Vegetative-Vascular Dystonia and Osteoalgetic Syndrome or Chronic Fatigue Syndrome as a Characteristic After-Effect of Radioecological Disaster: The Chernobyl Accident Experience

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ABSTRACT. The aim of this study was to determine whether the Chronic Fatigue Syndrome (CFS) definition could be applicable to the assessment of the medical aftermath of radioecological disasters and to investigate a possible psychophysiological basis of fatigue in Chernobyl accident survivors. One hundred randomly selected clean-up workers of the Chernobyl accident who presented with complaints of fatigue were examined neuropsychiatrically using MMPI profiles, Quantitative Electroencephalography (QEEG) and Somatosensory evoked potentials.

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(SSEP). Twenty-six percent of them met the CFS diagnostic criteria. Their absorbed radiation doses were less than 0.3 Sv, an exposure level that is not expected to produce a clear deterministic radiation effect. Clinical symptomatology included persistent fatigue, odd skin sensations, bizarre feelings in bones, muscles and joints, irritability, headache, vertigo, pain in the chest area, emotional lability, irritability, lack of concentration and memory, cognitive deterioration, depression signs and sleep disorders. Liquidators with CFS had the characteristic MMPI profile with increased hypochondria, depression, clear hypochondria, schizophrenia, hysteria, psychasthenia, and bizarre sensory perception scales. Spectral analysis of QEEG showed lateralised (left-sided) increase of θ-power (P < 0.001) and lateralised (left-sided) decrease of α-power (P < 0.001) and lateralised (left-sided) increase of β-power (P < 0.01). SSEP were characterized by increased latencies and decreased amplitudes. SSEP significantly differed by topographic abnormalities in the left temporoparietal area in liquidators with CFS. Associations between schizophrenia-like, hypochondriac and psychasthenic psychopathology and an increase of latency of SSEP P300 and N400 in liquidators with CFS were revealed. Thus, “Vegetative-Vascular Dystonia” and “Osteoalgetic Syndrome” cases following exposure to ionizing radiation as a result of the Chernobyl accident can be classified as CFS cases. The psychophysiological basis of fatigue in liquidators consists of dysfunction of the cortico-limbical structures of the left, dominating, hemisphere. CFS is one of the most important consequences of radioecological disaster, which results from an interaction of different hazardous environmental factors. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com>]

**KEYWORDS.** Chronic Fatigue Syndrome, Vegetative-Vascular Dystonia, Osteoalgetic Syndrome, ionizing radiation, Chernobyl accident, radioecological disaster

**INTRODUCTION**

Health after-effects of exposure to ionizing radiation, especially by small doses (those that do not provoke radiation sickness), in the former USSR were conceptualized as “Vegetative-Vascular Dystonia” (Autonomous Nervous System Dysfunction) and “Osteoalgetic Syndrome” (if chronic exposure with osteotropic radionuclides incorporation occurs) on the basis of studies of the medical aftermath of radioecological disasters in the radiochemical industry. Fatigue, headache, palpitations, ostealgia, myalgia, arthralgia, difficulty concen-
trating, dizziness, heat/cold intolerance, mood swings, diaphoresis, depression, anxiety, seizures were among the characteristic symptoms for these disorders (1-3).

Fatigue, physical anergia, headache, lumbago, neuralgia, myalgia, arthralgia are also typical for Atomic bomb survivors in Hiroshima and Nagasaki. These symptoms were integrated in “Genbaku Bura Bura Disease–Atomic Bomb Chronic Disease” of radiation, and are not psychogenic in origin (4-5).

It should be noted that even now the terminology Vegetative-Vascular Dystonia is commonly used in the countries of the former USSR. This diagnosis refers to etiologically heterogeneous abnormalities of the diencephalic-limbic-recticular complex, which manifest with lability of heart rate and blood pressure, diaphoresis, headache, chestpain, backpain, pain in limbs, vertigo, fatigue, weakness, irritability, affective lability, anxiety, memory and concentration deterioration, sleep disorders, and metotropia. Vegetative-Vascular Dystonia was the first typical diagnosis seen among Chernobyl accident survivors (6).

Experts of the International Chernobyl Project (IAEA, 1992) stressed the differences between diagnoses of mental and nervous system disorders in the USSR and Western countries. In this respect, terms, such as “Vegetative-Vascular Dystonia,” are not accepted in the West, where such disorders are usually classified as post-traumatic stress disorder (PTSD), anxiety, depression or somatoform disorders. According to the opinion of the IAEA experts, USSR medical doctors are physiologically- and neurologically-oriented in their diagnosis of mental disorders whereas medical practitioners of other countries aim to classify symptoms on empirical and pragmatic base (7).

However, the latter interpretation results in an underestimation of the health effects of ionizing radiation and an overestimation of the role of psychogenic traumatization following nuclear accidents. The Russian conception of “Vegetative-Vascular Dystonia” in irradiated patients is closer to Penfield’s “Diencephalic Autonomic Epilepsy,” with a paroxysmal activity focus at the hypothalamus, and to the etiologically heterogeneous radiation-psychogenic “Diencephalosis,” which was described in Atomic bomb survivors who developed Acute Radiation Sickness (8-10).

The incidence and prevalence rate of Vegetative-Vascular Dystonia among radiation-exposure survivors is significantly higher than those of the general population. Moreover, Vegetative-Vascular Dystonia
among survivors is associated with endocrine and immune disorders. However, such disorders are underestimated and misinterpreted by a majority of Western experts as somatoform disorders resulting from psychological stress only. To bridge the gap between East and West, we proposed, at the International Conference “The Effects of Low and Very Low Doses of Ionizing Radiation on Human Health,” June 16-18, 1999, University of Versailles, World Council of Nuclear Workers (11), that Chronic Fatigue Syndrome (CFS) is one of the most important health problems among Chernobyl accident survivors, a malady which could be triggered by low and very low doses of ionizing radiation together with psychoemotional stress. The data of this study was also kindly preliminary presented by Prof. Pierre Flor-Henry (Alberta Hospital Edmonton, Canada) as a poster at the 10th World Congress of the International Organization of Psychophysiology (IOP), Sydney, Australia, 8-13 February, 2000 (12).

CFS is characterized by unexplained persistent fatigue, myalgia, headache, cognitive, emotional and other disorders. The diagnosis of CFS is based on a number of clinical criteria and the exclusion of other diseases (13-15). CFS is a systemic disease with dysfunction of the main regulatory systems—nervous, endocrine and immune—and a predominance of cortico-limbic and hypothalamic-pituitary-adrenal axis abnormalities. Dysfunction of the hypothalamic-pituitary-adrenal axis and of the sympathetic component of the autonomic nervous system provide a reaction to stress, are the keypoints for understanding CFS symptomatology.

The aim of this study was to determine whether the CFS definition could be applicable to the medical aftermath symptomatology seen after radioecological disasters and to investigate the possible psychophysiological basis of fatigue among Chernobyl accident survivors.

SUBJECTS AND METHODS

The subjects of this study were one hundred randomly selected clean-up workers of the Chernobyl accident (liquidators) with fatigue and other symptoms which occurred after their participation in the clean up works in the Chernobyl exclusion zone. All of them were right-handed males at the age of 31-54 years at the moment of examination. Their absorbed doses of whole body irradiation were 0.03-3.5 Gy (M = 0.48 Gy; SD = 0.56 Gy). (One Gy-unit of absorbed
dose of ionizing radiation = 100 rad [radiation absorbed dose]. One Sv-unit of effective dose of ionizing radiation = 100 rem [rad equivalent man]. Regarding the Chernobyl accident, 1 Sv ≈ 1 Gy.) The control group—12 healthy age-matched male volunteers.

Neuropsychiatric examination was carried out using a CFS symptoms checklist (kindly provided by Prof. P. Flor-Henry, Canada) and the Goldstein’s CFS symptoms checklist together with the adapted version of the MMPI (16).

Quantitative Electroencephalography (QEEG) and Somatosensory evoked potentials (SSEP) were carried out with a 19-channel brain biopotentials analyzer “Brain Surveyor” SAICO (Italy). The brain electric activity was monopolarly registered with linked ears reference. Nineteen scalp electrodes were placed according to the “10-20” International System. Somatosensory evoked potentials (SSEP) were registered with 40 pain threshold electrocutaneous stimulation of the right median nerve on the lower forearm. The left median nerve was not stimulated. The nerve was stimulated by bipolar skin electrode with right-angled electrical impulses of 0.1 ms duration and 0.5 Hz frequency (1 per 2,000 ms). The cathode was situated proximal. The epochs selected for analysis were 50 ms for the short-latency SSEP and 1,000 ms for long-latency. Amplitudes were measured from peak to trough (μV) and latency from onset of stimulation to its peak (ms).

Statistical processing included Chi-square test, Student’s t test, correlational and regressional analyses (17). The paired t test was used to analyze data when a pair of measurements was obtained on each individual (18). Statistical processing was carried out with STATISTICA 5.0 and MS EXCEL 97 software.

RESULTS

The clinical prevalence of neuropsychiatric symptoms among liquidators was as follows: headache (87%), fatigue (82%), odd skin sensations (79%), myalgia (71%), irritability (70%), bizarre feelings in bones, muscles and joints (68%), osteoalgia (67%), lack of concentration and memory (66%), arthralgia (61%), cognitive deterioration (57%), depression signs (56%), emotional lability (55%), backpain (54%), vertigo (51%), chestpain (44%), and sleep disorders (40%). Healthy volunteers had no such symptoms.
Although the aforementioned clinical pattern is practically "classical" of CFS, there were two limitations: 1. the radiation dose that could produce any deterministic radiation effect, and 2. clear physical illness.

According to the CFS definition, this diagnosis should be avoided in the content of the possibility of deterministic radiation effects, for example acute radiation sickness. We assumed that a diagnosis of CFS is grounded if the effective dose of irradiation is less than 0.3 Sv. As a result, we carried out a selection of liquidators, based on the CFS-criteria, and especially 1. low doses of irradiation—less than 0.3 Sv (30 rem), and 2. an absence of verified physical illness. Finally, we diagnosed CFS in 26 liquidators who had no certain physical illness and had been exposed to radiation in doses less than 0.3 Sv.

The MMPI pattern of the liquidators with CFS was quite distinct (Figure 1) with peaks in MMPI scales for 1Hs (hypochondria), 2D (depression), HS’80 (clear hypochondria), 8Sch (schizophrenia), 3Hy (hysteria), 7Pt (psychasthenia), and ScB187 (bizarre sensory perception). By these MMPI scales, the liquidators with CFS dramatically differ from both literature normative data and the examined healthy volunteers (P < 0.001).

The QEEG pattern of the liquidators with CFS was also quite dis-

FIGURE 1. MMPI Profile of Liquidators with Chronic Fatigue Syndrome (n = 26)
tinct from that in healthy controls (Figure 2). Irradiated persons with CFS had increased spectral power of θ-range (> 4-7 Hz) (P < 0.01), especially in the left hemisphere (P < 0.001) and β-range (> 12-32 Hz) (P < 0.01), more in the left hemisphere (P < 0.01) than in the right one (P < 0.05), as well as a decreased spectral power of α-range (> 7-12 Hz) (P < 0.01), especially in the left hemisphere (P < 0.001). These data testify to more involvement of the left hemisphere with its over-activation (according to an increase of β-range and a depression of α-range in the left hemisphere) and limbic system (particularly, hippocampus) irritation (according to a significant increase of θ-range—“hippocampal” activity), especially in the left hemisphere.

At the projection area (left temporoparietal region–C3) on right medianus nerve stimulation, SSEP were characterized by increased latencies and decreased amplitudes of N20, P25, N140, P300 and N400 in the irradiated persons with CFS (Table 1).

SSEP significantly differed from those in controls by the presence of topographic abnormalities in the left temporoparietal area among irradiated people: their SSEP were characterized by decreased (P < 0.001) contralateral amplitudes (Figure 3) and increased (P < 0.001) contralateral latencies (Figure 4) of thalamo-cortical N20 and cortical P25 at the C3 on right medianus nerve stimulation.

Correlation between SSEP and MMPI were observed in the irra-
TABLE 1. Somatosensory Evoked Potentials of Liquidators with Chronic Fatigue Syndrome in Comparison with Healthy Controls

<table>
<thead>
<tr>
<th>SSEP parameter</th>
<th>Liquidators with CFS (n = 26)</th>
<th></th>
<th>Normal (n = 12)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Amplitudes, μV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N&lt;sub&gt;20&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>2.14 ± 0.82</td>
<td>−4.35</td>
<td>&lt; 0.001</td>
<td>3.27 ± 0.45</td>
</tr>
<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;</td>
<td>2.98 ± 0.78</td>
<td>−0.04</td>
<td>&gt; 0.05</td>
<td>2.99 ± 0.47</td>
</tr>
<tr>
<td>Laterality (C&lt;sub&gt;3&lt;/sub&gt;-C&lt;sub&gt;4&lt;/sub&gt;) (M ± SD)</td>
<td>−0.84 ± 0.96</td>
<td>t = −4.46</td>
<td>p &lt; 0.001</td>
<td>0.28 ± 0.43</td>
</tr>
<tr>
<td>Paired t test</td>
<td></td>
<td></td>
<td></td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>P&lt;sub&gt;25&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>2.33 ± 0.93</td>
<td>−6.46</td>
<td>&lt; 0.001</td>
<td>4.18 ± 0.39</td>
</tr>
<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;</td>
<td>3.15 ± 1.12</td>
<td>−2.35</td>
<td>&lt; 0.01</td>
<td>3.96 ± 0.47</td>
</tr>
<tr>
<td>Laterality (C&lt;sub&gt;3&lt;/sub&gt;-C&lt;sub&gt;4&lt;/sub&gt;) (M ± SD)</td>
<td>−0.82 ± 0.98</td>
<td>t = −4.27</td>
<td>p &lt; 0.001</td>
<td>0.22 ± 0.39</td>
</tr>
<tr>
<td>Paired t test</td>
<td></td>
<td></td>
<td></td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>N&lt;sub&gt;40&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>6.86 ± 3.05</td>
<td>−4.23</td>
<td>&lt; 0.001</td>
<td>11.09 ± 2.11</td>
</tr>
<tr>
<td>P&lt;sub&gt;300&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>15.58 ± 3.99</td>
<td>−4.28</td>
<td>&lt; 0.001</td>
<td>22.27 ± 5.08</td>
</tr>
<tr>
<td>N&lt;sub&gt;400&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>17.17 ± 5.28</td>
<td>−2.18</td>
<td>&lt; 0.05</td>
<td>21.27 ± 5.15</td>
</tr>
<tr>
<td>Latencies, ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N&lt;sub&gt;20&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>19.85 ± 1.56</td>
<td>2.03</td>
<td>&lt; 0.05</td>
<td>18.82 ± 1.03</td>
</tr>
<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;</td>
<td>18.96 ± 1.35</td>
<td>−0.56</td>
<td>&gt; 0.05</td>
<td>19.21 ± 1.01</td>
</tr>
<tr>
<td>Laterality (C&lt;sub&gt;3&lt;/sub&gt;-C&lt;sub&gt;4&lt;/sub&gt;) (M ± SD)</td>
<td>0.89 ± 1.04</td>
<td>t = 4.36</td>
<td>p &lt; 0.001</td>
<td>−0.39 ± 0.85</td>
</tr>
<tr>
<td>Paired t test</td>
<td></td>
<td></td>
<td></td>
<td>P &lt; 0.05</td>
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<tr>
<td>P&lt;sub&gt;25&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>25.74 ± 1.78</td>
<td>3.03</td>
<td>&lt; 0.01</td>
<td>24.09 ± 0.67</td>
</tr>
<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;</td>
<td>23.95 ± 1.59</td>
<td>−0.56</td>
<td>&gt; 0.05</td>
<td>24.28 ± 0.81</td>
</tr>
<tr>
<td>Laterality (C&lt;sub&gt;3&lt;/sub&gt;-C&lt;sub&gt;4&lt;/sub&gt;) (M ± SD)</td>
<td>1.76 ± 2.11</td>
<td>t = 4.25</td>
<td>p &lt; 0.001</td>
<td>−0.17 ± 0.72</td>
</tr>
<tr>
<td>Paired t test</td>
<td></td>
<td></td>
<td></td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>N&lt;sub&gt;40&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>148.11 ± 16.23</td>
<td>2.24</td>
<td>&lt; 0.05</td>
<td>136.62 ± 7.28</td>
</tr>
<tr>
<td>P&lt;sub&gt;300&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>266.36 ± 24.5</td>
<td>3.35</td>
<td>&lt; 0.001</td>
<td>241.82 ± 4.61</td>
</tr>
<tr>
<td>N&lt;sub&gt;400&lt;/sub&gt; C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>413.99 ± 24.01</td>
<td>3.82</td>
<td>&lt; 0.001</td>
<td>384.09 ± 16.01</td>
</tr>
</tbody>
</table>

Diagnosed patients with CFS as follows: the amplitude of SSEP N<sub>20</sub> at the C<sub>3</sub> correlated with HS’80-clear hypochondria MMPI scale (r = −0.4; P = 0.044) (Figure 5). The latency of SSEP P<sub>300</sub> at the C<sub>3</sub> correlated with 8Sch-schizophrenia (r = 0.43; P = 0.027) (Figure 6), 7Pt-psychasthenia (r = 0.53; P = 0.005) MMPI scales (Figure 7). The latency of SSEP P<sub>400</sub> at the C<sub>3</sub> correlated with HS’80-clear hypochondria MMPI scale (r = 0.52; P = 0.006) (Figure 8). No significant correlations between MMPI and SSEP were revealed among healthy controls.
FIGURE 3. t-Criterion for Amplitude of Somatosensory Evoked Potentials for the Left-Side, Projection Area C3 and Right-Side, Non-Projection Area C4 in Liquidators with Chronic Fatigue Syndrome in Comparison with Healthy Controls

FIGURE 4. t-Criterion for Latencies of Somatosensory Evoked Potentials for the Left-Side, Projection Area C3 and Right-Side, Non-Projection Area C4 in Liquidators with Chronic Fatigue Syndrome in Comparison with Healthy Controls

The aforementioned results testify to an association between schizophrenia-like, hypochondriac and psychasthenic psychopathology and an increase of latency of SSEP P300 and N400 in irradiated persons with CFS.

Thus, fatigue, "Vegetative-Vascular Dystonia" and "Osteoalgetic
FIGURE 5. Relationship Between Amplitude of Somatosensory Evoked Potential N20 in the Projection Area C3 and MMPI Subscale HS’80–Clear Hypochondria in Liquidators with CFS (n = 26)

Amplitude of SSEP N20 (mKV) in C3 vs. MMPI subscale HS’80–clear hypochondria

\[ HS'80 = 95.170 + 5.370 \times \text{Amplitude of SSEP N20 (C3)} \]

Correlation: \( r = -0.3975; P = .044 \)

FIGURE 6. Relationship Between Latency of Somatosensory Evoked Potential P300 in the Projection Area C3 and MMPI Scale 8Sch–Schizophrenia in Liquidators with CFS (n = 26)

Latency of SSEP P300 (ms) in C3 vs. MMPI scale 8SCH

\[ 8\text{Sch} = -27.22 + 0.4200 \times \text{Latency of SSEP P300 in C3} \]

Correlation: \( r = 0.43425; P = .027 \)
FIGURE 7. Relationship Between Latency of Somatosensory Evoked Potential $P_{300}$ in the Projection Area C3 and MMPI Scale 7Pt—Psychasthenia in Liquidators with CFS (n = 26)

Latency of SSEP $P_{300}$ (ms) in C3 vs. MMPI scale 7Pt

$7Pt = -23.40 + 0.37141 \times$ Latency of SSEP $P_{300}$ in C3

Correlation: $r = 0.52998$, $P = 0.005$

FIGURE 8. Relationship Between Latency of Somatosensory Evoked Potential $N_{400}$ in the Projection Area C3 and MMPI Subscale Hs’80—Clear Hypochondria in Liquidators with CFS (n = 26)

Latency of SSEP $N_{400}$ (ms) in C3 vs. MMPI subscale Hs’80—clear hypochondria

$HS’80 = -104.2 + 0.44193 \times$ Latency of SSEP $N_{400}$

Correlation: $r = 0.52010$, $P = 0.006$
 Syndrome” following exposure to ionizing radiation as a result of the Chernobyl accident can be classified as CFS. The psychophysiological basis of fatigue in liquidators with CFS is dysfunction of the cortico-limbical structures of the left, dominating, hemisphere.

CONCLUSIONS

1. Twenty-six percent of randomly selected liquidators of the Chernobyl accident met the CFS diagnostic criteria. Their absorbed doses following the Chernobyl accident were less than 0.3 Sv, an exposure level that is not expected to produce any clear deterministic radiation effect. Clinical symptomatology included persistent fatigue, odd skin sensations, bizarre feelings in bones, muscles and joints, irritability, headache, vertigo, chestpain, emotional lability, irritability, lack of concentration and memory, cognitive deterioration, depression signs and sleep disorders.

2. Liquidators with CFS had the characteristic MMPI profile with increased hypochondria, depression, clear hypochondria, schizophrenia, hysteria, psychasthenia, and bizarre sensory perception scales.

3. Spectral analysis of EEG showed a lateralised (left-sided) increase of θ-power (P < 0.001) and a lateralised (left-sided) decrease of α-power (P < 0.001) and a lateralised (left-sided) increase of β-power (P < 0.01).

4. SSEP were characterized by increased latencies and decreased amplitudes. SSEP significantly differed by topographic abnormalities in the left temporoparietal area in liquidators with CFS. Their SSEP were characterized by increased (P < 0.001) contralateral latencies and decreased (P < 0.001) contralateral amplitudes of thalamo-cortical N20 and cortical P25 in the left temporoparietal area C3 on right medianus nerve stimulation. The late components of SSEP were retarded and decreased in amplitude.

5. The value of the clear hypochondria MMPI subscale increased in a linear proportion to a decrease of SSEP N20 amplitude and to an increase of SSEP N400 in the left C3 central region. Associations between schizophrenia-like, hypochondriac and psychasthenic psychopathology and an increase of latency of SSEP P300 and N400 in liquidators with CFS were revealed.
6. These results underscore a possible cerebral basis for CFS, with abnormalities that probably localize to the cortical-limbic structures of the left, dominating, hemisphere. This study also revealed that CFS is a one of the most important consequences of radioecological disasters resulting from an interaction of different hazardous environmental factors. CFS should be included as a diagnostic category in the ICD-10.

REFERENCES


