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NEW ECHOCARDIOGRAPHIC METHODS IN DETERMINING THE HEART INSUFFICIENCY BASED ON 3D SPECKLE TRACKING TECHNOLOGY. THE SYSTOLIC HEART FAILURE (SHF) AND DIASTOLIC HEART FAILURE (DHF). THE DIFFERENCES

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Abstract

The purpose of the study is to analyze the differences in myocardial deformation through the 3D Strain analysis between the patients with systolic heart failure (SHF), patients with diastolic heart failure (DHF) as well as patients with no changes in the heart function. The ejection fraction (EF) was determined with 2D EF as well as 3D EF. 3D strain was analyzed through global longitudinal strain (GLS), global circumferential global strain (GCS), torso and the left ventricular muscle (VM) twist.

The differences of the parameters between the population with normal EF were analyzed (EF>50%), however with signs of diastolic heart failure (DHF), as well as cardiac insufficiency patients and EF, 50% (SHF). As an initial value for analysis was taken the 2D EF measured with the Simpsons modified formula (%) as well as the patient's clinical symptoms. In this paper are studied the end-diastolic as well as measurements of the left ventricle in the three groups of patients.

The 2D EF, 3DEF, 3D strain values were analyzed in these three groups of patients. As a referential initial value was taken the 2D EF above or under 50%, 3D EF expressed in %, GLS (the nominal value taken -15,9%) GCS with a normal value of -20, 8%. For twist as normal value was taken above 9.5, whereas for torso >1,51'/cm.

Patients with cardiac insufficiency, but with EF above 50% for analysis were taken based on the anamnesis as well as values gained in treadmill stress ECG under 5,5METS(NYHA II).

During the analysis of the results gained in these three groups, one can clearly see that the GLS values, as well as GCS in patients with EF under 50% and those above 50%, are lower in the population with no signs of cardiac insufficiency. Based on these data it is clear that these parameters can be used for diagnosing the classic cardiac insufficiency (with EF under 50%) as well as in people with cardiac insufficiency but with the same systolic function (EF above 50%)

From the gained results one can prove that the GLS is lower in the two groups of patients with cardiac insufficiency, whereas GCS in patients with DSF has a clear decrease of GLS, whereas GCS is in the normal grounds.

The importance of measuring these parameters, except for the difference in DHF is that people with decrease of all parameters of GLS and GCS which suggests longitudinal fiber damage and circumferential, possibility of improving the heart function is lower because of the more massive damage unlike those with damaged GLS only.

Keywords: heart failure, EF, global longitudinal strain(GLS), Global Circumferential Strain (GCS), LV mass, Torso of Left Ventricle (LV), LV Twist

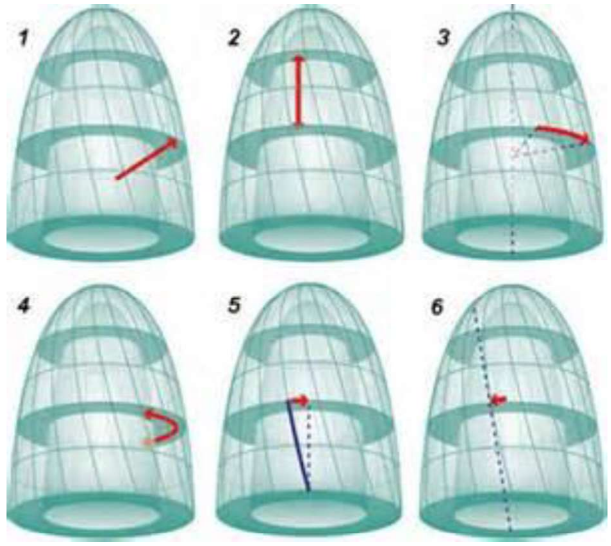
Introduction

From the beginning of echocardiography usage the diagnosis of the heart failure was based in the EF values of VM, where the value of EDF below 50% is taken as a primary marker for diagnosing PZ. This definition which defines Heart failure(HF) with EF value below 50% applies only for systolic heart failure (SHF), however does not explain the Diastolic Heart Failure (DHF) which is also known as Heart Failure with preserved systolic function.

Based on statistical data the normal ejection fraction (EF>50%) is present in more than 50% of the patients which have heart failure symptoms or are being treated by it.

EF of VM which is determined in a classical way, with M mode and 2D EF is dependent on the radial heart function. Due to incapacity of diagnosing the longitudinal and circumferential function with the standard echocardiography methods, the function of the heart which is very complex in these cases cannot be diagnosed properly. The complexity of the heart function stands in the

fact that it is dependant from the radial function, as well as from the longitudinal, circumferential and the cyclic movements of the heart (twisting and torsion of VM), as it was first explained by Leonardo da Vinci (fig 1-6).
Figure 1-6



(Fig.1 Radial movement Fig. 2 Longitudinal Fig. 3 Circumferential Fig. 4 Twist of heart Fig.5 and Fig. 6 Heart torso

From the anatomic data the longitudinal fibre of the VM are the fibers which are located in the level of endocardium, whereas the circumferential ones are in the epycardial levels. It is well known that the first function that gets damaged in VM in metabolic and degenerative diseases is the fibre damaging and the longitudinal function. This type of damage is characteristic in diabetes, arterial hypertension, infiltrative and hypertrophic cardiopathy, whereas the most advanced damages attack the circumferential fibres.

Starting from the fact that the measuring of the ejection function in M mode is dependent on the radial function of the heart, it is clear that 50% of the patients have signs of cardiac insufficiency. This is not shown with low levels of EF and it indicates that it is a result of the longitudinal damaging as well as circumferential damaging result. The radial heart function of the heart comes as a result of longitudinal and circumferential function, and as such it gets damaged in the later stages.

Only with Speckle tracking (ST) these complex heart functions can be analyzed, and especially with 3D strain. In this study we have used the Tomtec 4D LV analysis software, version 3.1 through which we have analyzed the radial strain, circumferential, longitudinal and the VM twist together with torso, which shows the maximal difference of the twist corrected with the VM length.

Materials and methods

In total 72 patients with cardiac insufficiency have been analyzed (34 male and 38 female) with the average age of 55 years (+/-20 years). Out of these patients, 46 had SHF (EF below 50%) and 26 with DF (EF above 50%).

In the group of normal EF values 22 people have been analyzed (12 male and 10 female) with an average age of 54 years (+/-19 years).

The echocardiography has been done with a commercial device (probe S3 with a harmonic Plus possibility, Sonos 7500 with 3D option, manufactured by Phillips healthcare, USA)

All of the 2D black and white images have been done on a Harmonic plus option and have been forwarded through Net link with Dicom protocol in the Tomtec software, which in itself contains Image arena, used for standard echocardiograph analysis as well as for EF determination with the modified Simpson formula from the apical 4C and 3C.

Images have been done with the matrix probe X4 in full volume mode, with pyramid60'x60', in complex 4 QRS. The gained images have been analyzed with Tomtec 4D LV analysis, which serves for a 3D analysis based on 3D speckle tracking technology (Tomtec,4D LV analysis ver3.1,TomtecGmbh).

Through 4D LV analysis 3D EF is diagnosed as well as LV mass in 3D images. Through this software end-diastolic volume (EDV), global longitudinal strain (GLS) values, global circumferential strain (GCS) as well as torso and VM twist are being measured.

Results

The study has been designed to verify the possible changes between the groups of the patients with normal EF values, patients with signs of cardiac insufficiency and EF >50%(DHF) as well as patients with cardiac insufficiency and EF <50%(SHF).

Patients and people involved in the control groups have been chosen randomly. During the study patients with approximate ages have been chosen.

The study is also random, the cases have been chosen with the patients who have shown signs of cardiac insufficiency in the Department of internal diseases in the Clinical Hospital in Tetovo, whereas in the group of the people with no diseases patients who had conducted routine check-ups have been chosen for the purposes of the study.

The patients with 2D above 50% and diagnosis of cardiac insufficiency have been taken out of the groups which have been treated as hospital cases for cardiac insufficiency, however which in standard echocardiograph values have had a normal EF.

In table 1 the values gained from the study have been presented and are grouped according to the diagnosis and EF.

Table 1

Parameters	Patients with SHF (EF<50%)	Patients with DHF (EF>50%)	Control group with EF >50%
2D EF(%)	27,4+/-9,4	54,2+/-2,6	64,4+/-6,7
3D EF(%)	32,6+/-11,6	46,36+/-6,38	59,22+/-6,7
EDV(ml)	177,3+/- 75	103+/-34	96+/-18
LV mass (gr)	225+/-92	158+/-52	139+/-31
GLS(-%)	-9,6+/-3,5	-12.6+/-2,3	-20,5+/-3,5
GCS(-%)	-12,16+/-4,08	-20,15+/-4,95	-28,2+/-5,49
Twist(')	5,9+/-3,4	9,9+/-6,1	17,3+/-7,2
Torsio('/cm)	0,7+/-0,4	1,3+/-0,8	2,28+/-0,5

2D EF of LV 3D Ef- of LV DSH heart failure (EF>50%) EDV - End-diastolic volume of LV GLS-Global longitudinal strain GCS-Global circumferential strain, LV mass of LV

Patients with SHF have EF determined with 2D echocardiography (2D EF), which is lower than the two other groups. In this group the average value of 2D EF is 27.4% +/- 9.4%, patients with DHF have values of 54.2 +/- 2.6%, whereas patients with normal heart function EF is 64.4 +/- 6.7%.

3D EF (EF measured with 3D echocardiography) in patients with SHF is 32.6 +/-11.6%, in patients with DHF is 46.36 +/-6.38%, vs the control group is 59,22+/-6,7%.

End-diastolic volume (EDV) in patients with SHF is 177,3+/-75 ml, in patients with DHF is 103+/-34 ml, %, vs. control group with96+/-18 ml. The normal value of the VM volume is <155 ml.

LV mass in patients with SHF is 225+/-92 gr, in patients with DHF is 158+/-52 gr , vse control group with139+/-31 gr. VM mass which is considered to be normal is <200 gr.

GLS(Global longitudinal strain) in patients with SHF is - 9,6+/-3,5%, in patients with DHF is -12,6+/-2,3 whereas in the control group is 20,5+/-3,5%.The normal value of the GLS is considered >-15,9%.

GCS(Global circumferential strain) in patients with SHF is -12,16+/-4,08 in patients with DHF is -20,15+/-4,95%, whereas in the control group is -28,2+/-5,49%. The normal value of the GCS is considered >-20,5%.

The twist which is defined as the sum of the apical and basal rotation of the left ventricular of the VM in patients with SHF is 5,9+/-3,4’, in patients with DHF is 9,9+/-6,1’ , whereas in the control group is 17,3+/-7,2’.The normal value of the VM twist is >11,5’.

Torsion of the VM in patients with SHF is 0,7+/-0,4’/cm, in patients with DHF is 1,3+/-0,8’/cm whereas in the control group is 2,28+/- 0,5’/cm. The normal value of the VM torso is >1,51’/cm.

Discussion

Based on the data gained from the groups of patients one can clearly see the changes that are registered in these two groups of patients as well as in the control group.

The 2D EF value is much lower in the group of SHF patients in comparison to the DHF patients) (27,4% vs 54,2%)(1,9) with a statistical significance of P<0,0001. This result is awaited as the EF value is what distinguishes SHF from DHF. The control

The same applies in 3D EF results where lower EF values are registered in SHF patients compared to DHF patients (32,6% in SHF vs 43,36 in DHF) (1,9) . The control group has a better EF value from the both groups which is 3D EF 59,22%.

In the measurements shown in Table 1 EDV increases in SHF can be seen, reaching 177 ml and which is above the maximal value of 150 ml (1). In the group with DHF we have EDV of 103 ml, whereas in the control group EDV is 96 ml (1,9) which falls in the category of normal VM. This proves that SHF, also known as congestive heart insufficiency has an increase of EDV compared to DHF, based on the greatest EDV volume in LV compared to DHF.

In table 1 one can also notice that VM mass is greater than SHF of 225 gr vs 158 gr DHF as well as 138 gr in the control group (2,6,7,9).

This increase in mass of SHF can be explained with an overall increase of the heart and activation of the compensatory systems such as RAS system and adrenergic system, which are characterized by myocardium remodeling due to excessively of their activation (1,3,9).

In the group of the patients with DHF this mass is greater in the majority of the group and which comes as a result of myocardium hypertrophy of the VM, which is a result of the basic diseases such as hypertension, diabetes, as well as activation of RAS and the autonomous sympathetic system (7).

When it comes to GLS one can clearly see the differences in the values between patients with SHF which have a GLS of -9,6+/-3,5% vs-12.6+/-2,3% in patients with DHF as well as -20,5+/-3,5 % in the control group (3,4,5,6,11). The characteristic of this analysis is the fact that GLS values starting from the normal (which are -15.9%) are lower in the two groups with cardiac insufficiency, even from those with SHF and DHF in comparison to the control group. It is also relevant that statistical significance between patients with DHF which have GLS of -12,6+/-3,5% versus the control group who have GLS values of -20,5+/-3,5% and it is clear that GLS values in the DHF group are lower than normal (3,4,5,6,11).

When it comes to GCS values in the SHF group they show levels of -12,16+/-4,08% vs -20,15+/-4,95 in patients with DHF as well as -28,2+/-5,49 in the control group (3,4,5,6,11). If we start from the normal values for GCS (which is -20.5%) one can clearly that in patients with SHF there is a significant decrease, whereas in patients with DHF the GCS is showing normal values. There is a great difference in values of GCS between the control group vs the group with DHF -20,15% and -28,2, but which is not emphasized so greatly as in GLS.

The twist in patients with SHF is 5,9+/-3,4 vs 9,9+/-6,1 in patients with DSH as well as 17,3+/-7,2 in the control group (7). The normal acceptable twist values are >11,5 (2,8,10).Starting from the gained results it is clear that low twist values are shown in patients with SHF. However, in patients with DHF twist values which are lower than normal, but with a great ST deviation, which shows that there is a great variety of twist values in patients with DHF (2,8,10). This situation is dependent on the length of the disease, where those with shorter periods of disease the twist of VM is normal, compared to those with greater length of disease with the twist values are lower.

In the VM torso values which normally is 1.50'/cm in patients with SHF is 0,7+/-0,4 vs1,3+/-0,8 in patients with DHF as well as 2,28+/-0,5 in the control group (2,8,10). It is clear that a great difference lies between the SHF group and the group of control, whereas in the DHF group where values are below normal, but with a great ST deviation which is dependent on the length of symptoms in the patients. Therefore, in patients with shorter history of disease of LV torso is normal, compared to those with longer history of disease.

Conclusion

1.GLS values are lower significantly in patients with SHF and DHF
2.GCS values are lower in patients with SHF, while in DHF , the values are close to normal, but with a great comparison from the persons with normal function of the VM.
3. Twist and torso of the VM are lower in patients with SHF. In patients with DHF these values are lower, but is opposite proportionally to a duration of disease (lower length of symptoms, higher twist and torso values and vice versa).
4. The usage of GLS and GCS can use as an indicator for diagnosing DHF. In this study the DHF is characterizes with normal EF and GCS values close to normal, or with low values of GLS.
5. The decrease of GLS and GCS explains the damage of the advanced VM, which has lower chances of recovery.
6. The analysis of the result from the twist and torso are clear in patients with SHF and those without symptoms. However, in patients with DSHF this proportion is more complex and dependent from the length of the symptoms, something which makes these applications in diagnosing DHF not applicable.
7. The lowering of the twist and torso in SHF explains a more advanced damaging of the LV myocardium.

References

1. Nesser HJ, Mor-Avi V, Gorissen W, et al: Quantification of left ventricular volumes using three-dimensional echocardiographic speckle tracking: Comparison with MRI. EurHeart J 2009; 30:1565–1573
2. Takahashi K, Al Naami G, Thompson R: Normal rotational, torso and untwisting data in children, adolescents and young adults. J Am Soc Echocardiogr 2010; 23:286–293
3. Baccouche H, Maunz M, Beck T, et al: Differentiating cardiac amyloidosis and hypertrophic cardiomyopathy byuse of three-dimensional speckle tracking echocardiography.Echocardiography 2012; 29:668–677
4. Galderisi M, Esposito R, Schiano-Lomoriello V, et al: Correlates of global area strain in native hypertensive patients: A three-dimensional speckle-tracking echocardiography study. Eur Heart J Cardiovasc Imaging 2012; 13:730–738.
5. Kleijn SA, Aly MFA, Terwee CB: Reliability of left ventricular volumes and function measurements using three-dimensional speckle tracking echocardiography. EurHeart J Cardiovasc Imaging 2012; 13:159–168
6. Ammar KA, Paterick TE, Khandheria BK, et al: Myocardial mechanics: Understanding and applying three-dimensional speckle tracking echocardiography in clinical practice. Echocardiography 2012; 29: 861–872
7. Hare JL, Brown JK, Leano R, Jenkins C, Woodward N, Marwick TH. Use of myocardial deformation imaging to detect preclinical myocardial dysfunction before conventional measures in patients undergoing breast cancer treatment with trastuzumab. *Am Heart J* 2009; 158:294–301.
8. Perez de Isla L, Balcones DV, Ferna´ndez-Golfı´n C, Marcos-Alberca P, Almeria C, Rodrigo JL et al. Three-dimensional-wall motion tracking: a new and faster tool for myocardial strain assessment: comparison with two-dimensional-wall motion tracking. J Am Soc Echocardiogr 2009; 22:325–30.
9. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European
    1. Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005;18:1440–63.
10. Seo Y, Ishizu T, Enomoto Y, Sugimori H, Yamamoto M, Machino T et al. Validation of 3-dimensional speckle tracking imaging to quantify regional myocardial deformation. Circ Cardiovasc Imaging 2009; 2:451–9.
11. Saito K, Okura H, Watanabe N, Hayashida A, Obase K, Imai K et al. Comprehensive evaluation of left ventricular strain using speckle tracking echocardiography in normal adults: comparison of three-dimensional and two-dimensional approaches. J Am Soc Echocardiogr 2009; 22:1025–30