Original paper

Echocardiographic correlates of dyspnoea during acute decompensated heart failure treatment

Korelacja duszności z parametrami echokardiograficznymi podczas leczenia ostrej niewydolności serca

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Słowa kluczowe: ostra niewydolność serca, duszność, echokardiografia, wizualna analogowa skala duszności.

Abstract

Introduction: Dyspnoea is frequent complaint reported by acute decompensated heart failure (ADHF) patients.
Aim of the research: To evaluate the association of dyspnoea intensity and resolution measured by the dyspnoea visual analogue scale (VAS) with structural and functional parameters obtained by echocardiography during ADHF treatment.
Material and methods: In 34 consecutive adult patients who required hospitalization due to ADHF, echocardiographic assessment was performed upon admission and at discharge, together with clinical and laboratory evaluation. The severity of dyspnoea was assessed with standardized 0–100 points VAS.
Results: At admission, in significant dyspnoea patients (VAS > 50 pts) as compared with non-significant dyspnoea (VAS < 50 pts), the right heart was more dilated and dysfunctional, mitral regurgitation was more advanced (right atrial area (RAA) 31.5 ±7.6 vs. 28.3 ±8.4 cm^2, $p = 0.04$; right ventricular outflow tract diameter 38.7 ±5.0 vs. 35.9 ±4.0 mm, $p = 0.01$; tricuspid annular plane systolic excursion 16.8 ±3.0 vs. 14.6 ±3.9 mm, $p = 0.008$; inferior vena cava 30.1 ±3.8 vs. 26.5 ±4.6 mm, $p < 0.001$; tricuspid regurgitation vena contracta width (VC) 6.7 ±2.0 vs. 4.7 ±2.1 mm, $p < 0.001$; mitral regurgitation VC 6.0 ±1.1 vs. 5.0 ±1.4 mm, $p < 0.006$). The admission dyspnoea score was not associated with left heart structure or left ventricular ejection fraction. In patients with significant dyspnoea reduction during treatment (ΔVAS ≥ 30 pts), but not in patients with weak dyspnoea reduction (ΔVAS ≤ 20 pts), significant decreases of RAA (30.9 ±5.1 vs. 25.7 ±4.9 cm^2, $p < 0.001$), tricuspid regurgitation peak gradient (45.9 ±11.0 vs. 34.9 ±6.9 mm Hg, $p < 0.001$), and mitral E/E' (25 ±7.6 vs. 20.6 ±4.8, $p = 0.01$) were observed.
Conclusions: Dyspnoea severity in ADHF patients is determined mainly by mitral regurgitation severity and right heart structure and function, whereas a dyspnoea decrease during treatment is associated mainly with the reduction of left ventricular filling pressure and right ventricular systolic pressure.

Streszczenie

Wprowadzenie: Duszność jest częstym, trudnym do obiektywnej oceny objawem zgłaszanym przez pacjentów z ostrą niewydolnością serca (ADHF).
Cel pracy: W badaniu podjęto próbę oceny zależności pomiędzy nasileniem duszności ocenianej wg wizualnej skali analogowej (VAS) oraz parametrami pracy serca w analizie echokardiograficznej podczas leczenia ADHF.
Materiał i metody: W grupie 34 pacjentów hospitalizowanych z powodu objawów ADHF przeprowadzono ocenę echokardiograficzną przy przyjęciu oraz wypisie wraz z oceną kliniczną oraz laboratoryjną. Ewaluację nasilenia duszności wykonano, używając standaryzowanej skali VAS (0–100 pkt).
Wyniki: Przy przyjęciu, u pacjentów z nasiloną dusznością (> 50 pkt VAS) w porównaniu z chorymi bez nasilonej duszności (< 50 pkt), struktury prawego serca były bardziej poszerzone i dysfunkcyjne, niedomykalność mitralna bardziej nasilona (powierzchnia prawego przedsionka (RAA) 31,5 ±7,6 *vs* 28,3 ±8,4 cm^2, $p = 0,04$; droga odpływu prawej komory 38,7 ±5,0 *vs* 35,9 ±4,0 mm, $p = 0,01$; pomiar wychylenia skurczowego pierścienia trójdzielnego 16,8 ±3,0 *vs* 14,6 ±3,9 mm, $p = 0,008$; żyła główna dolna 30,1 ±3,8 *vs* 26,5 ±4,6 mm, $p < 0,001$; szerokość *vena contracta* (VC) niedomykalności trójdzielnej 6,7 ±2,0 *vs* 4,7 ±2,1 mm, $p < 0,001$; VC niedomykalności mitralnej 6,0 ±1,1 *vs* 5,0 ±1,4 mm, $p < 0,006$). Nasilenie duszności przy przyjęciu nie wykazywało związku ze strukturami lewego serca ani z frakcją wyrzutową lewej komory. U chorych z istotnym zmniejszeniem nasilenia duszności podczas leczenia (ΔVAS ≥ 30 pkt), ale nie u pacjentów ze słabą redukcją duszności (ΔVAS ≤ 20 pkt), zarejestrowano istotne zmniejszenie RAA (30,9 ±5,1 *vs* 25,7 ±4,9 cm^2, $p < 0,001$), maksymalnego gradientu niedomykalności trójdzielnej (45,9 ±11,0 *vs* 34,9 ±6,9 mm Hg, $p < 0,001$) oraz wskaźnika E/E' (25 ±7,6 *vs* 20,6 ±4,8, $p = 0,01$).

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Wnioski: Nasilenie duszności w ADHF jest determinowane głównie przez stopień niedomykalności mitralnej oraz czynność prawej komory, a redukcja duszności jest skorelowana z obniżeniem ciśnienia napełniania lewej komory oraz ciśnienia skurczowego w prawej komorze.

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Introduction

Acute decompensated heart failure (ADHF) is the most frequent manifestation of acute heart failure with significant, nearly 5% in-hospital mortality and 27.2% one-year mortality according to the ESC-HF-LT (European Society of Cardiology Heart Failure Long-Term) registry [1].

Dyspnoea is the most common complaint, present in over 90% of patients with ADHF, significantly reducing the quality of life and affecting long-term prognosis [2]. Being a subjective, emotional feeling, dyspnoea is difficult to objectify and evaluate clinically. Currently, there is no widely accepted precise diagnostic tool for dyspnoea assessment in ADHF. Several standardized measures of dyspnoea like the University of California – San Diego Shortness of Breath Questionnaire, the Edmonton symptom assessment scale, Borg dyspnoea scale, numeric rating scale, and the dyspnoea visual analogue scale (VAS), have been validated mainly for patients with chronic lung diseases, and their usefulness for ADHF patients is uncertain [3–5].

Removing fluid overload and congestion is a cornerstone of ADHF treatment. Routine management of heart failure exacerbation includes daily adjustment of decongestive therapy to signs and symptoms of hypervolaemia, bodyweight or fluid balance, renal function, and natriuretic peptides [6]. Therapy that is modified according to clinical signs, and symptoms of congestion like orthopnoea and peripheral oedema, has been shown to be mildly effective in reducing dyspnoea and preventing recurrence of ADHF after discharge in a post-hoc analysis of DOSE-AHF (Diuretic Optimization Strategy Evaluation in Acute Decompensated Heart Failure) and the CARESS-HF (Cardiorenal Rescue Study in Acute Decompensated Heart Failure) trials [7]. Moreover, ADHF management based on Swan-Ganz catheter measures was not superior to a standard approach in the ESCAPE (Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness) trial [8]. Echocardiography is recommended during ADHF treatment to define a patient's haemodynamic state and its changes during hospitalization [9, 10]. Treatment of hypervolaemia using standardized echocardiographic protocols has been shown to reduce decongestion and improve prognosis during ADHF hospitalizations to a greater extent than standard therapy, in a study by Öhman *et al.* [11]. However, the correlation between echocardiographic parameters and severity of dyspnoea has not been precisely studied in ADHF. Guglin *et al.* [12] reported in a retrospective study in patients with ADHF a weak correlation between orthopnoea and dyspnoea on admission and invasively measured pulmonary artery pressures. Symptoms correlated inversely with left and right atrial size measured with echocardiography. Although acute changes in a few echocardiographic parameters predict clinical outcomes, their association with severity of dyspnoea and resolution of dyspnoea is largely unknown [13].

Aim of the research

Therefore, our study aimed to: (1) evaluate the association of dyspnoea intensity measured by the dyspnoea VAS with structural and functional parameters of the heart obtained by echocardiography in ADHF patients, and 2) to study the changes of these echocardiographic parameters depending on dyspnoea resolution during ADHF treatment.

Material and methods

Study population

In this prospective observational, single-centre study, we enrolled 34 consecutive adult patients hospitalized due to ADHF, which was defined as sudden worsening of the signs and symptoms of heart failure [14]. Patients were recruited in the Department of Cardiac and Vascular Diseases and Department of Diagnostics, Jagiellonian University Medical College, John Paul II Hospital in Krakow, Poland, between January 2018 and December 2020. Exclusion criteria included the following: other clinical phenotypes of acute heart failure (cardiogenic shock, pulmonary oedema), acute coronary syndrome, severe cardiac arrhythmias, venous thromboembolism, infection or sepsis at admission, kidney failure requiring dialysis, hyperthyroidism/ hypothyroidism, pregnancy, or puerperium.

Patient management and evaluation

All study participants received conventional pharmacological treatment according to the current European Society of Cardiology guidelines for the treatment of ADHF [9]. Participation in the study did not result in any intrusion into the therapy, which was determined solely by the patient's attending physician. A standardized questionnaire was used to collect patient demographic data, cardiovascular risk factors, comorbidities, and current treatment [15].

The usual diagnostic scheme, which included assessment of basic vital parameters (heart and respiratory rate, blood pressure, peripheral oxygen saturation (SpO_2)), was introduced in all patients. A resting electrocardiogram was obtained at admission to ex-

clude acute myocardial infarction changes or significant rhythm disturbances. Fluid balance and weights were monitored daily. Routine laboratory investigations were performed by standard methods. Additionally, serum N-terminal pro-B-type natriuretic peptide (NT-proBNP) was determined with electrochemiluminescence immunoassay (Roche Diagnostics, Mannheim, Germany) on the first day of treatment and at discharge.

A subjective assessment of the severity of dyspnoea was performed with a standardized 0–100 visual analogue dyspnoea scale [16]. The patients were asked to mark the level of dyspnoea on a linear scale on admission and during discharge, after lying down in the bed for 15 min. The cut-off point of the dyspnoea score was 50 points; values above 50 were defined as significant dyspnoea [3]. A significant improvement in dyspnoea was defined as dyspnoea score change ≥ 30 points, whereas values below 20 were considered as no improvement.

Echocardiographic evaluation

All the patients underwent transthoracic echocardiography on admission and on the day of discharge using Philips iE33 and Phillips Epiq ultrasound machines (Philips Healthcare, Eindhoven, Netherlands). The echocardiographic measurements were obtained according to the current guidelines [17, 18]. To evaluate the relationship between systemic circulation and dyspnoea, we analysed the following: left ventricular end-diastolic diameter (LVEDD), left ventricular ejection fraction (LVEF, measured with the Simpson biplane method); left ventricular outflow tract velocity-time-integral (LVOT-VTI), left atrial area (LAA); and the ratio of mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E'). In the assessment of mitral regurgitation (MR), vena contracta width (VC), proximal isovelocity surface area (PISA) radius, effective regurgitant orifice area (EROA), and mitral regurgitant volume (RV) were measured. As for pulmonary circulation, we evaluated right ventricular outflow tract diameter (RVOT), tricuspid annular plane systolic excursion (TAPSE), right atrial area (RAA), and tricuspid regurgitation peak gradient (TRPG).

The measurements were averaged from 3 consecutive cardiac cycles in patients with sinus rhythm and 3–5 consecutive cardiac cycles in those with atrial fibrillation. All examinations were performed per protocol by 2 independent researchers who analysed images offline using a dedicated workstation. The interobserver variability of echocardiographic measurements was below 10%.

The study was approved by the Bioethical Committee of the Jagiellonian University in Cracow, Poland (No. 122.6120.294.2015). The study was conducted in accordance with the ethical guidelines of the 1975 Declaration of Helsinki. All the patients gave written informed consent.

Statistical analysis

The study was powered to have an 80% chance of detecting a 20-point difference in VAS at the $\alpha = 0.05$ level. In order to demonstrate such a difference, 19 or more subjects were required based on the values of previous studies [19]. The continuous variables were presented as mean and standard deviation (SD), tested for normality of distribution using the Kolmogorov-Smirnov test, and then compared by Student's *t*-test for independent data or the paired *t*-test, as appropriate. A p-value ≤ 0.05 (2-sided) was considered statistically significant. Categorical variables were presented as counts and percentages. Data were analysed using Statistica 13.1 software (StatSoft Inc., Tulsa, OK, USA).

Results

Patient characteristics

The clinical characteristics of the study group on admission are shown in Table 1. At admission, all the patients were dyspnoeic, with a mean dyspnoea score of 82.40 ±8.81. N-terminal pro-B-type natriuretic peptide (NT-proBNP) was elevated in all the patients (Figure 1 A). During the treatment, a significant reduction in the dyspnoea score (of 34.10% to 45.00 ±10.95, $p < 0.001$) and in NT-proBNP (of 43.4%) was observed (Figure 1 A).

Comparison of groups according to the severity of dyspnoea on admission

Patients with significant dyspnoea had a higher respiratory rate and NT-proBNP compared with those without severe dyspnoea (Figure 1 B, Table 2). In the echocardiographic examination (Table 2), in the group with significant dyspnoea, RAA, RVOT, vena cava inferior diameter, and tricuspid valve regurgitation were larger, whereas the right ventricular systolic function was worse compared with the patients without significant dyspnoea. The severity of mitral valve regurgitation was higher in patients with significant dyspnoea. Of note, the dyspnoea score was not associated with LVEDD, LAA, LVEF, LVOT-VTI, mitral E/E' ratio, and TRPG.

Comparison of groups according to the improvement in dyspnoea during ADHF treatment

Regardless of the resolution of dyspnoea score during ADHF treatment (≥ 30 points or ≤ 20 points), improvement in LVEF and the reduction of right ventricular dimension, left atrial size, mitral and tricuspid regurgitation, and vena cava diameter was observed (Table 3). We did not observe a change in LVOT-VTI

Table 1. Baseline characteristics of patients on admission

Clinical parameter	Value
Age [years]	70.2 ±10.8
Women, *n* (%)	14 (41.2)
BMI [kg/m^2]	30.1 ±5.2
Comorbidities, *n* (%):	
Arterial hypertension	31 (91.1)
Diabetes mellitus	12 (35.2)
Atrial fibrillation	23 (67.6)
COPD/asthma	2 (5.8)
Coronary artery disease	15 (44.1)
Previous myocardial infarction	12 (35.2)
Previous CABG/PCI	12 (35.2)
ECG:	
QRS-complex duration [ms]	116.8 ±26.4
LBBB, *n* (%)	4 (11.7)
RBBB, *n* (%)	3 (8.8)
Echocardiographic parameters:	
LVEF (%)	34.2 ±12.9
Severe mitral regurgitation	10 (29.4)
TRPG [mm Hg]	44.1 ±11.6
Treatment, *n* (%):	
ACE-I	24 (70.5)
β-antagonists	34 (100.0)
MRA	24 (70.5)

Data are expressed as the mean value ± standard deviation for continuous variables and as n (%) for qualitative variables. ACE-I – angiotensin-converting enzyme inhibitors, BMI – body mass index, CABG – coronary artery bypass grafting, COPD – chronic obstructive pulmonary disease, LBBB – left bundle branch block, LVEF – left ventricular ejection fraction, MRA – mineralocorticoid receptor antagonists, PCI – percutaneous coronary intervention, RBBB – right bundle branch block, TRPG – tricuspid regurgitation peak gradient.

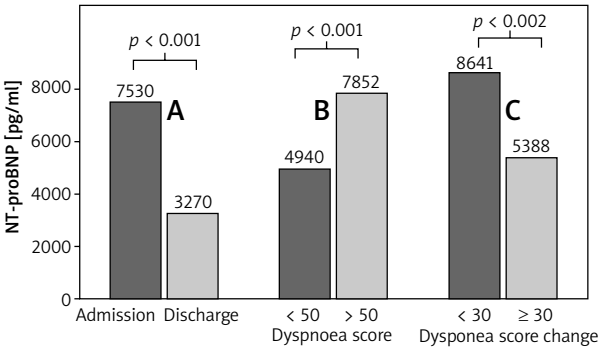

Figure 1. **A** – Changes in NT-proBNP during acute decompensated heart failure treatment. **B** – NT-proBNP level and dyspnoea intensity. **C** – NT-proBNP level and dyspnoea change

NT-proBNP – N-terminal pro-B-type natriuretic peptide.

and TAPSE in the group with or without a significant reduction of dyspnoea score during the ADHF treatment.

Of note, in the group of patients with a significant reduction of dyspnoea score during the treatment (≥ 30 points), a significant decrease of LVEDD, RAA, mitral E/E' ratio, and TRPG was observed (Figure 2). Also, a decrease in NT-proBNP and an increase in SpO_2 were observed only in the group with significant dyspnoea score reduction (Figure 1 C).

Discussion

The main findings of the present study are that: 1) the severity of dyspnoea in ADHF patients is connected with right heart function and structure and mitral regurgitation severity, but not directly with left ventricular ejection fraction and dimension; 2) improvement in dyspnoea during treatment is associated mainly with the reduction in left ventricular filling pressure and right ventricular afterload; and 3) dyspnoea may remain unchanged despite the treatment-induced improvement in LVEF, mitral, and tricuspid regurgitations, right ventricle size, and filling pressure.

Although the feeling of dyspnoea in ADHF is multifactorial, our results suggest that changes in pulmonary circulation are essential for its occurrence, because mitral insufficiency increases pulmonary capillary wedge pressure (PCWP), and pulmonary hypertension causes right ventricular and right atrial enlargement [20]. We observed mitral E/E' ratio reduction, but without normalization, and it is worth emphasizing that even a suboptimal change in left ventricular feeling pressure resulted in a decrease of right ventricular afterload and a subsequent dyspnoea reduction. This observation is enhanced with data from studies with lung ultrasonography, where resolution of lung congestion, dyspnoea, and a decrease in NT-proBNP correlated with left ventricular feeling pressure [11, 21]. In the MEDIA-DHF (Metabolic Road to Diastolic Heart Failure) study, patients with acute heart failure and reduced ejection fraction shared a similar phenotype of venous congestion and right ventricular dysfunction with those with preserved ejection fraction [22].

It is noteworthy that we observed a similar pattern of several echocardiographic parameters during ADHF treatment as in the ESCAPE trial, including a reduction in the right atrial, right ventricular, and inferior vena cava diameters and improvement in the severity of mitral regurgitation [8]. Interestingly we observed a reduction in left ventricular size, which has been shown to reduce the risk of death or heart failure rehospitalization after an ADHF episode [8]. Because this phe-

Table 2. Echocardiographic parameters SpO_2, respiration rate, and dyspnoea intensity

Parameter	Dyspnoea		*P*-value
	Not significant (≤ 50) *n* = 15	Significant (> 50) *n* = 19	
Systemic circulation:			
LVEDD [mm]	58.8 ±8.8	59.6 ±12.4	–
LVEF (%)	40.4 ±11.6	38.1 ±14.6	–
LVOT-VTI [cm]	15.8 ±4.6	14.4 ±4.1	–
Left atrial area [cm^2]	33.6 ±10.9	34.1 ±8.2	–
Mitral E/E' ratio	21.6 ±6.0	21.8 ±6.1	–
Mitral regurgitation:			
VCW [mm]	5.0 ±1.4	6.0 ±1.1	0.006
PISA [mm]	5.8 ±2.0	7.6 ±1.8	< 0.001
ERO [cm^2]	0.19 ±0.11	0.32 ±0.11	< 0.001
RV [ml]	26.7 ±13.2	39.3 ±15.6	< 0.001
Pulmonary circulation:			
RVOT [mm]	35.9 ±4.0	38.7 ±5.0	0.01
TAPSE [mm]	16.8 ±3.0	14.6 ±3.9	0.008
Right atrial area [cm^2]	28.3 ±8.4	31.5 ±7.6	0.04
TRPG [mm Hg]	38.2 ±10.2	42.1 ±12.0	–
TR VCW [mm]	4.7 ±2.1	6.7 ±2.0	< 0.001
Vena cava inferior [mm]	26.5 ±4.6	30.1 ±3.8	< 0.001
SpO_2 (%)	95.6 ±5.5	94.7 ±.6	–
Respiratory rate [per min]	14.9 ±2.4	17.2 ± 2.3	< 0.001

For abbreviations, see Table 1; ERO – effective regurgitant orifice, LVEDD – left ventricular end-diastolic diameter, LVOT-VTI – left ventricular outflow tract velocity time integral, PISA – proximal isovelocity surface area; mitral E/E' ratio – the ratio of mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E'), RVOT – right ventricular outflow tract diameter, RV – regurgitant volume, TAPSE – tricuspid annular plane systolic excursion, TR – tricuspid regurgitation, TRPG – tricuspid regurgitation peak gradient, VCW – vena contracta width.

nomenon was observed only in patients with significant dyspnoea decrease during decongestive therapy, we assume that this group has the lowest prevalence of residual pulmonary congestion.

Treatment of ADHF is associated with a decrease in left- and right-sided heart pressures in invasive measurements, the change of which has been shown to be concordant with echocardiographic assessment, particularly for right atrial pressure, pulmonary artery systolic pressure, and IVC diameter measurement and TRPG, respectively [8, 13]. Our study showing the impact of LV filling pressure as assessed by echo, left ventricular diastolic dysfunction, and secondary pulmonary hypertension on the feeling of dyspnoea emphasizes observations of the detrimental effect of residual pulmonary congestion on quality of life in ADHF [7]. However, previous research was not unambiguous in this aspect. In a Finnish study, a decrease in the mitral E/E' ratio preceded early decongestion, evaluated with lung ultrasonography, and was associated with lower 6-month mortality in patients with acute heart failure [23]. Conversely, the study based on data from the ESCAPE trial suggested a weak correlation between echocardiographic parameters and the severity of dyspnoea [8, 24].

Nevertheless, these were patients with a starting LVEF below 30%, probably chronically adapted pulmonary congestion. High loss to follow-up rates, in-hospital, and early mortality in ADHF might also have biased results of studies on echocardiographic correlates of dyspnoea in heart failure [12].

Therapy of ADHF using rapid cardiothoracic ultrasound protocols, e.g. CaTUS, based on cardiac filling pressures, inferior vena cava diameter, and lung assessment, have been shown to reduce symptoms and natriuretic peptides faster than standard management without ultrasound guidance [11]. A recent study showed the POCUS (point-of-care ultrasound) algorithm relying on mitral flow, mitral annular velocities, and lung ultrasound to have high accuracy in

Table 3. Echocardiographic parameters, respiration rate, SpO_2, NT-proBNP, and dyspnoea score change

Parameter	Δ dyspnoea score ≥ 30 (improvement) *n* = 18			Δ dyspnoea score ≤ 20 (no improvement) *n* = 16		
	Admission	Discharge	*P*-value	Admission	Discharge	*P*-value
Systemic circulation:						
LVEDD [mm]	61.2 ±10.2	59.3 ±10.7	0.002	59.9 ±12.9	58.7 ±11.8	–
LVEF (%)	35.2 ±13.3	39.9 ±11.2	0.007	36.8 ±17.0	41.2 ±14.8	0.01
LVOT-VTI [cm]	13.8 ±5.0	15.9 ±4.2	–	14.7 ±4.1	13.7 ±3.8	–
Left atrial area [cm^2]	33.7 ±4.6	30.0 ±3.7	0.009	38.2 ±12.2	35.1 ±12.8	0.04
Mitral E/E' ratio	25 ±7.6	20.6 ±4.8	0.01	24.1 ±8.9	20.8 ±4.8	–
Mitral regurgitation:						
VCW [mm]	6.0 ±1.4	4.9 ±1.3	< 0.001	6.3 ±1.0	5.6 ±1.1	0.009
PISA [mm]	7.0 ±2.4	5.3 ±1.4	0.001	8.3 ±1.4	7.1 ±1.2	< 0.001
ERO [cm^2]	0.31 ±0,10	0.17 ±0.09	0.001	0.37 ±0.12	0.28 ±0.08	0.01
RV [ml]	38.2 ±20.0	26.9 ±13.2	0.001	46.2 ±13.9	36.7 ±11.0	0.002
Pulmonary circulation:						
RVOT [mm]	37.2 ±3.9	34.9 ±3.0	0.006	41.2 ±5.8	38.6 ±4.7	0.04
TAPSE [mm]	17 ±5.2	16.3 ±4.0	–	14.4 ±4.1	14.9 ±3.2	–
Right atrial area [cm^2]	30.9 ±5.1	25.7 ±4.9	< 0.001	35.8 ±9.9	33.9 ±11.7	–
TRPG [mm Hg]	45.9 ±11.0	34.9 ±6.9	< 0.001	43 ±12.0	42.2 ±12.5	–
TR VCW [mm]	5.6 ±2.3	4.2 ±2.1	0.001	7.2 ±1.8	6.6 ±1.8	0.04
Vena cava inferior [mm]	27.2 ±3.6	22.8 ±3.9	< 0.001	29.4 ±4.4	25.9 ±5.0	0.006
SpO_2 (%)	92.2 ±5.3	96.8 ±1.4	0.04	94.8 ±4.0	96.3 ±2.0	–
Respiratory rate [per min]	18.8 ±1.7	14.5 ±1.2	< 0.001	17.9 ±2.5	16.0 ±2.2	0.001
NT-proBNP [pg/ml]	8641 ±7117	5330 ±5951	0.003	7350 ±4020	5625 ±3428	–

For abbreviations, see Tables 1, 2. NT-proBNP – N-terminal pro-B-type natriuretic peptide, SpO_2 – oxygen saturation.

diagnosing dyspnoea secondary to ADHF in the emergency department [25]. Furthermore, therapy based on echo-derived cardiac filling pressures resolves congestion faster and more effectively and may result in a greater improvement in dyspnoea [26]. Knowledge about the complex relationship between echocardiographic parameters, natriuretic peptides, and reported dyspnoea may help clinicians to differentiate the source of dyspnoea and to monitor the course of ADHF treatment.

Plasma NT-proBNP has been shown to correlate with mitral E', right ventricular systolic function, and the severity of tricuspid regurgitation in patients with dyspnoea enrolled in the PRIDE (ProBNP Investigation of Dyspnoea in the Emergency Department) study [27]. In another study on dyspnoea in emergency departments, NT-proBNP measurements had high diagnostic accuracy for LVEF < 40% and diastolic dysfunction in ADHF and pulmonary congestion [28, 29].

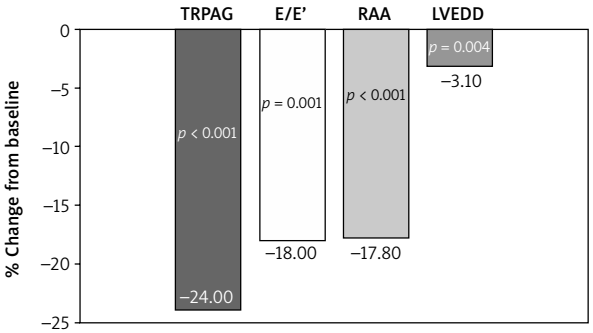

Figure 2. Echocardiographic parameters associated with dyspnoea score improvement ≥ 30 points during treatment. Data are shown as percentage change from the baseline value

TRPG – tricuspid regurgitation peak gradient, E/E' – the ratio of mitral peak velocity of early filling (E) to early diastolic mitral annular velocity (E'), RAA – right atrial area, LVEDD – left ventricular end-diastolic diameter.

Also, we enrolled patients with ischaemic and non-ischaemic heart failure and a high prevalence of atrial fibrillation, as reported in other ADHF studies [1, 12]. None of the patients was lost to follow-up, despite reported high in-hospital mortality [1] or incomplete long-term observations in other trials on dyspnoea in ADHF [12]. Finally, we believe that objectification and categorization of dyspnoea with VAS may be helpful for the development of protocols for other heart failure clinical trials.

Limitations: The study findings are limited by the sample size. However, the number of patients was sufficient to detect the intergroup differences based on the results of power calculation.

Our study reflects standard treatment for ADHF in a university hospital. The study duration was limited to the in-hospital phase of ADHF, and long-term observation might elucidate different dyspnoea-related factors [30]. Exercise echocardiography testing might have revealed other associations with dyspnoea, unavailable to detect in the resting examination; however, its use in the acute phase may be associated with additional risk for the patient [31]. We did not perform right heart catheterization because the aim of the study was to find easy to assess bedside tools valuable in the prognostication of dyspnoea relief. Of note, echocardiography parameters depend on heart rate and atrial fibrillation (AF) episodes. AF increases heart rate, deteriorates LVEF, and reduces mitral regurgitation parameters during episode [32]. Similarly, the impact on circulation haemodynamics may have adrenergic stimulation, connected with stress due to hospitalization and dyspnoea [33]. No change in heart rhythm was observed in our study group (AF or sinus rhythm from admission to discharge); the level of stress on admission and during hospitalization was stable.

Conclusions

We have shown that dyspnoea severity in ADHF patients is determined mainly by the mitral regurgitation severity and the right heart structure and function, whereas dyspnoea decrease during treatment is associated mainly with the reduction of left ventricular filling pressure and right ventricular systolic pressure. The relationship between dyspnoea severity and echocardiographic parameters may help clinicians to monitor the course of ADHF treatment.

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Conflict of interest

The authors declare no conflict of interest.

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