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Computerized Image Analysis in Differentiation of Skin Lesions Caused by Electrocution, Flame Burns, and Abrasion

ABSTRACT: In the practice of forensic science, sometimes, it is not easy to understand whether skin lesion is due to electrocution and to differentiate the thermal burns and abrasion-type lesions, especially when electricity source cannot be revealed by death science investigation. Based on the causes of the lesions, cases were classified into three groups. Group 1 included 30 deaths from electrocution. Group 2 included 30 deaths with flame burns. Group 3 included 30 deaths from traffic accident cases, which had abrasions. In this study, epidermal nuclear area, perimeter, nuclear form factor, nuclear minimum axes, nuclear maximum axes, and minimum axes/maximum axes ratio were measured. As a result, we think that computerized image analysis beside light microscopic examination can be useful in the differentiation of the electrocution, flame burn, and abrasion type lesions.

KEYWORDS: forensic medicine, computerized image analysis, electrocution, flame burns, abrasion, autopsy

Pathological examination of skin lesions may lead to diagnosis in deaths due to electricity. However, morphological changes in electrical burns were also observed in flame burns. In the practice of forensic pathology, sometimes, differential diagnosis between these two lesions can be very difficult to achieve. Furthermore, in abrasion-type blunt traumas morphological findings similar to those of the flame burns and electrocution were observed. For these reasons, sometimes, it may not be possible to achieve an exact diagnosis of suspicious lesions found in dead bodies.

Computerized image analysis measures length, perimeter, diameter, the degree of darkness of certain part of the cells with the computer technology; all are called "morphometry." This method provides objectivity to morphological examination by light microscope (1,2).

The purpose of this study is to determine morphometric changes that can be useful in the differential diagnosis of electrocution, flame burns, and abrasion by using computerized image analysis and to discuss the efficiency of this method in forensic medicine practice.

Materials and Methods

Based on the causes of the lesions, cases were classified into three groups. Group 1 included 30 deaths from electrocution. These deaths occurred either at home or at work and data about death scenes revealed the source of electricity of low voltage. These samples were taken from the "entrance wounds." Survivors treated for electrical lesions were not included in the study. Group 2 included 30 deaths due to flame burns. Survivors treated for flame burns or deaths from boiling water were not included in the study. Group 3 included 30 deaths from traffic accidents. There are abrasions in these cases. Survivors or those treated in hospital were not included in the study.

Data from the death scene investigations and macroscopic-microscopic autopsy findings allowed the determination of the cause of death in all cases. Specimens were obtained from skin lesions of fresh cadavers and fixed in formaldehyde solution. After washing with water, all specimens were dehydrated in ethanol, cleared in xylol, and embedded in paraffin. Sections were stained with hematoxylin–eosin. In all cases, it was ensured that autolysis should not be present in the sections and the sections included epidermis. In abrasion group, the features of the epidermis adjacent to the abrasion were evaluated.

The hematoxylin–eosin sections were examined with Nikon Eclipse 80i microscope. In all cases, the microscopic pictures of lesions were taken with a Nikon E 8400 digital camera (Nikon, Melville, NY). The images were transferred into the computer and were analyzed with morphometric writing (software) of SAMBA 4000 (Grenoble, France) image analysis system (Fig. 1). Filtration was performed with the limitation of the field in order to eliminate artifactual nucleus images by automatic filtration (area of each measured nucleus was restricted by a special software algorithm to eliminate artifactive nuclei).

Without discriminating the cases, 465 epidermal cell nuclei in the electrocution group, 320 epidermal cell nuclei in the flame burns group, and 523 epidermal cell nuclei in the abrasion group were evaluated. Nuclei were analyzed in respect of the parameters below:

- Nuclear area
- Nuclear perimeter
- Nuclear form factor
- Minimum axes of nucleus
- Maximum axes of nucleus
- Minimum axes/maximum axes ratio

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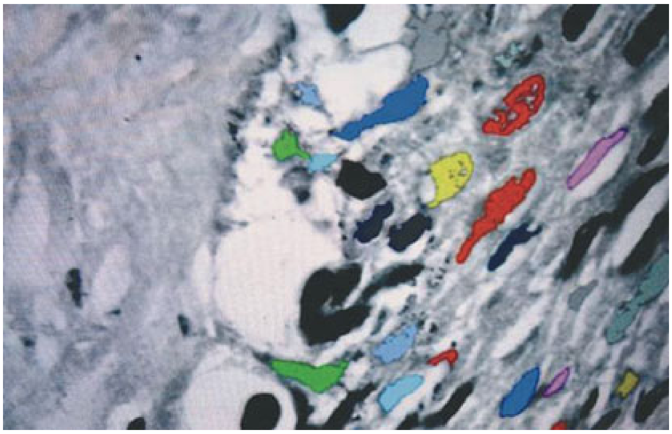

FIG. 1—*Selected squamous cell nuclei for morphometic analysis.*

Data were analyzed by unidirectional variant analysis and Tukey's test. Pearson's correlation analysis method was used to determine the correlation between the two variants. p-Values of 0.05 or less were considered as statistically significant.

Findings

Out of 30 electrocution cases, 29 (96.6%) were male and 1 (0.4%) was female. They were aged 25.4 years on average. Out of 30 flame burn cases, 20 (66%) were male and 10 (44%) were female. They were aged 33.6 years on average. All 30 individuals who died due to traffic accidents were male and at the mean age of 35.4 years.

Nuclear Area

In flame burns and abrasion-type lesions, the nuclear area of epidermal cells was higher than that of the electrocution group ($p = 0.001$ and $p = 0.000$, respectively). The significant difference was not determined between the flame burn and abrasion groups ($p = 0.985$).

Nuclear Perimeter

In the electrocution group, nuclear perimeter was considerably higher than that of the flame burns. The difference between the flame burns and abrasion group was not statistically significant ($p = 0.125$) (Table 1).

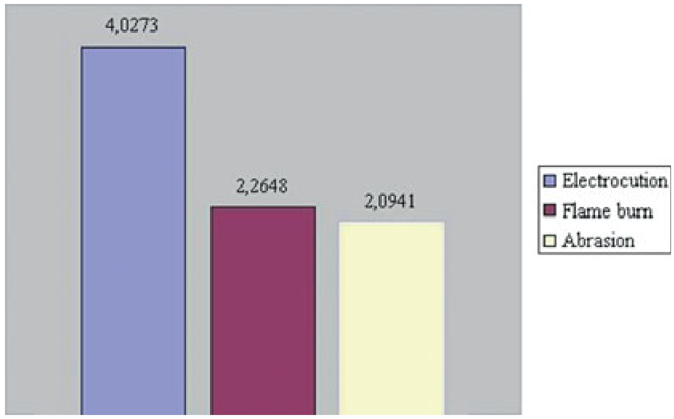

FIG. 2—*Nuclear form factor in epidermal cells.*

Nuclear Form Factor

In the electrocution group, mean nuclear form factor was found to be 4.0273, in the group of flame burns 2.2648 and in the abrasion group 2.0941 (Fig. 2).

In electrical lesions, nuclear form factor was significantly higher than that of flame burn and abrasion groups ($p = 0.000$ for flame burn and abrasion group). The difference between the flame burn and abrasion group was not statistically significant ($p = 0.318$) (Table 2).

Nuclear Minimum Axes

In the abrasion group, nuclear minimum axes was measured higher than that of the electrocution group ($p = 0.000$). There was no significant difference between electrocution flame burns ($p = 0.052$) and flame burn abrasion lesions ($p = 0.372$) (Table 3).

Nuclear Maximum Axes

The highest nuclear maximum axes were measured in the electrocution group. In electrical lesions, nuclear maximum axes were higher than that of flame burn and abrasion groups ($p = 0.000$ for both of them).

Nuclear Minimum Axes/Nuclear Maximum Axes Ratio

In the abrasion group, nuclear minimum axes/nuclear maximum axes ratio was higher both than that of flame burn and of

TABLE 1—*The relationships among the results of computerized image analysis in the electrocution group.*

Group		Area	Perimeter	Form Factor	d_{min}	d_{max}
Perimeter	r	0.818**	—	—	—	—
	p	0.000	—	—	—	—
	N	465	—	—	—	—
Form factor	r	0.060	0.587**	—	—	—
	p	0.199	0.000	—	—	—
	N	465	465	—	—	—
d_{min}	r	0.687**	0.516**	−0.020	—	—
	p	0.000	0.000	0.666	—	—
	N	0.465	465	465	—	—
d_{max}	r	0.842**	0.962**	0.482**	0.404**	—
	p	0.000	0.000	0.000	0.000	—
	N	465	465	465	465	—
$d_{min} - d_{max}$	r	−0.401**	−0.608**	−0.490**	0.225**	0.713**
	p	0.000	0.000	0.000	0.000	0.000
	N	465	465	465	465	465

**Correlation is significant at the 0.01 level (2-tailed).

TABLE 2—*The relationship among the results of computerized image analysis in the flame burn group.*

Group		Area	Perimeter	Form Factor	d_{min}	d_{max}
Perimeter	*r*	0.745**	—	—	—	—
	p	0.000	—	—	—	—
	N	328	—	—	—	—
Form factor	*r*	0.088	0.693**	—	—	—
	p	0.113	0.000	—	—	—
	N	328	328	—	—	—
d_{min}	*r*	0.824**	0.682**	0.186**	—	—
	p	0.000	0.000	0.001	—	—
	N	328	328	328	—	—
d_{max}	*r*	0.673**	0.942**	0.666**	0.496**	—
	p	0.000	0.000	0.000	0.000	—
	N	328	328	328	328	—
$d_{min} - d_{max}$	*r*	0.273**	0.159**	−0.022	0.713**	−0.031
	p	0.000	0.004	0.693	0.000	0.572
	N	328	328	328	328	328

**Correlation is significant at the 0.01 level (2-tailed).

TABLE 3—*The relationship among the results of computerized image analysis in the abrasion group.*

Group		Area	Perimeter	Form Factor	d_{min}	d_{max}
Perimeter	*r*	0.777**	—	—	—	—
	p	0.000	—	—	—	—
	N	523	—	—	—	—
Form factor	*r*	−0.030	0.536**	—	—	—
	p	0.498	0.000	—	—	—
	N	523	523	—	—	—
d_{min}	*r*	0.838**	0.774**	0.134**	—	—
	p	0.000	0.000	0.002	—	—
	N	523	523	523	—	—
d_{max}	*r*	0.729**	0.907**	0.466**	0.601**	—
	p	0.000	0.000	0.000	0.000	—
	N	523	523	523	523	—
$d_{min} - d_{max}$	*r*	0.027	−0.164**	−0.290**	0.311**	−0.398**
	p	0.543	0.000	0.000	0.000	0.000
	N	523	523	523	523	523

**Correlation is significant at the 0.01 level (2-tailed).

electrocution groups ($p = 0.006$ for both of them). A significant difference was not found between the electrocution and flame burn groups ($p = 0.970$).

Discussion

Electrical flow through the tissues can cause skin lesions called "joule burns." The term "burn" is also used for thermal effects or damages caused by chemical substances or radiation. Although their lesions have similar microscopic appearance, we know that the mechanisms of these processes are quite different (3–7).

In the practice of forensic science, sometimes, it is not easy to understand whether skin lesion is due to electrocution and to differentiate the thermal burns and abrasion-type lesions, especially when electricity source cannot be revealed by death scene investigation. Computerized image analysis is a method providing objectivity for the light microscopic examination, which is a subjective evaluation. Thanks to this method, from histological sections, the measurement of certain parts of cell nucleus can be achieved. For example, the measurement of length, diameter, perimeter, and the degree of darkness can be made possible (8). This method was used in pathology in varied cases, for example, the changes of hypertrophied myocardial cells, skin differentiations related to the age, elastic fiber differentiations in the different skin diseases, melanocyts in pigmented skin lesions, and prognostic factors of prostate carcinomas (9–14). Xu et al. (2) first used computerized image analysis in order to form an objective and quantitative index for electrocution lesion and to compare them with normal skin. They determined long axes/short axes ratio in 10 epidermal cells in 10 electrocution and 10 control cases. The results indicated that there was significant difference between normal skin and electrically injured skin in respect of the ratio of long/short axes of epidermal cell nuclei, 5.9325 and 1.4344 respectively.

In this study, epidermal nuclear area, perimeter, nuclear form factor, nuclear minimum axes, nuclear maximum axes, and minimum axes/maximum axes ratio were measured. The group which had the highest minimum axes of epidermal cell nucleus was the abrasion group. Maximum axes, namely, nuclear elongation, and perimeter were measured as highest in the electrocution group. Minimum axes/maximum axes ratio was significantly higher in the abrasion group compared with the other groups. These results suggest that nuclear areas, perimeter, and axes measurements can be used as an objective standard for determining the electrical lesion.

Diamond et al. (10) have defined a new measurement that they called "nuclear form factor" depending on the nuclear dimensions in prostate cancer cells. It has been suggested by these investigators that as nuclear form factor rises above 1, the nucleus goes far away from an ideal circle structure and this is important for assessment of prognosis.

In this study, nuclear form factor was higher than 1 point in all cases because nuclear elongation occurred in all groups. The data indicate that there was significant difference between electrical lesions and the other two groups in respect of the nuclear form factor (for both of them $p = 0.000$).

The claims of torture via exposure to electricity are rarely encountered in the practice of forensic pathology. A voltage of 110 or 240 can apply electroshock torture; magnetos producing low voltage electrical flow can also apply it. Because the lesions occurred by electrical torture are generally lost within a few weeks, in macroscopic examination skin lesion cannot be determined in the vast majority of the cases encountered (15,16). However, Şirin (14) suggests that histopathological changes can be determined in these cases and randomized skin biopsies must be performed and examined microscopically. As a result, we think that computerized image analysis with light microscopic examination can be useful in the differentiation of the electrocution, flame burns, and abrasion-type lesions.

Limitation of the Study

A limitation of the study is that comparing the electrical, thermal, and abrasion injuries, to normal skin has not been carried out.

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