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Serum Troponin I Level after External Electrical Direct Current Synchronized Cardioversion in Patients with Normal or Reduced Ejection Fraction: No Evidence of Myocytes Injury

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Summary

Background: External electrical cardioversion (EEC) has been suggested as a cause of myocardial damage, but results from several previously published studies are conflicting.

Hypothesis: The purpose of the study was to evaluate myocardial electrical injury caused by EEC.

Methods: After elective EEC for atrial fibrillation (AF), cardiac troponin I (cTnI) was measured in 193 consecutive patients attending the Cardiology Department of the San Maurizio Hospital of Bolzano for elective EEC of AF over a period of 13 months. External electrical cardioversion was performed by one of the attending cardiologists with a synchronized monophasic defibrillator. Blood sample for cTnI was taken 18–20 h after EEC.

Results: Of 193 patients, 183 (95%) were successfully cardioverted. Mean number of shocks was 1.46 and the mean total energy discharged per procedure was 379.4 ± 229.2 J. Cardiac troponin remained under the limit of confidence for all patients with a mean value of 0.017 ± 0.021 mcrg/l. No correlation between total energy delivered and cTnI was found. In the subgroup of patients with low ejection fraction, none had elevated cTnI, and no difference in cTnI values between these and patients with an ejection fraction > 40% was found.

Conclusions: The results of our analysis indicate that EEC caused no myocardial injury even in patients with low ejection fraction.

Key words: atrial fibrillation, external electrical cardioversion, myocardial damage, ventricular function

Introduction

External electrical DC synchronized cardioversion (EEC) for atrial fibrillation (AF) has been suggested as a possible cause of minor myocardial damage, and postcardioversion complications secondary to cardiac myocytes injury, such as enlargement of left cavities, postcardioversion heart failure, or pulmonary edema, have also been reported.[1–3]

Many investigators have studied the effects of cardioversion on the cardiac muscle by measuring serum levels of the biochemical markers reflecting myocardial damage. Cardiac troponin I (cTnI) has been reported to be the most specific and sensitive among conventional markers; however, the effect of EEC on the level of cTnI has not been well established. Recently, several workers have reported the detection of a mildly elevated level of cTnI or transient ST-segment elevation in some patients after elective EEC for AF, implying myocardial injury could have been caused by this procedure.[4–8] Other studies showed no change in serum levels of either troponin I or T.[1, 9–14]

To our knowledge there has not been any study of sufficiently large size addressing the effects of EEC and myocardial damage. Moreover, most of the troponin studies have included clinically unstable patients with raised levels of the biochemical markers, and only a small proportion of patients with reduced ejection fraction (EF) was studied.

To evaluate myocardial electrical injury caused by EEC, we performed an analysis of cTnI after elective EEC for AF in a large number of consecutive patients.

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Methods

Patients

In all, 193 consecutive patients attending the Cardiology Department of the S. Maurizio Hospital, Bolzano, between May 1, 2001, and June 30, 2002, for elective EEC of AF were included in the study. Patients with hemodynamic instability or unstable angina were excluded. Renal failure has been shown to be associated with elevated levels of cardiac troponin. To avoid false positive cTnI, patients with moderate or severe renal impairment, defined as stage 3 or more according to American National Kidney Foundation classification,[15] were excluded. In patients with previous myocardial infarction or cardiac surgery, EEC was carried out at least 1 month after the event. Statistical analysis was performed on the entire group of patients, and a subgroup analysis was conducted in those with an EF < 40%. The study complied with the Declaration of Helsinki and the local ethical committee approved the conduct of the research.

External Electrical Cardioversion

External electrical cardioversion was performed by one of the attending cardiologists. The sequence and the number of shocks delivered were at discretion of the individual attending physician. The EECs were performed in the morning using a protocol of increasing shock energies, until either sinus rhythm was achieved or the maximum energy of 360 J was reached. We used a conventional synchronized monophasic defibrillator (Code Master, Hewlett Packard Company, Andover, Mass., USA). Wet polymer gel pads (3M Health Care, St. Paul, Minn., USA) for transthoracic cardioversion were applied to the right parasternal area and the apex. In patients with a pacemaker, the pads were applied to the right parasternal area and the left scapula posteriorly and connected to the defibrillation unit. The surface of each electrode was 85 cm^2 for the anterolateral position and 115 cm^2 for the anteroposterior position.

Patients were preoxygenated with 100% O^2 for 1–2 min prior to induction of general anesthesia with intravenous propofol (2 mg/Kg). Successful cardioversion was defined as the conversion of AF to sinus rhythm for > 1 min after the shock.

Cardiac Troponin I

Blood sample for cTnI was taken 18–20 h after EEC by drawing 5 ml of blood into a tube with anticoagulant (EDTA) as cTnI release was reported to be maximal during this interval after myocardial damage.[9, 16] Cardiac troponin I was analyzed immediately after the sample was taken using a 1-step immunoenzymometric assay (Access Immunoassay System TpnI 33320, Beckman Coulter, Inc., Fullerton, Calif., USA). Detection limit for this assay is < 0.15 mcrg/l in healthy donors.

Transthoracic Echocardiography

Transthoracic echocardiography was performed the day after EEC according to the international guidelines of the American Society of Echocardiography.[17] The modified Simpson's method was used to calculate volumes and EF of the left ventricle. We measured left and right atrial volumes from the apical four-chamber view with the length-area method. All measurements were taken by the same observer, who was blinded to the results of the cTnI. We used an HP machine Sonos 5500 (Hewlett Packard), and the images were digitally stored on a magneto-optical disk.

Statistical Analysis

Data were analyzed using Microsoft excel version and the statistical program, Analyse-it (Microsoft Excel, Leeds, UK). Means, medians, and standard deviations were calculated for continuous variables. Means were compared using the two-tailed Student's test. For comparing categorical variables, the chi-square test was used. A two-sided p value < 0.05 was considered statistically significant.

The association between shock strength and the myocardial marker was determined by the Spearman rank correlation coefficient.

After testing the correlation between echocardiographic parameters and the values of cTnI by the Spearman rank correlation test, agreement between the parameters showing significant correlation and the cTnI values was analyzed using the Passing & Bablok regression method. The Cusum test for linearity was used to assess the kind of relationship between them.

Results

Clinical characteristics of the patients are shown in Table I. In all, 193 consecutive patients (mean age 67.3 ± 9.5 years) underwent cardioversion and blood sampling during the study period.

Of 193 patients, 183 (95%) were successfully cardioverted and 10 of these went back into AF almost immediately. The position of the electrodes had no significant impact on the success rate of EEC.

Patients received between one and three shocks; the mean number of shocks was 1.46 ± 0.66, with a maximum number

TABLE I Clinical features of the study group

Men/female (%)	114/79 (59.1/40.9)
Age (years)	67.3 ± 9.5
Body surface area (m^2)	1.9 ± 0.2
Underlying cardiopathy	
None (%)	14 (7.3)
Valvular (%)	35 (18.1)
Ischaemic (%)	17 (8.8)
Hypertensive (%)	109 (56.4)
Cardiomyopathy (%)	4 (2.1)
Other (%)	14 (7.3)

of three shocks per procedure. The first shock was successful in 124 (64.2%) of the patients. The total energy discharged per procedure was 379.4 ± 229.2 J (range 148–1173 J). Only two patients received total shock energies > 1000 J.

Cardiac troponin I remained under the lower limit of confidence for all patients included in the study, with a mean value of 0.017 ± 0.021 mcrg/l. There was no correlation between the total energy delivered and cTnI.

There were 17 patients with an EF < 40%. No difference in cTnI values was found between patients with low EF and those with an EF > 40%. However, within normal range, we found a significant correlation between levels of cTnI and left ventricular (LV) end-diastolic volume ($p < 0.01$), end-systolic volume ($p < 0.01$), and EF ($p < 0.01$). The Passing and Bablok test showed a significant inverse relation between EF and cTnI values with a nonlinear relationship between the parameters. On the other hand, a direct relationship was found between LV volumes and cTnI levels. The regression equation between EF and cTnI is shown in Figure 1.

Discussion

Our data on cTnI do not support the notion that EEC causes myocardial injury in patients with normal EF. Similar observation is also noted in our 17 patients with low LV EF. However, further investigations on patients with reduced cardiac function are needed because their number included in our study was small.

Cardiac troponin I has been reported to be the most specific and sensible among conventional markers for evaluating myocardial damage. It is specific to the myocardial cell and is not expressed in skeletal muscle after birth.[17] It is released within the first few hours after onset of myocardial damage and peaks at 12 to 24 h from onset. Elevated level of cTnI could be detected up to 7 days after myocardial damage, and this phenomenon, coupled with the enormous increase of its serum concentration far above the detection limit, renders the test highly sensitive and thus ensures the detection of minimal myocardial cell injury. The baseline levels of cTnI in the circulation appear to be either extremely low or zero in normal healthy individuals.[18] The results of our analysis indicate that EEC up to three energy applications caused no myocardial injury even in patients with low LV EF.

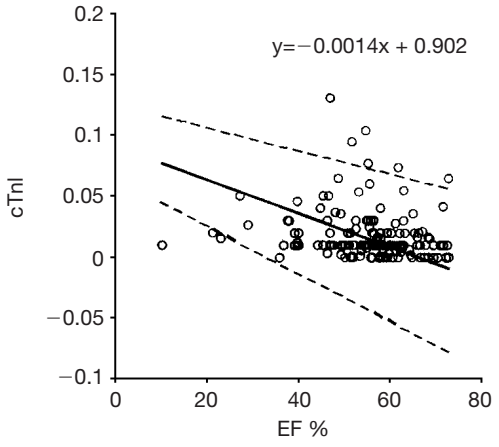

FIG. 1 Relationship between left ventricular ejection fraction (EF) and cardiac troponin I (cTnI).

To our knowledge, this is the first study that includes a large population and addresses the effects of EEC and myocardial damage. Previous studies were conducted in a small number of patients, and inclusion/exclusion criteria often were not strict; our results confirm those described in some previous studies.[1, 9–14] On the other hand, our findings are discordant with those of other studies involving smaller series of patients, demonstrating the presence of mild myocardial injury in some patients after elective EEC for AF.[4–8] Differences in inclusion criteria may account for the discrepancies in the observed conclusions. In fact, most of the cTnI studies showing an increase in this biochemical marker after EEC included clinically unstable patients, who could have had a rise of cTnI for other reasons such as myocardial ischemia. To avoid any confounding factor and false positive cTnI levels after EEC, our exclusion criteria were very strict.

The findings of our study have resulted in a change in the way EEC is now performed at our center. In the past, we had started EEC with a 150 or 200 J shock, gradually increasing the energy up to 300 and 360 J if sinus rhythm was not restored.[19] As we have established there is no myocardial damage after EEC, it is our current practice to start often with 300 J, especially in obese patients, resulting in a higher percentage of restoration of sinus rhythm after the first shock. Starting with high-energy shock would be preferable because most patients with AF typically need two or more lower-energy electrical shocks, culminating in the delivery of total energy of > 360 J. The new approach is also less time consuming. Some authors estimated, in fact, that an additional 20 min time was required to terminate AF in patients whose sinus rhythm was not restored after the first shock, with the consequent increase of cost for the procedure.[20] We did not actually experience such long delays required from a further shock, but time saving is always advantageous.

Our demonstration that cardioversion up to three energy applications, even with high cumulative energies, caused no modification of cTnI has other important clinical implications. In the setting of patients with life-threatening arrhythmias which require defibrillation or cardioversion, it is very important to recognize the etiology of the rhythm disorders, particularly when electrocardiographic changes after restoration of sinus rhythm are nonspecific or nondiagnostic. Understanding whether the arrhythmias in question are primary or secondary to an acute myocardial infarction is critical because of the prognostic and therapeutic implications.

Patients with primary ventricular fibrillation have a high rate of early recurrence and a markedly greater subsequent mortality than those of survivors of ventricular fibrillation associated with myocardial infarction. If the ventricular arrhythmias are triggered by an acute myocardial infarction, the risk

of subsequent malignant arrhythmia is only slightly greater than that in a patient with an uncomplicated myocardial infarction.[21]

Our study has definitely shown that the increase in cTnI in survivors of malignant arrhythmias is not mediated by electrical injury caused by EEC itself. As the maximum number of shocks per procedure in our study was three, we cannot, however, exclude that a higher number of EEC used in patients with out-of-hospital cardiac arrest could actually lead to an increase of cTnI.

Study Limitations

Presently, the standard of reference in DC shocks has changed to the biphasic shock. If no myocardial injury can be seen with monophasic shocks, the risk to detect injury with biphasic shocks would be even smaller, but this has to be demonstrated. The principal limitation of the study is the relatively small number of patients with low EF. Further investigations are needed for this group of patients.

Another limitation is the absence of baseline levels of cTnI. This was partially overcome by strict exclusion criteria, which avoided inclusion of patients with possible baseline elevated cTnI levels, such as those with hemodynamic instability, unstable angina, recent myocardial infarction, recent cardiac surgery, or advanced renal failure.

Conclusions

Our study has shown that EEC caused no myocardial damage as evidenced by absence of elevated cardiac cTnI level, even in patients with low EF. This is an important observation, as it has changed our clinical attitude toward EEC. We elect to apply the first EEC shock with a higher energy level, and this has led to a higher percent of restoration of sinus rhythm after the first attempt, thereby saving time and costs.

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