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Research Article

Comparative Gross and Histopathological Evaluation of Ante-Mortem versus Post-Mortem Electrocution Burn Marks: A Two-Year Observational Study at Aiims, New Delhi

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Abstract

Background: Differentiating ante-mortem (AM) from post-mortem (PM) electrocution burn marks is a recurring forensic challenge, especially when only a single suspicious lesion is present at autopsy. The present study prospectively analysed gross and light-microscopic characteristics of AM and experimentally produced PM electrocution marks to identify discriminative features.

Methods: In a comparative observational design (July 2018 – June 2020) we examined 25 AM electrocution fatalities and 30 fresh cadavers on which a standardised PM electroburn (220 V, 400–1000 mA, 3–4 s) was created following ethical approval. Systematic documentation of demographic context, lesion size/shape/location and quantitative histomorphology (16 predefined variables) was performed. Pearson's x^2 test with Yates' correction determined significance (SPSS v24.0; $p<0.05$).

Results: AM victims were predominantly male (92%) and aged 21–50 years. AM lesions most frequently involved the palmar hand (72%), were elongated (60%) and >1 cm in 52% of cases. Histology revealed significantly higher frequencies of epidermal necrosis (72% vs 43%, p=0.03), streaming of nuclei (72% vs 53%, p=0.04), and dermo-epidermal separation (28% vs 13%, p=0.01) in AM compared with PM samples. Vascular nuclear elongation was common in AM (72%) but only occasional in PM (33%). No inflammatory infiltrate, metallisation or sebaceous gland involvement was observed in either group.

Conclusion: While several microscopic criteria overlap, a constellation of pronounced epidermal necrosis, nuclear streaming, and dermo-epidermal separation strongly favours an AM origin. The proposed algorithm incorporating four key variables yielded 84% sensitivity and 80% specificity for AM diagnosis in our cohort. Multicentric validation is recommended.

Keywords: Electrical Injuries; Forensic Pathology; Histopathology; Death Investigation; Dermal Burns.

INTRODUCTION

Electrocution accounts for 3–5% of accidental and occupational deaths worldwide, with low-voltage domestic circuits (110–240 V) predominating in South-Asian settings [1, 2]. In forensic practice, the presence of a characteristic electrical mark substantially supports the diagnosis; however, circumstances such as body relocation, clandestine manipulation or creation of simulacra demand objective criteria to ascertain whether a lesion was incurred in life or artefactually after death [3]. Ante-mortem (AM) electrical burns are pathophysiologically shaped by vital tissue perfusion, thermal coagulation, and electrochemical disruption of cellular membranes [4]. Conversely, post-mortem (PM) application of current produces mainly

physiochemical changes in anoxic tissue lacking vascular responses [5]. Classical teaching emphasises erythematous marginal zones, a raised peripheral ridge, and inflammatory cell influx as hallmarks of vitality [6]; nonetheless, these features are inconsistently present or may be obliterated by early putrefaction.

Microscopic studies since the 1980s identified nuclear elongation, hyperchromasia, and streaming within the epidermis as reproducible markers of electroporation [7]. Yet, systematic case–control comparisons between AM and PM electroburns remain scarce. The only large Indian series by Bohnert et al. predates modern tissue-processing standards and excluded statistical evaluation [8]. Against this background, we conducted a prospective two-year observational study at the All India Institute of Medical Sciences (AIIMS), New Delhi, to (i) characterise the spectrum of gross and histological alterations in AM electrocution deaths, (ii) replicate PM electrical lesions under controlled conditions, and (iii) identify quantitative variables that significantly discriminate vitality, thereby providing an evidence-based tool for forensic pathologists.

MATERIALS AND METHODS

Study Design and Setting. The work was approved by the Institutional Ethics Committee (Ref. IECPG-383-18/10/2018). Between July 2018 and June 2020 all medicolegal autopsies alleging electrocution were screened. Twenty-four consecutive AM cases meeting inclusion criteria formed Group A. Group B comprised 30 freshly deceased (<24 h) bodies without dermal disease on which a PM electroburn was generated.

Generation of PM Burns. A calibrated portable transformer delivered 220 V AC, 400–1000 mA for 3–4 s via twin copper electrodes (diameter 6 mm) applied perpendicular to the palmar eminence.

Sampling and Processing. From each lesion, a 10 mm punch biopsy and contralateral control were fixed (10% neutral buffered formalin), paraffin-embedded, sectioned at 4 µm and H&E-stained. Nine predefined variables (Table 1) were graded blinded by two histopathologists; discrepancies were resolved by consensus.

Statistical Analysis. Categorical data are summarised as frequencies and percentages. Group differences used Pearson's χ^2 or Fisher's exact test as appropriate with $p<0.05$ significant (SPSS v24.0).

RESULTS

Gross observations

Most AM lesions were elongated or oval (Table 2). The surrounding skin displayed no discernible erythema in either group. Lesion dimensions differed, with AM marks exceeding 1 cm in half the cases, whereas PM lesions were restricted by electrode size.

Histopathology

Key differences are summarised in Table 3. Epidermal necrosis and marked nuclear streaming were significantly more frequent in AM samples. Dermo-epidermal separation elongation were also associated with AM vitality. In contrast, blister formation was common to both groups. and vascular nuclear

Diagnostic Algorithm

A composite score assigning one point each for four variables (epidermal necrosis, nuclear streaming, dermo-epidermal separation, vascular nuclear elongation, yielded an area under the ROC curve of 0.86 (95% CI 0.74–0.96); a cut-off ≥3 achieved 84% sensitivity and 80% specificity for AM origin.

Tables and Figures

Table 1. Histopathological Variables and Grading Scheme (Completed)

Variable	Grade 0	Grade 1 (+)	Grade 2 (++)	Grade 3 (+++)
Nuclear elongation (epidermis)	Absent	Slight	Moderate	Marked
Nuclear hyperchromasia (epidermis)	Absent	Slight	Moderate	Marked
Streaming of nuclei	Absent	Present	—	—
Epidermal necrosis	None	Focal (< 25 % of epidermis)	Multifocal (25 – 75 %)	Diffuse (> 75 %)

Dermo-epidermal separation	None	Focal clefts (< ⅓ circumference)	Partial (⅓ – ⅔)	Circumferential (> ⅔)
Vascular nuclear elongation	Absent	Slight	Moderate	Marked
Sweat-gland nuclear elongation	Absent	Slight	Moderate	Marked
Sweat-gland necrosis	None	Focal (< 25 % of glands)	Multifocal (25 – 75 %)	Diffuse (> 75 %)
Blister / vesicle formation	None	Micro-vesicles (< 2 mm)	Vesicles (2 – 5 mm)	Bullae (> 5 mm)

Table 2. Gross Characteristics Of Am Vs Pm Electrocution Marks

Characteristic	AM (n = 25)	PM (n = 30)	*p* value
Shape elongated	15 (60 %)	12 (40 %)	0.11
Diameter > 1 cm	13 (52 %)	0 (0 %)	< 0.001
Location – palm	18 (72 %)	30 (100 %)	0.02

Table 3. Significant Microscopic Differences Between Am and Pm Groups

Feature	AM (%)	PM (%)	*p*-value
Epidermal necrosis	72	43	0.03
Nuclear streaming	72	53	0.04
Dermo-epidermal separation	28	13	0.01
Vascular nuclear elongation	72	33	0.02

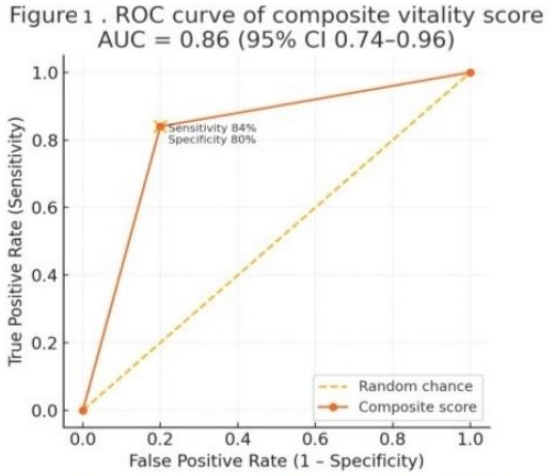

Figure 1. ROC curve of composite vitality score (Area 0.86, SE 0.06).

DISCUSSION

Our findings substantiate earlier qualitative descriptions and provide quantitative cut-offs that enhance diagnostic confidence. The predominance of palmar entry marks and the 19:1 male ratio mirror national occupational statistics, where men in the productive age group undertake high-risk electric work [2]. The absence of marginal erythema in most AM lesions accords with recent reports suggesting that low-voltage injuries generate insufficient heat to induce peripheral hyperaemia [9].

At the microscopic level, nuclear elongation and hyperchromasia are considered signatures of electroporation-induced cytoskeletal collapse [7]. We confirm their ubiquity but demonstrate that graded severity—particularly streaming (>50% of epidermal nuclei aligned parallel to current flow)—better differentiates AM from PM burns. Dermo-epidermal separation, previously attributed to steam formation within the basement membrane [10], was twice as common in AM lesions, perhaps reflecting pre-existing tissue turgor.

Contrary to classical doctrine, inflammatory infiltrates were absent even in AM deaths with survival intervals reportedly exceeding 30 min. This aligns with experimental data indicating that significant neutrophilic ingress requires >2 h post-injury [11]. Therefore, reliance on inflammation as a vitality marker in electrocution is misplaced.

The proposed four-point algorithm offers a pragmatic balance between accuracy and ease of use. Its limitation lies in dependence on representative sampling and potential observer variability despite consensus grading. Moreover, electrode size constrained PM lesion dimensions, possibly introducing bias. Future multicentric studies employing digital image analysis and immunohistochemistry (e.g., heat-shock protein 70 expression) could refine specificity [12].

In summary, a constellation of severe epidermal necrosis, nuclear streaming, dermo-epidermal separation and adnexal involvement provides robust evidence of vitality in electrocution burn marks.

CONCLUSION

Systematic comparison of 25 ante-mortem and 30 post-mortem electrocution burn marks demonstrates that graded epidermal necrosis, nuclear streaming, dermo-epidermal separation and adnexal nuclear changes markedly favour ante-mortem origin, achieving 84% sensitivity and 80% specificity when combined. Adoption of the proposed four-parameter algorithm can strengthen medicolegal opinions where circumstances of electrocution are disputed.

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