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Identifying Parameters Associated with the Use of Higher Discharge Energy in Electrical Cardio version for Persistent Atrial Fibrillation

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Abstract

Background: Direct current cardioversion (DCCV) is a safe and effective method of terminating persistent atrial fibrillation (AF) and recovering sinus rhythm (SR) rapidly.

Aims: This study aimed to identify the effectiveness of DCCV in patients with persistent AF and the descriptors that drive cardiologists to use higher discharge energy. In addition, whether these parameters are associated with greater DCCV efficacy was also assessed.

Methods: After a retrospective analysis of all consecutive DCCVs performed for persistent AF, we performed a multivariate analysis of factors associated with the choice of higher energy DCCV and the efficacy of DCCV in acutely achieving sinus rhythm.

Results: A total of 1853 DCCVs were performed in 1264 patients during the study period with a diagnosis of persistent AF. Applying one to three DCCV discharges in one series achieved SR in 89.6% of procedures. The mean energy of the DCCV was 119.0 J. The multivariate analysis then looked for parameters used by cardiologists to select DCCV energy higher than the median DCCV energy in our cohort. As a result, patient weight ($P<0.0001$) and amiodarone use ($P=0.0069$) were significantly associated with the choice of higher energy. However, in multivariate analysis, none of the examined parameters emerged as a potential predictor of success.

Conclusions: DCCV remains an effective method for the acute attainment of SR. In addition, cardiologists in this cohort subconsciously considered patient weight and amiodarone use as parameters for selecting higher energy for the first shock during DCCV. However, the multivariate analysis of patient outcomes did not support this practice for persistent AF.

Introduction

Direct current cardioversion (DCCV) is an integral part of a comprehensive approach to achieving and maintaining sinus rhythm (SR) in patients with atrial fibrillation (AF). It has undergone many technological and methodological changes since it was first described in 1962 [1]. Based on robust evidence, we now know the following: the adequate anticoagulation is required to prevent thromboembolic [2] and bleeding [3] complications; DCCV is safe after exclusion of left atrial appendage thrombus by adequately indicated transesophageal echocardiography [3]; how sedation/anesthesia should be managed during DCCV [4,5]; pharmacological therapy before DCCV increases the chance of achieving and maintaining SR [6,7]; in addition to the duration of AF [8,9], a measurement of functional and anatomical parameters of the atria is the most helpful factor in predicting the success of DCCV (right atrial emptying fraction is a better predictor of success in achieving and maintaining sinus rhythm than left atrial emptying fraction; similarly, right atrial size/volume is a better predictor of sinus rhythm than these parameters for the left atrium) [10,11]. Furthermore, the presence of comorbidities reduces the long-term maintenance of SR [12,13], including diabetes mellitus [14], left ventricular diastolic dysfunction [15], amyloidosis [16,17], and Fontan palliation in congenital heart disease [18].

For some factors, the published evidence is more ambiguous. Therefore, it requires further research [19], including the effect of patient

Key Words

Amiodarone, Atrial Fibrillation, Electrical Cardioversion

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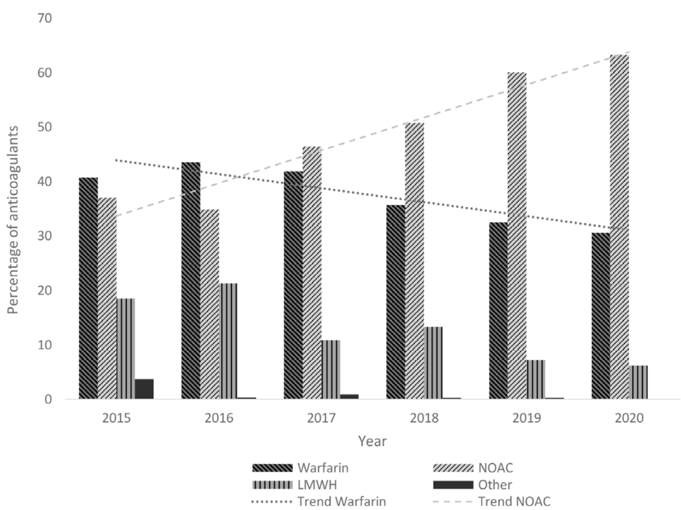

Figure 1: Types of anticoagulants in patients with atrial fibrillation by year

height and weight on DCCV success [8,9,20], antiarrhythmic pretreatment [7,21,22], and DCCV energy selection strategies [23,24]. Therefore, in this study, we focused on analyzing the factors that predict the DCCV energy choice strategy and whether this strategy is effective. The main long-term goal is to bring evidence-based data to develop an algorithm to minimize the shocks while increasing success in the future.

Methods

Patient selection

This study retrospectively analyzed consecutive DCCVs performed in a tertiary cardiac center over an uninterrupted period of 49 months. A total of 1896 procedures in 1366 patients were assessed. Only DCCVs due to persistent AF were included in the analysis, which yielded 1853 DCCVs in 1264 patients.

DCCV workflow

The cardiology consultant is responsible for the indication and preparation of the patient for DCCV. The actual DCCV was performed by a dedicated team consisting of a nurse specializing in acute care and a cardiology resident under the supervision of a cardiology consultant. First, adequate anticoagulation therapy for 3-4 weeks before DCCV was verified right before the procedure. Then, deep sedation with etomidate was provided, along with midazolam and fentanyl. In the case of high periprocedural risk (i.e., BMI > 40 kg/m^2, history of sleep apnea, or difficulty in the previous DCCV), an anesthesiologist was mandated.

Without a clear recommendation regarding the algorithm for selecting the DCCV discharge energy in the Czech Republic and European Union, the cardiologist chooses the actual DCCV energy based on his/her experience. In the event of a failure of the DCCV to restore the SR, a second and possibly third DCCV discharge was applied sequentially at the cardiologist's discretion while ensuring adequate sedation.

DCCV was performed using paddles in an anterolateral configuration with manual pressure. A 12-lead ECG was recorded within minutes of the DCCV. The team monitored the patient's vital signs and consciousness for another 120 minutes, at which point the patient was discharged with further care arrangements.

Data collection

Heart rhythm at one minute after DCCV was recorded, and the presence of sinus rhythm or atrial fibrillation was further used for statistical analyses in this study.

Table 1: Characteristics of patients with atrial fibrillation

Parameter	Statistic	All DCCVs	Successful DCCVs	Unsuccessful DCCVs	P-value
Sex					0.0606
Male	n (%)	1199	1063 (88.7%)	136 (11.3%)	
Female	n (%)	654	598 (91.4%)	56 (8.6%)	
Age, years	Mean (SD)	67.1 (10.2)	67.1 (10.2)	66.6 (9.7)	0.2383
	Median (Q1 - Q3)	68 (61 - 74)	68 (61 - 74)	67 (60 - 74)	
	Min - Max	16 - 91	16 - 91	41 - 91	
Height, cm	Mean (SD)	173.0 (10.1)	173.0 (10.2)	173.1 (9.3)	0.9903
	Median (Q1 - Q3)	174 (166 - 180)	173 (166 - 180)	174 (168 - 180)	
	Min - Max	140 - 205	145 - 205	140 - 199	
Weight, kg	Mean (SD)	92.9 (18.5)	92.8 (18.3)	94.0 (19.6)	0.5202
	Median (Q1 - Q3)	92 (80 - 104)	92 (80 - 104)	92 (80 - 107)	
	Min - Max	42 - 182	42 - 182	52 - 158	
BMI, kg/m^2	Mean (SD)	30.9 (5.2)	30.9 (5.2)	31.3 (5.7)	0.4748
	Median (Q1 - Q3)	30 (27 - 34)	30 (27 - 34)	31 (27 - 35)	
	Min - Max	16 - 55	16 - 55	19 - 49	
Type of antiarrhythmic					0.5458
Propafenone	n (%)	320	292 (91.3%)	28 (8.8%)	
Sotalol	n (%)	182	162 (89.0%)	20 (11.0%)	
Amiodarone	n (%)	698	632 (90.5%)	66 (9.5%)	
Dronedarone	n (%)	13	12 (92.3%)	1 (7.7%)	
Other	n (%)	98	88 (89.8%)	10 (10.2%)	
None	n (%)	542	475 (87.6%)	67 (12.4%)	
Type of anticoagulant					0.1366
Warfarin	n (%)	674	608 (90.2%)	66 (9.8%)	
NOAC	n (%)	928	838 (90.3%)	90 (9.7%)	
LMWH	n (%)	217	184 (84.8%)	33 (15.2%)	
Other	n (%)	7	7 (100%)		
None	n (%)	27	24 (88.9%)	3 (11.1%)	

Percentages were calculated based on number of all DCCVs in the corresponding parameter. P-value was obtained by the chi-squared test for categorical variables. Wilcoxon p-value was obtained for continuous variables to compare successful and unsuccessful DCCVs.

Table 2: Successful DCCV and energy of the last shocks in patients with atrial fibrillation

Parameter	
Number of DCCVs	1853
Number of successful DCCVs after one shock	1428 (77.1%)
Energy of the successful DCCV shock, J	
Mean (SD)	119.0 (18.7)
Median (Q1 - Q3)	120 (100 - 120)
Min - Max	50 - 200
Number of successful DCCVs after one or two shocks	1604 (86.6%)
Energy of the last successful DCCV, J	
Mean (SD)	122.9 (22.5)
Median (Q1 - Q3)	120 (100 - 120)
Min - Max	50 - 200
Number of successful DCCVs after second shock	176
Energy of the second successful DCCV, J	
Mean (SD)	154.3 (26.1)
Median (Q1 - Q3)	150 (150 - 150)
Min - Max	100 - 200
Number of successful DCCVs after one, two, or three shocks	1661 (89.6%)
Energy of the last successful DCCV, J	
Mean (SD)	124.6 (24.4)
Median (Q1 - Q3)	120 (100 - 150)
Min - Max	50 - 200
Number of successful DCCVs after third shock	57
Energy of the third successful DCCV, J	
Mean (SD)	173.9 (25.6)
Median (Q1 - Q3)	170 (150 - 200)
Min - Max	120 - 200

The following procedural and clinical patient data were collected from the medical records in the hospital information system: sex, age, height, weight, BMI, type of arrhythmia, type of antiarrhythmic drugs, type of anticoagulant, and the energy of the first, second, and third DCCV shocks.

The study was approved by the Ethics Committee of Agel Trinec-Podlesi Hospital (EK125/20) and was conducted in accordance with the provisions of the Declaration of Helsinki. All patients signed an informed consent to participate in the registry.

Statistical analysis

Continuous variables are presented as means with standard deviation (SD), medians with 25% and 75% quartiles (Q1, Q3), and minimum and maximum. Categorical variables are summarized using absolute counts and percentages. The relationships between patient characteristics and DCCV success were examined using the Wilcoxon and Mann-Whitney U tests for continuous variables and the chi-squared test for categorical variables with a 5% alpha level for significance. All potential predictors of DCCV success and predictors of higher initial shock energy were assessed using univariate logistic regression. Odds ratios and 95% Wald confidence intervals are presented with P-values. Parameters significant at the 10% level of significance ($P < 0.1$) were included in a multivariate logistic regression model. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

Results

Of the 1264 patients with persistent AF evaluated in this study, 992 (72.9%) had one DCCV discharge, whereas 356 (28.2%) had multiple. Of the 1853 DCCVs, 1199 procedures were performed in men (64.7%) and 654 (35.3%) in women. SR was successfully achieved in 1661 (89.6%) DCCVs. Failure, and thus the persistence of AF, occurred in 192 (10.4%) DCCVs.

Table 1 summarizes the patient characteristics and DCCV success rates in various groups. The mean age was 67.1 (10.2) years, and the mean BMI was 30.9 (5.2) kg/m2. Amiodarone was the most commonly used antiarrhythmic drug (698 procedures, 37.7%). Supplementary Table S1 shows the percentage distribution of DCCVs by patient age; most were performed in older patients (34.2% of patients aged 70-79 years).

SR was achieved after the first discharge in 1428 procedures (77.1%) with a mean energy of 119.0 (18.7) J. Cumulatively, SR was restored after the second and third discharges in 1604 (86.6%) and 1661 (89.6%) patients, respectively. The mean discharge energies of the second and third discharges were 154.3 (26.1) and 173.9 (25.6) J, respectively (Table 2).

One hundred and ninety-two DCCVs were unsuccessful, with an average discharge energy of 155.8 (35.4) J. Potential predictors of DCCV success were evaluated using univariate logistic regression. Parameters significant at $P < 0.1$ included sex and use of antiarrhythmic medication (Table 3). However, no predictor emerged as significant from the multivariate logistic regression model (which accounted for interactions between parameters).

In the study population, the median energy of the first DCCV was 120 J. Subsequently, the parameters that led physicians to choose higher energies (i.e., higher than the median) for the first DCCV were examined to identify (subconscious) decision-making patterns. Potential predictors of selecting a higher initial discharge were assessed using univariate logistic regression, as shown in Table 4. The multivariate model, which accounts for interactions between parameters, is shown in Table 5. Weight and amiodarone use emerged as significant predictors of choosing higher initial discharge energy. Statistically, our data suggest that for every 10 kg increase above the average weight, the chance of the cardiologist choosing a higher energy DCCV was 22% greater. In addition, if the patient was taking amiodarone, the chance of the cardiologist choosing a higher energy DCCV was 41% greater than in a patient who was not taking amiodarone.

Typically, we perform 30-35 DCCVs monthly at our center. During 2020, however, the monthly mean dropped to 24.5 due to Covid-19. A detailed yearly analysis of DCCV is shown in Supplementary Table

Table 3: Univariate binary logistic regression of possible predictors of DCCV success in patients with atrial fibrillation

Parameter	Odds ratio	95% CI	P-value
Sex (female vs. male)	1.366	0.985 - 1.894	0.0615[a]
Age, years	1.006	0.991 - 1.020	0.4544
Height, cm	1.000	0.985 - 1.015	0.9628
Weight, kg	0.996	0.989 - 1.004	0.3858
BMI, kg/m²	0.986	0.959 - 1.014	0.3275
Any antiarrhythmics (yes vs. no)	1.338	0.977 - 1.834	0.0699[a]
Amiodarone (yes vs. no)	1.173	0.857 - 1.605	0.3202
Propafenone (yes vs. no)	1.249	0.821 - 1.902	0.2993
Sotalol (yes vs. no)	0.929	0.569 - 1.518	0.7700
Dronedarone (yes vs. no)	1.389	0.180 - 10.735	0.7528
Other (yes vs. no)	1.018	0.520 - 1.993	0.9583

[a]Significant at 10% significance level.

S2. The median energy of the first discharge was 120 J. Amiodarone use decreased slightly from 56% in 2016 to 47.6% in 2020. Supplementary Figure S1 presents the success rates for each year, and Figure 1 shows a persistent decline in coumarin anticoagulation as DOACs began to dominate treatment. The distribution of antiarrhythmic drugs by age category is described in Supplementary Table S3. Amiodarone dominated in all age categories.

Discussion

The main objective of this study was to describe the success rate of DCCV in our cardiac center and to define the patterns of cardiologists' behavior leading to the choice of DCCV energy. We also evaluated whether these patterns lead to success and were associated with higher SR achievement during DCCV.

The overall success rate of DCCV in achieving SR in this unselected cohort of persistent AF patients was 89.6%, and this success rate was stable over the years. Nearly 90% efficacy is comparable to published data [7,20,25]. However, published improvements may offer a chance for better results. For example, using higher biphasic discharge energy (up to 360 J) [24], reducing transthoracic impedance by higher pressure on the patches (up to 80 N) [20], applying DCCV energy at the end of expiration or performing DCCV in an orthogonal arrangement with two defibrillators and four patches [26], showed improved efficacy.

The mean energy of the first DCCV was 120 J, with a success rate of 77.1%. However, this energy was lower than recommended in publications, indicating the need to analyze new potential algorithms for selecting DCCV energy [23,24].: an automatic algorithm with strictly defined discharge values or an algorithm based on probabilistic predictions that calculate the energy from the assumed predictors. Nevertheless, the attending cardiologists often chose "higher than expected" energy in selected patients in our study, suggesting their decisions were driven by specific patterns of intuitive behavior.

Higher patient weight and amiodarone use in the studied cohort were associated with (subconscious) selection of higher energy for the first DCCV discharge. Published data on the impact of patient weight on DCCV effectiveness is controversial, and our findings confirm the controversy. Higher weight was not associated with lower DCCV efficacy in the multivariate analysis. In contrast, lower energy can be speculated to have been chosen for low-weight patients to minimize the potential complications associated with DCCV. However, published safety data have not confirmed this suspicion, especially when using the so-called maximum fixed algorithm (up to 360 J, three times the biphasic DCCV energy discharge in one procedure) [24].

The use of amiodarone in this study led physicians to choose higher energy. Again, the published data are inconsistent on this issue. On the other hand, due to its known adverse effects, amiodarone is prescribed to patients with more severe comorbidities, patients in whom the physician assumes class I antiarrhythmic drugs have a lower chance of achieving and maintaining the SR. This fact may have subconsciously led cardiologists to choose higher energy for the first discharge. However, multivariate analysis of DCCV in this cohort did not show a significantly higher efficacy of DCCV in achieving SR with amiodarone.

The "physician-based" choice of energy in DCCV needs to be replaced with a standardized algorithm (or protocol) that will not be solely based on the knowledge of the success predictors or physician`s experience and intuition, as shown in the study. The discrepancies between the CHESS study and the OAFCP study in designing an effective predefined step-by-step strategy for DCCV energy selection

Table 4: Univariate binary logistic regression of possible predictors of a higher energy of the initial shock in patients with atrial fibrillation

Parameter	Odds ratio	95% CI	P-value
Sex (female vs. male)	0.727	0.559 - 0.945	0.0170[a]
Age, years	0.985	0.973 - 0.996	0.0087[a]
Height, cm	1.018	1.006 - 1.030	0.0039[a]
Weight, kg	1.021	1.014 - 1.027	<0.0001[a]
BMI, kg/m²	1.062	1.039 - 1.086	<0.0001[a]
Any antiarrhythmics (yes vs. no)	1.484	1.118 - 1.969	0.0063[a]
Amiodarone (yes vs. no)	1.456	1.141 - 1.858	0.0025[a]
Propafenone (yes vs. no)	0.895	0.645 - 1.241	0.5058
Sotalol (yes vs. no)	1.073	0.720 - 1.597	0.7302
Dronedarone (yes vs. no)	0.399	0.052 - 3.078	0.3781
Other (yes vs. no)	1.010	0.590 - 1.728	0.9716

Higher initial shock is a shock above the median level (i.e., >120 J).
[a]Significant at 10% significance level.

Table 5: Significant predictors of a higher initial shock energy in patients with atrial fibrillation

Parameter	Odds ratio	95% CI	P-value
Weight, kg	1.223	1.146 - 1.304	<0.0001
Amiodarone (yes vs. no)	1.405	1.098 - 1.799	0.0069

Higher initial shock is a shock above the median (i.e., >120 J).

will probably require a multicenter, randomized trial to make a definitive decision and introduce an explicit algorithm for DCCV energy selection in the guidelines.

Conclusion

DCCV is a safe and effective method of acutely restoring SR in patients with AF. However, none of the demographic or clinical parameters validated in our study predicted the need to choose higher energy DCCV. In contrast to this finding, our multi-year patient cohort analysis confirmed that cardiologists subconsciously and erroneously chose DCCV energies in higher-weight patients and those taking amiodarone.

Limitations

A limitation of this study was that it was a single-center retrospective analysis. The retrospective approach was also a major limitation for the possibility of obtaining additional covariates, such as duration of atrial fibrillation before cardioversion, presence of diabetes mellitus, arterial hypertension, sleep apnea syndrome, ischemic heart disease, or previous catheter ablation for atrial fibrillation. All these parameters would have been important factors for multivariate analysis evaluating an association with both the choice of DCCV energy and the resulting efficacy, as they may have been causally related to the patient weight, amiodarone use or other studied variables.

The retrospective analysis also accounted for the absence of data showing whether patients in our cohort had previously undergone DCCV and whether energy and outcome of previous DCCV played a role in energy selection in the current cardioversion we studied.

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Conflict of Interest

None declared.

Supplementary Figure S1

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