CASE STUDY

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COMPREHENSIVE PROGRAM OF NEUROTHERAPY FOR A VISUAL ARTIST WITH POST- COVID-19 SYNDROME FOLLOWING SARS-COV-2 INFECTION AND SEVERE COURSE OF COVID-19 TREATED IN LONG-TERM PHARMACOLOGICALLY INDUCED COMA

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SUMMARY

Background: The purpose of the study was twofold: (1) to present post-COVID-19 syndrome, which involves a variety of ongoing neurological, neuropsychiatric, neurocognitive, emotional and behavioral disorders resulting from SARS-CoV-2 infection followed by a severe course of COVID-19 treated in long term pharmacologically induced coma in a visual artist, which impacted on her artwork; (2) to present QEEG/ERP results and neuropsychological testing results in the evaluation of the effectiveness of a comprehensive neurotherapy program, with individualized EEG-Neurofeedback, and art-therapy in the reduction of post-COVID-19 syndrome in this artist.

Case study: Ms. G., 42, a visual artist, portraitist, with good health, became ill in May 2022. Allegedly flu symptoms appeared first. After a few days, shortness of breath joined in. The PCR test for SARS-CoV-2 was positive. The patient was hospitalized, referred to the ICU, put on a respirator and treated over 11days of a pharmacologically induced coma. Two months after leaving hospital the patient developed post-COVID-19 syndrome. She was diagnosed by an interdisciplinary team: a neurologist, neuropsychiatrist and neuropsychologist. A PET scan of her brain revealed extensive changes involving a loss of metabolism in various brain areas. The presence of complex post-COVID, neurological, neuropsychiatric, neurocognitive, emotional and behavioral disorders was found and a neuropsychiatrist suggested a diagnosis of post-COVID schizophrenia. She was refered to the Reintegration and Training Center of the Polish Neuropsychological Society.We tested the working hypothesis as to the presence of schizophrenia and there was no reduction in the difference of ERPs waves under GO/NOGO task conditions, like in the reference group with schizophrenia (see also Pachalska, Kaczmarek and Kropotov 2021). The absence of a functional neuromarker for schizophrenia allowed us to exclude this diagnosis and to propose a new disease entity, that being post-COVID-19 syndrome. She received a comprehensive two-component program of neurotherapy: (1) program A consisting in goal-oriented neuropsychological rehabilitation, including art therapy (see also: Pąchalska 2008; 2022b), and (2) program B, based on the most commonly used form of EEG-Neurofeedback: frequency/ power EEG-Neurofeedback, using 2 bipolar surface electrodes, with the protocols written for her specific needs (see also Thompson & Thompson 2012; Kropotov 2016). The comprehensive neurotherapy program lasted 10 weeks, EEG Neurofeedback and art therapy classes were conducted 3 times a week for 45 minutes each. We found that after the completion of the comprehensive neurotherapy program there was a statistically significant reduction in high beta activity compared to the normative HBI database, which is associated with a reduction of anxiety. Also, we observed the improvement of neurocognitive functioning in neuropsychological testing (a significant reduction of anxiety and a noticeable improvement in neurocognitive functions). It should be stressed that the artist was happy that she had regained the ability to create, and even sells her artwork, although her style of painting had changed.

Conclusions: Almost all the neurological, psychiatric, neurocognitive, emotional and behavioral disturbances, were reduced in their severity. The artist showed marked improvement and was able to return to painting. The artwork she produced after her illness is in high demand with art collectors. It can be also helpful in the reintegration of the Self System, and the improvement in her quality of life. Human Brain Index (HBI) methodology might be very useful in diagnosing and developing therapies for patients with post-COVID-19 syndrome.

Key words: SARS-CoV-2, pharmacologically induced coma, long COVID-19, post-COVID-19, sequelae

INTRODUCTION

Since the first confirmed case of COVID 19 was reported in Wuhan, China, on December 31, 2019, the novel coronavirus (SARS-CoV-2) responsible for this disease has caused a pandemic. Global statistics, as of end of March 2023, show that:

- 763.7 million people have been infected;
- 6.9 million people have died[1];

Although world statistics no longer provide the number of people cured one can easily calculate that 755.7 million people have survived. Many of the survivors, however, are still struggling with various sequelae of COVID-19 (Aknin et al., 2021; Taquet et al., 2021; Pachalska et al., 2022).

The clinical presentation of COVID-19 resulting from SARS-CoV-2 infection is mainly characterized by respiratory symptoms, but can equally include a diverse array of symptoms, including pulmonary (e.g., pneumonia, dyspnea on exertion), cardiac (e.g., ischemia, arrhythmia, myocarditis), gastrointestinal (e.g., diarrhea, anorexia) and neurological (e.g., headaches and dizziness, the loss of smell and taste) (see Aknin et al. 2021). Although SARS-CoV-2 is a respiratory coronavirus that causes COVID-19, and lung damage is to be expected; however, there is often damage to numerous other cells and organs, leading to an array of symptoms (Taquet et al., 2021). Nearly one-third of patients worldwide will experience post-COVID symptoms for weeks, months, sometimes a year or even longer after SARS-CoV-2 infection and the contraction of COVID-19 (Pąchalska 2022a). These results are similar to those following SARS in 2000, especially for patients who experienced severe symptoms and spent weeks in intensive care. However, COVID-19 differs in that a large subset of patients who did not even require hospitalization experience a recurrence of already preexisting or new symptoms for a long period after infection itself (Almeria et al., 2020). The health problems and/or complications lasting beyond 4 weeks, are now called post-COVID-19 syndrome or post-COVID conditions, long COVID-19, long-haul COVID-19, and post acute sequelae of SARS COV-2 infection (PASC) (Pierce et al. 2022). One can complain of malaise after exertion, cognitive impairment, sensorimotor symptoms, headaches, insomnia, depression and post-traumatic stress disorder (Taquet et al., 2021).This diverse constellation of symptoms that we can find in post-Covid-19 syndrome may be grouped into neurological, neuropsychiatric, neurocognitive and emotional disorders (Aknin et al. 2019, Pachalska 2022). The list of symptoms is broad, as complex disturbances of consciousness, emotional disturbances, including severe anxiety and aggression, and neurocognitive disturbances, including "brain fog", behavioral problrms and others can occur (Pierce et al. 2022).

The complexity of the symptoms that make up post-COVID syndrome, as well as the to date not fully understood mechanism behind its appearance, is the main reason why there are only a small number of articles devoted to modern

[1] WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data

functional neuromarker-based neurotherapy for patients suffering from this syndrome (see: Pąchalska 2022a).

The purpose of the study was twofold:

- to present post-COVID-19 syndrome, which involves a variety of ongoing neurological, neuropsychiatric, neurocognitive, emotional and behavioral disorders resulting from SARS-CoV-2 infection followed by a severe course of COVID-19 treated in long term pharmacologically induced coma in a visual artist, which impacted on her artwork;
- to present QEEG/ERP results and neuropsychological testing results in the evaluation of the effectiveness of a comprehensive neurotherapy program, with individualized EEG-Neurofeedback, and art-therapy in the reduction of post-COVID-19 syndrome in this artist.

CASE STUDY

Ms. G., 42, a visual artist, portraitist, with good health, became ill in May 2022. Allegedly flu symptoms (a runny nose, cough, a scratchy throat, fever, fatigue and difficulty in sleeping) appeared first. After a few days, shortness of breath joined in. The PCR test for SARS-CoV-2 was positive.The patient was hospitalized, referred to the ICU, put on a respirator and treated over 11 days of pharmacologically induced coma.Two months after leaving hospital the patient developed post-COVID-19 syndrome.The first symptoms included fatigue, sleep disturbances, loss of smell and taste, severe anxiety and bizarre behavior. The patient's husband reported that before the illness she had been a respected artist, loving wife and mother of a five-year-old daughter, and a wonderful woman. Now she is not the same person, she has a “brain fog”, can’t recognize her family, believed they are doubles and screamed at the sight of them. She also is emotionally cold and does not show any feelings. For example, when her daughter approached her, she pushed her and even beat her. She behaved similarly toward him, and at any sign of tenderness she would throw an object at him and shout: "run away you monster!." She also claimed that she was a clone, because in the hospital, when she was sick with COVID-19, doctors experimented on her and now she has to live in a different, unknown world. She has given up any, not only artistic, activity.

The patient was consulted by an interdisciplinary team: a neurologist, neuropsychiatrist and neuropsychologist. A PET scan of her brain revealed extensive changes involving a loss of metabolism in various brain areas (Fig. 1). These are characterized by an abnormally low blood flow in the prefrontal cortex and are similar to other subjects with "brain fog" or suspected schizophrenia (cf. Gershon and Rieder, 1992).

The presence of post-COVID syndrome includes:

- *neurological symptom* (headaches, smell and taste disorders, sleep disorders)
- *neuropsychiatric symptoms* (disorders of consciousness, including hallucinations and "brain fog");

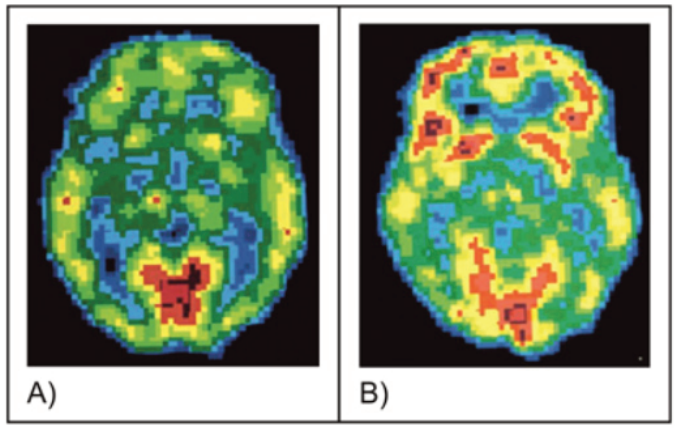

Fig. 1. PET scans of the brain: (A) Patient MsG's scan (taken one month after the disease) and (B) PET scan shows the brain of a healthy person.
Source: clinical material of Prof. A. Urbanik, MD, with permission

- *neurocognitive symptoms* (disorders of attention, working and long-term memory, and critical thinking);
- *emotional symptoms* (severe anxiety and aggression).

The neuropsychiatrist suspected the onset of post-COVID schizophrenia and, as the patient refused to be hospitalized in a psychiatric hospital, he referred her for further diagnosis and rehabilitation at the Reintegration and Training Center of the Polish Neuropsychological Society. The methods of testing included: documentation analysis, a structured interview, neurophysiological examination of brain functions, and standard neuropsychological tests of neurocognitive and emotional functions.

In Study 1, during the clinical interview, the patient was very anxious and with her whole body in trembles. After several minutes, hallucinations appear. She sees different objects on the wall (green swallows, colorful horses, crooked houses). She doesn't know how they got to the neuropsychologist's office. She claims that the green swallow, is calling out to her for help. When asked "What kind of help is the swallow asking for?" she claims it's a secret and she prefers to write down the answer to the request so that no one will hear. She then writes an incoherent, almost poetic, text (Fig. 2A), and then draws a hallucinated swallow with a pen (cf. Fig. 2.B). She claims that this swallow is from the "Kindergarten of Fun during an Epidemic," and often shouts to it that it is dying somewhere in a storm, or gives it some kind of command or sign.

NEUROTHERAPY PROGRAM

She received a comprehensive program of neurotherapy with two components:

- Program A, consisting in goal-oriented neuropsychological rehabilitation, including art therapy, aimed at the reduction of the neurocognitive dysfunctions (Pąchalska 2008, 2022a).

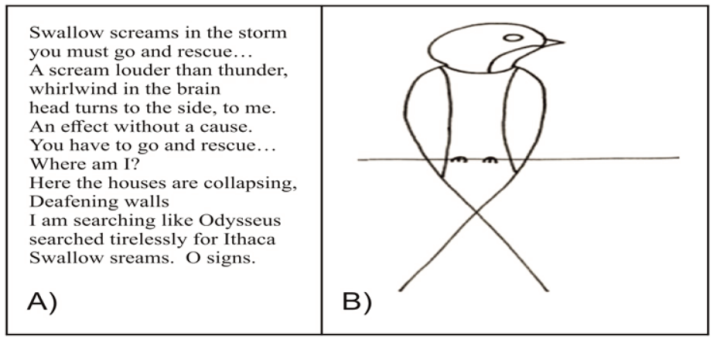

Fig. 2. Patient's creations: A) Text on hallucinated swallow's screams. B) Drawing of a hallucinated swallow
Source: clinical material by M. Pąchalska

- Program B, based on the most commonly used form of EEG-Neurofeedback: frequency/ power EEG-Neurofeedback, using 2 bipolar surface electrodes, called "surface neurofeedback". The individualized training protocol took into account the method of training, the place of application of bipolar electrodes at Cz-Fz points and the goal of training, lowering high Beta 20-30 Hz activity and rewarding low SMR (see also: Thompson & Thompson 2012; Kropotov 2016).

Comprehensive neurotherapy program lasted 10 weeks, EEG Neurofeedback and art therapy classes were conducted 3 times a week for 45 minutes each.

QUANTITATIVE ELECTROENCEPHALOGRAPHY (QEEG) RESULTS

The patient's EEG spectra were tested twice; the first test was performed before starting, and the second after completing the comprehensive neurotherapy program. These spectra were compared to the averaged EEG spectra of 100 healthy subjects from the normative database of the Human Brain Index (HBI) Institute in Chur, Switzerland, at an age comparable to that of the patient (see Fig. 3).

In Examination 1, the patient had high central beta rhythm activity, which was normalized in Examination 2. It is worth mentioning that the results of this study (before neurotherapy) served as a model for the development of the EEG neurofeedback individual training protocol.

EVENT RELATED POTENTIALS (ERPS)

The dynamics of event related potentials (ERPs) presenting the effect of the comprehensive program of neurotherapy on our patient outcomes is illustrated in Fig. 4 A and B.

First, we tested a working hypothesis of the presence of schizophrenia in this patient in comparison with a group of 100 patients diagnosed with schizophrenia in the patient's age from the normative database of the Human Brain Index (HBI)

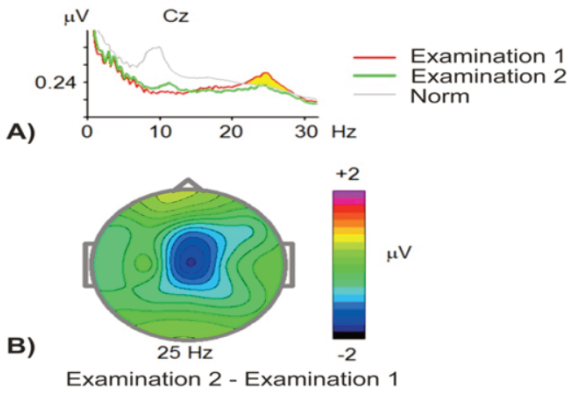

Fig. 3. Difference in EEG spectra: increment obtained after neurotherapy (study 2 minus study 1).
(a) The amplitude of the EEG spectrum of the patient under study during the GO/NOGO task, compared to the EEG spectrum of 100 healthy subjects from the normative database of the Human Brain Index (HBI) Institute in Chur, Switzerland, at the patient's respective age;
(b) difference in amplitude maps at 25 Hz (study 2 minus study 1).
Source: own material

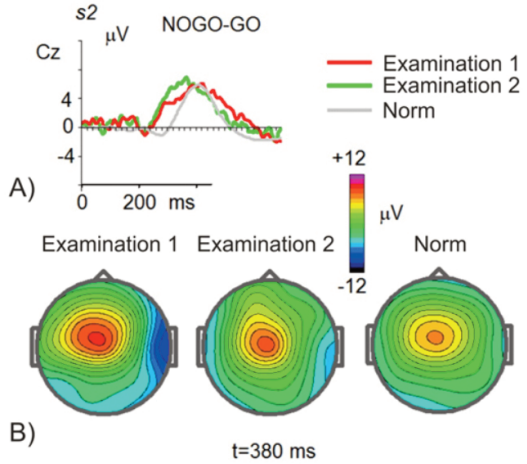

Fig. 4. ERPs under the conditions of the GO/NOGO task performed by the study patient
(A) wave form differences of ERPs under conditions of GO/NOGO task performance before (Examination 1) and after neurotherapy (Examination 2) compared to analogous wave form differences of ERPs in 100 patients with schizophrenia spectrum disorder from the HBI database at the patient's age.
(B) Maps of the difference in wave forms at 380 ms recording time in Examination 1 and Examination 2 compared to a control group of 100 healthy subjects from the HBI database at the patient's age.
Source: own material

Institute in Chur, Switzerland. According to the indicators from the database, in our patient there was not a characteristic significant decrease in the difference of ERPs waves recorded during GO/NOGO tasks (Fig. 4A) like in the reference group with schizophrenia (see also Pachalska, Kaczmarek and Kropotov 2021).

In other wards we did not find the pattern of brain function suggested that she had a neuromarker of schizophrenia. The absence of a functional neuromarker for schizophrenia allows us to exclude this diagnosis and propose a new disease entity, that is post-COVID-19 syndrome.

Second, we investigated the results before and after the completion by our patient of the proposed program in comparision to a control group of 100 healthy subjects from the HBI database at the patient's age.

We found that there was a statistically significant reduction in high beta activity as a result of neurotherapy compared to the normative HBI database (see Fig. 4B), which should be associated with a reduction of anxiety.

NEUROPSYCHOLOGICAL TESTING

The neuropsychological testing was designed to detect emotional and cognitive disorders in the patient, and to serve as a quantifiable outcome to assess the impact of neurotherapy in the treatment of post-COVID-19 syndrome, including anxiety and "brain fog".

The standardized Polish version of the Visual Analog Anxiety Scale was used to assess anxiety (Fig. 5). This is a simple method used to assess anxiety in medicine and psychology, which has been modified so that it is measured on a scale from 0 to 100 points. (see: Pąchalska, 2008).

In examination 1, before completion of the comprehensive neurotherapy program, the patient rated her anxiety by scoring 95/100 points on the scale, meaning a severe level of anxiety. In doing so, she stated that she was very afraid, although she did not know quite what she was afraid of. In examination 2, after neurotherapy, her anxiety decreased significantly and the patient scored 20/100 points on the scale, meaning a mild level of anxiety.

The standardized Polish version of the Mindstreams™ Interactive Computer Tests (Pąchalska, Kaczmarek & Kropotov 2014) used to assess neurocognitive impairment. Neuropsychological functioning as measured by these tests is pre-

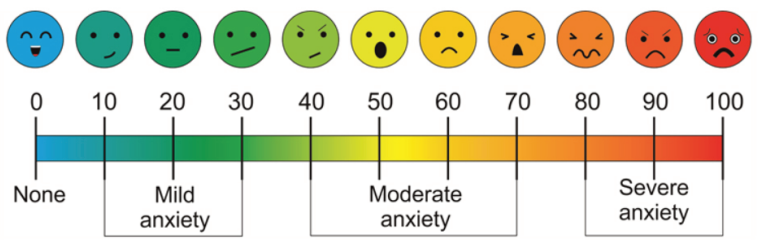

Fig. 5. Visual Analogue Anxiety Scale
Level of anxiety:
10-30 points. – mild anxiety
40-70 points. – moderate anxiety
80-100 pts. – severe anxiety
Source: Pąchalska (2008), modified

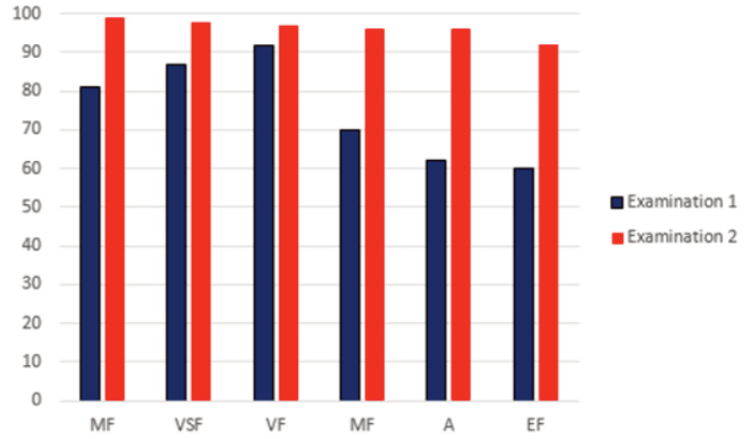

Fig. 6. Neuropsychological functioning as measured by the standardized Polish version of the Mindstreams™ Interactive Computer Tests.
Legend:
MF – Motor functions
VSF – Visual-spatial functions
VF – Verbal functions
M – Memory functions
A – Attention
EF – Executive functions

sented in Fig. 6. In Examination 1, before the completion of the comprehensive neurotherapy program, there were dysfunctions in all cognitive functions tested. The greatest dysfunctions occurred in the areas of attention, memory and visuospatial functions. In Examination 2, however, after completing the program, the patient was found to have improved in almost all tested functions. The parameters tested were close to normal. The patient was pleased that she had a better grasp of her surroundings and was more independent: she can cook dinner, do her shopping, and knows where she has left her car in the parking lot. She also knows where she has put things, only sometimes forgetting where she has put her glasses or pen.

To sum up, as a result of the neurotherapy administered to the patient, almost all of the neurological, neuropsychiatric and neurocognitive disorders comprising her post-COVID-19 syndrome have been resolved. The patient is aware of herself and her surroundings. Hallucinations and confabulations have subsided and anxiety levels have significantly decreased. However the symptoms of alexithymia still persist, although they are much smaller. These include:

1. *difficulty in identifying feelings* (DIF) and distinguishing between feelings and bodily sensations of emotional arousal;
2. *difficulty in describing feelings* (DDF) to others; limited imaginative abilities and having externally oriented cognitive thinking (EOT) (see also: Taylor et al., 1997; Damasio 1999).

Fig. 7. Artwork painted by the patient at the end of neurotherapy program entitled "Beautiful Mrs. J."
Source: material by M. Pąchalska

In the artist opinion the most important success of the proposed neurotherapy is the return to painting itself. It is noteworthy that in the process of art therapy, a new style was born in her creations, as the artist, who had previously done mostly portraits, now drew only one portrait drawing at the therapist's request and titled it "Beautiful Mrs. J." (Fig. 7). It was a close friend of the therapist, whom the painter knew, since the therapist, when showing her the pictures to copy, had said a lot of warm words about the portrayed lady.

It should be stressed, that during and after neurotherapy she mainly paints houses that are devoid of life. One such painting is illustrated in Fig. 8. It is a modified copy of painting by Wiliam Glackens made on the basis of a postcard at the end of art therapy program (the patient chose this one from 10 different postcards that illustrated houses). She motivated her choice by the fact that after her illness she still lives in some incredibly "empty world" in which she sometimes feels alienated.

Despite the fact that she titled the painting "My Empty World," she stated that she felt a flash of joy. It should be stressed that the artist was happy that she had regained the ability to create, and even sells her artwork, although her style of painting had changed.

The artist also stressed on several occasions that regaining her ability to paint meant returning to work. She also claimed that by being able to sell her works she is gradually regaining financial independence and self-reliance, which undoubtedly increases her quality of life.

Fig. 8. A modified copy of painting by Wiliam Glackens made by the patient on the basis of a postcard at the end of art therapy program entitled "My empty world"
Source: material by M. Pąchalska

DISSCUSSION

Our patient, who developed post-COVID-19 syndrome after SARS-CoV-2 infection followed by a severe course of COVID-19 was treated in long term pharmacologically induced coma. Two months later she expirienced a variety of symptoms: these included neurological, psychiatric, neurocognitive, emotional and behavioral disturbances. Similar longer-term health problems and/or complications lasting beyond 4 weeks after SARS-CoV-2 infection and COVID-19 contraction are also reported by other patients (Solomon, 2021; Aknin 2021; Pąchalska 2022). We have to point out that especially bothersome symptoms, as complained about by the patient's husband, was a brain fog[2], problem with her behavior and emotional coldness.

How do we explain the appearance of such symptoms?

Clinical examinations and research over the past two years suggest that severe COVID-19 disease is a consequence of the immune system producing an excessive number of inflammatory proteins called cytokines, sometimes referred

[2] The term "brain fog" is commonly used by patients and the medical community, there is no universally accepted definition of the term. In general, it refers to a symptom profile that includes attention deficit disorder, working memory loss and reduction of critical thinking (Garg et al., 2021). The presence of "brain fog" is one of the top symptoms reported by millions of people after SARS-CoV-2 infection and COVID-19 contraction (Krishnan et al. 2022).

to as a "cytokine storm," while post-COVID-19 syndrome is a consequence of an excessive, prolonged immune response (cf. Almeria et al. 2020). This mechanism leads to a crossing of the blood-brain barrier (BBB) and affecting various brain areas and therefore altering neuronal functions, including emotional, cognitive, and behavioural problems (cf. Almeria et al. 2020). It is also referred in the literature as NeuroCOVID-19 (Goldberg et al., 2020: MacQueen & MacQueen, 2021; Pąchalska 2022). The progression of brain damage associated with these mechanism is complex and not yet fully understood. It was only recently found that the BBB dysregulated in COVID-19 serves as a CNS entry route for SARS-CoV-2 (see; Krasemann et al 2022).

Brain fog, fatigue and sleep disturbances which occurred in our patient, are commonly reported by post-COVID-19 syndrome patients, and can be seen as a consequence of neuroinflammation (cf. Krishnan et al. 2022). Brain fog can be secondarily exacerbated by sleep disorders (cf. also Maciejewicz 2022) and other psychiatric disorders that occur in post-COVID-19 syndrome and which limit the patient's social activities. Given that the co-occurrence of a variety of symptoms referred to as post-COVID-19 syndrome frequently observed in patients, it is worth sensitizing mental health professionals that this is a challenge for modern medicine. The mechanisms involved in the development of post-COVID-19 syndrome and the factors affecting recovery from COVID-19 are still under observation and research. Current hypotheses include neurological factors, psychological factors, inflammatory and immunological reactions, and physical deterioration (Deng et al., 2021; Calabrese, 2020). The variety of symptoms, the involvement of multiple systems, and the various possible mechanisms suggest that the sequelae of COVID-19 can desintegrate the entire Self system (see; fig. 9), whether biological, emotional, or cognitive (see also: Pąchalska, Kaczmarek, Bednarek 2020).

They can also affect the social Self (breakdown of social ties) and cultural Self (disintegration of the value system) (cf. Pąchalska 2022) as occurred in the patient presented here.

It is therefore imperative to adopt an interdisciplinary approach to the diagnosis and treatment necessary in the treatment process of patients with post-COVID-19 syndrome. In addition to neurological, neuropsychiatric and neuropsychological examinations, it is important to use new neurotechnologies, especially the Human Brain Index (HBI) methodology, which is a very useful diagnostic tool in diagnosing and developing effective therapies for various brain dysfunctions (cf. Pąchalska, Kaczmarek and Kropotov 2014; 2021; Kropotov 2016). With this method, it was possible in the patient under study to:

1. exclude the possibility of post-COVID schizophrenia (no functional neuromarker of schizophrenia);
2. confirm the presence of anxiety disorders (the presence of the anxiety neuromarker), which can be exacerbated after SARS-CoV-2 infection;
3. develop a neurofeedback program tailored to the patient's needs;
4. confirm the effectiveness of the neurotherapy offered to this patient.

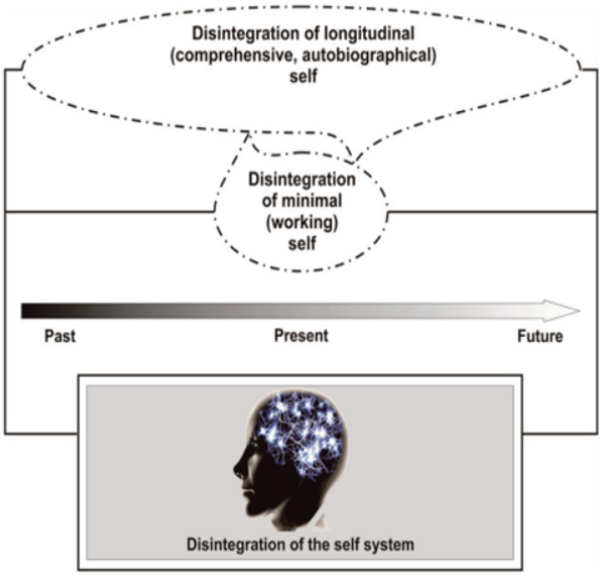

Fig. 9. Disintegration of the self system
Source: Elaboration by M. Pąchalska

What does this case teach us?

The patient studied had many of the complications reported by patients experiencing post-COVID-19 syndrome (cf. Aknin 2021) which is also referred to in the literature, as we mentioned above, as NeuroCOVID-19 (Goldberg et al., 2020: MacQueen & MacQueen, 2021; Pąchalska 2022). We know that there is neuron damage, as well as break down or modification of the neuronal connections that underlie normal cognitive, emotional and behavioral processes. This is what produces the persistence of the neurological, psychiatric and neuropsychological symptoms of neuroCOVID, including post-COVID syndrome, long after the virus itself has disappeared from the organism.

These symptoms can be extremely distressing for patients and can exacerbate anxiety in them. They therefore pose unique challenges for modern medicine. From the perspective of an individual patient, the variety and persistent nature of symptoms can lead to social isolation. These symptoms can be compounded by the unknown trajectory of the recovery process for a relatively new problem like post-COVID-19 syndrome (cf. Krishnan et al. 2022). The patient's symptoms of fatigue may make it difficult to seek professional help while struggling to cope with the demands of daily life and work. In addition, support from friends and family may diminish over time due to the persistent and complex nature of the symptoms, including emotional symptoms (anxiety and aggression). As with other chronic disorders, patients with post-COVID-19 syndrome may also experience negative interactions with medical professionals (nurses, doctors, ambulance workers) who suspect patients of exaggerating their symptoms (Ocon,

2013). Furthermore, post-COVID-19 syndrome is often just one of many health problems a patient has to deal with. This is because many patients have pre-existing various comorbidities that also require ongoing treatment, complicating the trajectory of recovery (Pąchalska 2022a).

It is worth mentioning here the problem of alexithymia, which appeared in our patient and, although significantly reduced after neurotherapy, and is still troublesome for her. Antonio Damasio (1999) noted that people with secondary (organic) alexithymia have destroyed neuronal connections between the paraventricular area of the frontal region and other brain structures, especially the limbic system (Fig. 10). Many studies of patients, especially after frontal lobe injuries, indicate that neuronal connections between the limbic system and frontal lobes (basal area) are particularly important for normal behavior and emotional processes (see also Pąchalska 2008). Recent studies of people with post-COVID olfactory and gustatory disorders, which was also the case in the patient we studied, show that these patients have damage to the anterior cingulate cortex and connections to the prefrontal cortex (cf. 2022a).

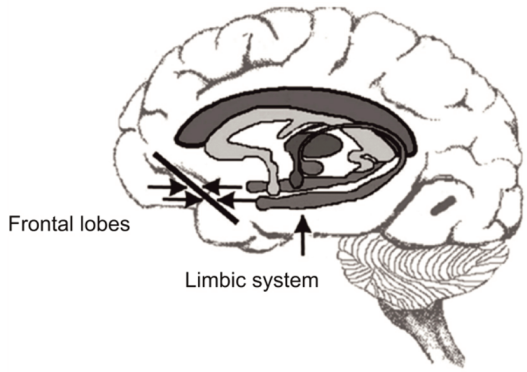

Fig.10. Destroyed connections (diagonal line) between the limbic system and frontal lobes (basal area)
Source: M. Pąchalska (2008), modified

Recall that the role of the prefrontal cortex is primarily to adapt the activity going on at a given moment to the circumstances, which is reflected in the numerous connections of this structure with the limbic system (Pąchalska, Kaczmarek and Kropotov 2014). It is hardly surprising, then, that a patient deprived of the prefrontal cortex's ability to control emotions develops a variety of emotional, cognitive and behavioral disorders.

To sum up, the diagnosis of neurocognitive dysfunctions following SARS-CoV-2 infection and COVID-19 contraction in patients, based on clinical observations and modern scientific studies (using a variety of neurometrics and psychometrics), is extremely difficult due to the variability and overlap of the symptoms (cf. Aknin 2021; Pąchalska et al. 2021, 2022a). However, it is essential for therapeutic success. The information we have presented in this paper provides the basis

for undertaking an interdisciplinary diagnosis of patients in order to make appropriate treatment recommendations. An interdisciplinary approach allows for testing by multiple specialists within the healthcare setting and can also provide effective therapy for patients with post-COVID-19 syndrome.

CONCLUSIONS

Almost all the neurological, psychiatric, neurocognitive, emotional and behavioral disturbances, were reduced in their severity. The artist showed marked improvement and was able to return to painting. The artwork she produced after her illness is in high demand with art collectors. It can be also helpful in the reintegration of the Self System, and the improvement in her quality of life. Human Brain Index (HBI) methodology might be very useful in diagnosing and developing therapies for patients with post-COVID-19 syndrome.

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