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CARDIOVASCULAR MEDICINE

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Objective: To compare the efficacy of cardioversion in patients with atrial fibrillation between monophasic damped sine waveform and rectilinear biphasic waveform shocks at a high initial energy level and with a conventional paddle position.

Design: Prospective randomised study.

Patients and setting: 227 patients admitted for cardioversion of atrial fibrillation to a tertiary referral centre.

Results: 70% of 109 patients treated with an initial 200 J monophasic shock were cardioverted to sinus rhythm, compared with 80% of 118 patients treated with an initial 120 J biphasic shock (NS). After the second shock (360 J monophasic or 200 J biphasic), 90% of the patients were in sinus rhythm in both groups. The mean cumulative energy used for successful cardioversion was 306 J for monophasic shocks and 159 J for biphasic shocks ($p < 0.001$).

Conclusions: A protocol using monophasic waveform shocks in a 200–360 J sequence has the same efficacy (90%) as a protocol using rectilinear biphasic waveform shocks in a 120–200 J sequence. This equal efficacy is achieved with a significantly lower mean delivered energy level using the rectilinear biphasic shock waveform. The potential advantage of lower energy delivery for cardioversion of atrial fibrillation needs further study.

External electrical cardioversion remains the technique of choice for restoring sinus rhythm in patients with persistent atrial fibrillation.¹ Most currently used external defibrillators deliver monophasic damped sine waveform shocks. However, it has been shown that a comparable or even higher rate of transthoracic cardioversion can be achieved with biphasic shocks.^{2,3} These studies assessed efficacy using step up protocols starting at low energy levels. However, 75% of the patients can be cardioverted successfully by the currently recommended 200 J initial energy level⁴ using monophasic shock waveforms. Our aim in this prospective randomised study was thus to compare the efficacy of monophasic and biphasic waveform shocks for cardioversion of patients with atrial fibrillation at this initial energy level, using a conventional paddle position.

METHODS

Patient population

Two hundred and twenty seven consecutive patients were enrolled in this prospective randomised single centre study

between August 2000 and January 2002. Criteria for inclusion were as follows: atrial fibrillation lasting more than 24 hours; a minimum period of medical treatment of three weeks with acenocoumarol or fenprocoumon, with an international normalised ratio (INR) of > 2.5 ; and absence of an intracardiac thrombus on a transoesophageal echocardiogram done within 24 hours of the cardioversion. Transthoracic echocardiograms were done in all patients within 30 days of the cardioversion in order to measure left atrial dimensions. Patients with untreated hyperthyroidism and pregnant women were excluded from the study. Patients who were cardioverted for arrhythmias other than atrial fibrillation (including atrial flutter) were not included in the analysis. Sixteen patients undergoing cardioversion for atrial fibrillation in the study period were excluded because of violation of the study protocol by the treating physician.

Protocol for cardioversion

Cardioversions were done under deep sedation using weight adjusted intravenous diazepam and etomidate in the postabsorptive state. Randomisation was achieved on the basis of the

Table 1 Clinical characteristics of the patients

	Monophasic	Biphasic	p Value
Number	109	118	
Female (%)	24.8	25.4	NS
Age (years)	59.9 (14.0)	59.6 (12.4)	NS
Height (cm)	176.4 (10.0)	177.9 (10.7)	NS
Weight (kg)	82.5 (19.8)	81.9 (20.8)	NS
Body mass index (kg/m ²)	26.5 (5.2)	26.5 (5.7)	NS
LA diameter (mm)	46.3 (8.4)	44.4 (8.9)	NS
Mean impedance (ohm)	68.5 (18.5)	80.1 (19.7)	NS
Impedance measured (n (%))	45 (41)	70 (59)	NS
Duration AF (days) (median (range))	41.0 (1–450)	20.5 (1–390)	NS
Duration AF unknown (n)	70	72	NS

Values are mean (SD) unless stated.

AF, atrial fibrillation; LA, left atrial.

Table 2 Drug treatment and underlying diseases in the patients

	Monophasic	Biphasic	
<i>Drug treatment</i>			
Digoxin	29 (27%)	13 (11%)	NS
Class Ic AAD	8 (7%)	13 (11%)	NS
β Blocker	18 (16%)	14 (12%)	NS
Class III AAD*	56 (51%)	75 (63%)	NS
<i>Underlying diseases</i>			
Valvar disease	19 (17%)	15 (13%)	NS
Lone AF	15 (14%)	25 (21%)	NS
Congestive HF	12 (11%)	11 (9%)	NS
Hypertension	12 (11%)	9 (7%)	NS
CAD	6 (6%)	5 (4%)	NS

*Sotalol or amiodarone.

AAD, antiarrhythmic drug; AF, atrial fibrillation; CAD, coronary artery disease; HF, heart failure.

patient's birthday. Patients born on an uneven day received a 200–360 J monophasic shock sequence; patients born on an even day received a 120–200 J biphasic shock sequence. Shocks were delivered by commercially available defibrillators. The monophasic damped sine wave shock was delivered by a Hewlett Packard M1722B defibrillator (Hewlett Packard Co, Andover, Massachusetts, USA) and the rectilinear biphasic waveform by a Zoll M series biphasic defibrillator (Zoll Medical Corporation, Burlington, Massachusetts, USA). Cardioversions were undertaken using an anterolateral paddle position, and were considered successful if sinus rhythm was restored for more than five seconds. Measurement of the shock impedance was given by the defibrillator.

Statistical analysis

Variables were expressed as mean (SD) or median (range) as required. Student's *t* test was used to compare continuous variables. A χ^2 test was done for comparison of non-dichotomous variables. A probability value of $p < 0.05$ was considered significant.

RESULTS

In the study period, 359 patients were cardioverted in our department. One hundred and thirty two were excluded from the analysis either because the cardioversion was done for atrial flutter or atrial tachycardia ($n = 116$), or because of violation of the protocol ($n = 16$). Using the above mentioned selection criteria, 227 patients were enrolled into the final analysis.

The clinical characteristics of the 227 patients who fulfilled the criteria for inclusion are listed in tables 1 and 2. The monophasic and biphasic groups were similar in age, sex distribution, body weight, height, body mass index, left atrial diameter, and antiarrhythmic drug treatment. The measured shock impedance showed no difference between the two groups. Shock impedance values were not available in all patients. Information about the duration of the atrial fibrillation was also not always available. In about half the patients where data were available, there was no significant difference in shock impedance and atrial fibrillation duration between the two groups.

Monophasic and biphasic shock efficacy

The comparisons of monophasic and biphasic shock efficacy are shown in fig 1. The first shock (200 J) was successful in 77 of 109 patients (71%) in the monophasic waveform group, and in 95 of 118 patients (81%) in the biphasic waveform group. This difference was not significant ($p = 0.08$). The cumulative success of two shocks was 106 of 118 patients (91%) for the biphasic waveform group (120 J and 200 J) and 98 of 109 patients (90%) for the monophasic waveform group (200 J and 360 J). Similar efficacy was achieved with a significantly lower mean delivered energy level ($p < 0.001$) using the biphasic shock waveform (159 J) compared with the monophasic shock waveform (306 J). There were no complications related to the method of anaesthesia used. In seven patients treated with the biphasic protocol there was early recurrence of atrial fibrillation within five seconds after the first (120 J) or second (200 J) shock. In the monophasic group early recurrence of atrial fibrillation occurred in three patients. These were all considered unsuccessful results. In one patient successfully treated with the biphasic protocol, recurrence of

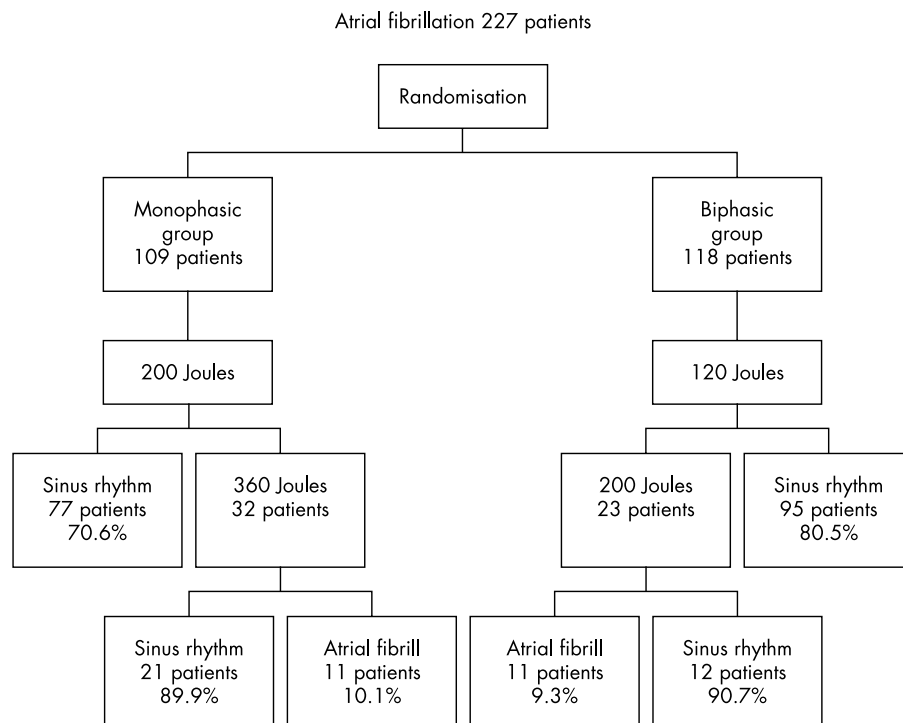


Figure 1 Study protocol and data on shock efficacy (%).

atrial fibrillation was noted after five seconds but within five minutes. This was considered as successful treatment.

DISCUSSION

In this study we could not confirm that cardioversion efficacy improves when biphasic shocks are used. The major finding of the study was that identical success rates can be achieved with monophasic and biphasic shock waveforms, selecting an initial energy level of 200 J and 120 J, respectively. As efficacy was similar with a lower delivered energy using biphasic shock waveforms, it seems necessary to investigate the potential clinical value of low energy cardioversion for patients with persistent atrial fibrillation.

Clinical value of the shock waveform

Biphasic shocks are more effective for endocardial defibrillation than monophasic shocks.^{5,6} For transthoracic ventricular defibrillation, biphasic and monophasic shocks are equally effective, but biphasic shocks require less energy for the same efficacy.⁷ A similar superiority for external cardioversion of atrial fibrillation has been reported recently by Mittal and colleagues using rectilinear biphasic waveform shocks.² Ricard and colleagues showed that for the same energy levels truncated exponential biphasic waveform shocks are superior in efficacy to monophasic waveform shocks.³ For defibrillation of ventricular fibrillation it was found that the ST segment 10 seconds after the shock was less impaired by biphasic waveform shocks than by monophasic waveform shocks in a study that included 297 patients.⁷

Biphasic waveform defibrillation produced less impairment of cardiac function as measured by echocardiography, arterial pressure, and recurrence of heart rate in a study using mechanically ventilated pigs.⁸ However, biochemical studies did not suggest any myocardial damage after cardioversion for atrial fibrillation.^{3,9,10}

Selection of the initial energy level

Based on a study by Joglar and colleagues,¹¹ it has been recommended¹² that a 100 J monophasic shock should not be used as the initial energy level for cardioversion of atrial fibrillation because of the relatively low success rate. Current recommendations^{13,14} suggest using higher initial energy levels because the success rate only becomes satisfactory at an energy level of 200 J or more (for monophasic waveforms), with a consequent decrease in cumulative delivered energy. According to the results of former studies with biphasic cardioversions, we hypothesised that a biphasic shock of 120 J may be as effective as a monophasic shock of 200 J.^{3,4} Indeed this study did not show any difference in first shock efficacy and cumulative efficacy between two step protocols using monophasic (200 J and 360 J) and biphasic (120 J and 200 J) shock waveform sequences for cardioversion. The advantages of low energy cardioversion are not yet proven, but it could have an important clinical impact. Furthermore we achieved a remarkable 90% overall success rate using biphasic low energy cardioversion. This may influence further strategic planning as it could reduce the need for internal cardioversion, an effective but invasive form of treatment.

Limitations of the study

Because different defibrillators were used, the study was not double blind. The number of patients was limited but relatively large compared with previous reports. Data were not complete regarding the duration of the current atrial fibrillation episode, a known predictor of successful cardioversion. Although we clearly demonstrated that equal efficacy could be

achieved with less delivered energy using biphasic shock waves, we did not attempt to assess its effect on atrial function, including differences in the development of atrial stunning.

Conclusions

For electrical cardioversion of atrial fibrillation, a protocol using biphasic waveform shocks in a 120–200 J sequence has the same efficacy as a protocol using monophasic waveform shocks in a 200–360 J sequence. This equal efficacy is achieved with a significantly lower mean delivered energy level in the rectilinear biphasic shock waveform. The potential advantages of a lower energy requirement for cardioversion of atrial fibrillation require further study in patients with persistent atrial fibrillation. However, as myocardial damage after cardioversion for atrial fibrillation has not so far been reported, there is no need for the immediate replacement of all defibrillators delivering monophasic waveform shocks.

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