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External cardioversion of atrial fibrillation: comparison of biphasic vs monophasic waveform shocks

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Aims It is well established in transthoracic ventricular defibrillation that biphasic truncated waveform shocks are associated with superior defibrillation efficacy when compared with damped sine wave monophasic waveform shocks. The aim of this study was to explore whether biphasic waveform shocks were superior to monophasic waveform shocks for external cardioversion of atrial fibrillation (AF).

Methods and Results Fifty-seven patients in whom cardioversion of AF was indicated were randomized in this prospective study, to transthoracic cardioversion with either monophasic damped sine waveform shocks or biphasic impedance compensating waveform shocks. In the group randomized to monophasic waveform shocks (27 patients), a first shock of 150 J was delivered, followed (if necessary) by a 360 J shock. In the biphasic waveform group (30 patients), the first shock had an energy of 150 J and (if necessary) a second 150 J was delivered. All shocks were delivered in the anterolateral chest pad position.

Sinus rhythm was restored in 16 patients (51%) with the first monophasic shock and in 27 patients (86%) with the first biphasic shock. The difference was statistically significant ($P=0{\cdot}02$). After the second shock, sinus rhythm was obtained in a total of 24 patients (88%) with monophasic shocks and in 28 patients (93%) with biphasic shocks. No complication was observed in either group and cardiac enzymes (CK, CKmb, troponin I, myoglobin) did not show any significant changes.

Conclusion This study suggests that at the same energy level of 150 J, biphasic impedance compensating waveform shocks are superior to monophasic damped sine waveform shocks cardioversion of atrial fibrillation.
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Key Words: Atrial fibrillation, external cardioversion monophasic shocks, biphasic shocks.

Introduction

External electrical cardioversion is considered the technique of choice for the termination of long-lasting episodes of atrial fibrillation (AF)[1,2]. The reported success rates range from 67 to 90%[2–5] and are achieved at high energy levels (360 or 400 J). Most currently available external defibrillators are using monophasic damped sine waveform. For those patients who fail external cardioversion using these defibrillators, high-energy external[3] or low-energy internal cardioversion have been proposed as possible options[5,6].

Recent work in internal ventricular defibrillation[7,9] and internal atrial defibrillation[10] have shown that biphasic waveform shocks are superior to monophasic waveform shocks.The aim of this study was to explore if biphasic waveform shocks are superior to monophasic waveform shocks for external cardioversion of atrial fibrillation.

Methods

Patient population

In this prospective, randomized, single-centre study, patients in whom external cardioversion of AF was indicated between September 1998 and March 1999 were enrolled. Inclusion criteria were: (1) AF lasting more than 48 h either paroxysmal (current episode $\leq$7 days) or chronic (current episode >7 days)[11]; (2) absence of

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thrombus on the transoesophageal echocardiogram performed in all patients within 48 h prior to cardioversion; (3) a minimum of 4 weeks' anticoagulation with warfarin or a similar agent and an INR>2·5 or intravenous or subcutaneous heparin for $\geq$72 h according to the recommendations of the Working Group on Arrhythmias of the European Society of Cardiology[12]; and (4) informed consent to participate in the study under the approval of the Institutional Review Board. Evaluation of patients included history and physical examination, transthoracic echocardiogram to evaluate left ventricular function, left atrial size, posterior wall and septal thickness, as well as the presence and nature of structural heart disease. Patients with hyperthyroidism, patients under 18 years of age and pregnant women were excluded from the study. The randomized process used a series of 10 envelopes containing either monophasic and biphasic, and one envelope was opened by the nurse before each procedure to determine the technique to be used.

Study protocol

The monophasic damped sine waveform shocks were delivered by a Codemaster XL Hewlett Packard (Andover, MA, U.S.A.) from a 32 μF capacitor, a 50 mH inductor and a resistance of 10 Ohms. Shocks were R-wave synchronized.

Biphasic waveform shocks were delivered by a Forerunner AED (Agilent-Heartstream, Seattle, Washington, U.S.A.) via a 100 μF capacitor. The energy of 150 J is produced by adjusting the two phases of the biphasic waveform in accordance with the patient's thoracic impedance.

All shocks were delivered through adhesive patch electrodes (Hewlett Packard model 17494A) with a surface area of 83 cm^2 or the Agilent-Heartstream patch electrodes with a surface area of 100 cm^2 placed in the anterolateral position, i.e. apex and right infraclavicular thoracic area.

The cardioversion protocol included two shocks for each group. Patients randomized to the monophasic group received an initial shock of 150 J and (if necessary) a second shock of 360 J. In case of failure, the patient was crossed oved to the biphasic protocol. Patients randomized to biphasic waveform shocks received a first 150 J shock and (if necessary) a second 150 J shock. The energy of 150 J was selected as it is the highest energy that the defibrillator used could deliver. If both biphasic shocks failed, the patient was crossed over to the monophasic protocol.

A shock was defined as successful if sinus rhythm was restored for a period $\geq$5 min.

Statistical analysis

Variables were expressed as mean ± standard deviation. Univariate analysis involving Chi-square for categorical variables, and Student's t-test for continuous variables were performed to assess possible differences in patient characteristics in the two groups, and comparison between the variables of monophasic and biphasic waveform shocks was made using the Chi-square or the. A two-tailed value of $P<0{\cdot}05$ was considered statistically significant. All analyses were used with Statview software.

Results

Characteristics of patients

Fifty-seven patients fulfilled the inclusion criteria. The clinical characteristics of these patients are shown in Table 1. The age range was 34–87 years with a mean of 68 ± 11 years. There were 39 men and 18 women with a mean weight of 78 ± 14 kg (range 54–145). Heart disease was detected in 47 patients (82%) and included hypertension (n=19), valvular heart disease (n=16), coronary artery disease (n=8), dilated cardiomyopathy (n=3) and Tetralogy of Fallot (n=1). Ten patients (17%) had idiopathic AF. The monophasic and biphasic protocol groups were similar in terms of age, sex, weight, heart disease, left atrial diameter, left ventricular ejection fraction, type and duration of current AF episode, and antiarrhythmic medications.

Results of cardioversion protocols

Results are summarized in Table 2. The first 150 J shock was successful in restoring sinus rhythm in 16 of 27 patients (59%) with the monophasic protocol and in 26 of 30 patients (86%) with the biphasic protocol. The difference was statistically significant ($P=0{\cdot}02$). Following the second shock, eight additional patients in the monophasic protocol group and two patients in the biphasic protocol group had sinus rhythm restored. Following crossover, one additional patient in each group was successfully cardioverted. The cumulative efficacy of the two shocks in the monophasic group and the biphasic group was not statistically significant. No complication was observed in both groups. Cardiac enzymes did not show any significant changes.Total CPK had a mean of 60 ± 29 for the biphasic group vs 59 ± 36 in the monophasic group. There was no detectable level of troponin I in either group.

Discussion

A search of the literature showed that this is the first reported study to suggess that biphasic waveform shocks are superior to monophasic waveform shocks for atrial cardioversion. A study of Mittal *et al.*[13] in abstract form also suggests that biphasic waveform shocks are superior to monophasic waveform shocks for

Table 1 Clinical characteristics of patients

Characteristics	Biphasic	Monophasic
Number of Patients	30	27
Age (years, mean ± SD)	69 ± 10	66 ± 12
Range	(46–83)	(34–87)
Male/female (n)	22/8	17/10
Weight (kg, mean ± SD)	79 ± 14	77 ± 17
Range	(60–111)	(54–145)
Heart disease (n)	25 (%)	22 (%)
Hypertension	11	8
Coronary artery disease	6	2
Mitral or aortic valve disease	7	9
Dilated cardiomyopathy	1	2
Tetralogy of Fallot	0	1
None	5	5
Left atrial diameter (mm, mean ± SD)	46 ± 6	46 ± 6
Range	(35–60)	(35–62)
Left ventricular ejection fraction (mean ± SD)	0·58 ± 0·10	0·56 ± 0·11
Range	(0·35–0·75)	(0·35–0·70)
Type of AF (n)		
Paroxysmal (<7 days)	2 (5 days–36 months)	2 (5 days–24 months)
Chronic (<7 days)	28 (range)	25 (range)

Table 2 Results

Sinus rhythm restored for more than 5 min	Biphasic n=30 Number (%)	Monophasic n=27 Number (%)	Statistical significance
First 150 J shock	26 (86)	16 (59)	P=0·02
Cumulative results after second shock	28 (93)	24 (88)	ns
Cumulative results after crossover	29 (96)	25 (92)	ns

transthoracic cardioversion of AF. The present study found that at the same energy level of 150 J, biphasic impedance compensating waveforms are superior to monophasic damped sine waveforms for cardioversion of atrial fibrillation.

Biphasic truncated exponential waveforms have been shown to be associated with defibrillation thresholds lower than monophasic waveforms, and are now currently used in both ventricular and atrial implantable defibrillators[7]. In addition, biphasic waveforms designed to compensate for the variation in transthoracic shock impedance between patients, have been developed in external defibrillators for the treatment of ventricular fibrillation[8,9]. A large prospective multicentre study[10], which compared efficacy of a first shock of a 130 J impedance compensating biphasic waveform with a 200 J monophasic damped sine waveform, found that both waveforms were equally effective with a success rate of 86%. Dramatic ST segment changes suggestive of myocardial injury were observed in the same study after high-energy monophasic shocks but not after biphasic shocks.

The ability to cardiovert AF with one shock rather than using two or more shocks has several advantages. Firstly, the fewer the shocks and the lower the energy used, the less the negative inotropic effects of the shock[14]. This could be an important clinical consequence, perhaps even exacerbating heart failure in patients at risk. Secondly, anaesthesia often needs to be re-administered for a second shock, therefore increasing the risk of anaesthesia-related complications and discomfort for the patient. Thirdly, many cardioversion procedures are conducted in high-cost localities throughout the world, where charges are tallied in minutes for space and personnel used. The authors estimate that an additional 20 min was required to terminate AF in those that did not have sinus rhythm restored after the first shock. In the U.S.A., the charges for this extra time would increase cost of the procedure. A high success rate with biphasic waveform shock may decrease the need for internal cardioversion or the use of antiarrhythmic agents prior to external cardioversion[15].

Limitations of the study

An ideal protocol comparing monophasic with biphasic waveform shocks would be double blind and should use two defibrillators similar in all characteristics except for the waveform. Unfortunately, such defibrillators are not available. No external defibrillator using biphasic

waveform is at present approved for clinical use. However, this study suggests that such defibrillators may be available in the future.

The limited number of patients included in this single-centre study did not allow the authors to show significant differences in success rates between 150 J biphasic and 360 J monophasic. It is possible that a study which includes 200 patients in each limb, will show a significant difference between monophasic and biphasic protocol groups.

Conclusions

This prospective randomized single-centre study suggests that at the same energy level of 150 J, biphasic impedance compensating waveform shocks are superior to monophasic damped sine waveform shocks for cardioversion of AF. Further studies using external defibrillators with biphasic waveform shocks are warranted.

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