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The effect of conducted electrical weapons on the human body

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Background and objective. Fatal accidents occur due to the effect of electric current on the human body. The most common reasons are invalid electrical installations or misuse of electrical devices, but rarely murder and suicide cases are possible. Recently, conducted electrical weapon handling cases which resulted in sudden death have been observed.

In this article we have provided our findings about the effects of conducted electrical weapons on the heart muscle, with emphasis on the use of conducted electrical weapons by officials.

Materials and methods. Lithuanian and foreign authors' findings about the effect of conducted electrical weapons on the heart muscle are analysed. Recommendations for the use of these weapons are made to the officials. The results are evaluated using descriptive statistical methods.

Results. The working principle of this weapon is the effect on striated muscles. The muscles contract reacting to electric impulses, hence the affected person cannot struggle with the policeman. Although this weapon was created as a safe tool to suppress aggressive persons, new researches revealed its dangerous effect on the heart muscle that caused fatal arrhythmias.

Conclusions. Stress on the body, systemic disease and the presence of chemicals in the body modify the body's response to electrical impulses that directly increase the risk of cardiac arrhythmia due to the developing of ventricular fibrillation and probability of sudden cardiac death. It is recommended to officials who use conducted electrical weapons that in the location of the event there should be qualified medical personnel (ambulance) able to provide the first aid in case of complications after the use of the weapon.

Key words: sudden death, arrhythmia, electrical weapons, lesions

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INTRODUCTION

Forensic medical experts practically encounter with technical electricity effect in household and industry rather than atmospheric electricity (lightning). The impact of electric stream conveys through the local injuries and general electrochemical, thermal and mechanic effects which are often leading to life-threatening conditions as cardiac and respiratory disturbances, ventricular fibrillation (VF), shock or even death (7, 8). The prevalence of electric injuries makes up to 1–2.5% of all traumas (4–6).

Conducted electrical weapons (CEWs) are made by different manufacturers based on the same principle – to generate high voltage short electric impulses. CEW as TASER® has been created for law enforcement as a safe alternative of usual weapons (e. g. guns). As compared with gun, it was thought that the working principle of CEWs is less dangerous because the target has been affected by electric current in direct contact or at distance (9). However, there is a lack of published data about fatal cases of CEWs usage and actual information about security measures. Practical guidelines about specific medical states before using of CEWs are needed (8, 14–15).

PATHOGENESIS

The electricity is distinguished to alternating and direct electric current (AC and DC, respectively). Direct current up to 500 V voltage is less dangerous than alternating current. The riskiness of both currents (AC and DC) equals at the voltage of 500 V. When the voltage is more than 500 V, DC becomes more dangerous than AC. In the ordinary practice the injuries by direct current are rare (19). The riskiness of injury by electric current depends on its physical characteristics. Circumstances of the incident and health state of the subject are also of great significance. The most dangerous injury rises by alternating electric current (frequency range 40–60 Hz), which causes VF (19, 21). Increasing electric current frequency the riskiness of injury declines, while high frequency current (from 10,000 to 1,000,000 Hz) has no harmful effect on the human body, even at the very high voltage (1,500 V) and at the high current strength (2–3 A) (18–21). The usable electric current voltage about 100–1,500 V is the most dangerous and even fatal for the human body (20). It was established that fatal injuries often occur when current strength is 100 mA (22).

The degree of injury by technical electricity depends on the way of electric current through the organism. The most dangerous ways are the following: through the brain or heart, when the left hand and left leg, right hand and left leg, left and right hands, chest or back and hands, head and legs or hands are connected into electric chain (18–21). Electric current is often going through the tissues characterized by ultimate electric conduction and minimal resistance. Electric resistance of tissues increases by the following sequence: blood, mucosa, liver, kidneys, muscles, brain tissue, lungs, tendons, cartilages, nervous and bone tissues, skin (10, 23, 25). Local microscopic lesions of skin injured by technical electric current are very specific. The burns, caused by the local effect of technical electricity, have all features of appropriate degree burn and electric stigma. CEW makes too low electric energy for the local skin burns or electric stigma, hence it is impossible to identify any morphologic lesions of skin in 10–20% cases of actions by electric current (26–27).

TASER® is a pistol-shaped weapon, using compressed nitrogen gas for shooting two probes of 9 mm or 12 mm in length from the magazine to individual clothes and / or skin. The weapon can be used at the distance of extended hand, without shooting probes, which could be directly touching individual clothes or skin. Wires are connected with the magazine through probes, which transmit the initial 50,000 V electric impulse, about 1,140 impulses / min at the frequency of 15–20 Hz, from 2 to 4 mA in strength**,** hence the electric current of one impulse reaches about 1,200 V (31). The working principle of the CEW TASER® (Figure) is based on electric stimulation to the endings of sensory and motor nerves in the neuromuscular junction, that causes spasmodic contraction of the muscle (3, 10).

Depending on voltage, respiratory and cardiovascular systems are most exposed (24–25). Hypoxia and heat exhaustion decrease tissue resistance to electric current (1, 2). Chronically ill with diseases of cardiovascular and respiratory, renal or endocrine systems (e. g. asthma, anemia), elderly and children, pregnant women, starveling and

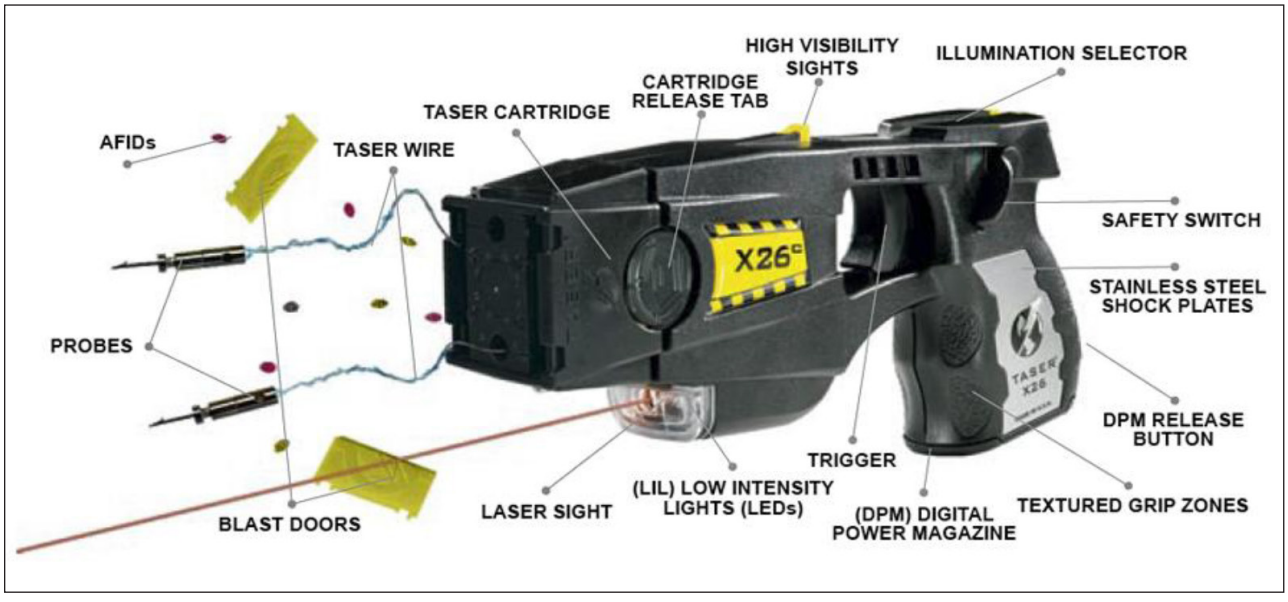

Figure. Conducted electrical weapon "Taser X26C"

drunk persons are more susceptible to the effect of electric current (10, 17).

Electric impulses acting on the chest may cause sudden, unexpected death. Sudden cardiac death is defined as heart stopping followed by the loss of breathing and consciousness. The heart rate of physically active, agitated or aggressive persons can often reach 150 bpm and higher, hence the electric output of CEW can increase heart rate to 240 bpm, causing ventricular tachycardia. The latter condition may run into VF, causing haemodynamic and cardiac arrest (31, 32). Clinical appearance of VF is irregular / abnormal heart rate (31), which may cause sudden cardiac death.

Heart diseases such as cardiac hipertrophy, coronary artery atherosclerosis, left ventricular dilation and fibrosis directly correlate with the risk of developing VF (31, 34–36). Trials have shown that the operation of the CEW (TASER®) in certain circumstances, where the electrodes are located closer to the heart, electrical discharge operation of the vector goes through the heart, and at a certain human condition, whether expressed in cardiac pathology (myocardial infarction, or other cardiac pathology), may cause heart rate / frequency changes and VF (17, 22, 28–31, 37–39). Electrical pulse effect in the sternal notch to the cardiac apex position along the cardiac axis which normally corresponds to the anatomical axis of the heart leads to a higher risk of developing ventricular fibrillation (31, 35). In obese individuals such electrical effects can also lead to the development of VF (31, 40, 41).

Electrical stimulation of TASER® by multiple electrical pulses one by one in a short period of time (less than 5 sec) can induce VF by causing ventricular capture during the vulnerable period of the T wave of the previous beat when all the heart muscle relaxes (electrocardiogram – ECG). The increased rate plus sympathetic effects can shorten ventricular refractoriness (excitability to another, stronger, stimulus), starting from the beginning of ventricular depolarization (agitation, the QRS complex) and continuing until the depolarization (T wave) end. When the ventricular refractory period is shorter (in tachycardia case), the permeability of the cells is faster and contrary (10–16, 31, 32, 42, 43). Since a blood pressure reduction results from the rapid rate, repeated shocks or those exceeding the recommended 5-second pulse duration can add an ischemic component and would be more likely to provoke VF (32, 43).

Clinical studies have proved that the electrical impulse of the shots can also cause physiological and / or metabolic changes. Effect of an electrical pulse weapon on a human for 15 seconds changes the acid-base balance (metabolic acidosis) and increases creatine kinase, electrolytes, stress hormone levels (3, 11–13, 31). Alcohol and heart disease works synergistically with electric discharge currents, increases risk of cardiac arrhythmias,

ventricular tachycardia and / or ventricular fibrillation (31, 44).

In individuals intoxicated by cocaine, methamphetamine, phencyclidine (PCP), or other stimulants electrical impulses of the shots increase the risk of cardiac arrhythmias, particularly when expressed in cardiovascular pathology. Alcohol in combination with antipsychotic drugs works synergistically. The antipsychotic drug group has the following adverse reactions, as hypotension, tachycardia, changes in ECG, hypertension, and in persons receiving antipsychotic medications and / or alcohol use, the electrical impulse weapon also increases the risk of the ventricular fibrillation development or even death (45).

PRACTICAL EXAMPLES

36 years old, 6,30 foot long, obese dead man's body was studied, who had an aggravation of mental disease before his death. From anamnesis it is known that the victim was previously diagnosed with schizophrenia and was treated in hospital for it. The victim became aggressive, started to pose a risk to himself and others, the police and the medical professionals were called. To tame the aggressive behavior of the victim hands and legs were bound and CEW TASER® was used. Trying to provide medical assistance, soon 36 years old man died from a sudden stroke.

In examination of the dead man's body, the signs of sudden cardiac death were identified: coronary artery atherosclerosis in the second stage, left anterior descending coronary artery stenosis up to 25% and weight of the heart 1.28 pound. Clozapine was found in the victim's blood. Significantly elevated level of potassium was found in the cardiac muscle which can be associated with a disorder of acute cardiac conduction. Increased irritability of the heart muscle provokes muscle fibrillation and heart failure.

Clozapine is an atypical antipsychotic drug which is characterized by sedative and antimuscarinic effects. It can cause myocarditis, pericarditis, pericardial fluid occurrence and death. The Novartis international pharmacologic database has recorded 213 reports of clozapine-induced myocarditis cases (1 in 14,000 patients per year). In 80% of cases myocarditis was confirmed at autopsy. Canada receives 7 reports of clozapine-induced cardiomyopathy and 3 reports of this drug-induced heart failure (45).

Taking into consideration the anamnesis data, autopsy and additional internal organs of the corpse and media research results, it is concluded that overt cardiac pathology, clozapine side effects, an aggravation of mental disease induced total stress on the body and possibly used CEW TASER® during detention could lead to acute cardiac disorder ending in death.

In the other case, 40 years old, 6, 07 foot long, obese dead man's body was studied. From the anamnesis data it is known that the victim was confused and aggressive before his death. In the medical history the victim had a mental illness and was treated in hospital for it. In the event location the police and medical team were called to tame the excited and aggressive citizen. In order to tame the aggressive behavior of the victim an electrical control device TASER® was used, and trying to provide the medical first-aid, soon the 40 years old man died from a sudden stroke.

In examination of the dead man body, the signs of sudden cardiac death were identified: coronary artery atherosclerosis in the third stage, left anterior descending coronary artery stenosis up to 70% and weight of the heart 1.91 pound, heart muscle full-blooded and small focal fibrosis in it.

Taking into consideration the anamnesis data, autopsy and additional internal organs of the corpse and media research results, it is concluded that overt cardiac pathology, stress and possibly used CEW TASER® during detention could lead to the acute cardiac disorder ending in death.

DISCUSSION

For several years the electronic control device effect on the heart has been analyzed and discussed in absolute security. In our exploration of clinical cases and literature data, deaths usually occurred soon after using the electronic control device (28). Trials have shown that the operation of the conducted electrical weapons (TASER®) in certain circumstances, when the electric current vector goes through the heart and at a certain human condition, whether expressed in cardiac pathology, and stress may develop cardiac arrhythmias and death (28–30). Acting by drugs, alcohol, antipsychotic and other medications human exposure to the

effect of electric currents intensifies and risk of developing ventricular fibrillation increases after electronic control device using (10, 12, 14, 16). It is not recommended to use CEW (TASER®) in the thoracic chest, heart projection, face area, as well as to avoid using this type of the weapon when a suspected person is taking antipsychotic drugs, is under the influence of alcohol or drugs or is in an unstable physical condition. Also note that the latter type of weapons use should be avoided in obese individuals who usually have expressed heart pathology of obesity. People taking antipsychotic medication that has adverse reactions for the heart are at higher risk group thus CEW use may cause an increased risk of VF and sudden death occurrence. Electrical pulse duration, electrode localization in the body and the time interval between the pulses of multiple start-up is directly related to the electric-induced VF increases of the risk of development (31, 46). The first electrical pulse lasting up to 5 seconds usually does not cause VF but the second and the same duration electrical impulse can already lead to VF (31, 35). Intervals between the pulses of multiple start-up should not be more frequent than 5 seconds therefore longer duration between the start-up of electrical impulses is necessary (31, 46). While writing this article and analysing the literature data, it was concluded that the data presented by animal studies should be taken reservedly. These studies investigated the effect of isolated CEWs at absolutely calm circumstances and underestimated other factors, such as stress on the body, systemic disease and the presence of chemicals in the body.

CONCLUSIONS

Stress on the body, systemic disease and the presence of chemicals in the body modify the body's response to electrical impulses that directly increase the risk of cardiac arrhythmia due to the developing of VF and probability of sudden cardiac death. It is recommended to officials using CEW that in the location of the event there should be qualified medical personnel (ambulance) able to provide the first aid in case of complications after the use of the device.

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ELEKTRINIŲ GINKLŲ POVEIKIS ŽMOGAUS KŪNUI

Santrauka

Įvadas. Paveikus žmogų elektros srove, dažnai ištinka mirtis. Tokie nelaimingi atsitikimai dažniausiai įvyksta dėl neteisingai instaliuotų ar netinkamai naudojamų elektros prietaisų. Galimi ir nužudymo, ir savižudybės atvejai. Per pastarąjį laikotarpį būta elektros impulsinio ginklo panaudojimo atvejų, kurie baigėsi staigia mirtimi.

Šiame straipsnyje aptariame elektros impulsinių ginklų poveikio žmogaus širdies raumeniui charakteristikas akcentuodami policijos pareigūnų naudojamų elektros impulsinių ginklų poveikį.

Tyrimo medžiaga ir metodai. Apžvelgti Lietuvos ir užsienio autorių duomenys apie elektros impulsinių ginklų poveikį širdies raumeniui ir pateiktos šių prietaisų naudojimo rekomendacijos policijos pareigūnams. Duomenys įvertinti aprašomosios statistikos metodu.

Rezultatai. Šių ginklų veikimo principas pasižymi poveikiu skersaruožiams raumenims. Reaguodami į elektros impulsą raumenys susitraukia, todėl šio impulso paveiktas žmogus negali grumtis su policininku. Nors šis ginklas buvo sukurtas kaip saugus prietaisas malšinti asmenų agresyvumą, naujai atlikti tyrimai atskleidžia, kad jis sukelia mirtinas širdies aritmijas.

Išvados. Stresas, sisteminės ligos ir cheminių medžiagų buvimas organizme keičia jo reakciją į elektros impulsus – didina aritmijos riziką dėl širdies skilvelių virpėjimo bei staigios mirties tikimybę. Pareigūnams, naudojantiems elektros impulsinius ginklus, rekomenduojama, kad įvykio vietoje kartu būtų kvalifikuotas medicinos personalas (greitoji pagalba), galintis suteikti pirmąją pagalbą po ginklo panaudojimo įvykus komplikacijoms.

Raktažodžiai: staigi mirtis; aritmija; elektros impulsiniai ginklai; sužalojimai