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Neuropsychiatric Aspects of Electrical Injury

The Nature of Psychiatric Disturbance

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The clinical spectrum of electrical injury (EI) is remarkably complex, with voltage, the character and duration of contact, and pathway being only some of the injury-related determinants. The specific neurologic effects of lightning strikes were described by early Greek physicians and neurologic effects have continued to be described since electric power was brought into our homes and work settings. Central and peripheral nervous system symptoms occur immediately postinjury to years later.[1] Initially, electrical injury was thought to be primarily related to tissue heating, and histopathology was consistent with this type of damage. However, the heating effects of electrical injury did not account for the special vulnerability of nervous tissue, as nerves have particularly low resistance and therefore low heat generation with electrical injury; nor did it account for the delayed central nervous system effects of electrical injury. A further understanding of the mechanism of EI and electrical field effects on nerve cells is discussed by Lee.[2] Further study is necessary to better understand delayed neurologic effects.

The accompanying social, emotional, and neuropsychological aspects of electrical injury have been alluded to in case studies.[3] However, there have been few systematic evaluations of EI patients, and no systematic psychiatric evaluations are reported. Daniel *et al.* did report that 8 of 9 EI patients evaluated by the Minnesota Multiphasic Personality Inventory (MMPI) were found to have profiles indicative of significant problems with emotional adjustment, with somatic preoccupation and depression with anxiety being prominent features of their profiles.[4] Assessment was not made of these patients' premorbid state, but all had been working prior to EI, and now most presented themselves as disabled. In the one longitudinal neuropsychological study, EI patients were studied for 5 to 9 years.[5] Severe depression was reported in 14 of their 16 patients, 11 of 13 employed patients lost their jobs, and 9 of 11 married patients were divorced during this period. Mancusi-Ungaro *et al.* reported on 10 EI patients referred with emotional problems after EI.[6] They hypothesized that EI patients may have more significant posttraumatic stress disorder (PTSD) than other burn patients, with subsequent poor prognosis for rehabilitation and return to work. Their findings did not clarify the diagnosis of PTSD. However,

the EI patients were reported to demonstrate high levels of distress, depressive symptoms, and a high early-dropout rate from the study.

In an attempt to clarify the nature of psychiatric disturbance that may occur after EI, we have begun to psychiatrically evaluate all patients referred for a multidisciplinary evaluation of both physical and psychological complaints. The goal of this evaluation is to determine the nature of premorbid and present psychiatric function as well as to determine which characteristics of the injury (i.e., voltage, loss of consciousness) and of the patient (i.e., education, IQ, previous psychiatric diagnoses) may relate to psychiatric sequelae after EI. Patients referred for this multidisciplinary evaluation include those with recent EI as well as those who have suffered injury in the past.

CASE STUDY

H.H., a 34-year-old man, was referred for psychiatric evaluation in March 1993, after being injured in August 1988, 4.5 years prior to testing. His primary complaints at the time of evaluation were weakness, numbness of both the right upper and the right lower extremity, anxiety, worry, and weight changes.

H.H. had been injured while helping another employee steady a large piece of steel when it came in contact with a 7200-volt overhead electrical line. He recalls feeling the electricity enter his hands and feeling as if he and his coworker were in "a ball of light". His coworker had a seizure and his clothing caught fire. H.H. could not help him because of a brief period of paralysis and injuries to his hands. He had no loss of consciousness, nor fall. His coworker lived, but was severely injured. H.H. was hospitalized for a few days for treatment of hand and leg wounds. He returned to work one month postinjury. Weakness and pain in his right arm and leg worsened and, after disagreements between H.H., the company, and the union, H.H.'s job assignment was changed to a "lighter" one. He has kept this job, but describes being harassed by both management and his coworkers.

At the time of psychiatric interview, H.H. was very concerned about increasing pain and numbness in his right arm and leg. He feared he would lose the ability to play his guitar. He spoke of his anger with his company for the way it had treated him and his coworker, who had only recently returned to work. His friend had litigation pending and was to go to trial in September 1993. H.H. explained that subsequent to this case he would decide whether he would pursue litigation against the company. He stated that his marriage had been greatly stressed because of his injury and his concerns about what might happen next to his body. He was frightened of losing his job and not being able to support his family.

On structured psychiatric interview,[7] H.H. denied having depressive symptoms for sufficient length of time or of severity necessary to make the diagnosis of major depression or dysthymia. He was found to have posttraumatic stress disorder (PTSD) (TABLE 1). In fact, he thought these symptoms had worsened over the 4 years since his injury.

H.H. also described that, at age 21, 13 years previously, he had acquired blurry vision and dizziness for which he sought medical evaluation. No physical cause for these symptoms was found after medical workup and he had been advised by his

TABLE 1. Posttraumatic Stress Disorder[8]

(A)	The person has experienced an event that is outside the range of usual human experience and that would be markedly distressing to almost anyone
(B)	The traumatic event is persistently reexperienced
(C)	Persistent avoidance of stimuli associated with the trauma or numbing of general responsiveness occurs
(D)	Persistent symptoms of increased arousal are present

doctor to seek counseling. He did so and he reported that these symptoms resolved when he dealt more directly with his anger toward his father, who had been physically abusive to H.H. when he was a child and who was presently quite ill and dying. This is an example of a specific kind of somatoform disorder, called conversion disorder (TABLE 2).

H.H. also endorsed being aware that "stress makes all my symptoms worse." He described much stress and was conscious of the relationship between increased stress and his perception of his physical symptoms. The diagnosis for the relationship between stress and the perception of physical symptoms is psychological factors affecting physical condition (TABLE 3).[8]

At the time of the interview, H.H. agreed that he would likely benefit from therapy as he had when he was 21 and said he would pursue therapy near his home. Additionally, he was advised that an evaluation for medication may be warranted to ameliorate some of the symptoms associated with his "on guard" state.

H.H.'s case was reviewed at the multidisciplinary team meeting. The neuropsychological assessment found H.H. to be of normal intelligence. However, he was experiencing fluctuations in attention and lapses in concentration that were interfering with his present learning, but did not lead to difficulties with forgetting when something was learned. On MMPI, H.H. had several elevated clinical scales consistent with depression. On sensory and motor exam of both upper extremities, it was noted that H.H. voiced symptoms out of proportion to the findings. His strength was good, but he did complain of increased pain and weakness after exertion. He was found to have decreased sensation over both thumbs, which would contribute to his sense of clumsiness. He had some mild decrease in range of motion in his right shoulder that was thought to be due to muscle stiffness and splinting by the patient. Nerve conduction studies were accomplished and he had mild conduction and amplitude abnormalities in his right ulnar nerve. These reports were consistent with our psychological understanding of the patient at the time of evaluation.

TABLE 2. Conversion Disorder[8]

(A)	A loss of, or alteration in, physical functioning suggesting a physical disorder
(B)	Psychologic factors are judged to be etiologically related to the symptom
(C)	The person is not conscious of intentionally producing the symptom
(D)	The symptom is not a culturally sanctioned response pattern and cannot, after appropriate investigation, be explained by a known physical disorder
(E)	The symptom is not limited to pain or to a disturbance in sexual functioning

TABLE 3. Psychological Factors Affecting Physical Condition[8]

(A) Psychologically meaningful environmental stimuli are temporally related to the initiation or exacerbation of a specific physical condition or disorder
(B) The physical condition involves either demonstrable organic pathology or a known pathophysiologic process
(C) The condition does not meet the criteria for a somatoform disorder

DISCUSSION

The primary diagnosable psychiatric disturbances that we anticipate finding in EI patients are listed in TABLE 4. Organic mental disorders should be diagnosed when symptoms are thought to be causally related to known medical illness or conditions (i.e., affective mood changes subsequent to steroid therapy). This category would best address the direct effect of electricity on the brain. The brain may be affected by electricity when it is in the current pathway, secondary to peripheral nerve stimulation or through mechanisms still to be elucidated. Further evaluations to clarify the brain effects of electricity may include SPECT (single-photon emission computed tomography) scans, which produce a picture of the metabolically active areas of the brain as measured by blood flow. This method of brain study may be superior to structural brain scans in detecting clinically relevant deficits in neuropsychiatric patients, particularly when physiological lesions are involved.[9] Additionally, in-depth neuropsychological evaluation may point to specific altered brain functions after EI in certain patients.

PTSD has been discussed in relation to the case presentation (TABLE 1). Symptoms of PTSD are thought to be caused by alterations in the neurobiology of the brain after trauma. Interestingly, one model used to induce aversion in animals is repetitive electric shock. Mancusi-Ungaro *et al.* suggest that electrical injury is an example of one-trial aversive conditioning, which is an extremely potent inducer of PTSD symptoms.[6] The relationship between the direct effect of electricity on the brain leading to PTSD symptoms versus the more commonly described effect of the traumatic experience on the brain needs to be further evaluated.

Depression is a commonly used word by physicians and it is the most common psychiatric disturbance. It is important to clarify the extent of depressive symptoms

TABLE 4. Psychiatric Differential Diagnosis

Organic mental disorders
Posttraumatic stress disorder and other anxiety disorders
Depression:
major depression
dysthymia
adjustment disorder with depression
Psychological factors affecting physical condition
Somatoform disorders:
conversion disorder
hypochondriasis
somatization disorder
somatoform pain disorder

and the length of time that the patient has been symptomatic to make adequate treatment plans. Remarkably, electricity in the form of electroconvulsive therapy (ECT) is used successfully to treat major depression. ECT induces a remission of depressive symptoms, although most often patients require some method of ongoing antidepressant treatment. A recent review of ECT dosage reported that the most efficacious electrical dosage as measured by a decrease in depressive symptoms must be individualized for each patient and should be at least 2.5 times the level needed to induce seizure in that patient.[10] This suggests that it may not be the seizure itself that affects depressive symptoms, but rather some other effect of electricity. EI may lead to depressive symptoms; ECT is an accepted treatment of major depression. Again, the direct effect of electricity on the brain must be clarified.

Somatoform disorders present with physical complaints that have little or no basis in known medical illness. The diagnosis of conversion disorder was reviewed in the case study as an example of this type of dysfunction. Because there is much to learn about the physical basis of many neurologic and neuropsychiatric abnormalities in electrical injury, this diagnosis is used with caution. It is well accepted, though, that humans may use their bodies to speak for their internal and unconscious states. When this occurs, patients suffer through their bodies and often become less and less functional. Intervention in this pattern can be difficult as secondary gain often reinforces these behaviors. It is also known that patients with diagnosable medical illness may have conversion symptoms that mimic their illness, as in the case of seizures and pseudoseizures. This condition is important to consider as patients often are able to grasp this concept when it is presented gently. They are then able to suffer less through their bodies and are able to do the underlying psychological work of gaining insight into their own dilemmas.

Barsky has described that there may be a vulnerability to somatoform disorders based on an individual's perception of normal bodily functions as extremely unpleasant or noxious.[11] Certain variables in the present experience can affect the perceived intensity of a given symptom at a particular time. Some of the most important variables are the patient's cognitive understanding of the bodily sensation, especially relating to the cause of the symptom, the situational context, the attention paid to the symptom, and the overall mood of the individual. When these variables are changed in a positive way by the medical team or through therapy, the patient may perceive the symptom as less frightening and less noxious and therefore may suffer less.

In summary, psychiatric evaluation must be a part of an overall evaluation of electrically injured patients. Psychiatric disturbance does complicate rehabilitation efforts, although it can often be quite treatable. Further study of EI patients, with longitudinal follow-up, may identify those most at risk for poor psychiatric outcome. Prospective study of all EI patients presenting to the hospital may be especially helpful.

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Neuropsychiatric Aspects of Electrical Injury

A Review of Neuropsychological Research

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It is well known that electrical injury can cause damage to the central nervous system, affecting both the brain and spinal cord. Both acute and delayed neurological syndromes have been reported[1,2] in victims of electrical injury involving a variety of symptoms, including loss of consciousness, seizures, aphasia, visual disturbances, headaches, tinnitus, paresis, and memory disturbance.[3] Neurologic sequelae can occur whether or not the head is a point of direct contact with the electrical current. Central nervous system damage results from direct thermal and mechanical effects of electrical shock, and histopathological changes in the central nervous system such as coagulation necrosis (death of tissue due to clotting of blood vessels), reactive gliosis (increase in nonneural support cells within the central nervous system as a response to injury), demyelinization (destruction of the protein covering to many nerves), vacuolization (small holes within the brain tissue), and perivascular hemorrhage (small areas of bleeding) have been documented.[4–6,9] Central nervous system damage may also occur from anoxia due to cardiorespiratory arrest or ischemic damage resulting from thrombosis.[4,6] Cause of death in fatal cases is generally ascribed to ventricular fibrillation with subsequent cardiorespiratory arrest.[7]

Diverse neuropsychological changes have also been reported in electrical injury (EI) patients including confusion, altered consciousness, visual disturbance, memory loss, compromised intellectual function, psychomotor problems, and aphasia.[8–13] In comparison to the medical literature, however, relatively little has been written about the neuropsychological effects of EI. The purpose of this paper is to critically review the existing neuropsychological literature on electrical trauma and to present a model for future studies.

Hopewell[8] described a patient who sustained a high-voltage injury and suffered cardiorespiratory arrest and coma for 4 days. Neurological examination during the subacute phase was interpreted as essentially normal, although the examining neurologist was struck by the patient's disorientation and continued memory problems during hospitalization. An EEG indicated left temporal slowing as well as bursts of theta slowing with frontal accentuation, although the record was read as being minimally abnormal. Neuropsychological evaluation conducted 7 days after