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In accordance with the resolution of the Higher Attestation Commission of the Ministry of Education and Science of the Russian Federation, the N.N. Burdenko Journal of Neurosurgery was included in the List of Leading Peer-Reviewed Journals and Periodicals issued in the Russian Federation where the main results of Candidate and Doctor Theses are recommended to be published.

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This issue of the N.N. Burdenko Journal of Neurosurgery is devoted to the recovery of consciousness after brain injury. The modern approaches to this problem by the participants of the III International Conference “Fundamental and Applied Aspects of the Recovery of Consciousness after Brain Injury: The Interdisciplinary Approach” held on September 21—22, 2012 in Moscow, the experts in various neurological disciplines (neurosurgeons, neurologists, neuroresuscitators, neuropsychiatrists, neuro-rehabilitologists, neurophysiologists, neuropsychologists, and clinical psychologists), are presented.

Editorial Board:
A.N. Konovalov, A.A. Potapov, O.S. Zaytsev, O.A. Maksakova,
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Managing editor: Academician of the Russian Academy of Sciences and the Russian Academy of Medical Sciences, Prof. A.A. Potapov
Anatomic, physiological, metabolic and neurotransmission mechanisms of structural and functional integrity of the brain, which underlies the entire mental activity, are attracting steady interest from researchers specializing in fundamental and clinical neurosciences [1—3, 10, 12—16, 18, 21, 22, 24, 28, 29, 33—35, 37, 39, 41, 43, 45].

Modern neuroimaging techniques have opened up new possibilities in studying structural causes of impaired consciousness and mechanisms of sensorimotor and cognitive impairment associated with various cerebral disorders [4, 5, 9, 10, 20, 30, 36, 39, 44].

The introduction of such new MRI sequences as DWI, DTI, T2* GRE, and SWAN has considerably enhanced detectability of microfocal non-hemorrhagic lesions and microhemorrhage into deep brain structures, i.e., lesions that form the basis for post-traumatic unconsciousness and mechanisms of sensorimotor and cognitive impairment associated with various cerebral disorders [4, 5, 9, 10, 20, 30, 36, 39, 43, 45].

The aim of this study was to investigate the relationship between the location and level of MRI-verified brain lesions, as well as severity and outcomes of the acute traumatic brain injury (TBI).

Case studies and research methods

A total of 162 patients (53 female and 109 male patients; mean age 29.6±12.8 yrs, age range 8—72 yrs) with varying grades of TBI underwent magnetic resonance imaging (T1, T2, FLAIR, DWI, DTI, T2* GRE, SWAN) were performed in 162 patients with acute TBI. Statistical analysis was done using Statistica 6, 8 software and R programming language. A new advanced MRI-based classification of TBI was introduced implying the assessment of hemispheric and brainstem traumatic lesions level and localization. Statistically significant correlations were found between the Glasgow coma and outcome scales scores (p<0.001), and the proposed MRI grading scale scores, which means a high prognostic value of the new classification. The knowledge of injured brain microanatomy coming from sensitive neuroimaging, in conjunction with the assessment of mechanisms, aggravating factors and clinical manifestation of brain trauma is the basis for the actual predictive model of TBI. The proposed advanced MRI classification contributes to this concept development.

Key words: traumatic brain injury, magnetic resonance imaging, a new MRI classification, predictive model of brain injury.

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N.N. BURDENKO JOURNAL OF NEUROSURGERY 1, 2014
7 — bilateral brainstem lesions at the level of the pons ± (2—6);
8 — bilateral medullary lesions ± (2—6).

Each subsequent group may include the symptoms of the previous one.

The data were processed using Excel, R and Statistica 6.0, 8.0 statistical packages.

Results

Spearman’s correlation analysis showed a strong correlation between the Glasgow Outcome GCS score (GOS) and GCS score that denotes the severity of TBI (r=0.63; p<0.001). This correlation is clearly seen on the plot of bivariate density (Fig. 1) and is indicative of the appropriateness of both scales for assessment of severity and outcome in patients with traumatic brain injury.

Table 1 shows the distribution of patients over level and location of brain lesions, as well as the data on incidence of coma and unfavorable outcomes (i.e., severe disability, vegetative state or death) within each group. As seen from Table 1, the increased frequency of deep supratentorial and stem lesions is associated with increased incidence of coma and unfavorable outcomes.

In our series of 162 patients, only 10 individuals had normal cerebral MRI and only one of those ten patients was comatose upon admission. All ten patients had favorable outcomes (good recovery or moderate disability). Nine (29%) of the 31 patients in whom the lesions were confined to cortical or subcortical structures (convexital contusions) were comatose, and only 4 (13%) patients had unfavorable outcomes. The involvement of corpus callosum, subcortex and stem is apparently associated with greater percentage of comatose patients and increased incidence of unfavorable outcomes (Table 1).

Given the fact that 2 of the 162 patients had medullary lesions we decided to develop an 8-level scale to classify the lesions. Statistical analysis revealed significant correlations between the GCS/GOS scores and the MRI score obtained according to the scale presented above (r=−0.62, r=−0.72, p<0.01). The correlation is also seen on the scatter plots and plots of bivariate density (Fig. 2, 3).

Table 1. Distribution of patients over the level and location of brain lesions, severity of condition and TBI outcomes

<table>
<thead>
<tr>
<th>Level /location of brain lesions (MRI data)</th>
<th>Total number of patients in the group</th>
<th>Distribution of patients within the group*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>comatose (GCS score ≤8)</td>
</tr>
<tr>
<td>1. No lesions</td>
<td>10 (6,2)</td>
<td>1 (10)</td>
</tr>
<tr>
<td>2. Cortical/subcortical white matter lesions</td>
<td>31 (191)</td>
<td>9 (29)</td>
</tr>
<tr>
<td>3. Corpus callosum ± 2</td>
<td>24 (14,8)</td>
<td>16 (67)</td>
</tr>
<tr>
<td>4. Basal ganglia, internal capsule and thalamus + 3</td>
<td>21 (13)</td>
<td>12 (57)</td>
</tr>
<tr>
<td>5. Bilateral brainstem lesions at any level ± 4</td>
<td>29 (17,9)</td>
<td>25 (86)</td>
</tr>
<tr>
<td>6. Bilateral midbrain lesions ± 4</td>
<td>30 (18,5)</td>
<td>28 (93)</td>
</tr>
<tr>
<td>7. Bilateral lesions to the pons ± 4</td>
<td>15 (9,3)</td>
<td>14 (93)</td>
</tr>
<tr>
<td>8. Bilateral medullary lesions ± 4</td>
<td>2 (1,2)</td>
<td>1 (50)</td>
</tr>
<tr>
<td>Total</td>
<td>162 (100)</td>
<td>106 (65)</td>
</tr>
</tbody>
</table>

Footnote. The numbers in parentheses represent the percentage of patients (%). * — n (out of the total number of patients in this group).
that attest to a high prognostic value of the new (expanded) MRI grading scale for traumatic brain lesions.

An analysis of the GCS and GOS scores showed that road traffic accidents (RTA) were associated with greater severity of brain injury and less favorable outcomes compared to other causes of TBI ($p<0.01$), which is explained by the additional impact of acceleration-deceleration and rotational trauma. Furthermore, analysis of the MRI findings revealed increased incidence of deep brain lesions (i.e. subcortical, thalamic, corpus callosum and brainstem lesions) in traffic-related injury ($p<0.05$).

MRI data presented below (Fig. 4—10) illustrate the grading criteria for assessing the level of acute post-traumatic brain lesions.

The following case report is an illustrative clinical example of bilateral brainstem lesion at the level of the bulbar nuclei. A 22-year-old female patient was admitted with TBI from a road traffic accident. She presented with clouding of consciousness (GCS score — 11), severe bulbar impairment and apneic episodes. The latter resulted in intubation with subsequent prolonged mechanical ventilation. The patient was then transferred to the Burdenko Neurosurgical Institute, where she underwent MRI and was diagnosed with brainstem lesions at the level of the bulbar nuclei (Fig. 9). During the course of intensive care, she recovered spontaneous breathing. In addition, a significant improvement in the bulbar symptoms and tetraplegia was noted. The patient was discharged conscious, with mild bulbar and pyramidal symptoms.

In our series of 162 patients, only 76 had MRI-verified brainstem lesions. Of these 76 patients, 68 (89.5%) were comatose, and 58 (76%) had unfavorable outcomes. A total of 8 (10.5%) patients with different levels of brain-
stem lesions had a decreased level of consciousness, but did not enter a coma. Meanwhile, 28 (62.2%) of the 45 patients with signs of deep hemispheric lesions were comatose, and the other 17 (37.8%) were soporose or somnolent (Fig. 11).

There is a certain difference between our findings on the frequency of brainstem lesions in traumatic coma and the data available from other studies, regarding assessment of severity, time frame for diagnostic procedures after injury, and MRI sequences used. As seen from Table 2, Firsching et al. [25] and R. Mannion et al. [31] reported the 57% and 28% rates of brainstem lesions, respectively. In our patients, these rates varied from 49 to 83%, provided that we had used new MRI sequences and significantly increased the time frame for diagnostic procedures after the injury. Our findings are indicative of a high sensitivity of the extended MRI scale for severity/level of injury and prediction of outcomes.

**Discussion**

The extensive use of neuroimaging techniques over the recent years has shown that despite continuous advancements, these methods have both advantages and disadvantages when used in a clinical setting [8—10]. Studies have shown that none of the modern techniques

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**Fig. 4.** MRI signs of supratentorial cortico-subcortical lesions (grade 2 according to the expanded MRI grading scale for brain lesions).

a — T1 sequence; b — T2 sequence; c — T2-FLAIR sequence.

**Fig. 5.** MRI scan of a 20-year-old patient (the GCS score – 5) 12 days after injury: the signs of lesions to the corpus callosum and subcortical structures. Diffuse axonal injury (DAI). The patient was comatose for 17 days.

The axial CT image (a) shows reduced density of the splenium, while T1-weighted MRI (b) depicts no clear lesions. T2-FLAIR images (c) show the actual extent of pathological changes related to the DAI: involvement of the corpus callosum, posterior limb of internal capsule, and globus pallidus on the left side (grade 4 according to the expanded grading scale for level and location of the traumatic lesions). The patient had an unfavorable outcome (severe disability).
is sensitive enough to detect every type of lesions in patients with acute and/or complicated TBI, or suitable for assessing the whole range of pathophysiologic responses of the brain at different periods after traumatic injury [9, 40]. The classification of traumatic brain lesions and, therefore, algorithms for diagnosis, treatment and prognosis is based on the knowledge of the injury biomechanics, neuromorphology data, and pathological mecha-

Fig. 6. MRI signs of unilateral brainstem lesions at midbrain level (pons) (grade 5 according to the expanded grading scale).

Fig. 7. MRI signs of diffuse axonal injury with bilateral midbrain lesions (grade 6 according to the expanded grading scale) in a 22-year-old patient after a road traffic accident. The patient had the GCS score of 4 and an unfavorable outcome (severe disability).

GCS score — 4; outcome — severe disability.

Fig. 8. MRI signs of bilateral brainstem lesion at the level of the pons (grade 7 according to the expanded grading scale).
nisms behind the clinical presentation, course and outcomes of traumatic diseases [19, 27].

Before neuroimaging, classification of TBI included consideration of clinical signs (depth and duration of unconsciousness, posttraumatic amnesia, neurologic abnormalities, and autonomic dysfunction) and pathomorphological findings.

After introduction of CT, new classifications were proposed, based on non-invasive in vivo visualization of structural brain lesions, as well as CT grading schemes for focal lesions due to contusion, diffuse lesions, and intracranial hemorrhage [6, 7, 11, 12]. L. Marshall et al. [32] proposed a CT-based classification for severe brain injury, which included consideration of indirect signs of secondary injury to the midbrain/brainstem structures and parabraiunit stems cisterns, as well as the volumes of evacuated or non-evacuated hematomas. This classification has become widely accepted for categorizing patients

Fig. 9. MRI scan of a 22-year-old female patient 5 days after a road traffic accident: bilateral lesions to the medulla oblongata, pons and the midbrain; right-sided thalamic and subcortical lesions (grade 8 according to the expanded rating scale). The patient was somnolent (the GCS score of 11), had abnormal bulbar signs and tetrapyramidal syndrome.

a—f — T2-FLAIR sequence; g — T2 sequence; h — diffusion regime — vasogenic edema is seen: apparent diffusion coefficient (ADC) — 1.08—1.17×10⁻³ mm²/s (normal values — 0.7±0.075×10⁻³ mm²/s).
R. Firsching et al. [25] conducted an MRI study in patients with acute severe TBI. The study demonstrated high incidence of lesions to the brain stem and helped authors provide a 4-grade MRI classification of severe brain injury. According to the authors, establishing the exact location of the primary and secondary brainstem lesions is crucial in predicting outcome in severe TBI. Although R. Mannion et al. [31] employed other MRI sequences (T2, FLAIR, GRE), they also emphasized the prognostic value of brainstem injuries in patients with severe TBI ($n=46$). However, the abovementioned studies strictly included comatose patients and did not employ quantitative evaluation of coma. Furthermore, in their definition of the level of brainstem lesions, the authors relied on the limited range of MRI sequences, and

**Table 2. Comparison of the MRI data on the frequency of brainstem lesions in comatose patients with TBI (GCS ≤8)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Our data</th>
<th>R. Firsching et al. (2001) GCS&lt;8</th>
<th>R. Mabbion et al. (2007) GCS&lt;9(?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI sequences used</td>
<td>T1, T2, FLAIR&lt; DWI, GRE</td>
<td>T1, T2, FLAIR, DWI, GRE</td>
<td>T1, T2, FLAIR, DWI, GRE</td>
</tr>
<tr>
<td>Days after injury</td>
<td>&lt;21</td>
<td>&lt;21</td>
<td>&lt;21</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>38</td>
<td>45</td>
</tr>
<tr>
<td>Brainstem lesions, %</td>
<td>83</td>
<td>68</td>
<td>49</td>
</tr>
</tbody>
</table>

**Fig. 10.** CT (a, b) and MRI (c—h) images in a 29-year-old comatose (the GCS score of 7) patient with multiple injuries arising from a motorcycle accident.

a, b — CT scan obtained upon admission: status post evacuation of left-sided parieto-temporal epidural hematoma: a small (≤ 10 mL) left-sided temporal crescent-shaped subdural hematoma in the posterior cranial fossa. MRI scans obtained at 4 days post-injury: c, d — T2 sequence; e, f — T2-FLAIR sequence; g, h — diffusion regime. In addition, there is an area of secondary ischemia covering several vascular basins and bilateral lesions to the dorsal medullary region (not visible on CT images). The patient had an unfavorable outcome (severe disability; tetrapyriramidal syndrome).

**Fig. 11.** MRI data on the incidence of brainstem lesions in patients with mild-to-severe TBI (based on the GCS score).
The study was supported by the Russian Foundation for Basic Research (grant No 13-04-12061).
The article reports the results of studying the relationship between MRI data on location/level of the brain lesions and severity/outcomes of trauma in patients with traumatic brain injury (TBI).

The relevance of this study is readily illustrated by the case reports provided in the article.

The researchers have used up-to-date MRI sequences, including DWI, DTI, T2* GRE, and SWAN, in a sufficient number of patients (162 patients in the acute phase of TBI). The authors used modern statistical software for data analysis, and their conclusions are based on the statistically significant findings. Detailed and comprehensible plots are used to illustrate results of the data analysis. The methodology of this study is readily illustrated by the case reports provided in the article.

The advance in modern neuroimaging techniques allowed prompt and accurate visualization of microstructural brain parenchyma changes in TBI, which, in turn, has increased our understanding of the mechanisms of neurological abnormalities in TBI, including depression of consciousness. In contrast to the previous grading systems for TBI that focused on clinical manifestations of TBI, the grading scale proposed by this team of researchers includes a combination of clinical and neuroimaging criteria, and thus allows for a more accurate representation of the essence of the pathological changes. This classification approach is a considerable contribution to the development of the prognostic model of TBI.

Thus, A.A. Potapov et al. have conducted an important study that has both scientific and practical relevance. The proposed grading system will enable improvement in predicting the outcomes in TBI patients and optimizing trauma care.

M. M. Ibatullin (Kazan, Russia)
The aim of the study was to determine and assess the prognostic EEG markers of consciousness in patients in long-term posttraumatic unconscious state (PUS). We analyzed the outcomes of dynamic (from 1.5 to 4 years after trauma; in some cases 7 and 16 years) EEG studies in 196 patients (mean age 30.6 years; range: 9—69 years) who were treated at the N.N. Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences in order to reveal the EEG parameters of the state of consciousness and to assess its dynamics. The results demonstrated that the dynamic characteristics of the EEG pattern (along with the analysis of equivalent dipolar sources of individual components) allow a researcher to characterize the severity of patient’s current state, to identify brain structures with the most expressed dysfunction, and to define a zone of a local cortical lesion and the general path of traumatic lesion development (quasi-dynamics of brain homeostasis). Baseline and reactive frequency characteristics of the EEG power spectrum (mean frequency — efficient frequency band) are the most important prognostic factors, especially when assessed 2—3 months after a trauma. The baseline interhemispheric EEG coherence (mainly, the frontal one) is an integrative characteristic of system brain activity: its change upon responses to an external stimuli are the parameters that maximally represent the level of consciousness depression, as well as the dynamics and potential of its recovery. Examination of EEG alterations in response to indifferent and functionally significant stimuli is highly informative for assessing CNS functionality and PUS pathogenesis.

**Keywords:** heavy brain injury, unconsciousness, EEG, power and coherence spectra, reactive changes in EEG.
The aim of this study was to perform a comparative analysis of the EEG data in the dynamics of post-sTBI recovery of consciousness to determine the most informative parameters in assessment of the current states of consciousness and routes of its alteration.

Methods

The data of comprehensive clinical and electroencephalographic examination of the dynamics of consciousness recovery in sTBI patients (196 individuals aged 9—69; mean age was 30.6 years) who had been treated in the N.N. Burdenko Neurosurgical Institute, were used.

After a sTBI and long-term (at least 10 days) coma, all the patients we in long-term postcomatose unconscious state (PUS). In 36% of cases, this state became chronic (up to several years), while in others it lasted from several weeks to seven months; further recovery of mental activity could reach the boundary (with respect to health) between the mild cognitive and emotional personality disorders, the level depended on a certain patient.

The nature of the examined brain injuries was multicompontent: 1) primary: either diffuse axonal brain injury or multifocal injuries of subcortical and cortical structures; 2) secondary effect of various pathological factors on stem structures (microcirculation disorder, secondary vascular reactions, brain edema and dislocation, and metabolic disorders caused by arterial hypoxemia).

A thorough clinical examination, including CT (Sytek-1800, G. Electric) and MRI (Signa, 1.0—1.5 T) along with surgical intervention were used to assess the topography and severity of brain, while pathomorphological data were used to assess lethal outcomes.

The current state of patient’s consciousness was assessed quantitatively according to the concepts on stages of postcomatose mental recovery [16, 17]. These concepts suggest that posttraumatic unconscious states are syndromes that emerge immediately after coma and alter one another: from the first postcomatose eye opening to the first contact with the patient (mainly as accurate execution of instructions). The posttraumatic unconscious states include the vegetative state and akinetic mutism, characterized by the absence of external signs of consciousness [15, 17] (i.e., productive contact, orientation in space, time, and one’s own identity. Contact recovery is altered by states (stages) of mutism with speech recognition and disintegration, which are classified (as well as the previously described states) as the syndromes of depressed consciousness but are characterized by the presence of an extremely limited verbal contact that cannot indicate a degree of orientation in one’s own identity and in space. Unstable execution of certain elementary instructions can become a chronic state and is regarded as the minimally conscious state. These stages of post-traumatic recovery of the mental activity are shown in Fig. 2a.

EEG examination (4—25 per patient) were performed during the development of PUS for 1.5—4 yrs (in some cases, postcomatose follow-up periods lasted as long as seven or even 16 years). Biopotentials were recorded according to the 10—20% scheme (10 or 18 channels) with 0.3—35 Hz bandpass and a 100 Hz sampling interval in the patients both at rest with their eyes closed and under afferent stimuli, promoting the more complete assessment of potential brain activity. Biologically (a red spot, a contrast band) and emotionally (a relative’s face or voice, etc.) relevant stimuli were presented to a patient along with the traditional non-specific stimuli (rhythmic photostimulation and a pure-tone sound) [45].

Examination of the EEG markers of attention, the basic component of human consciousness with a significant role in organization of cognitive processes and behavior, was a significant part of a study [71]. Attention disorders in patients with sTBI can be regarded as an axi-al disorder that accompanies all the stages of mental activity recovery. The authors analyzed the EEG markers of orientation response (to eye opening and a sound tone of variable frequency) and those of voluntary and involuntary attention to visual stimuli [48].

The EEG records were assessed both visually and using mathematical analysis: spectral coherence analysis of artifact-free EEG data 45—90 s long in a 0.4—30 Hz band using a Neurokartograph programming and computing complex (MBN, Russia). The increment of spectral analysis was 0.4 Hz. The estimated parameters included the mean power, mean frequency, and efficient frequency bandwidth of the power spectra, the upper frequency border (a frequency above which only 5% of the total power can be found), and the mean levels of EEG coherence in the 0.5—20 Hz range. Power, frequency and coherence parameters within the ranges of the main physiological levels (delta, alpha, and beta) of each patient were determined against baseline and functional loads. The informational and functional significance of these parameters was demonstrated in previous studies [2, 9, 34, 35].

The main attention was paid to examining the coherence as a measure of correspondence between the electrical activities in different sites of brain. According to the concepts of the M.N. Livanov’s [25] and V.S. Rusinov’s—O.M. Grindel’s [10, 35] scientific schools, parameters of spatial EEG synchronization are the main values showing the integrative intercentral interactions in the brain as a basis for formation of certain functional states in humans and for supporting person’s activities, including the mental one.

Baseline and reactive EEG parameters were compared with the available reference standard characteristics of adults (74 individuals) and, in a number of experimental series, with pediatric characteristics for various ages [32]. The latter observation is of special scientific
interest due to the available literature on similarity bet-
ween the dynamics of posttraumatic recovery of mental
activity and its formation through ontogeny [28].

Quantitative differences in spectral coherence EEG
parameters of patients were compared with the standard;
their dynamic alterations were assessed using nonpara-
metric Mann—Whitney test [6].

Three-dimensional localizations of equivalent dipole
sources (EDS) were recognized using BrainLoc 5.0 soft-
ware for a number of specific stable posttraumatic EEG
phenomena (dominant rhythms of the baseline EEG,
various types of local EEG slow wave activity, and parox-
ysmal events) [24]. The convergence between EDSs in a
number of EEG phenomena and the brain lesion areas in
sTBI patients was demonstrated in a number of previous
specialized studies [4].

Results and Discussion

The EEG patterns in sTBI patients are characterized
by strong deviations from the standard in the form of spa-
tial organization disorder, absence or considerable re-
duction of the alpha rhythm that is dominant in the nor-
mal state, while the slow-wave delta and teta EEG
rhythms increase (more typically in patients in a vegetati-
ve state) or, in contrast, high-frequency beta components
(at various mutisms) (Fig. 1a).

EDSs of pathological activities that were dominant
on EEG were localized in stem, subcortical, and basal
brain structures both in slow-wave activities and in higher
frequency beta and even alpha components (Fig. 1b),
which demonstrate under these conditions the irritation
of hippocampus and of other limbic structures of the
brain [3]. The data indicate that early postcomatose EEG
states are characterized by effects of either stem and sub-
cortical structures (PUSs in the form of the vegetative
state) or subcortical, diencephalic, and basal brain struc-
tures (various kinds of mutism) caused by inhibition of
the cortex function.

When a PUS is reversible, an ongoing process of con-
sciousness recovery is accompanied by gradual levelling
of the diffuse and focal slow waves or other kinds of visu-
al pathological disorders and by formation of a regular
standard alpha rhythm (Fig. 1c), while stability of general
and in particular the local disorders of the EEG pattern
6—18 months after an injury or longer is typical of chron-

Fig. 1. EEG characteristics typical of PUS at the vegetative (I) and akinetic mutism (II) stages.

a — EEG patterns; b — three-dimensional localization of significant (dipole coefficients over 0.9) equivalent dipole sources of typical activities: flashes of slow waves
in the vegetative state and beta activity in mutism; c — scheme showing seven brain “slices”, onto which EEG EDS were projected.
Fig. 2. Alterations of parameters of brain bioelectric activity in the course of consciousness recovery after sTBI.

a — stages of mental activity recovery after a long-term coma [16]; b — the correspondent dynamics of medium level of interhemispheric EEG coherences (Coh) (0.5–20 Hz) in the PUS observation group (n=55); c — typical alterations of the EEG pattern during the recovery of mental activity after sTBI.
ic unconscious state and attests to the fact that these states are caused by an immediate structural lesion of certain brain areas.

Meanwhile, EEG patterns vary even within one type of unconscious state (e.g., we have found seven kinds of the patterns typical of vegetative state and akinetic mutism) [46]. This fact attests to an expected polyvariance of structural and functional brain lesions that can cause a PUS. Our idea can be proved by current MRI data on multiple and alternate combination of lesions in the stem, subcortical, and cortical brain structures in sTBI patients [17], results of neurochemical studies [1, 52], and the variability of clinical patterns in sTBI patients [26, 39, 50—52].

Thus, M.V. Cheliyapina [41] identified and thoroughly examined two clinical-encephalographic syndromes during the development of posttraumatic unconsciousness. Clinical signs of dopamine deficiency were followed by stable enhancement of EEG beta activity at various stages of recovery of the mental activity (Fig. 3a), while in patients with clinical signs of choline deficiency, alpha activity of non-cortical genesis was typical of EEG even upon deep depression of consciousness (coma) followed by reorganization and standardization of the rhythm during the recovery (Fig. 3b).

Therefore, the dynamic features of the EEG pattern in a patient with PUS allow a researcher to characterize severity of the current patient’s state, to identify brain structures with the maximally severe dysfunction, and to determine the area of a local cortical lesion along with the general route of traumatic disease development (quasi-dynamics of brain homeostasis) but cannot immediately show the level and characteristic features of the current state.

An analysis of frequency parameters of the EEG power spectrum according to the mean frequency—effective frequency band parameters showed a significant correlation between the parameter and the outcome of sTBI [43].

This was obvious from analyzing both the baseline and reactive alterations in EEG. Differently directed reactive alterations in EEG can be identified both in comatose patients [14, 70] and in those in a vegetative state (in over 75% of cases). However, the patterned EEG reactions with enhanced pathological activity in a narrow frequency range (dominant focus) are unfavorable prognostic signs. In contrast, variative alterations with broadened EEG frequency range and approaching the standard are typical of patients with reversible unconsciousness [45].

However, an in-depth analysis demonstrated that the greatest difference between patients with reversible and irreversible sTBI appear within the observation period longer than three months (Fig. 4). The analysis was based on data of baseline EEG frequency parameters with respect to their prognostic informativity and considered the duration of the post-injury period; differences between the patients were assessed according to the deviations of the mean frequency—effective frequency band of the power spectra. The clinical data on stages of sTBI, on development of post-traumatic hemodynamics and CSF dynamics [26, 30, 64], and on development of neurodegenerative processes [19] substantiate this result and prove the thesis that two differently directed processes, structural and functional disorders and their compensation (recovery) are maximally active in the brain within a two–three-month period. This period might be critical both in terms of therapeutic effects and the potential of the recovery of mental activity.

As for the analysis of EEG coherence, it is worth emphasizing that the classical concepts of Russian researches on integrative functional intercentral connections underlying the formation of functional state and various activities, including the mental one [25, 35], have been proved by numerous experimental, psychophysiological, and clinicophysiological studies both in Russia and abroad. These concepts correspond to the ideas proposed by C. Stam [73] on a network organization of brain activity and to the ideas of some authors on significance of functional brain connectivity, which are based on the results of electrophysiological and neuroimaging studies [55, 58, 61, 75].

The results of EEG—fMRI correlation in various functional tests (e.g., eye opening and finger dexterity) in healthy persons prove the high functional significance of coherence [5]. Among all the qualitative EEG parameters, coherence alterations in certain frequency ranges (high frequency alpha (10.5—12.5 Hz) and beta activity (20—30 Hz)) best correspond to local fMRI response topography. Coherent connections of these functional rhythms of EEG are considerably enhanced at loads compared with the baseline.

The inhibitory state of the cortex in patients with posttraumatic PUS is shown by the significantly lowered coherent connections in the main EEG frequency bands. The dramatic atrophy of interhemispheric interaction (Fig. 1b), varying from 30 to 80% with respect to the standard and being accepted in the frontal cortical areas, is worth special emphasizing. This fact was first identified in a representative group of cases using statistical methods [72] and was confirmed in different samples of patients both in EEG examination using improved analysis techniques [12, 44, 63] and in recent fMRI examinations [60, 61, 74]. As determined earlier [3], atrophy of interfrential coherent connections of EEG can result both from an immediate injury of the frontal lobes or commissure tracts and from injury (disfunction) of brain regulatory structures at various levels.

In the course of consciousness recovery in PUS patients, interhemispheric coherent connections of the baseline EEG are gradually enhanced in a broad frequency band and a spatial gradient typical of the standard (its dominance in the frontal hemispheric areas) is recovered (Fig. 1b). However, the most dramatic (80%) and stable (several months or years) atrophy of interhemispheric in-
Interaction is well expressed in patients with chronic PUS (the phenomenon of functional hemisphere disintegration) and is its marker. The data on dynamics of interhemispheric coherence of EEG in PUS patients are in accordance with the study of callosum tracts in the same group of patients [17, 18].

An in-depth analysis of coherence alteration in the course of consciousness recovery in a narrow frequency range showed that its positive alterations are coupled with the normalization of interfrontal alpha connections at 10.5—12.5 Hz and with hypersynchronisation of beta activity by 17—23 Hz frequency in the left hemisphere (frontocentral, frontoparietal, and frontooccipital connections); this correlation is most distinctly expressed. These data are similar to the results of current EEG examination performed by other authors [63]. Positive shifts in the sphere of consciousness are mainly related to alterations in coherence (concordance) of EEG functional rhythms both in the frontal areas of both hemispheres and within the left one.

Fig. 3. Dynamics of biopotentials in patients with posttraumatic syndromes of dopamine (a) and choline (b) deficiencies.
I — EEG alterations; II — alterations of localization of the equivalent dipole sources.
Upon activation of visual attention, the presence of interhemispheric reactivity (including the frontal lobes) since the earliest postcomatose stages are the main signs typical of patients with reversible unconsciousness (Fig. 5), which indicates the potential of the fronto-thalamic system in supporting the selective voluntary attention [27].

Thus, the baseline interhemispheric (mainly frontal) coherence of EEG and its alteration in response to external stimuli are the integral parameters of systemic brain activity and are the signs that maximally reflect the degree of consciousness depression, its dynamics, and recovery potential.

This concept corresponds to the ideas proposed by S. Laureus [61] and J. Eriksson [56], which were based on fMRI results. According to these ideas, it is the hemispheric frontal areas (especially of the left one) that correlate with consciousness due to the fact that these areas are related to attention. Our data add the factor of significance of interhemispheric frontal activity coherence to these ideas.

The results of EEG coherence studies substantiate the prospects of targeted stimulating therapeutic measures in PUS patients. These have been proved in a series of cases in seven PUS patients. In five of them, even a single subthreshold rhythmical transcranial magnet-induced stimulation of the sagittal areas of premotor cortex (as a projection of the frontal system of attention, according to M. Posner [69]) was accompanied by a pronounced and stable acceleration of the recovery process along with positive alterations in the EEG pattern and enhanced coherence between the hemispheres and within the left hemisphere [47].

*Fig. 4. Frequency parameters of the EEG power spectrum in patients with reversible (a) and irreversible (b) PUS during the follow-up period under three months (I) and over three months (II) after an injury.*

X axis — mean frequencies of the spectrum; Y axis — the effective frequencies. Each circumference includes a totality of these parameters for all EEG derivations of an examination. A circumference drawn with a solid curve is a vegetative state; that drawn using a dashed curve represents akinetic mutism. A grey circumference is an area of values corresponding to the normative ones (N).
In current studies, we pay increasing attention to examining functionalities of PUS patients in our attempts to approach understanding of the nature of subjective emotions. The data proved by fMRI [60, 61] show that the functional status of PUS patients and their reactivity are mainly maintained by activity of the deep brain structures upon cortex inactivation. However, according to B. Merker [65], this does not preclude the presence of data processing, emotions, and self-consciousness in patients with the absence of external signs of consciousness; the processes are executed by cortical and subcortical structures even in the absence of the cortical interface.

When analyzing EEG alterations upon activation of optical attention in PUS patients and comparing the results with the literature data [38, 40], we hypothesized that there can be a similarity between these alterations and pediatric reactions: chronic PUS – with reactions of babies under six months of life; reversible PUS – with reactions of infants aged 12 months or older [49]. Results of joint studies conducted together with G.A. Portnova et al. [32] have confirmed this hypothesis: a similarity between EEG responses to tactile stimulation between the patient group with reversible PUS (coma 1 – the vegetative state) and 5—6-year-old children, in contrast to adults, was revealed. A similarity with pediatric EEG responses manifests itself both in terms of topography of alterations and specific behavior of certain frequency ranges.

Systemic reactive brain alterations caused by rather complex functional loads have recently been revealed in PUS patients using fMRI and evoked potentials [66, 69]. Thus, L.B. Oknina et al. [29] examined long-term cognitive components of acoustic evoked potentials (N100, N200, P300) and showed that patients with reversible depressed consciousness (even in vegetative state or akinetic mutism) could register responses both when listening to sound of different modalities and when being instructed to count relevant sounds.

![Fig. 5. Significant alterations of EEG coherence according to the ranges of physiological rhythms at eye opening in healthy individuals and in PUS patients.](image)

1 — the group of healthy individuals (n=10); 2—4 individual alterations caused by PUS: 2 — in a patient in chronic PUS (manifested as akinetic mutism with emotional reactions) ten months after sTBI; 3 — in a patient with the emergence of the state of minimal consciousness at the stage of akinetic mutism with emotional reactions seven years after sTBI; 4 — in a patient with reversible PUS at the stage of conversion from akinetic mutism to mutism with emotional reactions seven months after sTBI.
The data indicate a possible underestimation and obvious insufficiency of our knowledge on brain function- alities in PUS patients. Hence, further studies of this sub- ject are reasonable.

Conclusion

In patients with posttraumatic consciousness depression, various aspects of brain functioning are reflected by various EEG parameters. Simultaneous analysis of the dynamic parameters of the EEG pattern and of equivalent dipole sources of individual components allow a researcher to determine severity of the current patient’s state, to identify brain structures with the maximal dys- function, to find an area of a local cortical lesion, and to determine the general route of traumatic lesion development (quasi dynamics of brain homeostasis). Baseline and reactive frequency parameters of the EEG power spectrum (mean frequency—effective frequency band) have the maximum predictive value, especially when assessed 2—3 months after an injury. Baseline interspheric EEG coherence (mainly, the frontal one) and its altera- tions in response to external stimulation are the integral parameters of systemic brain activity, so they maximally demonstrate the degree of consciousness depression, its dynamics, as well as potential of its recovery.

Examination of functionalities and individual characteristics of reactive alterations in brain biopotentials in PUS patients are of special interest. In this case, the electrophysiological techniques have some advantages over fMRI: better time resolution, comfort, and economy. Results of these examinations can facilitate correction of treatment, accelerate the recovery of patients with post- traumatic consciousness, and make a contribution to un- derstanding of the functionalities of human brain.

Markers of the unconsciousness human functional- ity might be recognized in a slower part of the spectrum, in contrast to activities of a conscious person coherent to functional EEG rhythms: high-frequency alpha, along with beta and gamma rhythms. The “interface—brain— computer” approach is another promising technique for analyzing PUS patients.

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Electrophysiological studies in patients with long-term consciousness depression caused by a severe traumatic brain injury and other cerebral pathologies, which were performed at the Burdenko Neurosurgical Institute, are systemic and highly informative.

Identification of early objective qualitative EEG parameters that characterize the consciousness state is required to ensure timely prediction and early targeted correction of long-term unconsciousness after a severe brain injury. These were the reasons for a decades-long comparative analysis of EEG in dynamics of consciousness recovery after sTBI, which allowed the researchers to identify the most informative parameters of quantitative EEG.

Practicing neurosurgeons, neurologists, and specialists in intensive care and rehabilitation comprise the group of specialists who especially need information on significant differences in EEG parameters between patients in reversible and irreversible postcomatose states (PUS) within a time range of over three months after injury. This fact proves once again the necessity of the earliest (2—3 months after an accident) and adequate therapeutic measures that predetermine the prospects of mental activity recovery in this patient group.

Quantitative EEG techniques are used unreasonably rarely in current practical healthcare, while the authors have proved that parameters of interhemispheric (mainly, frontal) EEG coherence and its alterations in response to external stimulation are significant predictors of consciousness depression degree.

The article brings up new issues that predetermine the perspectives of further studies of states in patients with post-traumatic consciousness depression.

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Numerous studies are focused on causes of coma and post-coma disorders of consciousness in various forms of brain pathology [28, 29, 31, 45, 51]. They are highly relevant, since a deep coma lasting more than one week, as well as long-term (more than 1 month) post-coma disorders of consciousness, are prognostically unfavorable for complete mental recovery [4, 43].

It is known that normally there are three fundamentally different states of the brain activity. They are wakefulness, slow-wave sleep (SWS), and sleep with rapid eye movement (REM). Transition from one state to another one is regulated by activation or inhibition of strictly determined neurotransmitter systems. Thus, monoaminergic systems of the brainstem, cholinergic system of the anterior brain, histamine- and orexinergic systems are maintaining wakefulness. Dropping-off to slow-wave sleep occurs due to activation of the GABAergic and galaninergic system of the hypothalamus; further transition to the REM-sleep stage is associated with activation of choline-, glutamate- and GABAergic brainstem nuclei. Neurotransmitter systems are also involved in realization of impaired consciousness states in different forms of pathology; however, it is still unclear which system, being impaired, provides the maintenance of a particular variant of unconsciousness in a particular patient. Thus, this question is crucial for the development of recommendations on the selection of individual neuromodulator therapy of patients in states of impaired consciousness [3, 5]. One of the ways to solve the problem is to find clinical, biochemical and neurovisual biomarkers of dysfunction of various neurotransmitter systems in the brain based on the mechanisms of their close structural and functional interaction.

Neurotransmitter Basis of Consciousness and Unconsciousness

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The problem of consciousness recovery has been extensively studied over the years from the viewpoint of neuroanatomy, neurophysiology, neuropsychiatry, neurosurgery and general ideas of neurology. However, relatively little attention is paid to the role of neurotransmitter systems. Meanwhile, neurotransmitter system dysfunction caused by brain damage is one of the key obstacles to the recovery of consciousness and other neurological functions. Drugs modulating the activity of neurotransmitter systems are used to correct the dysfunctions; however, no clear indications for administration of these drugs are available. Thus, the study of the neurotransmitter mechanisms of impairment and recovery of consciousness in patients with different forms of brain pathologies is a topical issue at the present moment. This review provides a detailed analysis of current understanding of the aspects of unconsciousness as well as its neurotransmitter and neuroanatomical basis.

Keywords: traumatic brain injury, recovery of consciousness, unconsciousness, neurotransmitters.

Neurotransmitter basis of maintaining the level of consciousness

According to current data, the level of consciousness is maintained by the ascending reticular activating system (ARAS) of the brain, which is mostly a substrate of physiological concept rather than an anatomical formation. Anatomically, it is a part of the reticular formation of the brainstem from the pons to the thalamus. It additionally includes some nuclei of different neurotransmitter systems [73]. Several authors [18] distinguish the ventral pathway that passes through the hypothalamus and forebrain, and the dorsal pathway that activates the cortex via the thalamus. Stimulation of ARAS via the dorsal pathway occurs through spinothalamic sensory pathways that terminate in specific thalamic nuclei. In turn, they activate the cortex and nonspecific thalamic nuclei, which also send impulses to the cortex (see Figure). Via the ventral pathway, ARAS stimulates basal nucleus, which also has projections onto the cortex (Figure).

Activity of ARAS is regulated by inhibitory inputs from the anterior hypothalamus and the spinal cord. These systems provide a transition between different levels of activity in the state of wakefulness. Importantly, when ARAS is damaged, the number of afferent projections of many neurotransmitter systems onto the cerebral cortex is reduced, including those that activate the cortex, provide waking and maintain the level of wakefulness. Choline-, glutamate- and monoaminergic systems are especially important in this respect.

Cholinergic nuclei of the basal forebrain are more active during wakefulness than during sleep, while cholinergic neurons of pedunculopontine nucleus (PPN) are activated mainly during REM sleep and are responsible for the emergence of ponto-geniculo-occipital waves on
About 85—90% of afferents of brainstem cholinergic nuclei innervate various (specific and nonspecific) thalamic nuclei. Rostral intralaminar nuclei and additional paralaminar thalamic regions, which play a key role in maintaining the level of wakefulness, are characterized by the richest cholinergic innervation (from PPN, lateral and dorsal tegmental (LDT) pons nuclei) [8, 57]. Cholinergic projections onto the thalamic nuclei have a dual effect on their activity. On the one hand, they inhibit GABAergic neurons of the reticular nucleus, which inhibit excitatory neurons of anterior intralaminar nuclei, via M-cholinoreceptors. On the other hand, direct cholinergic projections onto the anterior intralaminar nuclei have an activating effect on them through nicotinic M-cholinoreceptors [57]. Thus, the simultaneous activation of cholinergic projections of brainstem and forebrain, which is registered during wakefulness and REM sleep, maintains the integrative function of the thalamus and may be a mechanism of modulation of perceived processes during wakefulness. This is evidenced by the results of some studies demonstrating that the basal forebrain cholinergic neurons are responsible for the formation of cognitive evoked potentials P300 [49].

Along with thalamus, brainstem cholinergic neurons innervate other parts of the brain involved in maintaining wakefulness, in particular, glutamatergic (midbrain reticular formation nuclei, pontine parabrachial and oral nuclei), cholinergic (basal forebrain nuclei) structures and the prefrontal cortex [18]. It is important that the cholinergic system is able to maintain active state of the cortex in absence of activation of monoaminergic (catecholamine-, serotonergic) systems [10], but in the obligatory presence of activity of the glutamatergic system [49].

It is possible that glutamate-containing neurons in the brainstem reticular formation (Figure) make the greatest contribution to the maintenance of the level of wakefulness. Thus, glutamatergic fibers from the parabra-
chial nucleus of the pontine reticular formation and the midbrain reticular formation have an activating effect on the nonspecific thalamic nuclei [26, 55, 65] and cholinergic basal forebrain neurons [24]. In addition, there is a hypothesis that the activity of the fifth layer of large glutamatergic pyramidal neurons plays a key role in maintaining the level of consciousness [14].

The important role in maintaining wakefulness is played by histaminergic neurons of the tuberomamillary nucleus of the posterior hypothalamus (Figure), which has an activating effect on the cortex, thalamus, cholinergic neurons of the basal forebrain and brainstem, perifornical area [23, 42] and an inhibiting effect on preoptic nucleus of the hypothalamus, which is involved in maintaining of sleep. Tuberomamillary nucleus, in turn, receives inhibitory (GABAergic) afferent inputs from the ventrolateral preoptic area (VLPO), which is most active during SWS.

The role of noradrenergic neurons of locus coeruleus (LC) in maintaining wakefulness is being questioned, as animals with more than 90% of LC neurons damaged could maintain wakefulness. Nevertheless, it was shown that the activity of these neurons increases during the wakefulness. Their activation inhibits the ventrolateral preoptic nucleus of the hypothalamus, which has an inhibitory effect on the systems of wakefulness [40, 55]. Taking into account the presence of two modes of activity of LC, it is assumed that the tonic activity mediates the maintenance of wakefulness level in general, while the phasic activity adjusts the level of attention. LC has a stimulating effect on some activating brain structures through α, and β, receptors. Thus, it was shown that noradrenaline increases the activity of forebrain cholinergic neurons via activation of β-receptors. In addition, LC inhibits GABAergic neurons of the basal forebrain [38] and the preoptic area [13, 20], supporting the sleep state, through α, receptors. LC also activates the cortex through the thalamus and additionally innervates its nonspecific (median and intralaminar) and specific nuclei [26, 32]. Noradrenergic neurons of the lateral tegmental area (ventral system) have numerous reciprocal connections with other brainstem neurons involved in homeostasis (regulation of blood pressure and heart rate), and probably modulate activity of the autonomic nervous system in different phases of sleep and during wakefulness. Thus, the main function of the noradrenergic system is regulating various functional neuronal networks rather than direct effect on particular processes. Moreover, it is assumed that the LC can affect the central nervous system (CNS) by neurosecretory pathway due to plentiful blood supply and direct contacts between noradrenergic neurons and capillaries.

Dopaminergic neurons of the ventral tegmental area of the midbrain can affect the level of wakefulness through connections with the thalamus, basal forebrain, the adjoining nucleus and the cortex. However, the level of activity of ventral tegmental dopaminergic neurons does not change during the sleep-wakefulness cycle. Dopaminergic pathways from the ventral periaqueductal gray matter, which cause weakening by innervating the thalamus, basal forebrain and the cortex, have recently been described [33]. It was shown that low doses of Dβ-receptor agonists can induce SWS, while antagonists of these receptor increase wakefulness level and interrupt REM and SWS sleep phases. Conversely, high doses of Dβ-receptor agonists increase wakefulness level, probably due to activation of postsynaptic Dβ receptors.

Serotonergic neurotransmission leads to a general increase in wakefulness level and decrease in SWS and REM sleep phases. Serotonergic pathways from the dorsal raphe nucleus of the medulla oblongata to the cortex, basal forebrain, medial and intralaminar nuclei of the thalamus are known [26]. However, the action of serotonin on these structures depends on the type of receptor location. Thus, stimulation of presynaptic 5-HT1A receptors increases the REM sleep phase and reduces the level of wakefulness, while stimulation of postsynaptic 5-HT1A receptors reduces REM sleep phase and reduces the level of wakefulness. [72].

There is another important neurotransmitter system involved in maintaining the level of wakefulness, i.e. neurons of perifornical area and lateral hypothalamus containing orexin. They have a direct activating effect on the cortex through nonspecific thalamic nuclei and through all of the aforementioned neurotransmitter systems [7, 50].

**Neurotransmitter basis of physiological unconsciousness**

It is known that in the reduction of wakefulness level (falling asleep) in a normally functioning brain is not a passive process, i.e., it is not achieved by simply turning the activating systems off. There are structures in the brain that are activated when the level of wakefulness is decreased (sleep patterns).

The most important of them include the anterior hypothalamus (ventrolateral preoptic nucleus and medial preoptic area) and the basal forebrain; all of them use gamma-aminobutyric acid (GABA) as a neurotransmitter. Ventrolateral preoptic nucleus (VLPO) sends inhibitory (GABAergic and galaninergic) projection to many structures activating the cortex, such as histaminergic neurons of tuberomamillary nucleus, dopaminergic neurons of the ventral tegmental area of the midbrain, the ventral periaqueductal gray matter, brainstem cholinergic nuclei, and serotonergic neurons in the dorsal raphe nucleus [61, 64]. VLPO neurons are activated immediately before EEG synchronization; their activity is enhanced with sleep depth [69]. The medial preoptic area of the hypothalamus inhibits orexinergic neurons of the perifornical area [34, 36], noradrenergic neurons of LC and serotonergic neurons of the dorsal raphe nucleus [70]. This area of the brain is activated during SWS and REM sleep phases. It is most active at the beginning of
sleep, then its activity gradually decreases, which is indicative of its role in the process of falling asleep [66]. GABAergic neurons in basal forebrain (giant cell nuclei) [38, 68] send projections to the perifornical area [22], the nuclei of the midbrain and the pons [60, 68]. Their activity, as well as the activity of VLPO neurons, correlates with the depth of sleep; however, it is more pronounced during the SWS rather than REM sleep [67].

**Neurotransmitter basis of pathological unconsciousness**

In comatose state and other disorders of consciousness regardless of their etiology (trauma, hypoxia/ischemia, hemorrhage-related vasospasm), there is a widespread reduction of background synaptic activity and transmission of excitatory neurotransmitters [52, 58]. Coma was shown to be associated with the presence of lesions in the oral and parabrachial nuclei of the pons (glutamatergic system of reticular formation), LC (noradrenergic system), the raphe nuclei (serotonergic system), laterodorsal and pedunculopontine tegmental nuclei (cholinergic system) [44]. Some authors [19] believe that it is damage to the parabrachial nucleus area or its projections onto the basal forebrain that cause coma and prolonged vegetative states.

Currently, there are several major neurotransmitter theories that presumably explain the formation of different stable states of impaired consciousness. One of them is the mesocircuit hypothesis [9, 58]. According to this hypothesis, functional abnormalities of the interaction between large neuronal connections of the forebrain appear first on the background of general reduction of excitatory neurotransmission [56, 59]. Connections of the forebrain include a complex system of interactions with the frontal cortex, the thalamus and corpus striatum; they are most vulnerable to multifocal brain injury. This hypothesis is based on a damage to the aforementioned dorsal path, the thalamus being its key structure. It is known that the central thalamus is highly innervated by cholinergic, serotonergic and noradrenergic afferents of the ascending activating system of the brainstem on the one hand [57], and by descending projections from the frontal cortex, providing regulatory functions in goal-directed behavior, on the other hand. It is believed that these ascending and descending actions on the central thalamus modulate the level of wakefulness in accordance with the general activity, different cognitive tasks, stress and other processes characteristic of the wakefulness state [25, 39, 46, 47, 57, 71].

The medium spiny neurons (MSN) in the striatum containing glutamate are the second key structure. They send inhibitory (GABAergic) projections to the internal segment of the globus pallidus (GP), which tonically inhibits the central thalamus in the absence of these inputs [21]. MSN activity is in turn regulated by incitant (glutamate) thalamostriatal, frontostriatal and hippocampal projections [27, 62]. The activity of MSN is also regulated by the dopaminergic system (from the ventral tegmental area and the substantia nigra) [35, 48]. Thus, inhibition of MSN activity due to reducing dopaminergic or glutamatergic modulation of these neurons or their direct damage may play a key role in dysfunction of neuronal systems in the forebrain and lead to the development of syndromes of impaired consciousness.

Another (dopamine) neurotransmitter hypothesis is based on frequent direct or indirect traumatic ascending (nigrostriatal and mesocorticollimbic) and descending (from the prefrontal cortex to the striatum and thalamus, from the anterior cingulate gyrus to the striatum) dopaminergic pathways, which consequently leads to the development of pronounced cognitive disorders [6]. It has currently been shown that interaction between the dorsolateral prefrontal cortex and the striatum plays an important role in regulating functions and working memory. This interaction is in turn modulated by the dopaminergic system [6, 15].

The third hypothesis is based on the disruption of the interaction between the noradrenergic and dopaminergic systems of the brain, which are known to jointly participate in regulation of mental activity (in particular, emotional reactions), motor and endocrine functions. First, we should note that they are characterized by similar topographical distribution and principle of organization. Thus, the basic nuclei of both systems are localized in the brainstem, where the long axons innervating almost all parts of the CNS originate. Individual nuclei (parabrachial and paranigral) contain both dopaminergic and noradrenergic neurons [2]. The existence of different variants of dynamics of the levels of norepinephrine (NE) and dopamine (DA) in blood plasma in an unconsciousness state and after recovery of consciousness in patients with severe traumatic brain injury is indicative of the importance of the interaction between these systems in maintaining the level of consciousness [1]. Earlier studies revealed that the noradrenergic system has a modulating effect on dopaminergic system. Thus, the damage of LC reduces the DA level in the limbic system structures (the arcuate nucleus and nucleus accumbens) and some subcortical structures (caudate nucleus) and increases the DA level in the substantia nigra and ventral tegmentum of the midbrain [41]. Stimulation of LC resulted in an increase of NA and DA content in the prefrontal cortex [17]. In the frontal cortex, DA release is strongly modulated by the noradrenergic nerve terminals [63]. This is important, since during wakefulness NA is responsible for the partial inhibition of cortical areas, while DA provides its specific activation (especially in motivational processes), searching for new information and new experiences. Moreover, it was shown that DA and NA are stored together in presynaptic vesicles of noradrenergic terminals in the prefrontal cortex of the frontal lobes; reuptake of both catecholamines occurs via noradrenaline transporters [12, 16]. Thus, both DA and NA are released in the frontal cortex...
upon excitation of noradrenergic fibers, i.e. there are two neurotransmitters in one site for a physiological state in this area of the brain. In this regard, a new approach to the pharmacological correction of cognitive impairment in frontal lobe dysfunction is possible, which is based on using selective inhibitors of DA transporters (e.g., atomoxetine) that increase DA and NA levels in the frontal cortex without affecting the DA level in the subcortical structures [11, 37, 53, 54]. Thus, it is important to note that the dopaminergic and noradrenergic systems are closely interacting as agonists or antagonists at virtually all CNS levels. Such interaction between these systems is probably important to maintain the level of consciousness and holistic mental activity.

Thus, prolonged abnormal sleep state (coma) and post–coma unconsciousness occur due to the disturbance of interaction between different neurotransmitter systems in the brain. Each pathological condition in a particular patient probably has its own pattern of imbalance between the major neurotransmitter systems involved in regulation of the sleep-wakefulness rhythm and regulation of mental functions.

Conclusion

Low-molecular-weight neurotransmitter systems in the brain closely interact with each other, which is an essential basis to maintain the level of consciousness and to provide mental activity. Each of these systems is rigorously organized, has its own receptors and complex regulation by other neurotransmitter and non–neurotransmitter systems, as well as self-regulation mechanisms. Thus, any pathological processes in the brain affect neurotransmitter systems in some way; the nature and localization of the process in different brain structures determine which one is most dysfunctional. In subsequent recovery processes, the significance of damaged brain structures gradually decreases, while the functional interaction of structurally intact neurotransmitter systems comes to the fore. This interaction underlies evolving stable and unstable clinical syndromes. Thus, studies focused on finding clinical (neurological, psychiatric, neuropsychological), biochemical and neuroimaging biomarkers of neurotransmitter system dysfunction are promising for pathophysiological justification of therapeutic modalities.

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The subject of the present article is highly relevant as it focuses on one of the most important fundamental areas of modern neuroscience, namely, functional neurochemistry of consciousness and unconsciousness. It should be emphasized that at present moment any such study can make a significant contribution to the further accumulation of knowledge on the pathophysiological mechanisms of disorders of consciousness, interaction of integrative neurochemical systems in health and disease, which ultimately gives basis for developing new methods of highly efficient therapy of disea-


Commentary

The subject of the present article is highly relevant as it focuses on one of the most important fundamental areas of modern neuroscience, namely, functional neurochemistry of consciousness and unconsciousness. It should be emphasized that at present moment any such study can make a significant contribution to the further accumulation of knowledge on the pathophysiological mechanisms of disorders of consciousness, interaction of integrative neurochemical systems in health and disease, which ultimately gives basis for developing new methods of highly efficient therapy of disea-

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ses leading to impaired consciousness. This work is also relevant due to the fact that there are very few contemporary reviews of functional neurochemistry and the main theories of pathologic physiology of consciousness. Meanwhile, many aspects of neurochemical organization of consciousness are insufficiently discussed in the literature. In particular, there is no unified viewpoint on the dominance of interactions between dopamine and noradrenaline in the dynamics of coma states, the role of particular structures of the ascending activating system, etc. The fact that the above problems are discussed in the present study makes this review especially valuable and relevant for some medical specialists (neurologists, neurosurgeons, anesthesiologists, psychiatrists, etc.).

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Recovery of Consciousness as Manifestation of Neuroplasticity

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Traumatic brain injury (TBI) is the cause of the vegetative state in approximately half of cases, which allows one to consider this etiopathogenetic form of consciousness impairment to be one of the models for studying its morphofunctional nature. It has been shown that morphological (diffuse axonal injury of subcortical white matter, necrotic changes in the cortex and thalamus) and functional (diaschisis) disorders, as well as sanogenetic processes occurring as a component of neuroplasticity underlie the clinical presentation of TBI. The objective of our research was to investigate the clinical and neurophysiological markers of consciousness recovery in 28—54-year-old patients in vegetative state (VS) after severe TBI by comparing the dynamics of clinical changes and electrical activity of the brain. In all patients, we evaluated the neurological status using the Glasgow Coma Scale (GCS) score; performed electroencephalography (EEG) and analyzed its spectral coherence; recorded and analyzed somatosensory evoked potentials; studied motor thresholds and the amplitude—time characteristics of motor potentials evoked in the course of transcranial magnetic stimulation; and repeatedly performed MRI and CT. For most patients, EEG revealed theta and delta rhythms, sometimes with signs of paroxysmal activity and those of interhemispheric asymmetry or low amplitude. It was discovered that reliable positive changes in amplitude—time characteristics of multimodal evoked potentials, reliable decrease in motor thresholds mostly in the left hemisphere, and an increase in amplitude of motor evoked potentials preceded clinical improvement by 5—7 days.

Keywords: impairment of consciousness, electrophysiological markers, transcranial magnetic stimulation.

Medical approach to the analysis of consciousness as a versatile human-inherent phenomenon considerably differs from that used in philosophy, theosophy, etc. First, physicians of various specializations (emergency physicians, neurosurgeons and especially neurologists) distinguish two interdependent components of consciousness: the awakened state and awareness. Second, consciousness is regarded as a dynamic indicator of the capacity of the central nervous system. In this connection, prolonged impairment of consciousness is one of the most fearsome syndromes when it accompanies diseases and traumas of the nervous system, since it is indicative of the critical condition of the brain and usually precedes lethal outcome.

Nowadays, significant progress has been made in understanding the nature of consciousness and its essence. In particular, it was found that the awakened state is defined by proper performance of reticular formation of the brainstem, hypothalamus and the basal area of the frontal lobe; whereas the awareness — by frontoparietal associative cortices [3]. Furthermore, two elements of awareness can be differentiated: awareness of the self, controlled by activity of the posterior cingulate gyrus, the precuneus (which has recently been seen as the strategic container of neuronal networks responsible for consciousness), the medial frontal lobe, and the temporoparietal junctions from both sides; and awareness of the environment for which the lateral parts of the frontal and the parietal lobes are responsible [4]. It was established that awareness of the self and the environment are in reverse correlation: focusing on one of them slows down the other (meditation provides the best illustration to this phenomenon) [10]. From neurophysiological perspective, the above—mentioned elements of consciousness are a reflection of the electrical activity of the corresponding neuronal assemblies, whereas the optimal level of awareness is determined by the balanced action of excitatory and inhibitory neurotransmitters on neuroglial networks. The great role belongs to the hold—mode neural networks located in right-handers in the medial prefrontal cortex, the posterior cingulate gyrus (the interior surface of the left hemisphere) and the lateral parietal zone (the exterior surface of the right hemisphere). These networks are most active when no task is present. They are inactive upon performance of goal—directed activities or concentration of attention and are characterized by the coherent neural oscillations with the frequency of less than 0.1 Hz and responsible for the self—talk process and fast spontaneously occurring thoughts [3].

The dynamic character of consciousness is its distinctive feature. Not only the wake—sleep cyclicity is its embodiment, but also the advancement of awareness as a person evolves through accumulation of experience and learning. On the other hand, certain diseases may cause degradation of personality (various types of dementia, acute toxic brain lesions), accompanied by “narrowing of consciousness”. That is why from the angle of clinical practice it is worth considering the consciousness continuum and clinical forms of the consciousness disorder (Fig. 1, 2).

It is clear that this continuum contains both natural forms of consciousness disorders, such as sleep, faint,
narcosis and the potentially unfavorable ones (coma, vegetative state, minimally conscious state).

Despite a wide practical knowledge gathered through managing coma cases, the “vegetative state” as a variant of coma outcome has not been included in the International Statistical Classification of Diseases and Related Health Problems (ICD-10) yet, even though the number of patients with CNS disorders that can be categorized as “vegetative state” is constantly rising all over the world. Moreover, there is a serious confusion of terms and methodological approaches to understanding the pathophysiological nature of this state and determining its clinical hallmarks and objective criteria of the possible outcome. The diagnostic criteria for vegetative state were agreed upon in 1995 at the International Congress on Rehabilitation Medicine, approved in 2001 at the European Congress on Intensive Care in Brussels and have been universally accepted. The term “vegetative state” stands for:

- no evidence of patient’s awareness of the self and the environment;
- no evidence of comprehended, reproducible, purposeful responses to auditory, visual, tactile, or noxious stimuli;
- recovery of the sleep-wake cycle;
- evidence of functional activity of the hypothalamus and the brainstem, sufficient for managing spontaneous breathing and hemodynamics;
- evidence of various cephalic (pupillary, oculocephalic, corneal, oculovestibular, pharyngeal) and spinal reflexes, bowel and bladder incontinence.

Criteria for the transformation of vegetative state into a more favorable clinical condition of the “minimally conscious state” are as follows:

- ability to follow simple commands (pursuit eye movement on request, tongue showing, get/quit the hold, etc.);
- ability to give yes or no responses verbally or with gestures;
- ability to verbalize intelligibly;
- sustained behavioral reactions to the relevant stimuli (appropriate crying or smiling in response to visual or auditory stimuli);
- purposeful reaching for objects, trying to hold them;
- sustained vision fixation and tracking the objects.

The pathophysiologic basis of the vegetative state is progressing Wallerian and transsynaptic degeneration of commissural and association fibers in the brain accompa-
nied by the low-rate cerebral metabolism (according to the PET data, the cerebral metabolic rate in patients with vegetative state is 40–50 % lower than the normal one [11]), which leads to suppression of cortical functions and ascending activating influence of the reticular formation. At the same time, it is clear that impairment of the cerebral metabolism has a zonal character as is observed mainly in bilateral prefrontal cortices and in the parieto-temporal cortex (i.e., zones that are normally most active in the people awake) [12]. It is remarkable that restoration of consciousness is not always accompanied by a significant change in the overall cerebral metabolic rate; what happens in this case is reactivation of the corticothalamocortical circuit as a result of axonal sprouting, restitution of synaptic activity and neuroplasticity-stipulated neurogenesis [6]. The drop in metabolism is caused by ischemia, hypoperfusion and hypoxia of neuroglia; biochemical impairments (misbalance of neurotransmitters and inflammatory mediators); malfunction of the blood—brain barrier and that of the liquid distribution in the brain; and lesions in parenchymatous organs. The area of irreversable changes in glia goes beyond the zone of primary injury (e.g. at TBI or stroke) and affects the zone of secondary injury where neurons are in the state of unstable equilibrium (“molecular contusion”) [2]. The zone of secondary injury is transformed under the influence of pathogenic factors generated in the primary injury zone (transmitter, hypoxic, cytotoxic, vascular and neurogenic circuits), which causes morphological decay of some neurons in this region, since neurons of the secondary injury zone are highly prone to an additional damage.

In the zone of secondary injury, neuroglia functions in a highly specific way characterized by local edema, tissue acidosis and vascular control impairment. Some cells in the zone of secondary injury inevitably die, whereas others survive the critical situation after the decay of the zone of primary injury and restore their original functions. The rest of the neuroglia cell pool has a limited lifespan and low vitality (as a result of incomplete reparation) [2].

Nevertheless, there is no strict correspondence between anatomical brain injury and the clinical picture; it depends on injury site, its magnitude and, most frequently, on the secondary processes taking place around the site (degree of both local and hemispherical cerebrovascular disorder, that of regional and hemispherical edema, causing transversal or axial displacement of the brain, etc.). Thus, S. Toutant et al. reported [22] that among the injured patients being in coma state (GCS score of ≤8) no longer than 2 days with basal cisterns unchanged, the rate of mortality or transition to the vegetative state was 28%: the positive treatment outcomes were observed in 35% of the injured individuals. With basal cisterns compressed, lethal outcome was detected in 46% of patients, whereas the positive outcome — only in 19% of patients. With basal cisterns not visualized, the rate of lethal outcomes or transitions to the vegetative state rose to 79% and the rate of positive outcomes dropped to 11%. When the median line was displaced laterally by at least 15 mm and CT scans showed no basal cisterns, the mortality rate was 100%.

Furthermore, the core trait of the central nervous system is that it makes all functional systems of the body involved in the pathophysiological processes. When the superior regulatory element, CNS, is damaged, extracranial disorders play the role of an additional pathogenic factor aggravating the disintegration and decay of neural tissue. Instability of neurons (mostly in the zone of secondary injury) and the non-cooperative autoregulatory mechanisms of the cerebral blood flow make the former highly perceptive to oscillations of the constitutional hemodynamics parameters. Any additional extracranial factor of any modality is enough to trigger further decay of neural tissue, crucial increase in the intracranial pressure, and general decompensation [3].

In clinical settings, the aforementioned pathophysiological patterns correspond to certain neurophysiological equivalents. EEG of patients in a vegetative state are likely to show a generalized slow wave activity (theta and delta rhythms), sometimes with signs of paroxysms and hemispheric asymmetry [5]. L. Phiroze [19] distinguished three EEG patterns in vegetative patients: diffuse polymorphic activity, alpha coma, theta coma and spindle coma. K. Higashi et al. [8] demonstrated for 47 patients that alpha activity predominated in EEG in 25% of cases. This activity was registered both at suppressed waking and when elements of consciousness were present. In patients who showed no clinical improvements for several years, alpha frequency was observed to increase within 10—13 s. The alpha rhythm akin to the normal one, beta rhythm (tolerant to photostimulation) and isoelectric recordings were recorded rarely (in 5—10% of the injured individuals).

Despite the abovementioned features of bioelectric activity, no distinct correlation between EEG rhythm patterns and the outcome of the vegetative state was found. Only an individual assessment of the specific data using spectral coherence analysis (especially that of functional loads) may allow one to hypothesize on the most probable way in which the particular vegetative patient will progress. Thus, D. Ingvar et al. [9] reported that prominent depression of electrical activity of the brain to the extent of isoelectric silence with no EEG dynamics in response to afferent stimulation was an indication of unfavorable prognosis: all patients with such EEG pattern have died within different time without any clinical improvements.

This fact makes it clear that continuous EEG monitoring is considerably more informative than single registration of the electric activity of the brain, in particular if polysomnography is performed. It has been found that the sleep architecture in vegetative state patients does not significantly differ from that of healthy people with an exception for slow recovery of the REM sleep stage [15]. Having studied the polysomnographic records of patients
with vegetative state induced by injury, a number of authors [12, 21] hypothesized that patients had cognition functioning although they were unable to express it (sleep slow waves of degree 3–4 detected in 85% of the injured indicated partial cortical functioning).

There are various approaches to monitoring the spontaneous and the evoked electrical activity of the brain, among which bispectral index (BIS) monitoring is the most commonly used one. Introduced in the early 1990s, this technique has quickly gained popularity and is nowadays employed in 160 countries, mostly in surgery. Every year more than 3 million cases of general anesthesia are performed using BIS monitoring; about 30% of operating rooms and more than 60% of intensive care units in the USA are equipped with BIS monitors. The magnitude of bispectral index corresponds linearly to the extent of deprivation of patient’s consciousness. Here, the value of 100 is assumed to stand for clear consciousness; 60–80, for superficial sleep, whereas the BIS index of 60–40 is considered to be optimal for performing general anesthesia. In this case the possibility of unnoticed recovery of a patient drops dramatically and is no more than 0.002%.

Auditory stimulation at different frequencies of the minimally conscious patients and healthy volunteers demonstrated that when the modality of the auditory stimulus is changed, the temporal lobe sends the signal to the frontal cortex to estimate its importance and generate the adequate response; having processed the information, the frontal cortex responds to the temporal lobe. The frontal cortex does not respond in vegetative patients [13].

Assessment of somatosensory evoked potentials (SEPs) currently is a widely used method to study the evoked electric activity of the brain, where the cortical component of SEP is regarded as the most responsive and valid index of consciousness restoration. Nevertheless, if the cortical component of SEP at traumatic coma is not registered, it does not mean that recovery is impossible, neither does the normal SEP at the acute hypoxic CNS damage guarantee that hypoxic coma will transform into the vegetative state.

Assessment of the central motor and sensory conduction is a promising trend in neurofunctional monitoring of consciousness. Here, the central sensory conduction is assessed by means of SEP, whereas the motor conduction is assessed by the data of transcranial magnetic stimulation (TMS). A delay in the sensory and the motor conduction is assessed by the data of transcranial magnetic stimulation (TMS). A delay in the sensory and the motor conduction is assessed by means of SEP, whereas the motor conduction nonspecifically indicates worsening of the brain functions during the vegetative state. In particular, total absence of motor response to TMS speaks of heavy damage to the motor cortex or the pyramidal tract, whereas the magnitude decrease and the latency increase in the motor response as well as its polymorphic form is indicative of subcortical lesions. Meanwhile, conduction velocity in the spinal cord, the brachial plexus and the peripheral nerves of such patients does not differ from the normal one.

A vegetative state lasting more than a month is considered persistent; “permanent” (chronic) vegetative state means that consciousness cannot be regained. This division is required to solve various medical, social, economic and legal issues arising in the course of treating such patients [18]. Many of these issues are still challenging even in countries with the well-developed infrastructure of rehabilitation and social security. That is why it is necessary to elaborate an approach to predicting the outcome of vegetative state to allocate patients to different units for performing targeted intensive therapy. Furthermore, it is important to study the vegetative state to understand the fundamental problems related to integrative brain activity, which maintains consciousness, cognitive functions and mechanisms of sanogenetic recovery (adaptive neuroplasticity) after a severe brain injury [1].

It is well known that a certain share of vegetative patients regain consciousness after some time. Since no treatment procedure with scientifically proved effectiveness is currently available, one can say that patients spontaneously regain consciousness when provided adequate care and nutrition. Which patient and when will recover is a question that has no answer; so one is only left to wait and hope. B. Jenett, who coined the term “vegetative state” in his same-titled study published in 2003, comments on the expected time of recovery for the vegetative patients with “…when the time comes”.

The only plausible explanation to this fact is that regaining consciousness in pathological state is stipulated by the capability of the patient’s body to reconstruct natural architectonics of the neural assemblies and impulse circulation within the reorganized network. Neuroplasticity is the trait responsible for these compensatory processes.

Brain neuroplasticity is a set of various processes of remodeling synaptic connections focused on the enhancement of performance of the neural networks. Neuroplasticity has the key role in the following processes:

— phylogensis;
— ontogenesis; new synaptic connections established through learning and already formed neural network require maintenance provided by the so-called natural neuroplasticity;
— recovery of the lost functions after the impairment of the peripheral and central nervous system provided by the so-called post-traumatic/post-stroke neuroplasticity.

Numerous experiments carried out on animals over the past two decades showed that functional organization of the neural structure of the brain is prone to fine adjustment through learning, as well as via nervous system impairment [2, 11]. Alteration of the structure of somatosensory cortices was studied under peripheral sensory loss, such as deafferentation caused by local anesthesia, tracheotomy or ligation of peripheral nerves or amputation. In these cases, the area of the cortex corresponding to the damaged skin receptive field became responsive to stimuli from the adjacent sensory sites, whereas the functional
area of the cortex neighboring deprived area expanded at the expense of the former [10]. If this process is acute, i.e. if it progresses within a few minutes, it is most likely caused by activation of “silent” intracortical connections. Such reorganization could be: a) reversible, which casts doubts on its adaptive value, b) lasting for about an hour; c) enhancing due to remodeling of neuronal formations in further months. Similar changes were observed in the primary motor cortex (M1) in patients with lesions of the peripheral nerves when cortical areas adjacent to the somatotopic zone corresponding to the injured part of the body were expanded. It was revealed that after the injury of the primary somatosensory area, the lost cortical representations relocate both to the adjacent and to the remote cortical fields. Thus, in monkeys after cerebral apoplexy with damage to the cortical field 3b, the central projection corresponding to tips of fingers (which are of great importance in behavioral patterns of primates) relocated to a new site of the field 3b. Moreover, it was discovered that in monkeys trained to reacquire sensorimotor skills, cortical representation of fingertips was recorded in the field 1, whereas the projection of cutaneous sensitivity of fingertips emerged in the field 3a, even though these zones had formerly been excited only by proprioceptive inputs, which proves the post-stroke neuroplasticity that is adjusted during rehabilitation [23].

Processes akin to the aforedescribed one have been observed upon lesions of the motor cortex. Thus, soon after the formation of the apoplexy site in the M1 cortical zone responsible for hand movements in monkeys, representation of the hand was found in the cortex to the center of the pathological site in the zone where the elbow and shoulder representations used to be located [20]. A special role of this newly formed representation was proved by its reversible inactivation using GABA-agonist, muscimol. In doing so, the authors observed sudden deprivation of purposeful movements in the opposite hand, whereas in the normal hand no changes were detected. On the contrary, inactivation of the premotor cortex and both supplementary motor areas on the same side with the lesion was not followed by any change in the movement pattern. Following the formation of the similar site in the M1 cortex of adult monkeys, inactivation of the premotor cortex on the same side with lesion was found to favor deprivation of the restored praxic functions in the normal hand allowing one to assume that the mechanisms underlying the post-stroke neuroplasticity vary depending on time parameters [14].

Experiments on animals showed that mastering motor skills in accordance with intensity broadens the area of cortical representation of the employed muscles. It has also been shown that after local damage to the M1 cortex, certain rehabilitation measures (e.g., forced treatment) are capable of reorganizing neural structure of the intact cortex adjacent to the damaged site [17]. This rearrangement possibly plays an important role in regaining motor functions by recruiting formations of the intact cortex.

Hypotheses introduced to explain the neuroplasticity phenomenon concerned both the ultrastructural and synaptic levels. Primary (natural) neuroplasticity takes places at several stages of the body evolution: a) during cyto- and histogenesis in the course of proliferation and specialization of dendrites and axons; b) during cell migration, differentiation and synaptogenesis; c) during the formation of neural networks, which is accompanied by apoptosis, axonal regression, degradation of cells and synapses. The latter stage allows for eliminating the excessive neural associations, which improves specificity of each neural network, especially via repetitive training (according to the Hebb’s concept), and thus strengthens neuroplasticity of the entire system [7].

The mechanisms of stabilization of synapses, especially those that control activity of α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptor (AMPA-receptor), underly “homeostatic” neuroplasticity, the most important Hebbian component of the common neuroplasticity regulation. Synchronism is one of the essential factors stipulating the optimal performance of the neural network components. Thus, in order to rearrange the structure of the cortical representation of auditory analyzer, the absolute synchronization between the time parameters of electrical stimulation of the basal ganglia and the auditory stimuli is needed. Neuroplasticity can be viewed as a change in activity of isolated neurons, synapses and time parameters within the systems of interacting neurons. It is possible that a combination of these mechanisms allows for control of consciousness recovery by rearranging the existing neural networks and developing new ones.

All these facts show how important it is to study the problem of origins and progression of the vegetative state. Knowing how to handle the application aspects of this issue will allow one to predict the possibility of consciousness recovery in vegetative patients and to develop devices for monitoring the efficiency of the used treatment and, finally, to get closer to understanding of the mechanisms of consciousness recovery.

Apparently, the half of coma cases with ensuing vegetative state are caused by TBI, which allows us to consider this ethiopathogenetic form of disorder of consciousness one of the best models to study its morphological and functional essence due to the fact that TBI pathogenesis has been studied considerably well. In particular, it has been proved that the clinical presentation of TBI lies, on the one hand, on morphological (diffuse axonal injury of subcortical white matter, necrotic changes in the cortex and thalamus) and functional (diaschisis) disorders, while on the other hand, sanogenetic processes occurring as a component of neuroplasticity.

The objective of the present study was to investigate the clinical and neurophysiological markers of consciousness recovery in 25 patients (aged 28—54 years) in vegetative state after severe TBI by comparing the dynamics of clinical changes and the electrical activity of the brain.
In all patients, we evaluated the neurological status, the Glasgow Coma Scale (GCS) score; performed electroencephalography (EEG) and analyzed spectral coherence; registered and analyzed somatosensory evoked potentials; studied motor thresholds and amplitude-time characteristics of the motor potentials evoked in the course of transcranial magnetic stimulation; repeatedly carried out MRI or CT.

EEG was recorded from 16 leads (10/20 scheme) using silver-chloride electrodes. The setting for the low-pass filter was 0.5 Hz, while that for the high-pass filter was 70 Hz. In order to obtain the main rhythms (alpha, beta, theta and delta) without distortion, the EEG sampling frequency was 256 Hz. After recording, we analyzed the spectral coherence of the data.

Somatosensory evoked potentials were recorded at stimulation of the median nerves by electrical impulses with duration of 0.2 ms, frequency of 3–5 Hz, and the current intensity of 10–15 mA using low frequency filter of 70 Hz and the high frequency one of 3 kHz. The analysis time was 50 ms at averaging 1000 responses in two sessions. We calculated the amplitude and latency of the cortical component P23 and the central sensory conduction time.

In order to assess the central motor conduction, we evaluated motor thresholds as follows: first, we checked out the best position of coil at which the evoked motor potentials generated at the side opposite to TMS had the highest amplitude and the minimal latency; calculated the thresholds causing motor response by increasing or decreasing TMS intensity with increment of 5%. Next, we analyzed the evoked motor potentials by placing the coil above the motor cortex of the right or the left hemisphere with frequency band comprising 30–3000 Hz; there were 4 averaging sessions, the averaged interval was to 150 ms.

As far as the neurological status of the examined patients is concerned, we detected the absence of cognitive functions, unawareness of the self and the lack of ability to interact with the environment. The patients could not fix their eyes and lacked speech and signs of understanding it. Meanwhile, the chaotic sequence in the sleep-wake cycle was observed. A total of 20 patients demonstrated persistent decerebrate and decorticate postures. All patients missed purposive efforts to reproduce behavioral responses to visual, auditory, tactile and nociceptive stimuli; along with that, they demonstrated excessive elementary movements (chewing, sucking and grabbing). A total of 18 patients showed significant trophic changes (bad sores), but kept intact autonomous hypothalamus and brainstem functions responsible for cardiac function and blood pressure. The average GCS score was 6.5.

The most often rhythmic activity recorded in EEG of the vegetative patients were theta and delta ones (20 patients); signs of paroxysm and hemispheric asymmetry (2 patients) or low-amplitude EEG (3 patients) were observed rarely. Interhemispheric connectivity was analyzed by calculating the interelectrode coherence between the frontal, temporal, central, parietal and occipital leads in the delta and theta range. Analysis of interhemispheric coherence revealed the delta range to contain extremely high values exceeding 90% (the highest values were recorded in the posterior parts of hemispheres). Analysis of the average interhemispheric coherence in the theta range demonstrated low values in the anterior, middle and posterior portions (the average values did not reach 60%). With functional loads applied, 10 patients showed an increased interhemispheric coherence within the range of 5–10 Hz, although these changes were not clearly zone-specific.

When studying SEP, upon stimulation of the right and the left median nerves, we managed to obtain peaks N19 and P23 in only 15 people. In all these patients, the amplitude-time parameters of the short-latency SEP indicated the increase in latency (21–27 ms) and the central sensory conduction time (8 ms), while P23 amplitudes decreased (0.2 μV).

Similar changes were observed in the study of the central motor conduction. Most patients showed a sudden decrease in the statistically average amplitude of motor responses (0.10–0.15 μV) at TMS of both the right and left hemispheres. An analysis of the time parameters revealed an increase in both latency (30–35 ms) and the central motor conduction (15–18 ms).

In order to assess the possibility of the clinical use of “prospective stimulators” of neuroplasticity to recover vegetative patients, they were divided into two equal groups. The first group of 12 people received therapeutic TMS sessions along with symptomatic treatment (15 mg of Neiromidin daily, administrated intramuscularly) during a month. TMS was performed daily over the prefrontal cortex and the brainstem with field density of more than 1.2 T; the impulse length of 0.2 ms and the frequency of 0.5–15 Hz). The second group of 13 people received only symptomatic treatment.

It has been found that the reliable positive changes in amplitude-time parameters of the multimodal evoked potentials, a reliable decrease in motor thresholds mostly in the left hemisphere and an increase in the amplitude of motor evoked potentials preceded clinical improvement by 5–7 days and were the most evident in patients from the first group. In particular, analysis of spectral coherence of EEG of patients from the first group indicated positive changes in electrical activity of the brain manifested as an increase in the main rhythm frequency and enhancement of the inter- and intrahemispheric connectivity. Interhemispheric coherence in the theta range responded most significantly to various afferent stimuli and photostimulation. Changes induced by verbal stimulation were observed mainly in the anterior and the middle parts, whereas those induced by visual stimuli were detected in the posterior parts. Similar statistically significant positive changes were detected for the central sensory and motor conduction mostly in first group patients.
Thus, the vegetative state is characterized by the absence of spontaneous mental activity (decortication) caused by extensive lesions (diffuse axonal injury) or subcortical dysfunction (akin to the long-term depression) with retained reflexes of diencephalon and brainstem, maintaining the sleep-wake cycle. According to our data, after 6 months in the vegetative state, patient’s chances of recovery drop dramatically due to the progression of necrobiosis in various neuroglia formations responsible for neuroplasticity. That is why time is the most important factor in treatment of such patients, whereas timely neurophysiological monitoring, neuroplasticity-stimulating therapy and proper prognosis of the disease progress are vital during the entire follow-up period.

The phenomenon of structural and functional disintegration between hemispheres and associative cortical centers underlying disorders of the consciousness presumably breaks the biological patterns of the projection of intracerebral impulses onto the cortex (in accordance with the Pavlov’s theory). Despite the multiple variants of primary CNS injury that causes vegetative state, the similarity of the clinical picture in different patients is obvious, which proves the fact that there are common pathophysiological mechanisms of the loss and recovery of consciousness. Determining these mechanisms will make it possible to advance treatment methods (medication, remedial gymnastics, physiotherapy, audio therapy), which are currently confined to care and proper nutrition of patients.

REFERENCES


Commentary

The present article reflects the modern medical approach to the analysis of consciousness and provides notion on its components (the awakened state, awareness of the self and the environment). The international criteria of vegetative state and those of transition into the minimal conscious state are given. Pathophysiological patterns of the aforementioned states and their neurophysiologic manifestations are considered. In authors’ opinion, the basis of consciousness recovery is the feature of nervous system known as neuroplasticity that has been actively studied in the past few years. In the present work, this term stands for sanogenetic mechanisms that start working in survived patients after brain injury. However, to be consistent, one should remember that neuroplasticity not only can be of sanogenetic character, but of pathogenetic as well, thus leading to a pathological dominating site that clinically manifests itself in persistent pathological state. Taking this fact into account, stimulation of neuroplasticity may not only lead to regaining consciousness, but hinder it as well. From
this point of view, conclusions of the authors’ research suggesting TMS and administration of Neiromodin to stimulate neuroplasticity must be reviewed more thoroughly and critically. Merely stating the fact that these measures cause positive changes in the evoked electrical activity and enhancement 5—7 days before the clinical picture improves appears insufficient. The attempt to compare groups that underwent successful and unsuccessful therapy and to figure out possible predictors of its efficacy would have been more enlightening. The future of the vegetative state treatment seems to lie in the personalized approach to each patient. For instance, the thesis research of E.V. Aleksandrova (2013) demonstrated that Neiromidin is effective in patients with signs of cholinergic deprivation (weakening of tonus and tendon reflexes), whereas amantadine sulfate (Mertz), in patients with glutamatergic excess (increased tonus and hyperreflexia). The therapy carried out without allowance for these individual traits is considerably less effective (by almost 2 times).

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It is known from philosophical literature that the cognitive process has three components: a method for obtaining the information, its quality and quantity, as well as the way of using the information. In this report, we discuss only the first factor, in particular, the method of cognition. When applied to medicine, the methods for obtaining information are usually regarded as two mutually exclusive groups. The first group comprises the scientific, logical, trendy and modern methods, while the second one includes the empirical, intuitive, traditional and outdated methods. The triumphal march of evidence-based medicine in the past two decades is an unstrained celebration of the first group and undeserved detraction of the second one. Meanwhile, the increased level of evidence in its formal sense inevitably alienates us from treating a particular patient and from the personalized therapy (see Figure).

The personalized, evidence-based treatment predicted by the geneticists will appear only in the far future. Furthermore, this approach will not be able to resolve all the complex clinical problems that inevitably arise as a result of dysfunctions associated with a brain damage.

The complete strikethrough of both medical experience and heuristic knowledge in therapeutic activities may lead to a situation when there will be nothing to prove, since unproved treatment methods will be rejected right away, and so we will have no chances to help the patients in these circumstances. In pharmacotherapy, the most recognized discoveries have been made using the heuristic approach rather than the evidence-based medicine one. Moreover, many of the first drugs, which belong to various pharmacological groups, have been borrowed from other areas of medicine. For example, the first antipsychotic drug (chlorpromazine, a phenothiazine derivative) was taken from the anesthetic practice; the first antidepressant (iproniazid, monoamine oxidase inhibitor (MAOI)) was borrowed from the phthisiatric practice, while the first anti-anxiety drug (meprobamate) was adopted from arthrology. The first tricyclic antidepressant (imipramine) and nootropic (piracetam) agents were developed as the antipsychotic and antidyskinetic drugs, respectively. Thus, only the empirical approach allowed these drugs to have found their place in clinical practice.

In the 1990s, the researchers from McMaster's University of Toronto started using the term “evidence-based medicine” (EBM). The background for the emergence of EBM was serious. With the technological advance, physicians have been flooded with information from which patients had to be protected. This idea was shocking in its novelty and prospects. Finally, the patient took a chance to get the most advanced medical care level without being afraid of becoming a victim of medical errors by an inexperienced physician. The methodology of the evidence-based research has been developed; clear criteria for quality of the obtained information have been established; and the main objectives of research have been scheduled as well as some legislation acts have been approved. For two decades, the entire medical community has been bombarded with the ideas of the apologists of this approach and the authors of this article have been among them. This work has yielded its results. Today, every educated person in our civilization knows that the patient cannot be treated by the methods that have not passed

**The Evidence-based Neurointensive Care: What's Next?**

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The work is devoted to the analysis of modern trends in the process of cognition in neurointensive care. In particular, the emergence and development of the method of “evidence-based medicine” in the treatment of patients with diseases and injuries of the brain were thoroughly analyzed. The positive features of the method were demonstrated. However, the authors focused on the limitations of the evidence-based approach, the main of which are the lack of an individualized treatment plan and the paucity of data obtained from randomized controlled trials. The authors propose to combine the “evidence” data and the “classical style” of treatment, which involves individual clinical judgment based on knowledge of the pathophysiology and pathomorphology, intelligent use of technology, retrospective analysis of the beneficial and adverse effects of certain methods, creation of a special data bank of the “natural” course of events, and development of an individual prognostic model. The authors believe that the use of standards is more appropriate during acute illness and trauma, while the classic style is better for chronic situations.

**Keywords:** evidence-based medicine, neurointensive care, therapy standards, personalized medicine.
Evidence-based medicine: the increasing quality of the evidence is inversely proportional to treatment personification.

through the selection of evidence-based medicine. The use of these methods is also unethical, unprofessional, as well as non-modern. This point of view has become so obvious that any distrust in the idea of evidence-based methods cannot be accepted.

However, the life makes its changes. And now, one of the brightest speakers, defender of the evidence-based idea, a brilliant scientist and medicine popularizer Jean-Louis Vincent [4] wrote, “at least nine out of ten treatments that we currently use in medicine have not been proved in terms of evidence-based medicine”. Why have they been not? It is because “70—80% of the already conducted multicenter clinical trials have been finished with the absence of any practical result”. We should think how much effort and money have been spent with no results. Furthermore, among those that have been finished effectively, “eight out of ten trials have demonstrated that the treatment was dangerous to be applied”.

Jean-Louis Vincent wrote it in 2004. Back in 1993, J. Moller et al. [3] published a research where they demonstrated on 20,802 surgical patients that the use of pulse oximetry did not reduce the overall mortality in the operating room (OR) and post-anesthesia care unit (PACU). The authors examined over 20,000 patients and found no benefit from the assessment of arterial oxygenation. Unfortunately, the scientific community has not taken this fact seriously. The format of this communication does not allow us to provide other typical examples. However, we think that their number is more than enough to understand the simple fact that the “evidence-based medicine will not save the world” at least in the next 50 years, when the era of P4 medicine will begin. The concept of P4 medicine was proposed by L. Hood [2] based on the individual genome sequences information. P4 medicine can be characterized by the following words: predictive, personalized, preventive, and participatory. In the meantime, we will be forced to treat patients without enough scientifically proved data.

This also applies to neurointensive care, in which only two facts concerning severe traumatic brain injury (TBI) have been definitely proved. These facts include the ineffective corticosteroid treatment and the risk of prophylactic hyperventilation. The expediency of such commonly used methods as conducting pulmonary ventilation and monitoring intracranial pressure have not been proven. Moreover, such parameters as the optimal levels of blood pressure, intracranial pressure, arterial blood oxygenation in different periods of disease and brain injury, have not been clearly defined yet. How is it possible that the most popular methods applied are not evidence-based?

The reason behind this lies in limitations of the evidence-based approach, which are inherent to it by definition. The main reasons include:
— complexity;
— the high cost;
— time expenditures;
— problems of comparing the results obtained in different hospitals;
— problem of comparability of the conditions of the patients surveyed in a multicenter study and in one’s own clinical practice.

Another important problem is the lack of clear definitions. If we give a very wide interpretation to a syndrome studied or a phenomenon observed, we do not obtain any results because of the absence of selected pa-
tients in a single phase of the disease, thus there are different types of etiology, etc. An illustration to this is the numerous useless attempts to evaluate the efficiency of treating sepsis and respiratory distress syndrome. On the other hand, when using a very narrow interpretation of the syndrome, we are at risk of not conducting an evidence-based research due to the inability to recruit a sufficient number of patients.

Verification of the treatment efficacy is another important issue for ethical reasons. The high efficiency of unusual administration of antibiotics (e.g., intrathecal injection) has been known from neurointensive care practice. However, there is no evidence basis for this treatment method, and physicians prefer to conceal it.

There are additional restrictions for treating comatose patients. First of all, it is the regredient nature of post-coma recovery. As a result, it is often impossible to distinguish between the effects of drugs and the spontaneous recovery. Additionally, there are many different neuro-resuscitative, neuro-surgical, and rehabilitative methods that prevent obtaining clear evidence-based evaluations. So it is rather difficult to understand why the patient’s condition has improved or worsened. Another important factor is the insufficient knowledge about the recovery process after severe injuries or brain diseases (the multifactor nature of prediction). This circumstance significantly affects the uniformity and comparability of the data for patients from the study and control groups.

The established medical traditions are the last but not least factor. Both physician’s confidence about the pharmacological agents and the lack of it impedes conducting randomized clinical trials (RCTs). In the former case, the physician sees the result of treatment even if there is none (this effect is known as the placebo effect). In the latter case, the physician does not see any treatment result even if it is obvious, or believes in non-pharmacological and/or other factors why the patients’ condition has improved (the nocebo effect).

What is the way out of this impasse? Only one fact is undeniable: the patient needs be treated. And in this case, we have to remember and rely upon the experience proved by long-term critical tradition. The “classical style” of treatment has always meant an individual clinical assessment that is based on the knowledge of the pathophysiology and pathomorphology, as well as the reasonable use of technology. In neurointensive care, it is the non-invasive and invasive hemodynamic and respiratory monitoring, neuromonitoring and computed tomography, as well as ultrasound methods. This allows one to establish feedback from patients, i.e. to monitor the changes in the patient’s condition during treatment. Based on this analysis, one should make decisions about the effective and ineffective treatments for each patient.

In addition, the “classical style” concept of clinical reasoning includes the following approaches:

— retrospective analysis of the beneficial and adverse effects of a method, including the use of a particular drug;
— creation of a special database of the “natural” course of events;
— development of a personalized prognostic model.

Returning to the evidence-based medicine, one should emphasize that the use of the “standards” and “proved” methods also requires experience, a lack of which may eliminate all the benefits of their use.

The combination of the conventional approaches and randomized clinical trials allows one to make a personalized treatment program. Based on the methodology developed at the N.N. Burdenko Neurological Institute, we have proposed the concept of pharmacological support for coma recovery [1]. This method will make it easier to prescribe the medication that either have or do not have the evidence base for their use in different clinical situations.

Joint neurointensive care and neuropsychiatric management of patients has shown that the “classical style” methods should be preferred in an emergency case under time pressure, while more options should be used in the case of protracted or chronic syndromes (including those suggested by the reasonable clinical experience).

Thus, neurointensive care that intelligently combines the “evidence-based” and the “classical” approaches is the next stage of neurointensive care.

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The problem described in this paper is highly relevant, since, having “satiated” with the principles of evidence-based medicine, the researchers do not want to accept the fact that some aspects of their activities are not recognized as effective and acceptable. In this regard, I have already made reports that had the same titles but were slightly different in their essence. This is probably the eternal dispute similar to the discussion between “Bavaria” and “Barcelona” football teams. In other words, is the general medicine and neurointensive care in particular a technology or art?

In fact, it is difficult to dispute over the use of evidence-based therapy. First of all, it is the double protection: the patients are protected from physicians’ “voluntarism”, as well as the physicians are protected against lawsuits through the strict treatment protocols. We have to pay attention to the fact how many “relics” have been eliminated from medical practice, which had a positive effect on the results of medical activity (such as the use of saluretics and the discovery of novel neuroprotective agents).

On the other hand, rigid standards can completely deprive the important component of treating any patient, the person-centeredness. Mentioning the risk of “prophylactic hyperventilation” might be a good example, since when we use this method to control intracranial pressure in each individual case, we have to find an answer to the following questions: why, whom, when and how long?

The main problem seems to be formulated as inadequate use of this approach with the unusual randomization patients rather than implementing the principles of evidence-based medicine. In other words, I agree with the authors that in order to obtain positive results, time-consuming and comparable research criteria (such as severity of injury, severity of the condition, levels of intracranial pressure, etc.) are to be considered. The combination of traumatic brain injury patients with the Glasgow Coma Scale (GCS) score from 3 to 8 into one research trial can only discredit the benefits of any multicenter studies.

What can be the way out of this dilemma? The benefit of any novel approach can be justified only when the basic treatment principles are implemented, which are common for most recommended protocols already including the principles of evidence-based medicine. Thus, the answer to the first question is the clear understanding of the most common rules. Next, it is the differentiated approach of our national medical schools to evaluate the severity of each individual patient, and then to clarify the indications and contraindications for using the personified intensive therapy in each clinical case. I believe that the subsequent evaluation of the studies, which have more than 20 inclusion or exclusion criteria, will help us to stand back on the way of “evidence-based medicine”.

This article is certainly useful for persons who are not satisfied with the results of treatment in neurointensive care, the rather complex medical area.

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Productive Mental Disorders in Post-Traumatic Disorders of Consciousness

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Productive mental disorders (PMD) are the result of pathological mental activity. Alongside with deficit disorders, PMD are the main characteristics of post-traumatic disorders of consciousness. PMD can be represented by different types of excitation, mistaken judgments (including paranoid ones, confabulations, false orientation), false perception (psychosensory, in particular, illusory and hallucinatory phenomena) and affective disorders. Occurrence and signs of PMD and their consequences were examined in 417 patients with brain injuries. It was found that occurrence of PMD in clear consciousness (in form of delirium, confusion, etc.) is often a sign of deterioration of cerebral and/or somatic status requiring urgent diagnostic and therapeutic measures. In another situation with PMD being revealed during emergence from coma, they are regarded as a prognostically favorable sign and require some correction only in case of long-term (more than 1—3 weeks) course. It was determined that PMD are characterized by: a) a gradual (after emergence from unconsciousness) aggravation and complications of clinical symptoms up to the moment when orientation in the environment is recovered; partial or complete regression of disorders can occur subsequently; b) the highest frequency and intensity with prevailed signs of dysfunction of any of the cerebral hemispheres and the lowest frequency in case of relatively symmetric bilateral and profound brain damage; c) the maximum variability and severity in adult patients (compared with children and individuals over 61 years of age). Irritation of different brain structures and their dissimulation, as well as pathological neuroplasticity in prolonged forms, may cause PMD occurrence.

Keywords: mental disorders, traumatic brain injury, consciousness recovery.

Consciousness disorder and recovery are the crucial clinical events in acute period of brain traumatic injury.

These events have been being studied for many years. In 1861, a German psychiatrist W. Griesinger [8] had already defined traumatic psychosis as an intermediate state between unconsciousness and clear consciousness and attributed productive to dissociation, that is, revival of different brain centers differing in time. In 1884, J. Jackson [9] found what underlay mental disorders caused by brain injuries in both “diffuse and focal dissolution”; he considered productive symptoms to be an “expression of activity of neural elements located within the lowest evolution levels that have not been affected by the pathological process”.

Current scientific literature is disproportional: studies on depressed consciousness (obtundation, semiconsciousness, and coma) considerably prevail over a relatively few studies on disintegrated consciousness syndromes (mental cloudiness and confusion).

However, successful treatment of a traumatic brain injury and prediction of its outcome needs appropriate understanding and assessment of all kinds of disordered consciousness syndromes. In contrast to depressed consciousness with deficit disorders (that is, the absence of the main signs of consciousness: vigilance, spontaneity, concentration, contact, etc.), syndromes of disintegrated consciousness must include the so-called productive mental disorders, which are a pathological result of mental activity disturbed by a disease that is available only provided that there is a certain balance between the preserved and lost functions. Productive disorders following a traumatic brain injury include various excitation states, mistaken judgments (including delusion, confabulations, and false orientation), false perception (psychosensory, including psychalias), and affective disorders.

K. Jaspers’ diagnostic criteria [10], which are a century old but still remain topical, can be applied to the syndromes of the disintegrated state:

1) distancing from reality (Abkehr), fragmentary and poor understanding of reality (up to lack of understanding); 2) disorientation: allopsychic (in the environment) and autopsychic (in one’s own personality); 3) incoherence in all mental processes (not only in thought and speech but in behavior and emotions as well); 4) lack of memorizing and total or partial amnesia during the psychosis period.

No common approach to classification of the syndromes of posttraumatic disintegrated consciousness is currently available. This situation can be mainly explained as follows: the researchers snap single clinic manifestations (e.g., agitation) from the clinical context and this inevitably leads to mixing of the syndromes that have different nature and manifestations (e.g., delirium and confusion) [7]. A differential diagnosis between the main kinds of disintegrated consciousness is presented only in a few psychiatric guidelines [6]; however, it also should be specified with respect to a certain clinical situation caused by a brain traumatic injury.

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Table shows an attempt at summarizing the clinical experience of the Group of Psychiatric Researchers of the N.N. Burdenko Neurosurgical Institute in examining patients with disintegrated consciousness.

In addition to determining clinical kinds of productive mental disorders, it would be reasonable to discriminate between the underlying pathogenic mechanisms: intoxication (presented mainly by delirium), disintegrative (presented mainly by confusion), epileptic (mainly, by twilight and automatisms), endogenous (mainly, by oneiroid), and stress-induced mechanisms (mainly, by affectively narrowed consciousness with hysteroidal signs).

Prevalent affection of a certain brain hemisphere also contributes to clinical signs of the examined pathology: twilights, automatisms, and speech-motor confusion are more usual upon injury of the left brain hemisphere, while oneiroids and amnestic-confabulatory confusion are more common upon injury of the right one [4].

Probability of productive disorders, along with their structure and prognosis, and consequences of traumatic brain injuries were the subject of own studies performed on 417 surgical patients.

The occurrence of the productive disorders (in form of delirium, twilight state, and confusion) in patients with clear consciousness is a common sign of aggravation of the mental and/or somatic status; therefore it requires urgent diagnostic and therapeutic measures. In other situations, when productive disorders occur at emergence from coma, they typically are a prognostically favorable sign and need correction only in case of the long-term (over 1—3 weeks) course.

Confused consciousness is the most common sign of severe brain traumatic injury, while productive disorders are detected in 79% of the cases and include motion, speech motor, and psychomotor agitations, confabulations, oneiroid, hallucinatory and delusion-like emotions.

Productive disorders as a part of the structure of consciousness disorders have the following typical features:

a) gradual (according to the emergence from unconsciousness) growth and complication of the clinical presentation up to the moment when orientation in environment is recovered; subsequent partial or total regression is possible;

b) maximum frequency and intensity when the injury signs prevail in one brain hemisphere, and the minimum ones when the depth brain injury is relatively symmetrical and bilateral;

c) maximum variability and expansion in middle-aged patients (compared with children and individuals over 60 years of age) [3, 5].

Both excitation and disintegration of various brain structures may underlie productive disorders [2]. Thus, interaction of the posterior areas of hemispheres and disintegration in frontal areas are typical of posttraumatic Korsakoff’s syndrome.

One of the important components in the pathogenesis of productive is neuromediator dysfunctions, in particular, those caused not only by relative dopaminergic excess and/or cholinergic deficiency but by catecholamine dissociation as well, or, to be more accurate, desynchronization (differently directed changes in dopamine and noradrenalin concentrations) [1].

Lack of current standards for care delivery for patients with productive consciousness disorders caused by traumatic brain injury [5] inspired the authors to elaborate an empiric algorithm for treating the states discussed in the article:

1. To determine and eliminate or weaken, if possible, the causes (including the elementary [pain and thirst] and special ones [plasma hyperosmolarity, progressive hypoxemia, initial hypercarnia, neuromediator disproportions, etc.]).

2. To ensure physical security of a patient and others (including retention and fixation, if necessary).

3. To treat a patient in a calming, kindly, and respectful manner.

4. To choose a main (initial) drug depending on a syndrome: neumoremetabolics (Noophen, Neuromidin, Cortexin); less frequently, benzodiazepines (Clonazepam, Diazepam) for patients with delirium and consciousness confusion; neuroleptics (Rispolept and Zyprexa) for patients with oneiroid, and antiepileptic agents

<table>
<thead>
<tr>
<th>Clinical sign</th>
<th>Delirium</th>
<th>Oneiroid</th>
<th>Twilight state</th>
<th>Confusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disorientation</td>
<td>In time or place</td>
<td>In environment, one’s own personality; often double orientation</td>
<td>Determined indirectly according to behavior</td>
<td>Peak (if not determined) — total</td>
</tr>
<tr>
<td>Perception disorders</td>
<td>True oculauditory illusions and psychalasias</td>
<td>Fantastic hypnoid, often pseudohallucinatory images</td>
<td>Rare, fragmentary determined only by outward signs</td>
<td>Poor, fragmentary; “life in the past” for some types of disorders</td>
</tr>
<tr>
<td>Delusion</td>
<td>Unstable, secondary with respect to false perceptions</td>
<td>Ideas of grandeur, outside influence, “the battle between Good and evil”</td>
<td>Ideas of persecution expected</td>
<td>Separate delirious delusion-like propositions</td>
</tr>
<tr>
<td>Emotions, prevailing affect</td>
<td>Anxiety, fear</td>
<td>Admiration, “charmedness”</td>
<td>Absence or dysphoria</td>
<td>Absence or perplexity, frequent alterations</td>
</tr>
<tr>
<td>Amnesia</td>
<td>Partial</td>
<td>Partial</td>
<td>Total</td>
<td>Total</td>
</tr>
</tbody>
</table>
(Depakine and Keppra) for patients with twilight consciousness disorder.

5. To prefer the safest drugs (e.g., if choosing from neuroleptics, the atypical ones: Seroquel, Zyprexa, and Risperdol instead of the most efficient ones (such as Haloperidolum and Azaleptin) that have the highest risk of adverse effects).

6. To wait until the main therapeutic effect, and to increase the dose, add “stronger” drugs, or combine drugs from various groups only if there is no therapeutic effect.

Further thorough studies of productive disorders caused by traumatic brain injury and development of scientifically grounded recommendations on their arrest are obviously necessary.

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Commentary

Diagnosis of mental disorders is topical in spite the fact that is has the over two-century history. The currently held Congress of American Psychiatric Association is expected to approve the diagnostic criteria of psychical and behavioral disorders within DSM-V; a similar section of the ICD-11 is being actively developed and is expected to be approved in 2015. However, the researchers are far from being unanimous in most of the analyzed issues. Taking into account the actual circumstances, the author’s interest in the problem analyzed in the article is rather reasonable and topical.

The so-called dimensional approach, which is based on the concept of independence of several clinical sign groups (values or dimensions) determined using mathematical analysis, is becoming more popular in diagnosis of mental disorders and in psychiatry in general. According to the categorical approach, the analysis is performed by determining the most common parameters and correlations between different disease signs (the clinicopatological analysis).

Although the dimensional approach has several advantages (it is possible to easily identify the diagnosed signs and objectify them; the diagnosis is highly unified and reproducible), clinicopsyhopathological analysis remains rather popular (especially in our country) in everyday clinical practice.

The author reviews the problem from the phenomenological positions. The article consists of literature analysis (including a historical aspect), description of the long-term own (and to a large extent unique) research and practical experience, and analysis of vast clinical data (417 surgical patients with traumatic brain injuries and consequences of the injuries). The differential and diagnostic criteria of cloudiness syndrome are reported. An analysis of clinical and dynamic parameters of the development of productive disorders in the structure of mental disorders and the empirical algorithm for treating these states are presented.

The results and conclusions are undoubtedly of interest and have considerable scientific and practical value.

A.B. Shmukler (Moscow, Russia)
Severe traumatic brain injury remains one of the main causes of severe disabilities in children. The state of cognitive functions, which largely determines the quality of a child’s life after a brain injury, is one of the significant parameters used to assess the outcomes of severe traumatic brain injuries [1]. Early identification of the disorder the higher mental function allows one to develop rehabilitation programs and to increase intervention effectiveness. The current concepts of neurorehabilitation with emphasis placed on early intervention impose absolutely new requirements both on instrumentation of neuropsychological assessment and on techniques of neuropsychological recovery training.

A conventional neuropsychological examination aimed at finding the mechanisms of disorders in certain mental processes implies verbal contact with patients. Neuropsychological work with a child experiencing long-term depression of consciousness has different aims: assessment of the dynamics of consciousness recovery with early neuropsychological diagnosis and early identification of the features in disorders of mental processes and consciousness generally to elaborate techniques for targeted neuropsychological recovery training. A.R. Luria has proposed the structural–functional model of brain activity, in which the brain is regarded as a substrate for mental processes (see Figure). The model separates the brain into three units: the first unit is the energy-related unit responsible for nonspecific activation; the second unit is associated with reception and processing of exteroceptive information; while the third one is responsible for programming, regulation, and control of the complex forms of mental activity, which control certain types of mental activity and execute behavioral programming [11, 12]. Severe traumatic brain injury with focal and diffuse brain lesions can lead to a situation when all three functional units of the brain are injured to a certain extent. Hence, a path of recovery and the contribution of each unit to consciousness recovery are the most significant issues. Normalization of the sleep—wake cycle, along with self-awakening and opening of eyes without regard to external stimuli, are typical steps in the common path of mental functions recovery. These components are supported by functions of the first unit of the brain (activation). In the further recovery process (according to the neuroimaging data available from literature), the auditory cortex is activated in response to verbal stimuli, which may be indicative of partial involvement of the second unit in maintaining the reception of external information (stimuli) [20].

Alterations in the subcortical-cortical-subcortical and cortical-cortical links in the course of consciousness recovery have been demonstrated in a number of studies. According to O.M. Grindel (cited by [7, 8]), recovery of

Significance of Executive Functioning in Children with Severe Traumatic Brain Injury at Different Stages of Consciousness Recovery. Neuropsychological Approach

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Severe traumatic brain injury leads to a sharp increase in the number of children with severe disabilities. Early identification of disorders of higher mental functions allows one to develop rehabilitation programs and increase intervention effectiveness. The aim of this study was to examine the executive function in children with severe traumatic brain injury at different stages of consciousness recovery and to develop a protocol for early neuropsychological assessment and intervention. The study involved 62 4–17-year-old children who had experienced severe TBI (Glasgow Coma Scale (GCS)≤8) at different age. Eleven of them were examined in a vegetative and minimal consciousness states using functional magnetic resonance imaging (fMRI) and neurobehavioral scales. Early neuropsychological diagnosis according to the Luria Pediatric Neuropsychological Battery test was performed in 51 children. MRI analysis demonstrated structural brain damage: bilateral cortical contusion of the frontal lobes and diffuse axonal injuries were the most frequent lesions. According to neuropsychological diagnosis, primary and secondary disorders of the executive functions along with disorders of the dynamics of psychic processes and modality non-specific memory disorders were the most frequent symptoms of early recovery. Early identification of the disorders of higher mental function using patient’s behavior analysis (neurobehavioral scales) made it possible to develop the monitoring protocol and the procedure for rehabilitation at early recovery stages.

Keywords: traumatic brain injury (TBI), children, executive function, neurobehavioral scales.
the electrophysiological activity of the brain is somewhat regular to some extent: from the total absence of any interaction between hemispheres at the stage of depressed consciousness to its partial formation at mental confusion and complete formation at the beginning of patient’s orientation. Cortical links are commonly recovered from the dorsal (occipital) to frontal lobes. According to neurophysiological data, inter- and intrahemispheric relations in the frontal lobes are the last ones to recover; only at this stage a patient becomes able to execute instructions and his/her executive function recovers to the extent that is possible according to the primary defect. According to the results of neurophysiological and neuroimaging studies, as well as clinical cases, three brain units are sequentially involved in mental activity, while the execution associated with the third structural–functional unit of the brain emerges only at later stages. In spite of this assumption, higher mental functions and conscious activity are supported by integrative function of all three units, although the contribution of each of them to post-traumatic consciousness recovery is qualitatively unique at every stage [11, 13].

According to the L.S. Vygotsky’s concept about sense and systemic structure of consciousness, “human consciousness has... different sense structure at different stages of its development ... and is executed by different systems of mental processes” (cited by [12]). For example, development of consciousness in child’s ontogenesis progresses from the leading role of immediate emotional impressions and diffuse motion reactions in infancy to complex forms of information processing based on subjective motions, actions, perception in toddlerhood, and to the leading role of speech and executive notion regulation [2, 12]. Although children recover after severe traumatic brain injury according to the same main vector (executive function component is enhanced), ontogenesis is not completely repeated after recovering from coma. Complete development since birth through acquisition of new skills is never reproduced; “recovery” (formation of something new) takes place under conditions of a disturbed system, lost links of the system of the brain mechanisms, each of which considerably contributes to execution of the child’s conscious activity and mental processes.

Among various neurobehavioral scales that have been successfully used in Russian and foreign practice to assess the dynamics of conscious recovery, the parameters that are maximally important for neuropsych—

![Structural and functional model of the brain integrative function](image)

**Structural and functional model of the brain integrative function [12, 16].**

a) first unit: 1 — corpus callosum; 2 — mesencephalon; 3 — parietooccipital fissure; 4 — cerebellum; 5 — brainstem reticular formation; 6 — uncinate gyrus; 7 — hypothalamus; 8 — thalamus;
b) second unit: 1 — premotor cortex; 2 — anterior central gyrus; 3 — central gyrus; 4 — motor cortex; 5 — prefrontal cortex area;
c) third unit: legend is the same as that in Fig. b.
logical monitoring should be mentioned. One of the main parameters in recovery of children with severe traumatic brain injury is the executiveness, which determines a possibility to recover patient’s cognitive functions and potentialities of neuropsychological rehabilitation training during further cognitive rehabilitation. What is executiveness? While one sense aspect of executiveness is the capability of conscious target behavior and conscious control over one’s own mental processes, executiveness in general implies complete recovery of patient’s consciousness. According to L.S. Vygotsky’s culture-historical approach [3, 4], ontogenetic development of child’s consciousness is tightly related to executive processes mediated by a sign. Hence, the mindfulness criterion cannot be totally eliminated from discussion of executiveness of the mental processes, movements and actions. A.V. Zaporozhets [10] demonstrated the development of executive movements when nonexecutive movements of a person acquire signaling meaning and become perceptible and, hence, executive and conscious. M.I. Lisina’s experiments (cited by [10]) in healthy individuals verified this idea and demonstrated that an individual needs orientation/exploration activity to express his/her signaling activity.

Nonexecutive spontaneous activity beyond targeted stimulation and the ability to perform any purposeless self-activity or activity independent of its adequacy are an important basis and a measurable parameter during the recovery of child’s consciousness. Gaze fixation and visual tracking, being signs of emergence from a vegetative state, are a purposeless self-activity of a patient [6, 8]. Orienting responses during patient’s recovery can be implemented within the main modalities: visual (object tracking, human figures and faces, etc.), auditory (turning one’s head/eyes/hands to a sound), motor (palpation, grabbing things within a bed, etc.) and their combinations. Therefore, the nonexecutive level of mental processes should be included in behavioral study of a patient during the recovery of his/her mental activity.

In clinical aspect, both executive and nonexecutive responses to internal and external stimuli are typical of the vegetative state of mental activity recovery. According to the classification proposed by T.A. Dobrokhotova [6, 8] and used in Russia, distinct gaze fixation and differential response to a stimulus of any modality (verbal or nonverbal emotional), distinct, non-generalized localization of noxious stimuli are typical of the stage of akinetic mutism with emotional reactions. Minimally conscious state is a term used in the foreign classification [19]; the negative minimally conscious state, (MCS–) is currently used to describe this patient group [20].

A number of behavioral manifestations important for observations during a neurobehavioral study, although containing formal nonexecutive activity, can be listed:
— nonexecutive attention to any stimulus;
— attention to a stimulus and its duration (seconds); concentration on a task or a problem;
— independent turn of the head/eyes towards a speaker, indicating focus on the contact;
— orienting responses (tracking the emotionally significant stimuli, relatives’ faces, one’s own mirror reflection and favorite things compared to the other stimuli).

According to the classification used in Russia [6, 19], the higher level, positive minimally conscious state (MCS+) or akinetic mutism with speech recognition can be characterized by one of the following behaviors: execution of simple commands, gestural/verbal yes/no responding, and any targeted behavior (movements and emotional response to external stimuli).

Some significant behavior types can develop at this stage earlier than execution of instructions or the yes/no response:
— exploration of one’s own body parts and face of a person who stands/sits nearby;
— exploration of things without a possibility of using them properly;
— the use of nonverbal communication;
— mimetic responses, gesture imitation;
— execution of reward instructions.

Thus, the behavioral patterns typical of a patient should be determined when performing neuropsychological evaluation.

The descriptive scales or neuroimaging (functional magnetic resonance tomography [20]) data are not sufficient to elaborate the rehabilitation approaches and develop recovery programs; hence, we mainly focus on neurobehavioral monitoring to evaluate the minimal changes in patient’s behavior.

We have analyzed 14 clinical cases and determined the following processes that should be presented in neuropsychological evaluation at early recovery:
1. **Communicability:**
— no communication attempts are made;
— inadequate characteristics of the contact (negativism, contact discrimination, etc.);
— nonverbal communication
— verbal communication with insufficient initiative;
— adequate verbal communication.

2. **Neurodynamic parameters of mental activity:**
— activity (awakening) state (independent: either spontaneous or stimulated);
— attraction of nonexecutive attention to the environment and the retention duration;
— attraction of executive attention to a stimulus and duration of attention to a stimulus or a task;
— duration of response latency when executing an instruction.

It is noteworthy that monitoring the neurodynamic parameters of mental activity reveals differences in patient’s activity parameters throughout a day, as well as his/her variable accessibility for various rehabilitations. No dynamics or worsening of the monitored neurodynamic parameters between examinations can be a result
of a low rehabilitation potential, insufficient rehabilitation program, or a sign of developing complications after a severe traumatic brain injury (e.g., posttraumatic hydrocephalus).

3. **Integrity of the analyzing functions and the recovery of perception (visual, auditory, and tactile):**
   - generalized non-differentiated reaction;
   - stimulated emotional mimic reactions;
   - distinct localization (visual, tactile, auditory or noxious) depending on stimulus modality.

4. **Executive level of movements and actions:**
   - nonexecutive orientation responses (i.e., any orientation response regardless of the modality of its manifestation);
   - targeted spontaneous responses free of directed external stimulation;
   - targeted movements and actions in response to an instruction.

5. **Instruction execution:**
   - execution of mimic instructions;
   - execution of reward instructions and instructions supported by other modalities;
   - execution of instructions according to verbal (sometimes written) instruction.

Thus, at minimally conscious state, a functional diagnosis can be specified by neuropsychological assessment of patient’s behavior with respect to the executive action component. The structural-topical diagnosis may reflect the features of the recovery of different brain structures: the vertically organized ones (subcortical-cortical organization), interhemispheric interaction, and the horizontally organized ones (cortical-cortical interaction). It should be understood that these generalization forms are aimed at solving various clinical problems, (e.g., functional diagnosis attesting to function disorders and the dynamics of individual rehabilitation) and allow one to refine the rehabilitation objectives at early stages.

The main problem associated with the minimally conscious state (MCS-) within early neuropsychological rehabilitation is preparing a platform for executive action. A thorough analysis of disordered functions helps a patient to develop his or her own way of recovery. For example, object tracking ensured by the visual function is not the only qualitative criterion of patient’s emergence from a vegetative state. The inability to maintain gaze fixation and object tracking under simultaneous emergence of other behavioral responses often correlates both with primary disorders of the analyzing system and severe disturbances of visual object perception. In such cases, development of an executive component, including the possibility to execute instructions, can be fulfilled through the auditory function (see Table). In contrast to the previous stage (of examination?) of stimulation from different modalities applied to a patient [9], it is reasonable to isolate the dominant modality and stimulus for further formation (facilitation) of the executive component.

The objectives of neuropsychological rehabilitation vary in accordance with the recovery stage [17].

As consciousness is recovered, beginning from the minimally conscious state (MCS+), early neuropsychological diagnostics becomes available, which is adapted with allowance for patient’s age and his/her functionalities (primary injuries of the analyzing systems and motion disorders of various genesis). The diagnostics makes it possible to assess the injuries of higher mental functions and the dynamics of their recovery.

Neuropsychological diagnostics during the first six months after a severe brain traumatic injury allowed the authors to determine the following deficiencies in 51 children [5, 15]:

- disorders of neurodynamic parameters of mental activity;
- modality non-specific memory disorders;
- disorders of regulatory functions, programming and control of activity (executive functions).

The following mechanisms of the impairment of executive functions were found:

1) pathologic impact of the emerged stereotypes causing problems in switching from one program element to another and from one program to another;
2) inability to inhibit direct responses to a situation causing impulsive behavior;
3) loss of initiative as a basic component of the motivation—needs sphere manifested as severe aspontaneity [14].

The objectives of neuropsychological rehabilitation at the stage of clear consciousness are obvious and have been sufficiently described. They are directly related to the detected mechanisms of the impairment of control functions. The following rehabilitation objectives are common for children with severe brain traumatic injury:

<table>
<thead>
<tr>
<th>Substages of the minimally conscious state (MCS)</th>
<th>MCS–</th>
<th>MCS+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of patient’s executive activity in neuropsychological contact</td>
<td>Nonexecutive level: orientation response</td>
<td>Executive level: execution of simple single-step instructions</td>
</tr>
<tr>
<td>Primary objectives of early neuropsychological rehabilitation</td>
<td>Determination of the dominant modality: visual, auditory, and tactile. Principle of the dominant stimulus</td>
<td>Broadening of the instructions based on patient's capabilities. Making instructions more complex. Decrease in nonspecific symptoms (pathological passiveness of mental processes)</td>
</tr>
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</table>
— to reduce the intensity of non-specific neuropsychological symptoms (aprasite and pathological passiveness of mental processes);
— to increase self-control over the course of both physiological and cognitive processes;
— to organize proper patient—environment interaction.

It worth mentioning that a longitudinal study including 135—17-year-old children in posttraumatic period (first six months and two years after an injury) showed a statistically significant recovery dynamics only for such components of the executive control of activity as pathological passiveness of mental processes [15]. Disorders in other processes of the control functions were either preserved or the dynamics of their regression was insignificant at repeated examination of the children two years later.

Thus, we determined the key role of an executive factor and executive control over psychological processes in early period of children’s rehabilitation after a severe brain traumatic injury, using our own data of continuous follow-up and stimuli. Further intensive clinical observations are needed to verify the concept, to specify the structure of neurobehavioral assessment, and to develop certain techniques for early neuropsychological rehabilitation.

REFERENCES


Commentary

The article deals with the urgent topic of neuropsychology: recovery of consciousness in children with severe traumatic brain injury and formation of executive mental activity. Occurrence of executive activity is the crucial moment in life of an unconscious patient. This is a point of considerable expansion of the entire range of active stimuli that can be used both for accurate diagnosis of cognitive functions and for further rehabilitation and judgments on outcome prognosis.

The greatest part of the work is the review of the theories concerning executive functioning. The author demonstrates good knowledge of classical Russian publications in neuropsychology and the current scales of consciousness assessment. Detailed lists of behaviors in patients with different states of consciousness are a significant advantage of the article. Observations of patients’ behavior and responses to various stimuli will allow one to detect the emergence of even the minimal executiveness of mental activity. Such lists of behavioral patterns during mental recovery can be refined and used to develop grading scales. Such a detailed stepwise description of patients’ behavior is indicative of the author’s deep clinical knowledge.

However, the article contains some controversial issues and unfortunate mistakes. First: “neuropsychological assessment” as applied to unconscious patients (in particular, in vegetative status) can be argued over, since specialized tests cannot be performed in patients in this state, while it is not only a neuropsychologist who monitors the patient but a resuscitationist, a neurologist, a psychiatrist, etc. as well. The author mentioned in the end of the article that as consciousness recovers, beginning from the minimally conscious state + (mu-
tism with speech recognition, according to T.A. Dobrokhotova and O.S. Zaitsev’s classification, when execution of simplest tasks can be performed, early neuropsychological diagnosis becomes feasible. Until that, neither neuropsychological assessment nor diagnosis can be performed. Second, the article title says “...in children”. Nevertheless, all the described clinical assessments of behavior recovery are universal both for children and adults. It would be interesting to know the details of revealing consciousness formation in children, if they are available. Third, the article is actually a theoretical review. The longitudinal study comprising 14 children is briefly mentioned in the end of the article (although referring to the author’s own previous article). However, the main positive dynamics in these children was the regression of passiveness of their mental processes. But this statement should be proved by at least specifying the nature and location of injuries, which strongly determine the observed neuropsychological syndromes. Finally, the article cites the papers by O.M. Grindel; however, we cannot find her name under the mentioned numbers in the References section. Meanwhile, O.M. Grindel et al. reported the electroencephalographic data on later recovery of interhemispheric relations in the frontal areas compared to the other brain areas during consciousness recovery several years earlier than the cited paper by J. Leon-Carrion et al. (2012).

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Teamwork as a Way to Recovery of Consciousness

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The conception of unconsciousness as a result of severe traumatic brain injury has recently considerably changed owing to high technologies. Neuroimaging techniques allow some patients who were previously considered by clinicians to be in vegetative state to prove their right for awareness. Combining physiologic and neurophysiologic signals also provides reliable quantitative estimates, clarifying the patient’s clinical condition. These “Third-Person View” approaches use the deterministic paradigm of stimulating the patient and leave the question regarding the content of patient’s inner experience open. Real-life practice has shown that the pattern of patient’s responses is determined not only by his deficits, but also by questions/stimuli, the context, and the identity of the questioner. Teamwork with a patient gives additional knowledge about the patient’s processes due to the “first- and second-person view”, as well as real-time changes. Recovery of consciousness goes through building of patient’s contacts with his own body and the world. Feedback in response to slightest signals from the patient is the basic principle. The feedback network between the patient and specialists results in a team as a nonlinear complex system. Energy, entropy and complexity are the characteristics of the state of the “patient—team” system. Impairment of consciousness can occur concomitantly with loss of vital functions (low energy), vegetative-visceral attacks (high energy, low order), motor excitement (high energy, high order), etc. Teamwork techniques aimed at optimizing the system state must be different in such cases. An increase in complexity of the system results increases the chances for recovery. Self-organization of the system is the key process in recovery of consciousness. An analysis of complex communicative process in the patient—team system can be used to create the general theory of consciousness.

Keywords: rehabilitation team, impaired consciousness, severe brain damage, complex systems theory.

The medical community has recently come to understanding of the relation between the outcomes of severe brain injuries and the quality of rehabilitation measures. This understanding leads to organizational and financial efforts aimed at creation of rehabilitation network in Russia. Neurosurgeons and intensivists typically focus on early physical rehabilitation of patients with severe acute brain injuries. In patients with long-term severe impairment of consciousness this work is reduced to a set of passive exercises and exposure to physical factors. This viewpoint is also rooted among neuro-rehabilitologists, leading to paradoxical consequences. Thus, the draft law on rehabilitation stated that “the lack of motivation to recovery is a contraindication” for including a patient in a rehabilitation program. The goal of this publication is to fill the gap between neuro-science and experience of specialists involved in rehabilitation of patients with impaired consciousness. From the author’s standpoint, neuro-rehabilitiology has a unique methodology of the rehabilitation team, which seems to be insufficiently clear to its agents. Better understanding of this point could both significantly improve the effectiveness of rehabilitation and complement the understanding of the phenomenon of consciousness. The article reflects the author’s view on interdisciplinary studies of the phenomenon of consciousness through its impairment and recovery. The study focuses on the work of the “proper rehabilitation team”, the mechanisms of its action and methods for researching the occurring phenomena.

Specialists’ concerns about the level of patient’s consciousness after severe traumatic brain injury occur at all stages of post-traumatic disease. Certainly, during the most acute period coma reflects the life-threatening brain condition of the patient that requires urgent surgical and resuscitation measures. However, during the less critical phase with self-maintaining control of vital functions restored, the specialists’ desire to see at least some glimpses of consciousness in the patient becomes somewhat irrational. In contrast to family members for whom their case is unique, we are aware of how often the patient’s behavior, care and interaction with the patient after emergence of the elementary forms of contact can make life of the family painful for many years. The need for “consciousness” of a patient during the rehabilitation is a completely rational aspect of the work: active participation of the patient is very important to achieve better results in less time. Rehabilitologists at the N.N. Burdenko Neurosurgical Institute have great experience and ability to compare, since in the 1980s, the “apallic syndrome” diagnosis was not a contraindication for recovering measures. The work aimed at establishing contact with patients with disorders of consciousness was started in 1992. Some techniques of process-oriented psychotherapy have become an integral part of this work. [1] Since the mid-1990s, when the psychological service was
founded at the department, a form of organization of work with patients gained importance comparable to the high professional level of specialists, and the team approach began to intuitively evolve [2, 3]. Team trend in Western neuro-rehabilitation appeared at about the same time, although first mentioning of the rehabilitation team appeared much earlier [4, 5].

1. Some concepts of consciousness. During the late XIX — early XX century, it was considered to be obvious in scientific psychology that conscious experience is a basic phenomenon of the discipline. Studies and even mentioning consciousness were largely restrained during the period of behaviorism (first half of the 20th century). Together with the return of the “mind” concept (in the second half of the last century), mentioning consciousness gradually returned into the cognitive science, mainly in connection with investigations of attention and short-term memory. At that time it was assumed that consciousness is nothing more than a form of information processing, and all the rich phenomenological experience was cut off. It was only in the early 1990s that it began to be understood that the methods used to study consciousness affect the perception of the consciousness itself. Scientific interest in consciousness has arisen primarily owing to the works of philosophers Dennett and Nagel [6, 7]. New journals (Journal of Consciousness Studies, Consciousness and Cognition, electronic journal PSYCHE) and organizations (Association of consciousness research, the Center of Consciousness Studies in Arizona, etc.) were established; dozens of monographs were annually published. Perhaps the process of integration to solve the problem was launched due to the accumulated technological capabilities. The cooperation has become especially productive since the 2000s. At the conferences organized by centers for studying consciousness, the representatives of quantum physics, neurological sciences, various spiritual practices, creative professionals, experts in the field of artificial intelligence, mathematicians, philosophers, psychologists, anthropologists, therapists, clinicians and artists try to reach a common understanding of the mind—body relationship, which is often reduced to the mind—brain interaction. As early as in 1994, the debate was blown by David Chalmers, a young Australian philosopher [8] who nowadays is considered to be one of the deans of the science of consciousness. He was the first who distinguished between “easy problems of consciousness” (related to the psychological functions) and “hard problem of consciousness”. Indeed, why is the work of the brain accompanied by subjective experience? Consciousness cannot be reduced to only cerebral processes, because there is also elusive qualia (blueness of blue, painfulness of pain, etc.) corresponding to the unique content that do not arise from biological concepts. Subjective experience cannot be generated by cerebral processes. This situation forced the representatives of neuroscience to avoid simplifications. Neurosurgeons have also started to understand the incompleteness of the unilateral search for consciousness in the depths of the brain. [9]

During 20 years, David Chalmers has been changing his views, considering the consciousness from the viewpoint of different systems of philosophy. Russian philosopher V.V. Vasil’ev [10] believes that the following statement is most accurate: “... mental states are the ontological preconditions for implementing physical causality and even the very existence of the physical properties. The existence of mental states associated with certain physical systems gives these systems an opportunity to take into account their own individual story in their behavior.”

One of the proposals of D. Chalmers, which was taken up by many philosophers, regards consciousness as the basic natural sequence:

Space—Time—Charge—Consciousness.

Since the early 1990s, the mathematician Roger Penrose has been trying to develop a general theory of consciousness. He has synthesized several areas of knowledge and put forward the synergic physical concept, in which the leading role belongs to self-organization processes occurring at the quantum level. The Orch OR (orchestrated objective reduction) theory, developed by P. Penrose and S. Hameroff [11], puts the mind into the core of physical nature of our universe. According to P. Penrose [12], the main obstacle for understanding of the phenomenon of consciousness is nowadays the incompleteness of quantum mechanics. The main Penrose’s thesis states that “Consciousness is not amenable to calculation and does not operate algorithmically... The brain is not a computer.”

Fig. 1 shows the main types of the concepts of consciousness.

Consciousness can manifest itself at different levels of human existence: the organism-wide, personal and social levels. The phenomena of consciousness (state) have an impact not only within their own level, but also at higher (or lower) levels. This statement is important for our subsequent conclusions. When organizing the experiment and analyzing the results it is also important to distinguish between methodologies addressed to different levels: artificial intelligence, neuroscience, clinical science, psychology, and philosophy.

Fig. 1. Schematic partition of the concepts of consciousness according to L. Strate [13].

Life as a combination of the soul and “flesh” is a negentropic, cybernetic and cognitive process, the indivisible “mind—body” system.
Studies devoted to artificial intelligence that were started in the middle of the XX century suggested that a computer analog of a human will be created and the secrets of human consciousness will be revealed. These studies have greatly expanded the capabilities of information technologies but did not solve the fundamental problem of understanding the human nature. The failure was apparently associated with the initially false premise. It became obvious that modeling of individual brain functions does not bring us to modeling of consciousness. Meanwhile, due to this direction, an integrated database of knowledge about the brain has been developed and the methods used by the information theories of consciousness have been formed (e.g., [14]).

Every scientific approach reduces some specific features of the object to create a model. Researchers in neurosciences usually choose reductionism, which reduces consciousness to separate functions [15].

2. Objective view of a clinician. Reduction is also typical of clinical science, although the clinical model is the most controversial one; it is the disturbance of “consciousness” as a result of damage to the “substrate”. The keywords in papers focused on this subject demonstrate searching for an object, but not a concept (prognostic factors, neurophysiological mechanisms of disturbance, etc.). The classification approach characteristic of the clinical practice was formed as early as in the XIX century [16]. Clinical study of consciousness is designed on a hierarchical basis; impairments of consciousness are associated with structural and functional destruction of the brain; injury severity and the current state are extrapolated to predict the outcome.

The neurological paradigm places the level of consciousness, cognitive, emotional and personality disorders on the same scale, assuming that mental recovery is linear. Options for the selection of the leading symptoms of impaired consciousness often reflect the capabilities of clinics, pragmatic goals, and area of expertise of a clinician. Here is a fragment of the scale defining the vegetative state (VS).

— No evidence of self-awareness or awareness of one’s environment; the patient is not able to interact with others.
— No evidence of stable, reproducible, purposeful or spontaneous behavioral response to visual, auditory, tactile or noxious stimuli.
— No evidence of understanding and expression of speech.

Let us note that it is paradoxical that the definition of the state of consciousness is given through the lack of evidence. Nevertheless, the agreement on the VS term led to agreement on other states. Thus, the medical community has accepted the term “state of minimal consciousness” (SMC) and its criteria [17, 18], which include the limited but clearly discernible evidence of self-awareness or awareness of the environment in the form of execution of simple instructions, gestural or verbal yes/no responses, distinct verbalization or purposeful behavior proportional to relevant external stimuli.

If we summarize various classifications, consciousness for a clinician is patient’s ability to establish contact with others, to respond to repetitive external stimuli with similar motor behavior, which is clear to an observer, and to join linguistic communication.

Let us note the viewpoint that is irrational but widespread in the medical community about the need for “stimulating therapy” in patients with VS and SMC. Demonstration of real and graphic objects, verbal load, music, etc. are recommended for those patients during wakefulness and often during sleep [19].

The higher the “level of contact” of a patient with impaired consciousness (various forms of interaction with the world), the more vague it is to define his state. Akinetic mutism, first described as early as in the 1940s [20], is well recognizable, although it is a continuum partially overlapping with the SMC.

The higher a patient moves along the scale of consciousness, the less the agreement upon definitions is. The scale of recovery from coma proposed by Russian authors [21] increases the number of stages of recovering consciousness through specification of various forms of behavior. The classifications narrow or broaden the list of attributes to split the concepts of consciousness (arousal—awareness). Following the English terminology, we additionally face the artificiality of the borrowed concepts (awareness has a slightly different meaning than consciousness or mind). Meanwhile, a good clinician would wittingly or unwittingly prefer the nonlinearity, focusing on a detailed story of the patient and reading both the conclusion and diaries in the case history.

3. The neuroimaging approach suggests that orientation only on the behavioral symptoms is the major drawback of clinical classifications of impaired consciousness. Functional magnetic resonance imaging (fMRI) has shown that in some patients whose condition was for a long time clinically qualified as VS, verbal and some other types of brain stimulation result in activation of the same brain areas as in people in clear consciousness. From the viewpoint of the researchers [22], it proves the presence of awareness. However, accumulation of data resulted in understanding that neuroimaging formulas are not universal. In some cases when the “active paradigms” were used, no signs of activation of cortical structures in conscious patients were revealed by fMRI. Additional doubts arise with respect to the practical individual significance of neuroimaging results, since the trend towards universality makes researchers limit the paradigms used. It is possible that those 90% of patients with VS who were suggested to be unconscious by fMRI just had not received their special stimulus. The absence of cerebral response may be indicative not only of the absence of “awareness”, but also of inappropriate motivation, cognitive deficits, psychological defense, etc. It is noteworthy that the Belgian Coma Science Group,
the undisputed leader in this direction, gradually moves towards combining the active and the so-called passive paradigm in the study of patients with severe impairment of consciousness. The use of the passive paradigm requires enriching the methodology, which has made researchers of the Coma Science Group to use non-linear EEG analysis [23]. The combination of two or more directions certainly broadens our understanding of functioning of the damaged brain, but makes little difference for a particular patient. Even the access to the entire set of brain responses to random external and internal stimuli leaves the question of how to overcome the barrier between a patient and the world unsolved.

In brain research, one searches for the targets responsible for consciousness, whether it is a local area or a link of the functional chain [24]. Stimulating agents and methods for delivering them to the affected area are varied, but the conceptual paradigm remains unchanged: the biochemical factor (drugs), physical effects (electromagnetic and other fields), the biological factor (stem cells, genetic engineering) should be directed to areas responsible for consciousness. However, no conclusive studies devoted to treatment of the disorders of consciousness are available thus far. We suggest that the complexity and the multi-level structure of the phenomenon of consciousness are the fundamental obstacles.

4. Regarding the rehabilitation team. What is the difference between the interaction of a rehabilitologist with the patient and the traditional clinical examination? In addition to the specific diagnostics, specification of the immediate and long-term goals of treatment, etc., the rehabilitologist should daily focus on special, volatile, features that are peculiar only to this particular patient.

The reality of clinical presentation is dynamic, nonlinear, random and often unpredictable. Nonlinearity is the law rather than violation of the developing process. This fact causes much strain, which continues for a long time in contrast to other branches of medicine. Only people who can deal with this uncertainty are efficient in the rehabilitation process, as well as in other training processes. Understanding the complexity of existence in the world is a step toward self-organization and building of professional activities.

During the past 15—20 years, the idea of the need for using a team approach has established in rehabilitation practice. Unfortunately, this view is schematic and is often reduced to elaboration of the rehabilitation program and analysis of the dynamics of patient’s condition during joint discussions, which differ little from the clinical analysis. Very few experts of rehabilitation centers realize how to interact with patients and colleagues within the team. Team composition and the rehabilitation program are usually determined in accordance with the list of the patient’s functional deficits. This viewpoint dominates in the organization of rehabilitation of patients with brain injuries. With this approach, the matter of the teamwork disappears and lost consciousness is regarded as one of the defects along with cognitive impairment.

There are examples of process-oriented organization of the team approach in the delayed period of traumatic brain injury. Thus, B. Wilson et al. [25] described the necessary steps to define the goals of the gradual recovery process, to separate and achieve these goals. They generally correlate with the common social skills to be learned by the patient, so the main roles are assigned to an occupational therapist, a social worker and a neuropsychologist. Rehabilitation at this stage is primarily a learning process. In the early rehabilitation of traumatic brain injury, deficit-based and socio-adaptive representations are inadequate as it is unclear, which specialist is “responsible” for the deficit of consciousness, whose aims and actions should set the tone in an attempt to restore it. The whole experience of rehabilitation shows that the recovery of disabilities is faster if patient’s activity is used, i.e. the patient is a participant rather than an object of the treatment process.

Psychologist Kurt Lewin, a researcher of group dynamics who addressed the aspects of small groups, has laid the foundations of the concept of a working team in the 1950s. He has demonstrated the proper way according to which a group of people gathered to solve a specific task should develop. Lewin noted that the group is more than just a sum of its individuals. He proposed an algorithm for estimating a well-functioning group, found that the team leaders must possess special skills, and showed that the effective group process can be developed and people can be taught it.

The ideas of team work were being developed within management psychology for a long time. The main principles of team activities were formulated in the 1970s. Thus, an interdisciplinary team (IDT) is a small group of specialists with different skills, created and working within an organization according to special rules, united by a common purpose, goals, which are implemented based on mutual responsibility.

The team work is most efficient when its own internal rules and principles of the organization are balanced, which provides favorable conditions for self-development.

The standards of a high-quality team include mutual respect, awareness of the boundaries of other people, a consensus about the method of work and decision making, and sensitivity to the level of comfort of the team members when focusing on an object, awareness of the importance of group processes, training through formal and informal exchange of ideas.

Team management should include the creativity of its members, their participation in self-organization and self-management, clarity of collective values and goals that define the behavior, mutual supervision, collective responsibility for the results and efficiency of work, development and use of the individual and group potential.

The work of IDT was for a long time analyzed mainly using semi-structured interviews and scales accepted.
from the studies devoted to the development of small groups, which evaluated the activity of each team member, openness to discussions, comfort of cooperation, and other characteristics. These studies were conducted mainly with flight and space crews, when it was possible to use long-term training on simulators. Staff training and team work are not only time-consuming but they require additional costs. In the aerospace industry, this direction has been developed for safety reasons. Large companies focused on the development of management have also supported such works. This led to the creation of a separate direction, the team-building industry. Research in the field of teamwork focused on creating a model that would be most effective in dealing with a limited class of problems. These models consider the following parameters: input (team structure), process (teamwork) and output (results of team work). Both individual performance related to the activities of the team and common defects (lack of trust between team members, inefficient interaction during discussions, unclear role distribution, defocusing a problem, poor time management, lack of coordination with the principles and objectives of the organization) should be evaluated.

The reason why the number of studies dealing with team approach in medicine is relatively small is related to the features of the research object and strict hierarchy of the clinics. Medical studies of a team were launched during the 2000s and mainly use the methods of corporate psychology. Despite the limitations associated with the feature of the object, some progress was achieved in these filed. There is no doubt that teamwork in this area is also a process, in which participants interact and work together to achieve the desired results [26]. Surgical and intensive care teams demonstrate the most compelling results of such research and training carried out at workplace and on simulators [27]. These groups operate in a complex and dynamic environment characterized by multi-component solutions with rapidly changing and uncertain situations, informational overload, rigid time constraints and severe consequences of errors.

The practice of using the team approach in neuro-rehabilitation appeared in Europe, America and Russia almost simultaneously in the early 1990s. More patients survived after severe cerebral damage; the structure of functional disorders became more complex, and the need for interdisciplinary contacts became apparent. Methods for evaluating the team work and types of trainings designed for surgeons were not very adequate because of the specificity of the object and the temporal characteristics of the process. Our object should to some extent endeavor to be a subject with our help, which was not taken into account by team-building guidelines.

As early as in the 1990s, regular IDT training courses for social workers were conducted with the help of British experts on medical management at the Children’s Republican Hospital in Moscow. The key principles were adapted to domestic reality and published [28]. Unfortunately, this experience was not accepted by the medical community and was not used in organization of rehabilitation network.

The main types of teams in medicine

Multidisciplinary team — team members work with the patient independently, each of them works with an object corresponding to his discipline. Typically, it is a group of independent experts working in various disciplines, following individual plans and specific tasks (medical emergency clinic; defect-oriented neuro-rehabilitation).

Interdisciplinary team — specialists are aware of other objects (patient’s problems) and the rates of changes, but are strictly confined by the scope of their profession (integrated treatment of neurosurgical diseases, disease-oriented rehabilitation). The collaboration is based on sharing information about the disease and treatment, the development of a program.

Transdisciplinary team — specialists are not confined to their discipline but coordinate their actions in accordance with the patient’s needs. This type is characterized by autonomy, the division of work tasks, flexible change of leadership, and shared decision making.

Western multicenter studies have shown that the interdisciplinary rehabilitation model is more efficient than the multidisciplinary one. First of all, this means that a coordinated, horizontal management is preferred to the vertical hierarchy [29]. Team activities are usually analyzed according to the skills and relations that form the team thinking. The teamwork can develop in the following directions:

— Executive skills training;
— Communication Training;
— Changing the attitude towards teamwork;
— Development of the problem-oriented team;
— Socio-integrative development of the team.

Research is conducted in the form of a partially standardized interview for the team members and questionnaires that are filled out by the chief executive of the clinic [30]. The database is formed using multicenter studies; however, in contrast to the neurosurgical studies, the results do not allow one to reach the level of strong evidence due to different systems of training specialists, different concepts of the team, different motivation levels, etc. [31]. This approach is useful for creating effective logistic schemes but lacks unique features of the rehabilitation process.

The features of national health care and problems of early rehabilitation forced us to search for a different way. The transdisciplinary team (TDT) model seems to be the most successful one with respect to rehabilitation of the neurosurgical patients in the most severe condition. First of all, this model requires free information flow in the group. Practical work is based on feedback from the patient and within the team, which allows for quick identification of phenomena in the life of the patient and coop-
Erative decision making about the next steps [32]. Back in the beginning of our journey, we have formulated the main tasks that should be solved by TDT in early rehabilitation, i.e. dynamic search for resource field, selection of the optimal tactics to overcome the problems of the patient, mutual learning, and mutual aid in the “burn-out” syndrome.

Analysis within TDT differs from the traditional clinical approach. In addition to formal reports in terms of each specialty, metaphors and associations are useful to interpret the events. The team leader can be changed during the analysis; competitive relations and polarization of opinions that push the team to changes are appreciated.

Searching for the reasons behind a particular event is not so important in patients with severe impairment of consciousness. The understanding of why it has emerged comes after the active response to the event. For promoting work with the person you need to get a hold of his existence at a level different from the actual knowledge about this person.

The methodology of teamwork in early rehabilitation is virtually absent, despite the fact that tasks for individual team members can be formulated by a resuscitator or neurosurgeon (e.g. enabling patient’s spontaneous breathing, preventing contractures, restoring swallowing, i.e. activation). Impaired consciousness is used as a criterion for assessing the condition when defining the problem. It makes a significant obstacle only for a rehabilitologist, since learning requires the active participation of the patient.

Uncertainty and elusiveness of consciousness is a challenge. What target should the team chose for its joint actions and what is the evidence of its achievement? Let us replace the poorly categorizable concept of “contact” with the meaningful “living movement” proposed by N.A. Bernstein who was honored by both physiologists and psychologists. Such movements are intrinsically related to search and oriented to the future. Living movement is the mastery of space and time rather than just movement of the body in space and time.

The team mainly deals with patient’s expressions; it can serve both as an instrument to access the impaired consciousness and a non-trivial tool to study this phenomenon. The team interacts not only with the patient’s deficits and resources, but also with the phenomena. In our opinion, it is useful to consider the team as a dynamic system existing in real time, which must continuously adapt to changing tasks and unpredictable perturbations in order to be effective.

A complex system is a set of elements and their properties, which are in dynamic relationship with each other. The whole is greater than the sum of its parts. The system is superior with respect to its elements. All parts and processes of the whole are interdependent and mutually influence each other. The “patient—team” system is a semi-open self-organizing system. The behavior of this system is rational and the source of variations lies within

The following features of the interaction can be identified in early neuro-rehabilitation:

**Patient**

Patient strives to maintain Status Quo and self-isolation. “Execution of instructions” is an unknown context for the patient. Family is a part of the system.

**Team**

The proper joining always results in getting an answer. The complementary relations prevail. Paradoxical game frame.

Fig. 2 shows a fragment of teamwork involving three specialists.

Rehabilitator’s task includes capturing signs of living movement, giving feedback to the patient and sharing this information with other team members.

We hypothesized that it is methodologically correct to use the following parameters characterizing the complex nonlinear systems: energy, entropy (information), the complexity in describing the dynamic state of the team. It turned out that the team members easily accepted these concepts and incorporated them into their own vision of the rehabilitative process. The course of systemic teamwork is shown in Fig. 3.

Methods of teamwork in early rehabilitation. Sequen- tial work of specialists is used most widely in Russian re habilitation centers. The protocol is strictly defined and patient’s workload is 4 or more sessions per day. Robotics is increasingly widely used. Specialists often work in pairs in the western clinics; this approach is normally used in the early period during sessions of physical rehabilitation of patients with severe motor deficits and impaired consciousness. Fig. 4 shows teamwork at the ICU.

Outpatient delayed rehabilitation programs are often conducted by a group of specialists. In our opinion, the more static patient’s condition is (regardless of severity of functional deficits), the more diverse should the team be. Different combinations of permanent team members, workspace and types of tasks are used.

Formulation of a problem for a specialist is conducted during the team discussion and may differ from the normal work within the discipline. Fig. 5 shows a session conducted by an exercise physiologist testing a hypothe sis of psychologists.

If a patient is “stuck” for a long time in the VS state, minimal consciousness or mutism, then joint work of the entire team is carried out. This session usually lasts 1 to 1.5 hours. Psychologists with special qualification usually act as team leaders. Physiotherapists, a rehabilitation specialist and a massage therapist can act as co-therapists. Thereby, the problem of extension of feedback area from the patient is solved.
**Fig. 6** shows joint work of a psychologist and an exercise physiologist.

Resistance and stress arise both in patient and team members during the working process. The team should change both structurally and functionally according to requirements of the moment.

Directive interaction increases the complexity of the system; the energy increases at the beginning, but then may decrease, while entropy mostly decreases. Patient’s space narrows. Joining and adjustment increase the complexity and entropy of the system, which leads to energy redistribution. Increased muscle tone decreases and living movement appears. **Fig. 7** shows a fragment of the joint work of a psychologist and an exercise physiologist, which is mainly aimed at increasing patient’ energy and possibility of its control.

As a result of changing system parameters, patients show signs of involvement in what is happening. These behavioral signs are being identified by process participants, appropriately processed and returned to the patient.

Team can begin to work with a patient at early stage, when the patient is on mechanical ventilation. At the same time, we have experience of delayed start, when the patient was admitted from another hospital or from home after being in a state close to VS for a long time. It is usually impossible to determine the patient’s rehabilitation potential during the first examination. Team managed to extend a “dialogue” with the patient in repeating cycles shown in **Fig. 3** in most rehabilitation processes. Along with this, motor abilities were changing [33]. However, we could not find methods for dynamic tracking of team processes for a long time.

5. **Interdisciplinary research methods.** A team operates between random and highly ordered states at the level of self-organized criticism. This subtle, but very significant condition is called the margin of chaos. This quality allows the teams to adapt to both instantaneous changes and changes in the task. From this position, the effective teamwork is a continuous effort aimed at stabilizing the inherently unstable system [34]. The team shows both stability and flexibility in the “sweet spot” due to supporting co-regulation and adaptive interactions between the participants.

While neuro-rehabilitation science was studying the team approach as a matter of practice, management science has made a significant progress in application of system models, involving quantitative assessment methods. Actually, at that time all anthropological sciences have adopted nonlinear methods, which enabled evaluation of teamwork skills (non-technical skills):

— Leadership;
— Decision making;
— Understanding of the situation;
— Cohesion;
— Energy management.

**Fig. 2.** Teamwork with patient M. 5 months after severe traumatic brain injury. Mutism with attempts to understand speech.

Two psychologists and an exercise physiologist are working with the patient during 1.5 hours. Game elements that enhance the dialogue are used together with other interaction methods.

**Fig. 4.** Teamwork with patient I. 2 years after intracerebral hemorrhage, aneurysm clipping, cranioplasty. VS, dependence on mechanical ventilation.

The rehabilitation team faced various problems during different stages of treating this patient. Before the last neurosurgery he was able to follow some instructions. At this stage, the main task is to enable spontaneous breathing.
The last 30—40 years were marked by considerable practical advance in methodology of nonlinear systems. Let us briefly list the methodologies used in these studies.

Chaos Theory is the mathematical formalism describing behavior of certain nonlinear dynamical systems, which are subject to a phenomenon known as chaos under certain conditions. We should take into account the so-called “butterfly effect” inherent in some chaotic systems, when a negligible action on the system can have large and unpredictable consequences somewhere else at another time. The apparatus of this theory has been successfully used to predict signal generalization in the brain, as well as in studies of certain types of cardiac arrhythmia.

Complex Systems Theory is a scientific and methodological concept of investigation of systems that helps us to understand, how complex systems generate simple behavior, in applied aspect. Cardinal change in the field of systems theory has occurred in the last quarter of XX century. This period of systemic research development is still in progress. Its main distinction is a change from investigation of equilibrium conditions to analysis of non-equilibrium and irreversible states of complex and highly complex systems. Nontrivial approaches to study of complex systemic units resulted in development of another direction, the synergy that offers interpretation of such an important phenomenon as self-organization. Self-organization is a process of adjustment of elements belonging to the same level of system by means of internal factors without external specific action (change in external conditions can also have stimulating effect). It results in appearance of a unit having higher quality level.

Let us note that it is self-organization that may be responsible for manifestations of consciousness in a patient as a result of working of the rehabilitation team. Researchers D. Pincus and S. Guastello [34], who have founded the International Society “Chaos Theory in Psychology and Life Sciences” in the late 1990s, outlined the basic provisions that should be followed:

— “biopsychosocial processes (BPS) are organized as nested hierarchical systems with fractal network connections and outputs;
— adaptive responses within such systems, i.e. changes towards the rigidity or flexibility, are implemented by BPS-integrative function;
— rigidity increases the short-term resistance to threats to system integrity;
— flexibility allows for new growth, connectivity and system integrity;
— the system evolves through bifurcations, chaotic transitions and changes in connections between its elements."

The applied research in the field of the team approach appeared over the past 5 years. These studies allow one to measure the processes and their impact on the result. Systemic analysis of motor techniques in sports team members has a high predictive value [35]. Based on registration of microinteractions one can understand the mechanisms...
of change in leadership as well as training and change in organization [36]. More complex experiments conducted using simulations and based on telemetric EEG allow associating brain activity features with output of teamwork. Thus, R. Stevens et al. [37, 38] used the systematic approach to analysis of the so-called cognitive neurophysiological synchronicities to demonstrate that the entropy changes in cerebral bioelectric processes synchronize in members of submarine crews during training.

We believe that a signal containing information about mechanical quasi-oscillating processes is useful for rehabilitation research. Our kinetography method allows measuring the functional state of a person and its changes during the real human behavior in the natural environment of decision making. In some situations, transitional processes of functional state of a group showed how leadership manifests in solving the common problem [40].

The point at issue is that the proper choice of a signal and nonlinear analysis techniques can significantly alter our understanding of human responses to external and internal stimuli. Our basic assumption is that when studying the phenomenon of recovering consciousness, it is necessary to measure the same parameters at different levels of the multilevel system, taking into account the timescale of the process being measured. Relatively inexpensive new tools allow determining the functional state of systems of different levels using a single set of variables. With proper design of the study it is possible to analyze mutual influence of multilevel processes. If time series of any variable are available, we can calculate the following system parameters:

Energy: $E = \sum_1^n \Delta t_i \cdot A_i^2$, where $A_i$ is the signal strength;
Complexity (e.g. fractal dimension);
Entropy: $H(E) = -\sum_1^n P_i \cdot \log P_i$, where $P_i$ is the probability of the $i^{th}$ energy level.

Authors of some clinical studies also tried to use signals of the body to assess the state of consciousness, appealing to higher simplicity and availability of monitoring and taking into account non-linearity of the studied processes. Thus, a study conducted at several European rehabilitation centers showed that the entropy of a cardiogram recorded in patients with the SMC, is a quite reliable correlate of the state of consciousness according to clinical evaluations and generated potentials [41].

Only various kinds of entropy are generally used in clinical studies. It is an informative systemic characteris-
tic, as change in entropy is associated with information. However, we believe that evaluation of one parameter only leads to reduction and transforms searching for phenomena into analysis of objects.

The methodological restrictions, which were preventing confirmation of our hypothesis about the role of team as a factor of changes in level of consciousness in our patients for many years, are virtually removed today. Not only technical means and flexibility in the use of nonlinear analysis methods are changing, but also the very idea of interdisciplinary team in scientific community. A trend towards evaluation of multilevel information in terms of transitional processes is expanding. Active paradigms (sequences of stimuli) become increasingly more complex, transitional from laboratory experiments to real life. The level of teamwork is the personalization of the active paradigm, its exact correspondence to the actualizing condition of a patient. This allows one to establish a consistent basic communication and then to restore the fundamental involvement of patients with severe traumatic brain injury into the human community and essential aspects of a person [42].

Conclusion

An “objective observer” focused on such attributes of consciousness as brain activity, spontaneous and provoked behavioral manifestations cannot grasp the content of consciousness [43]. The approach proposed in this article leaves the boundaries of “objective observation” without abandoning the scientific principles. As early as in 1996, a Chilean biologist, philosopher and specialist in neuroscience Francisco Varela [44] stated that phenomenology is the basis for interdisciplinarity. A rehabilitation team that reveals phenomena of the body during the dialogic work with patient (these phenomena being indicative of changing mental condition) can become one of the effective tools of the interdisciplinary science of consciousness. Team work can be studied using concepts of a complex system, which are mediated through increasing complexity, maintaining energy, increase and decrease in entropy, and transition from the regularity to margin of chaos. In this way, the “patient—team” system moves to self-organization. Both the entire system that generates information flows and the patient as one of its elements are changing during this process. This process leads to actualization of consciousness.

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Increasing the effectiveness of diagnostic, therapeutic and rehabilitation activities is one of the most topical issues at the moment. Development of the science and methodology of recovering functions of patients with diseases and injuries of the CNS makes it possible to proceed to the definitions and content of rehabilitation measures for these patients. Numerous studies resulted in recognition of the need for optimal use of early multidisciplinary form of rehabilitation measures. However, clear understanding of the content of rehabilitation programs for a particular patient, the acceptable amount of intervention based on informative and reproducible diagnosis, the sequence of stimulations, aspects of relationship between specialists of a multidisciplinary team in patient’s best interests are the subject for further study and improvement. The present work is a discussion on this topic, which is very rare in professional environment, and therefore it is undoubtedly relevant. The acute period or the first stage of rehabilitation, which is critical for the effectiveness of rehabilitation in general, makes this article even more important during the period of rehabilitation measures discussed in this paper.

The author clearly notices the key feature of the approach in the study of consciousness and shift of emphasis when considering the effectiveness of rehabilitation in general, making this article an important contribution to the field.
Considering the interaction between the physical and spiritual aspects towards the brain—consciousness combination, which certainly must define the methodology of approaches to the assessment of consciousness and possible impact on the latter. The theoretical premises of understanding of consciousness are analyzed. The article provides an interesting discussion of the features of clinicians’ work aimed at analyzing the state of consciousness, using the definitions and classifications of consciousness impairment, which in fact solely leads to increased understanding of the variability of patient’s responding or not responding to stimulation. In this regard, it is a priori assumed that the type of stimulation and the analysis method were selected correctly. But in reality it often has little to do with the process of altering consciousness.

The article gives an interesting analysis of the conceptual apparatus of teamwork in the medical community and aspects of interactions between specialists as they deal with rehabilitation problems that often occur within the multidisciplinary team and are not related to the patient.

Differences in understanding the multidisciplinarity and interdisciplinarity demonstrated by the author, as well as a suggestion related to introducing the transdisciplinarity concept, are interesting and promising for improvement of the work and enhancement of its performance.

In terms of organization of the rehabilitation process, the author unwittingly gave a clear definition of the role of a psychologist in the team, which is currently extremely important for understanding the content of training programs for specialists intended to work in clinics. These are medical psychologists (nowadays the lack of these specialists for rehabilitation work in the country is more than 700), health experts who must be able to clearly make a request to colleagues and to analyze the information obtained. The proposed method of teamwork using the model of “living movement” came very timely taking into account the little experience of work of skilled kinesitherapists (physiotherapists or exercise physiologists), speech therapists, resuscitators, who rose above themselves in professional identity and learned to perceive and analyze the information adequately, with the described patient models.

Suggestions for dynamic organization of work, changing leadership and concept of co-therapist are also very important for organizing teamwork. An extremely important understanding is being formed: the effectiveness of the process is determined by the methodology of developing a complex self-regulating “patient—team” system consisting of at least two complex co-systems, i.e. “the patient” and “the team”. We have not yet learned to perceive and analyze the patient’s resources. In addition, due to the shortage of skilled team members we do not even wonder about the need to develop an understanding that the form of interaction between team members during the clinical and social decisions directly determines the outcome. But these are only the tasks for the future. The author has correctly raised the question about the choice of methods for analyzing information received from the patient or a testing specialist.

We have obviously come to a new level of self-organization of cognitive process and influencing of the subject in state of altered consciousness. It is also clear that the serious disjunction between philosophy, scientific research and the process of implementation into routine practice of specialists, which allows developing the key issues of the already formulated suggestions, leads to negative trends in self-organization up to complete negation.

The work is highly relevant, interesting and it should be continued.

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Interest in the problem of consciousness occupies an increasingly prominent place in today’s world, expanding the variety of scientific approaches to this topic. The phenomenon of consciousness is considered from different angles: philosophy, mathematics, physics, neurosciences, medicine, and psychology. Perhaps, this polyphony creates additional complexity in understanding and, at the same time, provides a variety of descriptions. To date, science has not provided a unified, clear concept of what consciousness is, but there have been various attempts to describe this phenomenon. 

Studies of consciousness have been conducted in different directions that include theoretical approaches (such as neurobiological, informational, cognitive, quantum theories of consciousness) and numerous case studies of different aspects of consciousness (such as neural mechanisms, perception, behavior, altered states of consciousness, and transpersonal experience). 

The main problem is the very nature of consciousness and its relation to the physical world, to the brain and body. An Australian philosopher D. Chalmers [1, 10, 11] speaks of two problems of the mind–body interrelation: 

— the easy mind–body problem that means the study and explanation of various phenomena (attention, behavior, voluntary control, etc.) using modern science methods. These are the problems that are directly related to consciousness, are its expression, but do not constitute consciousness as such. 

— the hard mind–body problem that puts the question of how experience that arises on a physical basis and is formed by the known mechanisms becomes itself a subjective experience (qualia). 

However, an English mathematician R. Penrose [7, 8] has convincingly demonstrated that not all human thought processes can be algorithmic and provided examples of how a person can solve problems that are not algorithmic (Penrose tiling). R. Penrose bases his arguments on the Gödel’s incompleteness theorem, namely, that any complex system contains a statement that can neither be proved nor disproved in the framework of the very system. Based on this, R. Penrose claims that work of the brain, of consciousness, and of thinking cannot be formalized: “I want to say that the relevant processes in the brain cannot be modeled in principle” [7, p. 103]. 

R. Penrose speaks of “quantum consciousness”, i.e. about the relation between quantum effects of the interaction of subatomic particles and thinking. R. Penrose and S. Hameroff [14, 21] have believed that consciousness arises as a result of the transition from a quantum to the classical system, which occurs by means of the non-formalizable procedure of “objective reduction” (OR). The quantum system, in turn, is formed by a large number of coherent links among the so-called microtubules, a cytoskeleton of neurons on the basis of the protein tubulin. Numerous links among microtubules “orchestrate” the quantum coherences among them and the sub-
recent OR, which leads to the so-called “orchestrated objective reduction” (Orch OR). According to the authors, this is the sequence of reductions of quantum states that constitutes the subjectively experienced “stream of consciousness”.

According to D. Chalmers, quantum models can be an important step towards understanding of consciousness, but like other approaches they do not answer the main question: how quantum processes give rise to experience? Chalmers believes that the explanation of consciousness cannot be done without the phenomenological component, i.e. its subjective aspects: perceptions, emotions, feelings, etc. According to the two-aspect theory of Chalmers, information contains two interrelated aspects: physical, or external, and qualitative, or inner, experience. In addition, D. Chalmers claims that until this problem is solved, consciousness remains a mystery, which we can touch by means of observable phenomena.

When studying impaired consciousness, especially associated with acute brain lesions, one will inevitably face the specific and unusual phenomena. Psychological interaction with patients in post comatose states differs significantly from traditional psycho-corrective work. In patients in the post-comatose state, especially in the early period after injury, the ability to communicate is significantly impaired: the patient does not use speech, gaze, facial expressions, and gestures; does not change the posture; or his statements and actions are chaotic and have no apparent connection with the context of the actual situation. At this stage of rehabilitation, it is still impossible to speak about recovery of higher mental functions. The purpose of psychological correction is to recover the patient’s consciousness, his ways to interact with other people, himself, and the outside world. The main problems faced by a psychologist at this stage include establishing the contact with the patient, translating him into a state of “dialogue”, and sequential expanding of communication.

In recent years, neuroimaging studies using functional magnetic resonance imaging (fMRI) [9, 19, 20, 22] have been conducted on different forms of consciousness impairment in people after severe brain injuries. These studies have linked interests of neurosciences, medicine, and psychology. Despite the fairly large scientific breakthroughs in this area in recent years, the problem still remains relevant and highly debatable. According to the studies, signs of consciousness can also be found in people who are in deeply altered states of consciousness (ASCs), which are characterized by the absence of external, familiar to us, ways to manifest consciousness. Most studies of this kind are designed as follows: patients in various ASCs and patients in clear consciousness are offered the same tasks and instructions, such as to recall or imagine something specific. At this time, the state of the patient’s brain is detected using fMRI, EEG, and other research tools. As a result, it has been shown, in particular, that the same areas of the brain are activated in patients in clear consciousness, with locked-in syndrome, and in minimum consciousness, when they perform identical tasks. Such research methods are being permanently developed and improved. Currently, researchers have started to move away from the active paradigm described above to the so-called passive one, permitting the impossibility to obtain a response from the patient, even if he is conscious. Similar position even greater reinforces the need for developing tools to interact with the mental process in a person significantly limited in his manifestations. The task of a psychologist is to find a suitable “language” in which the interaction with the patient, personal communication to him will be possible.

For their part, the psychological approaches and psychotherapeutic directions rely on various models for the interaction of consciousness and unconscious processes. They use numerous practical tools of verbal and non-verbal methods of interaction with the contents of the unconscious and its awareness, e.g. an analysis of verbal and cognitive constructs, physical manifestations and patterns of a person as the embodiment of the unconscious, and often as traumatic experience (Reich, Alexander, Lowen, Keleman, Boadella, P. Levin, et al.).

However, few psychotherapeutic schools have techniques to work directly with altered states of consciousness. One of such directions is the process-oriented approach developed by A. Mindell [2—4, 6, 16—18, 23]. This direction of psychotherapy has been used at N.N. Burdenko Neurosurgical Institute for 20 years in working with patients in ASC caused by brain injuries [12, 13].

It is believed that psychological correction and psychological rehabilitation of neurological patients are performed if they have the clear mind and some, even minimal, ability to verbal communication. The targets of psychologist’s work are usually cognitive and emotional impairments, social adaptation problems, and neurotic syndromes.

The use of the process approach allows one to work with patients after severe brain lesions, regardless of the clinically determined ability to contact. The spectrum of states ranges from clear consciousness to coma (the vegetative state, the minimally conscious state, mutism, confusion, post-traumatic Korsakoff syndrome). In addition to the conventional psycho-corrective tasks, this approach is oriented at recovery of consciousness as well.

The central part of psychologist’s work is to establish communication with the patient incapable of a verbal contact at the stage when it is still impossible to judge on the presence or absence of aphasia. Such a communication represents a non-verbal “dialogue” with the patient formed by the psychologist, with a gradual expansion of the “dialogue” borders and involvement of other people and environmental objects in it.

The process-oriented approach was developed in the late 1970s by an American psychotherapist A. Mindell.
According to the definition, this is a “methodological approach to observing complex and subtle interactions between perception and behavior of a person, constructed in such a way that the results of the observation become immediately available for the person” [5, p. 149], i.e. become a part of his experience and are realized. This approach is phenomenological and transdisciplinary; it is oriented at the complex, multicultural, multi-level practice of awareness [2, 16].

Arnold Mindell is a Jungian analyst and physicist by his first education, which had an impact on the origins of process psychology, which are as follows:

— the Jungian analysis suggesting that every event has a purpose (teleological approach), the process of formation and development of the individuality is determined by means of integration of the own and collective unconscious into the daily life of an individual (individuation); the content of the unconscious (shadow), drives, which may contradict the basic mindsets of the person;

— the information theory, according to which human experience can be represented in the form of units (bits) of information;

— quantum physics as the basis for eliminating contradictions between experimental measurements and direct experience, between an external observer who partly marginalizes the inner experience and direct feeling of experience, establishing relationships between the observer and the object.

According to A. Mindell, the need for changing the paradigm, both for physics and for psychology, is associated with the “transition from the observer’s position to the participant’s position” [4, p. 43], from the description of experience to direct feeling of experience. Mindell enriched the traditional symbolic methods of working with the unconscious by phenomenological direct interaction with its content through verbal (beliefs, mindsets) and non-verbal (body experience) manifestations of a man. The access to the content of the unconscious in the process approach is performed through capturing information signals that are manifested in various modalities of the experience or perception channels. The following channels are distinguished: visual, auditory, kinesthetic (movement channel), proprioceptive (sensations and feelings), verbal, the channel of relations, and the so-called global channel (interaction with groups of people, and events in the world and environment).

Once the signals are detected, their unfolding begins by means of amplification that helps a person to increasingly identify himself with his unconscious, to realize it. This communication between the therapist and patient is called a process.

From the viewpoint of process-oriented psychology, human experience can be divided into two types: one, with which the person identifies himself, the so-called primary process or primary identity, and another, which the person denies, does not identify himself with it, is known as the secondary process. The capability of integrating these two types of experience is initially separating by a barrier, edge, obstacle, which is represented in the human mind as mindsets, beliefs, introjects, severe emotional distresses, complexes, etc., limiting one’s possibilities.

Thus, the process is a signal flow that unfolds along various channels. The skill of a process-oriented therapist is to observe, to amplify, and to unfold the process, especially unconscious signals, making the increasing content of the unconscious or extramental available to consciousness, bringing from the shadow contents that limit human individuation.

The process-oriented approach comprises a conception of the continuum of consciousness states. This classification differs from the traditional clinical hierarchy. It is not limited to the states resulting from deficiency of a particular function, but comprises clear consciousness and light ASCs, including non-pathological forms.

This model has an aspect important from the psychological point of view, the ability to meta-communication, A (Figure), which is defined as “the person’s ability to think of his experiences, both primary and secondary, to hold a coherent picture” [6, p. 190], which means critical awareness of himself and the outside world and is an important sign of awareness. This ability allows a person not to be “captured” by some single state, but to retain the possibility of observing as if from the side, with being involved in what is happening. With the deepening of ASC, the ability to meta-communication declines gradually to its complete absence.

B is the so-called conventional reality and ordinary state of consciousness. A person in this state is usually identified with the habitual and familiar aspects of himself. Meanwhile, upon insufficiency of meta-communication, this state can significantly limit the person in his individual development because of closedness of the person to new experience.

C are light ASCs. These are states, with which the person identifies himself for some time, i.e. is delved only into a part of this process. Certain mood prevails in
experiencing, meta-communication is complicated. These states arise from the strong emotional experiences, including traumatic ones, when a person is largely delved into this experience and it overshadows everything else.

D are the so-called extreme states of consciousness. In these states, the person is even less capable of meta-communication; the content of his experiences is very far from the conventional notions of reality. It seems that the person in this state does not give feedback in the usual sense and loses the ability to report on his experience. The person is very much delved into his state and does not practically correspond to the conventional reality, its rules and regulations, is not able to critically assess his own behavior and to correct it.

E are deep ASCs. In these states, the person does not come entirely into contact in a usual way, does not use meta-communication, “is entirely within his experience and needs someone who joins him there” [6, p. 195]. This joining is possible using special methods developed within the process approach when the psychologist temporarily takes over the function of the metacommunicator.

The basic principles of using the process-oriented approach to work with ASC are as follows: searching for and establishing adequate communication (“dialogue”) with the patient, gradual recovery of his ability to meta-communication. The system of feedback between the psychologist and a patient is used to construct such a “dialogue”. Then, based on this feedback, the physical and emotional resonance is formed. These levels are in permanent interaction.

Feedback (FB) is the signals/reactions in response to intervention of the therapist at a particular time.

Positive FB: “yes”, kinetic expansion, agreement, continued contact, deepening breathing, etc.

Negative FB: “no”, the lack of response, weakened breathing, interruption of contact, compression, etc. If the patient gives the negative feedback three times, then intervention should be changed.

Mixed FB: the above-mentioned signals are given simultaneously. The psychologist’s task is to determine which part of his intervention caused the positive FB and which caused the negative FB.

When working with the verbal feedback, it is very important to take into account the cultural aspect of life. This aspect can be partially omitted at early stages of non-verbal work.

As mentioned above, in addition to the feedback, resonance is an important basis of the contact and dialogue. If the resonance is not achieved, the interaction occurs at the level of the mask, transference—countertransference. The ability to capture and follow physical impulses and emotional processes of another person is called somatic resonance. As part of resonance, or independently, empathy stands that is the ability to respond emotionally to the affective experience of other person. The feedback, somatic resonance, and empathy are the basis for the formation of contact not only in recovery of impaired consciousness, but also in the ontogeny upon the formation of self-perception in a child up to three years old, and especially during the preverbal period, which forms “Self” of the person afterwards.

Thus, in the absence of the patient’s ability to verbal communication, establishing the non-verbal “dialogue” becomes the main form of interaction, and the verbal channel can be used only in one direction, from the psychologist to the patient. Goals and objectives of the “dialogue” are determined by the level of patient’s consciousness and his capabilities of manifesting himself in the outside world. At various altered states of the patient’s consciousness, the psychologist uses a common algorithm of work: captures signals of different modalities from the patient, strengthens them, integrates with each other, builds into the “dialogue”, corrects them depending on the feedback from the patient.

The process methodology of working with patients in ASC has been developed by A. Mindell and his colleagues since 1989 (the publication date of the first book by A. Mindell on this topic) and not on neurosurgical patients. The authors have repeatedly emphasized that patients in deep ASCs caused by brain injury are the most difficult group of patients to recover consciousness. We have been developing features of this work with neurosurgical patients at the Burdenko Neurosurgical Institute since 1991.

Let us list the main procedures of process therapy for working with patients with various ASCs:

— light ASCs (C, Figure) require to find a supporting resource state of the patient that will reduce the emotional charge, which will enable amplification of the meta-communicator.

— in the extreme states of consciousness (D, Figure), it is necessary to create a specially organized field, in which spontaneous manifestations of the patient can be used in the “dialogue” with him, to form effective ways for discharge of affect, which would promote its completion, thus ordering the behavior, increasing the awareness level. In addition to this, the technique called “Steal the state” can be used: there is a conception that one field cannot comprise two identical states, and if someone in the field reproduces some state, then the other gets an opportunity to change his state.

For example, let us consider one psychological session.

A 26-year-old female patient B. Diagnosis: severe closed head injury in a car accident. A severe brain concussion (diffuse axonal injury of the brain), intracerebral hematoma in the right hemisphere of the cerebellum, right hemiparesis, a contusion of the left eyeball. According to brain MRI, there are intracerebral hematoma in the right hemisphere, subarachnoid hematoma in the left temporal region, lesions in the corpus callosum and the white matter of the frontal lobes. The patient remained comatose for 1−7 days. After 3 weeks, a persistent restlessness gradually transforming into purposeless psychomotor agitation was observed.
The session was performed 2.5 months after the injury. The rehabilitation program had been conducted for the entire hospital period and included work of a psychologist who had used the process approach. Clinically, the state corresponds to hyperkinetic mutism with individual, poorly differentiable emotional reactions. The duration of the session was 1 h 15 min.

The patient was able to fix the gaze on objects, held eye contact for a while. She permanently moved within the bed. The patient needed close supervision because she did not assess the degree of danger, could fall.

There were many chaotic, unfinished movements; the patient did not identify herself with them, did not respond in any form to the questions “What are you doing now, what do your movements mean?”, breathing was frequent; the respiratory rhythm was “ragged”; the skin on the chest and face often reddened. The patient needed a rather large space; the session was held in the hall with a special coating in order to enable her to obtain the maximal freedom of movement. Because of the very high motor activity, the session was performed by the psychologist and two co-therapists.

Left alone, the patient started to move randomly the limbs, to lift her head and shoulders. The psychologist and co-therapists sequentially, as movements arose, began to lend soft support under the limbs, head and shoulders, using touches, providing a base to the patient, thereby giving the possibility to unfold the undertaken movement. Then, depending on the feedback signals from the patient, other interventions were used: amplification of movements (continuation of the movement initiated by the patient was performed using touches), delineation (movements were confined using touches).

During the session, the range of the patient’s movements was gradually increased, torso twists in different planes appeared. Besides the motor interaction, throughout the entire session the psychologist tried to maintain eye contact with the patient and accompanied all his actions with verbalization, questions to the patient, or encouragement (“You are doing it great, go ahead. What do you want to do now? Approve yourself more clearly”, etc.). Along with this, the non-verbal, sound interaction occurred: when the patient produced individual sounds (coughing, moaning, mooing, etc.), the psychologist joined the patient’s sound or repeated it exactly or with slight modification and modulation.

The patient’s movements gradually became of more directional character. Coherence and consistency of movements of different body parts increased significantly. The patient held longer eye contact with the psychologist. A short non-verbal “dialogue” of the therapist with the patient became possible with help of individual sounds. The rhythm of breathing smoothened gradually; the patient herself chose a comfortable position for her body and began to sight the objects around her. Distinct facial correlates of emotions appeared: smile, surprise, and embarrassment. Contact with others (psychologist and co-therapists) also became more emotionally charged. The patient’s behavior became more orderly. An opportunity appeared to interpret more clearly the patient’s manifestations, to name them, to assess them, which allowed the patient to relate herself to this and to demonstrate her attitude in the interaction with another person, i.e. to integrate and assimilate the experience.

As a result of the performed session, the patient’s restlessness was significantly reduced; differentiation of emotions appeared; the time spent in contact increased; elements of self-awareness manifested more clearly.

Long after the traumatic brain injury, when the patient was available to full contact, she said that she retained the partial memories of the conducted session, which became the first distinct memories after the traumatic brain injury.

—at deep ASCs, the technique of working with “minimal signals” is used. Patients in these states are almost completely deprived of the possibility of usual interaction with other people, the outside world, and themselves. Only the most minor manifestations can be detected, such as physiological body signals (e.g., breathing), micro-movements (e.g., micro-movements of fingers, limbs), and what appears on the patient’s face (facial expressions, for example, tears, smile, etc.). It is known from psychotherapeutic theory and practice that the person’s breathing pattern is closely connected with his emotions, and emotions, through movements and facial expressions, may become visible to other people even if they are not realized by the person himself. Spanning bridges between such manifestations facilitates integration of experience and its perception. Expression, which can be observed in a patient emerging from a coma, is minimal, often almost imperceptible. Nevertheless, it is very important to include the establishing communication in the context, when the psychologist is no longer just a bystander recording data but becomes a participant of the interaction, which in turn allows the patient to be a full partner of the “dialogue”. In this case, one of the basic principles is realized, namely, subjective, personal appeal to the person, regardless of the degree of impairment of his consciousness.

For example, one can use the technique of synchronizing the patient’s breathing rhythm with some his own spontaneous minimal movement or with touching a patient’s body part, in which the sensitivity is retained, to the breathing rhythm or multiples of it. Gradually, relying on feedback signals from the patient, the psychologist establishes a stable interrelation among the various physical manifestations of the patient himself and the signals that are imposed from outside. This is the beginning of the “dialogue”, which is based on non-verbal interaction. Then, the range of inter-corresponding signals is gradually expanded; the “dialogue” becomes more diverse. This work is necessarily accompanied by verbal
comments and appeals to the patient. For example: “I will take your right hand now and will shake it to the rhythm of your breathing”. It is possible to name clearly the patient’s actions: “You are now moving your left thumb”; it is possible to give open instructions: “Keep doing what you are doing”, etc.

Integration of different signals from the patient, personal appeal to him, and a personal response to his manifestations underlie non-verbal interaction, whose expansion leads to a decrease in randomness of the patient’s processes, to an increase in self-regulation and gradually restores his self-awareness.

It should be noted that in addition to process-oriented psychotherapy, upon working with these patients, techniques of body-oriented psychotherapy are effectively used, in particular, biosynthesis (D. Boadella) and integral–somatic psychotherapy of psychic trauma (P. Levin); however, a more detailed discussion of these approaches is beyond the scope of this article.

Currently, no reliable evidential base has been formed yet, which could support the effectiveness of the process-oriented approach when working with neurosurgical patients in ASC. To some extent, this is due to the objective difficulty faced by the phenomenological approach upon confirming evidence of its efficacy. It is necessary to create and develop opportunities for monitoring body manifestations and brain processes of the patient, to perform real-time monitoring and recording of the interaction between the psychologist and the patient and the process of establishing the “dialogue”, to find evidential procedures for the phenomenological approach. Nevertheless, despite the objective difficulties, there are already some studies aimed at evaluating the effectiveness of psychotherapeutic influences using neuroimaging [15]. However, so far they deal only with the verbal methods of psychotherapy. Accumulation of the consistent evidential base and conjunction of modern monitoring methods with the process-oriented approach will increase the effectiveness of applying the psychological techniques to recover consciousness.

Thus, the process-oriented approach is the phenomenological interaction between an external observer and immediately felt subjective experience (one’s own or that of another person) that turns the observer into a participant and makes it possible to feel the experience to a greater extent. In contrast to other psychotherapeutic approaches interacting with the unconscious, the process-oriented approach is the only direction with the developed tools for establishing contact with a person in deep ASC. This approach can be used to recover impaired consciousness in patients with brain lesions as well.

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The problem of recovery of consciousness, raised in the article, is like d’Artagnan: challenges a duel three at once: a psychotherapeutic technique, a psychological theory, and a methodology of interdisciplinary research.

A patient is comatose. What kind of psychotherapy can be talked about? Even the very word “psychotherapy” suggests an appeal to the mind of the patient. No psychotherapy is conceivable without establishing contact and “working alliance”. Coma, hence, makes psychotherapy impossible. Yet, the author demonstrates that, using the methods of process psychotherapy of Arnold Mindell, it is possible not to establish contact with the patient but to create contact, to form and to give rise to it. Usually contact is a prerequisite of psychotherapy; when working with the comatose patient, contact is the goal of therapy. If this goal is achieved, at least partially, a little clinical miracle happens, the patient’s consciousness recovers.

For the theory of cultural-historical psychology (L.S. Vygotsky, A.R. Luriya, A.N. Leontiev), this strange sequence, “contact first, then consciousness”, is not a surprise. L.S. Vygotsky conclusively has proved that the higher mental function in the ontogeny appears first in the intermental, interpersonal form, and only then “folds” in the intrapsychic form. These articles by S.B. Gusarova demonstrate that the same pattern is also typical of the situation of recovery of consciousness. Similar to a mother who accompanies, comments, and catches spontaneous movements and sounds of her baby establishes a sensually communicative medium, from which, sooner or later, individual consciousness of the baby originates, a clinical psychologist uses the process psychotherapy technique to create a “zone of immediate recovery” of consciousness. Reflection of this therapeutic situation using the concept of cultural-historical psychology is not only theoretically productive, but also methodically promising, because it allows the psychotherapist to enrich his tools, in particular, with sign-symbolic means.

Psychotherapeutic work with comatose patients puts a point-blank question regarding the relevant psychological theory of the “middle level” (i.e. regarding specific theoretical models that can serve as conceptual maps of this work). Similar rehabilitation tasks of movement recovery have been successfully solved on the basis of the Bernstein’s theory of levels of constructing movements. It is possible to assume that a multilevel theory of consciousness is also required for recovery of consciousness. These stratigraphic models of consciousness have been developed in Russian psychology by V.P. Zinchenko, O.S. Nikolskaya, and F.E. Vasilyuk. In particular, a number of psychotherapeutic techniques developed by O.S. Nikolskaya for working with autistic children are quite promising to be transferred to the field of psychotherapeutic care for comatose patients.

Not only the availability of adequate theoretical models and practical psychotherapeutic methods is important, but fluency in these methods. Communicative competence of a Russian physician lags significantly behind other aspects of his professional training; a physician often considers communication with a patient as an annoying, useless, and only time-consuming addition to main work, but not as a necessary structural element of professional activity, on which the outcome of treatment sometimes depends significantly. In the field of working with comatose patients, both a physician and a clinical psychologist need additional specialized training, during which special sensitivity, special observation, and special communication skills, primarily non-verbal, are trained.

However, the most difficult challenge to the problem of recovery of consciousness lies in the plane of the methodology of interdisciplinary research. With all ingenuity of approaches suggested by a number of authors, in particular by D. Chalmers and R. Penrose, this area is still dominated by metaphors rather than by philosophical and methodological concepts based on clinical material.

The meaning of the articles presented by S.B. Gusarova is primarily in stating the problem of consciousness recovery in comatose patients and in indicating the possible directions of its solution.

F.E. Vasilyuk (Moscow, Russia)
The Existential-Phenomenological Approach to Consciousness and Treatment of Unconscious Patients

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The human beings are characterized as subjects. Their essence is understood as Person. A treatment that does not consider the “subjective” and the Person would not correspond to their essence. For a sentient and autonomous being consciousness matters, but it does not fully unravel a human existence as Person. This has a therapeutic impact on the treatment of unconscious patients and gives a specific character to the treatment approach. Some instructions for therapeutic application of the phenomenological-existential concept and the phenomenological attitude towards unconscious patients or those having brain trauma are given. The role of consciousness in human existence is briefly reflected from an existential perspective.

Keywords: unconsciousness, consciousness, existential procedure, phenomenology, fundamental existential motivations.

An existential view of the human

What defines human and, apparently, differentiates him from other living beings is the special character of his existence, that of his being a subject. This fact stipulates certain angle to human, which is that he should be considered a subject. The treatment of human only as an object, which corresponds in misinterpreted evidence-based medicine to the main principle of natural sciences, adhering to only empirically supported procedures, does not reflect the human essence. Evidence-based medicine relies on two other factors as well: individual clinical experience of a physician and values and desires of the patient (G. Guyatt et al. [5]; D. Sackett et al. [23]), though attention paid to these subjective aspects is often insufficient (H. Wesling [27]). The human essence, its Person, stems from its subjectiveness1 (V. Frankl [4]; A. Längle [11]; R. Spaemann [25]). A human as Person is a being that was granted to himself and whose principal trait is that he possesses a right to have its own way and his own will. When a physician treats patient’s body, the patient is never just a “matter”. However much attention is paid to physiological, chemical and energy aspects, the human body is always something of a bigger scale, containing an untouchable essence in its depth. This “something that could not be apprehended” is Person, dignifying a human. In the present context we are interested to which extent consciousness defines human’s existence. Consciousness is often believed to be the same as dignity. Indeed, consciousness is associated with dignity to a large extent. Whenever a person makes decisions, or takes responsibility, or feels guilty, we speak of dignity. Decisions taken at one’s own will let him save his own dignity or dignity of the other person as it is up to a person to bear himself with dignity or to lose it. This is where consciousness plays the dominant role. The body is also inextricably connected with the human essence as it could be employed in either decent or disgraceful way of behavior, like that of sexual intimacy or in decisions related to treatment (again and again, the issue of whether measures sustaining life in end-of-life situations are appropriate for human dignity becomes the topic of discussion). The body and psyche are important forms of human existence, whereas consciousness, thinking and memory are its principal functions. Nevertheless, the essence of human lies significantly deeper. It is crucially important that physicians would realize the presence of this deep layer. Human is a sentient autonomous being. “Sentient” means that he is self-identified, which psychologically is mediated by reafferent neuronal loops and thus allows human to be given to himself. By “autonomous” we mean that human rests in himself, eventually does not depend on other people and circumstances in his decisions and self-formation, and acts on his own will. As a sentient autonomous being, human originates from himself and is

1According to the anthropological model adopted in modern existential analysis, a human is an entity of three dimensions: somatic, psychic and spiritual ones. Here, “spiritual” is understood not as the religious component, but as “human” in a human being (the one that differentiates him from plants and animal life). This is, for instance, his ability to make a choice or decision, to live up personal freedom and responsibilities, etc. The term “Person” corresponds to the spiritual dimension of human. We left it ‘as it is’, as a special term, accepted in the present psychotherapeutic paradigm as a synonym for spirit that each person possesses. It is free and is not prone to any diseases (all diseases occur in the somatomental dimension and may block the access to the depth of Person’s existence, simplifying his personality in such way). The main meaning of the term “Person” is close to the notion “essence”. (Note of the science editor).
able to form himself autopoetically\(^2\). There is nothing more we can say about these interior roots of Person: we do not know their nature or origin of life; the only fact we know is that these were not our efforts it was created with. Such limits of our knowledge should be treated with respect (R. Spaemann [25]; A. Längle [14]). Respect is an inner posture in which individual distances himself in order not to disturb the intrinsic value of the thing (in this particular case — the incomprehensibility of origins, namely, the incomprehensibility of Person).

What physicians treat are not dead bodies, but alive ones. While it lives, the body is the one entity with the physical vitality of life and the mental presence of one’s personal existence (V. Frankl [4]). The living body is filled with Person, it is the Person. Person in man represents spiritual strength, the “spark of life” that lies beyond our comprehension. “Man is always something more than what he knows of himself” said Karl Jaspers [8].

As far as it goes to the patients with deprived consciousness or who lost it temporarily due to an accident or a disease, there is a profound existential question: what counts in human life? What for it is important to live? What is the value of life? These existential questions indicate the importance of anthropological understanding of the man’s existence. This is the background to treatment. Each physician has his or her own anthropological view and existential understanding of what the man’s existence is (realized by him to a more or less extent), which defines his decisions in extreme situations.

But what is it that matters in life? Is the preserved consciousness, assuming one’s realization of his actions, the key factor? Or the most important thing is to remember what one has experienced and done? Does it mean that it is preserved memory that is crucially important for human existence? Or the defining factor is how much one has created in his life, that is, how broad his experience is? It turns out that it is not easy to answer these questions.

Existential answers refer neither to “to have”, nor to preserved functions, nor to spent abilities. From the existential point of view “existence” means that the man has been there with his body, his feelings, more or less consciously. This is what lies in the background. What counts is that the man had the possibility to be himself, came through many experiences, and had an inner dialog regarding his own senses and his body. It is where different aspects of the human existence, which may manifest itself in sometimes opposite forms like in body and psyche, coexist. Mediated by the man, they unite in spiritual dimension of personal existence (V. Frankl [4]; Fig. 1).

An interpretation that does not take into account this integrity of different dimensions of a man and leads to an approach that deals only with one dimension while neglecting others is called reductive. Such viewpoint damages the integrity of the individual and hurts its dignity.

It should be mentioned here that psyche and the body may manifest themselves in opposite ways (Fig. 2). While the body might have no reflexes, in the psyche dimension there might be fear and inner life. The fact that both dimensions comprise a unity is what defines human dignity and makes him impenetrable.

**Basic principles of treating consciousness disorders: “personal stimulation”**

The core basis of the approach to patients with consciousness disorders is that a man should be treated with respect, which means that one should take into account his autonomous nature and ability to make decisions as manifestation of Person. Being Person stands for being associated with the inner and the outer world, being on one’s own and being with others, (Fig. 3) regardless of whether the person is conscious or not.

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\(^2\)Autopoiesis (from Greek “creation, production”) is the term introduced in the early 1970s by Chilean scientists H. Maturana and F. Varela. According to their theory, all living beings (including human) are featured by “autopoietic organization” meaning that they are capable of reproducing themselves. The fact that an autopoietic system generates, “builds” itself and creates its own components could be compared to one’s “pulling himself by his own hair”. (Note of the science editor).
The man is open and incomplete at both poles, so he cannot deal without another other person. At the outer pole he is open towards differentness (of other people and the world) and at the inner — towards his own depth (personal intimacy). Psychotherapy can address both poles. As a matter of a principle it means accompanying the other in his world. The basis of all psychotherapeutic measures is to stay on the horizon where patient learns to deal with strangeness. Of course, such presence cannot be compared to the mechanical stimulation of the body, which physicians often resort to in order to wake up an unconscious patient. Instead of stimulating the object, one would rather address the personal level and try to enter the outer world of the patient, to be in front of him, to meet him with respect and keep in mind the depth of his personality regardless of whether he can act at the moment or not.

This double association with the inner and the outer world reveals the unique capability of human to be unconditionally open. Such perceptivity as if gives the man ‘antennas’ and makes his inner essence accessible from the outside. One may contact this self-contained dimension using body, psyche and noetic tools. This unconditional openness does not anyhow depend on the awake state of consciousness of an individual. It is well-known that the major part of the perceived information is not realized (P. Merikle et al. [19]). Even Pascal ([21]) noted that a sense has reasons impenetrable to the mind. The openness of the man’s experience as Person corresponds to the so-called phenomenal consciousness and concerns the notion of qualia, i.e. the issue of distinguishing the subjective content of the mental processes (A. Becker- mann [1]; M. Nida-Rumelin [20]).

When the consciousness of a severely injured patient becomes accessible again, there appears a question of how to reach Person of the patient. The basis of it is the dialog, the requesting and taking up personal position by both physician and the patient. A man who endured severe trauma and lost consciousness needs an outside assistance to get back to the existential dimension of life, to catch it. Accepting the givenness means one is ready to be, to live with new, most likely changed conditions and past experience. Patient is facing the existential choice of whether he is willing to live further or not. He needs an outside assistance and guidance in order to build the core existential structures inside (A. Längle [14]). Otherwise, treatment and recovery will be significantly slowed down (see the study of salutogenesis, tolerance and resistance by A. Längle et al. [10]).

At injury-caused traumas and crises damaging consciousness, psychotherapy is as much required as the personal contact and stimulation. Such experience may shatter one’s existence to the point after which one loses the prop and ability to revise (A. Längle [12, 13, 16]). Main steps in the assistance are stipulated by the theory of existential fundamental motivations (A. Längle, [14]) and have already been described by N.S. Ignatieva [7] in respect of after-coma states:

1. The first and foremost factor is to-be-here (Dasein) of a physician for the patient, his inner presence, being felt by the patient. This is an ontological basis.

2. The second aspect is emotional contact: it is necessary to establish emotional relationship with the patient, to address him, to be close to him, while observing one’s own feelings and revising them.

3. The third aspect is personal contact: a physician should talk to the patient even if one is not yet able to reply, adjust himself to feel the patient (attention focusing) and connect him with ‘his own’, important to him (to invite people close to him for instance) things.

4. The fourth aspect is to introduce perspective for the future (progress is always possible, even in the absence of consciousness, up to the death) and to outline the most prominent contexts of the particular patient’s existence like family, children and projects. As for the conscious level, it is of course, existence and decent future that are mostly considered.

In clinical practice, the aforementioned dimensions can be extended by special techniques used by psychologists and counselors. For instance, the first factor, namely to-be-here with the patient, could be extended if one silently concentrates on him, attentively looks at him, observes, makes inner contact, touches, keeps with the pattern “I keep you, with all that you are” etc.

The outside presence, an attempt to meet the man as Person and to focus his personal strength, stimulates his inner life. It also triggers the inner dialog and relationship with the inner self: trying to be himself, to find a way to himself in life (this could be called “existential consciousness”). At the later stage this inner presence may reveal itself. The man will be able to tell something about himself and to start a dialog. Realization-of-being-here relies on two traits of man as Person: being on his own in the inner world and being with the other person in the outside world. The former makes the man able to perceive impressions. This dimension is the most important at serious disorders of consciousness. “Being with others” defines relationships, contacts. Both dimensions create possibilities for the interchange and communication. In the end, this is what allows the man to be a part of the outer world again (see the personal model of revision and communication — A. Längle [9, 16, 17]).

3. The role of consciousness

In the context of our problem it is important to reflect the task of consciousness. What function does consciousness perform for a man? The main component of consciousness in the awake state is the self awareness,
meaning that person knows that he is he, who is doing and feeling something. D. Chalmers [2] develops this idea and suggests “… the mental state is consciousness on condition it has attributable feeling” or “… realizing is almost the same to having a subjective experience (ibd. 6). Furthermore, consciousness performs such tasks as thinking, remembering, perceiving, feeling, being alert (attentive and vigilant), decision-making and communicating. It permanently and intentionally focuses on the content that it seizes (realization is always a realization of something), etc. (see D. Chalmers [2]).

From the existential point of view, the principal function of consciousness is to be one’s own inner counterpart. It gives man the knowledge of being here. Realization is always equal to self-awareness: “I am the one doing it”. That is why consciousness is a basis for reflection; it is able to make the experience more intensive. This distinguishes consciousness as the means rather than the objective. The objective is to live, to be oneself and also, to a larger extent, to find, to become oneself.

Revising and reflecting “Me” depends on consciousness in the sense that it is consciousness that creates the inner vis-à-vis enabling deliberate integration and taking certain position towards the information and experience. This is what makes consciousness, existence as Person and selfhood close as consciousness processes are all realized (not on-the-spot, intuitive) decisions. Nevertheless, consciousness cannot be set equal to existence as Person, the human essence. Consciousness is not the content that defines man, but the means making functioning of “Me” possible and playing the crucial role in decision-making.

4. How does phenomenology contribute to treatment?

Contemporary methods for treating human psychosomatics indicate two significant aspects related to the personal existence that are essential when working with patients suffering from consciousness disorders. Both concern the importance of contact with the inner world of the patient as well as the ability to concentrate on the positive things. Thus, T. Wise [28] said: “According to works of Schmale and Engel it is necessary “to look into” the patient… in order to recognize both the subjective and objective phenomena of each experience that patient lives up.” For instance, C. Ryff and B. Singer [22] emphasized the positive basis of treatment: “the path of recovery is not only relieving the negative aspects, but also generating the positive ones”.

Phenomenology is the easiest way to achieve the “look into” and to activate positive strength that is typical of man as Person. By phenomenology we mean settings giving absolute freedom to the other person. His or her essence becomes visible due to the subjective impression that the observer gets at the ontological level. Thus, the observer impersonates the “reflection” of the other’s inner world using his own (A. Längle [18]). This leads to an intensive stimulation of the other’s essence. Such reflected and learned pattern allows one to obtain considerable amount of information about the other person, which contains information about himself as well. This is the approach of an attentive spirit-inquiring vision (M. Scheler [24]). Quoting Plesner, we can say that “what is required instead of a distanced mind-setting of an uninterested scientific observer is full participation of the man with all his resonating dimensions” (S. Strasser [26]).

The key background factor to it is Epochè, “bracketing” the previous assumptions, intentions and prejudices (E. Hysserl [6]). It can be (and should be) learned and trained. When it is possible, one is given space and left to freedom which is a key quality of Person.

Each man, because of his Person dimension, has a basic ability of phenomenological vision. It refers to the intuition by means of which we can recognize and see through the most important content. Thus, we can feel the hostile attitude towards us, even if the person demonstrates surface amiability. This deep vision sheds a new light on what is on the surface (external), provides it with another context, and clarifies discrepancies and contradictions (e.g., when person, despite seemingly friendly attitude, avoids closer contact).

The phenomenological approach results in understanding, seized content, the importance of which for existence becomes clear. This approach is especially efficacious towards people who lost consciousness and so cannot express themselves volitionally. However, they can be understood because of the openness of the observer and his willingness to feel based on the context and unconscious manifestations. The observer who does not hurry and lets the patient to influence him thus obtains unbiased information from minimal signals that the patient gives and from the impact that it has on the patient. He gets an impression, spots certain aspects; something excites and touches him. This is what one pays attention to in phenomenology. The fact that these are subjective perceptions does not contradict the importance of the perceived information, but makes them significant provided that the observer is indeed able to open himself, to get free of himself and his views (Epochè). Once information is retrieved, it reaches the observer and touches him: feeling what touches you is the core of understanding. While using the phenomenological approach, no information is added to the patient’s profile. His behavior is neither explained nor interpreted. This approach is different from the medical ones that are conventionally scientific (W. Dilthey [3]). Explanations are, of course, important as they bring together objective perception with empirical knowledge and the common laws. The explanatory procedure describes particular processes in the body. However, treatment should not be limited to it. Motto of the holistic treatment should sound as follows: “Explain symptoms, but also understand an individual who has them” What is required for understanding him is personal presence of a physician, a psychologist, a paramedic and a counselor. The ability to use the available
knowledge at professional level, to participate personally, to open up, to let oneself be approached is the crown of proficiency, as this way patient is not considered by dimensions, but approached holistically. The phenomenological approach creates the atmosphere of sensitiveness and amiability and thus allows patient to be understood. Translated from German by O.A. Lartchenko

**Scientific editing:** N.S. Ignatieva, O.A. Maksakova

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**Commentary**

The present article is written by an acknowledged expert in psychiatry, the founder of the contemporary existential analysis. It continues the more than a century-old argument between apologists of the quantitative and qualitative approaches to evaluating the human. In the era of differentiation of scientific disciplines, the academic objectifying approach has been a winner and still dominates in medicine. Nevertheless, by the end of the XX century psychological anthropology and phenomenology were given a wider conceptual and methodological basis. Addressing the noetic-subjective dimension of the human corresponds to the universally accepted humanistic tradition of medicine. From our point of view, substantiation of phenomenological study, care and extension of the zones of feeling that remain in difficult neurosurgical patients improves the quality of their rehabilitation. The present article is of apparent value as it enunciates a fresh approach to objectification of the subjective, human dimension of patients in a neurosurgical unit.

A.S. Barannikov (Moscow, Russia)
Traumatic Brain Injury: the Phases of Recovering the Contact with Self and the World and Existential-Analytical Work

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This article discusses the necessity for broadening the clinical approach to psychological rehabilitation of people after traumatic brain injury and for adding deficiency concepts underlying the approach, which reduce human internal life to the consciousness level solely and consider psychological processes only in terms of their defect. In this work, a process is reflected, which a person passes through in experiencing self and the world when emerging from “non-existence” (coma). The foundation is based on the basic components of existence: reference to the world, to life, self-reference, reference to the future (in accordance with the four fundamental motivations of A. Langle). They form phases (in terms of experience) for recovering contact with self and the outside world. As the 0th phase, experience of existence, the feeling of “I exist here”, is considered. Then the phases follow: “be able to exist” (1 FM); love to live, when own desires and feelings wake up (2 FM); recovery of self-image and the rationale of self-esteem (3 FM); and finally, the 4th phase is devoted to searching for the meaning (4 FM).

Keywords: existence, Person, rehabilitation, reference to self, reference to the world.

In a neurosurgical clinic, psychological assistance is often provided to people who have survived severe traumatic brain injury (TBI), which they acquired as a result of a car accident, gunshot wounds, physical abuse (assault and battery). These patients usually have experience of staying in coma and the vegetative state, which varies in duration (from several days to several months). Severe TBI is often combined with other physical injuries: fractures of the limbs, spinal cord injuries, rupture and confusion of the internal organs; the entire body was crushed.

This trauma is usually understood primarily (which is natural), and, unfortunately, only as a physical injury. All the efforts and attention of physicians are focused on surgical and drug treatment and support, while the main emphasis in subsequent rehabilitation is made on motor recovery. This attitude is present in relatives, many recreation therapists, and neurosurgeons: “If he (she) gets up and goes, then everything will be good. Walking without assistance is the most important thing”.

Within the traditional clinical approach, the mental life of a person after TBI is considered and analyzed only in terms of the present impairments of consciousness, quantitative (degree of depression of consciousness up to its full loss) and qualitative, which express different variants of consciousness disintegration or changes in mental processes that constitute the content of consciousness. First, this view reduces the person’s mental manifestations to the level of consciousness. Second, it reduces the understanding of consciousness to the level of cognitive processes (neuropsychological diagnosis and correction are usually implied when speaking about the recovery of consciousness). Third, this view presents solely the clinical judgment: to what extent the amnestic confusion is expressed; whether there are confabulations, phenomena of derealization and depersonalization, or onieoid state; to what extent the higher mental functions (HMF) are deficient, etc.

In this regard, it would be instructive to quote Karl Jaspers who in his fundamental work “General Psycho-pathology” indicated that “…mental life cannot be fully understood only as consciousness; neither can it be understood by means of conscious only” (K. Jaspers [13]). And also the work by Nikolai Berdyaev: “‘The Self’ is original, not deducible from anything and not reducible to anything. [...] “The Self” belongs not to nature, but to existence. “The Self” is original and primary. Consciousness is just inherent to it, and the unconscious is as well. “The Self”, immersed in existence, is primary, but not consciousness at all…» (N. Berdyaev, [2]).

The above quotes do not mean that the author of this paper denies the importance of consciousness in mental life and the necessity of such a judgment or medications prescribed by a psychiatrist for correcting certain states of a patient, or, let us say, the value of neuropsychological research with specification of the subsequent HMF correction program. What is meant is the expansion and supplementation of the deficient-clinical approach, the holistic view to the man who is not just a physical body or mental being possessing consciousness. Though, both pertain to human existence.

According to existential-analytical anthropology, the man presents the unity of three dimensions: physical, mental and spiritual; certain vitality and dynamics are associated with each of these dimensions. This model demonstrates the human openness, the possibility of di-
mensional divergence and also indicates the unity of the human existence, despite of its diversity and inconsistency (V. Frankl [11]). Therefore, to achieve the best results in mental recovery, the used methods should reflect this complex dynamics of human existence, because only in this case they will maximally conform to whom they are aimed.

This article is an attempt to look at a person who has survived a TBI from other coordinate systems, from other anthropological premises, to put the very research questions in a different way, and to analyze and summarize the existing practical experience from this point of view.

What happens to human existence when a person who received a powerful and crushing blow to his body, the supporting substance of existence, is in altered states of consciousness (ASCs), where his or her mental life seems to regress to the most archaic of its forms and manifestations, and then, after having travelled a long way, tries to attain the fullness (integrity) of life? What happens to the basic components of existence, which include: — reference to the world: the ability to physical survival and spiritual overcoming of existence, i.e. to ensure that “be able to exist” (the first fundamental motivation, 1 FM); — reference to life: the ability to live your life and get the joy of mental life, the ability to feel (2 FM); — reference to self: motivation to the authenticity and fairness, i.e. to “have the right to be who you are” (3 FM); — reference to the future: the person’s ability to contribute to the development of the world, i.e. to find and fulfill the existential meaning (4 FM) (A. Längle [6]).

Which way (which stages) does human experiencing of self and the outside world pass when emerging from non-existence (coma) and in which forms does it manifest itself at each of these stages? What happens to the person’s Self, which falls out of the world of objects (at the stage of coma and vegetative status) and is thrown back to itself? In what form is this “Self” presented to the person himself? How can we find an approach to it, an approach to his Person?

These issues often cause skepticism in doctors (neurosurgeons, neurologists, psychiatrists) and even in some psychological (psychotherapeutic) guild fellows. They say, about what the Self, what kind of personality, and, respectively, what kind of experience can we speak, if there is no consciousness, if significant lesions were formed in the brain due to injury? All this is an unscientific approach. This reaction is understandable within the scientific discourse, which considers only the structural-functional and cause-and-effect relationships, since natural sciences study only the objective laws, all the rest falls through the instrumental sieve of natural sciences.

Searching for answers to the raised questions leads to a study that uses the phenomenological method describing thoroughly all the phenomena that manifest to us in the course of communicating with the patient. Only in this way it is possible to understand how he or she experiences the world, other people, and self, and to get an access to the power that is able to put the person to movement in each phase of overcoming of this split introduced into his life by the injury. This method also allows one to see phenomena in their dynamics, but not just as a series of states: how they arise, how they manifest themselves in the course of development, and how they end, i.e. to reveal the process aspect.

Establishing psychotherapeutic contact: the body as a communication field

Psychological assistance begins with establishing contact. In this sense, the situation of working with a person in a minimally conscious state or in a vegetative state is not different from the conventional psychotherapy session, only the procedures and form of this contact will be different because of the lack of the verbal feedback. The verbal channel at this stage acts in one direction, from the therapist to the patient.

The channel with a two-directional flow of information is the body, which is simultaneously both the access channel to Person of the man, and a source of non-verbal responses (movements, respiratory rate and heart rate, facial expressions, etc.), i.e. the body acts as the communication field: here we perform an intervention and receive the response.

It should be noted that a number of publications have been devoted to working with patients in ASC (A. and E. Mindell, S. Tomandel, et al.), where the detailed description is provided for specific rules and techniques that allow one to come into contact with comatose patients2. So I will not dwell on their presentation.

I will only mention one of the basic principles underlying establishing therapeutic relationships within the existential-analytical direction, as it has, to our opinion, the fundamental significance when working with patients in similar states. The man is dialogic by his nature, and

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1According to the anthropological model adopted in the modern existential analysis, the concept of Person corresponds to the spiritual dimension of the man, which is free and not susceptible to any diseases. The main meaning of the concept of Person is synonymous with the meaning of the concept essence. At that, the “spiritual” is understood not in the religious sense.

2These papers have been written within the process-oriented approach to psychotherapy founded by Arnold Mindell. His first book on the topic “Coma. Key to Awakening: Working with the Dreambody Near Death” was published in 1989. It described working with comatose who, when awaken, talked about their experiences, which changed completely their ideas about life and death. As the author had noted at various times, people who were in coma as a result of extensive traumatic brain injuries responded positively to process-oriented work with non-verbal signals, but their path to awakening was longer. And this is an additional complexity of our work, because it often takes a long time for patients from the moment of injury until the speech recovery, and they usually forget their sensations and experiences. Disorders of HMF are another hindrance in realizing and expressing personal experience.
active reference from outside helps the man refer and establish proximity to himself (A. Längle [7]). Just as in the formation of mental structures, the man needs another person, YOU, so in recovery of structures once formed, but destroyed or lost due to injury, another person is needed, by whose reference and respectful attention, the affected structures of the Self (including structures of consciousness) and an access of the Self to Person are restored.

Recovery phases of contact with self and the world

In the situation of a severe physical trauma, the boundary of human existence comes maximally close, so that the person sometimes finds him- or herself at the very edge. It is, first of all, the physical survival and mobilization of resources for this (also including mental resources). In this situation, the person faces the fundamental question of existence: I exist, but can I exist here with the entities and conditions offered to me by the world? (A. Längle [5]).

There are cases when the patient’s contact with the outside world is so minimal that the question arises, whether he differentiates himself (his body) from the outside world, whether he feels his physical boundaries, or he is in a state of primordial fusion with the outside world (Tao state). Jung characterized this state as “the state of the absolute unconscious, complete rest, when nothing happens [...] when the conscious and unconscious are united so much that a person is neither conscious nor unconscious” (C. Jung [12]).

Based on the experience of working with patients, the following phases can be distinguished.

The 0th phase. Before understanding whether I am able to exist here, the person must experience “I exist here”, experience his presence. Therefore, the first phase of work begins with reinforcing and strengthening experience of existence, feeling that “I exist here”, “which can be experienced through his own body, because all that the person experiences in connection with his body is more real than if he would just think about it” (A. Längle; cited by the lectures within the long-term educational program on Existential Analysis, EA and Logotherapy). The body can be touched by another person or by myself; it brings the person closer to the reality of the material world, “I, as a body, exist here”.

The feeling of “I exist here” is, first of all, experiencing self embodied in a physical body (I am the body), which forms the outer boundary that allows the person to differentiate himself from the outside world. Feeling of constancy of existence of the body (“it exists”) leads to experiencing some center, basis, on which he can rely inside himself. This does not mean that in the 0th phase the person immediately develops a holistic sensual image of his body, but even these fragmentary feelings become “islands” of the reality, relying on which the person becomes able to draw the line between Self and not-Self.

I remember one of the rare cases where the patient retained memories of his being in an ASC. He said that he could open his eyes, could see, but did not see external objects. The image in front of his eyes was extremely vague: all lines merged, everything was shapeless. He could not understand what was happening. Everything was somehow vague. In this uncertainty, there was nothing he could catch on. Gradually, he began to sense something in his stomach. At first, it was hard to even understand what this sensation was, whether it was pleasant or not. But he felt it, and this fact was certain, which gave the reality feeling to his body, strengthened the patient in that “he is, he exists”. He perceived this sensation as a reference point, some kind of center, based on which he tried to internally reconstruct the image of his body (from the center to the periphery). Then the patient was trying to determine the quality of the experienced sensations: what it was: pain, tension, or something pleasant. The repertoire of sensations in the body was gradually becoming more diverse, and the feeling of own body was improving. Soon, visual images began to take shape, and he was able to distinguish the objects around him.

To increase the “I exist here” sensation during the process of working with patients, techniques of different schools of body-oriented therapy are used that are aimed at living the body as the first space, the first home for the person in this world, a sensation of its extension and external boundaries (e.g., the “theater of touches” technique used in thanatotherapy (V.Yu. Baskakov [1])). Procedures for working with breathing help feel the internal space of one’s own body and lead to a sensation of increasing of its volume, internal expansion (feeling the boundary from the inside). This is facilitated by emerging release, which arises due to relaxation upon work with breathing, from tightness (compression) that may be associated with muscle spasticity, respiratory disorders, etc. Experience with the foothold helps confirm experiencing the body’s lower boundary and feel greater confidence and stability. In this work, the techniques of grounding and centering are used, which are applied in the biosynthesis (D. Boadella [14]).

Disorders of physiological and somatic processes typical of this stage create a sufficiently high level of “troubles” for the Person, which is a hindrance for him in implementing contact with self and the world. Reducing the level of “troubles” helps the Person in this phase “catch” self at the ontological level and “frame” self. Working with the body “clears” an access of the Person to self, minimizing the existing obstacles due to the influence on functioning of the regulatory systems of the body. It has an effect similar to the influence of the method of biological feedback (BFB). However, the role of a “physiological mirror” here is performed by the psychologist who gives feedback to the patient. This results in stabilization of vital functions (breathing, heartbeats, blood pressure, normalization of saturation parameters). Psychomotor agitation is reduced; the attacks of vegetative paroxysms are either stopped or manifest themselves in a milder form, etc. Moreover, the feedback allows the pa-
tient to feel and strengthen the “reality” of his body (that it exists, and this is a real fact). This certainty gives a sensation of support in himself: “I can rely on the feeling that I, as the body, exist here”. Gestalts of sensations emerge from a general chaos that give the “shape” to existence of the person and are a support point on which he can rely.

Due to fine-tuning of the therapist on the patient’s processes (his rhythm and speed), the quiet co-presence (it is important to be able to just “be” with the patient), a necessary and sufficient amount of time to contact (the therapist does not interfere the patient to manifest self), a protected space for interaction is created, in which the patient may unfold, express self and feel good (1 FM).

It should be noted that bodily work provides the person with larger repertoire of experience (different quality of experience), and thus “pushes” him from the outside to the perception of quality. Patients who have been in an intensive care unit for a long time have received for a prolonged period of time monotonous or negative experience associated with own body, to which they have accustomed themselves. For example, numbness due to prolonged stay in one position, a sensation of discomfort associated with the tracheostomy tube, probe, etc. In the course of the therapeutic process, the person can experience his own body as a source of new or pleasurable sensations.

Simultaneously, working with the body creates conditions for the person’s individuality manifestation (3 FM). For example, relaxation leads to greater freedom in voluntary movements, fulfillment of which is hindered by a high muscle tone. The patient can better control his own body as an instrument of self-expression (expressive function of the body), and in the resulting space of freedom from physical “disturbances” we see the Person of the man in its uniqueness and individuality that manifests itself in the features of contact. The more of this space, the more the Person can manifest itself, and we can see and experience it more. It is like a beam of the sun that appeared in the gap between the clouds and illuminated everything around. This is the moment of Meeting with the other person. And we notice that one person is more fearful and cautious, while the other one is more open; one is rigid, while the other one is plastic; one fights for himself, while the other one does not, etc.

This view gives us an opportunity to meet our patients as individuals, as the Person with their unique world, in spite of illness that erases individual differences and makes them “vegetables” in the eyes of those who see only a “patient”, i.e. the sum of defects and disorders.

The 1st phase. After the feeling “I exist here” has strengthened enough inside the person, he can get in touch with the realities and entities of the outside world that put him in front of the fundamental question of existence: I exist here, but can I exist under the conditions that the world offers me? (A. Längle [6]). In this phase, we are talking primarily about the perception of the actual. I remember a narrative of one of my patients about her experiences during this period: “One eye saw red and the other saw yellow... I hit my head in the car; it was hard with me. I did not perceive anything external. It was easier with the internal, but it did not disturb me so much. It is important to understand the external”.

“To be able to exist in the world” is the central experience. For this, the person needs support and protected living space (A. Längle [5]), the development and expansion of which occur gradually. First of all, this is the physical space that immediately surrounds the person: what he can look at or what he can grope with his hands. And at first, it concerns the present moment, the here-and-now situation, because the past is often forgotten, and the future is not yet being built by the person (it is often questionable), so the person lives out of the time grid or in a different perception of time.

The first external space, in which the patient finds himself, is the bed he is lying on. Because of long lying, its boundaries in the person’s perception may merge with the boundaries of his own body. This phenomenon should be taken into account when establishing contact and this boundary should not be violated (one can not immediately sit down on the bed, put his hands on it, and so on). Otherwise, the patient may perceive this as a threat of invasion and will have to defend himself.

The person gradually becomes able to explore other types of spaces: the space of relations, the biographical space. The psychotherapist helps the patient relate his life with lots of facts and realities in order to make the perception of life and the world extensional. It brings security, makes the person more confident and free.

If the surrounding is dangerous for the patient, we can observe various fears, as well as coping reactions of the first FM: escape, manifesting itself in a specific form of psychomotor agitation and anxiety; aggression towards others, which has the nature of fight with threat, or auto-aggression; or stupor, when the person holds still, indicating with his whole appearance that he is not here. This understanding of the patient’s reactions is based on an analysis of the effects of interventions performed by the psychotherapist. Working with the perception of the actuality, as well as the formation of trusting relationships with the patient, which create a protected space, reduce these manifestations of the patient.

Various catheters and tubes inserted in the body, sensors attached to the chest, constantly squeaking equipment may be a frightening reality, since, for example, they present something incomprehensible. The person primarily needs the information of “what” and “why”. We tell the patient what surrounds him, and why it is necessary for him now; we encourage him to scrutinize what is around him. Everything that can be felt with hands is carefully felt. The main task is to transform the frightening to the helping. It gives the feeling of security in space, and also a sensation that he can rely on these devices, tubes, doctors. All this is “for” him. And then he becomes able to stand a difficult situation, because he starts feeling that he can exist with it.
In this phase, the aspect of the self-perception and, first of all, of the perception of one's own body, is important. Here we find the higher level of experience compared to the previous phase, where the transition occurs from the perception of “I am a body” to “I have the body”. The body stops to act as a subject only and starts to act as an object. This transformation is only possible due to the emergence of the person’s ability to distance from himself. The patient is able, to a greater extent, to see himself, to feel his body, to get an orientation in it, to control better his body, and, finally, to take it with all defects and limitations.

Once I worked in the emergency room with a young woman who was in psychomotor agitation. She was so restless that nurses had to fix her hands, so she did not break sensors attached to her body. She could not speak, but responded to questions with nods of the head (either affirmative or negative). I freed her hands, and she immediately began to palpate her face with her hands. Then I asked: “Are you worried that something is wrong with your face?” She nodded affirmatively. “Would you like to look at yourself in the mirror?” An affirmative nods followed. I brought the mirror. She inspected herself for a long time in it. After that, she became much quieter.

The important point in self-perception is establishing identity with self (3 FM). Whether the person is able to perceive a reflection in the mirror as his own, belonging to him? One of the patients said: “At first, I did not see myself in the mirror at all, did not recognize. Now, I recognize”.

Similar to the previous stage, in this phase, we do not see the person’s emotional manifestations. His face is still amimic, he is neither happy nor sad. Rather, it is possible to speak here about finding the stationary point. If the person starts to feel secure, he starts feeling that he can exist. The 2nd phase. In the internal world of the person who physically survived the difficult circumstances, experiencing of life comes with its inherent desires, joy and sadness, movement and change. The person becomes able to perceive the quality of things. He faces the second fundamental question of existence: “I exist, I can exist in this world, but do I love life? Do I want to live? What does life bring to my existence? Do I have desires? Am I able to have feelings? Am I glad with something?” (A. Längle, the lectures within the long-term educational program for EA and RT). The person’s task at this stage is to carry out existential breakthrough to the very life.

Over time, patients cease to be indifferent with respect to the stimuli making a certain impact on them, and begin to respond to the unpleasant things/discomfort that is primarily associated with their own bodies. For example, the patient becomes selective in food and refuses to eat what he does not like. Or he begins to make sounds, if he needs to change the position of his body (since he cannot do this without assistance).

Pleasure and displeasure are the stimuli that may put the person in motion and help vitality come free. But till the time, the person stays in a passive position of the “responder”. Later, he learns to manage the unpleasant stimuli, but not just to respond to them: first, with the help of another person and then without assistance. For example, the female patient responded extensively with crying to a strong muscle tension in the back, which arose during our sessions, and became arduous to contact. Her reaction had led to a cease of the session. She had gradually learned to relax the muscles, thereby eliminating the discomfort arising in this case. She later transferred this skill acquired under specially organized conditions to sessions with other specialists. This made her more free in contact and allowed her to proceed to accomplishment of more complex tasks, because she has learned to manage her impulses. Importantly, in the general form, this new skill also extends experience with respect to “can”.

It usually takes a long time that one’s own intention, a desire coming from the inside, has arisen in the person. People who have survived TBI very often speak about the lack of their own desires. At best, they respond to suggestions that come to them from the outside. This special detachment, stangeness, has persisted for a long time and greatly complicates the family and social relations of patients. People are separated by a “glass wall” from this world, their loved ones, and themselves. Nothing affects them emotionally. Patients often explain their emotional poverty by a lack of colorful and interesting events in their life, the same things happen every day. Here in working, it is necessary to pay attention to the following issue: what makes everyday life ordinary and gray? With this issue, we bring the patient to the position with which he lives his life. The ability to open up and enjoy the easiest things, to find something interesting to themselves and to engage themselves is especially important for people with significant movement limitations.

Long-term psychotherapy is required to restore the person’s ability to address to himself/others, to “hear” himself, to tune in the internal resonance with anything so that he could experience the values and feel emotions. It is often important to help the person rebuild the authentic value system. At this stage, it is important to work with the family as the immediate environment of the person, in which he must continually be called for his own desires and feelings, because he cannot call for himself. Otherwise, the person does not hear himself and replaces his own desires, feelings, and values with those of others. This leads the person to emotional death.

In this phase, we are also talking about personal processing of the injury that the person has got. This includes passing through all phases of sadness about the losses and devastations that the injury brought about in his world and life. The person faces such questions as “Can I still love life if these things have happened to it? What have I done that it all has happened to me? Do I have to thank myself? Is my life worth living it? Could something in my life be good for me?” All this must have been gone through to make a breakthrough to the perception of
fundamental value of life and to say again “Yes” to life (A. Längle, the lecture within the long-term educational program on EA and RT).

In the 3rd phase, the central point is the perception of self (self-image) and substantiation of inherent worth (3 FM) (A. Längle [5]). This phase is almost always associated with experiencing a deep personality crisis. If the person perceives losses and restrictions, which an injury brought to him, admits to himself the pain associated with this event, then he faces the question: “Can I still appreciate and respect myself?” Sometimes, in connection with an injury, central supports are destroyed, on which the person’s inherent worth was rested. For example, if the person substantiated inherent-worth just with achievements and successes, then when he is out of the running, it is difficult for him to have respect for himself and to recognize inherent worth of self. He feels pain, which can be so severe that he experiences the feeling that he is not able to stand it any longer. Then he begins to defend himself, denying the existence of defects and limitations. His picture of self is distorted and becomes unrealistic. The purpose of this crisis is that the person, having passed through this pain, could re-substantiate, on the realistic basis, his inherent worth and move to authentic attitudes. Only after that, the horizon of meaning can open for him (the 4th phase).

Another problem of the 3rd phase is associated with the authenticity. Patients report that due to injury, the internal speaking, the internal vis-a-vis, is lost, addressing to whom the person hears the Self (M. Buber [3]). Therefore, the inability arises to live one’s “own life”: the person does not understand what are his own desires and attitudes. Basic personal attitudes arising from the bottom of the Person are often replaced by alien, mechanically internalized attitudes of other people, which fill the resulting internal emptiness. Then we see a lost personality dissolving among others. A gap is formed between the Self and the Person. An intimate dialogic exchange between the Self and the Person is lost or limited, which hinders the person to realize his individuality, originality, and uniqueness, to discover and embody the meaning of his life.

In the 4th phase, the person’s task is to turn toward the world and to understand where his place is, what good things he can do for others. It is necessary to help the patient make the existential turn so that he would not ossify in a dependent position with respect to others, the world, would not consider himself a victim of circumstances.

In conclusion, I would like to say that the use of the existential-analytic approach for psychological rehabilitation of people who have survived TBI has the advantage of completeness and wholeness of a view on human existence with its diverse and often contradictory dynamics. This, in turn, allows one to find more effective methods of care and to begin psychotherapeutic work as soon as possible.

In addition, the view of the human being as the spiritual Person that is free and never gets sick (V. Frankl [10]), which underlies the existential-analytical anthropology, forms the psychotherapist’s position allowing him to see deeply these patients, to meet with the value of human life (which manifests itself outwardly in a very feeble form) and also to address actively to the spirituality that makes and leaves a human being the man, despite the destructions and defects of his body and personality, and even lost consciousness. This professional attitude has a great healing power both for the provider of help and for the receiver of it (for the psychotherapist, because it is prevention from burnout syndrome; for the patient, because primarily in a clinic, the person faces an object relation to self: when performing medical manipulations, body treatment procedures, examinations, etc.). A similar attitude that becomes a priority signal of the environment after an accident just amplifies a defect, the split acquired due to injury. If nobody from the depth of his Self calls YOU of another person, then a vacuum, emptiness, is formed. “Without YOU accepting me, the Self ceases. The reality dissolves, because it is no longer possible to catch on anything, and the person himself cannot hold it” (A. Längle, the lectures within the long-term educational program on EA and RT). Then he gradually begins to behave as an object, losing the ability to refer to self with his depth and uniqueness of his personality in contact with the outside world. And in the long-term period after an injury, we can often see people whose movements are fairly well recovered, but nothing affects them emotionally, they stay completely lost, lose their “own”, they are indifferent and unenterprising. Of course, there are the effects of trauma (both physical and mental (ICD-10, F06, F07, F09)), which cannot be eliminated, but it is possible to help the person find the field where he will be able to live his life. And this, from our point of view, is the art of psychotherapy of patients with an organic defect. An acquired deficiency determines only the parameters of this field (which is an additional obstacle to the implementation of existence), but does not deprive the person of the crucial opportunity to fulfill his life.

REFERENCES


Commentary

This work is devoted to the relevant topic: rehabilitation of patients who have survived severe traumatic brain injury. The peculiarity of this article is that the author, based on her long-term experience of psychological rehabilitation work at a neurosurgical hospital, suggests a new view of the rehabilitation process. The suggested approach considers the patient not only as the body-mental substance, but also as a spiritual essence having his own internal world. The loss of this world due to severe traumatic brain injury assumes its gradual acquisition during the rehabilitation process, which is performed through successive steps. The purpose of this rehabilitation is not only to recover the motor and elementary mental functions, but also to achieve subjective completeness of experiencing life. In this, the patient should be accompanied by a qualified psychologist and other medical personnel. Steps of psychological rehabilitation correspond to the main structural and procedural characteristics of experience in the form, in which they are described in the modern existential analysis. This direction of modern psychotherapy thoroughly discloses, both theoretically and methodologically, the structure and process of experiencing. N.S. Ignatieva describes the patient’s subjective experiences and basic forms of activity of the psychologist who accompanies the patient during rehabilitation work. The article by N.S. Ignatieva is undoubtedly of interest to physicians, psychologists, and medical personnel involved in rehabilitation of patients who survived severe traumatic brain injury.

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Topics to be covered in our next issue:

• Genetic characterization of glioblastomas in children and adults

• Intraoperative computed tomography and navigation in spine and spinal cord surgery

• Craniotomy in the Altai region in the V—III centuries B.C.