Left Ventricle Remodeling for Patients with Heart Failure and its Influence on Cardiac Performance

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Summary:

Background: Many cardiac diseases can cause cardiac hypertrophy developed by the established cardiac overload, such as long term of uncontrolled hypertension, valvuler disease or congenital anomaly and many more causes. If the cause of hypertrophy persists for long time it will generate heart failure, as a result changes in size, shape and function of the heart which refer as remodeling.

Objective: To investigate the types of remodeling in patients with heart failure, and study its relation with cardiac performance.

Patients and methods: The study included fifty normal individuals and fifty patients, only those patients who developed hypertrophy and failure were chosen. The study has included the measurements of many cardiac parameters obtained by the echocardiography examination. The measurements have included: Left ventricle internal diameter at diastole (LVIDd), Left ventricle internal diameter at systole (LVIDs), Peak velocity of early transmitral flow (E), Peak velocity of late transmitral flow (A), Isovolumetric contraction time (ICT), Isovolumetric relaxation time (IRT), Ejection time (ET), Ejection fraction (EF%), myocardial performance Index (MPI), Left ventricle mass index (LVMI), Posterior wall thickness at diastole (PWTd), Relative wall thickness (RWT) and Interventricular septum thickness at diastole (IVSTd).

Results: results of remodeling have shown nine patients expressed concentric hypertrophy, thirty seven patients have shown eccentric hypertrophy and only four patients were similar to normal. Many other changes were observed these are an exaggerated ratio of (E/A) goes up to four, an increase in the (LV) volume appeared on its dimension at systole for patients (54.63%), a reduced cardiac output for patients and insignificant small change in relative wall thickness (RWT).

Conclusion: In conclusion long term cardiac overload can induce hypertrophy, after a period of time heart failure may ensue. This can influence the shape and size of the heart together with a reduction in its performance.

Keywords: Heart Failure, Cardiac remodeling & left ventricular performance.

Introduction:

Heart failure results when the heart cannot efficiently supply the body with blood. Arteries deliver blood and oxygen to the body. If the blood supply decreases, the body's Requirement for oxygen may not be met. Diastolic and systolic are the two basic types of Heart failure. Diastolic heart failure happens when the heart cannot properly fill with blood. Systolic heart failure, the more common of the two, occurs when the heart does not efficiently pump blood from the ventricles to the body (1).The hearts of patients with systolic heart failure differ dramatically from those of patients with diastolic heart failure in regard to both gross and microscopic anatomic features (2, 3). A substantial number of patients with heart failure (HF) have preserved left ventricular ejection fraction (LVEF), variably defined as an (LVEF) less than 50% (5, 6).

LV Remodeling: - Patients with diastolic heart failure generally exhibit a concentric pattern of (LV) remodeling and a hypertrophic process that is characterized by a normal or near-normal end-diastolic volume, increased wall thickness, and a high ratio of mass to volume with a high ratio of wall thickness to chamber radius (7). By contrast, patients with systolic heart failure exhibit a pattern of eccentric remodeling with an increase in end-diastolic volume, little increase in wall thickness, and a substantial decrease in the ratio of mass to volume and thickness to radius (8). Ventricular remodeling describes the process of changes in heart size, geometry, and function that occurs in response to a variety of stimuli (9). An increase in heart size requires the integrated disassembly and reassembly of the extracellular collagen matrix and realignment of the myofilaments to avoid sarcomeric disruption (10). Left ventricular (LV) hypertrophy (LVH) requires similar structural remodeling

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of chamber architecture and a uniform increase in wall thickness so that wall force is equally distributed throughout the ventricular walls (11). Ventricular remodeling may be physiologic or pathologic. Physiologic remodeling occurs with normal growth, pregnancy, and prolonged aerobic or isometric physical exercise. Pathologic remodeling occurs in chronic pressure or chronic volume overload states that usually develop over a period of years12(). A unique type of pathologic remodeling occurs within hours to days after the abrupt loss of contracting myocytes following an acute myocardial infarction (MI) (13, 14). Thus, LV dilatation brings further LV dilatation, mitral regurgitation, heart failure, and sudden death from ventricular arrhythmias (15).

One of the methods for determining left ventricular mass is the so-called cubed (Teichholz) formula which assumes that the left ventricle is a sphere. The diameter of this sphere is the interior dimension of the left ventricle and the sphere wall thickness is that of ventricular myocardium (16). Heart failure and LV remodeling can affect the myocardial performance index (MPI).

Types of Remodeling: Heart Hypertrophy was divided into four groups according to Yuda S, et al (17). They were characterized as Normal Geometry, Concentric Remodeling, Concentric Hypertrophy and Eccentric Hypertrophy. This division depends on (RWT) and (LVMI).

Methods:

This study was performed during nine months in the nursing home hospital, the echocardiography section.The study included 50 patients with heart failure and 50 normal individuals who were attended the outpatient clinic in the nursing home hospital for investigation. The Age, height, weight, blood pressure and heart rate were recorded for both patients and normal subjects.

Measurement of left ventricular wall thickness, in addition to the parameters measured for volume determination to allow the calculation of left ventricular wall volume and estimation of left ventricular mass (LVM). For these calculations, it is assumed that wall thickness is uniform throughout the ventricle. The formula calculates the outer dimensions of the sphere and then the inner dimension, the difference being the presumed left ventricular myocardial volume. The cubed formula is expressed as LVM= 1.04× [(LVIDd+ IVSTd+ PWTd)3 – (LVIDd)3] – 13.6

This then gives the volume of the stylized sphere of the myocardium, which, when multiplied by the density of muscle (1.05 g/cm3), provides an estimate of left ventricular mass (18). And the left ventricle mass can be calculated as LVMI = LVM / BSA Where BSA is the body surface area Myocardial performance index (MPI) has also been

calculated as the ratio of the sum of isovolumic relaxation time and contraction time to the ejection time, so IMP = (IVCT + IVRT) / ET

It can be calculated either by measuring each of the three individual times or by subtracting the ejection time from the total systolic time as a measure of total isovolumic time (19), as shown in fig (1).
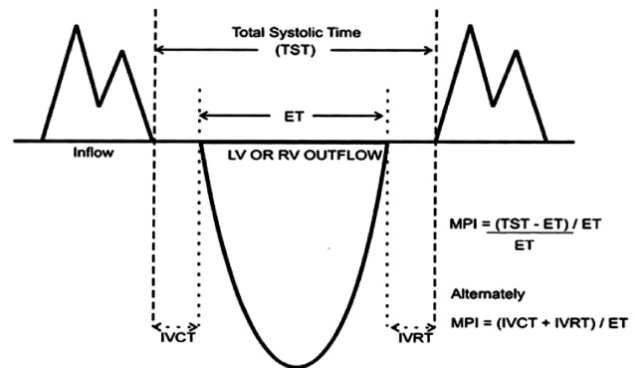
Figure 1: Derivation of the MPI from Doppler tracings of mitral and LV outflow.

Left ventricular internal dimensions at end systole (LVIDs) and diastole (LVIDd) were measurement using M-Mode echocardiography, the path of the M-mode ultrasound beam crosses the left ventricular chamber in a perpendicular plain to its posterior wall and the interventricular septum, and also the thickness of interventricular septum (IVST) and the LV posterior wall (PWT) at end diastole are measured. Transmitral blood velocity were measured by pulsed Doppler echocardiography, Peak E-wave velocity as the highest velocity of left ventricular early (rapid) filling and Peak A-wave velocity as peak velocity of left ventricular late filling during atrial contraction.(20)

Relative wall thickness is defined as (posterior wall thickness + interventricularseptal thickness)/left ventricular interior dimension. RWT= (PWTd + IVSTd) / LVIDd Relative wall thickness more than (0.45) has been considered as a threshold of pathologic left ventricular hypertrophy.

Results:

The assessment of the parameters changes between normal and patients were calculated by taking the ratio percent change between them, as (N-P)/N where N for normal and P for patients. In our results the remodeling was based on the change in the size and shape, i.e. Changes in the heart dimension in comparison with healthy individuals also for patients with heart failure. As we measured many variables we have divided our analysis into two categories: A- changes occurred in the myocardium such as thickness and size, these are, (RWT), (LVMI), (IVSTd), (PWTd),

(LVIDd), (LVIDs) and B-factors linked with blood flow (E), (A) and C- changes linked with cardiac performance some of these factors are belong to the diastolic and the others to the systolic function and other factors linked with cardiac cycle timing (ET), (IVCT), (IVRT).

Results have shown that (Four) patients have (RWT) < 0.45 and (LVMI) < 131 for men and <100 for women are considered as normal geometry. And (nine) patients have (RWT) >= 0.45 with (LVMI) >131for men and >100for women are considered as concentric hypertrophy, while (thirty seven) patients have (RWT) < 0.45 with (LVMI) >131for men and >100 for women are considered as Eccentric Hypertrophy (table1).

Table (1): Types of Remodeling

Male	Normal Geometry	Male	Concentric Hypertrophy	Male	Eccentric Hypertrophy
RWT<0.45 LVMI=<131	2	RWT>=0.45 LVMI>131	7	RWT<0.45 LVMI>131	23
Female		Female		Female	
RWT<0.45 LVMI=<100	2	RWT>=0.45 LVMI>100	2	RWT<0.45 LVMI>100	14
Total	4		9		37

The (LVIDd) is significantly higher in patients than in normal the percentage between the ratio of patients to the normal is (23.8%) with highly significant p-value. The difference even higher when we compare between (LVIDs) the percentage change between patient to the normal is (60%) p-value (HS), the change in the ratio of (LVIDd/ LVIDs) 1.18 for patients and 1.61 for normal respectively and the ratio percent for (LVIDd/LVIDs) between patients and normal is (26.7%) with p-value (HS), table (2) .

Table (2): Percent Difference between LVIDd & LVIDs between patients & normal.

Parameter	Normal Mean± SD	Patients Mean± SD	Change [(N-P)/N]X100%	Significance*
LVIDd(cm)	4.94± 0.61	6.12± 0.76	-23.8%	HS
LVIDs(cm)	3.15± 0.68	5.04± 0.72	-60%	HS
LVIDd/LVIDs	1.61± 0.26	1.18± 0.094	-26.7%	HS

*S for significant < 0.05, NS not significant & HS for highly significant <0.01

The change percent in deference of (IVRT) and (IVCT) between patients and normal are (11.11%) and (14.3%) respectively giving insignificant p-value (NS), while the change percent in (ET) is (27.65%), and the (MPI) value is (62.5%), giving highly significant p- value, (table. 3).

Table (3):Percentage difference of average values ± SD for each parameter between IVRT, IVCT, ET &IMP for normal & patients.

Parameter	Normal Mean± SD	Patient Mean± SD	Change [(N-P)/N]X100%	Significance*
IVRT (s)	0.09± 0.028	0.08± 0.040	11.11%	NS
IVCT (s)	0.07 ±0.019	0.06± 0.025	14.3%	NS
ET (s)	0.47± 0.087	0.34± 0.133	27.65%	HS
MPI	0.24± 0.059	0.39± 0.235	-62.5%	HS

*S for significant < 0.05, NS not significant & HS for highly significant <0.01

Results show deviation from normal in the average cardiac muscle thickness table (4). That the mean values (IVSTd) in control group less than that in patients group the change is (25.27%) this change appeared to be insignificant. The change in (RWT) between patients and control is (5.12%) and it is also statistically insignificant. in contrast the change in (LVMI) is high (70.31%) and the change is highly significant giving p-value (<<0.01) while the change in (PWTd) is not very high (8.73%) but it is highly significant as p-value (<<0.01).

Table (4):Percentage difference of mean values for each parameter between IVSTd, PWTd & RWT taken for normal & patients

Parameter	Normal Mean± SD	Patient Mean± SD	Change [(N-P)/N]X100%	Significance*
IVSTd	0.91± 0.20	1.14± 0.27	-25.27%	NS
PWTd	1.03± 0.35	1.12± 0.23	-8.73%	HS
RWT	0.39± 0.10	0.37± 0.09	5.12%	NS
LVMI	116.84± 53.1	199± 66.6	-70.31%	HS

*S for significant < 0.05, NS not significant & HS for highly significant <0.01

The passive transmitral velocity (E) is slightly lower in normal than in the patients (3.89%) with insignificant p-value, while the active transmitral velocity is much higher in normal than in patients (28.9%) with significant p-value. The value of the ratio of (E/A) is much higher in patients than in normal, giving change percent (54.63%) with highly significant p-value. The ejection fraction in patients is much lower than in normal giving change percent of (48.48%) also with highly significant p-value table (5).

Table (5): Change percent in the values of E, A and the ratio E/A between patients and normal

Parameter	Normal Mean± SD	Patient Mean± SD	Change [(N-P)/N]X100%	Significance*
E (m/s)	0.19±0.77	0.87± 0.39	-3.89%	NS
A (m/s)	0.76± 0.21	0.52± 0.42	28.9%	S
E/A	1.08± 0.43	1.21±1.67	-54.63%	HS
EF%	66± 9.64	34± 8.28	48.48%	HS

*S for significant < 0.05, NS not significant & HS for highly significant <0.01

The increase in the ratio of (LVDd/LVDs) is accompanied with an increase in (EF %) but the slope of the normal is less steep meaning that more increase in the ratio of (LVDd/LVDs) than patients for the same increase in (EF %). Figure (2)

Figure (2): shows the change in LVIDd/LVIDs with EF%.
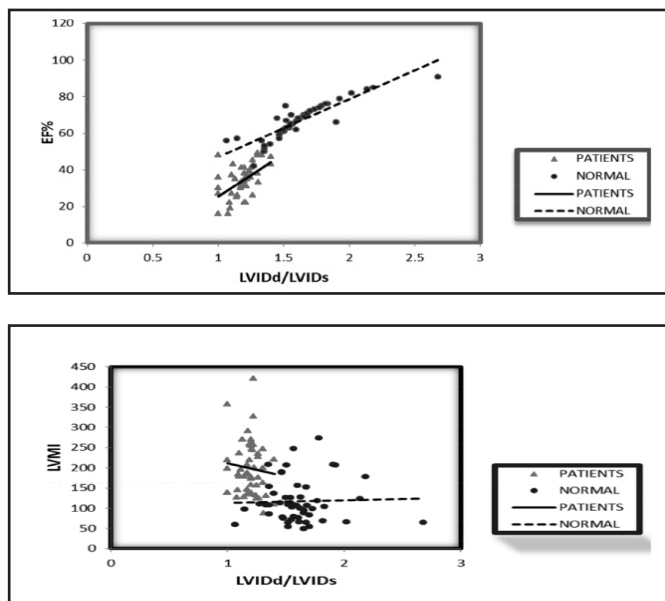
Figure (3): Relationship between LVMI and LVIDd/ LVIDs in normal and patients groups.

A decrease in the in the graph for (LVMI) versus (LVIDd/ LVIDs) as the value of the ratio of (LVDd/LVDs) is increased for patients while the curve is slightly rising for control i.e. as (LVIDd/LVIDs) is increased a slight increase in (LVMI) figure (3)

Figure (4) shows the change in (MPI) with (E/A). The slope of (MPI) stays almost constant for control with the increase in (E/A) may indicate no change in the cardiac performance while a decrease in (MPI) with the increase in (E/A) value observed for patients.

Figure (4): shows the change in MPI with E/A.
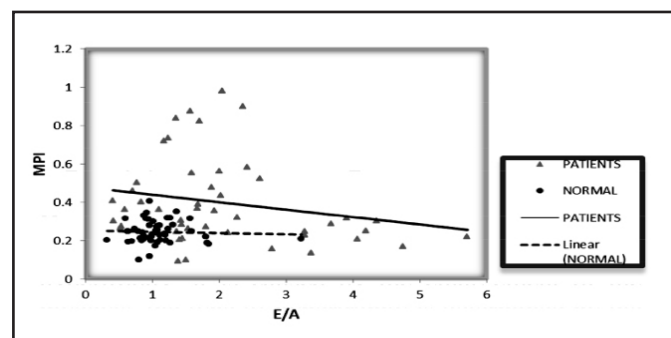
Discussion:-

The increase in the left ventricle size is termed as hypertrophy, it is caused by the enlargement of the myocyts, the type of hypertrophy is determined by the arrangements of sarcomers. Nine patients have LV thickness is abnormally increased higher than normal caused by pressure overload as seen in hypertension and aortic stenosis, It is characterized as concentric hypertrophy, and Thirty seven patients have another type of hypertrophy caused by (volume overload) they show an increase in the LV volume but the wall thickness is relatively similar to normal, such hypertrophy is seen in patents with mitral or aortic regurgitation. In this case the hypertrophy is characterized as eccentric hypertrophy table (1).

Many changes in the echocardiography such as reduction in the value of (LVIDd/LVIDs) table (2) may be caused by the larger volume of (LVIDs) giving inefficient LV contraction for patients and a consequent reduction in LV performance. Also changes in the relative wall thickness (RWT) and an increase in the average (LVMI) table (4). The reduction in the value of (A) may be caused by inefficient LA contraction table (5).

The change in the relative wall thickness (RWT) is small and not significant and the change in the (PWTd) is also small but highly significant, this insignificant change in (RWT) is expected because the value of (LVIDd) is higher in patients table (2) and the (RWT) index contains a division on the (LVIDd) as in the following formula

RWT= (PWTd + IVSTd) / LVIDd

This is caused by the type of our patients as most of them have eccentric remodeling characterized by increased LV volume and relatively similar to normal wall thickness.

By contrast to (RWT) the average (LVMI) is much higher in patients than in normal (70.31%) with highly significant p-value table (4). This result may be expected as the (LVMI) is obtained from the actual measurement of the LV mass then we may expect it is much higher than normal and because of that the thickness of concentric hypertrophied LV is usually much thicker than normal and in eccentric hypertrophy, although it has relatively similar to normal wall thickness, but the LV size is larger than normal giving high (LVMI).

We have calculated the ratio of (LVIDd/LVIDs) to investigate the difference in the change in the LV volume between the systole and diastole. The higher ratio of (LVIDd/LVIDs) with higher (EF %) for normal figure (2) is attributed to the higher contractility of LV muscle during contraction (systolic phase) which can increase (EF %) giving a change between patients and normal of (48.48 %) table (5). The decrease in the value of (LVMI) with the increase in (LVIDd/LVIDs) for patients means a smaller size for the LV at systole in which can increase the ratio of (LVIDd/LVIDs) indicate a better contractility, while the control the

curve is slightly rising i.e. as (LVIDd/LVIDs) is increased a slight increase in (LVMI) this phenomenon may be similar with athlete heart that the increase in (LVMI) is healthy (21) fig (3).

The reduction in (MPI) with increasing (E/A) is not very high in patients while almost no reduction in the value of (MPI) with (E/A) for controls fig (4). This result because of that (IVCT) and (IVRT) are higher for the normal and (ET) is much lower in patients which can increase the value of MPI for patients. This has caused a jump in the beginning of the graph for patients which has given a higher value of (MPI) at low (E/A), and lower value of (MPI) at high (E/A), a situation may indicate a pseudo improvement in cardiac performance as the exaggerated increase in (E/A) is an indication of deterioration rather than improvement in the cardiac performance.

In conclusion long term cardiac overload can induce hypertrophy, after a period of time heart failure may ensue. It can -1 - influence the shape and size of the heart; this includes an increase in (LVIDd), (LVIDs) and (LVMI), and an increase in the (IVSTd). 2- It causes a reduction in the change percent of (EF %). 3- And can cause an increase in the following values: a. (E/A). b. (MPI). c. (LVMI). And a change in (RWT) may depend on the type of remodeling.

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