Left Ventricular Geometry in Pregnancy-Induced Hypertension

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The changes induced by transient hypertension upon cardiac geometry (G) are unclear. Pregnancy-induced hypertension (PIH) offers a natural and spontaneous model of this condition. To assess geometric changes according to two-dimensionally guided M-mode echocardiography, we compared patients with PIH with normal pregnant women (NPW). Fifty-five women, aged 28.5 ± 7.5 years, with PIH (defined as blood pressure >140/90 mm Hg in the third trimester of pregnancy and without a history of hypertension) were compared with 57 NPW aged 30.7 ± 7.5 years.

Left ventricular mass index (LVMI) (Devereux formula) and relative wall thickness (RWT) (Ganau formula) were calculated by means of echocardiography done in the left lateral decubitus 2 to 4 days postpartum. Subjects were considered to have: normal geometry (NG) if both LVMI and RWT fell below the mean ± 1 SD or 2 SD; concentric hypertrophy (CH) if both were elevated; eccentric hypertrophy (EH) if LVMI was elevated and RWT was normal; and concentric remodeling (CR) if LVMI was normal and RWT was elevated. Comparisons were performed by the Student *t* test. Patients with PIH had higher LVMI (106 ± 29.4 *v* 90.6 ± 19.8 g/m^2; $P < .05$) and RWT (0.41 ± 0.07 *v* 0.38 ± 0.05; $P < .05$). Considering the mean ± 1 SD of NPW as the limit of normality the G pattern was NG in 26 (47%) and abnormal in 29 (53%), of which 14 (25.5%) had EH, 11 (20%) had CR, and four (7%) had CH. If we considered the mean ± 2 SD, the G pattern was NG in 46 (84%) and abnormal G in nine (16%), EH in four (7%), CR in three (5%), and CH in 2 (4%). According to these data, women with PIH had higher LVMI and RWT compared with NPW. The most frequent abnormal G patterns were EH and CR. Am J Hypertens 2000;13:226–230 © 2000 American Journal of Hypertension, Ltd.

KEY WORDS: **Pregnancy induced hypertension, left ventricular geometry, ventricular geometry.**

Arterial hypertension represents, by itself, a fundamental stimulus for the development of left ventricular hypertrophy. The mechanisms of both are well known and induction by angiotensin II, together with the expression of proto-oncogenes after its union to the membrane receptor, are perhaps the two most important.[1–3] However, left ventricular overload imposed by arterial hypertension is more complex than expected: although, in some patients, left ventricular mass increases, in others it remains within normal limits. There is evidence that remodeling of the left ventricle depends on the hemodynamic conditions of preload, afterload, left ventricular contractility state, and severity and duration of the process.[4,5]

Hypertrophy secondary to pressure overload has a great impact on the cardiovascular system and may develop with different patterns, generically called

Received March 15, 1999. Accepted July 6, 1999.

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0895-7061/00/$20.00
PII S0895-7061(99)00185-5

ventricular geometries. The latter depend on the relationship between wall thickness and ventricular cavity size. In the type known as "concentric remodeling," wall thickness predominates over ventricular cavity size; in "eccentric hypertrophy," the opposite relation takes place; and, finally, in "concentric hypertrophy," both are increased. Ventricular mass is normal in the first type and increased in the other two. Arterial hypertension is known as a long lasting chronic overload that induces important structural changes in the ventricular myocardium. On the other hand, little is known about the changes induced by acute pressure overload, as is the case of pregnancy-induced hypertension.

During normal pregnancy a number of hemodynamic changes take place, such as an increase in blood and stroke volumes, together with heart rate, and a decrease in peripheral resistance and blood pressure.[6,7]

A number of reports on pregnancy-induced hypertension have been published, with different results. However, there is a consensus that in patients with preeclampsia, peripheral resistance is increased, plasmatic volume is decreased, and stroke volume may be normal or decreased.[8]

The consequences of left ventricular overload on left ventricle anatomy can be expressed in different ways: 1) normal geometric pattern, with normal left ventricular mass and relative wall thickness; 2) eccentric remodeling, with normal mass and increased relative wall thickness; 3) eccentric hypertrophy, with increase in both parameters; and 4) eccentric hypertrophy, with increased mass and normal relative wall thickness.

Although patients with chronic arterial hypertension are exposed to long lasting pressure overload with enough time to develop changes in left ventricular geometry,[9] little is known about the changes produced by conditions of acute pressure overload, as in the case of pregnancy induced hypertension.

METHODS

Patients We studied 55 women with pregnancy induced hypertension whose ages were between 16 and 33 years (mean 28.5 ± 7.5 years). Arterial hypertension was diagnosed when systolic or diastolic pressures were >140/90 mm Hg in a resting/sitting position on at least two occasions during the third trimester of pregnancy. None of them had previous recordings or a history of arterial hypertension, and the blood pressure during the first and the second trimesters of the pregnancy was normal. These results were compared to the ones obtained in 57 normal pregnant women with ages that ranged between 16 and 34 years (mean 30.7 ± 7.5 years). Serial blood pressure measurements were obtained with a mercury sphygmomanometer with systolic blood pressure defined as phase I and diastolic measurement as phase V of Korotkoff sounds. The average of three recordings in a sitting position within a 3-min interval among them were considered. All of the measurements were done after a 10-min period of relaxation and the procedure was repeated on two occasions.

Left ventricular mass was calculated from left ventricular end diastolic cavity, and septal and posterior wall thickness obtained by two-dimensional (2D) targeted M-mode echocardiography performed in a left lateral decubitus position. Echocardiographic studies were performed with an Apogee ultrasound system (Interspect Ambler, Philadelphia, Pennsylvania) using a 2.25 and a 3.00-MHz transducer, and the operators were blinded to the blood pressure of the patients. Measurements of ventricular septum, posterior wall, and left ventricular cavity were performed according to the American Society of Echocardiography (ASE) criteria.[10] Left ventricular mass was calculated from these data using the Penn convention and the ASE guidelines.[10–12] The left ventricular mass index was determined as the ratio of left ventricular mass (in grams) to the body surface area (in square meters). The relative posterior wall thickness was measured at end diastole as the ratio between the double of posterior wall thickness to the left ventricular diastolic cavity diameter. The ventricular geometries considered were the four categories of left ventricular anatomic remodeling, taking into account the relative posterior wall thickness at end diastole and the left ventricular mass index. Patients had a normal left geometry if the relative posterior wall thickness at end diastole and the left ventricular mass index were under the values of those corresponding to normal pregnant women, and had concentric hypertrophy when both were increased. Left ventricular eccentric hypertrophy was identified as an increase in mass index with a normal relative posterior wall thickness at end diastole and concentric remodeling was defined as an increase in relative posterior wall thickness at end diastole with a normal left ventricular mass index.

Statistical Analysis Data were expressed as means ± SD. The statistical significance of the difference between the values of the four ventricular geometric groups was tested with analysis of variance and the χ^2 test with the Yates correction. Results were considered significant at $P < .05$.

RESULTS

Left ventricular mass index of patients with PIH was 106 ± 29.4 g/m^2, 95% confidence interval (CI) 98.24–113.76, versus 90.6 ± 19.8 g/m^2, 95% CI 85.46–95.74 g/m^2 in NPW ($P < .05$). Relative wall thickness in PIH patients was 0.41 ± 0.07, (95% CI 039–0.43) versus 0.38 ± 0.05, 95% (CI 0.37–0.39) in NPW, a differ-

ence that was statistically significant ($P < .05$) (Table 1).

Ventricular Geometric Patterns If we consider the mean ± 1 SD as the upper normal limit of LVMI and RWT of NPW (110.4 g/m^2 and 0.43, respectively), we obtained normal geometric values in 26 patients with PIH (47%), eccentric hypertrophy in 14 (25%), concentric remodeling in 11 (20%), and concentric hypertrophy in four (7%), versus 39 (68.4%), eight (14%), eight (14%), and two (3.5%), respectively, in NPW. However if we consider the mean ± 2 SD of the LVMI and RWT as the upper normal limit (130.2 g/m^2 and 0.48, respectively), we found a normal geometric pattern in 46 patients (84%), eccentric hypertrophy in four (7%), concentric remodeling in three (5%), and concentric hypertrophy in two (4%), versus normal geometric values in 53 (93%), concentric remodeling in three (5%), and eccentric hypertrophy in one (2%) in NPW (Fig. 1). The data for PIH patients compared to data for NPW were significantly different ($P < .02$), and the risk of having an abnormal geometric pattern was more than twice as high in PIH patients compared as in NPW (odds ratio 2.62, CI 1.13–6.16).

DISCUSSION

During normal pregnancy a number of hemodynamic changes take place, such as an increase in blood and stroke volumes together with heart rate, and a decrease in peripheral resistance and mean blood pressure.[6,7] These changes may be responsible for structural remodeling of the left ventricle by themselves[13,14]

Pregnancy-induced hypertension represents an adequate model to evaluate the consequences of acute pressure overload on the myocardium during a short period of time. These patients differ from normal pregnant women in the fact that peripheral resistance is increased, and plasma volume may be normal or decreased.[8] The heart must adapt its wall thickness to this increase in pressure load, to decrease parietal stress despite the short lasting overload.

In a previous study, Thomson et al[15] did not find significant changes in mass index between normal pregnant control subjects and pregnancy-induced hypertensive women. The absence of significant differences between both groups could be explained by the low number of patients in this study.

On the contrary, in our study, patients with pregnancy-induced hypertension had a significant increase in left ventricular mass, a situation that especially reflects an increase in septal and posterior wall thickness without changes in left ventricular diastolic diameter. We did not know the left ventricular mass before the pregnancy; however, it can be assumed that it was previously normal, because the patients had no history of hypertension or any other condition that could increase it. Recently, Degli Esposti et al[16] published data about preeclamptic patients who had increased left ventricular mass, together with systolic and diastolic dysfunction, in comparison with normal pregnant women.

Ventricular Geometry In our study, normal pregnant women had an average left ventricular mass index of 90.6 ± 19.8 g/m^2 together with a relative wall thickness of 0.38 ± 0.05. These results differ from those reported by Ganau et al,[9] who consider 106 g/m^2 as the normal upper limit for left ventricular mass. This figure corresponds to the mean value plus two standard deviations of normal women. Likewise, for these authors, the normal upper value of relative wall thickness was 0.44, which corresponds to the 95th percentile.

These different results may be due to differences in the population, because the pregnant patients studied by us had other hemodynamic modifications that can produce different changes in the structure and function of the left ventricle.

Having these limitations in mind, we found that if the mean value plus one standard deviation of normal pregnant women is considered as a normal limit, we obtained normal geometric values in 26 of our patients (47.3%), and abnormal in 29 (52.7%). In 14 hypertensive women (25.4%) eccentric hypertrophy developed, in 11 (20%) concentric remodeling developed, and in the last four (7.3%) concentric hypertrophy was observed. But when we considered the mean value plus two standard deviations as the normal upper limit in normal pregnant women, we obtained normal geometric values in 46 patients (83.6%), eccentric hypertrophy in four (7.3%), concentric remodeling in three (5.5%), and concentric hypertrophy in two (3.6%). The data found in our group of patients with pregnancy-induced hypertension, compared to those in normal pregnant women, were significantly different.

Ganau et al reported normal geometric values in 52% of patients when considering 106 g/m^2 as the normal upper limit for left ventricular mass and 0.44 as the normal upper limit for relative wall thickness. These authors found eccentric hypertrophy in 27%, concentric remodeling in 20%, and concentric hypertrophy in 8%.[9] These results are similar to ours; however, despite this, the cause of structural abnormalities of the left ventricle is different in both situations. Pregnancy-induced hypertension appears within a short time, is short lasting, and affects a healthy cardiovascular system free of previous pathological influences. Consequently the organism has not enough time to adapt itself to this pressure overload. On the other hand, in essential hypertension, the process develops progressively and the myocardium adapts it-

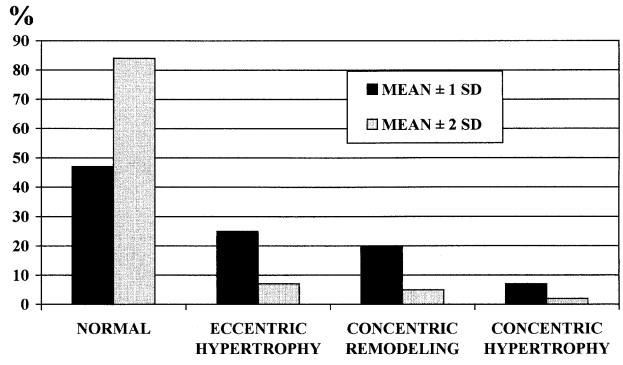

FIGURE 1. *Distribution of hypertensive pregnant women according to their geometric patterns of ventricular hypertrophy, considering the mean ± 1 SD and the mean ± 2 SD.*

TABLE 1. ECHOCARDIOGRAPHIC DATA

	NPW	PIH	*P* Value
LVDD (mm)	46.4 ± 4.6	47.2 ± 4.5	ns
LVSD (mm)	28.8 ± 3.9	29.5 ± 4.5	ns
IVST (mm)	8.9 ± 1.4	10 ± 1.5	0.001
LPWT (mm)	8.7 ± 1.3	9.3 ± 1.6	0.03
SF (%)	37.9 ± 5.6	37.7 ± 5.7	ns
RWT	0.38 ± 0.05	0.41 ± 0.07	0.02
LVMI (g/m^2)	90.6 ± 19.8	106 ± 29.4	0.004
WEIGHT (kg)	67.4 ± 13.7	71.1 ± 12.1	ns
HEIGHT (m)	1.58 ± 6.6	1.59 ± 6.9	ns
BSA (m^2)	1.68 ± 6.6	1.59 ± 6.9	ns

LVDD, left ventricular diastolic dimension; LVMI, left ventricular mass index; LVSD, left ventricular systolic dimension; IVST, interventricular septal thickness; LPWT, left posterior wall thickness; NPW, normal pregnant women; PIH, pregnancy-induced hypertension; RWT, relative wall thickness; SF, shortening fraction; BSA, body surface area.

self to decrease its wall stress. Concentric remodeling is the first step in the geometric changes that affect the myocardium. Several published reports discussed the different ways by which the left ventricle adapts to arterial hypertension. Acording to some reports,[5,17] left ventricular concentric hypertrophy is the most common observation, but there are exceptions to this rule. In a previous work,[18] we have observed that concentric and eccentric patterns appear with a similar frequency. Others[9] have remarked that eccentric hypertrophy and concentric remodeling are more common than concentric hypertrophy.

Eccentric Hypertrophy This change has been considered as a form of left ventricular failure due to pressure overload.[9] In normal pregnancy, changes in the left ventricular morphology may be found. During the second and third trimesters of pregnancy, there is a tendency for the left ventricular cavity and mass index to increase, but these disappear in a period of approximately 6 months after delivery.[14] The fact that pregnancy imposes a volume overload on the circulatory system represents a physiological explanation for this trend and for the greater incidence of eccentric hypertrophy, as we observed in our series. In the present study, no patient had overt cardiac failure, although we cannot rule out the possibility that this type of geometric remodeling may hide a latent form of contractile failure.

Concentric Remodeling This geometric type was common in our series and it is consistent with the mechanism suggested by Ganau et al, who proposed that the increase in peripheral resistance with a decrease in preload is caused by a contraction of the intravascular volume.[9] These conditions resemble those seen in patients with preeclampsia.[8]

Concentric Hypertrophy This type of geometric pattern is the one expected in those patients with an increase in afterload. However, it has been the less frequently observed in our series, and this may be explained by the fact that pregnancy-induced hypertension is a short lasting phenomenon.

Normal Geometry The majority of chronic hypertensive patients, even those with a relatively prolonged form of the disease, and those with pregnancy-induced hypertension show a normal geometric pattern. It may be possible that other issues, such as the contractile state of the myocardium, and even genetic causes can explain the lack of structural changes seen in patients with essential hypertension, as well as in patients with pregnancy-induced hypertension. Finally, we conclude that, although a normal pattern is the most common ventricular geometry found in patients with pregnancy-induced hypertension, this short lasting pressure overload is capable of inducing changes in the structure of the left ventricle.

REFERENCES

1. Starksen NF, Simpson PC, Bashopric N, et al: Cardiac myocyte hypertrophy is associated with c-myc proto oncogene expression. Proc Nat Acad Sci USA 1986;83: 8348–8350.
2. Komuro J, Shibazaki Y, Kurabayashi M, Yazaki Y: Expression of cellular oncogenes in the myocardium during the developmental stage and pressure overloaded hypertrophy of the rat heart. Circ Res 1988;62:1075–1079.
3. Taubman MB, Bek BC, Izumo S, Alexander RW, Nadal-Ginard B: Angiotensin II induction of c-fos mRNA in cultured rat aortic smooth muscle cells is independent of stimulation of Na+ H+ exchange (abstract). J Mol Cell Cardiol 1987;19(suppl IV):86.
4. Grant C, Green DG, Bunnel L: Left ventricular enlargement and hypertrophy. Am J Med 1965;39:895–904.
5. Grossman W, Jones D, McLaurin LP: Wall stress and

patterns of hypertrophy in the human left ventricle. J Clin Invest 1975;56:56–64.

6. Yeomans ER, Hankins GD: Cardiovascular physiology and invasive cardiac monitoring in heart disease during pregnancy. Clin Obstet Gynecol 1996;87:310–318.
7. Van Oppen AC, Stigter RH, Bruinse HW: Cardiac output in normal pregnancy: a critical review. Obstet Gynecol 1996;87:310–318.
8. Gifford RW, August P, Chesley LC, Cinningham G, Ferris TF, Lindheimer MD, Redman CWG, Roberts JM, Zuspan FP, Horan MJ, McNellis D, Roccella EJ, McDonald M: National High Blood Pressure Education Program Working Group Report on high blood pressure in pregnancy. Am J Obstet Gynecol 1990;163:1691–1712.
9. Ganau A, Devereux RB, Roman MJ, de Simone G, Pickering TG, Saba PS, Vargiu P, Simongini I, Laragh JH: Patterns of left ventricular hypertrophy and geometric remodeling in essential hypertension. J Am Coll Cardiol 1992;19:1550–1558.
10. Shan DJ, DeMaria A, Kisslo J, Weiman A, The Committee on M Mode Standardization of the American Society of Echocardiography. Recommendations regarding quantitation in M mode echocardiography: results of a survey of echocardiographic measurements. Circulation 1978;58:1072–1083.
11. Devereux RB, Reichek N: Echocardigraphic determination of left ventricular mass in man. Circulation 1977; 55:613–618.
12. Devereux RB, Alonso D, Lutas E, Gottlieb GJ, Campo E, Sachs I, Reichek N: Echocardiographic assesment of left ventricular hypertrophy: comparison to necropsy findings. Am J Cardiol 1986;57:450–458.
13. More SM, Sanders SP, Colan SD: Control mechanisms for physiological hypertrophy of pregnancy. Circulation 1996;94:667–672.
14. Poppas A, Shroff SG, Korcarz CE, Hibbard JU, Berger DS, Lindheimer MD, Lang RM: Serial assesment of the cardiovascular system in normal pregnancy. Circulation 1997;95:2407–2415.
15. Thompson JA, Hays PM, Sagar KB, Cruikshank DP: Echocardiographic left ventricular mass to differentiate chronic hypertension from preeclampsia during pregnancy. Am J Obstet Gynecol 1986;155:994–999.
16. Degli Esposti D, Borghi C, Cassani A, Crippa S, Bacchelli S, Immordino V, Boschi S, Bovicelli L, Ambrosioni E: Abnormal left ventricular structure and function in pregnancy complicated by preeclampsia (abstract). J Am Coll Cardiol 1998;31(suppl A):889.
17. Strauer BE: Structural and functional adaptation of the chronically overloaded heart in arterial hypertension. Am Heart J 1987;114:948–957.
18. Bellido CA, Piñeiro DJ, Iavicoli O, Lerman J: Ambulatory blood pressure monitoring in hypertensive patients with different ventricular geometries (abstract). Am J Hypertens 1994;7:146A.