Fast-track article

Initial energy for biphasic external electrical cardioversion of atrial fibrillation

Gennaro Miracapillo, Alessandro Costoli, Luigi Addonisio, Silva Severi

Division of Cardiology, Misericordia Hospital, ASL 9, Grosseto, Italy

Key words:
Atrial fibrillation; Cardioversion.

Background. **No international guidelines indicate the initial energy in biphasic external electrical cardioversion of atrial fibrillation (AF) actually. The aim of this study was to determine this value in order to find a reasonable compromise between the necessity of limiting tissue damage and of quickly restoring sinus rhythm as well.**

Methods. **Fifty-six consecutive patients with AF candidate to external electrical cardioversion were treated using adhesive anterior-posterior paddles and biphasic wave defibrillator Lifepack 12, with steps of 50 J. After 6 hours troponin I levels were measured.**

Results. **Thirty-four patients were cardioverted by 50 J (group A), 18 by 100 J (group B) and 3 by 150 J (group C). One patient was not cardioverted (success rate 98%). No significant differences were noted between groups A and B with regard to age, sex, weight, height, thoracic circumference, body mass index, body surface area, impedance, NYHA class, left ventricular ejection fraction, left atrial diameter, causes of heart disease, antiarrhythmic medications, and duration of current AF episode. No increase of troponin I levels occurred.**

Conclusions. **An initial shock of 100 J in the biphasic external elective cardioversion of AF is a valid and highly effective option. An initial shock of 50 J was effective in 61% of our population, and it is probably appropriated in patients with a lower weight and body mass index.**

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Address:

Dr. Gennaro Miracapillo

U.O. di Cardiologia
Ospedale
della Misericordia
Via Senese, 131
58100 Grosseto
E-mail: g.miracapillo@usl9.toscana.it

Introduction

According to international guidelines of external electrical cardioversion of atrial fibrillation (AF), the suggested initial energy should be 200 J when a monophasic shock waveform is used[1]. No guidelines indicate the first-choice energy in biphasic shock actually.

Several studies indicate the greater efficacy of biphasic shock waveform vs the monophasic one, the former requiring fewer shocks and a lower total energy delivered[2-4], with better success rates and a lower frequency of dermal injury.

The aim of this study was to determine the first-choice energy value for biphasic external cardioversion of AF in order to find a reasonable compromise between the necessity of limiting tissue damage and of quickly restoring sinus rhythm as well.

Methods

Patients enrolled were aged ≥ 18 years, hemodynamically stable and scheduled for elective cardioversion of AF.

AF was defined by the absence of organized atrial activity, presence of AF waves and irregular ventricular activity diagnosed by skilled cardiologists on a 12-lead surface ECG.

Exclusion criterion was the absence of informed written consent to the study.

Proper anticoagulation for AF of > 48 hour duration was required, according to international guidelines[1], as defined by either 3 weeks with an international normalized ratio (INR) ≥ 2.0 or intravenous heparin with transesophageal echocardiography[5] negative for left atrial thrombus. Anticoagulation was required for the 4 weeks after cardioversion.

Patients with AF of < 48 hour duration were treated with intravenous heparin from admission to cardioversion.

Transthoracic two-dimensional and Doppler echocardiography (Sequoia 512, Acuson) was performed before AF termination. The left ventricular ejection fraction was determined with the Simpson method and the left atrial size was measured at end-systole in the parasternal long-axis view.

Pharmacological cardioversion to sinus rhythm was attempted in all patients who

had no contraindications to antiarrhythmic drugs, before the procedure of external cardioversion. Amiodarone, propafenone and flecainide were recommended as first-choice antiarrhythmic drugs.

Identical cardioversion electrodes were used for all procedures (Quik-Combo, Medtronic Physio-Control). An anterior-posterior position was used, with the anode over the infrascapular area close to the spine and the cathode over the lower sternal border[6].

All cardioversions were performed with an identical defibrillator (Lifepack 12, Medtronic Physio-Control) that contained circuitry to deliver an impedance-compensated biphasic shock waveform. Impedance measurements were provided for each shock. All shocks were synchronized to the QRS complex on the surface ECG.

General anesthesia was at the discretion of the practitioner, although propofol was recommended.

Cardioversion was attempted with different pre-selected shock energies (50, 100, 150, 200 and 360 J) until cardioversion was obtained or the maximum step was reached. Successful cardioversion was defined by two consecutive P waves uninterrupted by AF occurring any time within 30 s of the shock.

All patients gave written informed consent before inclusion.

Cardiac troponin I levels were measured after 6 hours from the procedure, in order to evaluate eventual myocardial injury, as troponin I is a highly sensitive and specific marker of cardiac muscle damage[7].

Patients were followed up for procedure-related adverse events in hospital for 24 hours.

Continuous variables are presented as mean ± SD and analyzed with the two-tailed unpaired Student's t-test, analysis of variance and *post-hoc* Tukey test. Discrete variables are presented as percentage and analyzed with the χ^2 test or Fisher exact test. A p value of < 0.05 was considered as statistically significant. All calculations were made using an SPSS software package (version 12.0).

Results

The study enrolled 62 patients between March 2003 and February 2004. Six patients were excluded due to later assessment that the original rhythm was not AF, but atypical atrial flutter. Patients' characteristics and demographic data are reported in table I.

All patients were cardioverted but one: 34 at 50 J (group A), 18 at 100 J (group B), 3 at 150 J (group C). The cumulative success rate was 61% at 50 J, 93% at 100 J, and 98% at 150 J. The patient who was not cardioverted was a 79-year-old man suffering from AF for > 48 hours with a large left atrium (58 mm) and a moderate mitral regurgitation; cardioversion was attempted up to the last step (360 J, impedance 70 Ohm) without success.

Table I. Patients' characteristics and clinical demographic data.

No. patients	56
Age (years)	68 ± 11 (range 37-84)
Gender (M/F)	52%/48%
Weight (kg)	77 ± 13 (range 50-107)
Height (cm)	168 ± 10 (range 150-193)
Thoracic circumference (cm)	99 ± 9 (range 84-129)
Body mass index (kg/m^2)	27.4 ± 4.0 (range 20.8-38.2)
Body surface area (m^2)	1.87 ± 0.19 (range 1.46-2.31)
NYHA class	1.4 ± 0.7 (range 1-3)
I	66%
II	23%
III	11%
IV	0
Ejection fraction (%)	54 ± 8 (range 34-70)
Left atrial diameter (mm)	44 ± 6 (range 33-58)
Causes of heart disease	
None	19.2%
Valvular	44.2%
Hypertension	19.2%
Ischemic	11.5%
Idiopathic dilated cardiomyopathy	3.8%
Cor pulmonale	1.9%
Presence of valvular disease	
Mitral regurgitation	52.9%
Mechanical prosthesis	3.9%
Other	11.8%
None	31.4%
Presence of pacemaker	5.3%
Antiarrhythmic medication	
Amiodarone	65.5%
Propafenone	9.1%
Flecainide	1.8%
Beta-blockers	7.3%
Digoxin	1.8%
None	14.5%
Duration of current AF episode	
< 48 hours	30.4%
48 hours to 6 months	64.2%
6 months to 1 year	5.4%
> 1 year	0

AF = atrial fibrillation.

The total number of shocks was 84. The impedance of shocks at different steps of energy in the same patients showed no differences.

No significant differences were noted between groups A and B with regard to age, sex, weight, height, thoracic circumference, body mass index (BMI), body surface area, impedance, NYHA class, left ventricular ejection fraction, left atrial diameter, causes of heart disease, antiarrhythmic medications, and duration of current AF episode (Table II).

According to univariate analysis of variance and Tukey *post-hoc* test, group C showed no significant differences vs groups A and B with regard to the same variables except for impedance that was higher (83 ± 15 Ohm in group C vs 63 ± 10 in group A, $p = 0.003$, and 67 ± 8 in Group B, $p = 0.03$), but the number of patients in group C was too small (3 patients) to be correctly compared to groups A and B. From a clinical point of view, the 3 patients of group C were all females, heav-

Table II. Differences between group A and group B.

	Group A	Group B	p
No. patients	34	18	
Age (years)	69 ± 13	66 ± 9	0.38
Gender			
Male	18 (52.9%)	10 (55.6%)	0.10
Female	16 (47.1%)	8 (44.4%)	0.14
Weight (kg)	74.5 ± 11.4	81.3 ± 14.8	0.07
Height (cm)	168.5 ± 11.2	168.5 ± 6.9	0.99
Thoracic circumference (cm)	97.2 ± 8.2	101.2 ± 9.2	0.19
Body mass index (kg/m^2)	26.5 ± 3.6	28.6 ± 4.3	0.08
Body surface area (m^2)	1.85 ± 0.2	1.91 ± 0.2	0.27
Impedance (Ohm)	63 ± 10	67 ± 8	0.12
Troponin I (ng/ml)	0.03 ± 0.0	0.01 ± 0.0	0.38
NYHA class	1.5 ± 0.8	1.2 ± 0.4	0.09
I	21 (61.8%)	14 (77.8%)	0.06
II	8 (23.5%)	4 (22.2%)	0.29
III	5 (14.7%)	0	*
IV	0	0	*
Ejection fraction (%)	54 ± 9	55 ± 7	0.60
Left atrial diameter (mm)	44 ± 7	44 ± 6	0.68
Causes of heart disease			
Valvular	16 (47.1%)	8 (44.4%)	0.14
Hypertension	4 (11.8%)	5 (27.8%)	0.34
Other	6 (17.6%)	3 (16.7%)	0.36
None	8 (23.5%)	2 (11.1%)	0.40
Antiarrhythmic medication			
Amiodarone	23 (67.6%)	11 (61.0%)	0.07
Other	6 (17.6%)	4 (22.3%)	0.29
None	5 (14.7%)	3 (16.7%)	0.40
Duration of current AF episode			
< 48 hours	14 (41.2%)	3 (16.7%)	0.31
48 hours to 6 months	19 (55.9%)	13 (72.2%)	0.07
6 months to 1 year	1 (2.9%)	2 (11.1%)	0.60

AF = atrial fibrillation. * test not performed.

ier (85 ± 23 kg), smaller (168 ± 12 cm), had a longer thoracic circumference (109 ± 18 cm), a bigger BMI (29.8 ± 6.6 kg/m^2), and the duration of current AF episode was comprised between 48 hours and 6 months.

No complications were observed in any patient.

Post-procedure troponin I values resulted in the normal range (0.02 ± 0.05 ng/ml, range 0.0-0.17 ng/ml, normal values < 0.6 ng/ml) in all patients as well as there were no differences between troponin I values of groups A, B and C whose patients received cumulatively 50, 150 and 300 J respectively.

Discussion

Our study was planned to answer to the question of which initial energy should be delivered in biphasic external electrical cardioversion of AF. The American College of Cardiology/American Heart Association/European Society of Cardiology task force on practice guidelines for the management of patients with AF did not recommend specific biphasic shock energies and protocols[1].

Since the cumulative success rate in our series was 98% using 50 J steps up to 150 J, we can only debate about 50, 100 and 150 J shock delivery initial energies, whose respective cumulative success rates were 61, 93 and 98%. We cannot exclude that some patients could be successfully treated with < 50 J energies. On the other hand a more serious population than ours (worse ejection fraction, higher NYHA class, larger atrial dimensions, etc.) could need > 150 J to be cardioverted. Moreover, intermediate energy values were not tested, like for instance 75 J that could be equally effective.

We investigated which variables could identify those patients who might benefit most from an initial 50 J shock but none of the parameters reached the statistical significance, even if some of them were very near to a 0.05 cut-off, like weight (p = 0.07) and BMI (p = 0.08). We calculated the differences between these parameters using a two-tailed test (Table II). If a one-tailed test was planned in order to evaluate the superiority of one group vs another instead of the diversity, the statistical significance could be reached. In this case we could state that in group A weight and BMI were not significantly different from group B, but probably lower (p = 0.035 and p = 0.04, respectively).

Other subgroups of patients showed a favorable trend toward a 50 J cardioversion like those pre-treated with amiodarone and those in NYHA class I. Data about AF duration were contradictory, even if most patients of group B (cardioverted with 100 J) have had AF for > 48 hours. Probably the small number of patients undergoing this study makes these results not significant. These considerations were validated from a clinical point of view when group C was considered: these patients were heavier, had a higher BMI, a longer thoracic circumference, and a longer duration of AF current episode, but the number of patients considered in this group was too small to carry out a valid statistical test. Moreover we can confirm how few patients in NYHA class III and IV or with a duration of AF > 6 months were submitted to electrical AF cardioversion, probably due to the difficulties to maintain sinus rhythm in these patients after cardioversion, more than to the possibility of restoring it.

Transthoracic impedance showed no differences between groups A and B, while higher values were found in group C. An explanation to this fact is that we used a defibrillator that adjusts voltage and duration of the biphasic waveform according to body resistance. So impedance values are smoothed with no significant differences in those groups (A and B) where weight, BMI, thoracic circumference and body surface area are lower and lower energies are necessary.

Despite the described differences between groups A and B we are not able to indicate a precise cut-off of any variable in order to justify the use of 50 or 100 J as initial energy.

Since cumulative success rates of group A (50 J) and group B (100 J) were relatively high (61 and 93%) we can suggest the use of one of these steps as initial energy in order to find a good compromise between the benefit of using low energies and of performing cardioversion in a reasonable short time of general anesthesia. A very accurate selection of patients with a lower weight or a lower BMI or treated with amiodarone or in NYHA class I or with AF duration < 48 hours could benefit from a 50 J initial shock. On the other hand a 100 J initial shock could be highly effective with a shorter operative time.

Troponin I concentrations were always negative in all groups, also when three shocks were delivered, so myocardial damage was not demonstrated. Muscle damage due to electric injury is well known and was not investigated. The choice of a lower or higher step of energy delivery should not take into account a possible myocardial damage because it was not demonstrated using such low energies as 50 or 100 J or a combination of the two 50 and 100 J steps.

Since weight and BMI were near to statistical significance, the ratio between effective energy values and weight or BMI is another interesting point to investigate in order to estimate how many J/kg or J/(kg/m^2) could be delivered. In our series we find the following values: 0.95 J/kg (95% confidence interval 0.84-1.06) and 2.67 J/(kg/m^2) (95% confidence interval 2.37-2.97), but we think we should plan a more detailed protocol with more energy steps (25-50-75-100-125-150 J) to determine and to validate these ratios appropriately.

In conclusion, the present study cannot indicate an exact algorithm to predict initial energy for biphasic external electrical cardioversion of AF. We can propose the following suggestions: an initial shock of 100 J is a valid option since it was highly effective with a success rate of 93%; an initial shock of 50 J was effective in 61% of our population and it is probably appropriate in patients with low weight, low BMI, AF duration < 48 hours, NYHA class I, and pre-treated with amiodarone.

The ratio of 0.95 J/kg is a possible alternative that needs more studies to be evaluated.

No significant differences in impedance were observed between groups A and B. This is probably due to the use of a defibrillator that modifies shock voltage and duration according to the impedance registered at the beginning of discharge, minimizing the effects of different impedances. High values of impedance were recorded in group C, where 150 J were necessary to restore sinus rhythm, but the number of patients was too small for further considerations.

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