Original article

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Is haemodynamic evaluation with impedance cardiography in patients with heart failure undergoing testing of the implanted cardioverter-defibrillator of clinical importance?

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Abstract

Background: Identification of individual factors associated with high defibrillation threshold (DFT) seems to be of high clinical importance. Impedance cardiography (ICG) may be used for non-invasive evaluation of the haemodynamic status. Whether ICG parameters may improve identification of patients with high DFT has not yet been examined.

Aim: To evaluate clinical risk factors of high DFT including ICG parameters.

Methods: The study group included 69 patients with heart failure (aged 62.7 ± 9.5 years, NYHA class: I–III) selected for implantation of a cardioverter-defibrillator (ICD). Clinical assessment included physical examination, echocardiography and ICG monitoring before and after defibrillation.

Results: Initial defibrillation was unsuccessful in 17 (36.6%) patients. High DFT group was characterised by higher left ventricular end-diastolic diameter (LVEDD ≥ 5.6 cm: 100.0% *vs* 70.2%; p = 0.01), lower left ventricular ejection fraction (LVEF < 30%: 76.5% *vs* 44.7%; p = 0.024), higher baseline thoracic fluid content (one of ICG parameters) (TFC ≥ 35 1/kOhm: 29.4% *vs* 6.4%; p = 0.014) and more frequent amiodarone treatment (41.2% *vs* 14.9%; p = 0.025). A proposed algorithm based on predefined values of TFC, LVEF and LVEDD was shown to be effective in predicting high DFT (area under curve: 0.771).

Conclusions: Risk factors of high DFT include left ventricular enlargement, low LVEF, high TFC and amiodarone treatment. An algorithm including TFC measurement by ICG increases the efficacy of identification of patients with high DFT.

Key words: heart failure, implanted cardioverter-defibrilator, impedance cardiography

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INTRODUCTION

High defibrillation threshold (DFT) in patients with implantable cardioverter-defibrilator (ICD) is a serious clinical problem [1, 2]. Identification of factors predisposing to high DFT and patients who benefit most from DFT testing seems to have major clinical importance. With divergent opinions on the value of ICD testing [3], a practical clinical aspect has been brought to this research issue.

Impedance cardiography (ICG) is a modern tool of non-invasive monitoring that may be used in the assessment of patients with heart failure (HF). Some haemodynamic parameters measured by ICG, such as thoracic fluid content (TFC), have proven clinical value. As reported by Packer et al. [4], TFC > 35 1/kOhm and stroke index (SI) < 35 mL/m^2 are significant predictors of short-term HF exacerbation, as supported theoretically by the classification of the clinical pictu-

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re of HF based on chest volume status ("dry" *vs* "wet") and peripheral perfusion ("warm" *vs* "cold") [5]. It seems that the haemodynamic status may affect arrhythmia refractoriness to defirillation.

The purpose of our study was to evaluate risk factors of high DFT during ICD testing using monitoring of ICG parameters.

METHODS

Patients

We studied 69 consecutive patients with HF (mean age 62.7 ± 9.5 years) who underwent testing of an ICD implanted for primary or secondary prevention of sudden cardiac death (SCD) in our Department from April 2009 to June 2010. Results obtained in 5 (7.2%) patients in whom ICD monitoring was technically inadequate were excluded from the final analysis.

Baseline characteristics of the studied population are shown in Table 1. Final analysis included 64 patients, including 42 (65.7%) patients with ICD (DDD: 23 patients; VVI: 19 patients) and 22 (34.3%) patients with a cardiac resynchronisation therapy (CRT) device with defibrillation capability (CRT-D). Inclusion criteria included New York Heart Association (NYHA) class I–III HF with indications for ICD or CRT-D according to the current guidelines [6]. Single-chamber ICDs (VVI) were implanted in all patients with permanent atrial fibrillation (AF), and in patients with sinus rhythm and no evidence of sinus node disease and/or atrioventricular or intraventricular conduction disturbances. Patients had to receive optimal medical therapy and remain clinically stable for at least 4 weeks. Exclusion criteria included severe or uncontrolled hypertension, significant valvular heart disease requiring cardiac surgery, advanced renal failure, end-stage liver failure, severe pulmonary disease, haemoglobin (Hb) level < 10.0 g/dL, and commonly accepted contraindications for ICD implantation and testing (Table 1).

Table 1. Baseline patient characteristics (n = 64)

Male gender	56 (87.5%)
Age [years]	62.7 ± 9.5
BMI [kg/m^2]	27.3 ± 3.7
GFR [mL/min/1.73 m^2]	83.9 ± 40.8
NYHA class:	
I	10 (15.6%)
II	14 (21.9%)
III	40 (62.5%)
Echocardiography:	
LVEF [%]	30.7 ± 9.5
LA [cm]	4.73 ± 0.66
LVEDD [cm]	6.27 ± 0.83
LVEF ≤ 30%	34 (53.1%)
LA > 4.0 cm	53 (82.8%)
LVEDD > 5.6 cm	50 (78.1%)
SCD prevention:	
Primary	50 (78.1%)
Secondary	14 (21.9%)
Medical history:	
Ischaemic heart disease	48 (75.0%)
Previous myocardial infarction	47 (73.4%)
Previous PCI	26 (40.6%)
Previous CABG	15 (23.4%)
Diabetes	25 (39.1%)
Atrial fibrillation	5 (7.8%)
Medications:	
Beta-blocker	63 (98.4%)
ACE-I	54 (84.4%)
ARB	9 (14.1%)
Loop diuretic	52 (81.3%)
Thazide diuretic	4 (6.3%)
Statin	55 (85.9%)
Amiodarone	14 (21.9%)

ACE-I — angiotensin-converting enzyme inhibitor; ARB — angiotensin receptor blocker; BMI — body mass index; CABG — coronary artery bypass grafting; GFR — glomerular filtration rate, LA — left atrial dimension; LVEDD — left ventricular end-diastolic diameter; LVEF — left ventricular ejection fraction; NYHA — New York Heart Association; PCI — percutaneous coronary intervention; SCD — sudden cardiac death

ICD/CRT-D implantation

Cardioverter-defibrillators were implanted into the left subclavian area. We used single-coil defibrillating leads which were introduced into the right ventricular apex. All procedures were performed in operating room conditions in accordance with the accepted standards [7]. We used ICDs with increased maximum defibrillation energy > 30 J.

ICD/CRT-D testing procedure

In all patients, ventricular fibrillation (VF) was induced in general anaesthesia with midazolam and phentanyl. Arrhythmia was provoked using 1 J impulse in the T wave vulnerable period (shock on T) and if unsuccessful with rapid stimulation at 50 Hz (burst). The DFT was measured during a simplified testing procedure using increasing energy impulses of 15 J, 25 J, and the third shock with the maximal ICD energy of 35 J or 40 J. If the third ICD shock was ineffective, arrhythmia was terminated using an external cardioverter-defibrillator (one event in the study group). Throughout the testing, the device was reprogrammed in all patients to VVI pacing at the rate of 30 beats/min.

Echocardiography

Two-dimensional echocardiography was performed in standard parasternal, apical, and substernal views, with measure-

ments of left ventricular ejection fraction (LVEF [cm^2], Simpson method), left atrial diameter (LA, [cm]) and left ventricular end-diastolic diameter (LVEDD, [cm]) in the long-axis parasternal view.

Impedance cardiography

All ICD measurements were performed using a Niccomo device (Medis, Germany) in a supine position during ICD/CRT-D testing. We analysed recordings of approximately 2 min before and after defibrillation (at least 30 beats) and calculated haemodynamic parameters including SI, cardiac index (CI), Heather index (HI), acceleration index (ACI), velocity index (VI), systolic time ratio (STR), TFC, and systemic vascular resistance index (SVRI). In addition, we continuously recorded electrocardiogram (ECG) and the heart rate, and performed automated brachial artery blood pressure measurements every 2 min.

Statistical analysis

Statistical analysis was performed using the Statistica 7.0 software (StatSoft Inc.). Normal distribution of the data was assessed visually and using the Shapiro-Wilk test. Results are expressed as mean values ± SD for continuous variables and numbers and percentages for categorical variables. Differences between groups were tested using the Student *t* test for normal continuous variables, nonparametric tests for non-normally distributed continuous variables, and χ^2 and Fisher tests for categorical variables. Linear correlations were estimated using the Pearson correlation coefficient. We used uni- and multivariate logistic regression to analyse qualitative data. A p value < 0.05 was considered statistically significant.

For the purpose of study group comparisons, subgroups in regard to continuous variables were defined based on their generally accepted cut-off values (LVEDD > 5.6 cm; QRS > 120 ms; glomerular filtration rate [GFR] < 60 mL/min/1.73 m^2) or data reported in the literature (TFC ≥ 35 1/kOhm; SI < 35 mL/m^2) [4].

RESULTS

In all patients, device implantation and testing was not associated with any major complications. The device was reprogrammed (change of impulse polarity and shape) in 3 patients due to high DFT.

Initial ICD shock (first defibrillation, fDF) was successful in 47 (73.4%) patients, and the mean VF duration was 13.0 ± 6.0 s. Overall, we did not observe any significant changes of the haemodynamic parameters following defibrillation (Table 2). Baseline TFC was greater than 35 1/kOhm in 8 (12.5%) patients, and SI < 35 mL/m^2 was noted in 38 (59.4%) patients (Table 2).

Subgroup comparison based on fDF success

Depending on the success of fDF, patients were divided into two groups, with successful initial shock (fDF[+] group, n = 47, 73.4%) or requiring additional higher energy defibrillation shocks (fDF[–] group, n = 17, 36.6%) (Table 3).

In subgroup analysis, patients requiring higher energy defibrillation shocks were characterised by a significantly longer VF duration, higher LVEDD, lower LVEF, higher TFC, and more frequent amiodarone treatment (Table 3). High DFT correlated with TFC ≥ 35 1/kOhm (R = 0.31, p = 0.013), LVEF ≤ 30% (R = 0.28, p = 0.02), LVEDD > 5.6 cm (R = 0.31, p = 0.01), and amiodarone treatment (R = 0.28, p = 0.025).

Variables showing significant correlation with high DFT were entered into logistic regression analysis (due to methodological limitations, this analysis did not include LVEDD > 5.6 cm, present in 100% of patients in the fDF[–] group and undoubtedly of high prognostic value). In univariate ana-

Table 2. Selected haemodynamic parameters before and after defibrillation

Haemodynamic parameters	Before defibrillation	After defibrillation	P
TFC [1/kOhm]	29.1 ± 4.8	29.6 ± 6.9	0.61
CI [L/min/m^2]	2.24 ± 0.55	2.30 ± 0.56	0.54
SI [mL/m^2]	32.9 ± 8.8	33.7 ± 0.6	0.56
SVRI [dyn·s·cm^{-5}·m^2]	3194.5 ± 937.9	3089.1 ± 908.2	0.52
HI [Ohm/s^2]	7.36 ± 3.21	8.03 ± 4.08	0.70
ACI [100/s^2]	54.7 ± 22.1	53.4 ± 21.7	0.72
VI [1000/s]	30.8 ± 10.8	31.2 ± 10.9	0.90
STR	0.495 ± 0.171	0.513 ± 0.277	0.25
HR [1/min]	69.8 ± 4.8	69.3 ± 10.8	0.80
SBP [mm Hg]	120.3 ± 20.4	118.8 ± 23.1	0.71
DBP [mm Hg]	76.8 ±11.9	76.5 ± 12.3	0.91

ACI — acceleration index; CI — cardiac index; DBP — diastolic blood pressure; HI — Heather index; HR — heart rate; SBP — systolic blood pressure; SI — stroke index; STR — systolic time ratio; SVRI — systemic vascular resistance index; TFC — thoracic fluid content; VI — velocity index

Table 3. Comparison of subgroups based on the success of first defibrillation (fDF)

	Group fDF(+) N = 47	Group fDF(–) N = 17	P
Echocardiography:			
LVEF [%]	32.1 ± 10.2	27.1 ± 6.3	0.06
LA [cm]	4.69 ± 0.71	4.84 ± 0.53	0.45
LVEDD [cm]	6.12 ± 0.83	6.67 ± 0.67	0.017
LVEF ≤ 30%	21 (44.7%)	13 (76.5%)	0.024
LVEDD > 5.6 cm	33 (70.2%)	17 (100.0%)	0.01
Defibrillation			
VF duration [s]	10.2 ± 2.3	21.4 ± 6.1	< 0.0001
Haemodynamic parameters before defibrillation:			
TFC [1/kOhm]	28.5 ± 3.9	30.7 ± 6.6	0.11
CI [L/min/m^2]	2.24 ± 0.54	2.22 ± 0.61	0.89
SI [mL/m^2]	33.0 ± 8.9	32.4 ± 8.8	0.82
SVRI [dyn·s·cm^{-5}·m^2]	3167 ± 913.9	3269.5 ± 1026.7	0.70
HI [Ohm/s^2]	7.66 ± 3.16	6.52 ± 3.33	0.22
ACI [100/s^2]	54.7 ± 22.7	54.8 ± 21.0	0.67
VI [1000/s]	31.1 ± 11.1	29.8 ± 10.0	0.99
STR	0.496 ± 0.162	0.493 ± 0.204	0.92
HR [1/min]	69.7 ± 11.8	70.3 ± 14.9	0.85
SBP [mm Hg]	119.9 ± 21.0	121.1 ± 20.9	0.84
DBP [mm Hg]	76.5 ± 10.4	77.4 ± 15.8	0.78
TFC ≥ 35 1/kOhm	3 (6.4%)	5 (29.4%)	0.014
SI < 35 mL/m^2	29 (61.7%)	9 (52.9%)	0.53
Other parameters:			
Men	41 (87.2%)	15 (88.2%)	0.91
NYHA class > II	28 (59.6%)	12 (70.5%)	0.21
BMI [kg/m^2]	27.4 ± 3.8	27.0 ± 4.1	0.72
BSA [m^2]	1.71 ± 0.14	1.74 ± 0.13	0.34
Primary prevention of SCD	38 (76.0%)	12 (70.6%)	0.38
QRS > 120 ms	27 (57.5%)	12 (70.6%)	0.34
GFR < 60 mL/min/1.73 m^2	12 (26.7%)	4 (25.0%)	0.90
Statin	40 (85.1%)	15 (88.2%)	0.94
Amiodarone	7 (14.9%)	7 (41.2%)	0.025
Beta-blocker	46 (97.9%)	17 (100.0%)	0.54

ACI — acceleration index; BMI — body mass index; BSA — body surface area; CI — cardiac index; DBP — diastolic blood pressure; GFR — glomerular filtration rate; HI — Heather index; HR — heart rate; LA — left atrial dimension; LVEDD — left ventricular end-diastolic diameter; LVEF — left ventricular ejection fraction; NYHA — New York Heart Association; SBP — systolic blood pressure; SCD — sudden cardiac death; SI — stroke index; STR — systolic time ratio; SVRI — systemic vascular resistance index; TFC — thoracic fluid content; VF — ventricular fibrillation; VI — velocity index

lyses, high TFC, low LVEF and amiodarone treatment were significant predictors of high DFT (Fig. 1). However, these parameters did not remain independent predictors (TFC > 35 1/kOhm: odds ratio [OR] 4.8, 95% confidence interval [CI] 0.8–27.2, p = 0.07; LVEF ≤ 30%: OR 3.0, 95% CI 0.8–11.7, p = 0.1; amiodarone treatment: OR 3.1, 95% CI 0.8–12.5, p = 0.1) in a multivariate model that was better predictive of high DFT (p = 0.008).

The highest sensitivity (100%) of identifying patients at risk of high DFT was shown for LVEDD > 5.6 cm but specificity of this parameter was poor. The most specific predictive parameter was TFC ≥ 35 1/kOhm but its sensitivity was low. Based on these analyses, an algorithm was developed to identify patients at high or low risk of unsuccessful fDF (including TFC, LVEF and LVEDD) which was shown to have high predictive value (sensitivity 88.2%, specificity 66.0%) (Fig. 2).

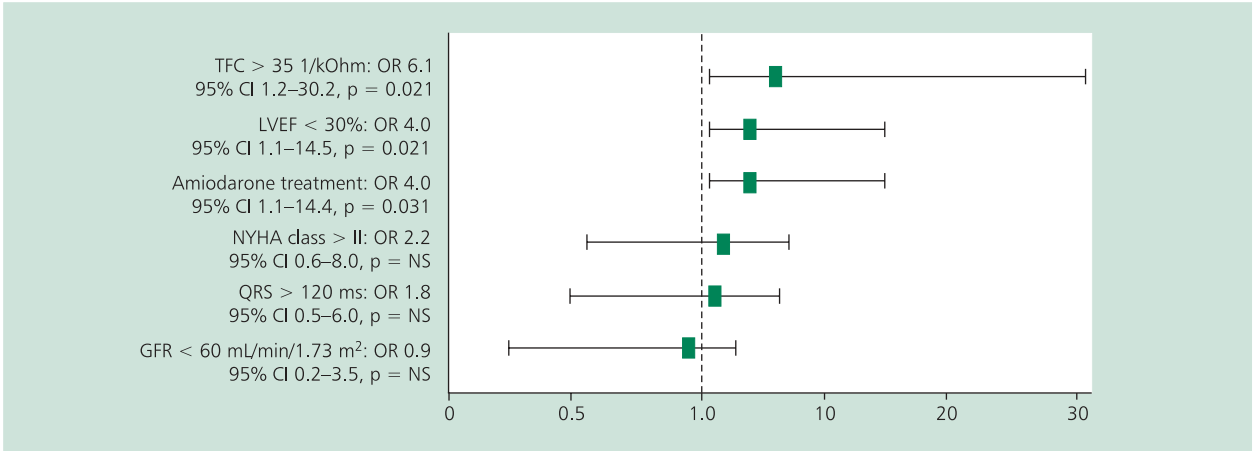

Figure 1. The effect of selected parameters on the risk of high defibrillation threshold (odds ratio [OR] values based on univariate analysis); CI — confidence interval; GFR — glomerular filtration rate; LVEF — left ventricular ejection fraction; NYHA — New York Heart Association; TFC — thoracic fluid content

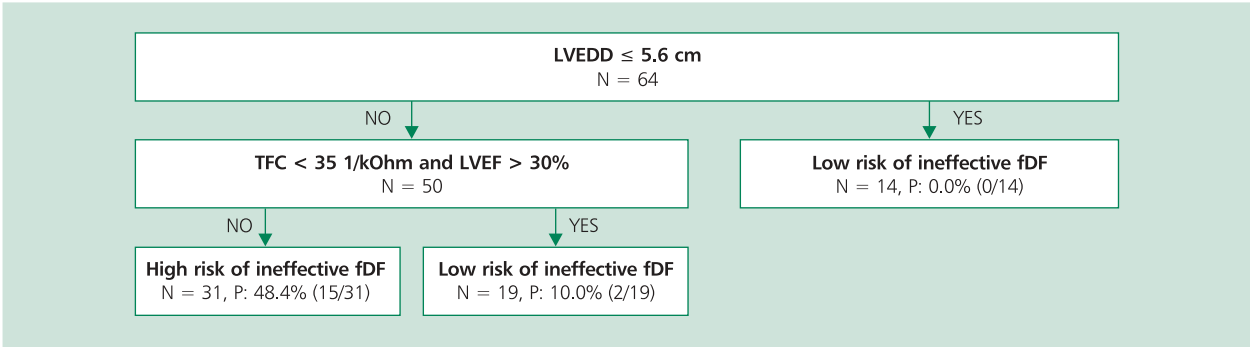

Figure 2. The suggested algorithm to identify patients at high or low risk of high defibrillation threshold; LVEDD — left ventricular end-diastolic diameter; LVEF — left ventricular ejection fraction; N — number of patients in a given subgroup; P — probability of ineffective first defibrillation (fDF); TFC — thoracic fluid content

Table 4. Comparison of false negative and false positive rates in predicting high defibrillation threshold

Parameter	Specificity [%]	Sensitivity [%]	AUC
LVEF ≤ 30%	55.3	76.5	0.659
TFC ≥ 35 1/kOhm	93.6	29.4	0.615
LVEDD > 5.6 cm	29.8	100.0	0.649
LVEDD > 5.6 cm and LVEF ≤ 30%*	66.0	76.5	0.712
Algorithm**	66.0	88.2	0.771

*Evaluation based on echocardiographic parameters only (without TFC); **As in Figure 2; AUC — area under curve; LVEF — left ventricular ejection fraction; LVEDD — left ventricular end-diastolic diameter; TFC — thoracic fluid content

Analyses of receiver operating characteristic (ROC) curves and area under curve (AUC) showed that the algorithm was significantly better at identification of patients with unsuccessful fDF than its component parameters analysed separately or the echocardiographic parameters only (Table 4, Fig. 3).

Taking into account the literature data regarding the effectiveness of deffibrilation in patients with CRT-D [8], we compared CRT-D(+) and CRT-D(–) subgroups and found significant differences only for LVEF (27.1 ± 7.4 *vs* 32.7 ± ± 10.0%, p = 0.026), SI (29.1 ± 7.7 *vs* 34.8 ± 8.8, p = 0.011),

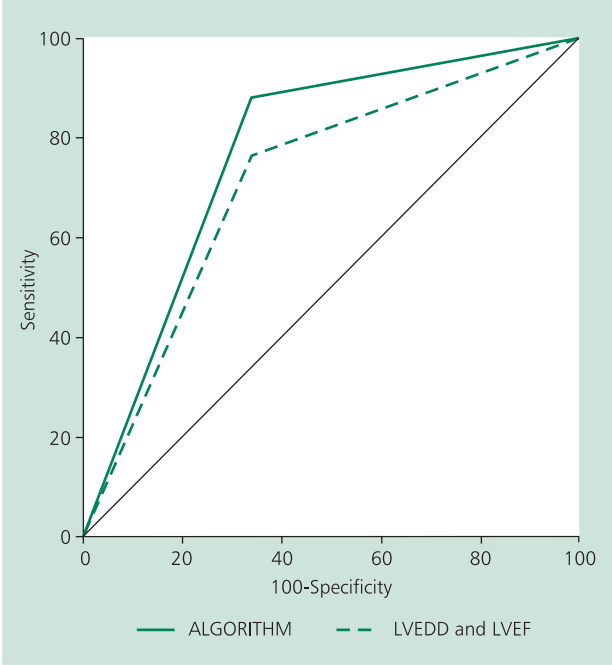

Figure 3. Receiver operating characteristic (ROC) curves for evaluation based on echocardiographic parameters only (LVEDD and LVEF) and for the algorithm including thoracic fluid content (ALGORITHM) in predicting risk of high defibrillation threshold; LVEDD — left ventricular end-diastolic diameter; LVEF — left ventricular ejection fraction

QRS width (171.2 ± 31.4 *vs* 122.1 ± 21.9 ms, $p < 0.00005$) and the frequency of NYHA class > II (n = 19, 86.4% *vs* n = 22, 52.4%, p = 0.007), but no differences in regard to the other analysed parameters including the success of fDF (n = 15, 68.2% *vs* n = 32, 76.2%, NS).

DISCUSSION

Frequency of ICD shocks significantly affects patient quality of life, and ineffective shocks increase the risk of adverse haemodynamic effects of prolonged arrhythmia. Debate continues regarding the value of testing these devices to determine safe and optimal DFT. There is no evidence that ICD testing itself affects long-term outcomes in these patients [9–11].

Lowest effective defibrillation energy undoubtedly depends on many factors that may be patient-related (such as patient clinical history, anatomopathologic characteristics, medications) or device-related (lead location and type, characteristics of the defibrillation impulse). Thus, identifications of variables that may be targeted by drug and device therapy, as well as identification of patients at increased risk of ICD testing complications seems to have particular importance.

Risk factors of high DFT

In our study, we showed that LV enlargement, low LVEF, high TFC and amiodarone treatment have a significant effect on ineffectiveness of low energy ICD shocks. The studied echocardiographic parameters were characterised by high sensitivity but low specificity of identifying patients at risk of ineffective fDF. Their significance as prognostic factors of high DFT has been proven previously [8, 12, 13]. Lubiński et al. [13] showed that LV enlargement (LVEDD > 5.8 cm: OR 2.1), low LVEF (LVEF < 40%: OR 1.9), height above 165 cm (OR 3.9) and periprocedural amiodarone treatment (OR 2.6) were significant predictors of ineffective defibrillation using < 15 J impulse. These observations of a high negative predictive value of normal LV dimensions are consistent with our findings, as none of our patients with LVEDD < 5.6 cm required a high energy defibrillation impulse.

Our study is the first report of haemodynamic evaluation using ICG in patients undergoing ICD testing. Thus, high predictive value of TFC, an indirect measurement of LV preload [14], seems to have particular importance. In previous studies, TFC was found to be a useful parameter in evaluation of chest volume status that is particularly helpful in differentiating causes of dyspnoea [15]. In a study by Packer et al. [4], TFC > 35 1/kOhm was found to be a clinically significant predictor of short-term HF exacerbation. Thus, ICDs of some manufacturers are currently equipped with an option of intrathoracic impedance measurement, generating alerts when a certain level of impedance is exceeded. This method was found to be effective in early detection of pulmonary congestion worsening [16] although it is limited by a significant rate of false positive results related to intrathoracic fluid retention due to non-HF causes (e.g. pneumonia). It was shown, among others, that changes in intrathoracic impedance may correlate with changes in LV volume and predict occurrence of ventricular tachycardia or VF [17, 18].

Based on these observations it is not surprising that some patients in the study group undergoing ICD implantation, although clinically stable, were characterised by increased intravascular volume in haemodynamic evaluation and probably required modification of drug therapy (most likely intensification of diuretic treatment). It is also possible that their hypervolaemia was a chronic condition that affected other measured parameters including LVEF and LVEDD. It is known that LV dilatation and impaired relaxation are significant risk factors of ventricular arrhythmia [13, 18]. At the same time, a prerequisite of successful defibrillation is delivery of the electrical impulse to the largest possible LV mass [19]. For this reason, patients with enlarged LV are more often resistant to low energy DF, which was also observed in our study group. Strobel et al. [20] reported a significant dependence of LV geometry on preload and its reduction. In a study in pigs, they found that even short-term occlu-

sion of the vena cava inferior, resulting in reduced intrathoracic volaemia, leads to a significant DFT reduction. These results may explain an adverse effect of high TFC on effectiveness of defibrillation.

Both literature data and our own experience show that TFC is a modifiable parameter that may be easily reduced by intensification of diuretic treatment. This is an important clinical observation, as preload reduction in some patients may contribute to improved LV haemodynamic function, decreased LV size and reduced risk of arrhythmia.

Careful analysis of the predictive value of selected haemodynamic parameters (LVEF, LVEDD, TFC) led to the development of a simple algorithm identifying patients at high risk of ineffective low energy defibrillation. Analysis of the ROC curves showed that inclusion of TFC in the algorithm increased its prognostic value, with higher sensitivity and larger AUC (Fig. 3, Table 4). Our algorithm defines a group of patients in which low energy defibrillation is likely to be successful. These are patients with (1) normal LVEDD; or (2) increased LVEDD with LVEF > 30% and TFC ≤ 35 1/kOhm. If a strategy of reducing indications for ICD testing were employed, these patients might be the first candidates to be exempted from such testing. Our algorithm also justifies the use of ICD with higher maximal defibrillation energy in the remaining patients in whom the risk of increased DFT approaches 50%. As noted by other authors [8, 18], such devices are larger and more expensive, and the decision to implant a specific device is irrevocable.

We intentionally did not include the effects of amiodarone on DFT in our detailed analysis of the probability of increased DFT. Data regarding the effects of amiodarone on DFT are inconsistent and hotly debated. Our findings are supported by some other [13] but not all reports [8, 18]. Undoubtedly, clinical indications for amiodarone treatment are so important that the observed phenomenon should not serve as a justification for a decision to withhold such therapy. However, as noted by Lubiński et al. [13], if amiodarone treatment is started in a patient with ICD, device testing should be considered after the drug loading.

In our study group, we did not observe any relationship between the effectiveness of defibrillation and other haemodynamic parameters, anthropometric parameters, GFR, QRS width, statin treatment, or NYHA class, although some of these parameters had been reported to have a significant effect on DFT [8, 13]. These discordant findings may be related to differences in regard to the patient clinical characteristics in various studied populations.

Limitations of the study

One limitation of our study was low number of patients in subgroups, particularly patients with TFC > 35 1/kOhm (n = 8), although this parameter was found to have large statistical power. When interpreting results, one should take into account variation within the study group regarding gender, concomitant disease and the type of implanted device, although there is no evidence that patients with CRT-D differed from patients with ICD in regard to other parameters than those related to indications to CRT (low LVEF, wide QRS).

CONCLUSIONS

1. Risk factors of high DFT in patients with ICD include low LVEF, increased LVEDD, higher TFC, and amiodarone treatment.
2. Adding TFC measurement by ICG to the clinical evaluation increases the efficacy of identification of patients at risk of high DFT.
3. Evaluation of long-term predictive value of the studied parameters requires further follow-up in a larger group of patients.

Conflict of interest: *none declared*

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Czy ocena hemodynamiczna metodą kardiografii impedancyjnej u chorych z niewydolnością serca poddawanych testowaniu wszczepionego kardiowertera-defibrylatora ma znaczenie kliniczne?

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Streszczenie

Wstęp: Istnieją sprzeczne doniesienia dotyczące wpływu impulsu elektrycznego wywołanego wyładowaniem kardiowertera-defibrylatora (ICD) na hemodynamikę układu sercowo-naczyniowego, a identyfikacja czynników sprzyjających wysokiemu zapotrzebowaniu na energię defibrylacji (DFT) oraz wyłonienie grupy chorych odnoszących największą korzyść z testowania DFT wydaje się mieć istotne znaczenie kliniczne. Testowanie funkcji ICD, pozostające standardowym postępowaniem po jego wszczepieniu, stanowi optymalną okazję do oceny klinicznej zjawisk hemodynamicznych związanych z defibrylacją. Kardiografia impedancyjna (ICG), jako nowoczesna metoda nieinwazyjnego monitorowania, może stanowić narzędzie oceny chorych z niewydolnością serca (HF), w tym indywidualnej odpowiedzi hemodynamicznej na defibrylację.

Cel: Celem pracy była ocena czynników ryzyka wysokiego DFT w czasie testowania funkcji ICD z zastosowaniem monitorowania metodą ICG.

Metody: Badanie przeprowadzono u 69 kolejnych chorych (średni wiek 62,7 ± 9,5 roku) z HF w I–III klasie wg NYHA, poddawanych testowaniu funkcji ICD wszczepianego w ramach prewencji wtórnej i pierwotnej nagłego zgonu sercowego (SCD). Jednostkę ICD implantowano w lewej okolicy podobojczykowej. Stosowano elektrody defibrylujące jednozwojowe, które wprowadzano w okolice koniuszka prawej komory, a DFT oznaczano, stosując uproszczony test o wzrastającej energii 15 J, 25 J i trzecie wyładowanie z ICD energią maksymalną 35 J lub 40 J. Ocenie echokardiograficznej poddano: frakcję wyrzutową lewej komory (LVEF), wymiar lewego przedsionka (LA) oraz wymiar końcoworozkurczowy lewej komory (LVEDD). Wszystkie pomiary ICG wykonywano za pomocą urządzenia Niccomo (Medis, Niemcy) z uwzględnieniem parametrów hemodynamicznych, takich jak: wskaźnik rzutu serca (CI), wskaźnik wyrzutowy (SI), zawartość płynu w klatce piersiowej (TFC), systemowy opór naczyniowy (SVRI).

Wyniki: Pierwsza defibrylacja (fDF) była skuteczna u 47 (73,4%) pacjentów. Zależnie od skuteczności fDF chorych podzielono na dwie grupy: osoby, u których była ona skuteczna [grupa fDF(+): n = 47; 73,4%] oraz osoby wymagające ponownych wyładowań wyższą energią defibrylacji [grupa fDF(–): n = 17; 36,6%]. W analizie porównawczej chorzy wymagający zastosowania wyższej energii charakteryzowali się m.in. większym LVEDD (LVEDD ≥ 5,6 cm: 100,0% *vs* 70,2%; p = 0,01), niższą LVEF (LVEF < 30%: 76,5% *vs* 44,7%; p = 0,024), większą wartością TFC (TFC ≥ 35 1/kOhm: 29,4% *vs* 6,4%; p = 0,014) i częstszym stosowaniem amiodaronu (41,2% *vs* 14,9%; p = 0,025). W analizie jednoczynnikowej istotne znaczenie w prognozowaniu wystąpienia wysokiego DFT miały: podwyższona wartość TFC (OR 6,1; p = 0,021), niska LVEF (OR 4,0; p = 0,021) i stosowanie amiodaronu (OR 4,0; p = 0,031). Uwzględniając powyższe analizy, opracowano algorytm identyfikacji chorych wysokiego i niskiego ryzyka nieskuteczności fDF, z uwzględnieniem wartości kryterialnych TFC, LVEF i LVEDD o wysokiej wartości predykcyjnej (AUC 0,771).

Wnioski: W przedstawionej pracy wykazano, że istotny wpływ na nieskuteczność wyładowania niską energią mają: powiększenie LV, niska LVEF, wysoka wartość TFC i leczenie amiodaronem. Ocena hemodynamiczna chorych poddawanych testowaniu funkcji ICD jest pierwszą taką próbą kliniczną. Dlatego też szczególnie wartościowa wydaje się obserwacja dotycząca wysokiej wartości predykcyjnej wskaźnika TFC, który pośrednio charakteryzuje obciążenie wstępne LV. Jak wskazują badania i doświadczenia własne autorów pracy, TFC jest parametrem modyfikowalnym, a jego istotne obniżenie łatwo uzyskać, intensyfikując leczenie moczopędne. Dokładna analiza wartości predykcyjnej wybranych parametrów hemodynamicznych (LVEF, LVEDD, TFC) pozwoliła określić prosty algorytm identyfikacji osób wysokiego ryzyka nieskuteczności defibrylacji małą energią. Wynik przedstawionej pracy wskazują, że u chorych z ICD/CRT-D kardiografia impedancyjna może być metodą przydatną w prognozowaniu wysokiej DFT.

Słowa kluczowe: niewydolność serca, kardiowerter-defibrylator, kardiografia impedancyjna

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