THE PHYSICAL AGENTS IN FORENSIC MEDICINE

THE BURNS - general aspects

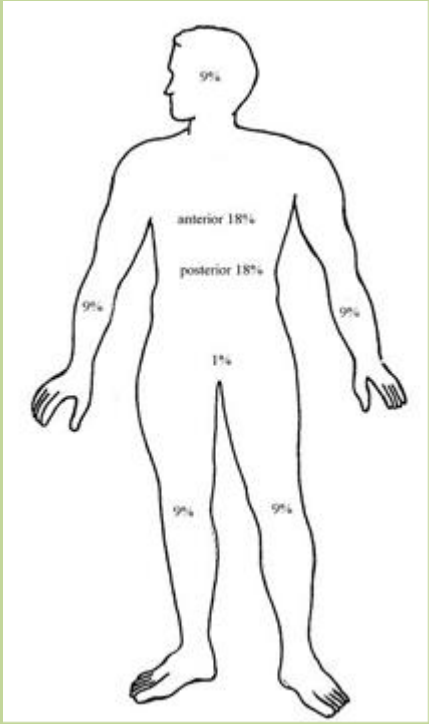
Definition: The burns represent injuries caused by a physical or chemical agent, which transfers energy into the living tissues, influencing the normal metabolic processes, usually followed by irreversible alterations and tissue death.

The severity of the burns depends on:

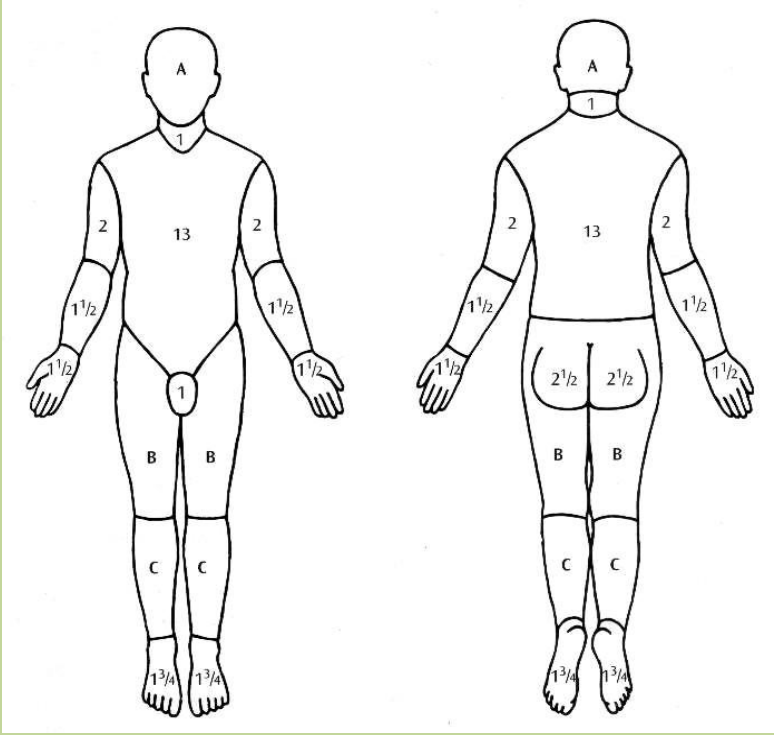
- size of the affected area,
- the depth of the burns,
- the morphological type of the burns,
- the age of the victim,
- prior health problems.

The severity of the burns is evaluated in relation with the affected % of bodily surface.

Wallace's rule of 9 - indicates the % of burned areas for every anatomical region (lethal >60%)



Lund and Browed's graphic (does not include the simple erithema). The alm of the hand + 1% bodily surface.



Mechanisms of thermal burns:

- *The radiated heat*
- usually minimal injuries, similar to prolonged sun exposure.;
- erythema, frequently associated with blisters;
- *Contact with a flame*
- produced by series of flammable substances
- is the cause of numerous death generating burns
- flammable gases burn the skin on a large surface, usually affecting only the epidermis
- the direct and prolonged contact with the flames can lead to carbonisation.
- *Contact with overheated vapours*
- generally affects the superficial layers
- - relatively short contact period
- prolonged contact may determine extended and serious injuries;
- *Contact with incandescent bodies*

- determines small but deep burns;

- *Contact with hot liquids*
- *H*ot water (50-60ºC) - important skin injuries, especially when it imbibes clothes
- because water gets cold relatively fast, the skin is not deeply burned
- Liquid metals (melted) exceed 200-300ºC
- they destroy the superficial layers, affect the muscles , determine severe necrosis.

Patho-physiology of the burns

- *The heat transfer* has a role of extreme importance in producing the burns, and the energy can be calculated, using specific physic laws. This heat transfer depends on a group of factors: the thickness of the skin, the keratin, and the sebum and perspiration glands, and generally, the tissue conductivity, water content and local blood flow.

- *The thickness of the skin* determines somehow the characteristics of the burns. Generally, the skin is thinner in young and elder, as compared to the intermediary ages. Its thickness is different for the parts of the body. The epidermis may be between 30 and 85 µm, whilst the derma is 500-2250 µm.

- *The local blood flow* is another parameter that influences the burns. A deficient peripheral circulation makes the skin more vulnerable at temperatures that normally would induce only superficial burns.

- *Time of action and the intensity of the thermal factor* are responsible of the aspects of the burn. There are some graphics that reflect the connection between time and temperature and the moment when discomfort, superficial or deep burns occur.

Local effects of the burns

= a combination between the effects of the heat and an intense acute inflammatory response (Arturson).

The patho-physiological events - phases:

- A first phase of intense forming of the local oedema, consequent to vascular dilation, to the increment of extra-vascular osmotic activity and to the increased microvascular permeability;
- A phase of transformation - the adherence of platelets and leukocytes to the endothelium is enabled;
- A last phase - a higher level of blood flow, necessary to sustain the metabolism of the burn + good antimicrobial protection

- *The interstitial oedema*
- *The cellular oedema*
- *The destruction of red blood cells*
- *Lymphatic drainage*
- *The surface of the injury* suffers transformations: loss of the impermeable keratin layer, - allows the water to evaporate

The inflammatory process initiated by high temperatures - phases:

- The histamine effects;
- The quininogen-quinine system effects;
- The arachidonic acid effects;
- The coagulation factors effects;
- The effects of extra-vascular invasion of the leukocytes.

The interaction between leukocytes and endothelial cells is characterised by alterations that enable the adhesion of platelets and leukocytes to the endothelium.

The systemic effects of the burns

The cardio-vascular response

The secondary blood volume decrease (hypovolemia) in burns is caused by:

- The massive interstitial oedema;
- The cellular oedema.
- Frequently the low protein blood level may lead to interstitial oedema in the unaffected tissues. The plasmatic losses exceed 4ml/kgh, in burns over 30% of the body surface. The highest level of protein loss is within the first 4-6 hours from the accident, followed afterwards by a substantial decrease, in 18-24 hours from the burn.

The diminished cardiac effort - even with a correct resuscitation, the cardiac function does not come to normal in the first 12-24 hours.

The post-combustion shock - the incapacity of the cardio-circulatory system to satisfy the nutritional and oxygen needs of the tissues, as well as the elimination of metabolites.

The major effects of the plasmatic losses are the oedema, blood concentration and low blood proteins.

In about a week of survival, a toxic syndrome is added to the post-combustion shock, determined by the absorbed albumin and by various enzymes coming from the injured marginal cells.

A severe infection may aggravate the patient's general condition.

The extreme pain in the early phases may determine disorders in the cortical and sub-cortical levels, especially of the cardio-vascular and respiratory centres of the medulla oblongata; these phenomena are frequently fatal.

The re-hydration determined the use of many fluids, usually with contradictory effects. The hydro-electrolytic equilibration, generally with fluids containing water and salt, is essential in the first 48 hours. The purpose of re-hydration is to induce a mild increase of interstitial sodium level.

The systemic effects of the burns

The metabolic response

- *The hyper-metabolism* is characterised by higher energy costs associated with trauma and sepsis, and it is one of the important mechanisms that appear secondary to severe burns. The clinical types, including exhaustion and emaciation are well known phenomena (Sneve).
- *The effect of environmental temperature over the affected organism is* another important element. Thus, trying to reduce hyper-metabolism by reducing the heat loss had a favourable effect in burned patients.
- *The lesion effect* is materialised both in the systemic response and in the local one (Wilmore). Glucose represents the main power source for tissues, leukocytes and macrophages, and the resulted lactic acid is recycled in the liver by transforming it back into glucose.
- *The endocrine response* (the action of catecholamines and steroids) is well known. The insulin level increases, but a certain resistance to its action may be observed; the result is hyperglycaemia and glucoseuria.
- *The nutrition effect* is another element to be considered in the evolution and prognosis of the burns. Using the fatty and muscular tissues as parts of the endocrine response determines weight and muscular mass losses.

The systemic effects of the burns

The immune response

- *The alterations of the unspecific defence* include the initial increase of the neutral leukocytes in the first 24 hours, followed by a decrease to a normal level within the next 2-4 days; their level increases again in the next 7-10 days from the accident (Sevitt).
- *The alterations of the immune defence* are represented by an initial decrease of the total level of lymphocytes in the early period after the burn, followed by reappearance in the spleen. Meanwhile, their level is low in the bone marrow and in the thymus. The toxins, the inflammation mediators, hormones, blood transfusions, inadequate nutrition, and medication represent *the causes of immune depression*

Pathology

The most frequently used classification of the burns, both in clinical evaluation and in forensic medicine is the following:

- First degree – local erithema and oedema affecting only the superficial layers of the skin;
- Second degree – superficial blisters, the result of epidermic layers disjunction. When the derma is affected, some deeper blisters can be observed;
- Third degree – full thickness burn, with dermal, hypodermic and subcutaneous necrosis;
- Fourth degree – local and regional carbonisation, affecting the muscles and bones.

Forensic classification

a. The erythema: superficial injuries of the skin, sun burn aspect, affecting the epidermis.

- redness, determined by the oedematous congestion of the skin
- a certain degree of discomfort
- the pain is due to the local vascular dilatory prostaglandins.
- the affected epithelium exfoliates within 5-10 days, without any residual scars, after complete healing.

b. *Partial skin burns:* the entire destruction of the epidermis, variable affected parts of the derma – 2 sub-types:

<u>Superficial burns</u>

- affect especially the hair follicles, the sebum glands and the perspiration glands,
- do not extend behind the limit between the derma and the fatty tissue
- important interstitial oedema appears
- the nervous receptors are exposed, so is extremely painful
- the new epithelium grows fast, healing in 10-14 days, with or without a scar.

Deep burns (dermal)

- small number of surviving epithelial cells
- extension in the subcutaneous tissues
- epitelium re-growth is slow
- the destruction of nervous terminations leads - decreased pain.

c. *Total skin burns*:

- all elements of the skin are destroyed
- may affect the deep subcutaneous tissues
- the thermal coagulation produces a lack of blood in the affected tissues;
- the destruction of the nervous endings – total local anaesthesia. I
- n the absence of infection, the burned surface can have a white, wax-like colour, or it may be brownish, hard, and dry, sometimes with a tinge of black - an eschar.

Carbonization

= the most advanced anatomical stage of the burns

The external aspect of a carbonized body:

- the boxer position - the flexion of the thighs on the basin, of the calves on the thighs, of the forearms on the arms and of the arms on the anterior face of the thorax.;

- reduction of the body volume and mass

- the skin - various aspects, proportional to the affecting temperature:
  - brownish to a black colour;
  - dry, smooth, shiny or not, with a particular resonance
  - more or less carbonized, sometimes even with the appearance of coal
  - friable and frequently totally destroyed
  - has fissures and linear transversal ruptures, more or less deep, mainly located at the flexion skin folds, especially in the upper third of the arms or in the lower third of the thighs,

Carbonization

Muscles can be:

- intact, pinkish (CO) or
- - if the skin is destroyed, dehydrated, more or less affected by the heat, light-brown colour.
- destroyed, revealing the bones, which are frequently fractured or with various degrees of carbonization.

The dislocation of the joints is also frequent. The ribs can be exposed, and the abdominal skin may have multiple ruptures or even the abdominal wall may disappear.

The face is unidentifiable. The hairy skin is more or less affected.

The cranium is altered, with fissures or even a real “explosion”, which makes the identification of the fractures produced when the victim was alive very difficult.

The cranial sutures are opened.

The pharynx, the larynx, the trachea and the bronchi - traces of smoke or soot

The lungs and the heart are relatively well preserved in the thorax when the wall is unaltered.

The abdominal organs are usually well preserved. When the abdominal wall is partially or totally destroyed, the organs, especially the liver and the kidneys have a “cooked” aspect.

The carbonization can be associated with important destruction of the body, with deep losses of tissue and even with spontaneous amputations of the extremities.

The forensic examination in burns

Diagnosing a burn

- morphological aspect of the lesions
- difficulties - blisters differentiated from those of various skin diseases, frostbites or putrefaction (microscopic examination)
- presence of traces of thermal agent on the body and clothes (soothe, flammable liquids, melted plastic etc)
- the ante-mortem burn - has a wider base, it is dark red and blisters can be seen around it; the ante-mortem blisters contain a white or reddish liquid, with a high leukocyte, fibrin and red blood cells level
- the presence of fibrin = the main element for differentiation between the ante-mortem and post-mortem burns, as well as with the frostbites.
- the post-mortem blisters - usually contain gas, rarely a pinkish liquid, with a low level of protein and leukocytes
- COHb blood levels - 30-40 % = certain proof of vital burns.

Diagnosing the cause of death in cases of burned bodies:

- the burns were vital or not
- establish the death generating mechanism.
- exclude other causes of death: smoke and gas inhalation; electrolytic alterations due to the plasmatic loss and to the intense dehydration; renal failure; intoxication; infection.
- the cherry-red colour indicates the presence of COHb - needs toxicological
- soot found in the larynx, trachea and bronchi - the victim was still breathing when the fire took place
- exclude other violent causes of death (e.g. mechanical asphyxia, gun shoot, various traumas).

The identification of the burned / carbonized bodies

- species can be approximated after anthropological studies, histo-chemical investigations and quantitative analysis of the mineral elements found in the bones.
- gender can be evaluated by the presence of the uterus (protected because of its anatomical position), or using the morphology and the dimensions of the skull and of the pelvis.
- An important role in the identification is played by the forensic examination of the teeth (because they resist at high temperatures)
- the DNA profile is extremely important for the identification.

Low temperatures: local effects - the frostbite

Frostbites = injuries, consequent to the action of low temperatures, characterized by the freezing of the tissues.

- **Risk groups**

  - persons who work at low temperatures,

  - persons accidentally exposed to extreme low temperatures (skiers, mountain climbers)

  - persons of extreme ages (children, old people),

  - homeless persons

  - persons with alterations of the mental status

  - long lasting standing position, especially at low temperatures

  - shock, tiredness, infections, improper nutritional status, alcohol

- Frostbites generally affect the limbs and the prominent parts of the body, more exposed to cold and draft (hands, feet, cheeks, ears, anterior face of the calf and cornea)

Pathology of the frostbites

First degree – in the beginning - vascular constriction, thus the skin is pale and cold. Passive congestion in the capillary vessels and veins follow and the skin becomes cyanotic, painful and then insensitive (numbness due to the paralysis of the sensitive nervous fibers);

Second degree – redness, swelling, blisters with clear or bloody content and reddish – grey, mortified bottom. Some skin ulcerations may be observed, their healing is extremely difficult;

Third degree – necrotic skin injuries - evolve as chronic ulcers;

Fourth degree – dry of humid gangrene in the affected area.

The gangrenous injuries have several distinct areas:

- total necrosis area, with a grey or black colour;
- degenerative irreversible processes, with ulcerations;
- reactive inflammatory processes;
- non-obvious pathological phenomena (endarteritis, osteoporosis), clinically evident only after a longer period of time.

The microscopic examination:

- vascular thrombi (especially venous)
- obstructive endarteritis in the small and medium size arteries - progresses to total obstruction
- haemorrhage and a decay of the myelin layer in the nervous trunks, may be seen
- hyaline decay, necrosis, and, sometimes, late sclerotic reactions in muscular fibers

Clinical aspects of hypothermia

In the human body, the main functions are stopped at a temperature of 24-25°C.

- Exposing the body at low temperatures generates the “cold” sensation, to which the body responds with shivers (intensification of the muscular activity), as well as with the contraction of the hair follicle muscles, thus reducing the losses. Furthermore, a great amount of glycogen is eliminated from the liver, this being the main source of thermal genesis. The heat loss is diminished by the peripheral vascular constriction and perspiration blockage.
- Exposure to cold environments, especially of elderly subjects, can lead to a central temperature below 35°C, followed by a series of significant alterations. Therefore, the skin becomes pale, the pulse is weak, almost imperceptible, and the respiration is minimal. Meanwhile, the blood pressure drops, cardiac rhythm problems occur and the arterial pH decreases, following the metabolic acidosis. The cardiac debit is low and the perfusion is inadequate.
- The hypothermic shock is characterized by a decrease of the blood flow in the small vessels, with low oxygen levels, acidosis, sludge, which determines thrombosis, accumulation of mineral acids and tissue damage. All of these initiate the activation of the cellular elements in the small vessels.
- If the body temperature drops with a few degrees, one considers that hypothermia is installed.
- The clinical signs are not so obvious when the temperature is higher than 35°C.
- Below 32°C the muscular activity cannot compensate the loss, therefore the situation becomes serious;
- below 28°C the patient can die, even with proper treatment,.

Clinically, hypothermia has three phases:

- First phase (37-32°C) – shivers and skin vascular constriction, without any other significant signs;
- Second phase (32-34°C) – the response reaction appears, and the thermal genesis signs disappear, combined with a progressive alteration of conscience, low heart rhythm, low respiratory frequency and low blood pressure;
- Third phase (below 24°C) – the organism cannot compensate the heat losses and a general paralysis appears.

Pathology of hypothermia

The general aspect – scarcity of elements

- red colour of the lividities (only indicates the fact that the body was exposed to a cold environment)

- pinkish or pink-brown areas, with irregular borders, around the knees, elbows and hips - hypothermia can be suspected

- sometimes the gastric mucosa has numerous brown or black ulcers (may be observed in other types of ante-mortem stress)

- subjects with psychiatric disorders may hide in cold, isolated places. Often they get undressed (Knight's „hide-and-die syndrome"

- the frozen body has a wood-like consistence – false rigor mortis

- the skin is immobile, forming a common structure with the subjacent anatomical layers.

- the brain and the meningeal membranes are hyperaemic; small meningeal haemorrhages can be seen; large amounts of spinal liquid can be found in the sub-arachnoidal space and ventricles

- the gastric mucosa often (85-90% of cases) shows brownish blood suffusions – the Vishnevski's spots.

The forensic diagnosis of hypothermic death

- accidental, suicidal, or criminal.
- most frequent type – accidental
- suicide – rare, seen especially in mentally disordered patients and alcoholics
- murder by hypothermia – mainly in cases of children deliberately exposed at low temperatures.

THE EFFECTS OF ELECTRICITY

Characteristics of the electrical power

Electrocution takes place when the electrons pass through a circuit within the body, represented by various tissues and heading towards the ground.

- The alternative current is more dangerous for the organism. Its effects are directly proportional with the frequency, with a maximum found at 50 Hz. Over this limit, increasing the frequency determines a loss of the dangerous effects, and at very high frequencies, it has a therapeutic effect.
- The continuous or galvanic current is generated by various electrostatic utensils or by chemical generators (batteries, accumulators). It inhibits the central nervous system (CNS), whilst the alternative current has an exciting effect. At equal tensions, the alternative current is more dangerous that the continuous one, because it determines heart rhythm disorders. Generally, a current becomes life threatening when it has a tension over 65V for the continuous current, and beginning at 25-30V for the alternative current with industrial frequency (50Hz).
- The induction current usually determines only electrical traumas, rarely electrocution, because its intensity is low (for example the spark plugs of the internal combustion engines, although they have a tension of 20,000V, the injuries are mild, because the intensity of the current is low).

THE EFFECTS OF ELECTRICITY

The effects of the current on the organism can be divided in: the thermal effect and the non-thermal effect.

The destruction of the tissues produced by the current induced heat is related to their electrical resistance. The skin in the palm of the hands, dry, thick can have an electrical resistance of 1 million Ω/cm^2, while the resistance of the wet skin is only 1,000 Ω/cm^2. The difference between the electrical resistance of the internal tissues is relatively small, so that the entire body can be considered as a conductor with the resistance of 500-1,000 Ω (Cason).

The effect of the resulted heat is determined by the surface of the transverse section of the conductor (Hunt). Therefore, the destruction of the extremities, with smaller section surface is more severe, as compared to that of the trunk.

The non-thermal effect of the current is related to its intensity;

- a current of 1-2 mA produces only an unpleasant sensation
- when the intensity reaches 10 mA, the muscles begin to contract
- an alternative current of 15-20 mA determines continuous contractions, inducing the so-called sticking effect. As a result, the victim is usually incapable to break away from the electric source.
- when an alternative current of 225 mA passes through the heart it can cause ventricular fibrillation
- a current of 100 mA that passes through the brain can lead to loss of consciousness
- at intensities exceeding 1 A, the passage of the current through the brain suppresses the cardio-respiratory centre and may lead to generalized convulsions.

THE EFFECTS OF ELECTRICITY

Patho-physiology of electrocution

- Electrocution can happen in the following ways:
  - *Direct mono-polar contact*: touching the body with a single source, in just one area of the first;
  - *Direct bi-polar or multi-polar contact*: it has several types – the contact with a source with two or more parts of the body, which is isolated from the ground, therefore the current passes through the body from side to side, thus forming a derived circuit; another type is represented by the contact with two different sources of electricity, with two parts of the body, resulting a short-circuit between them;
  - *Indirect contact*: the body is in contact with an electrical source through elements with random action (e.g. the fire-fighters through the water jet that falls on an electric source);
  - *Voltaic arch*: is a type of mono- or multi-polar indirect contact (between the body and the electric source is a layer of air).
- Usually, the entrance point of the current into the human body is the hand that touches an electrical conductor, and a limb (superior or inferior) frequently represents the exit. In both cases, the current passes through the thorax – the most vulnerable zone, because of the risk of cardiac shock or respiratory paralysis. According to Joule's law, a fraction of the current is transformed into heat, directly proportional to the resistance.
- The factors implicated in the effects of the current are:
  - Tension: the resistance is as low as the tension is high;
  - Intensity: It is in inverse proportion with the resistance;
  - Type of the current: the body is resisting better to continuous current;
  - Contact surface: the bigger it is, the lower the resistance of the body;
  - Number of contacts: the contact surface increases with the number of contact points;
  - The position of contact points: a contact point placed at the head is more dangerous than one placed on one of the limbs;
  - The period of contact: the energy transfer is directly proportional with the time of contact;
  - Individual factors: there are some people with a high sensitivity for electricity.

THE EFFECTS OF ELECTRICITY

In the body, the current radiates from the entrance point, especially following the blood vessels, with a higher conductivity, because of their liquid content. If the passage of the current through the body affects the vital thoracic organs, then the electrocution can be fatal.

The effects of the current on the organism can be mechanical (the high tension), thermal (because of the transformation in heat) and biochemical (electrolysis).

- The mechanical effects are characterized by skin ruptures, injuries of various organs or even fractures, as a consequence of the violent muscular contractions determined by the electricity. Morphologically, they are similar to the action of those produced by mechanical agents, but have an emphasized expression at the entrance and exit points (superficial or deep wounds, muscular ruptures, injuries of the joints and fractures).
- The burns and carbonization, usually necrotic, without any inflammatory signs, represent the thermal effects of electricity. They are the consequences of the conversion in heat of a part of the electric energy that passes through the tissues. The intensity of the electrical burns is directly proportional to the power generated by the current and to the period of action. As a result of the heat, some tissues may coagulate, or be totally destroyed. This process of thermal coagulation of the epidermal structures determines the electric mark. In serious cases, with a prolonged contact, powerful currents and high resistance, the electrocution may lead to the carbonization of a segment of the body, especially a thoracic limb, rarely of the entire body.
- The biochemical effects consist in migration of certain ions into the tissues, oedema, and metal is infiltrated in the contact area etc. The action of the electric field, especially in the case of continuous current determines electrolytic dissociation that leads to the transformation of fats in fatty acids.

THE EFFECTS OF ELECTRICITY

The result of the action of the electricity is related to the affected body region, organ or tissue.

- In the CNS, strong currents produce inhibition and weak currents – excitation. No matter what was the nature of the currents, coma is possible to appear after electrocution. Initially the convulsions may lead to disconnection from the electric source; also it is possible that a strong muscular contraction produces a severe electrocution, because of the fact that the hand is tightened on the conductor. In these severe forms, respiratory paralysis may occur as a result of the inhibition of the respiratory centers; also death by ventricular fibrillation is possible. In case of surviving, more or less serious psychiatric consequences are possible (amnesia, confusion, and paresis).
- In the muscular mass, the current determines a spastic contraction, directly proportional with the tension. The extremely fast passage of the current through the muscles determines a generalized contraction of the muscles and a short respiratory stop. Consequent to the passage of electricity, atrial or ventricular fibrillation may occur.
- On the vessels, the electricity has an intense constriction effect, followed by arterial hypertension.

THE EFFECTS OF ELECTRICITY

The action of electricity on the human body has two types of effects: one upon the body (the electric shock) and on the contact points (local lesions).

- *The electric shock* is a complex phenomenon that includes the reaction response of the organism in front of the action of electricity. It is characterized in the beginning by a painful muscular spasm, especially in the contact area, generalizing in the following period of time. This includes also the vascular system, generating arterial hypertension. Respiratory arrest and loss of consciousness follow next.
- High heart frequency and fibrillation (atrial more frequently than ventricular) are associated. As a result of cramps and atrocious pains, the victim is thrown to the ground. Consequently to the spasm of the thoracic muscles, of the vessels, and to the alterations of the contractility and of the heart rhythm, pulmonary stasis appears. This cascade of pathological phenomena has as a result general hypo-oxygenation, with severe injuries of the brain and annihilation of some brain functions. The electric shock is reversible, so that death by electrocution can be considered initially as a type of false death.
- The functional injuries of the CNS are caused both by the reflex inhibition and neuronal modifications, resulted from the mechanical, thermal and biochemical effects of electricity, and indirectly by the low levels of oxygen, caused by the cerebral circulatory modifications and peripheral respiratory insufficiency.
- The cardiac alterations are the consequence of the direct effect of electricity on the heart, and sometimes of a reflex effect that affects the automatic heart system and generates problems of myocardial irrigation and heart failure.

THE EFFECTS OF ELECTRICITY

Pathology of electrocution lesions

- Usually there is a focal entrance point, where the electricity is concentrated, and the energy must be sufficient to produce thermal lesions. These can be multiple, but frequently uncharacteristic. Most frequently they appear on the hands and must be extremely attentive examined. When rigor mortis determines a contraction of the hands, these must be forced open, even by cutting the tendons of the flexor muscles of the fingers, in order to examine properly the tips of the fingers.

The specific injuries for burns are the electric mark, electric oedema, epidermal lysis, tissue burns and skin metal staining.

The electric mark appears more frequently at the entrance point, sometimes at the exit point or even on the passage.

- It appears like a skin depression, hardened, and with a discoloured area around it. It is usually round, but it is possible to be oval or oblong; its colour is grey-yellowish, with slightly erected margins. The maximally dimensions are of 1 cm; sometimes it can be greater. In some cases, the mark can reproduce the shape of the conductor, or skin folds can hide it. The electric mark is rarely accompanied by inflammatory or vascular reactions (Fig. 5).
- Microscopically, a pale coloration of the epidermal cells is seen. The superficial layer is flattened, with disappeared structure. The cells in the basal layer have an oblong shape, similar to the nuclei. In the epidermis, there are some spots where the cells are swollen or necrotic. In the derma, there are some empty, cavernous spaces. Deeply, the derma has a homogeneous and dense aspect, with some chromatin remains from the nuclei of the connective cells. The connective fibers are fusioned and hyaline aspects may be observed. The blood vessels are dilated, filled with blood, and in their walls and around them haemorrhages and thromboses are found. The nervous fibers within the vascular walls are thickened.

THE EFFECTS OF ELECTRICITY

The electric oedema is a hump of various sizes of the tissues in the contact area. It is usually hard, associated to a skin discoloration.

- *Epidermal lysis* can be observed sometimes around the electric mark, and it is favoured by skin moisture. This alteration consists in the separation of the epidermis because of the destruction of the connective filaments from between the Malpighi cells, followed by the appearance of blebs.
- *Skin burns* are seen in the contact area and they usually are complex, with extensive tissue injuries and effects on the internal organs. They are circumscribed injuries, of various dimensions, hard, do not bleed and resistant to putrefaction. They can be found at the entrance and exit points. The skin looses elasticity, becomes dry, hardened, and has a brown-yellowish, grayish or black discoloration. Blisters with inflammatory reaction rarely surround the burns caused by electricity. When the burn is deep, it can produce the carbonization of the bones, which become friable, white and sometimes fractures can be found. In the case of extended burns, the skin is severely affected and external specific lesions are seen ("crocodile skin" aspect), but the characteristic internal signs miss.
- Microscopically the surface and the deepness of the injury are larger than the electric mark. The muscles show signs of a waxy, vitreous or granular degeneration. Inside the muscular fibers hyaline transverse bands can be seen, especially in the muscles placed away from the entrance point. Vascular thromboses are frequent, as well as rupture of the vascular walls and haemorrhages around the vessels and inside the vascular wall. The skin has thermal injuries, but it seems that there are some characteristics of the electrocution. The nuclei of the cells are disposed in parallel lines around the affected area.
- *Skin metal staining* is specific for electrocution, characterized by the staining of the skin with metal particles originating in the conductor. This alteration can be revealed with the aid of some biochemical reactions.
- The extremely powerful electrical currents can generate destructive injuries, such as irregular wounds. Some may have the aspect of deep, penetrating craters similar to the gun shoot wounds. The brain can suffer sometimes a coagulation necrosis that gives it the aspect of "boiled egg".

THE EFFECTS OF ELECTRICITY

The context of electrocution

- The most controversial problem in the case of death presumably produced by electrocution is that regarding the death-generating syndrome.
- The death consequent to the electrocution is installed after a period of ventricular fibrillation (low-tension currents), of the inhibition of the nervous centers (powerful currents) or of mechanical asphyxia due to the paralysis of the respiratory muscles (weak currents).
- The most frequent cause of death by electrocution is ventricular fibrillation, as the effect of the current on the myocardium and on the excitatory system. In this case the victim is pale, as opposed to the cases when death occurs after respiratory paralysis, when the victim is cyanotic. In the latter the electricity determines the spasm of the diaphragm and intercostal muscles, blocking the respiratory movements.
- From a forensic point of view, the electrocution is usually accidental, both in the industrial and domestic environments.

3.5. The electric arch

- The electric arch is produced when the electric potential is great enough to surpass the resistance of the air between the electric source and the conductor.

3.6. Lightning

- Injuries caused by atmospheric electricity are extremely complex and death resulted from such an incident is very difficult to explain.
- Lightnings are several kilometres long and of some centimeters wide. Although they last for only fractions of a second, the intensity of the current is extremely high (from 200,000 to millions of Amperes) and the tension can reach 20 million V; the air is heated to temperatures up to 20,000°C.
- In such conditions it is obvious that surviving from this kind of accident is an exception. The contact with such a current may lead to cardio-respiratory arrest.
- The injury resembles the shape of a leaf (“lightning figure”), but in many cases this sign may not be present.
- When it is present, it can persist for 2-3 days in those who survive; in corpses it disappears much sooner. A lot more frequent are the reddish lines on the skin, similar to the perspiration lines; therefore many bodies show no signs that may lead to lightning. The internal examination of the body can find ruptures of various organs or more or less extended and deep wounds.

THE EFFECTS OF ATMOSPHERIC PRESSURE

The effects of low atmospheric pressure

- It is well known that the optimum pressure for the human organism is situated around 760 mmHg. Any significant deviation from these values may lead to more or less severe injuries.
- The accidents produced by the exposure at a low atmospheric pressure affect especially in persons who work at high altitudes (pilots, mountaineers). The clinical signs appear at various heights, related to individual and environmental characteristics, most frequently around 2,000-3,000 meters. The partial pressure of the oxygen decreases in parallel with that of the atmospheric pressure, and, at a greater altitude, low temperature has an aggravating effect.
- The symptoms induced by low pressure are included in the generic name of altitude disease. In the beginning the face becomes cyanotic, and dyspnoea, muscular fatigue and somnolence appear next. Peripheral collapse, stupor, vomiting, renal blockage and chaotic, irregular respiration appear in more severe cases.
- The ascent is fast (e.g. the pilots), the decrease of the partial pressure of the oxygen determines general muscular impotence, loss of sight and of hearing, and somnolence and coma. Coming back at a low altitude determines the disappearance of these signs. Both in fast ascents and descents, the tympanum can be broken and the result may be associated with dizziness, collapse and pulmonary haemorrhage.
- Death is the result of a complex of factors, the main being the absence of oxygen, following the decrease of its partial pressure. The autopsy can show small visceral haemorrhages, in the timpani and nasal cavities, and general asphyxia signs.

THE EFFECTS OF ATMOSPHERIC PRESSURE

The effects of high atmospheric pressure

- The accidents produced by high atmospheric pressure are found in persons whose activities consist in deep-sea dives. In those work places, the air is compressed at a pressure of almost two or four atmospheres, with a high level of carbon dioxide.
- The nitrogen embolism generates the effect of sudden decompression. When the atmospheric pressure grows rapidly, a group of symptoms appear, such as ear, dental and sinus pain, dizziness, nose bleeding.
- When a brutal decompression takes place, the nitrogen that is rapidly eliminated may affect tissues and in the capillary vessels the gas blocks the circulation. As a result, death by gas embolism is possible. In these situations, the autopsy finds in the right heart a lot of blood with foam aspect. The lungs show signs of asphyxia, oedema and emphysema.