Diffuse Electrical Injury – A Study of 136 Subjects

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Abstract—**Some electrical injuries defy explanation by the theories of thermal damage or electroporation. In rare electrical contacts, symptomatology arises that is remote to the theoretical current pathway and is often disproportionate to the parameters of electrical contact. The rarity with which this type of *diffuse electrical injury* (DEI) occurs often leads to diagnoses that the symptoms are of a non-organic nature. An on-going web-based interactive survey is being used to locate and query individuals suffering from rarely occurring responses to electrical contact. The research results indicate that there is a symptomatology fingerprint associated with the class of electrical shock injury studied.**

Keywords—**Diffuse electrical injury, disproportionate electrical injury, electric shock, low voltage electrical injury**

I. Introduction

Electrical injury research has focused on injuries which produce gross tissue damage or physical symptoms that can be explained by the voltage, duration of contact, and/or theoretical current pathway. (The theoretical current pathway is the linear path of the electrical current from entry point to exit point). This study focuses on "diffuse electrical injury" (DEI), a rarely occurring class of electrical injury in which there exists diffuse symptomatology that has components which exist remote to the theoretical current pathway. This type of injury produces remote physical, and often neurological and/or neuropsychological symptoms which exist even in the total absence of a theoretical current path that includes the brain [1][2].

II. Literature Review

The literature supports two modes of tissue injury in electrical contacts: *thermal injury* and *electroporation*. Thermal injury, resultant from resistive heating of tissues, is a proportional response to tissue resistance, current density and duration of contact. Thermal injury occurs only along the current pathway. Given the energy requirements to heat tissue and the time constraints for heat diffusion, remote injury from tissue heating is often very limited [3][4][5]. Electroporation is a theory that recognizes that in the presence of a significant enough electrical field, cell membranes will rupture, disrupting the metabolic functioning of the cell, and causing cell death [6]. Electroporation can cause slow cellular death that is consistent with the often noted delayed onset of neurological sequelae following electrical contact [7]. As with thermal injury, electroporation can only occur along the current pathway.

DEI cases, leave researchers in a quandary to explain the causal connection between electrical contact and those symptoms that appear to be pathway independent. MRIs, CTs, and nerve conduction studies offer only inconclusive support for the presence of physical injury in such cases [8]. An early study by Weeks demonstrated no current passage through the brain in limb-to-limb electrical contact [9]. Absent a theoretical current pathway that would dictate electrical involvement with the brain, the prevalent theory is that unexplained neurological and neuropsychological symptomatology following an electrical contact are of a non-organic etiology. Victims of these contacts are most often given the diagnoses of posttraumatic stress disorder and other anxiety disorders, depression, psychological factors affecting physical conditions, and somatoform disorder (including conversion disorder, hypochondriasis, somatization disorder, and pain disorder) [10].

III. Methods

Research in DEI has been limited somewhat by its rare occurrence. That rarity makes it difficult to recruit enough subjects to a research site to participate in lab research studies. The difficulty is magnified further when studying the occurrence of DEI in individuals who have suffered no gross external injury but still present broadly diffuse symptomatology (disproportionate DEI). Through the use of the World Wide Web, geographically scattered individuals suffering from diffuse electrical injury can now be located and surveyed. The goal of the study was to obtain a statistical "fingerprint" description of the symptomatology common to this rare, disabling type of injury.

The design of this research was as follows:

1. A detailed list of electrical injury symptoms was developed.
2. A web-based survey was created to retrieve data from the target population from which an analysis of the electrical contact could be made and from which a study of post-contact symptoms could be conducted.

3. The survey website was then made visible via multiple search engines.
4. Software was developed to analyze the respondent data along a wide variety of axes.
5. Comparisons were made of post-contact symptom data to baseline data using the Chi Squared test.
6. It was then determined if the results suggested a common symptom set.

Current literature supports the concept that the World-Wide Web holds great promise as a mechanism for questionnaire-based research [11]. A study by Davis found that findings from web-based questionnaire research are comparable with results obtained using standard procedures such as paper-and-pencil format in a researcher's office [12]. Studies have demonstrated that research subjects are just as likely to respond to a Web survey as a mail survey, and that the computerized Web interface may also facilitate self-disclosure [13]. Furthermore, many of the criticisms of online data collection are common to other survey research methodologies [14].

The survey consisted of eight sections, which included demographics; history of prior or present litigation or workman's compensation; information about electrical contact (place, date, voltage, entry and exit data, loss of consciousness, and duration of contact); pre-existing conditions (population baseline); and symptoms arising at the following time points: immediately, three weeks, three weeks to six months, and six months post electrical contact.

Due to the large amount of information included in the survey, the results presented herein are limited to examining symptoms present at least six months post electrical contact as compared to the population reported pre-existing symptom set (baseline).

For analysis purposes, DEI subjects were defined to include all valid respondents suffering from neurological or neuropsychological symptomatology where the theoretical current pathway did not include the brain. All such subjects thus presented with symptoms remote to the theoretical current path.

IV. RESULTS

Of almost 300 surveys received to date, 136 met the criteria for this study. Those chosen reported electrical injury with a set of long-term symptoms existing greater than 6 months with some symptomatology suggesting an origin that was remote to the theoretical current pathway. The demographic characteristics of the population are presented in table I. A baseline for each symptom was established by tracking the frequency of occurrence of pre-existing symptoms among the survey population. A Chi Squared analysis was performed on each symptom in each symptom group (diffuse systemic, neuropsychological, and path-related) based on the hypothesis that the post-contact frequency was significantly greater than the population baseline frequency. Analysis presented in Table II reveals that there was a significant pre-post difference between the symptom groups ($p<0.001$) with the greatest significance occurring among those symptoms presenting as the largest post shock percentage of occurrence. Muscle aches (63%) followed by muscle spasms/twitches (53%) and general fatigue (51%) were the diffuse physical symptoms most often reported post electric shock. General forgetfulness (50%), fear of electricity (49%) followed by insomnia and sleep disorders (48%) were the neuropsychological symptoms most frequently reported. Tingling in the hands (58%), numbness in hands (55%) and pins and needles in hands (49%) were the path-related symptoms most often endorsed post contact.

TABLE I

Group Demographics N = 136

	Totals for DEI Surveys
By Contact Voltage:	
110 Volts	22
220-240 Volts	31
240-1000 Volts	25
1000-2500 Volts	8
2501-5000 Volts	1
5001 Volts -10,000	14
> 10,000 Volts	18
Other	17
Total	136
By Loss of Consciousness:	
No Loss of Consciousness	62
<1 Minute LOC	35
> 1 Minute LOC	34
Unspecified	5
Total	136
By Gender:	
Male	98
Female	37
Unspecified	1
Total	136
By Contact Duration:	
< .5 Second Duration Contact	16
.5 to 1 Second Duraction Contact	19
1 to 5 Second Duraction Contact	25
5 to 30 Second Duration Contact	30
.5 to 1 Minute Duration Contact	20
Greater than 1 Minute Duration	20
Unspecified	6
Total	136

TABLE II

Percent of Occurrence For Symptoms Ranked by "All Experiencing DEI" Group with Chi Square Comparison to Population Baseline (N=136)

Symptoms	Post%	Chi Value	P Value
Systemic (Diffuse) Physical Symptomatology			
Muscle Aches	62.50%	67.813187	0.00000
Muscle spasms or twitches	52.94%	46.387469	0.00000
General fatigue	50.74%	52.451074	0.00000
General physical weakness	50.00%	48.705807	0.00000
General exhaustion	47.79%	38.302289	0.00000
Chronic general pain	41.91%	37.241301	0.00000
Weakness in joints	41.18%	35.905476	0.00000
Stiffness in joints	41.18%	37.960784	0.00000
Weight gain or loss	38.24%	34.725602	0.00000
Back problems	36.76%	18.661526	0.00002
Dizziness	36.03%	28.930775	0.00000
Muscle cramps	34.56%	28.400902	0.00000
Lack of physical coordination	31.62%	17.180793	0.00003
Extreme physical sensitivity	28.68%	22.767857	0.00000
Sensitivity to Light	27.94%	25.589036	0.00000
Heart palpitations	22.79%	17.619433	0.00003
Excessive perspiration	21.32%	13.795515	0.00020
Excessive thirst	20.59%	16.268908	0.00005
Neuropsychological Symptomatology			
General forgetfulness	50.00%	29.0	0.00000
Insomnia or other sleep disorders	49.26%	50.908344	0.00000
Fear of electricity	47.79%	51.6375	0.00000
Personality Changes	46.32%	44.270833	0.00000
Increased emotional sensitivity	45.59%	45.649839	0.00000
Unexplained moodiness	43.38%	51.075556	0.00000
Memory loss - short term	43.38%	54.095911	0.00000
Unusual anxiety	42.65%	39.968889	0.00000
Reduced attention span/loss of concentration	42.65%	32.746929	0.00000
Lack of motivation	42.65%	32.746929	0.00000
Sexual dysfunction	38.24%	38.595754	0.00000
Easily confused	36.03%	28.888497	0.00000
Unexplained sadness	34.56%	30.877987	0.00000
Feeling of Hopelessness	33.82%	23.013596	0.00000
Increased temper	33.09%	18.801843	0.00001
Nightmares	32.35%	32.08133	0.00000
Panic attacks	31.62%	23.026455	0.00000
Crying Spells	27.94%	25.519773	0.00000
Inability to cope	27.21%	15.082956	0.00010
Cognitive losses (loss of reasoning skills)	23.53%	18.750638	0.00001
Lack of usual communication skills	22.06%	13.628157	0.00022
Random Fears	20.59%	10.367649	0.00128
General disorientation	20.59%	14.460759	0.00014
Agressive Behavior	20.59%	22.754651	0.00000
Marital or Family problems (that did not exist prior to injury)	20.59%	16.268908	0.00005
Memory loss - long term	15.44%	25.699169	0.00000
Fear of crowds	14.71%	12.73004	0.00036
Path Related Symptomatology			
Tingling in Hands	58.09%	71.547826	0.00000
Numbness in Hands	55.15%	59.78022	0.00000
Pins and needles in hands	48.53%	50.111366	0.00000
Tingling in arms	47.06%	47.117682	0.00000
Weakness in Grip	42.65%	40.703819	0.00000
Headache	40.44%	30.777935	0.00000
Numbness in Arms	40.44%	40.936455	0.00000
Ringing in ears	36.76%	28.280398	0.00000
Severe headache or migraine	35.29%	25.887654	0.00000
Tingling in legs	34.56%	39.39278	0.00000
Numbness in Legs	33.82%	35.643319	0.00000
Chest pains	33.09%	25.994709	0.00000
Blurred Vision	25.74%	24.152888	0.00000
Hearing loss	17.65%	7.7596044	0.00534
Dry eyes	17.65%	18.133333	0.00002
Unusual Constipation	11.76%	7.7714286	0.00531

The authors tested two further hypothesizes. First, it was hypothesized that there would be no significant difference in the endorsement of those symptoms occurring at a statistically higher rate than the baseline in a comparison between the group of DEI subjects who experienced gross external thermal injury at the time of contact and those that experienced no gross external thermal injury Second, it was hypothesized that DEI was voltage independent. Chi Squared analysis validated both hypotheses.. (The results are not presented herein in tabular form because of space limitations.).

V. DISCUSSION

A large number of symptoms known to be reported following electric shock have been studied in a population limited by (1) time following electrical contact and also limited by (2) theoretical current pathway. The results indicate with clear statistical significance:

- There is a fingerprint symptomatology including (1) path dependant, (2) diffuse path independent, and (3) neurological (neuropsychological) path independent characteristics that occur with statistical significance following some electrical contacts.
- Diffuse electrical injury does not correlate to either the voltage of contact or the level of observed thermal injury at the instant of contact.

VI. Conclusions

Diffuse electrical injury is a class of electrical injury that defies the common theories that explain tissue damage from electrical contact. Thermal and electroporation type injuries require that symptomatology be path related and proportional to either the energy delivered during the electrical contact or the field strength. In DEI, the injuries can occur even in the absence of any traditional thermal or path related injury. Such diffuse injury might best be characterized as "disproportionate" DEI. It is further observed that DEI type injuries occur without correlation to the voltage of the contact or the immediate injury from the contact. The result is an injury that presents with symptomatology both on and beyond the theoretical current pathway. Most interesting is the presence of neuropsychological symptomatology absent any observed or theoretical brain involvement. Finally, this researcher notes that most often it is reported that DEI type symptomatology flies below the level of modern diagnostic technology leading to a broad array or organic and non-organic diagnoses. Given the statistical fingerprint associated with DEI, it is likely that there exists as of yet undefined mechanisms of injury from electrical contact.

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