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Accuracy of Left Atrial Strain in Predicting Left Ventricular End Diastolic Pressure: Comparative Study Tissue Doppler Imaging and Invasive Assessment

Saud M Elsaughier[1]*, Ramadan Ghaleb[1], Mohamed K Slama[1] and Mohamed A Saleh[2]

[1]Department of Cardiology, Aswan University, Cairo, Egypt
[2]Department of Cardiology, Ain Shams University, Cairo, Egypt

Abstract

Background: The ratio of the early transmitral inflow velocity to the mitral annular early-diastolic myocardial velocity (E/Em ratio) determined by tissue Doppler imaging (TDI) has been increasingly applied as a non-invasive method for evaluating the left ventricular filling pressure (LVFP). This study aimed to assess the performance of TDI parameters and the left atrial global longitudinal strain as non-invasive surrogates for the LVFP and to compare the accuracy of these two parameters across different striae of LVEF.

Methods: The study included 96 patients with a sinus rhythm, various EFs and an invasive recording of the LV pressure; these patients were split into four groups of 24 patients each according to their EF (>55%, 45–54%, 30–44%, and<30%). Both the medial and lateral E/Em ratios were quantified for all participants by 2D TDI; the peak atrial contraction strain (PACS) and peak atrial longitudinal strain (PALS) were obtained.

Results: There was a substantial correlation in terms of the global PALS and invasive LV end-diastolic pressure (LVEDP) in all groups (r=0.70, P<0.0.00), while the lateral E/E', showed a significant correlation in only two groups: preserved and mildly impaired EF(r=0.42, P=0.023; r=0.439,P=0.32; respectively).

Conclusion: Patients with a somewhat impaired or preserved LVEF, the lateral E/E' ratio and global PALS showed a fair correlation with the LVEDP. For patients with a moderate or extreme impairment, the E/E' ratio showed a poor correlation with the invasively determined LVFP. The global PALS demonstrated the most suitable estimation of the LVFP.

Keywords: Tissue Doppler Imaging (TDI); Left Ventricular Filling Pressure (LVFP); Left Atrial Global Longitudinal Strain (PALS); Peak atrial contraction strain (PACS)

Introduction

In developed countries, heart failure is an important cause of the hospitalization of individuals aged 65 and above. In Egypt alone, approximately 3 million patients are hospitalized every year. These figures include people with a primary or secondary heart failure diagnosis. The inclusion of acute heart failure (AHF) accounts for approximately 7 million hospital days annually [1].

In patients who are suffering from chronic failure of the left ventricle, an increased left ventricular filling pressure (LVFP) is a significant predictor of both cardiac symptoms and prognoses independent of the LV ejection fraction (LVEF) [2]. Profit has been reported that left atrial (LA) dilatation detected by echocardiography strongly and independently predicts many cardiovascular outcomes as it reflects chronic exposure to increased LVFP [3,4].

Left heart catheterization allows the accurate and direct determination of some haemodynamic variables for estimating the LVFP; however, the procedure is invasive and carries the risk of many complications [3].

Although it is widely applied, the actual utility of the ratio of the early transmitral inflow velocity to the mitral annular early-diastolic myocardial velocity (E/E' ratio) has been called into question by some studies involving subjects with either a severely impaired LVEF or a normal LVEF [5]. Recently, the peak atrial longitudinal strain (PALS), determined using speckle-tracking, has been found to be better than the E/E' ratio for assessing the pulmonary capillary wedge pressure (PCWP) or LV end-diastolic pressure (LVEDP) in people with a severely impaired LVEF [6].

Methods

Study population

A total of 96 patients with compensated heart failure indicated for left heart catheterization were included. This sample of the group was chosen so that four precisely split groups could be created according to the LVEF (≥ 55%; ≥ 45% to 54%; ≥ 30% to 44%; and<30%).

All patients selected were aged>18 years, had a normal sinus rhythm and provided written informed consent. All patients underwent a clinical evaluation to verify the symptoms and/or signs of heart failure. The patients were scheduled for cardiac catheterization after receiving optimal medical therapy and achieving a euvolemic or near euvolemic status. All of the patients underwent 2D and Doppler echocardiography within 24 hours of catheterization. Patients with recent acute coronary syndrome<48 hours, prosthetic valves, mitral regurgitation greater than grade two, any kind of implantable cardiac device, pericardial disease or insufficient imaging quality of the LA endocardial border were excluded.

Cardiac catheterization

For this study, we used a catheter (6-F, multipurpose) that was balanced according to the pressure in the atmosphere. It was then injected into the distal end of the fluid-filled lumen via the haemostasis valve. It was advanced into the LV cavity through a retrograde radial or femoral artery approach. The pressure measurements were acquired with a manometer-tipped catheter with high fidelity. The manometer was then calibrated according to the pressure and evaluated using the fluid-filled catheter at end diastole. An elevated LVEDP was defined as>12 mmHg [7].

***Corresponding author:** Saud M Elsaughier, Department of Cardiology, Aswan University, Cairo, Egypt, Tel: +2001157166779; E-mail: Soud_elsoughier_66@yahoo.com

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Two-dimensions echocardiography

The subjects underwent examination by ultrasound to evaluate the position of their left lateral decubitus. The machine in place used a Philips S5 transducer (Philips IE 33, Philips, Andover, MA).

Standard 2D, M-mode and tissue Doppler echocardiograms were obtained in the apical 4- and 2-chamber and left parasternal views according to the American Society of Echocardiography (ASE) guidelines. Dimensional measurements of the LV and LA and the LVEF were obtained using the biplane method, or Simpson's rule. The diastolic LV filling velocity was acquired according to the recommendations of the ASE. The standard index for LV diastolic function was derived from the late (A) diastolic and early (E) peak diastolic LV filling ratio. The area-length system was used to quantify the LA volume. "From the apical four- and two-chamber views, the QRS time interval on electrocardiography (ECG), as well as timing of mitral and aortic opening and closing, were evaluated by pulse-wave Doppler.

Early-diastolic (E') and late-diastolic (A') annular velocities were obtained by averaging respective values measured at the septal and lateral sides of the mitral annulus. The mean E' and the derived E/E' ratio were used as load-independent markers of ventricular diastolic relaxation.

Speckle-Tracking Echocardiography (STE)

For this analysis, the apical four-chamber view was acquired through traditional 2D greyscale echocardiography alongside a stable ECG recording while the subject was holding their breath. The data from 3 consecutive breaths were stored in a cine loop format. The frame rate hovered between 60–80 shots per second [8].The analyses were conducted offline after defining the endocardial border manually in the systolic frame and adjusting the region of interest (ROI) width. The software system (QLab version 9.0) automatically created a tracing of epicardial activity, generating longitudinal strain curves for six atrial segments using "frame-by-frame tracking" of the natural acoustic markers through the cardiac cycle. The automatically traced endocardial borders were then manually validated, and if required, modifications were performed before the software was allowed to perform data analysis.

The longitudinal PALS or peak atrial strain, gauged towards the reservoir phase end, was measured by creating an average of all global PALS values. The peak atrial contraction strain (PACS) was also evaluated in as an average all global PACS values.

Statistical Analysis

This analysis was conducted with SPSS (S-PLUS Stats Software) for Windows (version 20.0, SPSS, Inc., Chicago, Illinois). The Kolmogorov-Smirnov test was applied to all variables to gauge normality. If the test result was significant, the distribution of the variable was considered non-normal.

In other cases, normality was confirmed by evaluating the distribution for skewness and kurtosis. Normally distributed continuous variables are presented as the mean ± standard deviation; non-normally distributed continuous variables are presented as the median and range. Categorical variables are presented as percentages and numbers.

Non-normally distributed continuous variables were compared using the Wilcoxon test for two related samples and the Mann-Whitney U test for two unrelated samples. After confirming a normal distribution, paired and unpaired t-tests were conducted to compare data. Variables that demonstrated a significant relation to the results of interest were then included in the multiple regression model. An unpaired, two-tailed Student's t-test was used to compare quantitative variables. Fisher's exact test was further used for qualitative variables. A P value of less than 0.05 was considered significant.

A receiver-operating characteristic (ROC) curve was created to examine sensitivity, on the y axis, compared with 1-specificity, on the x axis. The area under the ROC curve (AUC) was used as an indicator of the positive and negative predictive values.

Results

This study enrolled 96 heart failure patients divided into 4 equal groups according to their LVEF. Clinical, echocardiographic and catheterization data of the study groups can be viewed in Table 1. The invasively measured LVEDP was found to be high (≥ 12 mmHg) in 46 patients (47.9%) and normal (<12 mmHg) in 50 patients (52.1%). The clinical features showed no substantial variances between the normal and high groups (Table 1).

Demographic features		**Two-D Echo features**	
Age in years	50.56 ± 17.28	LVEDD (cm)	5.29 ±1.13 (8.5-3.1)
Mean ± SD	(18.0 – 83.0)	LVESD (cm)	3.9 ± 1.19 (7.2-1.7)
Male gender Count (%)	66 (67.7%)	LVEF (%)	49.2 ± 13.7 (75-15)
DM	27 (28.1%)	Tissue doppler features	
HTN	29 (30.2%)	Peak E cm/s	69.9 ± 27.3 (147-34)
Overweight	26 (27.1%)	E/A	1.22 ± 0.86 (5.2 – 0.5)
Obese	40 (41.7%)	Septal E' cm/s	5.8 ± 2.25 (11.7-3)
Pulmonary HTN	3 (4.2%)	Lat E' cm/s	7.6 ± 2.88 (13.2 – 3.6)
		E/Sep E' cm/s	13.5 ± 8.11 (38.9-6)
		E/Lat E' cm/s	9.8 ± 5.16 (23.2 – 3.7)
Cardiac cath. features		**Speckle tracking**	
Nor. pressure	50 (52.1%)	Global long strain%	24.4 ± 13.1% (56.2-3)
High pressure	46 (47.9%)	PACS%	13.2 ± 8.3% (37-1)

Table 1: Demographic, echocardiographic and catheterization data.

Analysis of the tissue Doppler imaging (TDI) parameters for the whole

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study group showed no significant differences in the peak early diastolic velocity at the septal and lateral mitral annuli (septal and lateral E') among the LVEDP groups. The peak mitral inflow velocity (E) was significantly greater than the peak annular velocity for both the septal and lateral mitral annuli (Table 2).

	Normal LVEDP (n=50)	High LVEDP (n=46)	P value
Septal E' cm/s	6.23 ± 2.03	5.91 ± 2.84	0.192
Lat E' cm/s	8.01 ± 2.74	7.33 ± 2.75	0.133
E/Sep E' cm/s			<0.001
	11.59 ± 6.35	16.77 ± 8.13	
			*
E/Lat E' cm/s			<0.001
	8.98 ± 4.16	12.42 ± 4.37	
			*
Global long strain%	27.99 ± 13.14	11.89 ± 7.47	0.000*
PACS%	15.20 ± 8.56	6.28 ± 5.51	0.000*

Table 2: Comparing LVEDP against pulsed wave Doppler and tissue Doppler values. *Significantly greater than the peak annular velocity

Testing the correlation between the E/Lat e' and LVEDP using Pearson's test revealed R value of 0.369 and 0.47 for the septal and lateral mitral annular velocity, respectively (P<0.001 for both). Further analysis of this correlation after splitting the cohort into the 4 LVEF groups is shown in Table 3.

	Invasive LVEDP	
Tissue Doppler	**r value**	**P value**
Septal E' cm/s	-0.093	0.366
Lat E' cm/s	-0.019	0.856
E/Sep E' cm/s	0.369	<0.001**
E/Lat E' cm/s	0.466	<0.001**
Global long strain%	-0.708	<0.001**
PACS%	-0.601	<0.001**

Table 3: Correlations between invasive LVEDP and tissue Doppler. ** Significant correlation

The E/Lat E' ratio showed a significant correlation with the LVEDP only in patients with a normal and mildly impaired LVEF, not in patients with a moderately or severely impaired LVEF.

On the other hand, analysis of the speckle-tracking parameters showed a significant difference in both the PALS and PACS between the high and normal LVEDP groups (Table 1). Pearson's test showed a significant negative correlation of both the PALS and PACS with the LVEDP (Table 4).

On further analysis of the correlation after dividing the patients into the 4 groups, the PALS sustained a significant correlation across all LVEF categories.

ROC curves were plotted for the E/Sep E' ratio (Figure 1), E/Lat E' ratio (Figure 2), PALS% (Figure 3) and PACS% (Figure 4) in predicting the LVEDP. The PALS showed very good specificity (83.67%) and sensitivity (73.91%).

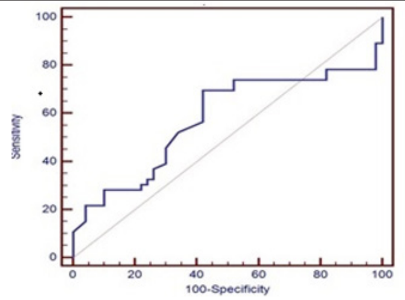

Figure 1: ROC curve for E/Sep E'.cm/s.

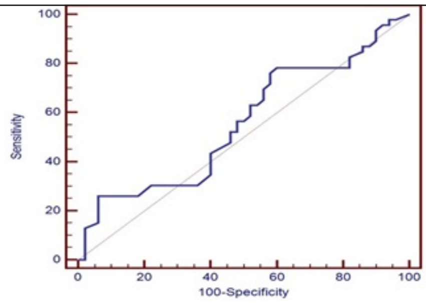

Figure 2: ROC curve for E/Lat_ E'.cm/s.

Tissue Doppler and Speckle Tracking	EF[illegible]0%		EF (30%-45%)		EF (45%-55%)		EF 55%	
	Invasive LVEDP		Invasive LVEDP		Invasive LVEDP		Invasive LVEDP	
	r value	P value	r value	P value	r value	P value	r value	P value
Peak E cm/s	0.111	0.606	0.012	0.956	-0.199	0.352	-0.289	0.171
E/A	0.427	0.037***	0.117	0.587	0.476	0.019***	-0.344	0.1
Septal E' cm/s	-0.023	0.917	-0.271	0.2	-0.31	0.141	0.142	0.509
lat E' cm/s	0.325	0.121	0.03	0.888	-0.303	0.15	-0.507	0.011***
E/Sep E' cm/s	-0.034	0.874	0.058	0.789	0.264	0.212	-0.323	0.124
E/Lat E' cm/s	0.258	0.233	-0.245	0.248	0.439	0.032***	0.462	0.023***
Global L strain%	-0.599	0.035***	-0.548	0.042***	-0.557	0.006***	-0.512	0.011***
PACS%	0.498	0.013***	-0.177	0.409	-0.482	0.020***	-0.311	0.139
LA vol AP 4 ml	-0.133	0.537	0.349	0.095	0.657	0.000***	0.109	0.613

Table 4: Correlations between invasion LVEDP and tissue Doppler Speckle tracking parameters in each group of EF. * Significant difference

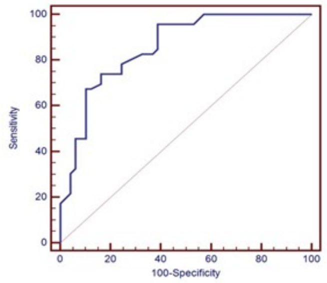

Figure 3: ROC curve for PALS%.

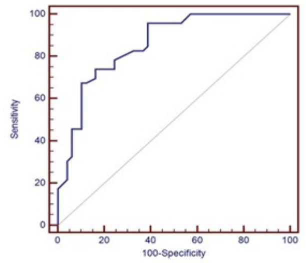

Figure 4: ROC curve for PACS%.

Discussion

Invasively measured LVFPs, such as the LVEDP and PCWP, have more accurate diagnostic and prognostic value in heart failure management. However, these methods are invasive, carry the risk of complications, are expensive, and are difficult to routinely employ in regular practice, especially in terms of AHF, for which they are required, the most. Accordingly, there is a need for non-invasive, sensitive and specific alternatives for the LVFP [9-11].

LVEDP ≥12 mmHg was used as the cut off for defining an abnormally high LVFP and has been tested and validated in many previous studies [7,12,13].TDI has been considered a good non-invasive tool reflecting abnormalities in the LV pressure for the past few decades; however, recent studies have published controversial results about the sensitivity and accuracy of TDI.

STE is a novel modality for the assessment of all 3 LA functions (reservoir, conduit and pump) and has been validated against non-invasive [14,15] and invasive indicators of diastolic function. The reliability and accuracy of STE in the assessment of LA functions is supported by many studies conducted in healthy individuals and patients with heart failure [6,7,16-18]. STE has the advantage of overcoming the angle dependency that was considered a significant disadvantage of TDI that limited the reproducibility of its results [5,19].

In this study, the E/Lat E' ratio and the global PALS (as the most closely correlated TDI and STE parameters, respectively) showed significant differences between patients with a normal and high LVEDP and showed significant correlations with invasively measured LVEDP values.

In the large body of evidence regarding the relationship between the TDI-derived E/e' ratio and the directly measured LVFP, there is obvious variation in their degree of correlation [20].This is possibly because TDI results are greatly angle dependent and are frequently affected by the movement of the whole heart during systole and diastole.

Moreover, the reliability of the TDI-derived E/e' ratio as a predictor of the LVFP in the unique subset of patients with a severely impaired LVEF has been repeatedly criticized in many studies [5,21]. Cameli et al. conducted a study of a group of participants with severely impaired systolic function, i.e., LVEF<35%, and reported a non-significant correlation between the TDI-derived E/e' ratio and the mean PCWP [6]. In a larger study of patients with LVEF ≤ 35%, performed by Mullen et al., no correlation was found between E/e' and PCWP [5]. Mullen et al. also found that E/e' lacks any sensitivity and specificity for differentiating between PCWP>18 mmHg and ≤ 18 mmHg, particularly with more dilated or more impaired LVs.

Accordingly, in this study, the correlation of E/Lat E' and PALS% with the LVEDP was re-examined after splitting the study group into 4 categories by the LVEF. E/Lat E' was correlated with the LVEDP only in patients with normal and mild LVEF impairment and failed to show any correlation in patients with LVEF<45%. In contrast, PALS% sustained a significant correlation with the LVEDP across all LVEF categories. e ROC curves show that an E/Lat E' ratio of ≤ 4.4 predicted LVEDP>12 mmHg with a sensitivity of 26%, specificity of 94% and a poor AUC of 0.557, while a PALS of ≤ 15% predicted LVEDP>12 mmHg with a sensitivity of 74%, specificity of 81% and AUC of 0.857.

Similar to our results, in a recent study by Cameli et al., 4 equal groups of patients were recruited according to their LVEF (normal, mild, moderately impaired and severely impaired LVEF); in this study, E/e' showed a poor correlation with the invasively measured LVEDP in patients with a moderately and severely impaired LVEF but a strong correlation in patients with a normal and mildly impaired LVEF.

The lack of reliability and accuracy of E/e' in predicting LVFP and LV diastolic function in subjects with a severely impaired EF can possibly be explained by LV fibrosis and reduced cardiac output, which subsequently cause the restriction of mitral annular motion during systole and early diastole, leading to the ratio of the LA pressure (E) to LV relaxation (e') becoming an unreliable indicator of the LVFP.

Limitations

Our study had some limitations worth mentioning. The number of females was small in our study group. The accuracy of TDI and STE results are operator dependent and view dependent. The lack of special software for LA speckle tracking is considered a current limitation; we used LV speckle-tracking software instead. Until now, there have been no accepted normal values for the LA strain or strain rate. We used end-hole catheters connected to a digital pressure dome for the invasive pressure assessment. While micro-manometer-tipped catheters are better for direct pressure measurement, they are expensive, unavailable and reportedly linked with an increased embolization risk.

Conclusion

In this study, both E/Lat E' and PALS were good surrogates for the LVFP and were correlated to the invasively measured LVEDP during left heart catheterization. E/Lat E' showed a statistical correlation (and was weak) with the LVEDP only in cases with LVEF ≥ 45%. The PALS was identified as a reliable and sensitive non-invasive surrogate for the LVEDP that maintained a good correlation in all LVEF categories.

Confirmation of written informed consent from the participant (or if age of the patient is under 20, consent from a substitute person (an individual considered to be able to express the intention and interests of the patient, such as parental authority or legal representative of the patient)). All of the requirements listed above must be met for inclusion in the study.

References

1. Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Turner MB (2013) Heart disease and stroke statistics-2013 Update: A report from the American heart association. Circulation 127: 6-245.
2. Gottdiener JS, Kitzman DW, Aurigemma GP, Arnold AM, Manolio TA (2006) Left atrial volume, geometry, and function in systolic and diastolic heart failure of persons and gt; or=65 years of age (the cardiovascular health study). Am J Cardiol 97: 83-89.
3. Schober KE, Luis Fuentes V, Bonagura JD (2003) Comparison between invasive hemodynamic measurements and noninvasive assessment of left ventricular diastolic function by use of Doppler echocardiography in healthy anesthetized cats. Am J Vet Res 64: 93-103.
4. Bruch C, Grude M, Müller J, Breithardt G, Wichter T (2005) Usefulness of tissue Doppler imaging for estimation of left ventricular filling pressures in patients with systolic and diastolic heart failure. Am J Cardiol 95: 892–895.
5. Mullens W, Borowski AG, Curtin RJ, Thomas JD, Tang WH (2009) Tissue Doppler imaging in the estimation of intracardiac filling pressure in decompensated patients with advanced systolic heart failure. Circulation 119: 62-70.
6. Cameli M , Lisi M,S Mondillo, Padeleletti M, Ballo P, et al. (2010) Left atrial of longitudinal strain by speckle tracking echocardiography correlates well with left ventricular filling pressures in patients with heart failure. Cardiovascular Ultrasound 8:14.
7. Matteo C, StefaniaS, Maurizio L, Daniele M, Sergio LM (2016). Correlation of left atrial strain and doppler measurements with invasive measurement of left ventricular end□diastolic pressure in patients stratified for different values of ejection fraction. Echocardiography 33: 398-405.
8. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, et al. (2006) Recommendations for chamber quantification. Eur J Echocardiogr 7: 79-108.
9. De Oliveira RKF, Ferreira EVM, Ramos RP, Messina CMS, Kapins CEB, et al. (2014). Usefulness of pulmonary capillary wedge pressure as a correlate of left ventricular filling pressures in pulmonary arterial hypertension. J Heart Lung Transplant 33:157-162.
10. Easby D, Dalrymple P (2009) Monitoring arterial, central venous and pulmonary capillary wedge pressure. J Anaesth Intensive Care 10:38–44.
11. Sharkey SW (1987) Beyond the wedge: Clinical physiology and theSwan-Ganz catheter. Am J Med 83: 111–122.
12. Kuroda T, Shiina A, Suzuki O, Fujita T, Noda T, et al. (1989) Prediction of prognosis of patients with idiopathic dilated cardiomyopathy: A comparison of echocardiography with cardiac catheterization. J Med 28:180–188.
13. Ommen SR, Nishimura RA, Appleton CP (2000) Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressures: A comparative simultaneous Doppler-catheterization study. Circulation 102: 1788-1794.
14. Prasad A, Popovic ZB, Arbab-Zadeh A, Q Fu, Palmer D, et al. (2007). The effects of aging and physical activity on doppler measures of diastolic function. Am J Cardiol 99 : 1629-1636
15. Grossman, William, Baim D (2014) Cardiac Catheterization, Angiography, and Intervention. Am J Cardiol 1-17.
16. Mentz RJ, Fiuzat M, Wojdyla DM, Chiswell K, Gheorghiade M, et al. (2012) Clinical characteristics and outcomes of hospitalized heart failure patients with systolic dysfunction and chronic obstructive pulmonary disease: Findings from OPTIMIZE□HF. Eur J Heart Fail 14: 395-403.
17. Mann DL, Bristow MR (2005) Mechanisms and models in heart failure: The biomechanical model and beyond. Circulation 111: 2837-2849.
18. Kusunose, KH Motoki, ZB Popovic, JD Thomas, AL Klein, et al. (2012) Independent association of left atrial function withexercise capacity in patients with preserved ejection fraction. Heart.
19. Galderisi MP, Lancellotti E, Donal N, Cardim T, Edvardsen, et al. (2014) European multicentrevalidation study of the accuracy of E/e: Ratio in estimating invasive left ventricular filling pressure: EURO-FILLING study. Eur Heart J Cardiovasc Imaging 15: 810-816.
20. Lang CC, Struthers AD (2013) Targeting therenin-angiotensin-aldosterone system in heart failure. Nat Rev Cardiol 10: 125-34.
21. MJJV McMurray, S Adamopoulos, SD Anker, A Auricchio, M Böhm, et al. (2012) ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012 The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. Eur Heart J 33:1787-1847.