

response.<sup>20</sup> Our group has previously found that, among patients with a history of sustained ventricular arrhythmia, patients with class Ia agent exacerbation during electrophysiologic testing had increased mortality and risk of sudden death at follow-up.<sup>2</sup> The present study is the first to evaluate the predictive value of provocative procainamide to identify patients at risk for future life-threatening arrhythmias who may potentially benefit from ICD therapy.

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## Comparison of Rectilinear Biphasic Waveform Energy Versus Truncated Exponential Biphasic Waveform Energy for Transthoracic Cardioversion of Atrial Fibrillation

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**Success rates of cardioversion with a defibrillator using the truncated exponential biphasic waveform (with a maximum energy of 360 J) and a defibrillator using the rectilinear biphasic waveform (with a maximum energy of 200 J) were randomly compared in 145 patients. Success rates at 50, 100, 150, and 200 J were not significantly different, but**

**2 patients who did not achieve cardioversion after a 200-J maximum energy shock by the rectilinear device underwent successful cardioversion with a 360-J shock by the truncated exponential device after crossover. ©2004 by Excerpta Medica Inc.**

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Until recently, external cardioversion has been performed using devices with a monophasic damped sine wave. With these devices, success rates for cardioversion were reported to be 70% to 90%.<sup>1-4</sup> With the advent of biphasic devices, higher success rates have been reported.<sup>1-4</sup> Different energy waveforms have been used in different biphasic devices, and the success rate for cardioversion may be different in

Variable	Truncated Exponential Group (n = 74)	Rectilinear Group (n = 71)	p Value
Age (yrs)	65 ± 14.8	64 ± 15.2	0.7
Men/women	40/34	44/27	0.33
Weight (kg)	83.7 ± 19.1	84.9 ± 20.5	0.72
Height (cm)	170.4 ± 10.9	173.5 ± 9.4	0.13
BSA (m <sup>2</sup> )	1.98 ± 0.25	2.01 ± 0.26	0.48
Duration of AF (d)	206 ± 512	165 ± 314	0.56
Cardiac diagnosis			
CAD	16	21	0.41
Valvular	5	15	0.03
Hypertension	3	2	0.65
Hypertrophic cardiomyopathy	2	3	0.65
Idiopathic dilated cardiomyopathy	4	3	0.71
Other	4	4	1
No known heart disease	23	8	0.1
Left atrial dimension (mm)	46 ± 11	45 ± 7	0.56
Left ventricular ejection fraction (%)	52 ± 14	53 ± 15	0.65
Antiarrhythmic drugs			
Class I	4	6	0.53
β blocker	33	43	0.25
Amiodarone	15	9	0.22
Sotalol	8	2	0.06
Other class III	1	1	1
Calcium channel blocker	21	21	1
Digoxin	23	19	0.54
Diuretics	21	20	0.88

BSA = body surface area; CAD = coronary artery disease.

Joules	Truncated Exponential Group (n = 74)	Rectilinear Group (n = 71)	p Value
50	54% (40)	61% (43)	0.43
100	84% (62)	79% (56)	0.45
150	92% (68)	93% (66)	0.81
200	97% (72)	97% (69)	0.97
360	97% (72)		

these devices.<sup>1,4</sup> In previous studies comparing monophasic and biphasic devices, a device using the rectilinear biphasic waveform appears to have a better success rate than a device using the biphasic truncated exponential waveform at similar energy levels.<sup>1,4</sup> However, we are not aware of published studies directly comparing the 2 biphasic waveforms in the same patient population. This study prospectively compares success rates of 2 devices using a rectilinear biphasic waveform or a truncated exponential biphasic waveform at various energy levels in the same patient population.

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During the study period, 145 patients were prospectively enrolled at our institution. Patients were eligible for this study if they were ≥18 years of age and were undergoing direct-current cardioversion for atrial fibrillation (AF). Patients with AF for ≥48 hours had to undergo anticoagulation with warfarin for ≥3 weeks to achieve an international normalized ratio of ≥2.0 before enrollment. Patients who had not undergone anticoagu-

lation for ≥3 weeks were treated with heparin and underwent transesophageal echocardiography before cardioversion, documenting the absence of a left atrial thrombus. Anticoagulation was continued for all patients for at least 3 to 4 weeks after cardioversion. Patients were excluded from the study if they were in atrial flutter or atrial tachycardia. The rectilinear biphasic waveform device used in this study was a Zoll Biphasic M (Zoll Medical Corporation, Burlington, Massachusetts) with a maximum energy level of 200 J. The truncated exponential biphasic device was a Medtronic Physio-Control Lifepak 12 (Medtronic Inc., Minneapolis, Minnesota) with a maximum energy level of 360 J. Self-adhesive cutaneous pads, either the Pro-Pad by Zoll or the Quik-Combo pads by Medtronic were used for cardioversion. These were placed on the anterior and posterior chest wall. Patients were sedated with morphine and midazolam before cardioversion. Their heart rate, rhythm, blood pressure, and oxygen saturation were monitored throughout the procedure. The study was approved by the institutional review

board of Montefiore Medical Center and informed consent was obtained from all patients.

Patients were randomized to either the truncated exponential biphasic or the rectilinear biphasic device. In both groups, the initial shock energy was 50 J. In the rectilinear biphasic group, if a 50-J shock was unsuccessful, the energy was increased progressively to 100, 150, and 200 J at 3-minute intervals until successful cardioversion was achieved. In the truncated exponential biphasic group, if the 50-J shock was unsuccessful, the energy was increased to 100, 150, 200, and 360 J at 3-minute intervals until successful cardioversion was achieved. If cardioversion was unsuccessful with the originally randomized device at the maximum energy level (200 J for the rectilinear biphasic device or 360 J for the truncated exponential biphasic device), the patient was crossed over to the other device and received a shock at the maximum energy level of that device. Successful cardioversion was defined as the restoration of sinus rhythm lasting >5 seconds after defibrillation.

Comparisons of dichotomous and continuous variables between the 2 groups were performed using the chi-square and *t* tests. The success rate of the first shock (50 J) and the cumulative success rates of the subsequent shocks at different energy levels were compared by Fisher's exact test. A *p* value <0.05 was considered significant.

The study enrolled 145 patients between October 1, 2000, and December 31, 2002. Patient enrollment was prospective, but nonconsecutive, because of refusal to participate in the study by patients or attend-

ing physicians. In addition, when 1 of the devices became unavailable to us during this period, patient enrollment was temporarily suspended. Of the 145 patients enrolled in the study, 74 were randomized to the truncated exponential biphasic group and 71 were randomized to the rectilinear biphasic group (Table 1). Patient characteristics are listed in Table 1.

The cumulative success rates of cardioversion in the 2 groups are listed in Table 2. There was no statistically significant difference in success rates between the 2 groups. In the rectilinear biphasic device group, 2 patients had unsuccessful conversion to sinus rhythm after the maximum energy shock of 200 J. They were crossed over to the other device and both achieved successful cardioversion with a 360-J shock by the device. In the truncated exponential biphasic group, cardioversion was unsuccessful with the maximum energy shock of 360 J in 2 patients. After they were crossed over, cardioversion was still unsuccessful in each of these patients with a 200-J shock with the rectilinear biphasic device. Patients in both groups tolerated cardioversion well. There were no significant complications associated with either of the biphasic shocks. Although skin burn was not evaluated systematically, no patient had more than a first-degree burn. No patient required hemodynamic support after cardioversion. There were no reported strokes within 30 days of cardioversion.

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The results of this study indicate that by using biphasic defibrillators AF was converted to sinus rhythm in 97% of patients by a transthoracic method. At the energy levels tested in this study, success rates were not significantly different between rectilinear biphasic and truncated exponential biphasic devices. Because the truncated device has a significantly higher maximum energy output (360 vs 200 J), there may be clinical situations in which the truncated exponential device can be used when the rectilinear device fails to restore normal cardiac rhythm. In our study, 2 patients who could not be successfully cardioverted with the maximum energy shock of 200 J by the rectilinear biphasic device were successfully converted to sinus

rhythm with the truncated exponential biphasic device.

In a study by Mittal et al,<sup>1</sup> monophasic waveforms were compared with rectilinear biphasic waveforms. The cumulative success rate with the rectilinear biphasic device using up to a 170-J shocks was 94%. In a study by Page et al<sup>4</sup> comparing monophasic and truncated exponential biphasic waveforms, the cumulative success rate of the truncated exponential biphasic device using up to a 200-J shocks was 90%. From these studies, it appears that success rates of the rectilinear biphasic waveform energy may be higher than those of the truncated exponential biphasic waveform energy. However, these studies were not direct comparisons of the 2 waveforms at the same energy levels in the same patient population. In our study, at all energy levels tested (50, 100, 150, and 200 J), success rates were not significantly different between the 2 devices.

A potential limitation of our study was that although the study was randomized and prospectively conducted, the relatively small sample size may have led to an unequal distribution of patients between the 2 groups. In addition, because of the small sample size, our study may not have had sufficient power to detect a difference between the 2 devices. Despite the limitations, there may be clinical situations in which the truncated exponential device, which has a significantly higher maximum energy output (360 vs 200 J), can be used successfully when the rectilinear device cannot restore normal rhythm, such as obese patients with AF or patients in ventricular fibrillation who are refractory to defibrillation attempts.

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