Mood and Cognition after Electrical Injury: A Follow-up Study

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Abstract

Individuals who have experienced an electrical injury have been reported to demonstrate both acute and delayed cognitive and psychiatric symptoms. The present study assessed 20 electrically injured patients who underwent neuropsychological evaluations twice following their injury. Time since injury, time between assessments, and longitudinal mood changes were evaluated for their potential impact on simple and complex attention outcomes. As an overall group, there was little change over time from low average to average baseline attention/concentration performance. However, results indicated that longitudinal increases in depressive symptoms were consistently associated with poorer performance on a measure of simple and complex attention. Loss of consciousness, litigation status, baseline injury status (acute vs. post-acute), and time between evaluations were not significant predictors of changes in cognitive performance. Implications for the treatment of comorbid psychiatric issues and for future research on victims of electrical trauma are discussed.

Keywords: Electrical trauma; Electrical shock; Depression; Attention; Psychopathology; Psychiatric

Introduction

Individuals who have experienced an electrical injury often report physical, cognitive, and affective changes. Compared with individuals who have been victims of other traumatic experiences, electrically injured (EI) patients endorse more somatic and internalizing affective distress (Wicklund et al., 2008). Measured rates of psychiatric disorders among EI patients have ranged from 57% to 87.5% (Grossman, Tempereau, Brones, Kulber, & Pembrook, 1993; Hooshmand, Radfar, & Beckner, 1989; Kelley, Takachenko, Pliskin, Fink, & Lee, 1999) in the extant literature. A recent study of consecutive EI patients found that 52% met criteria for one psychiatric diagnosis, whereas another 26% met criteria for two or more psychiatric diagnoses, with depressive disorders and/or “post-traumatic stress disorder (PTSD)” as the most commonly observed conditions (Ramati et al., 2009b). Understanding how psychiatric symptoms and cognitive functions are associated with each other over time may inform treatment practices for EI patients.

Post-injury deficits in attention, processing speed, and motor domains of functioning have been documented in controlled studies of EI patients (Pliskin et al., 1998, 2006). Pliskin and colleagues (2006) found that differences between EI patients and electrician controls in attention/mental speed and motor functions were not attributable to depressive symptoms. No differences were noted between groups in working memory, visual memory, or verbal memory (Pliskin et al., 2006). While neuroimaging studies of this population are sparse, a recent investigation utilized a functional magnetic resonance imaging paradigm and found greater activation in prefrontal systems during a working memory task among EI patients compared with controls, as well as greater activation in neocortical sensorimotor systems during a visual sensory task (Ramati et al., 2009a). Such findings suggest possible compensatory central nervous system changes in EI patients when completing functional tasks.
In a study of verbal memory among EI patients with and without a diagnosis of PTSD, Ammar and colleagues (2006) found significantly lower performances on measures of learning and free recall in EI patients with PTSD compared with those not suffering from PTSD. Moreover, Ammar and colleagues also reported higher susceptibility to proactive interference among EI patients with PTSD. Grigorovich, Gomez, Leach, and Fish (2013) examined memory, attention, and executive functions between EI patients with and without PTSD and found that individuals with PTSD had significantly worse performance on measures of immediate and delayed memory. Among patients with PTSD, it is also possible that delayed cognitive sequelae are associated with delayed-onset PTSD symptoms or neurological conditions (e.g., Ghosh, Gupta, & Kohli, 1995; Reisner, 2006). Findings from these studies suggest that psychiatric disturbance may contribute to observable deficits in attention and executive functions in EI patients. However, the interaction between these neuropsychological sequelae and their trajectory over time post-injury requires more investigation.

Limited prior research suggests that some neuropsychological symptoms may not manifest until EI patients are beyond the acute stage of recovery. For example, Pliskin and colleagues (1998) noted an increase in depressive and overall neuropsychological symptoms when comparing EI patients assessed post-acutely (more than 3 months following injury) to those assessed acutely (less than 3 months following injury). Moreover, Bailey, Gaudreault, and Thivierge (2008) documented both acute and delayed-onset self-reported neuropsychological symptoms in EI patients over the course of 1-year post-injury. Barrash, Kealey, and Janus (1996) found deficits in verbal learning and memory in 18 survivors of high-voltage electrical injuries in the acute, short-term, and long-term epochs since the original injury. The authors noted that reactive mood disturbance was more common in the post-acute recovery phase and that the evaluating neuropsychologists believed that cognitive deficits were likely attributable to this marked increase in distress (Barrash et al., 1996). Increasing likelihood of one or more psychiatric diagnoses with more time post-injury was shown in a sample of EI patients, with higher psychiatric morbidity between 3 and 24 months post-injury and the highest prevalence among those more than 2 years post-injury (Ramati et al., 2009b). Notably, those EI patients with a psychiatric diagnosis displayed poorer cognitive performance compared with those without a comorbid psychiatric condition (Ramati et al., 2009b).

Although these studies suggest that some EI patients are prone to psychiatric and cognitive disturbance that can intensify over time, conclusions are limited by either a lack of prospective follow-up or complete reliance on self-report measures. The current study examined EI patients who were assessed at multiple timepoints following their injury. In addition to evaluating potential differences between acute and post-acute injury groups, we assessed the extent to which prospective mood changes between assessments were associated with longitudinal changes on tasks measuring simple and complex attention. We predicted that Beck Depression Inventory (BDI) change scores would be associated with change scores on both simple and complex attention tasks.

Method

Participants

Twenty-five EI patients were selected from a pool of 203 potential participants assessed by the multidisciplinary Chicago Electrical Trauma Research Institute (CETRI). These 25 participants were selected because they also completed a follow-up neuropsychological evaluation with CETRI. Of this group, 20 participants completed all outcome measures utilized in the study and comprised the final sample. Individuals eligible for the study were EI patients who received emergency and acute care services at the University of Chicago Hospitals or the University of Illinois-Chicago Medical Center, in addition to EI patients acutely managed at other institutions who were later referred for post-acute evaluation and treatment. Demographic characteristics of the final sample are presented in Table 1. The research completed in accordance with the Helsinki Declaration and approved by the Institutional Review Board.

Neuropsychological Evaluation

All participants passed one or more symptom validity measures that were included in the study. Of the 20 participants in the sample, 17 received a passing score on the Rey 15-item exam (Rey, 1964), and 3 passed both the Test of Memory Malingering (Tombaugh, 1996) and the Victoria Symptom Validity Test (Slick, Hoop, & Strauss, 1995). One patient scored below the recommended cut-off on the Rey 15-item exam at the baseline assessment, but then passed the same test at the follow-up. As a part of the larger neuropsychological test battery, patients were administered the Trail Making Test (Reitan, 1958) and the Stroop Color and Word Test (Golden & Freshwater, 2002) to assess simple and complex attention. Depending on when participants were evaluated, either the BDI or the BDI-II (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961; Beck, Steer, & Brown, 1996) was used to evaluate mood symptoms. BDI scores are reported as raw scores, and a change score (time 2 – time 1) was calculated in order to quantify the
trajectory of mood symptoms for each participant. Scores for the Stroop Color and Word Test are reported as age and education-corrected $T$-scores for the four categories: Color, Word, Color-Word, and Interference (Golden & Freshwater). The Trail Making Test scores are corrected for age, education, gender, and ethnicity and reported as $T$-scores (Heaton, Miller, Taylor, & Grant, 2004). Change scores were calculated based on baseline and follow-up $T$-scores for both of these measures.

For both baseline and follow-up evaluations, participants were administered additional neuropsychological assessments (described in detail within Pliskin et al., 1999) if they were clinically indicated and based on each participant’s functional capability. For example, some patients were evaluated with the California Verbal Learning Test-II (Delis, Kaplan, Kramer, & Ober, 2000) to assess verbal memory, whereas others were assessed using the Repeatable Battery for the Assessment of Neuropsychological Status (Randolph, 1998). The average length of time between injury and the baseline neuropsychological evaluation within the sample was 12.4 months ($SD = 15.6$; range: $0.03–44.0$ months), and the average length of time between first and second assessments was 22.5 months ($SD = 22.6$; range: $1.5–91.0$ months). To remain consistent with previous research (e.g., Pliskin et al., 1998; Ramati et al., 2009b), participants were grouped based on time since injury at their baseline assessment into acute (<3 months since injury) and post-acute (>3 months since injury) groups.

**Data Analysis**

Analyses were conducted in three stages. First, independent samples $t$-tests were utilized to evaluate whether relevant baseline variables (i.e., full scale IQ [FSIQ], litigation status, loss of consciousness during injury) were associated with cognitive outcomes. Second, a series of linear regression analyses were employed as the primary analyses in order to evaluate potential effects of categorical and continuous predictors on cognitive change scores. To evaluate cognitive domains over time, acute versus post-acute injury status (i.e., less than vs. greater than 3 months since injury), changes in depression symptoms, and time between assessments were utilized as predictors. Change scores for attentional cognitive outcomes were utilized as the dependent variables. Finally, additional descriptive statistics are presented examining BDI score subgroups in order to contextualize results from the linear regression analyses.
Table 2. Mean scores and mean change scores between baseline and follow-up assessments

<table>
<thead>
<tr>
<th>Score</th>
<th>Mean (SD) for T1</th>
<th>Mean (SD) for T2</th>
<th>Mean (SD) for T2 − T1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stroop (T scores)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word</td>
<td>37.83 (8.97)</td>
<td>36.30 (11.69)</td>
<td>−1.53 (6.17)</td>
</tr>
<tr>
<td>Color</td>
<td>40.35 (7.70)</td>
<td>39.25 (9.68)</td>
<td>−1.10 (5.14)</td>
</tr>
<tr>
<td>Color-Word</td>
<td>41.15 (8.93)</td>
<td>43.25 (11.24)</td>
<td>2.10 (7.45)</td>
</tr>
<tr>
<td>Interference</td>
<td>49.0 (10.35)</td>
<td>51.15 (9.61)</td>
<td>2.15 (6.75)</td>
</tr>
<tr>
<td><strong>Trail Making (T scores)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>46.55 (11.16)</td>
<td>47.60 (12.65)</td>
<td>1.05 (8.90)</td>
</tr>
<tr>
<td>B</td>
<td>47.0 (9.00)</td>
<td>49.70 (11.06)</td>
<td>2.70 (8.44)</td>
</tr>
<tr>
<td>BDI (raw scores)</td>
<td>12.90 (11.43)</td>
<td>13.90 (11.55)</td>
<td>1.00 (7.83)</td>
</tr>
</tbody>
</table>

Table 3. Descriptive statistics for relevant outcome variables based on BDI changes

<table>
<thead>
<tr>
<th>Measure</th>
<th>Nature of BDI score over time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Worse (n = 8)</td>
</tr>
<tr>
<td>Stroop Color change score, M (SD)</td>
<td>−5.88 (6.81)</td>
</tr>
<tr>
<td>Stroop Word change score, M (SD)</td>
<td>−6.25 (2.76)</td>
</tr>
<tr>
<td>Stroop Color-Word change score, M (SD)</td>
<td>−1.63 (6.84)</td>
</tr>
</tbody>
</table>

Results

Descriptive statistics are presented in Table 2 including change scores for the BDI, Stroop Color and Word Test, and Trail Making Test variables across both timepoints. On average, overall sample scores were relatively stable between the baseline and follow-up evaluations for measures of mood and attention. Independent sample t-tests determined that baseline FSIQ, baseline litigation status, and presence of loss of consciousness during injury were not associated with the outcome variables, so these variables were excluded from further analyses.

For all regression analyses, proportion of variance explained was determined by the adjusted $R^2$ statistic. Regression analyses did not produce a significant model outcome for the Trail Making Test change scores (parts A and B) or Stroop Color and Word Interference change scores. For the Stroop Color and Word Test Word change scores, the overall model explained 32% of the variance in outcome variable, $F(3, 16) = 3.97, p = .027$. BDI change scores significantly predicted Word change scores ($\beta = −0.72, t = −3.08, p = .007$), whereas acute versus post-acute injury and time between evaluations were not significant predictors. For the Stroop Color and Word Test Color change scores, the overall model explained 59% of the variance in outcome variable, $F(3, 16) = 10.13, p = .001$. BDI change scores significantly predicted Color change scores ($\beta = −0.94, t = −5.17, p < .001$), whereas acute versus post-acute injury and time between evaluations were not significant predictors. For the Stroop Color and Word Test Color-Word change scores, the overall model explained 38% of the variance in outcome variable, $F(3, 16) = 4.86, p = .014$. BDI change scores significantly predicted Color-Word change scores ($\beta = −0.66, t = −2.97, p = .009$), whereas acute versus post-acute injury and time between evaluations were not significant predictors.

In order to further clarify the above findings, descriptive statistics for the Stroop Color and Word Test outcome variables were calculated separately for three subgroups: those that reported more symptoms of depression at follow-up compared with baseline (“worse”), those that reported a stable number of depressive symptoms at follow-up compared with baseline (“stable”), and those that reported fewer depressive symptoms at follow-up compared with baseline (“improved”). These descriptive statistics are presented in Table 3. On average, individuals who experienced an increase in depressive symptoms during the study also performed more poorly on the presented outcome measures, whereas those who had stable or reduced BDI scores generally displayed improvement on the same measures.

Discussion

The current study examined the cognitive status of EI patients who were assessed an average of 1 year after their electrical injury and then re-examined around 23 months later. In the overall sample, there was little change over time for the cognitive outcome measures, with mean performances ranging from low average to average. However, results indicated that worsening depressive symptoms between baseline and follow-up evaluations were associated with poorer performances on the Stroop Color and Word Test, but not the Trail Making Test, whereas stable or improved depressive symptoms generally held the opposite pattern. Baseline
injury group (acute vs. post-acute), time between evaluations, baseline FSIQ, litigation status, and loss of consciousness during injury were not associated with outcome change scores.

The finding that increased depressive symptoms were associated with poorer performance on attention tasks is consistent with prior research exploring psychiatric and cognitive sequelae within the EI patient population (e.g., Ammar et al., 2006; Barrash et al., 1996; Grigorovich et al., 2013; Ramati et al., 2009b). For at least a subset of EI patients, the presence of psychiatric symptoms during the post-acute phase of injury appears to have a detrimental impact on some areas of cognitive functioning. However, it is also possible that cognitive change may precede psychiatric symptoms or that these changes occur independently of one another (e.g., Primeau, 2005; van Zomeren, ten Duis, Minderhoud & Sipma, 1998). Regardless, such results underscore the importance of early screening and intervention for psychiatric conditions among EI patients, as these efforts may help to reduce (or prevent the exacerbation of) additional neurocognitive decline. Although cognitive deficits have been shown to manifest regardless of mood symptoms (Pliskin et al., 2006), treatment of psychiatric disorders may prevent the exacerbation of cognitive symptoms during the post-acute recovery period. It remains unclear why mood symptom changes were associated with performance on the Stroop Color and Word Test and not the Trail Making Test. One possibility is that the Trail Making Test T scores were corrected for more demographic variables.

The lack of significant prospective findings based on baseline post-injury group (acute vs. post-acute) and duration of time between evaluations may be an artifact of our small sample size and the high variability within the sample for these variables. Indeed, Duff and McCaffrey (2001) have noted that considerable changes may occur early on during the “acute” period as defined in the present study, and our lack of a consistent and early baseline limited our ability to observe such changes. Based on previous findings (Bailey et al., 2008; Barrash et al., 1996; Ramati et al., 2009b), we may have expected to see greater mood or cognitive decline among the post-acute group. Although the absence of such findings may highlight the limits of previous cross-sectional studies, replication using a more substantial sample size and measurement of other treatment variables is needed in order to rule out subtle neuropsychological changes as a function of post-injury time. However, it also should be noted that the absence of practice effects could suggest “decline” in the sample to some extent, although we believe that replication studies are needed prior to considering this possibility. With regard to litigation status and loss of consciousness, while our finding that litigation status was unrelated to outcome variables is consistent with prior research in EI patients (e.g., Barrash et al., 1996; Wicklund et al., 2008), our lower number of individuals who experienced a loss of consciousness during injury (n = 3) likely limited our ability to detect any potential effect.

There were several limitations in the present study. Results should be interpreted with caution given the small sample size. Furthermore, we did not assess for ongoing psychiatric treatment variables that may have been associated with the outcomes, and only used one psychiatric measure. The cognitive battery was limited. We also did not assess for premorbid educational problems. Because of the convenience sample, self-selection bias may have been present, and it is possible that those participants who chose to return for a follow-up evaluation were experiencing greater morbidity than those who only completed the baseline assessment. Moreover, the variable duration between baseline and follow-up evaluations likely limited our ability to detect specific neuropsychological patterns that may emerge among EI patients during the post-acute period of recovery. Further, the sample was fairly homogenous (e.g., predominantly white male adults), which limits the generalizability of the findings. Finally, there are a number of ways to assess change over time. Although the present study used change scores, future studies might consider the use of Reliable Change Indices to account for test reliability and practice effects.

Despite these limitations, this is one of the few longitudinal studies to evaluate mood and cognitive variables among EI patients. Findings from the present study add to the existing literature suggesting the importance of early intervention for psychiatric symptoms, which can be salient predictors of cognitive changes over time among EI patients. Future studies are needed to further clarify central nervous system changes among EI patients, to more systematically measure the interaction between cognitive and affective variables longitudinally, and to document the role of pharmacological and psychosocial interventions for EI patients in the potential prevention of neuropsychological sequelae following initial injury.

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Conflict of Interest

None declared.
References


