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ULTRASTRUCTURAL CHANGES IN THE SKIN AFTER ELECTROCUTION

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The conclusion that death has been due to electrocution is something which the investigator has always to bear in mind. At the microscopic level a distinctive combination of morphological changes has been described in the skin: swelling of the stratum corneum with the formation of empty spaces of different sizes, stretching of the cell nuclei of the stratum basale and stratum spinosum resembling a whirlpool, with the formation of curious shapes in the form of brushes and fishtails, swelling of the collagen fibers with some degree of basophilia, a response of the blood vessels, etc. [1-3, 7]. Investigations of the skin with scanning and transmission electron microscopes have shown partial conglomeration and conglutination of the tonofilaments, which lie parallel to the longitudinal axis of the stretched cell nuclei, injuries of the cell and nuclear membranes, rarefaction of the cytoplasm, precipitation of nuclear and cytoplasmic material on fragments of the nuclear membrane, destruction of mitochrondria, separation of the basement membrane from the underlying connective tissue, and other changes [4-6, 8]. Meanwhile dependence of the morphological changes in the skin on the voltage of the electric current, the character of contact, its duration, and other factors, which is also of great forensic-medical importance, has not been adequately studied.

Ultrastructural changes developing as a result of electrocution were studied in experiments in which different voltages were used.

EXPERIMENTAL METHOD

Experiments were carried out on 20 male black and white guinea pigs weighing 250-300 g. Injuries were produced with a stabilized alternating electric current of 380 and 220 V with a frequency of 50 Hz, applied through iron electrodes with an area of 1 cm^2 for 10 sec. The electrodes were securely fixed to the animals' footpads (dry contact), under hexobarbital anesthesia. The animals died immediately after electrocution. Material for electron-microscopic study was fixed in glutaraldehyde and processed by the usual method. Pieces of skin for histologic investigation were fixed in formalin, embedded in paraffin wax, and stained with hematoxylin and eosin, with picrofuchsine, by Mallory's and Cason's metods, with toluidine blue, by Perls' method, and by the PAS reaction.

EXPERIMENTAL RESULTS

After the action of an electric current of 380 V on the skin a definite combination of morphological changes was discovered. Macroscopically injuries could be seen on the skin of the animals' limbs immediately beneath the electrodes, measuring from 0.1 × 0.1 to 0.5 × 0.5 cm, firm to the touch, with a depressed whitish gray base and raised edges. Sometimes partial charring of the skin was observed, in the form of brownish black deposits. As a result of the uneven surface of the skin of the feed the shape of the injuries did not always correspond exactly to the configuration and dimensions of the electrode. Microscopically, homogenization and compaction of the keratin scales were observed in the epidermis, tears of different sizes and shapes were formed in the center of the lesions, and sometimes zigzag tears shaped like flashes of lightning were seen (Fig. 1a). The changes were most marked in cells of the stratum basale and stratum spinosum. Their nuclei became hyperchromic

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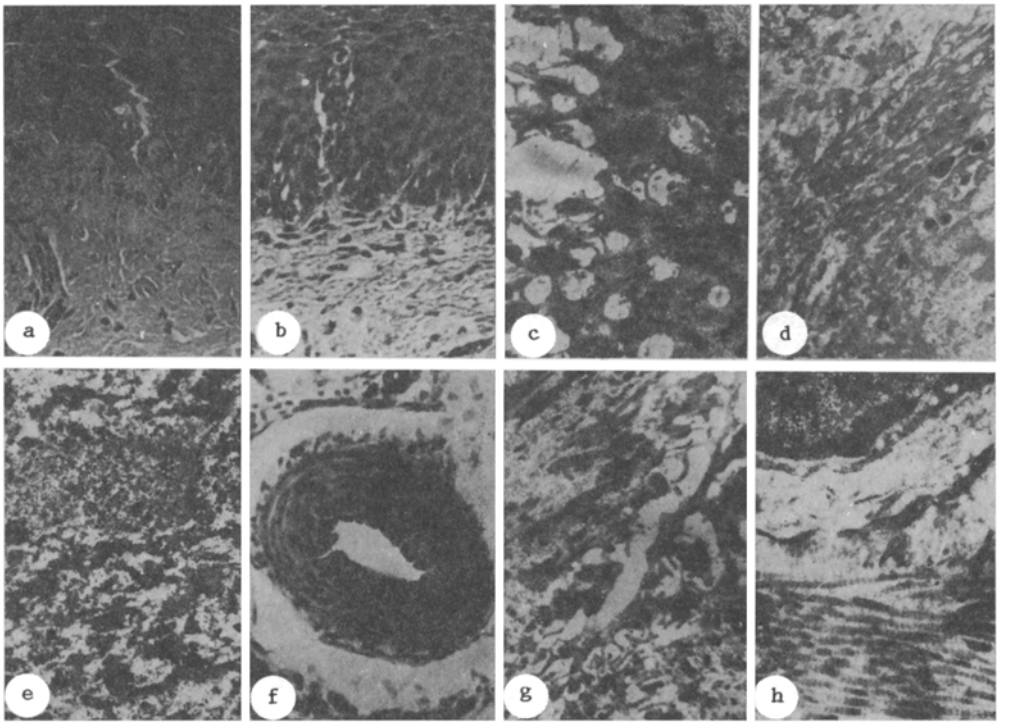

Fig. 1. Changes in skin caused by electric current: a) Zigzag tear resembling flash of lightning in epidermis. Hematoxylin-eosin. 200×; b) Cavities around papillae of dermis. Heamtoxylin-eosin. 200×; c) Numerous electron-optically empty vacuoles in cytoplasm of cells of stratum spinosum. 18,000×; d) Orientation of tonofibrils of cells of stratum spinosum in direction of lines of force. 12,800×; e) Granular degeneration of collagen fibers in zone of electric marker. 16,000×; f) Spasm of artery in zone of electric marker with severe deformation of inner elastic membrane. Toluidine blue. 200×; g) Widening of intercellular spaces in stratum spinosum. 8000; h) Preservation of structure of collagen fibers of dermis. 16,000×.

and pycnotic. They were deformed: elongated, forming "palisade"-like figures, or "whorls" with orientation along the course of the lines of force of the electric current applied. Along the perimeter of the papillae of the skin cavities of different sizes were formed (Fig. 1b). Electron-microscopic investigation revealed marked widening of the intercellular spaces in the stratum spinosum of the epidermis, with preservation or rupture of the desmosomes, accompanied by the formation of numerous electron-optically empty vacuoles. Vacuoles also were observed in the cytoplasm and nuclei of the cells (Fig. 1c). The tonofibrils were oriented definitely in the direction of the lines of force of the electric current (Fig. 1d).

Collagen fibers in the dermis were swollen and formed extensive structureless regions. The boundaries between individual fibers could not be distinguished. In this zone depolymerization of glycoproteins was observed in the form of fields, with confluent foci showing a positive PAS reaction. Staining with toluidine blue revealed redistribution and modification of the glycosaminoglycans of the ground substance, in the form of areas with delicate β- and γ-metachromasia. Electron-microscopic investigatin revealed complete destruction of the collagen fibers with granular degeneration in the center of the lesion (Fig. 1e). In some cases complete or partial necrosis of the epidermis was observed. At some distance from the center of the lesion a state of severe spasm of the blood vessels was observed: the arterial walls of muscular type were loosened in structure, the fibers were fragmented, the inner elastic membranes severely deformed and contracted, as if crimped (Fig. 1f). The arterioles also were in a stage of paralytic constriction. Solitary erythrocytes observed in the lumen of the capillaries were considerably deformed, also reflecting a state of spasm.

The clearly outlined boundary of the lesion revealed by the PAS reaction, particularly in the dermis, must be specially emphasized. Sometimes modified melanin granules could be

seen in the intercellular spaces in the form of partially fragmented inclusions with high electron density. Under the influence of a 220-V electric current changes in cells of the epidermis, collagen fibers, and cutaneous blood vessels were similar in character, but in this case the degree of injury was weaker. Often there was only a tendency toward hyperchromia, pycnosis, and stretching of the basal cells in one direction. A less extensive response of the glycoproteins and proteoglycans (very weak β-metachromasia), affecting only the center of the lesion, was observed. At the ultrastructural level widening of the intercellular spaces was inconstantly observed, with partial destruction of the cells and organelles or even with rupture of the cell and nuclear membranes, with expulsion of their fragments outside the cell (Fig. 1g). By contrast with the disturbances caused by a current of higher voltage, the changes in the collagen were less marked and the structure of the collagen fibrils was preserved (Fig. 1h).

Under the influence of an electric current acting on the skin profound destructive changes thus take place in both epidermis and dermis. Histochemical and ultrastructural characteristics of these lesions enable differential diagnosis of skin injuries depending on the voltage of the electric current applied. The morphological changes discovered can be used as criteria by the forensic pathologist when making the differential diagnosis from mechanical and thermal injuries (abrasions, wounds, burns). On the basis of this combination of morphological changes the boundaries can be clearly defined and the dimensions of the site of application of the electrode can be judged.

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