ORIGINAL ARTICLE

CONTENTS

The value of biomarkers in predicting the course of heart failure of ischemic genesis in patients with atrial fibrillation and diabetes mellitus

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ABSTRACT

Aim: To study the prognostic value of biomarkers in patients with heart failure of ischemic origin with concomitant atrial fibrillation and diabetes mellitus.
Material and Methods: 398 patients with heart failure (HF) on the background of post-infarction cardiosclerosis (198 women and 200 men) were included in the study. Patients were divided into 3 groups depending on the HF phenotype: Group I – 167 (42.0%) patients who had reduced LV EF (≤ 40%); II group – 133 (33.4%) patients with moderately reduced LV EF (41-49%); Group III – 98 (24.6%) patients with preserved LV EF (≥ 50%).
Results: In HF patients with reduced LVEF, compared to patients who had moderately reduced and preserved FE, IV FK according to NYHA and AF are more often diagnosed 70.1%, against 53.4% and 38.8%; c2 = 25.57, p = 0.0001); higher one-year mortality (12.0%, against 1.5% and 4.1%), approximately the same frequency of RH; higher levels of NT-proBNP (by 16.2%, at p = 0.015) and ST-2 (43.0 [38.3 – 47.3] ng/ml, against 41.0 [35.8 – 44.6] ng/ml and 41.2 [37.0 – 44.6] ng/ml, with p = 0.004). The NT-proBNP / BNP ratio > 10.17 AU had a higher prognostic value compared to NT-proBNP for PG.
Conclusions: In patients with heart failure of ischemic genesis with concomitant atrial fibrillation and diabetes mellitus, the NT-proBNP /ST-2 ratio >17.12 AU has the greatest prognostic value (Se=85.1%; Sp=80.0%). The frequency of RH in this group reaches 97.6% during the year.

KEY WORDS: biomarkers, diabetes mellitus, heart failure, atrial fibrillation

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INTRODUCTION

The average prevalence of HF, according to data from different countries, ranges from 1.5 to 5.5% [1, 2]. With age, the prevalence of this pathology progressively increases, reaching 10% or more among people over 70 years of age [3]. The most common etiological factor of HF in Europe and the USA today is coronary heart disease (CHD), which, according to epidemiological and multicentre clinical studies, is diagnosed in 60-75 % of such patients.

The study of risk markers could expand the possibilities of stratifying the early and separate prognosis of patients with HF. Biological markers are widely used in the clinic as a reliable tool for predicting the course of heart disease and assessing therapeutic effects [4-6]. The development of a standardized strategy for monitoring and intervention in patients with HF requires further improvement due to various etiological factors of HF, its phenotypes, and the presence of comorbid conditions [7].

AIM

To study the prognostic value of biomarkers in patients with heart failure of ischemic origin with concomitant atrial fibrillation and diabetes mellitus.

MATERIALS AND METHODS

The study protocol was approved by the local Ethics and Deontology Committee of Ivano-Frankivsk National Medical University. All research methods involving patients were performed in accordance with the ethical standards of the Declaration of

Helsinki. Patients were enrolled in the study at the time of hospitalisation in the cardiology department due to HF decompensation. We examined 398 patients of the Caucasian race with HF aged 45-65 years (54.3±7.2 years). 226 (56.8%) had permanent HF, 102 (25.6%) had concomitant type 2 diabetes mellitus.

Inclusion criteria: signed informed consent, history of myocardial infarction (MI), verified diagnosis of HF stage C, NYHA class II-IV. Exclusion criteria: failure to sign informed consent, haemodynamically significant valvular heart disease, HF of other etiologies, thyroid suppressive treatment, clinical hypothyroidism, thyrotoxicosis, inflammatory diseases, decompensation of diabetes mellitus, CKD stage IV.

Diagnosis and treatment of AF and HF were carried out according to the clinical protocol for the provision of medical care to patients with atrial fibrillation and heart failure approved by the Order of the Ministry of Health of Ukraine of 03.07.2006 No. 436 and by the European Society of Cardiology (ESC) Guidelines for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2021 [3].

Serum levels of thyroid-stimulating hormone (TSH) (normal range - 0.3-4.0 mIU/l), free T3 (T3v) (normal range - 2.5-5.8 pmol/l), and free T4 (T4v) (normal range - 10-25 pmol/l) were determined using reagent kits, blood glucose (normal range - 4 -5.5 mmol/l), glycated haemoglobin (normal range - up to 5.6%) were measured using reagent kits (TSH-ELISA, свT4-ELISA and свT3-ELISA, Hema, Ukraine).

To determine the serum level of Galectin-3 (detection range (0.156 - 10.0) ng/ml), ST-2 (detection range (12.5 - 250.0) ng/ml), BNP (normal range - (30 - 2500) pg/ml), NT-proBNP (detection range (10 - 35000) pg/ml), reagent kits were used ("Human Gal3(Galectin-3) ELISA Kit" (FineTest®), "ST2 Rapid Test" (Aspect-PLUS®), "BNP Rapid test" (NanoEnTek) and "IF1002" (GP Getein®), respectively). Enzyme-linked immunosorbent assays were performed using a semi-automatic immunoassay analyzer "Immunochem-2100" (High technology, USA).

The ratios were calculated: ST-2/Galectin-3 (UL), NT-proBNP/BNP (UL), NT-proBNP/ST-2 (UL), and NT-proBNP/Galectin-3 (UL).

The instrumental methods included electrocardiography (ECG), daily ECG monitoring, and echocardiography (Echocardiography).

The resting ECG was recorded in 12 standard leads using an electrocardiograph "Electrocardiograph, ECG 8820G" (Germany).

Daily ECG monitoring was performed using the ABPM50 system (England).

Doppler echocardiographic examination was performed using the ultrasound diagnostic system "CARIS-PLUS" (Biomedice, Italy). The end-diastolic and end-systolic dimensions (EDD and ESD, respectively) of the left ventricle (LV), thickness of the interventricular septum (IVS) and LV posterior wall (LVPW), diameter of the left atrium (LA), right ventricle (RV) and other parameters were determined. LV end-diastolic volume (EDV), LV end-systolic volume (ESV), LV end-diastolic index (EDI), LV end-systolic index (ESI), LV ejection fraction (LVEF), LV myocardial mass (LVMM) and its index (LVMI) were calculated.

Patients were followed up for 1 year, and the presence of rehospitalization for HF decompensation (or intravenous loop diuretics as prescribed by a cardiologist) was taken into account. Mortality was taken into account.

At the first stage of the study, all 398 patients were divided into three groups depending on the phenotype of HF:

Group I - 167 (42.0%) patients with reduced LVEF (LVEF ≤ 40%);

Group II - 133 (33.4%) patients with moderately reduced LVEF (LVEF 41 - 49%);

Group III - 98 (24.6 %) patients with preserved LVEF (LVEF ≥ 50 %).

Statistical analysis. The analysis of the normality of the distribution of indicators was performed using the Shapiro-Wilk test. The data are presented as median (Me) and interquartile range [8] (the distribution of data differed from normal). Quantitative indicators were compared using the non-parametric Mann-Whitney test. If it was necessary to compare the values of the indicator simultaneously in three or more groups, nonparametric one-factor Kruskal-Wallace analysis of variance (for k-groups) was used. The difference among the frequencies of traits in the groups was assessed by Pearson's $\chi 2$ criterion (with Yates' correction when the number of traits was less than 10). The odds ratio (OR) with 95% confidence interval (CI) and the reliability of the frequency distribution were calculated using the $\chi 2$ test with the Mantel-Haenszel correction. The difference between the values was considered statistically significant at a significance level of $p < 0.05$. ROC analysis was used to determine the prognostic levels of serum biomarkers and their correlations. A pairwise comparison of ROC analysis parameters for different values was performed. Statistical processing was performed using Statistica for Windows Release 10.0 and MedCalc® (Statistical Software version 22.020 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2024. SN: CN1WY-V5Q8-CQZC-MSKR-11HM-GVQ1D).

Table 1. Features of the course of heart failure in patients with different phenotypes of the disease (n = 398)

Indicator, units of measurement	Phenotype of CH			χ^2; p
	With reduced LV EJECTION FRACTION (≤ 40 %) (n = 167)	With a moderately reduced LVEF (41 – 49 %) (n = 133)	With preserved LVEF (≥ 50 %) (n = 98)	
1	2	3	4	5
Gender: - women, n (%)	80 (47,9)	70 (52,6)	48 (49,0)	0,693;
- men, n (%)	87 (52,1)	63 (47,4)	50 (51,0)	> 0,05
FC NYHA: II, n (%)	30 (18,0)	54 (40,6)	53 (54,1)	76,773;
III, n (%)	102 (61,1)	79 (59,4)	45 (45,9)	0,0001
IV, n (%)	35 (21,0)	0	0	
Obesity, n (%)	68 (40,7)	39 (29,3)	34 (34,7)	4,233; > 0,05
Pre-obesity, n (%)	87 (52,1)	81 (60,9)	49 (50,0)	3,388; > 0,05
Type 2 diabetes mellitus, n (%)	34 (20,4)	37 (27,8)	31 (31,6)	4,621; > 0,05
AF, n (%)	117 (70,1)	71 (53,4)	38 (38,8)	25,572; 0,0001
RH, n (%)	67 (40,1)	67 (50,4)	45 (45,9)	3,194; > 0,05
Mortality, n (%)	21 (12,6)	2 (1,5)	4 (4,1)	15,851; 0,0001
BNP, pg/ml	90,5 [83,4 – 92,8]	90,5 [80,9 – 90,8]	90,5 [80,5 – 90,8]	> 0,05
NT-proBNP, pg/ml	883,0 [427,5 – 2284,1]	760,0 [320,0 – 1664,0]	760,0 [350,0 – 1357,5]	0,015
ST-2, pg/ml	43,0 [38,3 – 47,3]	41,0 [35,8 – 44,6]	41,2 [37,0 – 44,6]	0,004
Galectin-3, pg/ml	1,9 [1,3 – 2,2]	1,9 [1,5 – 2,2]	1,9 [1,5 – 2,7]	> 0,05
ST-2/ Galectin-3, U	24,3 [17,2 – 34,5]	21,5 [17,7 – 30,8]	21,1 [15,6 – 30,0]	> 0,05
NT-proBNP / BNP, U	9,6 [3,0 – 25,2]	8,7 [3,5 – 18,3]	8,7 [4,2 – 14,3]	> 0,05
NT-proBNP / ST-2, U	21,6 [6,6 – 48,4]	21,2 [7,4 – 37,0]	21,1 [15,6 – 32,0]	> 0,05
NT-proBNP / Galectin-3, U	445,8 [149,1 – 1158,0]	442,8 [224,5 – 954,2]	344,9 [195,9 – 818,6]	> 0,05

RESULTS

The analysis demonstrated that patients with HF with reduced LVEF, compared with patients with moderately reduced and preserved LVEF, had less frequent NYHA class II (18% vs. 40.6% and 54.1%, respectively) and more frequent class IV (21.0%; c2 = 76.77, p = 0.0001), AF (70.1% vs. 53.4% and 38.8%; c2 = 25.57, p = 0.0001), as well as higher one-year mortality (12.0% vs. 1.5% and 4.1%, respectively; c2 = 15.85, p = 0.0001), and approximately the same incidence of HF; higher levels of NT-proBNP (by 16.2 %, p = 0.015) and ST-2 (43.0 [38.3 - 47.3] ng/ml, vs. 41.0 [35.8 - 44.6] ng/ml and 41.2 [37.0 - 44.6] ng/ml, p = 0.004) (Table 1).

The subsequent ROC analysis demonstrated that the RH for HF decompensation risk among patients with reduced LVEF increases with serum levels of NT-proBNP > 843.0 pg/mL (sensitivity - 71.64 %, specificity - 66.00 %, p < 0.0001), galectin-3 > 1.30 ng/mL (sensitivity - 94.03 %, specificity - 37.00 %, p = 0.0001); ratios: ST-2 / Galectin-3 ≤ 16.34 units (sensitivity - 40.30 %, specificity - 96.00 %, p < 0.0001), NT-proBNP / BNP > 10.17 units (sensitivity - 71.64 %, specificity - 70.00 %, p < 0.0001) and NT-proBNP / ST-2 > 21.61 units (sensitivity - 71.64 %, specificity - 66.00 %, p < 0.0001). ROC analysis did not reveal any other plausible patterns in the group of HF patients with reduced LVEF (Table 2).

Comparison of ROC analysis data was carried out at the next stage of work. The value of the NT-proBNP/ BNP ratio has a higher prognostic value for RH in patients with reduced LVEF compared with NT-proBNP (0.707 versus 0.692, respectively; p = 0.0164) (Table 3). The analysis does not reveal any other plausible patterns (see Table 3).

Table 2. Predictive value of serum biomarker levels and their correlations in patients with HF with different disease phenotypes for readmission during the year (ROC analysis)

Indicator, units of measurement	Phenotype of patients with HF (n = 398)		
	With reduced LVEF (≤ 40 %) (n = 167)	With a moderately reduced LVEF (41 – 49 %) (n = 133)	With preserved LVEF (≥ 50 %) (n = 68)
1	2	3	4
BNP, pg/ml			
dividing point (cut-off value)	> 92,8	≥ 86,18	≥ 94,6
area under the curve (AUC [95 % CI])	0,517 [0,439 – 0,595]	0,615 [0,526 – 0,698]	0,506 [0,404 – 0,609]
sensitivity, %.	88,06	49,25	88,89
specificity, %.	27,00	74,24	20,75
P	> 0,05	0,019	> 0,05
NT-proBNP, pg/ml			
dividing point (cut-off value)	> 843,0	> 320,0	> 1456
area under the curve (AUC [95 % CI])	0,692 [0,616 – 0,761]	0,560 [0,472 – 0,646]	0,532 [0,428 – 0,633]
sensitivity, %.	71,64	79,10	91,11
specificity, %.	66,00	36,36	30,19
P	< 0,0001	> 0,05	> 0,05
ST-2, ng/ml			
dividing point (cut-off value)	> 48,58	> 43,04	> 29,23
area under the curve (AUC [95 % CI])	0,500 [0,422 – 0,578]	0,561 [0,473 – 0,647]	0,521 [0,418 – 0,623]
sensitivity, %.	22,39	41,79	95,56
specificity, %.	86,00	78,79	16,98
P	> 0,05	> 0,05	> 0,05
Galectin-3, ng/ml			
dividing point (cut-off value)	> 1,30	> 2,17	> 2,15
area under the curve (AUC [95 % CI])	0,666 [0,589 – 0,737]	0,612 [0,524 – 0,695]	0,662 [0,560 – 0,755]
sensitivity, %.	94,03	44,78	57,78
specificity, %.	37,00	95,45	88,68
P	0,0001	0,0261	0,0047
ST-2/Galectin-3, U			
dividing point (cut-off value)	< 16,34	≤ 17,58	≤ 17,95
area under the curve (AUC [95 % CI])	0,678 [0,601 – 0,748]	0,588 [0,500 – 0,673]	0,644 [0,540 – 0,738]
sensitivity, %.	40,30	37,31	55,56
specificity, %.	96,00	92,42	83,02
P	< 0,0001	> 0,05	0,0126
NT-proBNP / BNP, U			
dividing point (cut-off value)	> 10,17	> 10,17	≤ 18,20
area under the curve (AUC [95% CI])	0,707 [0,631 – 0,774]	0,577 [0,489 – 0,663]	0,519 [0,416 – 0,621]
sensitivity, %.	71,64	50,75	91,11
specificity, %.	70,00	66,67	30,19
P	< 0,0001	> 0,05	> 0,05

Table 2. Cont.

NT-proBNP / ST-2, U dividing point (cut-off value)	> 21,61	> 12,38	≤ 32,86
area under the curve (AUC [95 % CI])	0,693 [0,618 – 0,762]	0,538 [0,449 – 0,624]	0,530 [0,426 – 0,631]
sensitivity, %.	71,64	68,66	88,89
specificity, %.	66,00	43,94	30,19
P	< 0,0001	> 0,05	> 0,05
NT-proBNP / Galectin-3, U dividing point (cut-off value)	> 170,60	> 133,27	≤ 733,97
area under the curve (AUC [95 % CI])	0,570 [0,491 – 0,646]	0,530 [0,442 – 0,617]	0,597 [0,493 – 0,695]
sensitivity, %.	89,55	88,06	86,67
specificity, %.	36,00	25,76	39,62
P	> 0,05	> 0,05	> 0,05

The risk of RH in patients with moderately reduced LV EF increased with a serum level of BNP ≥ 86.18 pg/mL (sensitivity - 49.25%, specificity - 74.24%, p = 0.019), galectin-3 > 2.17 ng/mL (sensitivity - 44.78%, specificity - 95.45%, p = 0.0261) (see Table 2). ROC analysis did not reveal any other plausible patterns in the group of HF patients with moderately reduced LVEF. A comparison of the areas under the ROC curves of BNP and galectin-3 levels did not reveal a difference in the prognostic value of RH in patients with moderately reduced LV EF (z = 0,04; p > 0,05) (Table 4).

In the group of patients with preserved LV EF, the risk of RH increases with a serum level of galectin-3 > 2.15 ng/ml (sensitivity - 57.78 %, specificity - 88.68 %, p = 0.0047) and the ratio of ST-2/Galectin-3 ≤ 17.95 units (sensitivity - 55.56 %, specificity - 83.02 %, p = 0.0126) (see Table 2). A comparison of the areas under the ROC curves of galectin-3 level and ST-2/Galectin-3 ratio did not reveal a difference in the prognostic value of RH in patients with preserved LV EF (z = 0,84; p > 0,05) (Table 5).

DISCUSSION

In the ValHeFT therapeutic trial (Valsartan Heart Failure Trial), BNP and NT-proBNP remained independent predictors of overall death, cardiovascular death, and emergency hospitalization in HF patients with reduced LVEF after adjustment for age, sex, comorbidities, and biochemical parameters [8]. In the I-PRESERVE study, an increase in circulating NT-proBNP in HF patients with preserved LVEF was a predictor of fatal clinical outcomes and rehospitalization [8]. Another study also demonstrated that plasma BNP >100 pg/mL and NT-proBNP >600 pg/mL were independent predictors of LV diastolic dysfunction [9]. In AF and DM, the concentrations of the above biomarkers increase dramatically [8]. In AF, these changes are associated with more severe ischemia and biomechanical myocardial stress [8]. In diabetes mellitus, a decrease in glomerular filtration rate (GFR) and enzymatic degradation by neprilysin, as well as biomechanical myocardial stress and volume overload are likely to be important [8]. Previous preclinical and clinical studies have demonstrated the central role of galectin-3 in the progression of extracellular remodeling and extracellular matrix accumulation, which promotes fibrosis and impaired global myocardial contractility and relaxation, accompanied by increased arrhythmogenic activity and dilatation of the heart cavities [1, 10-16]. Increased expression of galectin-3 is detected in acute/acutely decompensated and chronic HF regardless of its phenotype and etiology [17]. In HF, the concentration of galectin-3 in the peripheral blood correlates positively with the level of NT-proBNP and negatively with GFR [10].

Although the expression of galectin-3 increases in proportion to the severity of HF, the diagnostic value of NTpro-BNP was better than that of galectin-3 [18]. On the contrary, the prognostic value of GH in the progression of HF for galectin-3 was higher than that of NT-pro-BNP [18]. Other authors have noted that the combination of NTpro-BNP and galectin-3 in patients with HF more accurately reflects the risk of fatal events than each of these biomarkers alone [19]. In patients with a positive response to HF treatment, no significant dynamics of galectin-3 in the blood was found, whereas the concentration of NT-pro-BNP significantly decreased [19]. Compared to other biological markers, including BNP, galectin-3, and growth/differentiation factor-15, ST2 is characterized by the lowest biological variability

Table 3. Comparison of the prognostic value of serum levels of biomarkers and their correlations in patients with HF with reduced LV ejection fraction, relative to re-hospitalization (ROC curves)

Indicator, units of measurement	Area under the curve (AUC)	Difference in area	z	p
NT-proBNP, pg/ml	0,692 [0,616 – 0,761]	0,025 [0,084 – 0,135]	0,45	> 0,05
Galectin-3, ng/ml	0,666 [0,589 – 0,737]			
NT-proBNP, pg/ml	0,692 [0,616 – 0,761]	0,014 [0,094 – 0,122]	0,25	> 0,05
ST-2/Galectin-3, U	0,678 [0,601 – 0,748]			
NT-proBNP, pg/ml	0,692 [0,616 – 0,761]	0,015 [0,003 – 0,027]	2,40	0,0164
NT-proBNP / BNP, U	0,707 [0,631 – 0,774]			
NT-proBNP, pg/ml	0,692 [0,616 – 0,761]	0,002 [0,010 – 0,013]	0,32	> 0,05
NT-proBNP/ST-2, U	0,693 [0,618 – 0,762]			
Galectin-3, ng/ml	0,666 [0,589 – 0,737]	0,011 [0,024 – 0,064]	0,63	> 0,05
ST-2/Galectin-3, U	0,678 [0,601 – 0,748]			
Galectin-3, ng/ml	0,666 [0,589 – 0,737]	0,040 [0,070 – 0,150]	0,72	> 0,05
NT-proBNP / BNP, U	0,707 [0,631 – 0,774]			
Galectin-3, ng/ml	0,666 [0,589 – 0,737]	0,027 [0,082 – 0,137]	0,49	> 0,05
NT-proBNP/ST-2, U	0,693 [0,618 – 0,762]			
ST-2/Galectin-3, U	0,678 [0,601 – 0,748]	0,029 [0,080 – 0,137]	0,52	> 0,05
NT-proBNP / BNP, U	0,707 [0,631 – 0,774]			
ST-2/Galectin-3, U	0,678 [0,601 – 0,748]	0,016 [0,091 – 0,123]	0,29	> 0,05
NT-proBNP/ST-2, U	0,693 [0,618 – 0,762]			
NT-proBNP / BNP, U	0,707 [0,631 – 0,774]	0,013 [0,004 – 0,030]	1,54	> 0,05
NT-proBNP/ST-2, U	0,693 [0,618 – 0,762]			

Table 4. Comparison of the prognostic value of serum levels of biomarkers in patients with HF with moderately reduced LV EF, relative to re-hospitalization (ROC curves)

Indicator, units of measurement	Area under the curve (AUC)	Difference in area	z	P
BNP, pg/ml	0,615 [0,526 – 0,698]	0,002 [0,121 – 0,126]	0,04	> 0,05
Galectin-3, ng/m	0,612 [0,524 – 0,695]			

Table 5. Comparison of the prognostic value of serum biomarker levels and their correlations in patients with HF with preserved LV EF, relative to re-hospitalization (ROC curves)

Indicator, units of measurement	Area under the curve (AUC)	Difference in area	z	P
Galectin-3, ng/m	0,662 [0,560 – 0,755]	0,019 [0,025 – 0,063]	0,84	> 0,05
ST-2/Galectin-3, U	0,644 [0,540 – 0,738]			

[20]. The content of sST2 above 35 ng/mL retains its prognostic value for total death, cardiovascular death, and the risk of hospitalization due to HF, regardless of the etiology and phenotype of HF and CHF [20].

CONCLUSIONS

1. In patients with heart failure with reduced left ventricular ejection fraction, compared with patients with moderately reduced and preserved left ventricular ejection fraction, are more likely to be diagnosed with NYHA class IV and atrial fibrillation; higher one-year mortality. Approximately the same incidence of re-hospitalization; higher levels of NT-proBNP and ST-2. The ratio of NT-proBNP/BNP > 10.17 units has a higher prognostic value compared to NT-proBNP for re-hospitalization.
2. The risk of re-hospitalization in patients with moderately reduced left ventricular ejection fraction is equally increased at levels of BNP ≥ 86.18 pg/mL and galectin-3 > 2.17 ng/mL. With preserved left ventricular ejection fraction, the risk of re-hospitalization increases with galectin-3 levels > 2.15 ng/mL or an ST-2/Galectin-3 ratio ≤ 17.95 units.

REFERENCES

1. McMurray JJ, Trueman D, Hancock E et al. Cost-effectiveness of sacubitril/valsartan in the treatment of heart failure with reduced ejection fraction. Heart. 2018;104:1006-1013. doi:10.1136/heartjnl-2016-310661. DOI
2. Robertson RW, Howard K, Meisberger E et al. Successful pharmacist intervention to optimize guideline-directed medical therapy in heart failure patients. Journal of the American College of Cardiology. 2020;75(11):958. doi:10.1016/S0735-1097(20)31585-0. DOI
3. Berezin EA. Perspektyvni napryamky medykamentoznoho likuvannya hostroyi ta khronichnoyi sertsevoyi nedostatnosti Sertseva nedostatnist' ta suputni zakhvoryuvannya. [Perspective directions of drug treatment of acute and chronic heart failure Heart failure and comorbid conditions]. 2018. https://www.researchgate.net/publication/324678758_Perspektivnye_napravlenia_medikamentoznogo_lecenia_ostroj_i_hroniceskoj_serdecnoj_nedostatocnosti (Ukrainian)
4. McDonagh TA, Metra M, Adamo M et al. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) With the special contribution of the Heart Failure Association (HFA) of the ESC. European Heart Journal 2021; 42: 3599-3726. doi:10.1093/eurheartj/ehab368. DOI
5. Voronkov LG, Lyashenko AV, Tkach NA, Paraschenyuk LP Chronic heart failure as a multimorbid condition. Ukrainian Journal of Cardiology. 2019;26(4):90-101. doi:10.31928/1608-635X-2019.4.90101. DOI
6. Petyunina OV, Kopytsia MP, Vyshnevska IR. Biomarker ST2 pry sertsevo-sudynniy patolohiyi. [Biomarker ST2 in cardiovascular pathology]. Ukrayins'kyy medychnyy zhurnal. 2018;2(124):III/IV. doi:10.32471/umj.1680-3051.124.125212. (Ukrainian) DOI
7. Berezin AE. Up-to-date clinical approaches of biomarkers' use in heart failure. Biomed Res Ther. 2017;4(6):1341-1370. doi:10.15419/bmrat.v4i06.178. DOI
8. Masson S, Latini R, Anand IS et al. Direct comparison of B-type natriuretic peptide (BNP) and aminoterminal proBNP in a large population of patients with chronic and symptomatic heart failure: the Valsartan Heart Failure (Val-HeFT) Data. Clin Chem. 2006;52:1528–38. doi:10.1373/clinchem.2006.069575. DOI
9. Kraigher-Krainer E, Shah AM, Gupta DK et al. Impaired systolic function by strain imaging in heart failure with preserved ejection fraction. J Am Coll Cardiol. 2014;63:447–56. doi:10.1016/j.jacc.2013.09.052. DOI
10. Billebeau G, Vodovar N, Sadoune M et al. Effects of a cardiac rehabilitation programme on plasma cardiac biomarkers in patients with chronic heart failure. Eur J Prev Cardiol. 2017. doi:10.1177/2047487317705488. DOI
11. Berezin A, Kremzer A, Samura T et al. The utility of biomarker risk prediction score in patients with chronic heart failure. Eur Heart J. 2015;36(1):509-47.
12. Kovalyova ON. Semantychnyy analiz ta klinichne znachennya komorbidnosti ta mul'tymorbidnosti. [Semantic analysis and clinical importance of comorbidity and multimorbidity]. Ukrayins'kyy terapevtychnyy zhurnal. 2019;2:79-86. doi: 10.30978/UTJ2019-2-79. DOI
13. Chow SL, Maisel AS, Anand I et al. Role of Biomarkers for the Prevention, Assessment, and Management of Heart Failure: A Scientific Statement From the American Heart Association. Circulation. 2017. doi: 10.1161/CIR.0000000000000490. DOI
14. O'Donoghue M, Chen A, Baggish AI et al. The effects of ejection fraction on N-terminal ProBNP and BNP levels in patients with acute CHF: analysis from the ProBNP investigation of dyspnea in the emergency department (PRIDE) study. J Card Fail. 2005;11(5):S9–14. doi: 10.1016/j.cardfail.2005.04.011. DOI
15. Pyvovar SM, Rudyk IS, Lozyk TV et al. The effect of beta-blockers on a course of chronic heart failure in patients with a low triiodothyronine syndrome. Wiad Lek. 2020;73(7):1402-1409. doi: 10.36740/wlek202007118. DOI
16. Seferović PM, Jankowska E, Coats AJ et al. The Heart Failure Association Atlas: rationale, objectives, and methods. Eur J Heart Fail. 2020;22(4):638-645. doi: 10.1002/ejhf.1768. DOI
17. Boulogne M, Sadoune M, Launay JM et al. Inflammation versus mechanical stretch biomarkers over time in acutely decompensated heart failure with reduced ejection fraction. Int J Cardiol. 2017;226:53-59. doi: 10.1016/j.ijcard.2016.10.038. DOI
18. Karayannis G, Triposkiadis F, Skoularigis J et al. The emerging role of Galectin-3 and ST2 in heart failure: practical considerations and pitfalls using novel biomarkers. Curr. Heart Fail. Rep. 2013;10:441-9. doi: 10.1007/s11897-013-0169-1. DOI
19. Ahmad T, Fiuzat M, Pencina MJ et al. Charting a roadmap for heart failure biomarker studies. JACC Heart Fail. 2014;2:477-88. doi: 10.1016/j.jchf.2014.02.005. DOI
20. Tang WH, Wu Y, Grodin JL et al. Prognostic Value of Baseline and Changes in Circulating Soluble ST2 Levels and the Effects of Nesiritide in Acute Decompensated Heart Failure. JACC Heart Fail. 2016;4:68-77. doi: 10.1016/j.jchf.2015.07.015. DOI

CONFLICT OF INTEREST

The Authors declare no conflict of interest

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