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Outcome of occupational electrical injuries among French electric company workers: A retrospective report of 311 cases, 1996–2005☆

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ABSTRACT

This study reviewed records of all electrical incidents involving work-related injury to employees Electricité de France (EDF) from 1996 through 2005 and analysed data for 311 incidents. The results are compared with 1231 electrical incidents that occurred during 1970–1979 and 996 incidents during 1980–1989. A total of 311 electrical incidents were observed. The medical consequences of electrical incident remain severe and particularly, the current fatality rate (3.2%) is similar to that recorded in the 1980s (2.7%) and 1970s (3.3%). Among individuals with non-fatal incidents, any change has occurred in the prevalence of permanent functional sequelae (23.6% in the 1970s *vs.* 27.6% in the 1980s and 32.5% currently). An increase in the incidence of neuropsychiatric sequelae (5.4% in the 1980s *vs.* 13% currently) has been observed and they are now the second most common type of sequelae after those directly related to burns. Among the neurological sequelae, peripheral nervous system disorders are the most common, as observed in the 1980s. Since the definition of post-traumatic stress disorder (PTSD) has changed between the two periods, we can only report that the current prevalence of PTSD is 7.6%. This study emphasises the need for specific management of neurological and psychological impairments after electrical injuries, including especially early recognition and initiation of effective treatment.

1. Introduction

The passage of the current through the body or along its surface may dissipate certain quantity of energy and can have two main effects: temporary modification of the physiology of an organ or the whole body in the form of inhibition or excitation and an electrothermal effect. The consequences of electrical injuries (functional and unsightly scars) follow early or late side effects and develop into permanent sequelae that can be immediate or delayed, transient or permanent.

Several recent publications have described different neurological complications of electrical injuries involving both cerebral (symptoms loss of consciousness, headaches)

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and peripheral (*e.g.*, sensory loss, paralysis and neuropathic pain) symptoms [1–6] and permanent psychological damage ([3,5,7–9]).

Since the 1950s, Electricité de France (EDF), the French power company, has conducted successive retrospective studies of electrical incidents occurring among employees to appreciate the effectiveness of safety procedures and to improve the medical management of these injuries. Previous studies have already been published covering the periods 1959–1969 ([10–12]), 1970–1979 [13,14] and 1980–1989 ([14,15]). We carried out another large study in order to describe the sequelae after electrical incidents occurring from 1996 through 2005.

Electrical shocks that occurred in EDF workers over the 10-year period 1996–2005 were recorded with their medical consequences. According to the definitions of the International Electrotechnical Commission (IEC), we are considering that an electrical injury may result from direct passage of an electrical current through the body (electrification of a living organism) or from short-circuit (that includes arc and flash: *cf.* Appendix 1) with sufficient strength and duration to produce a convulsive or thermal effect. Electrocution is a fatal electric shock [16]. Our study includes the employees of Electricité de France-EDF (158842), Réseau de Transport d'Electricité-RTE (8515), and Electricité Réseau Distribution France-ErDF (36110) that are in charge of production, transportation and distribution of electricity in France. We can reasonably consider that our study population is quite inclusive of all electrical workers in France

The purpose of this survey is to describe the trends of the incidence and severity of electrical incidents by comparing these recent data with the older studies. Furthermore, the study examines the symptoms and acute and long-term effects of occupational electrical injuries focusing on Neuro-psychiatric sequelae. We studied the records of electrical injuries that occurred in EDF employees over the 10-year period 1996–2005 and their medical consequences.

2. Methods

This study presents results of an uninterrupted time series study design that started in 1949. The same protocol has been followed throughout. Here we reviewed annual data on electrical shocks for the 1996–2005 study period. To obtain an exhaustive collection of each electrical incident with sick leave, we reviewed databases from several EDF sources: the Prevention and Safety Department provided statistical data and technical assessments; the Medical Department of Specific Health Insurance fund, provided anonymous electrical incident medical forms; and the Medical Compensation Committee which provided data on the workers' compensation, return to work and other occupational aspects.

The information for each injury was recorded on an anonymous and a confidential routine sheet with 52 items to be completed by the occupational physician. These items are global data (age, voltage, age, gender, the type of work, day of the week); burns characteristics (mechanism, degrees of the burn, location, burn standard units); burn sequelae; functional burn sequelae; unaesthetic sequelae (scarring) associated with burns; cardio-respiratory sequelae; Neuropsychiatric sequelae; neurological sequelae; sensory sequelae; sick leave and disability rates.

The data sets were analysed statistically with SAS V9.2 software. Confidence intervals (95%) were calculated with Poisson regression for rate data to evaluate the trends in electrical trauma consequences. We are used Fisher's exact test to examine the differences in severity of electrical injuries and psychological sequelae among groups exposed to different voltage levels.

3. Results

During the 1996–2005 study period, 403 incidents involving sick leave were recorded. Occupational physicians were unable to complete the questionnaires (or the questionnaire could not be used) for 92 of them. We therefore study the 311 remaining cases. In all, 3.2% were fatal, for a mean of 1 death per year. Two hundred seventy six persons were burned, that is 88.7% of the survivors (Tables 1a and 1b).

3.1. *Characteristics of the victims*

The yearly mean of incidents was 31 ± 8.58 (range: 12–43) incidents. All injured workers but one were male. Mean age at injury was 36.7 years $\pm$ 8.59 (range: 19–59) and all these workers had been previously fit to work.

3.2. *Classification of electrical injuries*

Electrical injury may results from direct passage of an electrical current through the body (electrification of a living organism) or from a short-circuit (that includes arc and flash) (incidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero) with sufficient strength and duration to produce a convulsive or thermal effect. Electrocution is a fatal electric shock [16] (see Glossary attached as an appendix).

Our main types of injury can result from contact with electricity: fatal injury, electric shock, burns and falls. As usual, electrical burns, all caused by alternating current (50 Hz in France), have been classified as follows: very high voltage burn (VHV > 50,000 V), high voltage burn (1000 V <HV < 50,000 V) and low voltage (LV < 1000 V). In our study, most of the injuries were burns (88.7%; $n = 276/311$). This proportion is not significantly different from that recorded in the 1980s (91.5%; $n = 911/996$) and 1970s (92.8%; $n = 1142/1231$) ($p = 0.7\%$). Three types of electrical burns can occur,

Table 1a – Outcome of 311 work-related electrical injuries at EDF (1996–2005).

Outcome	Number of cases	Percentage
Fatal cases	10	3.2
Non fatal cases	301	96.8
Complete recovery[a]	(195)	(64.7)
Sequelae[b]	(98)	(32.5)

[a] This information was available for 293 victims.
[b] Early and/or late onset of effects developing into permanent consequence.

Table 1b – Comparison of outcome of injuries registered between 1970 and 1979, 1980 and 1989 and 1996 and 2005.

Outcomes	1970–1979 study		1980–1989 study		1996–2005 study		*p* value[c]
	Number of cases	Percentage among EDF workers	Number of cases	Percentage among EDF workers	Number of cases	Percentage among EDF workers	
Frequency of electrical accident	1231	0.11	996	0.08	311	0.032	<0.001

Outcomes	1970–1979 study		1980–1989 study		1996–2005 study		*p* value[c]
	Number of cases	Percentage among accident	Number of cases	Percentage among accident	Number of cases	Percentage among accident	
Fatality injury	41	3.3	27	2.7	10	3.2	0.7
Severe injury	80	6.5	56	5.6	16	5.1	<0.001
Burns	1142	92.8	911	91.5	276	88.7	0.8
Permanent sequelae	290	23.6	275	27.6	98	31.5	0.2

[c] Confidence intervals (95%) were calculated by using the Poisson regression.

depending on the type of incident: arc burn, electric burn and mixed burn can generate electrical burns: (see Glossary). Most of the electrical burns in our study were secondary to arc burns (70%; *n* = 187/276) and were mainly correlated with low voltage incidents 75.8%), they are not differ from other thermal burns (Fig. 1a and b). Electro-thermal burns, resulting from passage of electricity through the body, were less common (20.2%; *n* = 54/276). Mixed burns that combined the features of both arc and electro-thermal burns accounted for only 24 (9%) of the burns.

3.3. *Outcome*

The fatality rate, one reflection of the severity of electrical incidents, was 3.2% (*n* = 10/311) (Tables 1a and 1b). Nine of the 10 deaths were immediate due to electrocution (defined as

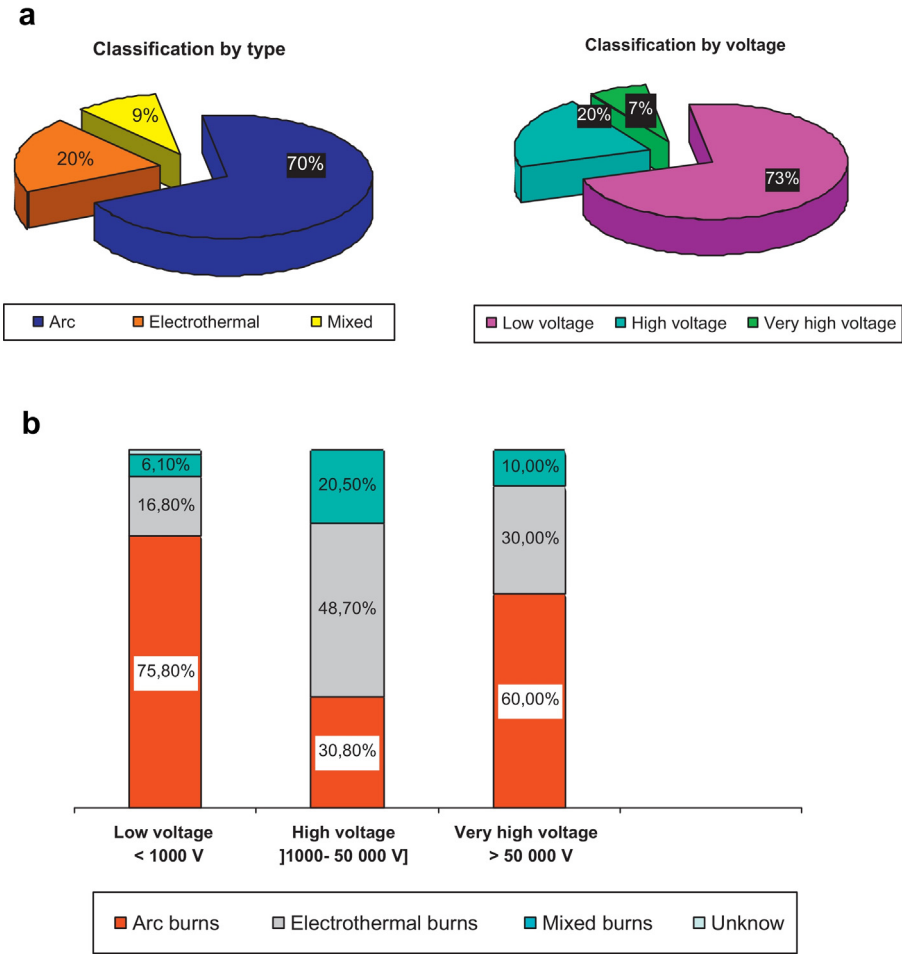

Fig. 1 – (a) Classification of 276 electrical burns by type. (b) Classification of 276 electrical burns according to their type and current voltage.

immediate death directly related to the passage of current through the body leading to ventricular fibrillation). In one case, death occurred 111 days after the incident due to severe mixed burns. The voltage was high voltage in six cases and low voltage in four.

The frequency of functional disability (32.5%; $n = 98/301$) is another severity marker, as is hospitalisation for medical assessment and monitoring (35.4%, $n = 110/311$).

Among the 276 employees with burns, nearly 80% involved the head/neck and hands/wrists. Third-degree burns were located primarily on the hands and wrists (79.4%). In over 61% of cases, the burn area was extensive (1–10% of the body surface). In 28%, <1% of the body surface was burned and in 10% the burns involved >10% of the body surface. Most of the burns (66%) were low voltage arc burns covering 1–10% of the body surface. In 16 cases, surgical treatment was required: 14 skin transplants, three fasciotomies and four amputations. All the amputations (left forearm, right thumb, left fifth finger and metacarpus, left third finger) followed a high voltage current contact. In our study, burns were the main cause of morbidity from electrical incidents.

3.4. *Evolution of electrical injury consequences*

To assess the evolution of the consequences of electrical injuries, we compared the findings from this study period to those of previous decade-long studies of EDF workers. The fatality rates, frequency of sequelae and distribution of 1754 injuries occurring during 1959–1969 in 95,750 employees [11], 1231 injuries occurring during the 1970–1979 in 113,750 employees and 996 injuries occurring during 1980–1989 in 115,138 employees [15,14] are compared in Fig. 2.

3.5. *Sequelae of burns*

In our study, ninety-eight (32.5%) permanent functional sequelae were recorded among the 301 injured employees and 95 (34.4%) among the 276 subjects with burns. The three main types of sequelae are shown in Table 2 and Fig. 3. The sequelae were directly related to the burns in 83.2% of cases ($n = 79/95$), were neuropsychiatric in 37.9% ($n = 36/95$) and affected the neuro-sensory organs in 11.6% ($n = 11/95$) (Table 2).

Neuropsychiatric sequelae, including neurological and neurobehavioral impairments, were one of the most common functional sequelae. Neurological sequelae mainly involved the peripheral nervous system. One-half ($n = 10/20$) were related to high voltage incidents with passage of current through the body. Injured workers had common features: the occurrence of initial sensory symptoms ($n = 3/20$) and an association with neurobehavioral impairments ($n = 6/20$). Sequelae more rarely involved the central nervous system (central nervous deficit due to brain destruction following passage of the electrical current through the brain ($n = 1$) and persistent vegetative state following an anoxic brain injury after a low voltage incident ($n = 1$)).

Post-traumatic stress disorder (PTSD) was diagnosed according to DSM IV criteria: (A) exposure to a traumatic event; (B) persistent reexperience; (C) persistent avoidance of stimuli associated with the trauma and numbing of general responsiveness; (D) persistent symptoms of increased arousal; (E) symptoms present for >1 month; (F) significant impairment in social, occupational or other important areas of functioning [17]. Twenty-one cases of PTSD were recorded: these were complete in 14 cases and incomplete or mild in seven. The majority of cases of PTSD were related to high voltage incidents ($n = 11/21$) with passage of current through the body ($n = 7/21$). Among them victims had initial neurological ($n = 11/21$) or cardiovascular symptoms ($n = 3/21$) occurred, one had a cardiac arrest and one circulatory collapse.

Sequelae directly related to burns were disabling and ugly scars, pain, fibrosis and joint stiffness or amputations. Seventy-nine (31.2%; $n = 79/95$) were associated with anaesthetic and functional sequelae and 75 (94.9%; $n = 75/95$) had only unsightly sequelae.

Sensory organ disorders were encountered in 11 cases. Ocular sequelae ($n = 5/11$) included arc injury ($n = 2$), delayed cataract ($n = 2$) and bilateral cataract following a low voltage incident with a 2 year delay ($n = 1$). There were three cases of retinal damage including one complicated by bilateral blindness. Auditory sequelae ($n = 6/11$) resulted from passage of current through the head, arc burns or head injury, and

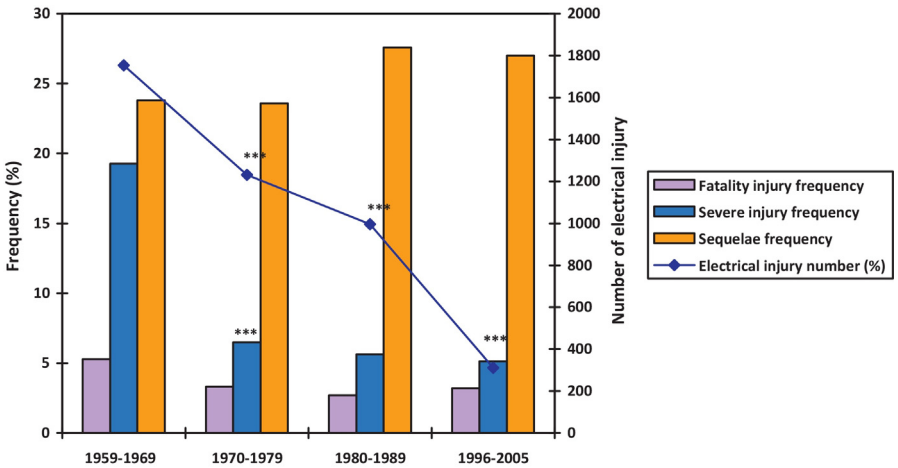

Fig. 2 – Fatality rate and sequelae frequency among EDF workers with work-related electrical accidents in three retrospective studies.

Table 2 – Analysis of sequelae occurred after work-related injuries at EDF (1996–2005).

Type of sequelae	Number of cases	Percentage among 95 victims with permanent burns sequelae
Directly related to burns	79	83.2
Disabling and ugly scars, pain, fibrosis and joint stiffness without amputation	(75)	(94.9)
Amputations	(4)	(5.1)
Neuropsychological	36	37.9
Neurologic	20	21.1
Peripheral nervous disturbance	(18)	(90)
Central nervous system	(2)	(10)
Neurobehavioral impairments	21	22.1
Posttraumatic stress disorder complete	(14)	(66.7)
Posttraumatic stress disorder incomplete	(7)	(14.3)
Milder forms	(4)	(19)
Sense organ disorders	11	11.6
Ocular sequelae	5	45.5
Sequelae of arc injury (photophobia)	(3)	(60)
Electric cataract (bilateral in 1 case)	(2)	(40)
Auditory sequelae	6	54.5
Hearing loss without tinnitus	(3)	(50)
Hearing loss with tinnitus	(2)	(33.3)
Tinnitus	(1)	(16.7)
Cardiovascular	0	0
Orthopaedic	0	0
Renal	0	0

consisted of conductive or sensori-neural hearing loss ($n = 5$) and/or tinnitus ($n = 3$).

3.6. *Level of disability and work-days lost*

According to the French social security compensation system, the level of work-related disability is assessed by a complex method of calculation translated afterwards into a percentage. Each type of impairment for every organ or system is stated objectively and the subjective complaints of each victim are also taken into account. When a work-related injury does not lead to sequelae the level of disability is 0%. For one victim suffering multiple sequelae, every percentage disability related to the impairment of an organ is summed to obtain the overall level of disability.

Final disability level is assessed only once the medical examination establishes that the impairment to an organ will not evolve further (either improving or worsening). It should be underlined that in some cases the evolution can continue to evolve during many years. Disability level was available for 292 of our victims. Most survivors (73%; $n = 195/292$) had no sequelae. Seventy-three survivors (25%) had a mild level of disability and six (2%) sustained very serious injuries (Fig. 4).

The number of work-days lost is expressed as the median, mean, minimum and maximum (Table 3 and Fig. 4).

4. Discussion

The number of incidents during this period dropped very significantly in comparison to the 1959–1969 figures: by 83.79% ($p < 0.0001$). The current fatality rate is nonetheless similar to that recorded in the 1970s (3.3%) and the 1980s (2.7%) ($p = 0.69$). This improvement in the number of electrical incidents is undoubtedly due to a combination of investments in technical improvements, modernisation of the networks and materials, and prevention policies.

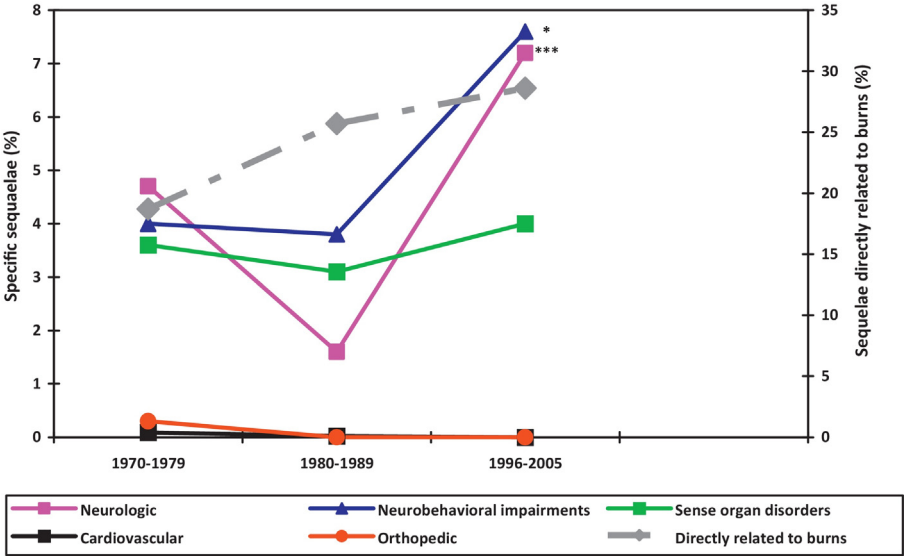

Fig. 3 – Sequelae frequencies among EDF workers with work-related electrical accidents in three retrospective studies.

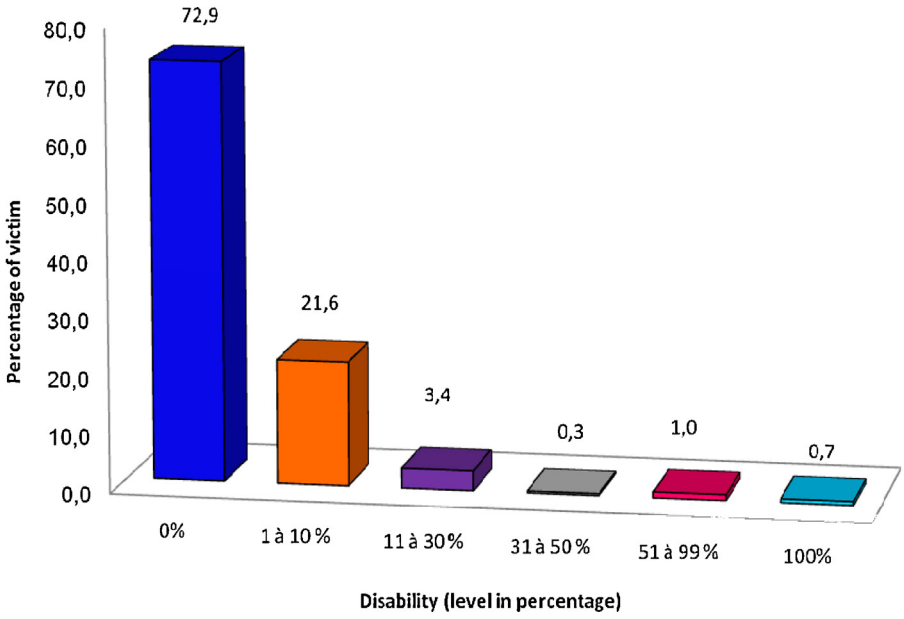

Fig. 4 – Level of disability related to functional consequence of electrical injuries among 292 victims with sequelae.

We observed more injuries in the group exposed to low voltage (<1000 V) high voltage (>1000 V): 72.9% compare to 27.1%, but no significant difference in the rate of severe injuries ($p = 0.3$). Similarly, injury severity did not differ significantly between workers with and without PTSD ($p = 0.11$). Due to our small sample (5 severe cases and 14 PTSD cases) these data should be interpreted with caution. Our outcomes are consistent with Pliskin's observations [1] but differ from the results of Sun's retrospective study which found that severity of injuries was positively correlated with voltage [18]. This study thus shows that the fatality rate from electrical incidents has not changed significantly (3.2%) from that reported in the 1980s (2.7%) [15,14] and 1970s (3.3%) [13] ($p = 0.69$) (Tables 1a and 1b and Fig. 2). Moreover, the fatality rate from electrical incidents remains higher than that of all occupational incidents (0.067% in 2005 in France and 0.11% in 2010) [19,20]. This confirms that electrical injuries continue to represent a very serious occupational hazard.

In our study, nine deaths occurred immediately due to ventricular fibrillation related to the passage of current through the body, six at high voltage and four at low voltage. This raises the question of the importance of rapid access to an automated external defibrillator to deliver an immediate electric shock [21].

Our study also shows that the frequency of permanent functional sequelae among burned employees is similar (30.5%; $n = 95/311$) to that reported previously (27.7% in the 1980s) ($p = 0.4$) [13,15,14]. However, the types of sequelae changed considerably. Since the 1960s, the proportions of two types of sequelae have decreased in frequency. There has been a dramatic decrease in orthopaedic sequelae resulting from vertebral column or limb trauma (from 3% in the 1970s to 0% in the 1980s) because of fall prevention. Similarly, cardiovascular sequelae have also decreased in frequency from 0.4% in the 1970s ($n = 5/1142$) to 0.1% ($n = 1/938$) in the 1980s and 0% in our study, due to improved resuscitation procedures. The frequency of sequelae directly related to burns has increased between the 1970s and the 1980s (18.7% *vs.* 25.7%) and there is a plateau since 1980s (28.6% in our study) despite specific management of burns in specialised burn units.

The frequency of sensory organ disorders is stable among injuries. The frequency of auditory sequelae was 5.4% in the 1980s *vs.* 6.3% in our study among victims with permanent burns sequelae ($p = 0.7$). The frequency of ocular sequelae was 5.1% in the 1980s *vs.* 5.3% in our study ($p = 0.9$).

Neuropsychiatric sequelae appear to have increased (Table 2). The frequency of neurologic disturbances was 5.4% ($n = 15/276$) in the 1980s *vs.* 22.1% ($n = 20/95$) in our study

Table 3 – Work days lost among non fatal accident with exclusion of the persistent vegetative state at EDF (1996–2005).

Type	Median	Mean	Min	Max
All non fatal electrical injury (196)[a]	17.5	76.6	1	1119
Victims with neuro-psychic sequelae				
Neurobehavioral impairments	107	236	21	719
Peripheral nervous system sequelae	182	328	0	1027

[a] This duration was not available for 41 victims.

($p = 0.0004$). The most common were either sensory deficits of the upper limbs ($n = 18/20$) or motor deficits (median nerve with canal tunnel syndrome ($n = 1$), external popliteal sciatic nerve ($n = 1$)). Central nervous system disorders were rare ($n = 2/20$) but severe. One case suffered from a loss of brain tissue due to the passage of the electric current through the body, entering *via* the upper limb and exiting through the skull. The other case was in a persistent vegetative state following a low-voltage electrical incident, which is a known risk factor [2]. Both of these injured workers were very severely disabled (level of disability between 90% and 100%).

PTSD was well known well before its official recognition in the DSM III (1980) (revised in the DSM IV and in the ICD 10 in 1990 as ''a delayed or protracted response to a stressful event or situation (of either brief or long duration) of an exceptionally threatening or catastrophic nature, which is likely to cause pervasive distress in almost anyone'' (F43.1 Post-traumatic stress disorder). It was for example called ''soldier's heart'' during the United States Civil War [22]. The notion of war trauma has expanded to other events, such as disasters, assault, rape and sexual abuse and occupational incidents among others. Consideration of the psychological dimension of occupational incidents by occupational physicians (who previously focused mainly on the physical effects) and of course a better understanding of the syndrome has led to its recognition in certain work situations.

PTSD is no longer or not only related to ''the exceptional consequence of an extreme situation'' mentioned in ICD-10. Its occurrence has been recognised in workers (for example, train drivers, electricians and pilots) who were suddenly and violently with the risk of death their own or others.

In our professional context we underline some major consequences that can severely impede the rehabilitation necessary for the return to work: the guilt feelings; endless questions about what could or should have been done to avoid the incident; quasi-permanent reminiscences that hinder concentration on other activities and persistent avoidance and emotional numbing which usually require a change of professional occupation.

The frequency of PTSD (complete, incomplete or milder forms) was 13% ($n = 36/276$) in subjects with permanent burns sequelae in the 1980s and 21.1% ($n = 20/95$) in the present study ($p = 0.09$). Although both studies used DSM definitions, comparisons are difficult due to some changes in the diagnostic criteria. Indeed, the DSM-IV criteria (since 1994) used in the present study differ substantially from the DSM-III criteria (since 1980) used in the 1980s study. Furthermore, changes have recently been proposed to the DSM-IV diagnostic criteria to refine the diagnosis because of concerns about its construct validity [23]. It has been shown that removing anxiety/mood disorder symptoms do not change the prevalence rate [24] and that the strongest support was found for an inter-correlated four-factor model: intrusion, avoidance, numbing, hyper-arousal [25]. Moreover, the prevalence of PTSD varies greatly depending on the time of screening [26]. It is well recognised that patients without any symptoms of PTSD while hospitalised may develop PTSD after discharge [27]. Electrical injury patients with psychiatric conditions exhibit poorer cognitive performance (verbal memory, executive functioning and attention) compared to electrical injury patients with no post-injury psychiatric problems.

Neuropsychiatric evaluation and cognitive rehabilitation, when appropriate, should be considered an important part of the management of electrical injury patients at all phases of recovery [28,29].

Psychological sequelae do not appear to be correlated to the severity of the incident. Any significant correlation between injury severity and PTSD ($p = 0.3$) has been observed. Contrary to expectations, psychological sequelae occurred in only one of the four individuals (25%) who underwent an amputation, but the small sample size (fewer than 5 observed cases), makes the interpretation of the result very delicate. This lack of systematic correlation between severity and PTSD is confirmed by an Australian study of 119 individuals suffering an electrical injury. Among six people with PTSD, three were not victims of serious incidents [8].

Recently, a prospective study reported a prevalence rate of PTSD of 26% at 52 days post-electric shock and 28% at 1 year [30]. The prevalence rate of PTSD in our study is similar (22.1%, $n = 21/98$) with a longer follow-up; since our victims were followed until stabilisation of their organ impairment. The results of the study of Bailey et al. [30] and our results are similar even though only patients with theoretical risk factors for arrhythmias were included in the Bailey's study, whereas our study included the whole spectrum of electrical injuries. Furthermore, Bailey's study is limited by the number of patients lost to follow-up, especially at the first-year of follow-up, whereas none of our patients was lost.

An electrical incident with passage of current through the body is the only risk factor for PTSD currently identified [30]. This would suggest that electrical injury PTSD is specific. The specificity of profiles of psychological distress after electrical injury have been characterised with the MMPI-2 (Minnesota multiphasic personality inventory) [31].

We believe that the most important causal factor in PTSD is the traumatic event itself even if other factors are likely to influence PTSD development. According to Van Loey's study which showed that the long-term outcome appears dependent on factors different from the first response [32]. Ultimately, other factors, such as childhood psychological trauma, chronic adversity, and familial stressor influence PTSD development. The most important remains the level of danger perceived by the individual exposed to the trauma [33].

Whatever the trauma responsible for PTSD, risk factors such as those described in a previous population-based cohort study [34] play a central role in explaining the trajectory of post-traumatic stress. Emotional distress has been demonstrated to be the dominant feature influencing long-term outcome of patients after electrical injury [35]. In a retrospective study of 4762 military personnel from the UK, personal appraisal of the threat to life during trauma emerged as the most important predictor of PTSD [36]. This agrees with the results of a prospective study of 50 184 subjects which showed that combat exposure was the main risk factor [37].

Prolonged exposure therapy (in the context of a behavioural therapy) has been reported to be effective at improving

PTSD symptoms in 60–65% of trauma victims suffering from PTSD and the results are supported by new therapies such as imagery rescripting and reprocessing after failed prolonged exposure for PTSD following industrial injury [38].

In a retrospective study of 4762 military personnel from the UK, personal appraisal of the threat to life during trauma emerged as the most important predictor of PTSD [36]. This agrees with the results of a prospective study of 50,184 subjects which showed that combat exposure was the main risk factor [37].

The cost of work-related electrical injuries can be evaluated by determining the number of work-days lost (Table 3) and the level of disability (Fig. 4). Our study indicates a 6-fold increase in median number of work-days lost in victims with neurobehavioral impairments and a 10-fold increase in those with peripheral nervous system sequelae. The high cost of rehabilitation of work-related electrical injuries is due to sequelae with a long recovery period and disability consequences.

5. Conclusions

This retrospective study confirms the need for early recognition and treatment of neurological and psychiatric impairments after electrical injury. It can be speculated that most Neuropsychiatric disorders are likely due to the fear of a threat to the integrity of the body. The level of danger perceived by the individual exposed to the trauma probably influence PTSD development.

The best ''treatment'' for electrical injury is prevention, including continual emphasis on safety training and education [39].

Ethical approval

Ethical approval for this study was obtained from the EDF Medical Council (Institutional Review Board).

Conflict of interest

The authors declare they have no competing financial interest. The authors' freedom to design, conduct, interpret, and publish the research described in this work was not compromised by any controlling sponsor.

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This manuscript is dedicated to Dr Elisabeth Gourbière and her involvement in prevention and research on electrical burns.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.burns.2013.08.008.

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