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Electrocution: A Review of 155 Cases with Emphasis on Human Factors

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ABSTRACT: A total of 155 cases of electrocution were investigated to determine the role of human factors, such as carelessness and intoxication, as contributions. The cases were retrieved by computer coding from the repository of the Armed Forces Institute of Pathology, covering the period 1955–1988. The cases are predominantly of military origin. Cases were divided into low-voltage electrocution (N = 47), high-voltage electrocution (N = 79), lightning strikes (N = 16), and unclassified (N = 13). For each group, data is presented on the circumstances of the incident and the pathologic and toxicologic findings. Blatant carelessness, misuse or improper maintenance of equipment, and intoxication are analyzed as contributory factors.

KEYWORDS: pathology and biology electrocution, lightning, accidents, human factors, alcohol

Electrical fatalities are relatively uncommon. There are about 1500 cases of electrocution annually in the U.S., including 100 to 200 cases of lightning deaths [*1,2*].

Factors determining the type and extent of electrical injury include voltage, type of current (AC versus DC), area and duration of contact, skin resistance, and path of current flow [*1,3*]. Clothing and wetness of the environment are also significant variables.

The effects of electricity include skin and tissue burns [*4*], vascular damage [*5,6*], fractures due to high temperature or tetanic contractures [*6,7*], cataracts [*8*], neuropathic changes [*4*], and associated trauma (falls for example). Metal transfer at contact points can also occur [*4*].

Death from electricity may result from ventricular fibrillation, as commonly seen in low-voltage, alternating-current electrocution. High voltage may cause respiratory arrest, due to tetanic contraction of respiratory muscles, or damage to the brain's respiratory control center [*3,4,9*].

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Most low-voltage electrical injuries are accidental [*1*,*10*,*11*] and commonly involve household appliances and tools. High-voltage injuries are reportedly usually industrial [*12*] or involve mischievous activities [*13*].

The study of human factors involved in electrocution could contribute to improved electrical safety. Thus, we reviewed electrocution cases that were referred to the Armed Forces Institute of Pathology to investigate circumstances, prevalence of pathologic findings, and roles of contributory factors such as blatant carelessness, improper use or maintenance of equipment, and intoxication. Results are presented and preventative measures addressed.

Materials and Methods

Cases computer coded as "electrocution" for the years 1955–1988 were recovered from the repository of the AFIP. The cases were predominantly of military origin and were submitted from locations worldwide. Records varied significantly in quality and depth. No judicial electrocutions were included.

Results

A total of 165 cases were recovered. Of these, 155 were usable; 10 were excluded (one drug overdose, 9 inadequate records). The demographic characteristics reflect a military origin. Virtually all cases involved males (98%). The age distribution was as follows: 5% first decade, 33% second decade, 44% third decade, and 17% fourth decade or later. No significant differences in the data were perceived over the time period studied.

Cases were classified traditionally as low voltage (<1000 volts), high voltage (>1000 volts), or lightning. Thirteen (9%) of the cases were unclassifiable due to inadequate documentation; 47 (30%) were low voltage; 79 (51%) were high voltage; and 16 (10%) were lightning cases. This data is presented as Fig. 1. High-voltage electrocutions were more common than low-voltage electrocutions in this series, differing from other series reporting equivalent numbers [*1*,*14*]. This difference might represent the frequent use of high-voltage electrical equipment (field radios, etc.) in the military environment.

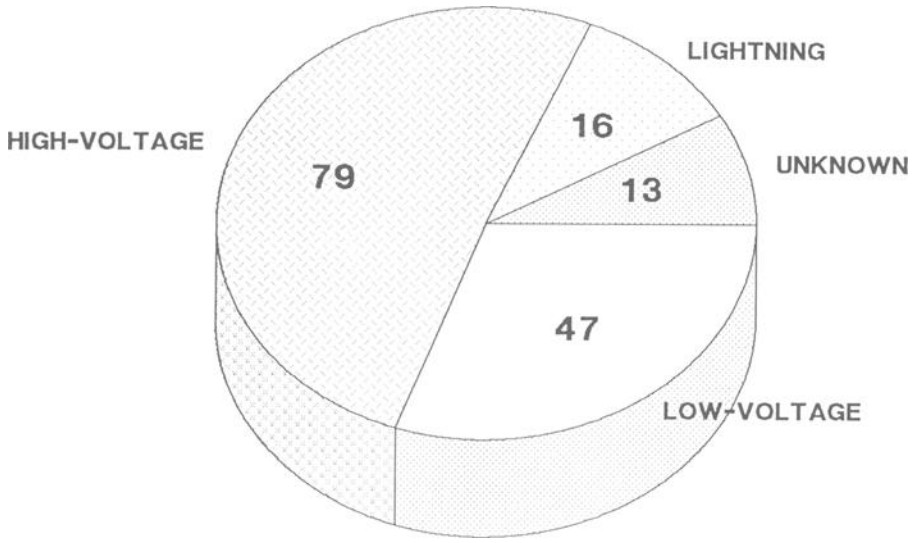

FIG. 1—*Classification by type of electrocution.*

Extracted tabulations of certain clinical and pathological findings are presented in Table 1. Victims were observed to yell out, followed by collapse [*14*] in approximately 10% of the cases. Tetanic muscular contractions [*9*] were observed in less than 10% of the cases. An agonal cry as well as tetany were noted equally in both high- and low-voltage electrocution. Pathologic findings are similar to other reports [*1,4,14*]. Electrical burns were documented in 85% of high-voltage cases, in 62% of low-voltage cases, and 44% of lightning strikes. These burns were located on the hands only in 7% of high-voltage cases, while 40% of the low-voltage cases exhibited burns on the hands only. Of 16 lightning deaths, 7 (44%) displayed burns, but the characteristic fern pattern (Lichtenberg sign) was noted in only three cases. Middle-ear hemorrhage [*15*] was seen in one lightning case. However, documentation of middle ear examination was not common. Cardiac-muscle fragmentation was seen in four cases of high-voltage electrocution, but detailed microscopic examination of the heart was not common. Characteristic vascular lesions (coagulation and tunica media disruption) were documented in only two cases (one low voltage, one high voltage). Clothing was examined in a minority of cases (27/155) with the following prevalance of burns: Low-voltage, zero of six cases (0%), high-voltage, 17 of 17 (100%) and lightning, three of four (75%). Associated trauma was present in approximately 10% of the cases, usually received from falls from heights (often from roofs during antennae adjustment or from utility poles).

The manner of death was classified as accident in 141 cases (including 16 lightning cases), suicide in one case, and undetermined due to inadequate documentation in 13 cases. No cases were reported as homicides.

The location of the fatal events could be determined in 140 cases, as shown in Fig. 2. In this series, the electrocution occurred in the home in 34 cases (24%), at work in 70 (50%), in public places in 30 (21%), or in other places in 6 (4%). Of the low-voltage cases, 24 (51%) occurred at home, 14 (30%) at work, 6 (13%) in public, and 3 (6%) in other places. Of the high-voltage cases, 9 (11%) occurred at home, 47 (60%) at work, 20 (26%) in public, and 2 (3%) in other places. In other words, of the cases occurring at home, 26% were high voltage and 71% were low voltage; of the cases occurring at work, 67% were high voltage and 20% were low voltage; of the cases occurring in public, 67% were high voltage, 20% were of low voltage, and 13% were lightning strikes.

Circumstances of the 47 low-voltage incidents are shown in Figs. 3 and 4. The use of defective tools or wirings could be identified in eight cases (17%). Eight (17%) other cases involved the use of tools or appliances while the victim was immersed or standing in water (four bath tubs, two swimming pools, two wet floors); for example, one man in a tub was electrocuted while adjusting the plug from a lamp in the outlet next to the tub. Two of these 8 cases involved previously known shock hazards. Tabulation of cases identified as involving defective tools and water-related electrocutions are shown in Tables 2 and 3.

Circumstances and activities of the 79 high-voltage incidents are shown in Figs. 3 and 5. In 31 of the 79 cases, the circumstances were sketchy or unknown, although the underlying activity leading to the electrocution could be determined in many of these

TABLE 1—*Clinical and pathologic findings.*

	Low-Voltage	High-Voltage	Lightning
Number of incidents	(47)	(79)	(16)
Yelled out	5 (11%)	8 (10%)	1 (6%)
Tetany	3 (6%)	5 (6%)	0 (0%)
Burns	29 (62%)	67 (85%)	7 (44%)
Trauma	5 (11%)	10 (13%)	0 (0%)

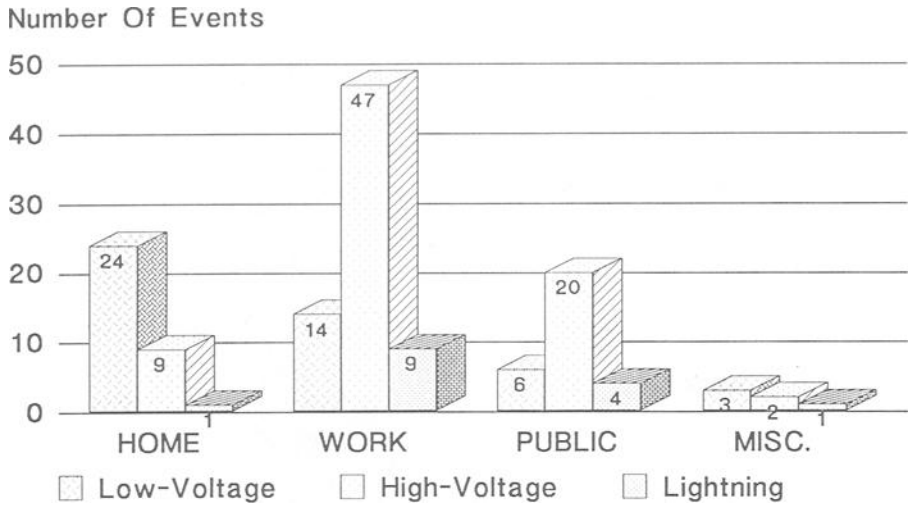

FIG. 2—*Location of electrocution.*

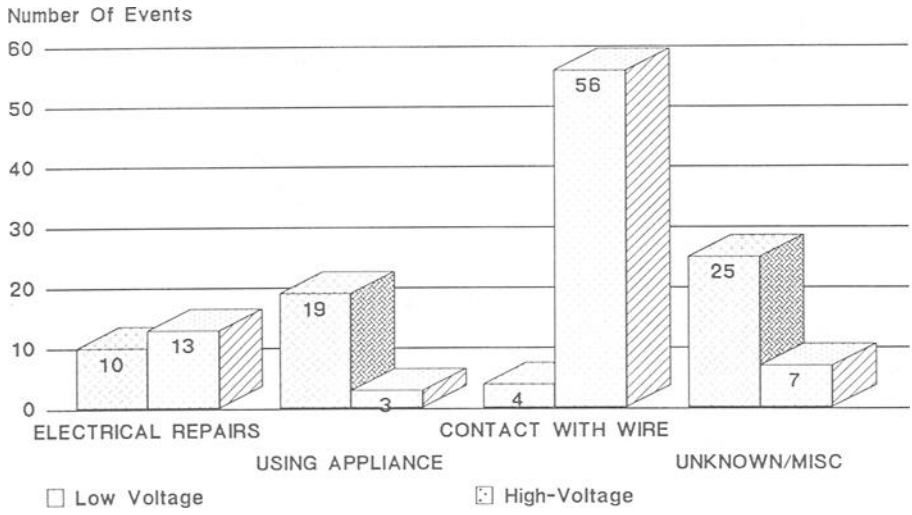

FIG. 3—*Activity related to electrocution.*

cases. High-voltage electrocutions resulted from contact with high-voltage wires in 56 (78%) of the cases. In 34 of these wire-contact cases, the victim was reported to be manipulating a TV antenna or similar metal rod that accidently made contact with an overhead power line. Occasionally, this is an occupational injury involving a military radio communications setup. Eight (11%) cases involved victims who climbed utility poles in wanton disregard to the obvious danger; each of these cases was unrelated to work and involved a positive blood-alcohol count. Electrocution during high-voltage repair work occurred in eight cases (11%) and from downed power lines in six cases (7%).

Lightning deaths tended to occur in open spaces. Three cases involved sports fields (one case each of fishing, golfing, and soccer). The other cases involved a military training

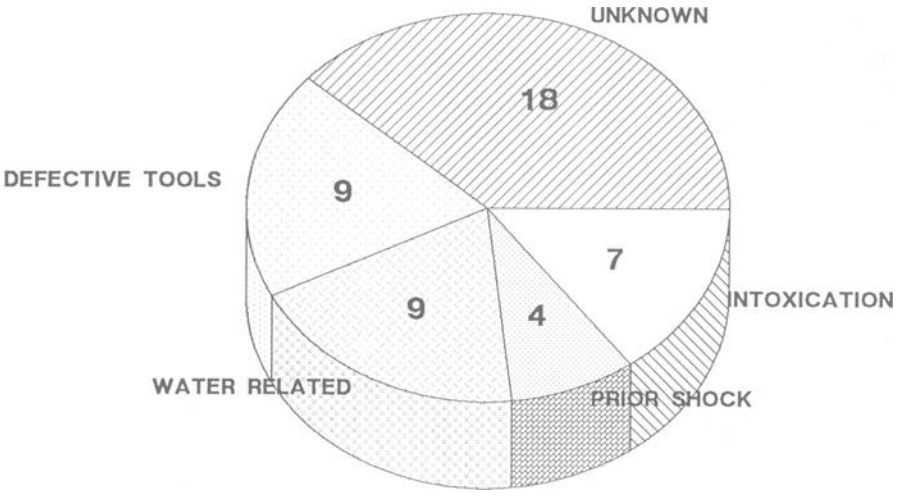

FIG. 4—*Circumstances of low-voltage electrocutions.*

TABLE 2—*Defective tools/wiring.*

2 Drills
1 Toaster
1 Air Conditioner
1 Lamp
1 Battery Charger
1 Field Telephone
1 Defective Wiring

TABLE 3—*Water-related electrocutions.*

4 Lights	(3 bathtubs, 1 pool)
1 Hair-Dryer	(bathtub)
2 Drills	(wet floor in house)
1 Fan	(pool)

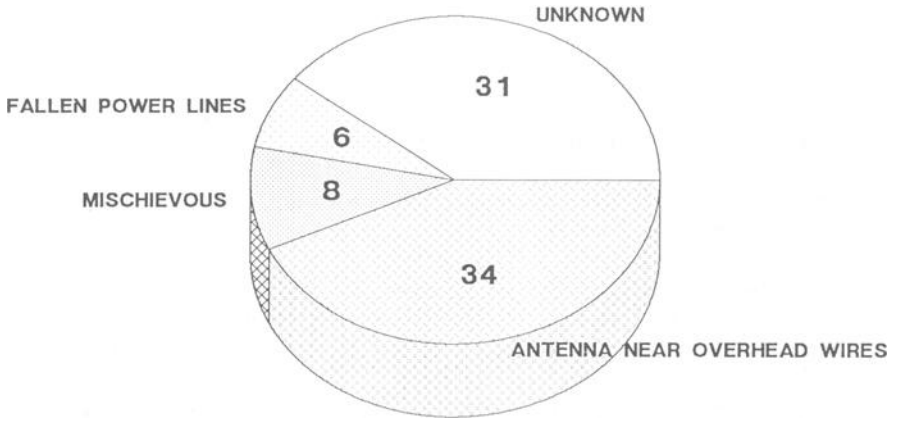

FIG. 5—*Circumstances of high-voltage electrocutions.*

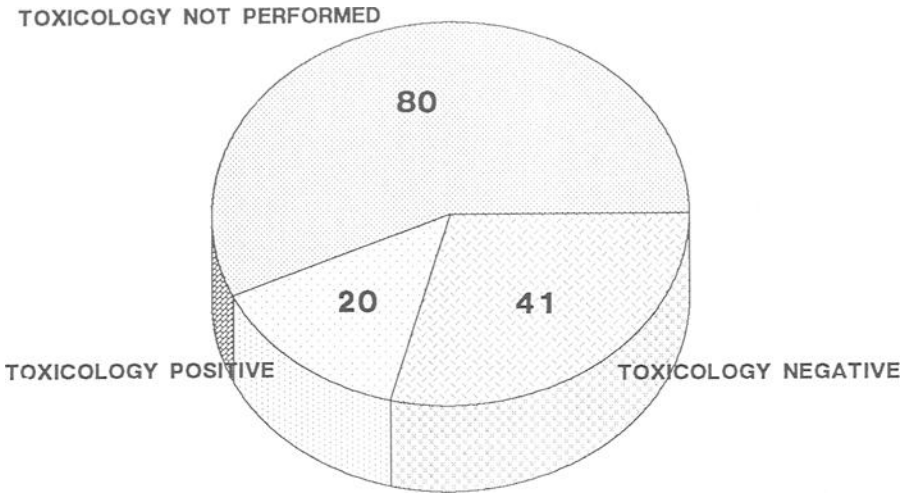

FIG. 6—*Toxicologic analysis of electrocutions.*

exercise (an occupational injury) and a person merely walking down a street. One case involved the collapse of a soldier using a field telephone, an unusual but previously reported event [*16*].

Toxicologic studies are summarized in Fig. 6. Toxicologic studies were undertaken in less than half of the cases investigated, but a positive blood-alcohol count (BAC > 0.1%), which might impair function and contribute to an accident, was noted in 19 of the 61 cases tested (31%), seemingly greater than might be expected in a routine population sample. In many cases, the BAC was greater than 0.15% and other evidence of intoxication was noted. Amphetamines were found in one case; and in another case, LSD was found in the victim's pockets.

Discussion

A review of the circumstances and human factors was undertaken, as this might determine preventability of such incidents [*17–19*]. An analysis of scene, circumstances, electrical equipment, and toxicologic studies to supplement autopsy is useful in the investigation of electrical deaths. Factors that seem to contribute to low-voltage electrocution include intoxication, use of electrical devices on wet surfaces, or faulty electrical devices. Factors that seem to contribute to high-voltage electrocution involve manipulation of antennae or similar devices near overhead wires and blatant carelessness such as recreational climbing of utility poles. It is not certain how many potential electrocutions may be reasonably anticipated (defective tools, for example); however, attention to wet surfaces, equipment maintenance, and installation of ground-fault interruptor boxes and awareness of overhead high-voltage wires may prevent many of these types of accidents [*14*]. Understanding human and behavioral factors that may lead to electrocution might contribute to improved safety.

References

[*1*] Wright, R. K. and Davis, J. H., "The Investigation of Electrical Deaths: A Report of 220 Fatalities," *Journal of Forensic Sciences*, Vol. 25, No. 3, July 1980, pp. 514–521.

[*2*] Massello, W., "Lightning Deaths," Medical Legal Bulletin (Virginia), Vol. 37, No. 1, January–February 1988, pp. 1–10.

[3] Sanchez, A., Larsen, S. J., Myklebust, J., and Cusick, J. F., "Electrical Injuries," *Surgery, Gynecology and Obstetrics*, Vol. 149, No. 1, July 1979, pp. 97–108.
[4] Perper, J. A. and Wecht, C. H., *Microscopic Diagnosis in Forensic Pathology*, Charles C Thomas, Springfield, IL, 1980.
[5] Hunt, J. L., McManus, W. F., Haney, C. P., and Pruitt, B., "Vascular Lesions in Acute Electrical Injuries," *Journal of Trauma*, Vol. 14, No. 6, June 1974, pp. 461–447.
[6] Jellinek, S., *Elektrische Verletzungen*, JA Barth, Liepzig, Germany, 1932.
[7] Solem, L., Fischer, R. P., and Strate, R. G., "The Natural History of Electrical Injury," *Journal of Trauma*, Vol. 17, No. 7, July 1977, pp. 487–491.
[8] Hanna, C. and Fraunfelder, F., "Electric Cataracts," *Archives of Ophthalmology*, Vol. 87, No. 2, February 1972, pp. 184–191.
[9] Werner, A. H., "Death by Electricity," *New York Medical Journal*, Vol. 118, October 1923, pp. 498–500.
[10] At-Alousi, L. M., "Homicide by Electrocution," *Medicine, Science and the Law*, Vol. 30, No. 3, July 1990, pp. 239–246.
[11] Fernando, R. and Liyanage, S., "Suicide by Electrocution," *Medicine, Science and the Law*, Vol. 30, No. 3, July 1990, pp. 219–220.
[12] Luce, E. L. and Gottlieb, S. E., "True High Tension Electrical Injuries," *Annals of Plastic Surgery*, Vol. 12, No. 4, April 1984, pp. 321–325.
[13] Burke, J. F., Quinby, W. C., Bondroc, W. C., McLaughlin, W., and Trelstad, R. L., "Pattern of High Tension Electrical Injury in Children and Adolescents and Their Management," *American Journal of Surgery*, Vol. 133, No. 4, April 1977, pp. 492–497.
[14] DiMaio, D. J. and DiMaio, V. J. M., *Forensic Pathology*, Elsevier, New York, 1989.
[15] Weiss, K. S., "Otologic Lightning Bolts," *American Journal of Otolaryngology*, Vol. 1, No. 4, August 1980, pp. 334–337.
[16] Johnstone, B. R., Harding, D. L., and Hocking, B., "Telephone-related Lightning Injury," *Medical Journal of Australia*, Vol. 144, June 1988, pp. 706–709.
[17] McLaughlin, E., Joseph, M. P., and Crawford, J. D., "Epidemiology of High Tension Electrical Injuries in Children," *Journal of Pediatrics*, Vol. 89, No. 1, July 1976, pp. 62–65.
[18] Katcher, M. L., "Scald Burns from Hot Tap Water," *Journal of the American Medical Association*, Vol. 246, No. 11, September 1981, pp. 1219–1222.
[19] Wickens, C. D., "The Effects of Control Dynamics on Performance," in Handbook of Perception and Human Performance, Vol. II: Cognitive Processes and Performance, K. R. Boff, L. Kaufman and J. P. Thomas, Eds., New York: Wiley, 1986.

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