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Klinik Çalışma

Electrocution-related mortality: a review of 351 deaths by low-voltage electrical current

Elektrik çarpmasıyla ilişkili mortalite: Düşük voltajlı elektrik akımı ile gerçekleşen 351 ölüme ilişkin bir derleme

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BACKGROUND

We describe herein the characteristics of lethal injuries caused by low-voltage electrical current (electrocution), the most frequent injury caused by electrical current.

METHODS

Nine hundred forty-five cases over a period of 41 years (1965-2006) were reviewed, of which, 351 electrocution cases were identified. The descriptive statistical analyses were carried out with the application of SPSS 11.0 software.

RESULTS

Electrocution accounted for 37.14% of all studied electricity-caused injuries. The average age of the victims was 35.25 years. The average age of male victims was 36.19 years and of female victims was 32.55 years. The distribution by gender showed a significant prevalence of the male sex (74.07%). Among the circumstances leading to electrocution, household accidents (78.06%) prevailed over occupational accidents (13.39%). Suicides were significantly rarer (7.41%). 66.10% of all electrocution cases occurred during the summer period from June through September.

CONCLUSION

Household accidents prevail among the circumstances under which electrocution occurs, with an insignificant difference in the male/female proportion in this group. The majority of electrocutions occurred during the summer period (June-September). The results obtained in this research can help in the development of a differentiated strategy for the prevention of electrocution, while taking into consideration gender, age and season of the year.

Key Words: Electrocution; low-voltage electrical current.

AMAÇ

Bu yazıda, düşük voltajlı elektrik akımının (elektrik çarpması) yol açtığı ölümcül yaralanmalar, elektrik akımı nedeniyle görülen en sık yaralanmaların özellikleri değerlendirildi.

GEREÇ VE YÖNTEM

Çalışmada, 351 tanesi elektrik çarpması olan 945 olgu, 41 yıllık bir periyod (1965-2006) boyunca belirlendi. Tanımlayıcı istatistiksel analizler SPSS 11.0 programı kullanılarak yapıldı.

BULGULAR

Elektrik çarpması, çalışmaya alınan elektrikle oluşan bütün hasarların %37,14'ünün nedeniydi. Kurbanların ortalama yaşı 35,25 idi (erkek ortalama yaş 36,19; kadın ortalama yaş 32,55). Cinsiyete göre dağılımda erkek cinsiyeti (%74,07) belirgin şekilde daha sıktı. Elektrik çarpmasına yol açmış bulunan koşullar arasında, ev kazaları (%78,06) iş kazalarından (%13,39) daha çok görülmekteydi. İntiharlar anlamlı şekilde nadirdir (%7,41). Tüm elektrik çarpması vakalarının %66,10'u yaz döneminde, Haziran'dan Eylül'e kadar oluşmuştur.

SONUÇ

Ev kazaları, erkek/kadın oranının anlamlı bir farklılık göstermediği bir grupta daha hakim gözükmektedir. Olguların çoğunluğu yaz döneminde (Haziran - Eylül) ortaya çıkmaktadır. Bu araştırmadan elde edilen bulgular, cinsiyeti, yaşı ve yılın sezonu göz önüne alarak elektrik çarpmasını önlemeye yönelik farklı bir strateji oluşturulmasına hizmet edebilir.

Anahtar Sözcükler: Elektrik çarpması; düşük voltajlı elektrik akımı.

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Lethal injuries caused by low-voltage electrical current (electrocution) are considered to be the most frequent injuries caused by electrical current.[1,2] Nevertheless, their epidemiological characteristics remain insufficiently studied. For the purposes of prevention and limiting the cases of illness and death caused by low-voltage electrical current, certain data are needed. The purpose of this research was to present a quantitative characteristic of epidemiological data describing electrocution.

MATERIALS AND METHODS

The research was conducted in eight districts of the Republic of Bulgaria and covers a period of 41 years (1965-2006). We examined manually 63,825 autopsy reports and their relevant forensic medical files. Of these, 351 cases of electrocution were identified.

Data are expressed as a mean value ± SEM (standard error of the mean). Statistical analysis was performed by analysis of variance test followed by Student t test for unpaired values. Calculations were done with the help of a statistical program (SPSS 11.0). Values of $p<0.05$ were considered significant. In order to draw a linear trend, we applied the method of the least squares. To identify the age group exposed to highest risk, we divided the victims into eight age groups in compliance with the requirements of the United Nations[3] (Table 1). In order to clarify the impact of gender on the distribution of cases based on their age, we compared the relative share of men and women in the different age groups separately (Table 2).

RESULTS

Electrocution accounted for 37.14±5.05% of all studied injuries caused by electrical current. The average age of victims was in the fourth decade, i.e. 35.25±2.97 (n=351, SD=19.86, range: 1 month - 81 years). For males, the average age was 36.19±3.44 (n=260, SD=19.88, range: 1 - 80 years), while for females, the average age was lower, at 32.55±5.81 years (n=91, SD=19.8, range: 1 month - 81 years) with insignificant difference ($t=1.51$; $p>0.05$). Children and adolescents under 18 years of age accounted for 21.65±4.31% of all electrocution cases, representing 0.12±0.02% of all forensic medical autopsies done. The average age of minors was 7.16±6.38 years (n=76, SD=19.87).

The analysis of data contained in Table 1 shows a significant difference between the relative shares of Age Groups I and II. The difference between Group II and Group III was established as statistically unreliable while the difference of relative share between Group III and Group IV was statistically reliable. The difference of relative share between Group IV and Group V was established as insignificant while the difference of relative share between Group V and Group VI was statistically reliable. Finally, the difference of relative share between Group VI and Group VII was established as insignificant.

Table 1. Age distribution of victims by their number and relative share

Group UN	Age (years old)	n	%	± Δ	t	p
I	< 1	1	0.28	0.55		
II	1 – 14	67	19.09	4.4	2.63	<0.01
III	15- 24	42	11.95	2.8	1.03	>0.05
IV	25 – 44	114	32.47	4.9	3.09	<0.01
V	45 – 59	89	25.34	4.55	1.21	>0.05
VI	60 – 75	34	9.67	3.09	2.28	<0.05
VII	76 – 90	4	1.2	1.14	1.14	>0.05
VIII	> 90	0	0	0	0	
Total		351	100			

Table 2. Distribution of the victims by number and relative share according to gender and age

		Male			Female			t	p
Group UN	Age (years old)	n	%	± Δ	n	%	± Δ		
I	< 1	0	0		1	100			
II	1 – 14	43	64.18	11.48	24	35.82	11.48	2.61	< 0.01
III	15- 24	34	80.95	11.87	8	19.05	11.87	3.96	<0.001
IV	25 – 44	88	77.19	7.7	26	22.81	7.7	5.8	<0.001
V	45 – 59	66	74.16	9.21	23	25.84	9.21	4.56	<0.001
VI	60 – 75	27	79.41	13.59	7	20.59	13.59	3.43	<0.001
VII	76 – 90	3	75	42.43	1	25	42.43	1.01	>0.05
VIII	> 90	0	0	0	0	0	0	0	
Total		261	74.07	4.58	90	25.93	4.58	9.01	<0.001

When distributing the cases by gender, the male sex showed a prevalence at 74.07±4.58% (n=261) compared to the female sex at 25.93±4.58% (n=90), and the ratio between the male and female gender was 2.86 : 1, with a statistically reliable difference (t=9.01; p<0.001).

The analysis of data contained in Table 2 proves that the differences of relative share between males and females were significant for Age Groups II through Group VI. Group I contained only one victim while Group VIII contained no electrocution victims; thus, no p values were given for these groups. Despite the proven insignificant difference in Group VII, unreserved acceptance of the results is questionable because of the small number of cases in this group, which we consider quite insufficient to serve as a basis for drawing firm conclusions.

Among the circumstances under which electrocution occurred, household accidents (HA) prevailed, at 78.06±4.33% (n=274), over occupational accidents (OA) causing electrical injuries 13.39±3.62% (n=47), with a significant difference (t=11.63; p<0.001). Cases of suicide (S) were markedly rarer 7.41±2.74% (n=26). One person died in the act of perpetrating theft (T) of energized conduits (0.28±0.55%). In three of the cases (0.85±0.96%), the circumstances under (U) which electrocution had occurred could not be established (Fig. 1).

We succeeded in specifying a concrete reason for the accidents (n=351) in 291 (82.91±3.93%) cases, while in 60 (17.09±3.93%) cases the necessary information could not be ascertained in a retrospective inquiry.

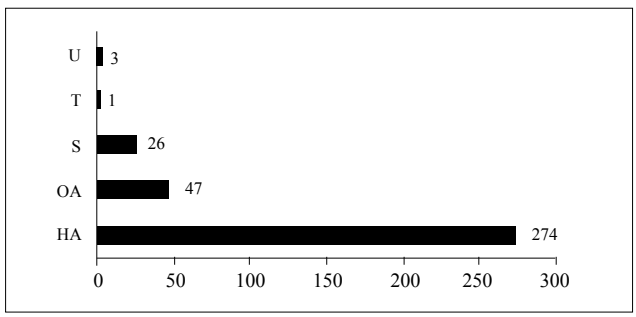

Fig. 1. Number of cases according to the circumstances leading to the electrocution.

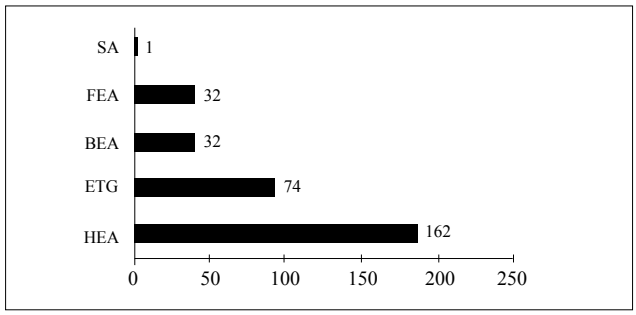

Fig. 2. Distribution of the number of cases by the cause of the accident.

The majority of electrocutions were caused by household electrical appliances and lights (HEA) (53.23±1.44%; n=152) (Fig. 2). This group included 82 (53.95±5.72%) males (1-80 years old), with an average age 27.81±6.14 (SD= 19.87) and 70 females (46.05±5.72%) (1-81 years old), with an average age of 33.17±6.91 (SD=20.67). The male/female ratio in this group was 1.17: 1 and the difference in their relative number was insignificant (t=0.86; p>0.05).

The second most important group was that of the victims electrocuted by contact with the electricity transfer and distribution grid (ETG): 25.43±5% (n=74). This group included 62 (83.78±9.17%) males (2-77 years old), with an average age of 36.69±7.05 (SD=19.82) and 12 females (16.21±8.4%) (1 month-68 years old), with an average age of 25.26±16.14 (SD=19.94). The male/female ratio in this group was 5.16 : 1, and the difference in their relative share was significant (t=5.81; p>0.001). The difference between these two leading groups was statistically reliable (t=4.13; p<0.001).

The third place by relative number of lethal accidents was shared between victims of contact with building electrical appliances (BEA): 11±3.6% (n=32) [males 31 (11-71 years old), average age: 40.55±10.01 (SD=19.92) and 1 female aged 57] and victims of farming electrical appliances (FEA): 11±3.6% (n=32) [males 31 (22-77 years old), average age: 48.48± (SD=19.19) and 1 female aged 59]. The differences in the relative share of these two groups compared to the second major group (ETG) were significant (t=1.92; p<0.05). One death (male, age: 57) was attributed to the use of a specially constructed suicidal appliance (0.34±0.67%).

The cases were quite unevenly distributed throughout the calendar year (Fig. 3). The lowest number of electrocution cases was observed in December (n=6) and the highest in August (n=75). The summer season from June through September accounted for 66.10±

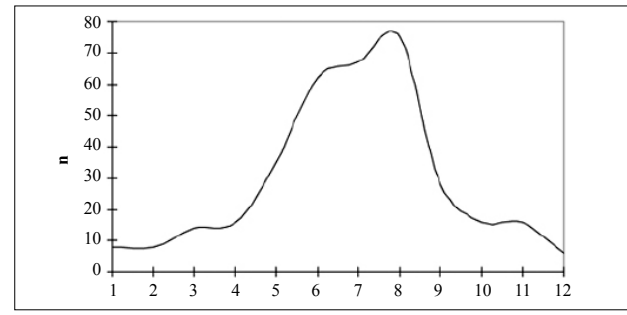

Fig. 3. Distribution of the number of cases according to month of the calendar year.

4.95% (n=232) cases of injuries caused by low-voltage electrical appliances.

DISCUSSION

The frequency of electrocution according to our earlier researches[4] was 42.06% or 0.51 per 100,000 residents, which nearly coincides with the result obtained in this present research; however, the frequency varies in a rather wide range in other diverse researches, i.e. from 20.43% to 80.83%[1,5-7] because the pathogenesis and pathophysiological features of electrical injury are more complex than once thought. The relative contributions of thermal and pure electrical damages depend on the duration of electric current passage, the orientation of the cells in the current path, their location and other factors. If the contact time is brief, non-thermal mechanisms of cell damage will be most important and the damage is relatively restricted to the cell membrane.[8] When contact time is much longer, however, heat damage predominates and the whole cell is affected directly. These parameters also determine the anatomic tissue distribution of an injury. Damage by Joule heating is not known to be dependent on cell size, whereas larger cells are more vulnerable to membrane breakdown caused by electroporation.[8] Cells do survive transient plasma membrane rupture under appropriate circumstances or if therapy is applied quickly. If membrane permeabilization is the primary cellular pathologic condition, then the injured tissue may be salvageable, and the challenge for the future is to identify a technique to promptly reseal damaged membranes.[8] Direct electro-conformational denaturation of macromolecules such as proteins has also been identified as a tissue-damaging mechanism.[9]

When comparing our results with the results found in the literature, it could be concluded that our values are insignificantly lower than the results obtained by other authors,[5] and the victim's age is also a highly variable value. In the literature, victims' ages ranged between 21.1 to 41.6 years,[1,5,10] while our results reached the upper limit of that range. All authors are unanimous that male victims prevail within a range between 76.36% and 98%,[5,7,10] and thus our results approximate closely the results obtained by other authors and fall at the lower limit of the researched range. One exception is our result of an insignificant difference between genders in the group of household electrical appliances/lights group, which has not been confirmed in the available literature. Our research established that the relative share of children and adolescents and their relative age were lower than those found by certain authors.[11] In contrast with certain researches,[10] we established a larger share of household accidents. Electricity-caused occupational accidents were determined by certain authors[12-15] to vary in a wide range from 26.47% to 81%. The values determined in this report (13.39%) are closer to the values obtained in our previous researches.[16]

The frequency of suicide cases varies rather widely according to the researches. Out of all autopsied electricity victims, the frequency of suicidal electrocutions varied from 0.65%[17] through 7.77[12] to 29%,[10] and accounted for 0.04%,[18] 0.15%[19] and 1.98%[17] of all forensic medical autopsies. Our study population included one case of suicidal electrocution committed using a specially constructed device, similar to that described by Risse et al.[20]

The cyclic seasonal distribution of low-voltage injuries is an undisputable fact, in which the greatest concentration of cases appears in the summer season. Here again we observed a diversion of values. While this research established 66.1% and our earlier studies established values of, other authors reported values ranging from 38.2%[21] to 42.64%.[10]

The conducted analysis is notable with regards to the wide range of studied indices. Such large differences between minimum and maximum values in age, gender, seasonal occurrence, and other characteristics described by various authors are likely the result of a complexity of reasons and are possibly explained by our hypothesis regarding territorial non-uniformity;[22] that issue awaits clarification by the researchers.

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