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Case Report

Case report: Significant quantitative MRI brain volumetric finding associated with electrical brain injury

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ABSTRACT

Electrical injury (EI) occurs when current comes in contact with the body, and can result in skin burns, tissue damage, respiratory arrest, and death in some cases. Many EI patients experience neuropsychological deterioration and show symptoms of memory problems, post-traumatic stress disorder (PTSD), sensory disturbances, depression, and other cognitive deficits. In this study, we present the uncommon case of a 43-year-old male with a statistically significant increase in his right lateral ventricle after coming into contact with stray voltage. Upon injury, he sustained retrograde amnesia and first-degree burns on his right underarm and on the dorsal aspect of both forearms; the total surface area affected was 3.3%. One month later, he began experiencing anxiety, depression, memory problems, PTSD, and insomnia, all of which persisted up to at least six years after the electrical injury. The patient's magnetic resonance imaging scans were used to perform quantitative volumetric analysis and identify various regions of interest that were statistically significant against Functional Biomedical Informatics Research Network (FBIRN) controls. We ran a two-sample *t*-test of the patient against FBIRN controls (n = 42, mean age = 34.12 years, SD = 11.02 years, females = 14, males = 28) with gender and age as covariates. Regions of interest were identified (P < 0.5) using the contrasts generated in the two-sample *t*-test, and fractional anisotropy values were extracted from the patient and male controls (n = 15, mean = 41.47 years, SD = 8.22 years). We found an increase in the patient's right lateral ventricle 2 standard deviations above the mean value of the controls, consistent with right-sided fractional anisotropy abnormalities found in the statistical comparison.

1. Introduction

Electrical injury (EI) is responsible for approximately 1000 deaths and 3–5% of all burn admissions per year in the US [1]. EI victims are not only hospitalized for burns, but also for skeletal muscle tetany, respiratory muscle paralysis, or ventricular fibrillation [1]. However, these statistics do not include the victims that mainly suffer from the neuropsychological, neurological, and psychiatric sequelae associated with EI.

While the past literature shows that EI sequelae is typically associated with burns due to the current's thermal load and the body's tissue resistance, the literature also shows that remote psychiatric effects are indicative of and distinct to EI [2,3]. White matter abnormalities after EI have also been found on magnetic resonance imaging (MRI) scans [4], particularly hyperintensities in the cerebral corticospinal tract [5–7].

2. Case report

2.1. Case presentation

One morning in the spring of 2009, the 37-year-old patient was walking his dog in a densely populated city, when his dog stepped in a puddle of melted snow and suddenly jumped upwards, yelped, and started convulsing and defecating himself. The patient bent down on his right knee and grabbed the dog with his left arm as he held himself up with his right hand, which was in the puddle. He reported a "buzzing feeling" traveling up his right arm. After bringing his dog to safety, the patient returned to the site, got down on both knees, put both hands in the puddle, felt a "humming" sensation travel up both arms and felt "stuck" in that position for 2–3 s (no-let-go phenomenon).

Immediately after the shock, the patient sustained burn marks and experienced short-term memory loss and fatigue. Three days

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later, the patient saw an internist and reported upper right quadrant pain, headaches, numbness, weakness, fatigue, insomnia, and minimal, first degree burn marks on his right underarm and on the dorsal aspect of both forearms. The surface area was 1.1% for each forearm, and an additional 1.1% for the right underarm, for a total affected area of 3.3%. One week later, the patient received MRIs of the lumbosacral spine, cervical spine and brain which all reported no abnormalities. One month later, the patient visited a psychologist regarding anxiety, insomnia, and depression, and was diagnosed with post-traumatic stress disorder (PTSD) and retrograde amnesia. Three months after the electrical injury, the patient saw an ophthalmologist regarding pain behind his right orbital and "drooping" of the right side of his face; he was diagnosed with Bell's palsy.

Two years after the incident, the patient had an orthopedic evaluation for right side body pain, loss of right hand motor control, right hand tremors, pain behind the right orbital and headaches with no orthopedic abnormalities found. The following day, the patient visited a neurologist and a different ophthalmologist regarding the same symptoms, with no abnormalities found.

Three years after the electrical injury, the patient visited a neurologist regarding hypesthesia in the right side of the face and to pinpricks to the right hand, severe pain in the right arm and hand, moderate pain in the left arm and hand, and was diagnosed with electrocution neuropathy. Five months later, the same neurologist noted improvement of the pain in the right arm and hand area. During the same year, the patient visited a therapist and was diagnosed with PTSD, severe anxiety, and situational depression and was prescribed psychotherapy as treatment.

Six years after the injury, additional documentation of the damage sustained from the electrical injury was needed to provide objective evidence as part of a lawsuit against the electric company responsible for the exposed wires. The patient visited our laboratory for an MRI DTI and quantitative volumetric analysis, and a clinical neuropsychologist for an exam. At the time of the neuropsychological exam, the patient was taking Bupropion XL, Clobex, Hydrocodone/Acetaminophen, melatonin, Klonopin (clonazepam), Namenda (memantine), Neurontin (gabapentin), and medical marijuana. On the Diller-Weinberg Test, the patient missed 39/47 stimuli, and his visual encoding/processing speed on specific Wechsler Adult Intelligence Scale (WAIS-IV) subtests was between the 1st and 5th percentile. On the dominant finger-tapping test, the patient scored in the 5th percentile. His performance on a timed task of fine motor dexterity was impaired between 2 – 3 standard deviations below the mean, and his motor and processing speed index was in the 2nd percentile, which is typical residual of electrical injury. The patient scored 20 less points on his Performance intelligent quotient (PIQ) than his Verbal IQ (VIQ), which is statistically significant and notably unusual. He scored as severely depressed on his Beck, and has had severe chronic pain and PTSD symptoms in the clinical range.

The patient's past medical history was significant for meningitis at age 10, and arthritis and hypertension as an early adolescent. The patient underwent several unrelated orthopedic surgeries from sports related injuries, with the last surgery being sixteen years before the electrical injury. According to his ex-fiancé, the patient was very social and outgoing before the electrical shock, while he became withdrawn and isolated afterwards. The patient enjoyed activities such as surfing, swimming, hiking, basketball, and skateboarding, all of which he was unable to do, or did differently, after the injury.

At the time of the incident, he was in good health and working as a physical trainer.

2.2. Investigations

The patient received an MRI scan in the spring of 2015. The scan was acquired using a 3 T Siemens MRI scanner that captured 160 images using T1-weighted magnetization-prepared rapid gradient echo sequences of the sagittal view, and 93 images using echo planar multidirectional diffusion weighting imaging. The first set of images was uploaded onto CorTech Lab's NeuroQuant software for volumetric analysis (Table 1).

The second set of images were preprocessed using the Functional Magnetic Resonance Imaging of the Brain (FMRIB) software library (FSL) and were then compared against 42 Functional Biomedical Informatics Research Network (FBIRN) controls (n = 42, mean age = 34.12 years, SD = 11.02 years, females = 14, males = 28) using Matlab's Statistical Parameter Mapping (SPM) feature for diffusion tensor imaging (DTI) analysis. After running a two-sample *t*-test with age and gender as covariates, SPM then generated positive and negative contrasts for the patient ($p < 0.01$, voxel = 30), which showed areas of significantly increased or decreased fractional anisotropy (FA) values of the patient. These contrasts were then overlaid with the patient's MRI scans using the Volume Imaging in Neurological Research, Co-Registration and Regions of Interest included (VINCI) image analysis software. VINCI was also used to outline regions of interest (ROIs); the most significant are shown in Fig. 1. Fifteen of the 42 FBIRN controls (mean = 41.47 years, SD = 8.22 years, males) were loaded onto VINCI. The patient's ROIs were then pasted onto the control images. The mean FA values of the patient and the controls were recorded and then, using Microsoft Excel, a P-Score was calculated for each region of interest (ROI).

The patient's and control's structural segmentation images (Fig. 2) of the brain and skull were taken from the NeuroQuant quantitative volumetrics output, while the ROI was segmented out from the 3D volumetric brain image. The skull outline was visualized, volume-rendered, and adjusted for opacity using Advanced Visual Systems (AVS) software. The ROI was visualized as an isosurface map and arbitrarily colored blue to be distinguished from other brain structures.

3. Discussion

3.1. Background/Theory

Most electrical injuries happen in the workplace, while some occur in household settings [8]. In dense cities that experience heavy snow during the winter, like Boston or New York City, residents are at a higher risk of electrocution through stray voltage when the snow starts to melt [9–11]. Stray voltage is the unintended occurrence of an electrical potential between two objects due to a fault in an electrical system (e.g. a live wire or a poorly insulated power system) and is defined to be less than 10 volts by the U.S. Department of Agriculture [12]. These circumstances, coupled with the increased conductance caused by high-salinity snowmelt, can charge normally non-threatening metal objects, or puddles with ample amounts of stray voltage.

Electrical injury occurs when a person has at least two points of contact with two sources of different voltage, one of which may be the earth ground [13]. The extent of electrical injury is dependent on the voltage, amperage, path of and type of the current (alternating current (AC)/direct current (DC)), duration of contact, and premorbid state of the patient [14]. The current passing through an object with resistance in an external electric field can be calculated using the following equation:

$$V = IR \quad (1)$$

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