Assessment of the cardiovascular effects of electroconvulsive therapy in individuals older than 50 years

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Abstract

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To evaluate the impact of electroconvulsive therapy on arterial blood pressure, heart rate, heart rate variability, and the occurrence of ischemia or arrhythmias, 38 (18 men) depressive patients free from systemic diseases, 50 to 83 years old (mean: 64.7 ± 8.6) underwent electroconvulsive therapy. All patients were studied with simultaneous 24-h ambulatory blood pressure and Holter monitoring, starting 18 h before and continuing for 3 h after electroconvulsive therapy. Blood pressure, heart rate, heart rate variability, arrhythmias, and ischemic episodes were recorded. Before each session of electroconvulsive therapy, blood pressure and heart rate were in the normal range; supraventricular ectopic beats occurred in all patients and ventricular ectopic beats in 27/38; 2 patients had non-sustained ventricular tachycardia. After shock, systolic, mean and diastolic blood pressure increased 29, 25, and 24% (P < 0.001), respectively, and returned to baseline values within 1 h. Maximum, mean and minimum heart rate increased 56, 52, and 49% (P < 0.001), respectively, followed by a significant decrease within 5 min; heart rate gradually increased again thereafter and remained elevated for 1 h. Analysis of heart rate variability showed increased sympathetic activity during shock with a decrease in both sympathetic and parasympathetic drive afterwards. No serious adverse effects occurred; electroconvulsive therapy did not trigger any malignant arrhythmias or ischemia. In middle-aged and elderly people free from systemic diseases, electroconvulsive therapy caused transitory increases in blood pressure and heart rate and a decrease in heart rate variability but these changes were not associated with serious adverse clinical events.

Introduction

Electroconvulsive therapy consists of inducing a controlled convulsive seizure by electric stimulation of the brain. Cerletti and Bini (cited in Ref. 1) first introduced this modality of therapy in 1938 for the treatment of schizophrenia and since then this procedure has also been used as an effective treatment for major depression, bipolar affective

disorders, drug-resistant patients and those more likely to have adverse effects such as pregnant and childbearing women, and the elderly (1,2).

The rate of adverse effects is usually low and mortality is estimated at 1:1000 to 1:10,000 cases (3,4); almost 2/3 of these deaths are of cardiovascular origin and therefore cardiac risk must be assessed (5). The main cardiac complications are asystole, cardiac rupture, and myocardial infarction (3); other complications include subdural hematoma and subarachnoid hemorrhage (4). The most common adverse effect is a transient memory deficit after seizure, although many patients complain that their memory never returns completely (2).

In a review of the literature we did not find any detailed study on the cardiovascular effects of electroconvulsive therapy in individuals older than 50 years. Thus, the aim of the present study was to assess the impact of electroconvulsive therapy on systemic arterial blood pressure, heart rate and heart rate variability and the possible occurrence of cardiac arrhythmias and/or ischemia in individuals older than 50 years.

Material and Methods

The study was approved by the Institutional Ethics Committees. From March 1998 to July 2001, 120 patients older than 50 years were referred to our institution for electroconvulsive therapy for major depression, resistant to drug therapy. Patients were excluded if they presented at least one of the following conditions: severe arterial hypertension (6), cardiac and non-cardiac diseases, persistent electrocardiographic alterations that could hinder the analysis of ventricular repolarization (bundle branch block, marked left ventricular hypertrophy, atrioventricular block, cardiac pacemaker) or continued use of medications. We selected 38 patients, 18 men and 20 women, aged 50 to 83 years (mean: 64.7 ± 8.6); 14 patients

(37%) were older than 65 years. Patients, or their close relatives, gave written informed consent to participate in the study.

Study protocol

Drugs were withheld 3 to 7 days before electroconvulsive therapy. All patients were submitted to detailed clinical evaluation by one of the investigators, and to simultaneous 24-h blood pressure and electrocardiographic (Holter) monitoring. Monitoring started 18 h before electroconvulsive therapy and continued for at least 3 h after the procedure.

Electroconvulsive therapy was performed between 8:00 and 11:00 am. All patients were asked to fast for at least 8 h; none of them were wearing dentures, contact lenses or any ornament and all were wearing hospital clothing. The procedure room was equipped with a defibrillator and drugs necessary for cardiopulmonary resuscitation. Technical procedures were performed according to the standard routines of the laboratory, as reported by Moreno et al (1). Electrodes were placed bilaterally on the frontal areas to record cerebral activity and on the temporal areas for electrical stimulus conduction. Etomidate (0.2-0.3 mg/kg) was administered as a short-acting anesthetic; atropine was not used as a preanesthetic because it influences heart rate and could mask possible bradyarrhythmias during the procedure. Curarization was done with succinylcholine (0.5 mg/kg). The Guedel airway was used to optimize oxygen ventilation with a mask and Ambu bag during the convulsive crisis; a protective device was placed between the dental arches. Mecta SR-2 (Lake Oswego, OR, USA) and Thymatron DGx (Lake Bluff, IL, USA) devices were used to trigger the convulsive crisis; the electrical charge ranged from 250 to 350 millicoulombs (mC). The Mecta device has waves of the fixed, biphasic and short-pulse type, with 17- to 576-mC capacity, a constant current of 550-800 mA, 6 phases, and frequency of 0.5 to 2.0 s. The

Thymatron device has a basic exit mode of 25 to 504 mC and operational exit mode of 50 to 1000 mC, and the load control is calibrated in percentages. The devices also monitored the electroencephalographic activity and recorded the tonic-clonic seizures. Electrical stimulation lasted less than 1 min. Seizures were considered to be effective when lasting more than 20 s (1). Blood pressure, electrocardiographic tracing and oxygen saturation index were monitored before and during each convulsive seizure because ventilation was not interrupted during convulsion. The mean duration of the convulsive seizure was 38 ± 5 s. After the seizures, all patients remained under medical and nursing care until complete recovery. All patients received food prior to hospital discharge.

Ambulatory blood pressure monitoring was performed with Spacelabs 90207 devices (Spacelabs, Redmont, WA, USA), programmed to make measurements every 10 min, except during sleeping hours (23:00 pm to 6:00 am), when the measurements were made every 20 min. Systolic, diastolic and mean blood pressure was recorded and monitoring lasted at least another 3 h after electroconvulsive therapy.

Data were analyzed using Spacelabs software. Baseline values were obtained as the mean values of 6 measurements before shock; after the electric stimulus, we considered the mean values of the following 6 measurements. During shock, the peak values of systolic, diastolic and mean blood pressure were noted and compared to the mean values before and after shock. Data were excluded from analysis if any artifacts were present.

Electrocardiographic Holter monitoring was performed with Marquette 800 portable amplitude-modulated two-channel devices (Marquette 9428; Marquette Medical Systems Milwaukee, WI, USA). Two bipolar leads, CM5 (exploring electrode in the V5 position) and CM1 or modified D2 (exploring electrode in an inferior lead) were used

(7). To obtain the neutral value, an electrode was placed close to the last costal arches, next to the midclavicular line.

After the monitor was withdrawn, the tapes were analyzed with the MARS system (Marquette). Maximum, minimum and mean heart rate values, as well as heart rate variability, were determined, and the occurrence of ST-segment deviations and arrhythmias was recorded. Baseline heart rate values were obtained as the mean values recorded 10 min before shock. Heart rate was then recorded minute-to-minute until 30 min after shock.

Heart rate variability was determined by frequency-domain analysis according to the guidelines of the American Heart Association (8). Holter monitoring data were analyzed by the MARS system. For the analysis of heart rate variability we used the measurements of seven 4-min intervals before shock, a 4-min interval during shock and seven 4-min intervals after shock. The following frequency bands were extracted from the power spectrum: total power or wide band (WB): 0.003-1.7 Hz; very low frequency (VLF): 0.003-0.04 Hz; low frequency (LF): 0.04-0.15 Hz; high frequency (HF): 0.15-0.4 Hz. The LF/HF ratio was also determined. Data are reported as milliseconds (ms) and the values before and after shock were compared.

Arrhythmias were diagnosed and analyzed manually; supraventricular and ventricular extrasystoles, and the atrioventricular and intraventricular conduction defects were recorded. The number of extrasystoles/hour was compared before and after shock considering the total recording time.

An ischemic episode was defined as a transient ST-segment elevation, or horizontal or downsloping ST-segment depression from baseline of 1 mm or more, measured 60 to 80 ms after the J point, and lasting 1 min or more (7,8).

Patients or close relatives received a questionnaire and were instructed to report their activities and the occurrence of any symp-

tom and to press the event buttons under these situations. The event buttons of both recorders made it possible to identify the moment when the electrical stimulus was triggered.

All data recorded from ambulatory monitoring were analyzed by expert technicians and reviewed by the investigators.

Statistical analysis

Data are reported as mean ± SD. Repeated measures one-way ANOVA was used to compare heart rate and heart rate variability between time points (9,10). The level of significance was set at 0.05. The Wilcoxon rank sum test was used to compare the incidence of arrhythmias and blood pressure before, during and after shock (9,10). Ischemic episodes were not subjected to statistical analysis because of the small number of events.

Results

Twenty-four-hour monitoring

Blood pressure, heart rate and heart rate variability curves showed a circadian pattern, except during shock. The highest values of mean systolic, diastolic and mean blood pressure occurred between 9:00 and 10:00 am (154.2 ± 19.9, 116.0 ± 13.4, and 96.0 ± 10.7 mmHg, respectively) and the lowest values occurred between 3:00 and 4:00 am (117.0 ± 16.1, 87.2 ± 13.0, and 70.1 ± 12.0 mmHg, respectively); the mean decrease at night was 10.4% in systolic blood pressure and 9.9% in diastolic blood pressure, including 9 (23.6%) patients with mild arterial hypertension. Heart rate varied from 121.9 ± 19.6 bpm (between 10:00 and 11:00 am) to 57.8 ± 13.5 bpm (between 5:00 and 6:00 am). The frequency bands of heart rate variability are listed in Table 1.

All patients had at least one isolated supraventricular extrasystole; 4 (10.5%) had more than 10/h and 2 (5.3%) presented non-sustained atrial tachycardia before and after shock. Ventricular extrasystoles occurred in 27 (72.9%) patients; 2 (5.3%) had an isolated episode of non-sustained ventricular tachycardia before shock. One asymptomatic patient (2.6%) had, on average, 1028 ventricular extrasystoles/h before shock and 1046 after shock. Another patient (2.6%) had intermittent left bundle branch block during electrocardiographic recording, which was not associated with symptoms or shock. There were no other arrhythmias.

Holter recordings demonstrated silent myocardial ischemia in 3 patients. Two of them had ischemic episodes before and after shock; one had 10 episodes and the other 44 at different times during the recording period and also immediately after shock. The third patient had two brief episodes of ischemia only after the procedure. All 3 patients remained asymptomatic during ischemia and did well after electroconvulsive therapy.

Electrical shock was identified in both recordings through a line of interference coinciding with the pressing of the event buttons. Patients were subjected to electroconvulsive therapy at different times but the time of shock was adjusted to 9:00 am.

Effects of electroconvulsive therapy

Blood pressure changes are depicted in

Table 1. Spectral components of 24-h heart rate variability.

Component	
VLF	21.3 ± 7.6
LF	13.4 ± 6.6
HF	9.1 ± 5.1
WB	27.7 ± 10.7
LF/HF	1.9 ± 2.3

Data are reported as means ± SD in ms for 38 patients. VLF = very low frequency; LF = low frequency; HF = high frequency; WB = wide band; LF/HF = low/high frequency ratio.

Figure 1. Systolic blood pressure increased 29%, from 128.3 ± 13.2 mmHg 1 h before shock, to 165.6 ± 31.5 mmHg during shock (P < 0.001), returning to 129.8 ± 14.1 mmHg after 1 h. Mean blood pressure varied from 98.7 ± 11.2 mmHg 1 h before shock to 123.0 ± 25.9 mmHg during shock, a 25% increase (P < 0.001), returning to 101.0 ± 10.7 mmHg after 1 h.

Diastolic blood pressure increased 24%, from 83.2 ± 10.6 to 103.5 ± 23.2 mmHg during shock (P < 0.001), returning to 84.6 ± 10.5 mmHg after 1 h. There was no difference between blood pressure values before and after shock.

Heart rate changes are depicted in Figure 2. Maximum, minimum and mean heart rate values were always higher during shock compared to baseline (P < 0.001). Mean peak of maximum heart rate (133.6 ± 20.2 bpm) occurred in the first minute after shock and was significantly higher (58%) than the baseline value (84.3 ± 14.1 bpm). Maximum heart rate decreased gradually until the 5th minute after shock (95.5 bpm); after 15 min, it increased again but its values were lower compared to shock. Minimum heart rate increased 29% at the first min after shock (74.4 ± 13.7 to 95.9 ± 18.6 bpm) and then gradually decreased; after 8 min, it increased again and after 25 min it was similar to peak values. Mean heart rate increased 46% from 79.5 ± 13.8 to 116.5 ± 18.2 bpm in the first min after shock, then gradually decreased until the 5th min (91.7 bpm); after 14 min, it increased again.

Heart rate variability is depicted in Figures 3 and 4. All components increased during shock and then decreased (Figure 3). LF/HF ratio did not change significantly (P = 0.177); the lowest value (1.46) occurred immediately after shock and the highest (1.95), 12 to 16 min later. The highest mean values were recorded during shock (VLF = 50.9 ± 31.8 ms, LF = 22.7 ± 18.5 ms, HF = 11.8 ± 7.1 ms, and WB = 58.8 ± 35.4 ms). The lowest values were recorded 8 to 16 min
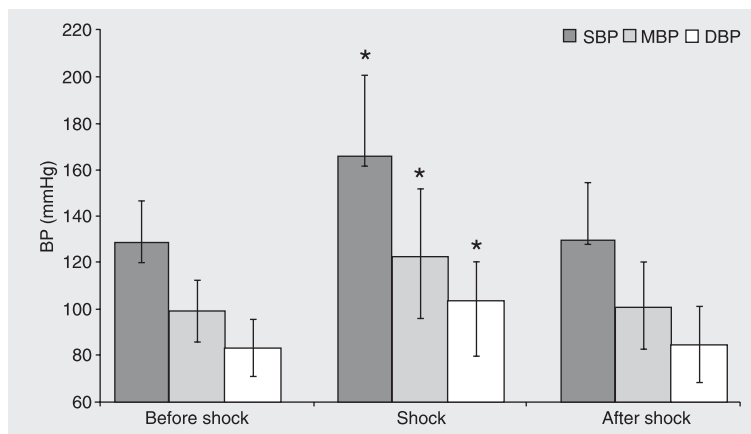

Figure 1. Blood pressure before, during and after shock. N = 33 patients. SBP = systolic blood pressure; MBP = mean blood pressure; DBP = diastolic blood pressure (mmHg). *P < 0.001 compared to before and after shock periods (Wilcoxon rank sum test).
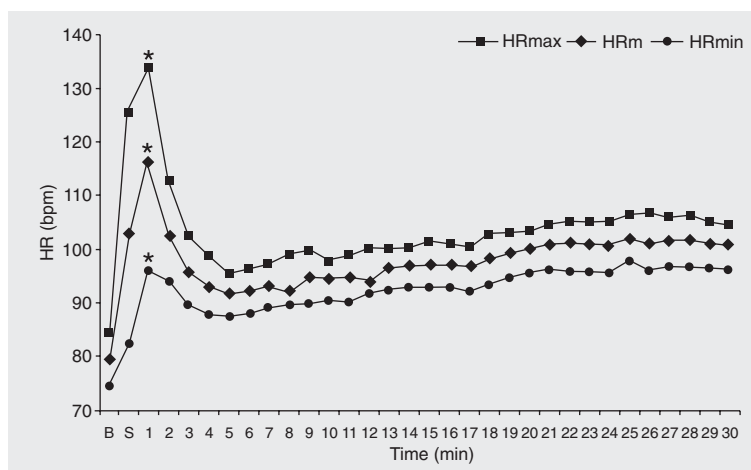

Figure 2. Heart rate before, during and after shock. N = 32 patients. HRmax = maximum heart rate; HRm = mean heart rate; HRmin = minimum heart rate; B = baseline; S = shock. *P < 0.01 compared to all other periods (repeated measures one-way ANOVA).
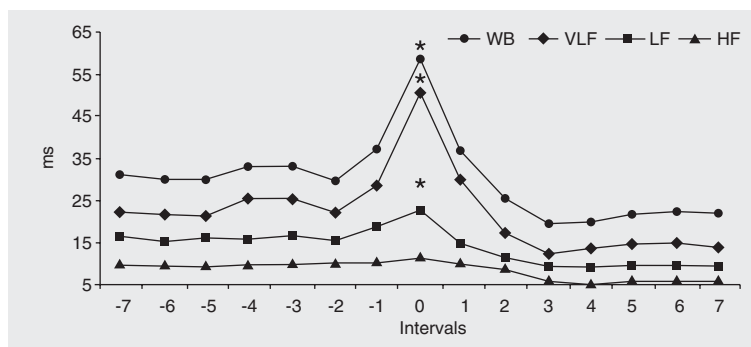

Figure 3. Frequency bands of heart rate variability before, during and after shock. N = 28 patients. WB = wide band; VLF = very low frequency; LF = low frequency; HF = high frequency; 4-min interval before (-7 to -1), during (0) and after (1 to 7) shock. *P < 0.01 compared to all other periods (repeated measures one-way ANOVA).

after shock (VLF = 12.1 ± 5.6 ms, LF = 8.8 ± 5.6 ms, HF = 5.5 ± 2.9 ms, and WB = 19.1 ± 7.4 ms). Figure 4 shows the pattern of heart rate and heart rate variability during and after shock.

Arrhythmias and ischemia

The type of arrhythmias that occurred before electroconvulsive therapy did not change after shock. The supraventricular extrasystoles/h were 8.8 ± 23.8 before and 5.1 ± 12.5 after shock (P = 0.685); ventricular extrasystoles/h increased from 42.0 ± 197.2 to 46.8 ± 200.3 (P = 0.016), without adverse effects. One patient had transient ST-segment changes only after shock; they lasted 2.0 and 2.25 min and were suggestive of ischemia. Two other patients had episodes of silent ischemia during the recording time, not necessarily related to shock.

Discussion

Since the very beginning of electroconvulsive therapy, it was recognized that the procedure induced tachycardia and arterial hypertension (11,12), but the consequences of these effects were not analyzed in depth. In the present study, we started monitoring patients one day before electroconvulsive
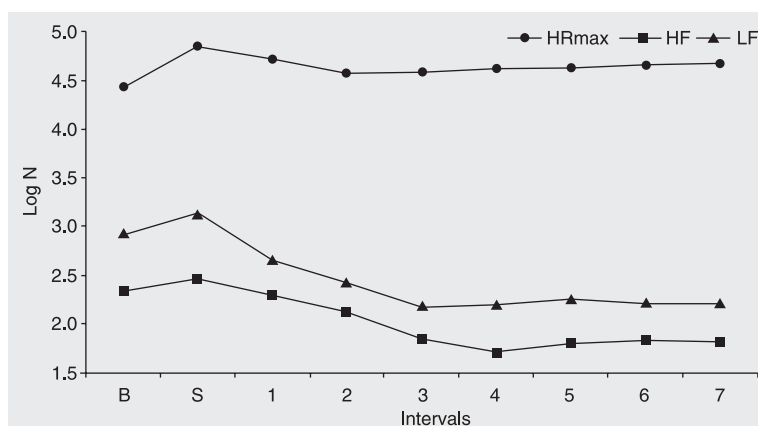

Figure 4. Maximum heart rate, high frequency and low frequency bands of heart rate variability during shock. HRmax = maximum heart rate; HF = high frequency; LF = low frequency; B = baseline; S = shock; intervals +1 to +7; Log N = Neperian logarithm.

therapy in order to identify cardiovascular changes not related to the procedure; the observed spontaneous events would then be compared to those directly caused by shock.

At the time of shock, we observed significant increases in blood pressure and heart rate. These changes may be due to myotonic reflexes, direct stimulation of the sympathetic nervous system and norepinephrine release from the adrenal medullae (13,14). It is still debatable whether or not the seizures may have a direct effect on the observed cardiocirculatory changes; patients with spontaneous convulsions have smaller increases in blood pressure and heart rate whereas patients undergoing electroconvulsive therapy but not experiencing convulsions (frustrated seizure) have the highest reported increases in these parameters (15). Long-lasting convulsions do not necessarily induce the most significant increases in blood pressure and heart rate (16).

It is possible that the autonomic overdrive may not be the only fact responsible for cardiocirculatory changes; ganglionic blockade (17) and elevated circulating catecholamines may play a role (18) and ß-blockers may counteract these effects (19).

Our results are similar to those obtained by Rumi et al. (20), who reported significant increases in blood pressure and heart rate during shock in young adults, returning to baseline values after 25 min. Our patients continued to have higher heart rates 1 h after shock and their peak values of blood pressure were smaller. These differences may be related to particular cardiovascular responses in the elderly as compared to young people (21); there is an age-related reduction in tonic cardiac vagal inhibition of heart rate and cardiac output, as well as elevated sympathetic activity (22,23) and counteracting vascular α-adrenergic desensitization, explaining why the responses to stress are attenuated in the elderly (23).

We recorded significantly increased blood pressure and heart rate after shock;

these sudden elevations may increase the risk of cardiovascular events such as myocardial infarction, brain hemorrhage and stroke, especially in older patients. Lack of adequate control of cardiocirculatory parameters may lead to long-lasting cognitive defects (24), mainly because of cerebral edema and the passage of neurotoxic macromolecules through the blood-brain barrier during cerebral hypoperfusion (25). The routine use of drugs that attenuate the hypertensive peak and tachycardia induced by electroconvulsive therapy is controversial and only recommended for patients with associated cardiovascular diseases (26,27).

We did not observe a long-lasting sinus pause or transient bradyarrhythmias immediately after shock, but they may occur and death due to asystole has been reported (28). Electric shock is associated with intense vagal stimulation even when convulsion does not occur, suggesting that the shock and not the convulsion is responsible for the parasympathetic discharge (29) which can be prevented by atropine (1).

The analysis of heart rate variability during shock is important because significant changes in autonomic function have been described in depressive disorder (30). Some investigators have observed that, after electroconvulsive therapy, clinical improvement is associated with decreased levels of plasma catecholamines after the procedure (18). In addition, there are reports demonstrating that electroconvulsive therapy may influence the recovery of parasympathetic function (31) and improve depression.

In the spectral analysis of heart rate (32,33), the LF/HF ratio reflects sympathovagal imbalance (34). Decreased heart rate variability is considered to be a strong and independent predictor of cardiovascular mortality (33). Major depressive disorder may also be associated with reduced vagal modulation (30) and some investigators have reported the influence of treating depression on sympathovagal imbalance (31,35).

Major depression is predictive of cardiac events and death even when there is no evident cardiac disease (36), leading to the hypothesis that the reduction of vagal activity in this affective disorder may trigger arrhythmic events (33). In our study, the LF/HF ratio did not change significantly, leading us to conclude that both components were well balanced. The high frequency component did not increase during shock but it decreased 2 min after it, demonstrating a decrease in parasympathetic activity at that time. The low frequency component, partially reflecting sympathetic activity, increased after shock and then decreased. These changes demonstrated that the sympathetic activity predominated during electric stimulation. Vagal activity did not change during shock when compared to the period before it; on the other hand, it decreased more slowly than sympathetic activity after shock and reached the lowest values 16 min thereafter. Both high and low frequency components decreased after shock; heart rate remained elevated, but was lower than during electroconvulsive therapy. This fact could be related to increased circulating catecholamines (18).

Nahshoni et al. (31) described changes in heart rate variability 72 h after electroconvulsive therapy in elderly individuals, with a significant decrease of the low frequency component and of the LF/HF ratio. The authors did not analyze the immediate effects of shock on heart rate variability but the significant increase of vagal modulation after it coincided with clinical improvement of depression. Schultz et al. (35), on the other hand, reported that the improvement of depressive younger patients after electroconvulsive therapy correlated with a decrease in vagal activity 24 to 36 h after the procedure. The results of the two studies are conflicting but the patients of Schultz et al. (35) were younger and the authors analyzed only the high frequency band and did not consider the LF/HF ratio. Our study is unique in that

it analyzed heart rate variability specifically at the time of electrical stimulation.

Electroconvulsive therapy did not trigger malignant arrhythmias in our patients, in agreement with the results obtained by Rumi et al. (20) in young people without systemic diseases. In contrast, Zielinski et al. (37) reported the prevalence of arrhythmias in patients with previous cardiac diseases.

We observed episodes of silent myocardial ischemia in 3 patients at different times during the 24-h recordings and not necessarily related to shock. It is possible that these patients had definite coronary artery disease, although they did not experience cardiac events. Gould et al. (38) described electrocardiographic changes suggesting myocardial infarction in a 75-year-old woman submitted to electroconvulsive therapy who did not exhibit myocardial necrosis or pericarditis. Other investigators have reported the same observation (39). In animal models, electroconvulsive therapy induced increases in blood pressure and heart rate, ventricular ectopic beats and T-wave inversions during hypothalamic stimulation (40).

Clinical implications

In healthy individuals older than 50 years, electroconvulsive therapy can be considered a safe therapeutic method, although it causes transient but significant increases in blood pressure and heart rate and sympathetic stimulation. No significant arrhythmias or ischemia or other adverse clinical effects occurred during and after the procedure. Nevertheless, we think that elderly people with preexisting organic diseases are at risk for cardiovascular events because of the observed cardiocirculatory changes and should be carefully evaluated.

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