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Original Research Article

Histomorphological changes of skin in electrocution deaths - A study in a tertiary care hospital

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ABSTRACT

Background: Electrocution deaths (EDs) is one of the important causes of negative autopsy with no gross pathological findings in almost half of all cases. The history surrounding the cause of death and circumstantial evidence is sometimes ambiguous and poses great difficulty. Hence, this need to be coupled with histopathological examination to arrive at the diagnosis.

Materials and Methods: Retrospective study was conducted with entry and exit wound of skin samples among 17 cases of EDs Total- 46 skin samples. Corresponding normal skin was used as control. The histomorphological changes of skin were noted in both entry and exit wound separately and its association with electrical voltage was studied and statistically analysed.

Results: The maximum EDs were due to high voltage (47.06%) at the workplace (70.5%) and were accidental in nature (100%) predominantly affecting males (88.24%). Upper extremity was the chief area of wounding (51.7%). Most common gross abnormality was ulcer/crater (82%) in entry wound followed by bulla formation (70%). Commonly exit wound showed splits in skin (75%). The most common histopathological finding in entry as well as exit wound was dermoepidermal separation (88%, 75%), coagulative necrosis of epidermis (82%, 66%) and nuclear streaming (76%, 50%) respectively.

Conclusion: Histopathological changes in skin give the supportive evidence in determining the cause of death especially in case of negative autopsy. The important microscopic features of electrocution are dermoepidermal separation, coagulative necrosis, and nuclear streaming.

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1. Introduction

Electrocution is one of the major public health concerns with high morbidity and mortality. Electrocution mainly occurs due to poor maintenance of electric equipment, misuse, and carelessness and lack of knowledge of electrical hazards coupled with lack of safety measures.¹⁻³ Death due to electrocution is considered as an unnatural death caused by the passage of electric current either high or low voltage into the body.^{4,5} Maximum number of electrocution deaths (EDs) occurs with low voltage i.e., between 110-380V in

which voltage range of home and industry exists.⁶ While high voltage (>600) EDs mainly occur at work and are mostly accidental.⁷

Skin is the most frequently involved tissue in electrocution injuries, but electrocution changes can also be seen in heart, muscles, intra-abdominal organs, bone, neural tissue, and orbit.⁸⁻¹⁰ Electric marks on skin, which is specific and diagnostic of contact with electricity, is one of the strong indications of death by electrocution.¹¹ The electric marks show a significant variety of gross morphology.¹² However, reduced cutaneous resistance and low voltage of current are two factors that facilitate the traceless passing of current through skin.¹³ When the

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characteristic findings of electrocution on the body are absent, histopathological study of the skin can be helpful to ascertain the cause of electrocution by excluding the other possible cause of death and by circumstantial evidence collected from the incidence site.

Several recent studies have affirmed that histological examination could be an important aspect in diagnosis of electrocution.^{11,12,14} Currently, the diagnosis of death from electrical injury quite often is based on histopathological findings and electric contact marks.¹² Therefore, there is a possibility to make a firm diagnosis of suspicious lesions in dead bodies.¹⁵ Hence, the study aims to analyse cutaneous gross and microscopic changes of skin in cases of EDs and its association with respect to its electrical voltage in cases of EDs to establish the cause of death in medicolegal autopsy.

2. Materials and Methods

The retrospective study was done at the department of pathology at a tertiary care hospital, between January 2017 to December 2019. Medical records of patients who expired due to electrocution in the study period were reviewed. The study comprised of all EDs having specific electric mark on the skin. Deaths from any other cause, thermal and lightning electrocution deaths were excluded from the study. The Ethical committee clearance was obtained from the institutional ethical committee before the study initiation.

Following post-mortem, autopsies of all non-lightening ED at department of Forensic Medicine, specimen of skin comprising of suspected entry and exit wound along with normal skin as control sent to Pathology department were examined. A detailed history of the victim like age, sex, occupation, manner of death, type of voltage, and place of death were obtained from the medical records. The skin samples were preserved in 10% neutral buffered formalin and were examined for gross changes. The sections were then subjected to routine histopathological tissue processing and stained with Haematoxylin and Eosin. On microscopy, the histopathological changes in skin observed in both entry and exit wound were recorded in a proforma and analysed. Each case comprised of an entry wound, exit wound, and control skin. All 17 cases had suspected entry wounds, only 12/17 cases had exit wounds and 17 controls were received from corresponding normal skin.

2.1. Statistical analysis

R v4.1.1 was used to analyse the data. Categorical variables are given in the form of frequency table and the dependency was analysed using Chi-square test. Continuous variables are given in Mean \pm SD/Median (Min, Max) form. $P \leq 0.05$ indicates significance.

3. Results

The study included 46 skin samples from 17 non-lightening ED whose age ranges from 7 years to 65 years with mean age of 34.53 ± 15.54 years and male to female ratio being 7.5:1. Most of the ED occurred at workplace (70.5%) during their job and electric line man commonly succumbed to electrocution (29.4%). Most of the job-related deaths occurred due to high voltage (58.8%) which is the voltage supplied for major industries and overhead transmission wires and domestic causes were of low voltage. All the EDs were accidental (100%) in nature (Table 1).

Upper extremity (51.7%) and lower extremity (31.0%) were the most common areas of electrical injuries. Entry wounds predominantly involved upper extremity and exit wound the lower extremities. All 5 cases which did not have exit wound probably died in wet location where skin lowers the electrical resistance. The gross changes at both sites of wound appear to be almost similar with slight variation in exit marks. Most common gross abnormality in entry wound was ulcer/crater (Figure 1) over the skin (82.3%) followed by blister/bulla formation (70.5%). Splits in the skin/laceration (75%) was the most common observation in the exit wounds (Figure 2). The microscopic examination of skin showed the epidermis, dermis with underlying subcutaneous tissue. The histopathological changes in both entry and exit wound are quite similar with slight difference. Both entry and exit wound showed dermoepidermal separation (clefting) as the most common finding i.e., 88% and 75% respectively followed by epidermal necrosis (82, 66%) and nuclear streaming (76%, 50%; Table 2).

The nuclei of epidermal cells at the site of electrical burn showed stretching and narrowing of the contour to produce a palisade like appearance which are pyknotic, darkly stained on Hematoxylin and Eosin. This peculiar distortion of nuclei specially at basal layer of epidermis is called nuclear streaming which is pathognomonic for passage of electric current. Dermoepidermal separation was observed in most of the cases. (Figure 3). There was microvesicle formation at multiple foci of epidermis in both entry and exit wounds (47%, 17% respectively) i.e., separation of intraepidermal cells. Coagulative necrosis of dermal collagen with loss of adnexal structures appeared faintly basophilic on H and E stain (homogenisation of dermis) was noted predominantly in entry wound (5 cases, 29%) and not in exit wound. Epidermal necrosis in entry wounds is significantly associated with high voltage electrocution ($P=0.04$), (Figure 4) While there is no significant association of other microscopic features with respect to its voltage (Table 3) Table 4 shows no significant association of any microscopic features with respect to its voltage in exit wounds.

Table 1: Baseline characteristics

Variables	N (%)
Age (years)	
0–10	1 (5.88%)
11–20	2 (11.76%)
21–30	3 (17.65%)
31–40	5 (29.41%)
41–50	3 (17.65%)
51–60	2 (11.76%)
61–70	1 (5.88%)
Gender	
Female	2 (11.76%)
Male	15 (88.24%)
Nature of work	
Lineman	5 (29.4%)
Field work – farm fence	3 (17.6%)
Domestic	4 (23.5%)
Playing	1 (5.8%)
Other job	4 (23.5%)
Voltage	
High voltage	8 (47.06%)
Low voltage	4 (23.53%)
High/low voltage	4 (23.53%)
Nature of death	
Accidental	17 (100%)
Suicidal or homicidal deaths	0 (0.00%)

Table 2: Affected body parts, gross appearance, microscopic appearance of the skin in entry and exit wounds

Affected body parts	Entry wound	Exit wound
Upper extremity	12 (70.5%)	03 (25.0%)
Lower extremity	02 (11.8%)	07 (58.3%)
Chest and abdomen	02 (11.8%)	01 (8.3%)
Head and neck	01 (5.9%)	01 (8.3%)
Gross appearance		
Ulcer/crater on the skin	14 (82.3%)	
Split skin/ Laceration	-	09 (75%)
Blisters formation	12 (70.5%)	05 (41.6%)
Skin discolouration	08 (47.0%)	02 (16.6%)
No abnormality	02 (11.7%)	01 (8.3%)
Microscopic appearance		
Dermoepidermal separation (cleaving)	15 (88%)	09 (75%)
Epidermal necrosis (coagulative necrosis)	14 (82%)	08 (66%)
Nuclear streaming	13 (76%)	06 (50%)
Microvesicle formation	08 (47%)	02 (17%)
Homogenization in dermis	05 (29%)	-
Hemorrhage and congestion	04 (24%)	04 (33%)
Inflammatory response	01 (6%)	-
Normal skin	01 (6%)	01 (8%)

Table 3: Association of Histopathological findings in entry wound with voltage

Microscopic features	Subcategory	High Voltage	Low Voltage	p-value
Dermoepidermal separation (clefing)	No	0	2 (33.33%)	0.12 ^{MC}
	Yes	11 (100%)	4 (66.67%)	
Epidermal necrosis (coagulative necrosis)	No	0	3 (50%)	0.04 ^{MC} *
	Yes	11 (100%)	3 (50%)	
Nuclear streaming	No	3 (27.27%)	2 (33.33%)	1.00 ^{MC}
	Yes	8 (72.73%)	4 (66.67%)	
Microvescicle formation	No	5 (45.45%)	4 (66.67%)	0.62 ^{MC}
	Yes	6 (54.55%)	2 (33.33%)	
Homogenization in dermis	No	6 (54.55%)	6 (100%)	0.12 ^{MC}
	Yes	5 (45.45%)	(0%)	
Hemorrhage and congestion	No	8 (72.73%)	5 (83.33%)	1.00 ^{MC}
	Yes	3 (27.27%)	1 (16.67%)	
Inflammatory response	No	11 (100%)	5 (83.33%)	0.37 ^{MC}
	Yes	(0%)	1 (16.67%)	

Chi square test with Monte Carlo simulation, * indicates statistical significance.

Table 4: Association of Histopathological findings in exit wound with voltage

Microscopic features	Subcategory	High Voltage	Low Voltage	p-value
Dermoepidermal separation	No	3 (27.27%)	5 (83.33%)	0.06 ^{MC}
	Yes	8 (72.73%)	1 (16.67%)	
Nuclear streaming	No	7 (63.64%)	4 (66.67%)	1.00 ^{MC}
	Yes	4 (36.36%)	2 (33.33%)	
Epidermal necrosis	No	5 (45.45%)	4 (66.67%)	0.62 ^{MC}
	Yes	6 (54.55%)	2 (33.33%)	
Microvescicle formation	No	7 (63.64%)	6 (100%)	0.25 ^{MC}
	Yes	4 (36.36%)	(0%)	
Hemorrhage and congestion	No	9 (81.82%)	6 (100%)	0.52 ^{MC}
	Yes	2 (18.18%)	(0%)	

MC – Chi square test with Monte Carlo simulation.

**Fig. 1:** Entry wound on palm**Fig. 2:** Exit wound on Sole

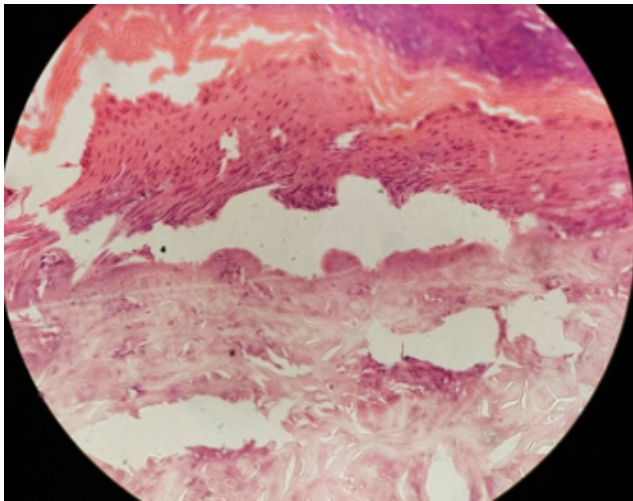


Fig. 3: Dermoepidermal separation with nuclear streaming (H & E Stain, X40)

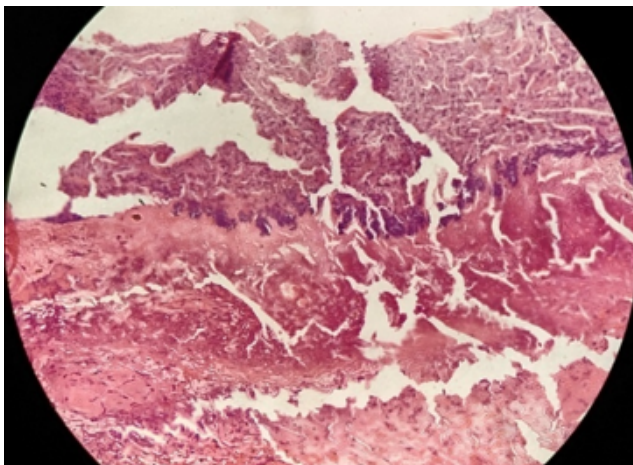


Fig. 4: Epidermal necrosis (H & E Stain, X40)

4. Discussion

The medicolegal investigation in EDs needs greater and mindful detailing as it is an important cause of negative autopsy. In cases with no electric contact marks, uncertain history, and anecdotal evidence coupled with histopathological examination of skin can be of great help in arriving at the diagnosis of ED. The present study showed that histological signs both at the site of entry and exit wounds with respect to its voltage facilitated the diagnosis of suspicious lesions during autopsy.

Electrocution results in an unnatural death. With the widespread use of electricity, the incidence of fatal and non-fatal electric injuries increased. In our study, all of them occurred accidentally;^{1,3,8,16} however, homicidal, and suicidal deaths were stated in few reports.^{1,16} Maximum number of EDs were in the age group of 21 to 50 years (65%) which was similarly observed in other

studies. Consistent to our study, males are the predominant victims as they are frequently exposed to the electrical menace.^{1,3,16,17}

Previous studies reported majority of deaths due to low voltage electricity, which is commonly used in households and at workplaces in India.^{8,13,16} Majority (74%) of investigated deaths occurred during leisure time, while the rest occurred at workplace.^{1,18} The present study showed predominantly occupation related deaths (70%) due to high voltage current while the remaining occurred at domestic places (29%) which partly correlated with other studies.^{1,2,19} Direct contact with the power line might be the probable reason behind high rate of EDs with high-voltage electrical currents.⁷

Although, the skin offers maximum resistance to the electric current, water still lowers the resistance of the skin and electric current density.²⁰ Hence, no electrical marks can be found when death occurs in or near moist and water places. In the present study, 5/17 cases did not have exit wound probably due to similar reason. The most frequent site of entry wound was upper extremity in (70.5%).^{7,21} Obvious exit wound was commonly seen on the sole of the feet or other parts of lower extremities (58.3%), which is in accordance with other studies.^{1,21}

Electric marks caused by electric injuries show varied gross morphology. Grossly electric marks are round to oval with a shallow crater. The crater floor is lined by pale flattened skin. In some marks there will be skin infringement within or near margin of crater, resembling that of a broken blister²² which is similarly seen in the present study suggesting dermoepidermal separation. Walia et al., study reported epidermis and dermis were involved in most (70%) of the cases while metallisation or inflammatory response of the tissues, blister formation, was not present in any of the cases.¹⁵ Sometimes, the skin mark is distinctly pale, but there may be hyperemia of skin immediately beyond it. We noticed skin discolouration, most of them pale area in 6 cases and zone of redness in other 2 cases. Therefore, microscopic findings like epidermal and dermal separation, coagulative necrosis in both entry and exit wounds helps in arriving at the diagnosis of electrocution death. Dermoepidermal separation is formed by space between epidermis and dermis due to the gas liberated from heat.²³ Coagulative necrosis of the underlying dermis and subcutaneous tissue occurs due to denaturation of the protein which gives a bluish colour in haematoxylin and eosin stain.²⁴ Further, in our study, epidermal necrosis in entry wounds was mostly due to high voltage electrocution ($P=0.04$). However, proper internal and external examination can help in ruling out the other causes. The incidence of dermoepidermal separation, coagulative necrosis of epithelium and nuclear streaming were comparable with other studies.^{1,4,5} Other similar studies also showed dermo-epidermal separation in 100%,⁴

90.9%,²⁵ 73.3–83.3% cases; necrosis in 90.9% and 66.6%⁴ cases. Few studies reported that streaming of nuclei in the basal epithelial layers is the other predominantly seen histopathological change in the peripheral areas of electric injuries (96%), but in the present study the basal epithelial layer in most of the cases was extensively destroyed or lost due to electrical injury.^{11,17,21} Other studies described bulla formation in 22.5% cases in epidermis¹⁴ and 5% cases in dermis,¹⁴ vacuolisation in 12.5% cases,¹⁴ micro-blistering in 81.8% cases.²⁵ Death is mainly due to ventricular fibrillation and respiratory paralysis.

The study revealed that histological changes are supportive in differentiating EDs from other types of injuries to facilitate proper diagnosis during autopsy. The presence of epidermal necrosis, a characteristic microscopical feature, suggesting electrocution produced by high voltage electrical current. This indicates forensic surgeons can rely entirely on the histopathological findings of organs to conclude the cause of EDs.

Similar cutaneous changes may be found in cases of flame burns and abrasions since thermal energy or hyperthermia plays an important role in causation of these lesions and may mislead the diagnosis. Subepidermal separation also occur in flame burns or abrasions however intraepidermal separation is most frequently seen in electrical lesions. So intraepidermal separation alone or a combination of intraepidermal and subepidermal separation in a lesion is most likely to be caused by electricity. Epidermal nuclear elongations are prominent in electrical lesions while they are mild in abrasions. Dark nuclear staining is marked and homogenization of dermis can be deep in abrasions. Coagulative necrosis of both epidermis and dermis is absent in abrasions but less frequently present in flame burns.^{11,15}

Previous reports stated that nuclear elongation and streaming are caused by the polarization effect of the current.² But it has recently been postulated that these nuclear changes are caused by expansion resulting from heat since they are also seen in flame burn lesions. The nuclear changes are significantly seen in higher proportion of electric injuries and they are seen in variably low proportions in flame burns and abrasions.¹¹

5. Conclusion

Electric contact mark is diagnostic criteria for electrocution in cases of suspected sudden death. Further, histopathological changes in skin give the supportive evidence in determining the cause of death especially in case of negative autopsy as these changes are found consistently in most of the fatal electrocution. The important microscopic features of electrocution are dermoepidermal separation, coagulative necrosis, and nuclear streaming. EDs in many situations are accidental, and they can be prevented by taking proper precautions,

regular inspection, and maintenance by authorized persons. Further, there should be ongoing laws and security crusade for decreasing the mishaps from electrocution at domestic and industrial places. Instructions should be followed, and regular inspection and maintenance should be done by the authorised person.

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None.

7. Conflict of Interest

The authors declare that there is no conflict of interest.

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None.

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