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Original Research Paper

Diagnosis of Electric Injuries: Histopathological Examination

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Abstract

The biggest challenge for a Forensic Pathologist is in the diagnosis of electrocution. This study consists eleven cases of electrical shock, which were brought to Mamata General Hospital Khammam, Andhra Pradesh; from Sept 2007 to Oct 2008. The characteristic feature of electrocution being electric contact mark over the body was not present in all mostall cases. Some time it is difficult for Forensic Pathologist to obtain electric mark by histopathological examination. The diagnosis of electrocution is confirmed by histopathological changes in skin. In all cases identified as dead due to electrocution samples were collected, preserved and undertaken for histopathological examination. The main objective is histopathological examination could be an important aid in diagnosis of Electrocution, where the findings were suggestive of electrical injuries. Considering the histopathological changes, nuclear steaming, dermo-epidermal separation and coagulative necrosis were the commonest features in skin with electric contact mark.

Key Words: Electric current, Joule Burn, Streaming of Nuclei, Histopathological changes

Introduction:

The diagnosis of electrocution is poses great difficulty in front of Forensic specialist in most of the cases. Findings such as joule burns were present in many cases of electrocution but in some cases no gross pathological findings can be seen, and at that time, Forensic Pathologist must rely on history and circumstantial evidence. The Forensic Pathologists sometimes try to diagnose electrical deaths by histopathological findings in the skin and viscera. The microscopical changes depend upon electric current which are mainly due to the burns produced by heat and the proof of the electrical burns could produce its own specific microscopic changes.

The streaming of the nuclei is the most characteristic and consistent microscopic feature found in the skin of electricalburns. [1] This palisading appearance of nuclei alone is not evidence of electrocution because these changes are also seen in other cases; they are valuable and useful from the forensic stand point when the circumstantial evidence and other corroborative evidencesare coupled. [2]

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The site of entry of an electric current into the body may lack any visible marks or in some cases may show extensive charring with heat coagulation of the muscles .Most of fatalities are a result from the passage of current. The shape and size of the mark will correspond with the shape and size of the source of the current. The pathognomic features of electrocution are electric marks and joule burns.They are seen when low or medium voltage current is involved. [3]

Electrical marks are not always obvious especially on the hands of manual workers. The electric mark is specific for contact with electricity as a proof of electrocution, when the electric mark is present; there is strong presumption of death due to electrocution.

Most of the times, the forensic pathologist is able to diagnose the electrical injuries with pathognomic marks; however in absence of typical mark he may face problems. In such conditions circumstantial and laboratory evidences aid in the diagnosis. [4]

In electric burnsacroreaction is positive but in thermal burns it is negative. In electrocution the cause of death is ventricular fibrillation, which is confirmed by autopsy findings. [5]The primary concern of this study is histopathological findings could be an important aid in the diagnosis of deaths by electrocution.

Effects of Electro Trauma on Body:

The extent of electricalburns depends upon the voltage involved, amount of current flow, the area contacted, and the duration of

contact with the electrical source. The contact mark or joule burn indicates entrypoint of current into the body and depends on the body resistance as well as the current pathway.

Cooking effect of current occurs at points of the poor insulation; the ion mobilization of cellular fluids takes place, resulting in damage to cell membranes. When theresistance of skin is diminished, penetration of current in to the skin allows. [6] The current passes through the skin producing heat, which causes boiling and electrolysis of tissue fluids.

The skin explodes and rolls back from the surface. The skin offers high resistance whereas blood offers low resistance and as such within the body, electricity tends to be conducted along the blood vessels. [7]

1. ElectricInjuries due to Low Voltage:

Electric mark: The characteristic electric burn mark is the diagnostic feature when body contact with electricity. At times it may be absent, but when present, raises a strong presumption of death by electrocution. [8]

Joule burn: It is specific and diagnostic feature of contact with electricity and is found at the point of entry of current. When the contact is prolonged, the skin mark becomes brown and with further contact, there may be charring. This is known as Joule burn. [9]

If the conductor contains copper, the electric mark shows bright green color.The electrical mark may have a distinctive pattern that of the conductor, especially there is a linear wire or a shaped metal object. When the tip of the wire or rod is at right angle to the skin, the mark may be present as a circular holepenetrating skin, muscle, and even bone simulate a bullet hole.

Joule burn is commonly found on exposed parts of the body, especially on the palmer aspects of hands. [10]Joule burn is endogenous thermal burn due to the heat generated in the body from electric current. Presence of a current mark gives important information how the current path taken place and have a charactestic greyish white parchment like appearance.

In some cases, there may not only be wound of entry but also wound of exit. These exit wounds are variable in appearance but have some features of wound of entry .The tissue in and around exit wound get split and more damage is seen in the form of punctured or lacerated wounds instead of formation of craters, as in entry wounds specially. Exit wound is mostly found on soles of feet. [11]

2. Electric injuries due to High Tension:

Injuries by high tension current are by direct contact, or an indirect which is due to arcing or flash-over.

Flash burns results from poor contact with live wire and resistance of dry skin. When a very high voltage current passes by and not through the body, the intense heat resulting from flash–over may produce burns resembling thermal burns. [12]

Very high voltage currents may produce massive destruction of tissue with loss of extremities, rupture of organs, charring of bones, and fusion into pearl like bodies. [13]

Metallization is a specific feature of electrical injury and lightning stroke, the particles of the conductor may have entered the skin, where they may be identified by specific stains; likely to be seen in full development only in the latter circumstance. The face of the victim may become darkened, The color is varied by the composition of the conductor i.e., brown or black if of iron, or yellow- brown if of copper, although copper salts may leave a blue mark on the skin.

This feature is due to the volatilization of the metal particles which are driven in to the skin. It can occur when medium voltage current is passed through the skin. [14]

Small grey-green areas may be present in the floor of the electric mark. Metallization in most of the marks produced by low or medium voltage may be detected only under low magnification or by histo-chemical examination. A positive test is a proof of electrocution.

The Acroreaction Test: applied for the identification of electric marks by demonstrating metal particles on the skin surfaces by simple color reactions. The test is based primarily on the solubility of the metal present e.g., iron, copper, aluminum, nickel or zinc, in either hydrochloric or nitric acid.

Microscopic Features in Electrocution:

Electrical burns usually represent very high temperature burns, and produces characteristic finding of severe thermal denaturation of the collagen causing it to stain blue in the ordinary Hematoxylin and eosin staining. The epidermis is elevated with micro blisters developing within the squamous epithelium as well as in the external horny layer.

These blisters are due to cooking effect on the tissue and represent defects through which the steam exited. [15] Large vacuoles produced by the heat also appear with in the epidermal cells. In addition, the nuclei of the

epidermal cells at the site of an electrical burn shows a peculiar distortion with stretching and narrowing of the contour to produce a palisade like appearance, this change is called streaming of the nuclei. These flattened cells usually stain darker than the normal cells with Hematoxylin and eosin. [16]

When contact is prolonged, the skin in the electrical mark acquires a brown tint and gets charred. These changes are called joule burn, a term which distinguishes flash burns.

Electric marks are produced by the conversion of electricity into the heat within the tissues, hence termed “endogenous burns” to distinguish them from “flash” or “exogenous” burns. Heat generated in the skin and more especially in the corium and subcutaneous tissues causes the fluid to boil to produce blisters. When the process is prolonged, the steam thus generated bursts through the skin.

The skin mark turns brown and becomes a joule burn.The characteristic of electrocution being electric contact mark over the body, is absent in many cases.

Sometimes it is very difficult for the forensic pathologist to find proof of an electrical mark, in those circumstances helps histopathological examination. From Forensic stand point, the diagnosis of electrocution is confirmed by histopathological changes in skin and presence of electric injuries.

In our study, it was found that histopathological examination could be an important aid in diagnosis, where the findings were suggestive of electrical injuries. Of these changes, the most common findings were streaming of nuclei, dermo-epidermal junction separation, and coagulation necrosis.

Repeated examination of the clothes and body of the victim, description of all external injuries and specific features of electrical burn marks by electric current, confirmation by histopathological findings, performing a full autopsy and exclusion of other causes for death will help for diagnosis of electrocution.

Material and Methods:

Present study was carried out at Mamata General Hospital attached to Mamata Medical College, Khammam during one year period from Oct 2007 to Sept 2008. All the cases of electric shock reported have been evaluated. Data was collected in a Proforma, samples preserved, and histopathological examination was done analyzed and compared with previous studies and conclusions were drawn.

Observations:

In present study, 11 cases were died due to electrocution, histopathology samples were preserved**,** histopathological examination was performed on 11cases, and 10of the cases were suggestive of electrical injury. The proof for cause of death due to electrocution is confirmed by histopathological findings and specific electric marks, circumstantial evidences.

Demonstration ofthe skin changesat the point of contact, the epidermis on microscopical examination shows evidence of apparent flattening with some distortion of the shape of cells along the direction of the current.

The epidermis is often separated and elevated with micro blisters within the squamous epithelium as well as in the horny layer. Nuclei of epidermal cell at the site of an electrical burn frequently show stretching and narrowing of the contour to produce a palisading appearance.

These features are often referred as streaming of the nuclei. Proof of an electric mark is obtained by histopathological examination, which is very difficult for forensic pathologist.

It is observed that the histopathological examination could be an important aid in diagnosis. Out of these 11 cases, nuclear streaming was reported in 10cases (90.90%).

This is most important and consistent microscopic appearance of the nuclei of the stratum basalis and also seen in deep layers of skin withnuclear elongation. These elongated nuclei are pyknotic and mostly seen in peripheral areas of electrical injuries.

Histologically dermo-epidermal separation with vacuolization, the forming of spaces or cavities within cells was reported (90.90%) Microscopically the coagulative necrosis ofcells in the epidermis and dermis was found in 10 cases. [90.90%] The depth of the necrosis is useful for whether the burns produced are due to electricity or not.

In case of electricity, borders are indistinct whereas in thermal necrosis they are well demarcated.Blister formation was noted positively in (81.81%) Metallization of skin with trace evidence, deposit of metallic electrode on the skin surface was reported in 8 cases (72.72%0.The presence of dark stained metal particles at the entry wounds are characteristic of electrical injury which is due to deposition of conductor metal onto the skin.

We observed that ventricular fibrillation was cause of death.In present study almost all scientific enquiries related to electrical injuries were focused on the changes at the point of contact of the skin with electric current. These

specific changes noted and proved with histopathological methods.

Discussion:

In all cases of suspected electrocution, the investigation of electrical burns should involve an attempt to discover the point of contact with the energized source and the point of contact with the ground. In each case, one must appreciate how the electrical circuit was completed from the source, through to the victim and to the ground.

In low voltage electrocution, examination of the device should be done rather than examining the body which will often provide the cause of death because burns may not be present. Thus one can make a diagnosis of electrocution without an electrical burn based on the circumstances of the death, negative autopsy findings and the examination of the electrical device used at the time of death.

In high-voltage electrocution, tissue from the victim may be adherent at the point of contact with the source of the current**.** The clothing should be examined carefully for burns, melting, or other evidence of thermal damage that represents points of contact with electrically charged object.

Electric mark and joule burn are the pathognomic features of electric shock when low or medium voltage current is involved. High-tension currents cause gross electrical injuries, which are a result of direct contact, flash–over or thermal burns. Electric marks are not always obvious especially on the hands of manual workers. Proof of an electric mark is obtained by histological and histochemical examination or electro-microscopic methods which are useful for a forensic pathologist to rule out the cause of death due to electrocution.

Circumstantial findings are corroborative in cases of electrocution. The present study observed that the histo-pathological examination could be an important aid in diagnosis of electric injuries. The skin changes at electrocution site; basically it is an electrical burn. These local lesions are usually found in the hands or fingers at points of entry and exit of electric current, which are more severe and observed mostly over feet or opposite hands.

In present study, in ten cases findings were suggestive of electrical injuries at these sites histopathologically.Nuclei of epidermal cell at the site of an electrical burn frequently show stretching of and narrowing of the contour to produce a palisading fashion of appearance. This change is often referred as to streaming of the nuclei. Of these changes, the most common findings are streaming of nuclei in 10 cases, and dermo-epidermal junction separation in 10casesand coagulative necrosis in 10 cases. These findings are similar to studies carried by authors. [1, 4, 11, 15]

Presence of associated features may be useful for diagnosis of electric injuries such as elongation of the cells in the skin layers. Blister formation was noted positively in 9 cases [81.81%].These are consistent with authors. [4, 6] Death due to electrocution was confirmed by supportive histopathological changes in organs and skin. Histopathological changes were seen in the entire skin specimen, who had contact mark. The histopathological changes as vacuolization and honey comb appearance in the deep layers of epidermis and dermis of skin formed by gas spaces from heated tissue fluids splitting the cells apart was less significant.

In India the domestic voltage supply is higher [220 v] then western countries [110v]. This may be cause for separation of epithelial cells and absence of honey comb appearance. Break or breach in epidermis along with separation of epithelial cells adjacent to breach is seen with vertical orientation of nuclei. [8, 13]

When cases present with electric contact marks which are evident, histopathological findings were used as supportive evidence for cause of death.

However in where electric contact mark was absent, positive histopathological findings were used to give the cause of death as electrocution. [5, 6] Tissue from the victim may be adherent at the point of contact with the source of the current.This explains that the low voltage electric accidents were present with contact mark and high voltage electric accidents invariably present as flash burns. These are consistent with authors. [14]

The causes for the electric injuries are thoroughly investigated on grounds of safety and compensation. Human negligence was mainly responsible for electrical accidents.

Autopsy reveals petechial hemorrhages present in white matter of brain, pleura, and pericardium with dilated heart and visceral congestion. No specific gross internal findings of organs were observed at autopsy. Similar findings were made by authors. [15]

In present study the most common histopathological lesions were nuclear streaming, dermo-epidermal separation with vacuolation, and coagulation necrosis. Similar findings are noted by authors. [4, 6, 15]

Electrical accidentsinvolving low voltage constitutes (83.87%) while high voltage constitutes (16.12%).These are consistent with authors. [8, 14]This could be explained that the

low or medium voltage current are mainly responsible for the electrical injuries while home appliance and equipment handling at work place whichare increases the electrical accidents. In low or medium voltage accidents, the electrical injuries are present as contact mark. These are consistent with authors. [11, 14, 15]

Determination of the histological appearances of the electrical wounds are rather controversial,as some changes formerly claimed to be specific for electrical lesions have been shown to be thermal in nature.There is little that is absolutely pathognomic of electrical,as opposed to purely thermal, burns.

Conclusions:

Most of low voltage electric injuries were present with contact wounds.

- Electric contact mark is pathognomic of electrocution.
- Histopathological changes were used as supportive evidence in giving cause of death in presence of contact mark.
- Histopathological changes were used to give cause of death where no electric contact marks were found.
- Histopathological changes are present in 10 specimens of skin with contact mark.
- Heart specimens were observed for specific features of electrocution.
- Kidney specimens were nonspecific. Petechial hemorrhages found in white matter of brain.

At present the diagnosis of death from electrical injury quite often is based on histopathological findings and electric contact marks.

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Table 1: Histopathological Changes

S.N.	Pathological features	Cases (%)
1	Streaming of nuclei	10(90.90)
2	Dermo-epidermal separation	10(90.90)
3	Degeneration of collagen in dermis with Coagulative necrosis	10(90.90)
4	Pyknoses of nuclei	6
5	Hyperkeratosis	5
6	Micro blister formation	9
7	Degeneration of collagen in Keratin layer	4
8	Metallization	9