The Effect of An Electric Current on Human Body (A Review)

Assist. Lect. **Yasir Khaleel Almusawi,**
Assist. Lect. **Maha Raad Hashim Al-Sammarraie**
and Assist. Prof. Dr. **Mukaram D. Shikara***
Medical Lab. Techniques Department, Al-Esraa University College, Baghdad/ Iraq.
***To whom all correspondents must be addressed.**

تأثير التيار الكهربائي على الجسم البشري (مقالة مرجعية)

م. م. ياسر خليل الموسوي،
م. م. مها رعد هاشم السامرائي،
أ. م. د. مكرم ضياء شكارة

قسم تقنيات المختبرات الطبية، كلية الاسراء الجامعة، بغداد\العراق

Abstract

According to World Health Organization (WHO), four people are killed every week by electrocution in the last decade while 3% of people (suffered from electrical injuries) were admitted to emergency wards.

The severity of electric injury depends on the electrical resistance of the human body which depends upon several factors such as the long duration of electric contact, type of the current (AC or DC), intensity of the current (amperes/voltages), sites of entry and exit points, wet or dry body, individual metabolism of the person, sweat glands activity, human body mass, type of the tissue it travels through and its resistance, the amount of lipids and fats in that tissue and the general health of the person.

Entry and exit sites of an electric current are confusing since the electric current changes direction many times during entering the body depending on the resistances of tissues and organs.

The survival of the person depends solely on the efficiency and rapidity of medical treatment especially as the liver as the first organ suffered from an electric shock and should be evaluated first. In most cases, the liver showed portal vein thrombosis, biliary duct enlargements with beginning of cholangitis (inflammation of a bile duct) and pneumobilia (A presence of air bubbles in the biliary tree). The presence of air bubbles leads to inflammatory and the presence of bacteria inside biliary tree

The brain will not be affected by an electric shock unless the entry point was the head. Otherwise, an electric shock will daze the person or can short-term amnesia, respiratory arrest or seizure, while the heart is sensitive to an electric shock that will disrupted the heart rhythm and burned soft tissues and decreased blood pressure which affected electrolytes balance which lead to the failure of the kidneys.

The kidney is the only organ responsible for the removal of all damaged tissues of the skin and other organs of the body which will put a heavy load on the functions of the kidneys, especially the removal of all fatty deposits

It is very hard to diagnose long-term effects of electric shock on the human body, but in general, the victim will feel eye problems, generalized pain and joint stiffness with itching. The victim will face psychological effects such as reduced cognitive abilities, post-trauma stress disorder (PTSD) and anxiety

Keywords: Lesions, synapses, cirrhosis, electric necrosis, entry and exit points.

المستخلص

يتم قتل اربعة اشخاص كل اسبوع صعقاً بالكهرباء خلال العشر سنوات الماضية حسب منظمة الصحة العالمية، ويتم علاج 3% من الأفراد (الذين يعانون من اصابات كهربائية) سنوياً في اجنحة الطواريء في المستشفيات.

تعتمد شدة الأصابة الكهربائية على مقاومة جسم الأنسان للكهرباء على عدة عوامل أهمها مدة التلامس الكهربائي الزمنية، ونوع التيار (مستمر او متردد)، وشدة التيار (أمبير/فولت)، ونقطتي دخول التيار الكهربائي وخروجه، ومدى جفاف الجسم او رطوبته، والتمثيل الغذائي للفرد، ونشاط الغدد العرقية، وكتلة الجسم، ونوع الأنسجة التي ينتقل عبرها التيار الكهربائي ومقاومتها، وكمية دهون الجسم، والصحة العام للفرد.

مصطلح نقطتي دخول التيار الكهربائي وخروجه محير، لعدم تقابل النقطتين داخل الجسم، نظراً لقيام التيار الكهربائي بتغيير اتجاهه عدة مرات داخل الجسم، واعتماداً على مقاومة الأنسجة والأعضاء للتيار الكهربائي.

يعتمـد بقـاء الفـرد على قيـد الحياة علـى كفـاءة العلاج الطبـي وسـرعته، ويعد الكبـد أول عضـو يتأثـر بالصدمـة الكهربائية، ممـا يؤدي الى عـدة اعـراض منها تخثر داخـل الوريـد البابي-الكبـدي، وتضخـم قناة الصفـراء، وتكـون فقاعـات هوائية داخل الأوعية الدموية للصفراء.

بصـورة عامـة، لا يتأثـر المخ بالصدمـة الكهربائيـة الا اذا كانت نقطـة الدول هي الـرأس، ولكن سـتؤدي الصدمـة الكهربائية الى حالة مـن الذهول أو فقـدان الذاكرة على المـدى القصيـر، او توقـف التنفس، بينمـا يتأثر القلـب بالصدمة الكهربائيـة التي يمكن ان تعطـل نظـام القلـب، وتحـرق الأنسـجة الرخـوة، وينخفض ضغـط الدم، كمـا تتأثر الكليـة بشـكل كبير لكونها المسـؤولة عن ازالة جميع انسـجة الجسـم التالفـة بالصدمة الكهربائية، وازالة الرواسب الدهنية.

مـن الصعب تشـخيص الآثـار بعيـدة المـدى للصدمـة الكهربائية، ولكن بشـكل عـام، سيشـعر الفـرد المصاب بمشـاكل في العيـن، والم عـام، وتيبس فـي المفاصل مع حكـة شـديدة، وتتضمـن الآثار النفسـية ضعف القـدرات المعرفيـة، واضطـراب ما بعد الصدمة والقلق المبالغ به.

الكلمات المفتاحية: Lesions, Synapses, Cirrhosis ,Electric necrosis, Entry and Exit Points

Introduction

When the first commercial electric lines were established, people were killed due to accidently misuse of electricity. The first accident with electricity leads to death happened when a stage-carpenter in Lyon, France touched 250-volts AC generator in 1879. Since then, universities and medical establishments began to conduct studies to understand the effects of electricity on human beings (Liu, 2018; Kunwar *et al*, 2021).

Different effects of electric shock were tried to evaluated which were defined in a simplest way as (a sudden violent response to electric current flow through any part of a person's body) and various theories concerning suspended animation and action of electricity on the central nervous system were proposed (Cerri *et al*, 2013).

When the electric current passes through the body, whether direct (AC) or alternating (DC) electric current, it causes tissue damage which are known as (Primary electrical injuries), while (second electric injuries) are the injuries caused by the falling of the person and hitting the floor forcibly.

In contemporary time, there is a wide dependence on electricity which can lead, if the necessary precautions are not met, to different types of accidents (some of them are deadly). For this reasons, an understanding about the work of electric current paths through the body can be of great help to any clinic which can minimize any medical and surgical problems (Fineschi *et al*, 2006; Agaa *et al*, 2016).

According to World Health Organization (WHO), four people are killed every week by electrocution in the last decade with the admission of 3% of people (suffered from electrical injuries) to emergency wards or burn units. It was emphasized that the extent of electric-burns is more severe compared with non-electrical burns. For this reason, all experiments (past and present) used different kinds of animals as well as postmortem studies for the bodies who died by electrocution (Torres-Duran, 2006; Agbenorku *et al*, 2014; Abbate *et al*, 2022).

The objective of this review is to show different paths that an electric current can take to pass through the body, and how this current can be conducted and how can influences the nature of injuries and their types.

Electrical injury

It is defined as any physical harm to the body caused by electric current. This harm can be light tingling sensation or severe destruction of skin and organs, pain and may be death.

Dry human body has high resistance and will allow less current to flow, while wet body has low resistance to electricity.

Tissues (skin, bone, muscles, tendons, corneas, etc.) must be recovered quickly after electrical injury, usually between 12–24 hours after the electric shock (Agaa *et al*, 2016).

Accidental electric shocks can occur without any intention. Most children will have an electric shock by touching bare live wires or tried to put metal needles through the openings of electric sockets for fun, while adults can hit by electricity during cleaning electric instruments or trying to replace faulty sockets. Sometimes, a person can get lucky when the electricity throws him/her away or that person could pull away from the live current and survive (Arnoldo and Purdue, 2009; Soar *et al*, 2010).

AC and DC

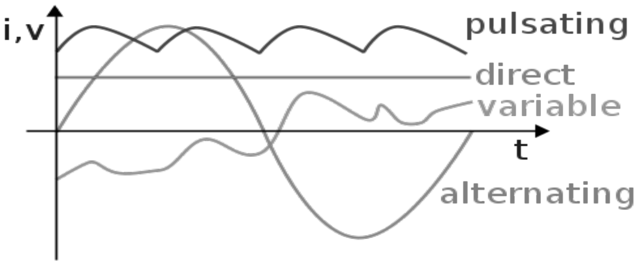

Fig.1. Types of electric waves

Two types of electrical currents are used: An alternating current (AC) and direct current (DC).

AC is an electrical current that reverses the route of electron flow numerous times every second. It main use is to feed houses and most commercial centers.

DC is an electrical current that flows in one direction-route. Its main use is in car batteries, medical appliances like defibrillators and other low voltage applications.

Both types can cause tetany (spasms or seizing), cardiac fibrillation, respiratory muscle paralysis and cardiac dysrhythmia upon electrical shock, but AC is considered the more dangerous, since the body can tolerate DC more than AC (Song and Wang, 2014; Xiu and Loul, 2016).

Severity of electric injuries

The severity of electric injury depends on the electrical resistance of the human body which can alter considerably during the passage of an electric current.

The electric resistance of a human body depends upon several factors such as the long duration of electric contact, type of the current (AC or DC), intensity of the current (amperes than voltages), sites of entry and exit points, wet or dry body, individual metabolism of the person, duration of time, sweat glands activity, human body mass, the type of the tissue it travels through and its resistance, the amount of lipids and fats in that tissue and the health of the person (Miller and Zachary, 2017).

This create a lot of problems during the investigation of electric current related accidents, since the electrical engineer thinks only in term of the applied-amperes and voltages applied, while but the physician thinks of paths in which current flowed inside the body (Mondal and Keisling, 2013; Meng *et al*, 2016).

Any body organ which is found close to the direct path of electricity will be likely to be affected and death can occurs easily if an electric current passed from the right arm and move towards the end of the leg. In other words, the electricity will pass directly through the chest cavity.

The brain does not be affected unless the electric current (in rare occasions) enters from the skull (Cao, 2014; Meng *et al*, 2016).

So most of the time, the organs within chest cavity are mainly affected as a result of an electric shock. These include heart, lungs, kidneys, intestines, lever etc. An electric shock may directly cause death in three ways: paralysis of the breathing center in the brain, paralysis of the heart, or ventricular fibrillation (uncontrolled, extremely rapid twitching of the heart muscle). It is generally believed that ventricular fibrillation is the most common cause of death in electric shock (Mondal and Keisling, 2013; Meng *et al*, 2016).

An electricity current of 0.25 milli-amperes (mA) will not affect the body, while electricity current above 10mA travels (through the muscles of the hand) will causes fingers to contract and hold the source of the current firmly and this will increase the time of contact between electricity current and the muscles which will increase the severity of electrocution.

If the electricity current travels (through the muscles of the legs), it will causes the extended of the limbs due to the burning and ruptured of tendons and ligaments which explained why the victim will be propelled many meters away. In many experiments, it was shown that skeletal muscles sustained the largest temperature rise and then heated adjacent tissues. (Khelif *et al*, 2003; Cheung *et al*, 2013; Cheng, 2015(.

Entry and exit sites

There are always two burns' sites in the body referred to them as (Entry and exit sites). It indicates that the electric current will enter the body from one point and exit it from another point, for example, current will enter through the finger of one hand and exit from the finger of the other hand.

Actually, the flow of an electric current through the body follows two paths: the surface of the skin and along the blood circulatory system.

These two terms are confusing since the electric current will change direction many times during a second or two seconds as soon as it enters the body depending on the resistances of tissues (Bailey *et al*, 2019; Deng *et al*, 2021).

These two terms are confusing too since they can be compared with entry and exit points of a bullet. The entry and exit points of a bullet are opposite each other in the body and in many times, the bullet will not exit but embedded inside the body. In electric injury, the point of entry is situated far away from the point of exit (Bailey *et al*, 2019).

The wounds of both entry and exit could be severe, so it's essential for the physician to try hard to identified enter and exit wounds which is not an easy task at all especially with the internal damage inside the body, so it is recommended that the patients suffer from electric injuries must be put under observation for a week to understand the prognosis fully (Fish and Geddes, 2008; Daskal *et al*, 2019).

It is important to emphasis that the damage of the tissues increased with the increase of amperes especially at the entry and the exit points of the current. It was noticed the presence of edema, coagulations and swelling of muscles at these points (Sherman and Trans, 2006; Kim *et al*, 2019; Lovaglio *et al*, 2019).

Burns of the tissues

Several factors affect the resistance of the body such as the type of the organ's tissues, so blood vessels and nerves have low resistance, while bone and skin have high resistance.

The dry skin has a high resistance which results in extensive superficial burns but limiting deeper conduction of harmful current comparing with wet moisture skin.

Superficial burns can occur (even with a lower voltage) on the surface of the skin, but high voltages may cause internal burns (which are difficult to heal) leading to the failure of an organ in the body. This may lead to death (Markiewicz-Gospodarek *et al*, 2022).

The survive of the person depends solely on the efficiency and rapidity of medical treatment since the heat produces by electricity current can cause necrosis and destructions of cell membranes (Fish *et al*, 2009).

The heat produces during electric current passage depends greatly on the amount of the resistance. With high resistance, a rapid increase of heat occurs with a great damage to the tissues (formation of lesions) located along the path of the electric current.

The less resistance organ may escape injuries or has a minimum amount of them, but the electric current (when pass through it) may cause greater damage to other internal organs (Fish et al, 2009; Alnuaimi *et al*, 2011).

In general, and according to Joule's Law, the amount of the damage of the tissues is proportional with the square of the intensity of the electric current (I) as in the following equation:

$$Q=I2\cdot R\cdot t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where generated heat (Q) is equal to the square of the intensity (I) multiplied by resistance (R) and time (t).

This equation explains the importance of an increase in the amperes determines multiple extensive lesions than an increase in the voltages (Guler and Seyhan, 2001; Kulkarmi and Gandhare, 2015).

Burns to tissues and organs; cardiac arrest, muscle spasms, damage to nervous system, and other unexpected consequences can be caused by an electric shock.

External burns can be treated entirely, but internal burns of organs are hard to heal since all the internal organs of the body lack nerves connected to the pain center of the brain, so the electrified person feel nothing. The burns of the interior organs can cause the production of a high amount of wastes that can cause serious kidney problems (Alivandi and Ehadi, 2007; Cao, 2014)

Liver

The liver is the first organ suffers from an electric shock, it should be evaluated first. The hepatocytes, in case of high voltage electricity that creates heat, can be easily damaged which (may) lead to necrosis.

In most cases, the liver showed portal vein thrombosis with thick walls, biliary duct enlargements which show the beginning of cholangitis (inflammation of a bile duct) and pneumobilia (A presence of air bubbles in the biliary tree). The presence of air bubbles leads to inflammatory and the presence of bacteria inside biliary tree (Sherman and Tran, 2006, Yildiz *et al*, 2011).

A polymorphism of hepatic lesions (such as biliary tree lesions, portal thrombosis, necrotic lesions and abscesses) was, sometimes, affected the person. Thrombosis can be either occurred by excessive activation of the coagulation cascade on the external pathway or due to the damage of vascular branches with extensive endothelial lesions caused by an electric current. If the treatment was slow, necrotic lesions of the liver will be replaced by fibrosis scars or cysts resulting in (multiple hepatic abscesses) which inhibit (to several extents) the defense mechanism of the liver (Ladurner *et al*, 2005; Ponziani *et al*, 2010).

Nervous system shock

The brain will not be affected by an electric shock unless the entry point was the head. Otherwise, an electric shock will daze the person or can short-term amnesia, respiratory arrest or seizure.

In rare cases, the damage to the brain or nerves can develop up after several weeks/months of an electric shock and that will depend largely on the extent of the injuries (Cao, 2014; Berg, 2019).

Neurons receive and generate electrical impulses by electrochemical reactions which transmit information that evolved elaborate mechanisms for generating electrical signals based upon the flow of ions across their neuronal plasma membranes, even though they are not intrinsically good conductors of electricity. This is occurred because neurons, like all cells, maintain different concentrations of electrolytes cross their cell membranes (Bean, 2007; Berg, 2019).

At resting phase, neurons initially are permeable to potassium ions (K+), while impermeable to sodium ions (Na+), so due to this and other few reasons, a net negative charge develops on inner axoplasm and a net positive charge develops in the fluid outside the axon. This develops a potential difference called resting potential.

When a stimulus is applied, (whether is mechanical, thermal or chemical), the permeability of the axon membrane increases for Na+ leading to rapid influx of Na+ ions followed by reversal of polarity at that site and hence it is depolarized (Ladurner *et al*, 2005).

This depolarization works as a stimulus for the adjacent region of the axon which continues leading to flow of impulse in the form of "Electric current", so, neurons work like little chemical batteries that produce ions which set up an electrical potential.

There is a slight difference between neurons and a battery, since scientifically neurons do not conduct electricity, since what is traveling along axons are not electrons, but "waves" of rapidly changing ionic charge differences, between axon cytosol and the extracellular matrix.

Healthy cells have a membrane potential of ≈≈ 60–70 mV, all using an Na+- K+ pump (Na+/K+-ATPase), driven by ATP energy.

The protein molecules (with the cellular membrane) bind three ions of sodium. During activation, the three ions of sodium were rejected and two ions of potassium will move inside the cell as can be seen in the following figure, and this will produce a wave of successive charge potential changes, moving along the neuron's axon. (Pivovarov *et al*, 2019).

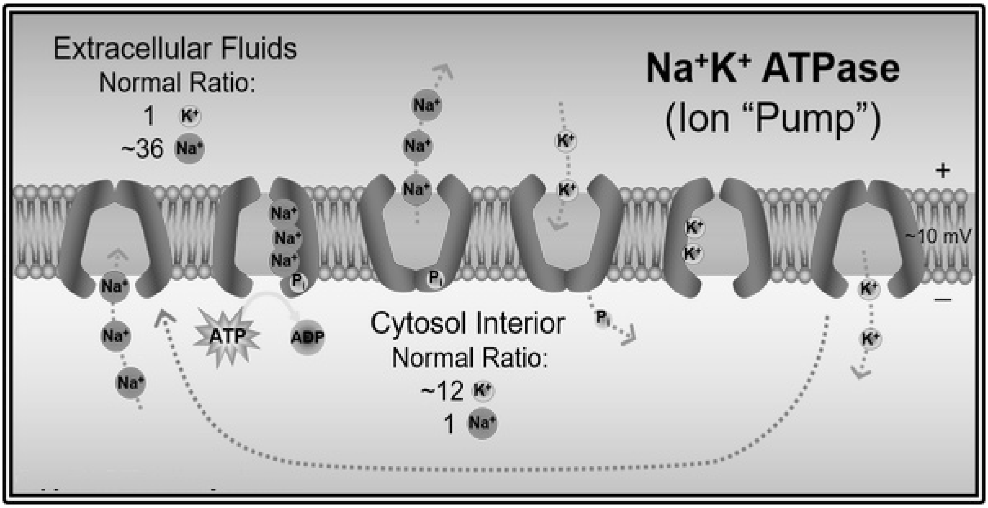

Fig.2. Sodium–Potassium Pump

It flows only forwards and not in both directions due to two reasons: a quick potassium-driven repolarization below threshold levels and due to the refractory period of sodium channels who stay inactivated for long enough to let the action potential pass by.

Fig.3. Penaeus monodon

In humans and other mammals, the nerve signals travel about 120 meters/second, while the fastest nerve signals are found in *Penaeid* shrimp (*Penaeus monodon*) which reach 210m/s. Theses speeds are so low comparing to the speed of an electric wave (few meters to few kilometers per second)(McGraw *et al*, 2001; Emerenciano *et al*, 2022).

Axons and dendrites can, in fact, carry signals in both directions, but they don't due to the asymmetric structure of the synapses and the different signal propagating properties of dendrites vs. axons (Kim *et al*, 2019, Lovaglio *et al*, 2019).

Another factor in the directionality of neurons is that dendrites propagate signals differently from axons. Dendrites are structured to propagate low-voltage analog signals, whereas axons propagate (relatively) high-voltage "binary" pulses. This is due to the slightly different signal amplifying molecules on the dendrites vs. the axons.

There are two exceptions in which signals propagate backwards, one happens naturally. When the neuron fires, not only does a big pulse travel down the axon, but also a small pulse travels in the reverse direction on the dendrites. This back-propagating electrical pulse helps the synapses know when to strengthen or weaken by helping the synapses figure out when an input signal led to an output spike (called spike-timing-dependent plasticity or STDP) (Smith and Otis, 2003, Naundorf *et al*, 2006; Kole *et al*, 2007).

While the other exception happens experimentally when the end of an axon is stimulated electrically to the spiking level, a full spike will travel backwards towards the cell body, called an "antidromic spike." This doesn't happen normally in the brain and has to be triggered artificially (Scot *et al*, 2007, Shu *et al*, 2007).

The nerves have low electric resistance and when nervous system was affected by external electricity current, a pain, tingling, and numbness and weakens occurred, but it can be recovered quickly. In severe case, the central nervous system can be affected to the extent of causing amnesia, seizure or respiratory arrest (Kole *et al*, 2007; Shu *et al*, 2007).

In general, the brain will not be affected unless high voltage electric current will hit the body, since CNS as a whole consumes the electricity. In most severe cases, the brain may be affected immediately or weeks will be passed before the effectiveness can be shown. Short-term memories region can be affected immediately while long-time memories region remains unattached. The electric current travels among the neurons slowly and in one direction and the information required is carried in the form of alternating current (Kress and Mennerick, 2009).

Sometimes, it is possible to experience an (electric shock) within the nervous system and this known as (brain zap).

The brain zap is an electric shock with dizziness or disoriented and occurs mostly as a side-effect when a person stops taking certain long-time medications (antidepressant mostly). It did not harm the brain but can cause a kind of (amnesia, headache or fatigue). It bothersome and irritate the person and do away after few weeks (Papp and Onton, 2018; Papp *et al*, 2022).

Heart injuries

The pulses of the heart are controlled by electrical impulses (cardiac action potentials) generated from (pacemaker cells). These cells are located in the sinoatrial (SA) node situated in the back wall of the right atrium. These cells are the natural pacemaker.

It is impossible for outside electric current to interfere with the pulses of heart unless it was directed to the heart (Priori *et al*, 2005; Farwell and Gollob, 2007).

If a weak electric current was passed through the chest, it can result in ventricular fibrillation. If the treatment was delayed, this will become lethal since the heart muscle cells will be moved independently and a cardiac arrest can occurred.

If electric current was high, it will interfere with the rhythm of electric pulses of the heart causing (arrhythmia) or a (cardiac arrest) leading to the death of the person (Pawlik *et al*, 2015; Chen *et al*, 2016; Waldmann *et al*, 2018).

The heart is sensitive since an electric shock can disrupt the heart rhythm, and for this reason, controlled electric shocks are used medically as a treatment to restore normal sinus rhythm (NSR).

Muscles

High level shocks will burn all soft tissues and induce a muscle contraction which will decrease blood pressure which affects electrolytes balance and this will lead in most cases to the failure of the kidneys (Tse *et al*, 2016).

If a low electr0ic currency passed through the body, only tingling or buzzing sensation can be felt, but no injury.

In general, muscles, ligaments and tendons will be tear and burn as a result of the electric shock. When a current travels through flexor muscles, such as those present in forearms, the fingers will have sustained contraction and closed. The victim will not be able to let go of the source of the current, making the duration of the contact longer and increasing the severity of the shock (Lund *et al*, 2000; Manegold *et al*, 2007).

A violent spasm occurred when an electric current travels through extensor muscles. The victim will be propelled many meters away if an electric current passes through hip extensor muscles and lengthen them (Lund *et al*, 2000; Perret *et al*, 2009).

Microorganisms after burns with electric current

Biofilms are invisible communities of microscopic microorganisms that can be found anywhere and everywhere in moisture, nutrients and surfaces. After an electric shock, microorganisms will be growing rapidly inside the burns of a human's skin. Biofilms should be treated quickly before causing further harm to the body. Antibiotic treatment not only prevent the infection of the skin, but prevent a potential infection of the necrotic areas located in the inner structures (Kennedy *et al*, 2010; Song *et al*, 2016; Guest *et al*, 2020; Comerci, 2022; Hussain *et al*, 2022;).

Pseudomonas aeruginosa was the most bacteria isolated from the wounds caused by electricity (Fineschi *et al*, 2006; Kunwar *et al*, 2021).

Respiratory system

If a high electric current hit the lungs directly, severe visceral injuries can occur. The respiratory system can be paralyzed and the heart-beat can either become very fast and irregular or can completely stop beating (Fineschi *et al*, 2006).

Burns may occur in lower lobes. The injuries can be fatal unless life-saving treatment was applied. Due to the few cases, the pathogenesis is not entirely understood (Karamanli and Akgedik, 2017; Nizhu *et al*, 2020; Chen *et al*, 2021)

Kidney injuries

High tension electricity can causes massive necrosis to all deep structures such as muscles, vessels and nerves and these may lead to acute renal failure. The kidney is the only organ responsible for the removal of all damaged tissues of the skin and other organs of the body, and this will put a heavy load on the functions of the kidneys, especially the removal of all fatty deposits (Chauhan *et al*, 2004; Ho *et al*, 2020; Teramoto *et al*, 2020).

Digestive system

The gastrointestinal (GI) system coordinates electrical activity through the tract. Normal mechanical functions depend on the highly coordinated activity of this electrical excitation, whose disruptions can lead to disorders, but not life-threating (Tse *et al* 2016).

The growth of intestinal cells' bacteria is affected by electric currents and electromagnetic fields generated by the smooth muscles of the small intestine (Camilleri *et al*, 2006). A severe electric shock may affect GI motility which lead to disorders such as achalasia, Allgrove syndrome, gastroparesis, pyloric stenosis, functional dyspepsia and unexplained nausea, vomiting and diarrhea (Dellon and Ringel, 2006; Abell *et al*., 2009).

Long term effects

It is very hard to diagnose long-term effects of electric shock on the human body, but in general, the victim will feel eye problems, generalized pain and joint stiffness with itching. The victim will face psychological effects such as reduced cognitive abilities, post-trauma stress disorder (PTSD) and anxiety

Conclusion

The electrical resistance of the human body depends upon the long duration of electric contact, type of the current (AC or DC), intensity of the current (amperes/voltages), sites of entry and exit points, wet or dry body, individual metabolism of the person, sweat glands activity, human body mass, type of the tissue it travels through and its resistance, the amount of lipids and fats in that tissue and the general health of the person.

Identifying entry and exit sites after electric shock is very difficult and the survival of the person depends solely on the efficiency and rapidity of medical treatment.

In most cases, the liver showed portal vein thrombosis, biliary duct enlargements with beginning of cholangitis (inflammation of a bile duct) and pneumobilia (A presence of air bubbles in the biliary tree). The presence of air bubbles leads to inflammatory and the presence of bacteria inside biliary tree

The brain will not be affected by an electric shock unless the entry point was the head. Otherwise, an electric shock will daze the person or can short-term amnesia, respiratory arrest or seizure, while the heart is sensitive to an electric shock that will disrupted the heart rhythm and burned soft tissues and decreased blood pressure which affected electrolytes balance which lead to the failure of the kidneys.

The kidney is the only organ responsible for the removal of all damaged tissues of the skin and other organs of the body which will put a heavy load on the functions of the kidneys, especially the removal of all fatty deposits

Most studies concerning electric shocks concentrate on liver, while they are very limited studies concerning the effect on heart and kidneys.

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