

Epidemiology and Diagnostic Problems of Electrical Injury in Forensic Medicine

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1. Introduction

The first fatal electrical injury reported in scientific literature was in France in 1879 (Jex-Blake, 1913). A stage carpenter was killed at Lyon by the alternating current of a Siemens dynamo giving a voltage of about 250 volts at the time. The first electrocution death in UK was in 1880, close to Birmingham (Jex-Blake, 1913). Samuel W. Smith was the first person in the United States to die after electrocution by a generator in Buffalo, New York, in 1881 (Daley, 2010). Since those first cases the annual number of electrical injuries and deaths from electric shock have steadily increased as a result of the widespread use of electricity and the application of electrically powered machinery.

Although electricity is a relatively recent invention, humans have always been exposed to the devastating electrical power of lightning and understandably attributed it to supernatural powers (Koumbourlis, 2002). Beginning around 700BC the ancient Greeks depicted lightning as a tool of warning of their god of thunder Zeus (O'Keefe Gatewood, 2004). In Roman mythology Jupiter used thunderbolts as a tool of vengeance and condemnation, thus those struck by lightning were denied burial rituals. For the Vikings, lightning was produced by the hammer of Thor the Thunderer as he rode through the heavens. In the East, early statues of Buddha show him carrying a thunderbolt with arrows at each end. In Chinese mythology the goddess of lightning, Tien Mu, used mirrors to direct bolts of lightning. African tribes, the Native American Navajo culture and many others also have specific beliefs about lightning.

Benjamin Franklin is generally regarded as the father of electrical science, the person who proved that lightning is an electric phenomenon and that thunderclouds are electrically charged with his famous kite experiment (O'Keefe Gatewood, 2004). He constructed a kite and flew it during a storm. When the string became wet enough to conduct, Franklin, who stood under a shed and held the string by a dry silk cord, put his hand near a metal key attached to the string, causing a spark to jump.

Today it is known that lightning is a phenomenon not restricted to the Earth planet only. It is observed in the atmosphere of Jupiter (Little, 1999), and in this sense lightning presents danger to flying craft and their crew as well (Uman, 2003).

1.1 Definitions and terms

Electrical injury, electrical shock, electrocution are often used as synonyms when trauma caused by electric current is being discussed. In this text "electrical injury" is used as the

term with the broadest meaning. The existing various definitions of “electrical injury” are principally similar. The Russian Bolshaya medicinskaya encyclopedia defines electrical injury as an injury caused by electric current or a result from contact with lightning. K. Duff and McCaffrey distinguish between electrical injury and lightening injury (Duff, 2001). The former they define as the sequelae due to accidental contact with man-made or generated electrical power and the later as a sequelae of naturally occurring lightening strike. According to the Merck manual electrical injury is a damage caused by generated electrical current passing through the body (Cooper, 2009).

1.1.1 Terms

Information for the following terms is presented as a basic explanation of electricity and the effects of electrical energy (CDC, 1998).

- *electricity* (electric current) - is the directed flow of an atom's electrons (the negatively charged outer particles of an atom) through a conductor such as wire. Its main characteristics which determine the hazard effect of electricity on the human body are:
- *voltage* - the force or pressure that causes electricity to flow through a conductor, measured in volts (V). Usually household current is 110 to 220V. Anything over 500V is considered high voltage. Life threatening levels of voltage are above 50-60V. Death occurs in 25% of cases in contact with electricity of 127-380V; in 50% of contacts with 1000V; and in 100% if the voltage is 3000V. A more important characteristic is the difference of the voltage at the entrance and exit of the electric chain. A difference up to 24 V is considered acceptable according to international safety norms;
- *power/strength* - is the flow of electrons from a source of voltage through a conductor and is measured in amperes (Amps). The contact with a current with more than 60 mA per 1 sec is life threatening, and above 100 mA is usually lethal. Current up to 50 mA is accepted as less dangerous for direct current and up to 10 mA for alternating current.
- *type of current* - electrical current is categorized as direct current (DC) or alternating current (AC). Direct is the current which flows in one direction only (as in a car battery). Sources of direct current are batteries, solar cells, dynamo, etc. Alternating current (AC) is the current which flows back and forth (a cycle) through a conductor. It is more dangerous than the direct current.
- *rate* - the rate of the cycles (back and forth) of the alternating current per second is measured in Hertz. The normal rate in Europe is 50 cycles per second or 50 Hertz. In the United States it is 60 cycles per second [or 60 Hertz (Hz)]. Most dangerous is electricity with a rate of 40-60 Hertz; electricity with a rate of approximately 500 kilohertz is not dangerous.
- *resistance* - is the ability to impede the flow of electricity. Most of the body's resistance is concentrated in the skin. The thicker the skin is, the greater its resistance. A thick, callused palm or sole, for example, is much more resistant to electrical current than an area of thin skin, such as an inner arm. The skin's resistance decreases when broken (for example, punctured or scraped) or when wet. If skin resistance is high, more of the damage is local, often causing only skin burns. If skin resistance is low, more of the damage affects the internal organs. Thus, the damage is mostly internal if people who are wet come in contact with electrical current, for example, when a hair dryer falls into a bathtub or people step in a puddle that is in contact with a downed electrical line

- *duration of exposure* - the longer the person is exposed to the current, the worse the injury
- *pathway of current* - the path that the electricity takes through the body tends to determine which tissues are affected. Because alternating current continually reverses direction, the commonly used terms "entry" and "exit" are inappropriate. The terms "source" and "ground" are more precise. The most common source point for electricity is the hand, and the second most common is the head. The most common ground point is the foot. A current that travels from arm to arm or from arm to leg may go through the heart and is much more dangerous than a current that travels between a leg and the ground. A current that travels through the head may affect the brain
- *electric arc* - continuous, high-density electric current between two separated conductors in a gas or vapour with a relatively low potential difference, or voltage, across the conductors. According to the power the current can jump from centimetres up to a meter. Electric arcs across specially designed electrodes can produce very high heats and bright light.
- *lightning* - an abrupt, discontinuous natural electric discharge in the atmosphere, characterised with a high strength in the range of 100 000 amps and voltage of several millions volts for a very short period - less than 0,0001 sec. A lightning has thermal, light, acoustic and mechanic damaging influence.
- *electric sign / burn mark* - a specific skin damage at the point of contact of the current with the skin. It is a coagulating necrosis. Their typical macroscopic characteristics are relatively small size - diameter up to 1cm or less, craterlike, round or with a groove form, grey-whity colour, thick bottom and shaft-like edges. Their existence is a morphological proof for the influence of electrical current. Most often they appear at the point of entrance of the current in the human body, so the mechanism of connection between the body and the chain can be clarified.
- *metallization* - a process of coating metal on the surface of non-metallic objects; in the case electrical injury the metal from the current conducting object is coated on the point of contact with the skin. The colour of the metal depends on the type of the metal contained in the conducting object. This is a morphological sign for the influence of electric current. It determines the point of contact between the body and the current; it can provide information for the conducting object.
- *electroshock weapons* - a group of incapacitating weapons used for subduing a person by administering electric shock aimed at disrupting superficial muscle functions. They achieve continuous, direct, or alternating high-voltage discharge 20 000V-80 000V, causing pain, shock, muscle spasms. Duration of the electroshock for more than sec can cause loss of orientation, coordination, and sometimes sleeplessness (insomnia).
- „lightning figures" - paralytic dilatation of subcutaneous blood vessels with specific form: tree or fern - like, occurring on the path of the current along the body in the cases of a person affected by atmospheric electricity.

2. Classification of electrical injuries

Electrical injuries can be classified in different ways:

2.1 According to the sources of electricity

2.1.1 Injuries from natural sources of electricity

- Injuries from atmospheric electricity – lightning and globe lightning
- Injuries from biological electricity – mostly fish
- Static electricity

2.1.2 Injuries from technical sources of electricity

- domestic electricity – 110 -250 V
- technical electricity – up to tens of thousands volts
- weapons using electricity – electro-shockers, electro-guns

2.2 According to the severity of the damages electrical injuries are principally

2.2.1 Fatal injuries – also called electrocution

2.2.2 Non-fatal subdivided as (CDC, 1998)

- electric shock
- electrical burn
- electrical falls

2.3 According to the circumstances at which electrical injuries occur

2.3.1 Forensic cases

- homicides with electricity
- suicides with electricity

2.3.1 Accidents

- domestic accidents
- occupational accidents
- leisure accidents

3. Epidemiology of electrical injuries

Despite significant improvements in product safety, electrical injuries are still the cause of considerable morbidity and mortality.

The frequency of non-fatal electrical injuries is usually presented based on routinely collected, easily accessible hospital or other medical records. Data from a Survey of Occupational Illnesses and Injuries (SOII) for the period 1992-2002 suggest that rates for electrical shock in USA for the 10 year period remained steady at 2 per 100 000 workers. The electrical burn rate remained steady at 1 per 100 000 workers (Cawley J, 2006). Data of this kind depends largely on the severity of trauma and on the accessibility of health services. Adequate analysis of incidence of nonfatal – electrical injuries would require prospective population studies.

Epidemiology of fatal electrical injuries can be more adequately studied based on vital statistics and national death registers. Electrical injuries fall in the class “External causes of death”. In the 10th revision of ICD this is class XX with codes W85, W86 and W87. In the older 9th version of ICD, electrical injuries are included in class 18 under code 925 – accidents caused by electric current. Data from the detailed mortality database of WHO reveals that mortality from electrical injuries in the European region varies more than **hundred times** (figure 1.) (WHO, 2010).

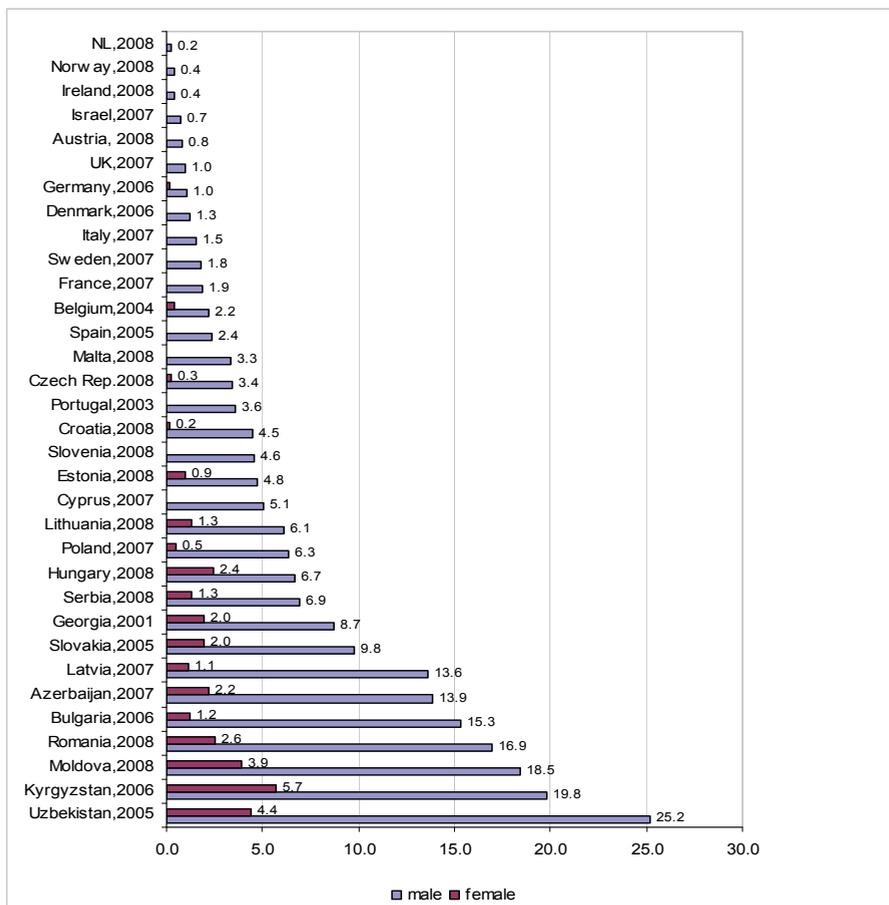


Fig. 1. Age-adjusted mortality rates from electrical injuries per 1 million population, European region

There is a clear East - West gap in relation to fatal electrical injuries mortality in Europe. Rates are much higher in Eastern European countries like Moldova, Romania, Bulgaria, Uzbekistan. This fact clearly needs attention and explanation. While the discrepancy affects both genders men living in Eastern countries are the most affected group.

Because severe electrical injuries tend to occur primarily in the workplace, they usually involve adults between 40 - 50 years of age (figure 2). In Western European countries, where mortality rates are lower, children up to the age of ten years are almost not affected. In eastern European countries with higher mortality rates all age groups are affected including youngest children.

Electrical injuries (excluding lightning) are responsible for approximately 500 deaths per year or 0.63 per million people in the United States (CDC, 1998). For Australia and New Zealand mortality from electrocution for 2007-2008 is also less than 1 per million population (ERAC, 2008). Generally, trends of mortality rates from electrical injuries are

decreasing in most of the countries and especially in the developed parts of the world. (WHO, 2010)

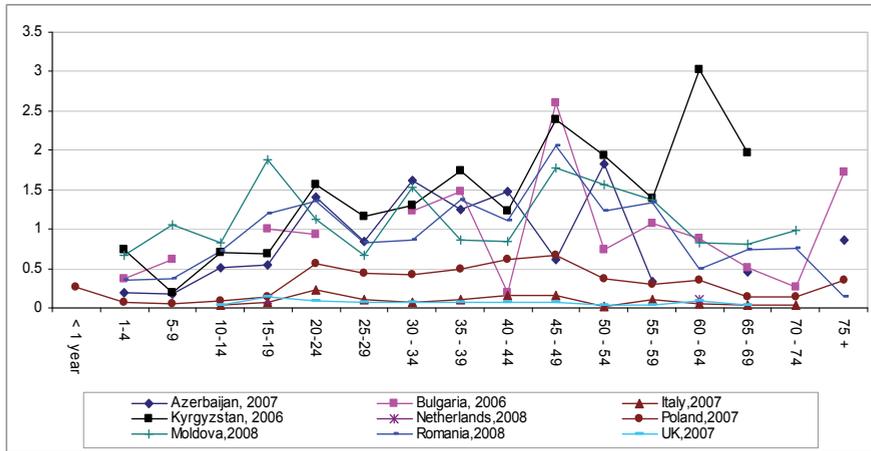


Fig. 2. Age-specific mortality rates from electrical injuries for the European region, per 1 million population, European region (WHO EDMDB)

A substantial number of papers add to the information from routine mortality statistics by reporting numbers of electrical injuries for different geographic areas (table 1).

First author, year	Source of data	Type of el. injury	Area	Period	Cases	Details
Akcan, 2007	Retrospective review of autopsy report	cases of electrocution among children	Adana, Turkey	1999–2004	37 cases; mean age 11.35; age range 18 months - 18 years;	31 (83.8%) cases male; all deaths - accidental
Dokov, 2008	Retrospective review of autopsy reports	electrocution	Central and Northeastern Bulgaria	1980–2006	485 cases, 413 cases in men; mean age 37.3 years, rate of fatalities 1,29 per 100 000 per year	24% occupational injuries; increase in summer
Lindstrom, 2006	Retrospective review of National Cause-of-Death Register;	cases coded with ICD-codes E925 and W85–87; suicides and deaths by lightning excluded	Sweden	1975 - 2000	285 cases; 269 men; mean age 38 years, age range 10 months– 92 years	151 of fatalities in leisure time; 132 in an occupational situation;
Lucas, 2009	retrospective review of autopsy reports at the Northern	electrocution	Northern Ireland	1982 – 2003	59 cases; age range 17 months - 80 years; rate of electrical fatalities	50 cases accidental, 9 suicides; increase in summer

	Ireland State Pathologist's Department				, 1,4 per 1 000 000 per year	
Nguyen, 2004	Retrospective review of 10 provincial and 2 territorial coroners' offices across Canada (no data for Nova Scotia)	fatalities in children 0-19 years from electrocution, including lightning	Canada	1991-1996	21 cases median age 13.2 years; 5 of these were cases of lightning strikes	
Pointer, 2007	Retrospective review of death certificates from Australian Bureau of Statistics	Cases coded with T75.4, T75.0, W85, W86, W87, or X33, in underlying cause or additional cause of death,	Australia	1 Jan. 2001 - 31Dec. 2004	162 cases; 2 per 1 mln population for 4 years; 7 cases of deaths from lightning- all males from 16-57 years	42% domestic accidents
Rautji, 2003	Review of autopsy reports and hospital records	electrocution	South Delhi	1996-2001	153 cases	3 cases without burn marks, 1 suicide
Sheikhzadeh, 2010	Retrospective review of autopsy report	electrocution	Tehran, Iran	2002 - 2006	295 cases, age range, 11 months - 75 years with a mean age of 28.99; 279 male cases	285 accidents (188 occupational) 10 suicides; no burn marks in 16 cases; increase in summer
Taylor, 2002	Bureau of Labor Statistics Census of Fatal Occupational Injuries	fatal occupational electrocutions	USA	1992 - 1999	2525 cases, 98.6% in males	most among 20-34 yrs, whites and indians; increase in summer,
Tirasci, 2006	Retrospective review of autopsy reports	electrocution; lightning excluded	Diyarbakir, Turkey	1996-2002	123 accidental cases, mean age 20,7, range 2-63 years of age; 86 male	31% of cases b/w 0-10 yrs. of age; lack of burn marks in 11,4%; 56 cases domestic; increase in summer;
Turkmen, 2008	Retrospective review of autopsy reports	electrocution	Bursa city, Turkey	1996-2003	63 cases (59 males); mean age 32.5; age range 5 to 62 years	Most in 30-39 yrs of age; 63,5% occupational accidents; usually in summer
Wick, 2006	Retrospective review of autopsy reports	electrocution	Adelaide, Australia	1973-2002	96 cases in total, of whom 87 males	

Table 1. Studies of fatal electrical injuries based on forensic records for the period 2000-2010

The diversity of these studies not only in terms of time periods but also age groups, types of electrical injuries covered makes their direct comparison impossible. Generally these studies confirm that electrical injuries are much more common among men. Almost everywhere in the world electrical injuries are more common in the summer season. The reasons for this repeated observations are that during the warmer months of the year people dress lightly and lose the protective effect of clothes, the skin is wet and the threshold for electrical stimulus of the heart is much lower. (Ajibaev, 1978)

Approximately half of the total number of electrocutions are occupational accidents, and constitute the fourth leading cause of work-related traumatic death (5–6% of all workers' deaths). The other half of electrical fatalities are domestic or leisure accidents, mostly associated with malfunctioning or misuse of consumer products.

3.1 Suicide by electrocution

While most deaths due to electrocution are accidental in nature, the forensic specialist should be familiar with electrocution as a method of suicide. Such cases are rare and usually described as casuistical. We have conducted one of the largest studies covering a period of 41 years (1956-2006) and eight regions (from 28 in total) in Bulgaria, a country with a high rate of fatal electrical injuries in Europe (Dokov, 2009).

From 63 825 reviewed autopsy reports 945 were cases of electrocution deaths and 59 of the later were suicides by electrocution. This accounts for 0,09% of all reviewed autopsies and 6,2% of all electrical fatalities. Males prevail definitely (54 of the victims) over females. The mean age of the victims was 45 ± 6 years (ranging from 14 to 75years). The methods used for suicide were quite diverse (figure 3) with high and low voltage electricity used with a similar frequency. This finding contrasts with the reports from Northern Ireland (Lucas, 2009) where all nine victims identified for a 21 year period had used the domestic electricity supply, usually by removing the insulating sleeving of electrical flex so as to expose the wires.

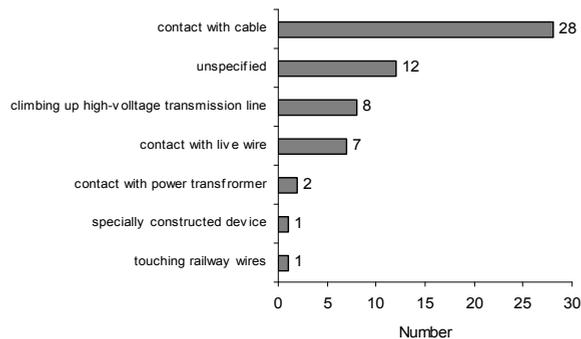


Fig. 3. Methods of suicide by electrocution

In addition we have identified a somewhat cyclical pattern of suicides by electrocution with peaks in the middle of the week and in September, with summer the typical season.

3.2 Epidemiology of lightning strikes

Lightning strikes cause serious injuries in 1000-1500 individuals each year (Adukausakeine, 2007). European countries with higher mortality from electrocutions have

also a higher rate of lightning fatalities. Romania, Moldova, Bulgaria, have more than 1 fatal lightning strike per million population per year (figure 2).

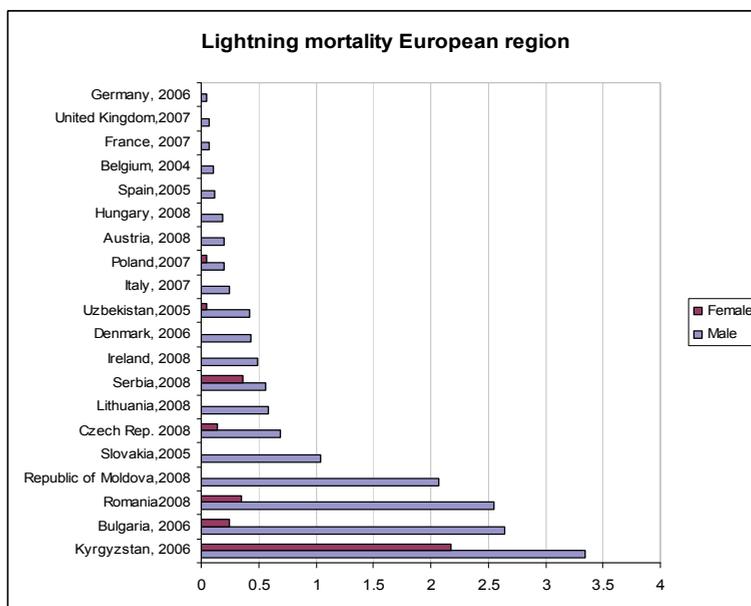


Fig. 2. Lightning mortality in the European regions, by gender, per 1 million population

In a review of lightning strike deaths for the USA, based on data from both the National Centers for Health Statistics (NCHS), the Census of Fatal Occupational Injuries (CFOI), the authors find a total of 374 struck-by-lightning deaths occurring during the period 1995-2000 (an average annualized rate of 0.23 deaths per million persons) (Adekoya, 2005). The numbers of lightning deaths are highest in Florida and Texas.

Between 75% and 85% of all lightning deaths are to men in the age group 25-45 years. Thirty per cent of all deaths involve people who work out of doors and 25% involved people participating in outdoor recreations.

Investigations of lightning strikes around the world demonstrate that the predominance of strikes is in summer months in mid-afternoon in moist atmospheric tropical and mountainous environments (Uman, 1971).

Data from WHO data- base regarding the European countries (for a fifteen year period) indicates that lightning fatalities trends are stable. At the same time one of the studies covering the longest - 41 year period (1965-2006) from Bulgaria indicates that lightning fatalities might exhibit a cyclic trend (Dokov, 2009). For Bulgaria it is suggested to be around 30years.

While lightning fatalities can be successfully analyzed based on available mortality data, it is much more difficult to obtain figures on lightning injury. The ratio of deaths to injuries is likely to be between 2 and 10. Those who are fortunate enough to recover from lightning strike frequently suffer severe and prolonged psychological damage, characterized -by withdrawal, depression, fatigue, sleep disturbance, difficulty with fine mental and motor functions, paraesthesias, headaches and storm phobias (Andrews, 1992).

4. The process of forensic medical diagnosis in case of electrical injury

4.1 Examination at the scene of death

In a case of electrical injury the examination at the scene of death has to be carried out from a team of a policeman, forensic medical specialist and a technical expert (power engineer). The tasks of the engineer are to provide evidence for the sources and reasons of electrical flow and to assure all necessary precautionary and safety measures during the inspection. The forensic medical expert needs to pay special attention to the following problems during the inspection:

In cases of an accident with technical electricity: The forensic expert needs to determine is there a contact with source of electricity – wires, devices etc., and the position of the victim in relation to them. The specialist has to look for circumstances facilitating the accident, such as increased dampness, wet clothes, lack of protective clothing, gloves, shoes, etc. On the clothes can be found signs of electrical influence (burns, other electrical sings); on the shoes there might be breaks at the points of entrance or exit of the electric chain; burns; melted nails; magnetized metal objects. Electrical burn-marks should be looked for carefully on the body, but in up to 20% of cases they might be missing. The outer inspection of the body can provide evidence of mechanic injuries - a result of falling from electrical pylon or a roof, or other not typical burns. In the case of a suicide, uncovered wires can be wrapped or fixed in some way to the body, and a letter might be left.

Information for the beginning and the course of the accident should be collected from witnesses during the process of inspection, together with information on the clinical picture before the time of death of the victim.

In cases caused by high voltage technical electricity or electric arc – deep local burns or even carbonization at the point of contact can be found, metallization, stings or burns of hairs, external traumatic injuries due to throwing back of the body. Such cases do not cause diagnostic difficulties.

In cases of an accident from electric weapons can be found changes identical with electrocution from low voltage electricity – round, point like burns or hyperemia 5-7 mm in a diameter.

In cases of an injury with atmospheric electricity there is a specific surrounding situation. The victim is most often in the open, after a lightning storm, under a tree. Signs of atmospheric electrical influence in the surrounding environment can be found – burns or tree splitting, melted or magnetized metal objects or parts of constructions. Very often the clothes of the victim are severely torn and the body might be denuded. Hairs on the head might be singed, hairs on the chest or genitals might be intertwined, and the typical for electrical influence sequelae as burns of different stages can be observed including carbonization of parts of the body.

4.1.1 Practical tasks of the forensic medical expert during the examination at the scene of death

- To check that all necessary safety measures are in place before the begging of the inspection;
- To prove the fact of death;
- To make a detailed description of the position of the body in relation to the sources of electricity (outlet, wires, devices);
- To describe the status of the clothes (wet/dry), presence of protective gloves, shoes, condition of instruments with which the victim had worked;

- To look for evidence for electrical influence (electric burn signs, non-specific burns, metallization);
- To look for traumatic injuries, their character and relation to the death;
- To estimate the time of death;
- To describe all observations and facts; to inform the leader of the inspection about the observations and assure their existence in the inspection protocol.

4.1 Post-mortem examination in the autopsy room

4.1.1 Outer inspection of the body

The first task of the forensic expert is to look for evidences for the influence of electricity such as the presence of electrical burn, electrical burn-marks, metallization on the skin etc. In the case of contact with high voltage electricity – wide burn areas on the skin and deeper tissues can be caused and observed reaching to carbonization (Pictures 1-2).



a)



b)

Picture 1. High voltage/20KV/ injuries

High voltage electricity can cause damages from distance – so called electrical arc. It also causes burns. Diagnostics in such cases is not a problem.



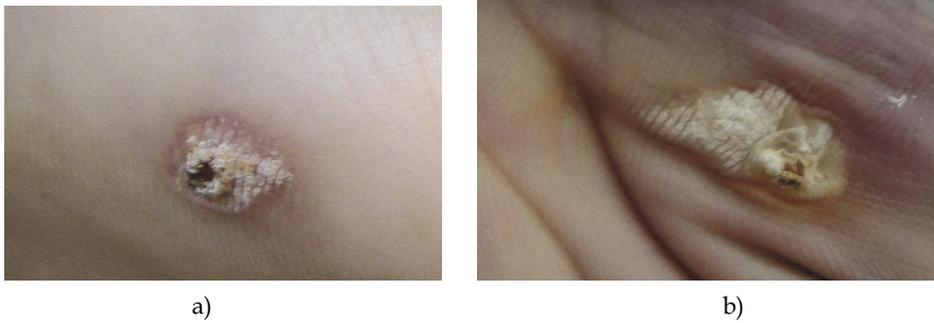
a)



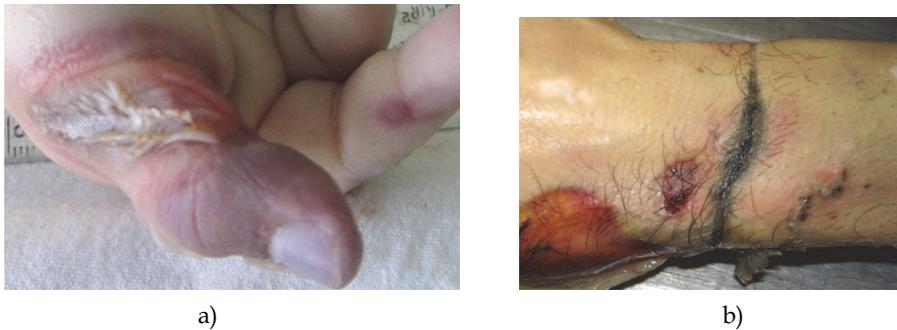
b)

Picture 2. High voltage injuries

In the case of influence of electricity with low voltage, electrical burn marks appear. Their usual macroscopic view is with round-like or oval shape, sometimes they are an imprint of the form of the electro-conductive object (Pictures 3-4).



Picture 3. Low voltage injuries on feet



Picture 4. Low voltage injuries on palm (a) and metalization of skin of the leg (b)

The central area of the damage is hollow and the edges are above the level of the surrounding skin. The skin in the damaged area is dry, thick grey-yellowish in color. In areas without horn layer of the skin they look like chafes.

Microscopic view: multiple cavities in the horn layer with various shape can be observed. Often fissures are formed on the borderline with the epidermis, reaching sometimes to complete tearing off of the horn layer. After colouring with haematoxylin eosin some focuses with basophilic colour can be found. Deposition of metal particles from wires can often be observed in such focuses. In the cell layers of the epidermis, cells and their nuclei are with elongated form. Vortex, chains and similar figures are formed at some spots. Blood vessels in the derma reveal various changes – spasm, paresis of some vessel, others are empty, without blood or with haemolysed blood. Such a complex of morphological changes in skin in the zone of contact with electro-conductive surface can be viewed as specific for the influence of technical electricity.

Important:

- The presence of electrical burn marks does not necessarily mean that the cause of death is electrical injury. Electrical burn marks often can be observed for a period of months in people who have survived electrical injury.
- Electrical burn marks can appear after the moment of death.
- A contact with electroconductive object with low voltage can cause death without burn marks which happens in as much as 20% of the cases.

4.2.2 Changes in the internal organs as a result of electricity

In cases of death from domestic or technical electricity a picture of sudden death is usually observed. Broken bones, formation of bone purls and other traumatic injuries of internal organs are possible in cases of high voltage injuries. A specific feature which appears in some cases of death from atmospheric electricity is perforation of the tympanum.

Microscopic changes in internal organs (Naumenko, 1980, Nazarov, 1992):

In the brain - oedema around vessels and cells, focal hemorrhages around vessels, vacuolization and karyolysis in the pyramidal cells. No specific changes have been described in neurons.

In myocardium - dilation of blood vessels, cyanosis to stasis, focal haemorrhages, interstitial oedema, fragmentation of muscle fibres. Often the cross striation of fibres is missing. There are small but multiple focal necrosis in myocardiocytes.

In lungs - spasm of the bronchi with epithelial swelling, interstitial oedema, focal haemorrhages, circulatory disturbances.

Walls of blood vessels - areas with destruction of the intima might be observed, together with necrotic changes of the smooth muscle fibers from medium layer, tendency for thrombosis. (Xuewei, 1992)

Kidneys - oedema of the renal pelvis mucosa, swelling of the epithelium of the kidney channels, homogenization and desquamation, circulatory changes similar to those observed in all other internal organs.

Liver - focal necrotic changes in hepatocytes. Cyanosis in blood vessels with focal haemorrhages around vessels.

Death from electrocution is a result of several different mechanisms - heart ventricle fibrillations, paralysis of respiratory muscles, paralysis of the respiratory center, shock and late sequels (as a result of burns or injury in the cases of longer survival). In the cases of electrocution the so called delayed death is possible to occur - as a result of fatal arrhythmia, thrombosis or myocardial infarction after two-three hours, sometimes several days after the accident.

4.3 Practical tasks of the forensic medical expert during the post mortem examination

- Repeated examination of the clothes and the body of the victim.
- Description of all external injuries and fixing those through schemes and/or pictures. Finding specific features for the influence of electricity and adequate description of the electrical burn marks in terms of localization, distance from main body lines and points, distance from the feet basis, shape, size, color (gray, black, shades in the case of metallization of the skin), relief of the surface (craterlike, uneven etc.), edges (exfoliated, raised, uneven, thick, friable, burned) is of greatest importance most.
- Performing a full autopsy and exclusion of other causes for death.
- Taking materials for laboratory tests /histological, chemico-spectroscopic etc/

During the autopsy the expert should try to answer the following questions:

- Has death occurred as a result of electricity ?
- What was the position of the victim at the point of the electrical injury?
- Which part of the body was in contact with the source of electricity?
- Which were the entrance and exit points of the electrical current?
- Is there evidence for metallization providing information on the characteristics of the conductor with which there was a contact?

- Are there circumstances facilitating the electrical injury (condition of clothes and surrounding environment, changes as a result of diseases.)?
- Is there evidence for self inflicted electrical injury

5. Conclusion and future research directions in the area

Until the present moment almost all scientific enquiries related to electrical injuries were focused on the changes at the point of contact of the skin with the electric current.

Future work should redirect its attention towards the search for specific changes in target organs as a result of the influence of electric current – such as heart, brain and blood vessels. These are the organs whose damage is directly related to the process of death. It is our deep conviction that such specific changes occur and should be possible to be proved with histological, histochemical, electro-microscopic or other methods.

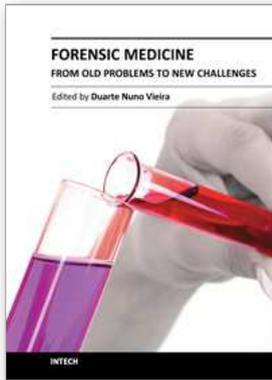
At present the diagnosis “death from electrical injury” quite often is based on indirect criteria. Strict, definitive unambiguous diagnosis is still awaiting its discoverers.

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