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Clinical presentations and hemodynamic parameters in patients hospitalized due to acute heart failure stratified by the left-ventricular ejection fraction

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ABSTRACT

Background: Currently, one of the most common causes of hospitalization, especially in the elderly, is heart failure (HF) exacerbation. In nearly 95% of patients, this is caused by fluid overload. There have been studies comparing the rates of comorbidities and biochemical disturbances in HF patients; however, their hemodynamic parameters have not yet been assessed. Thus, the aim of this study was to compare the clinical presentations and hemodynamic parameters assessed via impedance cardiography (ICG) in patients hospitalized due to acute HF, stratified by the left-ventricular ejection fraction (LVEF).

Methods: This study enrolled 102 patients, aged > 18 years, hospitalized due to decompensated HF. Ninety-seven patients (74 men, 23 women) underwent echocardiographic examination. Biochemical and hemodynamic parameters were assessed on the day of admission and, subsequently, every other day during hospitalization. Based on echocardiographic findings and the ESC guidelines the study group was divided into the following subgroups: HFrEF (EF < 40%), HFpEF (EF > 50%), and HFmrEF (EF 40–49%).

Results: The HFrEF group, which constituted 60.8% of patients (n = 58), was predominantly male (P = 0.0005); and most had elevated N-terminal pro-brain natriuretic peptide levels (P = 0.0008). The HFpEF and HFmrEF subgroups, jointly (n = 38), were characterized by higher systolic blood pressure (P = 0.0001), and lower hemoglobin levels (P = 0.003). The hemodynamic assessment showed that HFrEF patients had higher total fluid content (P = 0.005) and lower systolic time ratio (P = 0.0002).

Conclusions: Despite similar clinical presentation, patients with HF exhibited different values of hemodynamic and biochemical parameters depending on their LVEF; this indicates non-homogeneity of pathomechanisms and causes of HF decompensation.

Key words: heart failure, acute heart failure, hemodynamic parameters, impedance cardiography, left-ventricular ejection fraction

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Introduction

Diagnostics and treatment of acute heart failure (AHF) are one of the key problems in intensive cardiac care [1]. The prognosis remains poor, with in-hospital mortality of 4.1–13.9% [2–6]. The current European Society of Cardiology (ESC) guidelines emphasize the need for urgent AHF management [2, 7]. In order to be effective, management should be based on detailed clinical assessment, aiming to identify the key mechanism of cardiovascular decompensation [8]. Whereas most patients with heart failure (HF) and left-ventricular ejection fraction (LVEF) < 40% (i.e. HF with reduced ejection fraction, HFrEF) exhibit evidence of fluid accumulation and fluid redistribution to the lungs, which leads to pulmonary congestion, those with HF with mid-range (mildly reduced) ejection fraction (HFmrEF) and HF with preserved ejection fraction (HFpEF) typically

show more diverse pathomechanisms [9–13]. The latter two subgroups (HFmrEF and HFpEF) constitute an increasing proportion of patients with AHF [14,15,16]. These patients are typically elderly, often with concomitant diabetes mellitus, hypertension, atrial fibrillation, and/or obesity [17, 18]. Their treatment may, therefore, present more challenges, as recommendations for their management are based mainly on expert opinions.

Thus, it is useful to search for diagnostic methods that would provide additional data compared to that obtained from routine assessments, while at the same time being simple enough to be used in intensive-care settings. These conditions seem to be met by impedance cardiography (ICG), a simple, non-invasive method of assessing the hemodynamic parameters that reflect the cardiac function as a pump (including cardiac index (CI), stroke index (SI), systemic vascular resistance index (SVRI)) and thoracic fluid content (TFC) [19].

Therefore, the aim of this study was to compare clinical presentations between subgroups of patients hospitalized for AHF stratified by LVEF, with a particular emphasis on their hemodynamic profiles.

Methods

This prospective, observational study enrolled patients of both sexes, aged > 18 years, who were admitted to the Department of Cardiology and Internal Diseases due to decompensated HF (defined based on ESC guidelines) in the period between November 2014 and March 2017 and required intravenous diuretic treatment.

Exclusion criteria were: 1) unstable angina; 2) history of acute coronary syndrome (ACS) within the last 12 weeks and/or coronary artery bypass grafting (CABG) surgery within the last 12 weeks; 3) cardiac resynchronization therapy (CRT) introduced within the last year (or planned CRT implantation within the next 24 months); 4) non-cardiogenic shock; 5) valvular disease or other acquired heart defects requiring surgical intervention; 6) hypertrophic cardiomyopathy; 7) severe pulmonary hypertension or other severe lung condition (severe form of chronic obstructive pulmonary disease (COPD) or bronchial asthma); 8) poorly controlled hypertension; 9) anaemia (haemoglobin < 10.0 g/dL); 10) acute and/or decompensated non-cardiovascular disease; 11) end-stage CKD and/or ongoing hemodialysis therapy; 12) severe or chronic inflammatory disease, severe infection (including febrile conditions, radiologically-confirmed pneumonia, suspected septic shock); 13) neoplastic disease; 14) severe psychiatric disorder; 15) the lack of informed consent.

The study protocol was approved by the Military Institute of Medicine Institutional Review Board (approval No. 14/WIM/2012), and all study participants provided their written informed consent. This study was registered at ClinicalTrials.gov (NCT 02355769).

Clinical examinations were conducted with a particular emphasis on the history of symptoms, concomitant diseases, and current medication. The following were measured on physical examination: heart rate (HR), office systolic blood pressure (SBP), office diastolic blood pressure (DBP), and basic body parameters.

Laboratory tests were conducted on fasting peripheral venous blood samples, collected in the morning (7:30–8:30 a.m.). The following hematological and biochemical parameters were measured: hematocrit, as well as hemoglobin, urea, creatinine, N-terminal pro-brain natriuretic peptide (NTproBNP), high-sensitivity troponin T (hsTnT) levels. The estimated glomerular filtration rate (eGFR) was estimated based on the Modification of Diet in Renal Disease (MDRD) study equation [20].

Echocardiographic examinations were conducted with Vivid S6 (GE-Healthcare, USA) and Vivid 7 (GE-Healthcare, USA) ultrasound systems and evaluated cardiac chamber dimensions, left ventricular wall thickness and contractility, ejection fraction with the biplane Simpson's method, as well as valvular structure and function. Echocardiography reports included any moderate-to-severe mitral, tricuspid, and/or aortic regurgitation; severe aortic stenosis; as well as the numerical values of the following parameters: left ventricular end-diastolic diameter (LVEDD), right ventricular end-diastolic diameter (RVEDD), interventricular septum (IVS), left atrial (LA) diameter, measured in the parasternal long-axis view.

Impedance cardiography (ICG). All ICG measurements were performed with the Niccomo™ device (Medis, Germany) within 24 hours of admission, after 10 minutes of rest in a sitting position. Data was recorded during a 10-minute assessment and exported to the dedicated software (Niccomo Software). The final analysis included mean values of hemodynamic parameters, such as: TFC [1/kOhm], calculated from basic impedance (Z0) as its reciprocal: TFC = 1000/Z0; SI, calculated using the Sramek and Bernstein formula for stroke volume (SV) = $VEPT \times dZ_{max} \times LVET/Z0$ and indexed to body surface area to yield SI [mL/m^2]; CI [$(mL/min)/m^2$], calculated as SI×HR; acceleration index (ACI [$1/100*Ohm/s^2$]), expressing the maximum acceleration of blood in the aorta from the moment the aortic valve opens; velocity index (VI [1/1000*Ohm/s] expressing the maximum velocity of blood in the aorta from the moment the aortic valve opens; Heather index (HI [$Ohm*s^2$]), characterizing the maximum contraction force of the left ventricle, corresponding to cardiac inotropism; SVRI [$(dyn \times s)/cm^5/m^2$)], calculated as 80×(MBP–CVP)/CI, where CVP is central venous pressure (with an assumed value of 6 mm Hg).

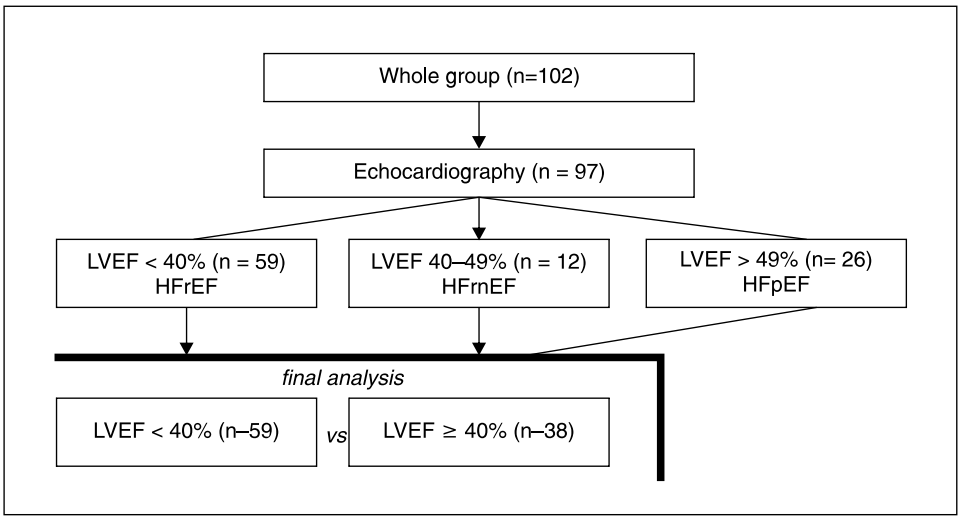

Figure 1. Analysis assumptions — compared subgroups (HFrEF — heart failure with reduced left ventricular ejection fraction; HRmrEF — heart failure with mid-range left ventricular ejection fraction; HFpEF — heart failure with preserved left ventricular ejection fraction, LVEF — left ventricular ejection fraction)

Statistical analysis. The statistical analysis of data was conducted with the use of MS Office Excel 2013 and Statistica 12.0 (StatSoft Inc.). Data distribution was presented on histograms and evaluated visually. The results for qualitative variables were expressed as numbers and percentages; while continuous (quantitative) variables were expressed as means ± standard deviation (SD). For a comparative analysis, the study group was divided into two subgroups: patients with LVEF < 40% (n = 59) and LVEF ≥40% (n = 38) (Figure 1).

Results

Clinical characteristics

The subgroup with LVEF < 40% comprised predominantly men with ischemic HF etiology. These patients were younger than those in the LVEF ≥ 40% subgroup (Table 1). Nonetheless, the two groups showed no significant differences in terms of the New York Heart Association (NYHA) functional class, rates of dyspnea, or a history of edema, or pathological weight gain. Physical examination of patients with higher LVEF showed higher blood pressure values, higher rates of peripheral edema, and lower rates of peripheral hypoperfusion. The subgroups differed only slightly in terms of medication, with higher rates of angiotensin-converting enzyme (ACE) inhibitors in the LVEF ≥ 40% subgroup.

The echocardiographic examination showed the mean LVEF value in the study population of 37.3 ± 14.1%, LVEDD of 59.2 ± 10.2 mm, RVEDD of 35.3 ± 5.7 mm, and LA dimeter of 47.3 ± 0.60 mm. In comparison, patients with LVEF < 40% had larger cardiac chamber dimensions, higher rates of moderate/severe mitral regurgitation, with lower rates of moderate/severe aortic stenosis (Table 2).

The mean NT-proBNP level in the LVEF < 40% subgroup was significantly higher than that in the subgroup with better LVEF (Table 3). There was a significant correlation between LVEF values and NT-proBNP levels (R = -0.38; P < 0.0001). At the same time, patients with LVEF ≥ 40% had significantly lower hemoglobin levels and hematocrit values, with comparable markers of renal function.

The two compared subgroups differed significantly in terms of hemodynamic profiles. Patients with LVEF < 40% exhibited lower SBP values, lower values of cardiac function as a pump (SI, CI, HI, ACI, VI), higher TFC, and a less favourable ratio of pre-ejection period (PEP) to left ventricular ejection time (LVET) (Table 4, Fig. 2). These differences were confirmed when we assessed the correlation of these parameters with LVEF.

Discussion

our findings demonstrated that the clinical presentation of decompensated HFrEF differs from that of HFmrEF/HFpEF. Our observations regarding age differences, sex distribution, HF etiology, echocardiographic findings, and comorbidities are essentially consistent with those presented in earlier reports. Impedance cardiography proved to significantly differentiate patients from the two evaluated subgroups. Patients with higher

Table 1. The comparison between patients with LVEF < 40% and LVEF ≥ 40% — patients characteristics

	LVEF < 40% N = 59	LVEF ≥ 40% N = 38	P	Whole group N = 97
	n (%)/ mean ± SD			
Age, mean ± SD	68.1 ± 13.2	76.7 ± 9.5	0.0005	71.5 ± 12.6
Male, mean ± SD	50 (84.8)	24 (63.2)	0.015	74 (76.3)
NYHA class				
Mean class NYHA [-], mean ± SD	3.32 ± 0.57	3.32 ± 0.52	0.897	3.32 ± 0.55
class III, n (%)	37 (62.7)	25 (65.8)	0.773	62 (63.9)
class IV, n (%)	22 (67.3)	13 (34.2)	0.773	35 (36.1)
HF de novo, n (%)	16 (27.1)	10 (26.3)	0.931	26 (26.8)
Ischemic etiology, n (%)	41 (69.5)	21 (55.3)	0.003	62 (63.9)
CLINICAL EXAMINATION				
Dyspnea at rest, n (%)	26 (44.1)	15 (39.5)	0.655	41 (42.3)
Dyspnea on effort, n (%)	58 (98.3)	38 (100.0)	0.420	96 (99.0)
Orthopnoe, n (%)	45 (77.6)	30 (79.0)	0.875	75 (77.3)
Edema, n (%)	44 (74.6)	31 (81.6)	0.421	75 (77,.3)
Pathological weight gain, n (%)	23 (39.0)	14 (36.8)	0.832	37 (38.1)
PHYSICAL EXAMINATION				
HR [bpm], mean ± SD	89.4 ± 25.3	82.3 ± 20.1	0.220	86.6 ± 23.5
SBP [mmHg], mean ± SD	127.3 ± 25.6	147.2 ± 27.0	0.0001	135.1 ± 27.2
DBP [mmHg], mean ± SD	80.2 ± 12.8	83.3 ± 12.8	0.282	81.4 ± 13.5
BMI [m^2/kg], mean (SD)	28.9 ± 5.8	31.5 ± 6.9	0.094	29.9 ± 6.3
Hypertension (SBP > 140mmHg, DBP >90mmHg), n (%)	6 (10.2)	19 (50.0)	0.00006	25 (25.8)
Hypotension (SBP < 90mmHg), n (%)	3 (5.1)	2 (5.3)	ns	5 (5.2)
Tachypnoe, n (%)	14 (23.7)	6 (15.8)	0.345	20 (20.6)
Rales, n (%)	58 (98.3)	38 (100.0)	0.783	96 (99.0)
Edema, n (%)	40 (67.8)	34 (89.5)	0.014	74 (76.3)
Peripheral hipoperfusion, n (%)	9 (15.3)	1 (2.6)	0.046	10 (10.3)
CONCOMITANT DISEASE				
Prior MI, n (%)	32 (54.2)	10 (26.3)	0.007	42 (43.3)
Hypertension, n (%)	34 (57.6)	30 (79.0)	0.031	64 (66.0)
Atrial fibrillation, n (%)	29 (49.2)	22 (57.9)	0.400	51 (52.6)
Moderate-to-severe valvular disease, n (%)	18 (30.5)	15 (39.5)	0.477	33 (34.0)
Procedure: ICD, n (%)	10 (17.0)	0 (0.0)	0.040	10 (10.3)
Procedure: CRT, n (%)	5 (8.5)	1 (2.6)	0.040	6 (6.2)
Diabetes mellitus, n (%)	29 (49.2)	19 (50.0)	0.935	48 (49.5)
COPD, n (%)	10 (17.0)	5 (13.2)	0.614	15 (15.5)
CKD (stadium ≥ 3), n (%)	16 (27.6)	12 (31.6)	0.674	28 (28.9)
MEDICATION USE BEFORE HOSPITALIZATION (available for 95)				
ACE-I, n (%)	30 (52.6)	28 (73.7)	0.039	58 (61.1)
ARB, n (%)	5 (8.8)	5 (13.2)	0.495	10 (10.5)
B blocker, n (%)	41 (71.9)	33 (86.8)	0,086	74 (77.9)
Aldosterone antagonists, n (%)	22 (38.6)	9 (23.7)	0.129	31 (32.6)
Diuretics, n (%)	40 (70.2)	29 (76.3)	0.511	69 (72.6)
Iwabradine, n (%)	0 (0.0)	2 (5.3)	0.080	2 (2.1)
Digoxin, n (%)	3 (5.3)	3 (7.9)	0.605	6 (6.3)
Amiodarone, n (%)	10 (17.5)	3 (7.9)	0.180	13 (13.7)

ACE-I — angiotensin-converting-enzyme inhibitors; ARB — angiotensin II receptor blockers; BMI — body mass índex; CKD — chronic kidney disease; COPD — chronic obstructive pulmonary disease; CRT — cardiac resynchronization therapy; DBP — diastolic blood pressure; HR — heart rate; ICD — implantable cardioverter defibrillator; MRA — mineralocorticoid receptor antagonista; NYHA — New York Heart Association; SBP — systolic blood pressure

Table 2. The comparison between patients with LVEF < 40% and LVEF ≥ 40% — echocardiography

	LVEF < 40% N = 59	LVEF ≥ 40% n=38	p
	n (%)/ mean ± SD		
LVEDD [mm], mean ± SD	65.0 ± 8.4	51.4 ± 6.6	0.000001
RVEDD [mm], mean ± SD	36.4 ± 6.2	33.7 ± 4.6	0.081
LA [mm], mean ± SD	48.7 ± 5.2	45.6 ± 6.7	0.015
LVEF [%], mean ± SD	27.7 ± 6.5	52.2 ± 8.3	0.000001
MR[85], n (%)	32 (65.3)	14 (38.9)	0.016
AS[85], n (%)	2 (4.1)	7 (19.4)	0.023
AR[85], n (%)	0 (0.0)	2 (5.6)	0.095
TR[85], n (%)	19 (38.8)	15 (41.7)	0.707

Upper index — number of subjects with sufficient valve assessment; AR — aortic regurgitation; AS — aortic stenosis; LA — left atrium; LVEDD — left ventricle end-diastolic dimension; RVEDD — right ventricle end-diastolic dimension; LVEF — left ventricle ejection fraction; MR — mitral regurgitation; TR — tricuspid regurgitation

Table 3. The comparison between patients with LVEF < 40% and LVEF ≥ 40% — laboratory data on admission

	LVEF < 40% N = 59	LVEF ≥ 40% N = 38	p	Whole group N = 97
	mean ± SD			
Creatinine [mg/dl], mean ± SD	1.36 ± 0.49	1.24 ± 0.55	0.148	1.31 ± 0.51
eGFR MDRD [ml/min/1.73 m^2], mean ± SD	61.5 ± 24.2	63.2 ± 23.0	0.644	62.2 ± 23.6
Urea [mg/dl], mean ± SD	55.8 ± 29.4	51.6 ± 21.6	0.615	54.2 ± 26.6
NT-proBNP [pg/ml], mean ± SD	7991 ± 8463	3453 ± 3031	0.0008	6213 ± 7195
hsTnT [ng/l], mean ± SD	124.5 ± 292.2	79.2 ± 212.2	0.219	106.9 ± 263.4
Hb [g/dl], mean ± SD	13.1 ± 2.0	11.8 ± 2.4	0.003	12.6 ± 2.3
Hematocrit [%], mean ± SD	39.8 ± 5.7	36.4 ± 6.6	0,003	38.5 ± 6.2

eGFR — estimated glomerular filtration rate; Hgb — hemoglobina; hsTnT — high-sensitive cardiac troponin T; NTproBNP — N-terminal fragment of the prohormone brain-type natriuretic peptide

LVEF seemed to have less pronounced abnormalities in their hemodynamic profile, with higher values of parameters indicating cardiac function as a pump and lower TFC. However, it is worth noting that the symptoms reported by patients with HFmrEF/HFpEF were not any less pronounced than those reported by patients with LVEF < 40%.

Although, the whole study group was predominantly male, the proportion of men was noticeably lower in the HFmrEF/HFpEF subgroup. Data from AHF registries show the proportion of women in this subgroup to range from 53% to 72.4% [21–24].

The patients from the HFmrEF/HFpEF subgroup were older and had higher rates of concomitant chronic conditions and lower rates of post-infarct HF etiology [21]. Patients with HFrEF are known to have higher rates of coronary artery disease, while those with HFpEF have higher rates of atrial fibrillation, hypertension, and anaemia [6, 17, 18, 25]. Particularly interesting were our findings on anaemia, which are consistent with earlier reports on higher rates of this condition in HFpEF [26, 27]. Our findings regarding the rates of chronic kidney disease (CKD) being comparable in both subgroups were also consistent to those reported in many registries [23, 28–31]. However, Bishu et al. [27], who assessed renal function based on cystatin C levels, demonstrated higher rates of CKD in patients with HFmrEF/HFpEF, which was most likely due to the selected diagnostic marker, as cystatin C is highly sensitive [32, 33–36]. Quiroz et al. made similar observations, finding higher admission creatinine levels in patients with LVEF > 50% [21].

In our study, the two subgroups differed the most in terms of the rates of hypertension, with as many as 50% of HFmrEF/HFpEF patients presenting with a blood pressure of over 140/90 mmHg. This is consistent with earlier reports [6, 27, 37] and may be responsible for the higher rates of renin-angiotensin-aldosterone system (RAAS) inhibitors in the subgroup with LVEF ≥ 40%, although some reports have indicated higher rates of calcium-channel blockers and alpha-blockers, rather

Table 4. The comparison between patients with LVEF < 40% and LVEF ≥ 40% — impedance cardiography

	LVEF < 40% N = 59	LVEF ≥ 40% N = 38	p	LVEF vs.	
	n (%)/ mean ± SD			R	P
IMPEDANCE CARDIOGRAPHY					
HR [bpm], mean ± SD	83.8 ± 22.8	77.7 ± 20.1	0.188	-0.03	0.784
SBP [mmHg], mean ± SD	114.6 ± 16.9	136.1 ± 29.5	0.0002	0.38	0.0001
DBP [mmHg], mean ± SD	73.7 ± 11.5	72.2 ± 12.0	0.418	-0.04	0.718
SI [ml*m^{-2}], mean ± SD	36.0 ± 10.4	44.4 ± 13.7	0.004	0.30	0.005
CI [ml*m^{-2}*min^{-1}], mean ± SD	2.86 ± 078	3.12 ± 0,80	0.208	0.24	0.026
HI [Ω•s^{-2}], mean ± SD	7.82 ± 4.77	12.0 ± 6.75	0,002	0,38	0.0003
ACI [1*100^{-1}*s^{-2}], mean ± SD	59.6 ± 23.3	77.1 ± 39.1	0.051	0.25	0.022
VI [1*1000^{-1}*s^{-1}], mean ± SD	38.2 ± 15.7	48.1 ± 25.5	0.120	0.22	0.047
SVRI [dyn*s*cm^{-5}*m^2], mean ± SD	2424 ± 733	2292 ± 802	0.457	-0.17	0.131
TFC [1*kOhm^{-1}], mean ± SD	37.4 ± 8.2	33.7 ± 6.5	0.009	-0.28	0.005
STR [%], mean ± SD	0.54 ± 0.33	0.36 ± 0,13	0.001	-0.38	0.0002
PEP [ms], mean ± SD	137.5 ± 62.1	103.2 ± 34.0	0.003	-0.38	0.0002
LVET [ms], mean ± SD	272.5 ± 47.7	303.1 ± 62.8	0.018	0.18	0.100
SI < 35 ml/m2, n (%)	23 (38.9)	8 (21.1)	0.041	-	-
TFC > 35 kOhm, n (%)	34 (57.6)	12 (31.6)	0.012	-	-

ACI — acceleration time índex; CI — cardiac índex; DBP — diastolic blood pressure; HI — Heather índex; HR — heart rate; LVET — left ventricular ejection time; PEP — pre-ejection period; SBP — systolic blood pressure; STR — systolic time ratio; SVRI — systemic vascular resistance índex; TFC — thoracic fluid contente; SI — stroke índex; VI — velocity index

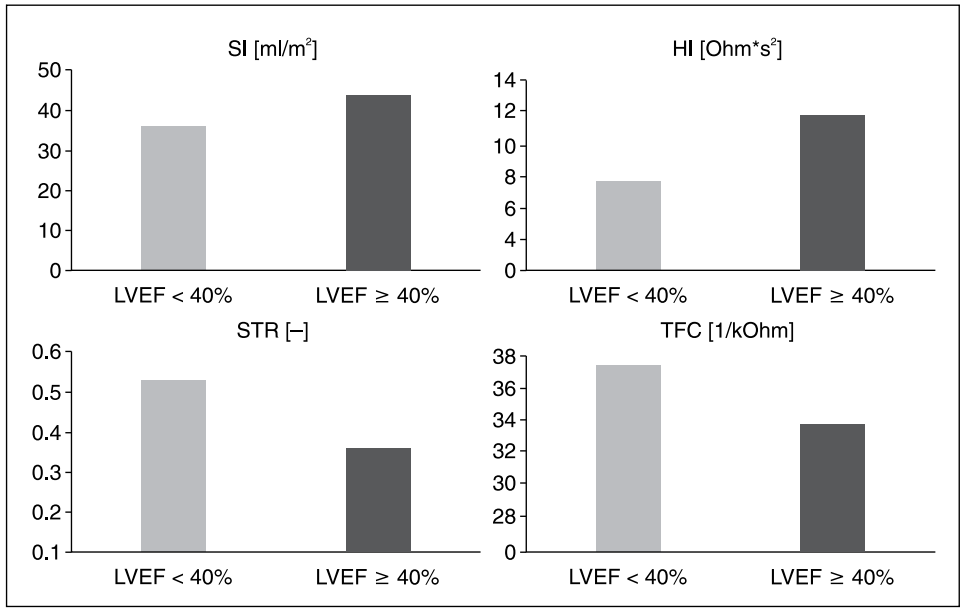

Figure 2. The comparison of hemodynamic parameters between patients with LVEF < 40% and LVEF ≥ 40%

than RAAS inhibitors, in patients with HFpEF [24, 27]. The lower rates of RAAS inhibitor use in patients with HFrEF may have been due to the higher rates of objective clinical contraindications (e.g. hypotension, renal dysfunction, hyperkalemia) in this group.

Our findings demonstrated that, in comparison with patients with HFrEF, patients with HFmrEF/HFpEF had lower natriuretic peptide levels [38–40], which could indicate a lower myocardial load in the latter subgroup. However, the fact that the HFmrEF/HFpEF subgroup

had higher rates of obesity may have also played a role, as low levels of natriuretic peptides may be due to increased natriuretic peptide absorption by adipocytes [41] as well as their reduced production as part of disrupted hormonal metabolism in the obese [42].

Impedance cardiography assessments revealed significant differences in hemodynamic profiles between the study subgroups stratified by LVEF. To our knowledge, this is the first report of this kind. Our findings demonstrated low LVEF to be reflected by lower ICG parameters of cardiac function as a pump (SI, CI, HI, ACI, VI). The values of these parameters in the HFrEF subgroup were comparable to those presented in earlier reports. Kaszuba et al. demonstrated a relationship between the ejection fraction and PEP, LVET, and STR, although that particular study included patients with no manifestations of HF exacerbation [43]. On the other hand, the hemodynamic profile of left ventricular function in the HFmrEF/HFpEF subgroup more closely resembled that in patients with uncomplicated hypertension. Studies evaluating hemodynamic parameters in hypertensive patients showed that even diastolic dysfunction alone was reflected in lower values of SI, VI, ACI, and HI as well as a higher SVRI [44, 45].

It seemed advisable to compare the subgroups also in terms of TFC, a parameter useful in differentiating the causes of dyspnea and assessing pulmonary congestion [46, 47]. We found that, although the rates of patients with elevated TFC were considerable in both subgroups, they were noticeably higher in patients with HFrEF (57.6 vs. 31.6%). Only one in three patients with HFmrEF exhibited marked pulmonary congestion. This indicates that diuretic treatment in this subgroup may not always be as effective as expected.

Our findings clearly showed differences between the hemodynamic profiles of patients with HFmrEF/HFpEF and of those with HFrEF. This suggests that the reported symptoms could be due mainly to other, concomitant conditions (poorly controlled hypertension, arrhythmia, or acute exacerbation of CKD, etc.). An ostensibly "better" hemodynamic profile does not exclude a poor clinical condition and severe symptoms. Moreover, the complexity of potential pathomechanisms makes it more difficult to select optimal treatment. Therefore, the diagnostic assessments in these patients should help select a treatment most suitable for the predominant cause of HF exacerbation.

Our findings may explain why it is so difficult to obtain robust scientific evidence for the effectiveness of selected medications in treating patients with HFmrEF/HFpEF. In such a non-homogeneous group [1, 48] the use of varied regimens, based on individual hemodynamic profiles may be a better management strategy. Therefore, ICG may be a practical tool in this group of patients, as its usefulness in selecting optimal treatments based on the individual hemodynamic disturbances has been already demonstrated in patients with hypertension [49, 50].

Study limitations

One indisputable limitation of our study is the small sample size. The observed differences in hemodynamic profiles may have been partly due to the uneven distribution of the sexes between the two subgroups. However, this fact should not be a significant confounding factor, as both subgroups were predominantly male. Another significant limitation was the 24-hour window allowed for hemodynamic assessment, as the hemodynamic profile may change even within less than an hour of initiating effective treatment. On the other hand, the varied time of echocardiographic examination was less problematic, as the LVEF value during clinical stabilization is considered to be the most reliable prognostic factor.

Conclusion

This study confirms earlier observations on the differences between patients with significantly impaired left ventricular systolic function versus those with mildly impaired and preserved left the ventricular systolic function. Despite the fact that left ventricular function does not determine the severity of clinical presentation in patients with decompensated HF, the observed differences in hemodynamic parameters demonstrated a non-homogeneity of the pathomechanisms and causes of decompensated HF. These findings prompt further studies on the use of ICG in patients hospitalized due to HF exacerbation.

Disclosure of interest: The authors declared no conflict of interest

List of abbreviations

ACEI — angiotensin-converting-enzyme inhibitors
ACI — acceleration index
AHF — acute heart failure
AR — aortic regurgitation
ARB — angiotensin II receptor blocker
AS — aortic stenosis
BMI — body mass index
CI — cardiac index
CKD — chronic kidney disease
COPD — chronic obstructive pulmonary disease

CRT — cardiac resynchronization therapy
CVP — central venous pressure
DBP — diastolic blood pressure
EF — ejection fraction
eGFR — estimated glomerular filtration rate
ESC – European Society of Cardiology
Hgb — hemoglobin
HF — heart failure
HFmrEF — heart failure with mid-range ejection fraction
HFpEF — heart failure with preserved ejection fraction
HFrEF — heart failure with reduced ejection fraction
HI — Heather index
HR — heart rate
hsTnT — high-sensitivity troponin T
ICD — implantable cardioverter defibrillator
ICG — impedance cardiography
IVS — interventricular septum
LA — left atrium
LVEDD — left ventricular end-diastolic diameter
LVEF — left ventricular ejection fraction
MDRD — modification of diet in renal disease
MRA — mineralocorticoid receptor antagonist
NTproBNP — N-terminal pro-brain natriuretic peptide
NYHA — New York Heart Association
PEP – pre-ejection period
RVEDD — right ventricular end-diastolic diameter
SBP — systolic blood pressure
SD — standard deviation
SI — stroke index
STR — systolic time ratio
SVRI — systemic vascular resistance index
TFC — thoracic fluid content
TRC — the time interval between the R-wave peak (in ECG) and the C-point (in ICG)
TR — tricuspid regurgitation
VI — velocity index

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