescents.

Objective: The aim of the present study was to investigate right atrial dysfunction in obese pediatric patients and Compare echocardiography findings between these patients and non-obese controls.

Methods : Doppler echocardiography was performed on 50 obese pediatric patients (mean BMI=29.8 kg/m²) and 46 lean healthy controls. Systolic and diastolic function in both ventricles was investigated through conventional Doppler echocardiography. Right atrial function was evaluated using Color Doppler Myocardial Imaging (CDMI).

Results: No differences were detected between groups with regard to left ventricular ejection fraction. The S wave of the free Wall of the right ventricle was similar in both groups (13.8 ± 1.7 vs. 13.7 ± 1.6, p=0.655). The e'/A' ratio in the right Ventricle was significantly lower in the obese patients (0.9 ± 0.4 vs. 1.2 ± 0.3, p=0.007). CDMI analysis of the right atrium and inter-atrial septum showed significantly lower, strain and strain rate in obese patients (82.6 ± 29.8 vs. 98.6 ± 38.7, p=0.020; 3.9 ± 1.0 vs. 4.4 ± 1.2, p<0.001; 50.9 ± 25.0 vs. 81.1 ± 21.6, p<0.001; and 2.2 ± 1.0 vs. 3.3 ± 0.8, p<0.001, respectively).

Conclusion: The findings of the present study suggest incipient right atrial dysfunction, which may be secondary to an incipient impairment of myocardial relaxation in the right ventricle in obese children (BMI above 95th percentile).

Keywords: Atrial function; Obesity; Pediatrics

Introduction

Obesity has become an epidemic in both developed and developing countries. Statistics from the United States of America reveal a 32.2% rate of obesity among adult men and 25.5% among adult women [1]. It is estimated that Five to 10 million adult individuals in the United States alone have severe obesity (body mass index ≥ 40 kg/m²) [2]. In developing countries, the prevalence of obesity has reached more than 20% of the population. Reports on the pediatric population (children and adolescents aged two to 19 years) reveal that 11.9% are at or above the 97th percentile of the body mass index (BMI) for age, 16.9% are at or above the 95th percentile and 31.7% are at or above the 85th percentile [3]. Ten percent of children starting school in the United Kingdom are already obese [4]. Cardiovascular complications associated with obesity contribute to high rates of morbidity and mortality. Structural and functional alterations in the heart, such as left ventricular hypertrophy, diastolic/systolic dysfunction and atrial enlargement, are well established in adult and pediatric patients with obesity [5-10]. Left atrial dysfunction with left ventricular diastolic dysfunction in subjects with preserved systolic function is well established in patients with hypertension [11,12]. There is strong evidence that left atrial enlargement and dysfunction are associated with an increase in morbidity and mortality rates in patients with cardiovascular disease and present clinical relevance with respect to the rate of long-term events, survival and the risk of developing atrial fibrillation [13]. Using Doppler-derived strain and strain rate (SR) in the evaluation of hypertensive patients, Guan et al. found that left atrial myocardial dysfunction and the E/e' ratio in the left ventricle correlated negatively with left atrial SR [11]. However, conflicting results are reported for obese patients. Di Salvo et al. studied nonhypertensive children using strain and SR and found reduced left and right atrial function in the obese group [14]. On the other hand, Gulel et al. compared left atrial function using tissue Doppler imaging in adults with BMI ≥ 30 Kg/m² versus those with a BMI < 30 Kg/m² and found no difference in atrial function between groups [15]. The aim of the present study

was to compare right atrial function in obese pediatric patients (BMI $> 95^{\text{th}}$ percentile) with no comorbidities and lean controls (BMI $< 85^{\text{th}}$ percentile) using strain and SR data derived from color Doppler myocardial imaging.

Methods

Obese pediatric patients six to 18 years of age with a BMI above the 95th percentile were prospectively recruited from the nutrition clinic of a university hospital (*Universidade Federal de Minas Gerais*) in Belo Horizonte, Brazil. The control group was formed by children aged six to 18 years with a BMI below the 85th percentile recruited from the general pediatrics clinic of the same institution. Patients with a history of hypertension, diabetes mellitus, endocrinological disorders, hereditary or inflammatory systemic diseases, sleep apnea (according to parents' information) and athletes were excluded in both groups. This study received approval from the Human Research Ethics Committee of the institution and written informed consent was obtained from all participants and/or parents. The participants were weighed in light clothing without shoes using a Welmy[®] scale with a capacity of 300 Kg and accuracy of 100 g. Height was measured with a stadiometer (accuracy of 0.5 cm). BMI was calculated using the conventional formula of weight in kilograms divided by the square of height in

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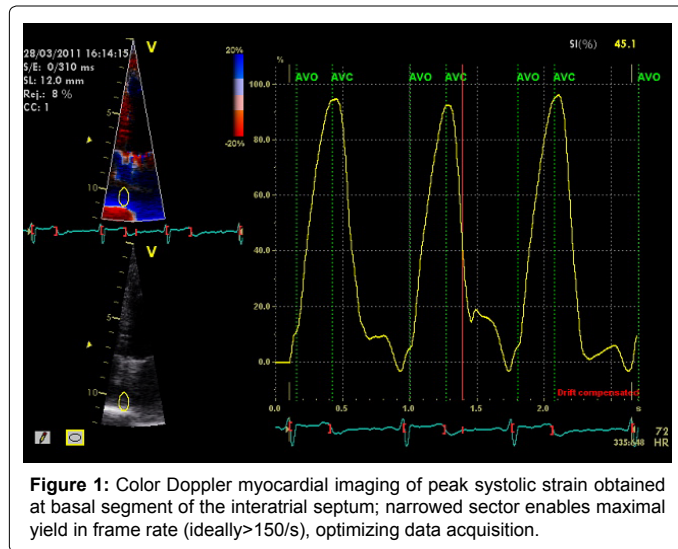


Figure 1: Color Doppler myocardial imaging of peak systolic strain obtained at basal segment of the interatrial septum; narrowed sector enables maximal yield in frame rate (ideally >150/s), optimizing data acquisition.

meters. Obesity was defined when BMI exceeded the 95th percentile for gender and age based on reference values [16]. Blood pressure was determined using standard methods with an appropriate cuff size on more than three different occasions. Only patients with systolic and diastolic blood pressure values below the 90th percentile for gender and height were included in the study [17].

A comprehensive Doppler echocardiogram with color flow mapping and tissue Doppler imaging were carried out for all patients using commercially available hardware and software (Vivid 7; GE Vingmed Ultrasound AS, Horten, Norway) and an electronic high-resolution multi-frequency transducer. A single experienced certified cardiologist performed all measurements. The mean values of three consecutive cardiac cycles were obtained for all echocardiographic parameters. Left ventricle (LV), end-systolic left ventricular diameter, end-diastolic left ventricular diameter, left ventricle free wall and septum thickness were determined based on the recommendations of the American Society of Echocardiography [18]. LV ejection fraction (EF) was calculated using the Teichholz method [12]. Left atrial volume was evaluated using the biplane area-length method from apical 4-chamber and 2 chamber views and indexed to body surface area [19]. For patients in whom an adequate tricuspid regurgitation (TR) spectral Doppler profile could be obtained, peak TR velocity was measured to calculate the right ventricle-right atrium gradient using the modified Bernoulli equation [$(\text{TR jet velocity})^2 \times 4$] [20].

Right ventricular (RV) systolic and diastolic function was assessed using pulsed-wave tissue Doppler imaging (PW-TDI) at the tricuspid annulus. The velocity of the S, A' and e' waves was determined. The e'/A' ratio of the right ventricle (RV) was also calculated [21]. All measurements were the mean of three consecutive heartbeats. Color Doppler-derived strain and SR were obtained by placing a 10-mm sample volume in the medial part of free wall of the right atrium and inter-atrial septum from the apical 4-chamber view [22]. The image sector was narrowed to allow the highest frame rate (>150 frames/sec) and the imaging angle to the wall was kept as low as possible to allow better parallel alignment to the wall of interest. Peak systolic strain and SR were measured (Figure 1).

Statistical Analysis

The primary outcome was the comparison of strain and SR images of the right atrium and inter-atrial septum in the two groups. The

sample size was calculated using the indexed LV mass from a previous study [23]. A sample of 45 patients in each group was calculated to provide a 90% power to detect a clinical effect (increase equal or greater than 30%) in LV mass, with a significance level (alpha) of 0.05 (two-tailed) [24]. The secondary outcomes were clinical data, Doppler echocardiographic parameters and PW-TDI values for the assessment of right ventricular systolic and diastolic function.

The normality of the data was tested to choose parametric vs. non-parametric tests. To characterize the sample, frequency distributions were used for qualitative variables and descriptive measures (mean, median, standard deviation) were used for quantitative variables. The Student's t-test was employed for comparisons between groups when variables followed normal distribution and the Mann-Whitney test was employed for data with non-Gaussian distribution. A significance level of 5% was considered on all statistical tests [24]. Intra-observer variability regarding strain and SR values was calculated in a sample of 20 randomly selected obese patients. Analyses were performed using the Statistical Package for Social Sciences version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Ninety-six patients were recruited - 50 in the obese group (OG) and 46 lean individuals in the control group (CG). Table 1 displays the clinical, demographic and standard echocardiography data in both groups. Age was similar in both groups. In the OG, 50% of the patients were male and in the CG, 48%. Heart rate was higher in the OG, but remained in the normal range. All patients were situated below the 90th percentile for systolic and diastolic blood pressure. However, mean systolic pressure and diastolic pressure were higher in the OG.

Standard echocardiography and PW-TDI

M mode LV diameter and LV mass corrected for height^{2.7} were higher in the OG. The left atrium diameter was also significantly larger in the obese patients in comparison to the lean controls. No statistically significant difference in EF was detected between groups. The RV e'/A' ratio was significantly lower in the OG (Table 2). Although within the normal range, the RV-right atrial gradient (measured by TR jet velocity) was slightly higher in the OG.

Strain and SR derived from color Doppler myocardial imaging

Systolic strain and SR of the basal segment of the free wall of the right atrium and the interatrial septum were significantly lower in the obese patients.

Variables*	Patients	Controls	p-value
Age (years)	11.7 ± 3.4	11.5 ± 3.1	0.409
Height (cm)	151.8 ± 14.5	144.5 ± 18.6	0.0340
Body mass index (kg/m ²)	29.9 ± 5.4	17.7 ± 2.6	<0.001
Diastolic blood pressure (mmHg)	63.0 ± 10.0	58.1 ± 6.3	0.006
Systolic blood pressure (mmHg)	97.2 ± 13.0	90.5 ± 10.0	0.007
LV end-diastolic diameter (mm)	44.5 ± 4.6	40.7 ± 5.6	<0.001
LV end-systolic diameter (mm)	27.5 ± 3.4	25.9 ± 3.3	0.020
LV ejection fraction (%)	68.2 ± 6.2	68.3 ± 5.3	0.931
Left atrium dimension (mm)	31.4 ± 4.0	27.1 ± 4.4	<0.001
Left atrium indexed volume (mL/m ²)	11.6 ± 15.6	22.8 ± 6.3	<0.001
LV mass/height ^{2.7}	51.0 ± 10.8	40.3 ± 12.7	<0.001
RV/RA gradient (mmHg)	20.7 ± 3.7	19.1 ± 3.4	0.041

Table 1: Clinical and standard echocardiographic features of patients and controls *Data expressed as mean ± standard deviation LV = Left ventricular; RV = Right ventricular; RA=Right atrium

Variables*	Patients	Controls	p-value
RV diameter (mm)	16.5 ± 4.6	15.0 ± 5.4	0.124
RV peak systolic velocity (cm/s)	13.8 ± 1.7	13.7 ± 1.6	0.655
RV peak early diastolic velocity (cm/s)	15.5 ± 2.5	15.8 ± 3.7	0.301
RV peak late diastolic velocity (cm/s)	10.4 ± 2.6	8.9 ± 1.9	0.004
RA early-to-late diastolic velocity ratio	0.9 ± 0.4	1.2 ± 0.3	0.007
RA Doppler-based strain† (- %)	82.6 ± 29.8	98.6 ± 38.7	0.020
RA strain rate (1/s)	3.9 ± 1.0	4.4 ± 1.2	0.030
BAS based strain† (- %)	50.9 ± 25.0	81.1 ± 21.6	<0.001
BAS strain rate (1/s)	2.2 ± 1.0	3.3 ± 0.8	<0.001

Table 2: Right ventricular TDI and atrial strain and SR features in patients and controls

*Data expressed as mean ± standard deviation

† Doppler-based strain

LV = Left Ventricular; RV = Right Ventricular; RA= Right Atrium; BAS = Basal Segment Atrial Septum

Reproducibility

Intraclass correlation coefficients for intra-observer variability regarding strain and SR for the RA and inter-atrial septum were 0.94^c, 0.93^c, 0.90^c and 0.97^c respectively.

Discussion

Standard echocardiography of obese pediatric patients with no comorbidities revealed a larger left atrial diameter, increased LV mass and the absence of systolic left ventricular dysfunction (Table 1), which is in agreement with previous studies [10,23], Data reported by Di Salvo et al. show left and right atrial dysfunction in obese pediatric patients. Moreover, the present study demonstrates a reduction in right atrial strain and SR in obese children and adolescents in comparison to lean controls [14].

Tissue Doppler image revealed no difference between groups regarding systolic right ventricular function (Table 2). In a previous study analyzing right ventricular function, our research group found an increase in strain and SR in obese pediatric patients and speculated that the hyperdynamic state found in obesity due to an increase in preload may influence RV strain and SR [10]. It is possible that decreased RV strain and SR is only detected later on in the obesity process, when the incipient RV systolic dysfunction overcomes the increase in preload and after load [6]. In the present study, the RV e'/A' ratio was significantly lower in the obese group (Table 2), which suggests an incipient impairment of myocardial relaxation of the right ventricle in these children and adolescents that may explain the decreased strain and SR in the RA in this type of patient.

Limitations of the Study

The obese children in the present study did not undergo polysomnography, which is the gold standard for the detection of sleep apnea and cause of pulmonary hypertension. However, since these children exhibited no clinical evidence of sleep apnea, it was not considered appropriate to submit them to this exam.

Conclusion

The present study demonstrates that obesity in children, even in the absence of comorbidities, is associated with right atrial deformation and incipient RV diastolic dysfunction. These findings underscore the importance of the early prevention of obesity in the pediatric population.

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