The Impact of COVID-19 on Voice, Speech, and Language: An Interdisciplinary Study of COVID-19 Survivors

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ABSTRACT

The long-term effects of a COVID-19 infection are complex and may pose significant challenges for individuals and societies. Thus, it is important to understand the full impact it may have on many aspects of a survivor's life, including their voice, speech, and language. The study aimed to diagnose the types of speech disorders that occur in COVID-19 survivors, to investigate how long the speech disorders last, and to determine whether or not there was any correlation between the patient's age and their score in each of the categories of the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scale. A total of 30 people aged between 30 and 60 years (15 men and 15 women) participated in this study. A speech evaluation was conducted using 4 types of tests: recordings of spontaneous speech, a test of repetition of words and sentences, a monologue, and a series of automated word sequences. The perceptual evaluation of the patients' speech was carried out by means of the GRBAS scale. We found that the majority of patients (25 out of 30) used excessive force to produce voice. We also found a significant weakening of the ability to produce voice immediately after the disease in all subjects. No significant correlations were found between the patient's age and individual scores on the GRBAS scale. Our findings highlight the multifaceted nature of the impact of COVID-19 on communication abilities, underscoring the need for collaborative efforts across various fields to effectively address the challenges faced by COVID-19 survivors.

Keywords: COVID-19; speech disorders; speech pathology; speech therapy

INTRODUCTION

The Sars-Cov-2 virus is currently a serious problem for many societies, both due to its prevalence and the challenges it poses for many countries. The restrictions caused by the lockdown, the high number of new infections, and new mutations of the virus have affected not only the lives and functioning of COVID-19 patients (and then COVID-19 survivors), but also their entire families. The complex long-term effects of COVID-19 infection create the need for a comprehensive rehabilitation of COVID-19 survivors in many areas, including communication.

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The medical treatment of people infected with COVID-19 may require the use of neurological data on the pathomechanism of the disease and on the multi-organ complications associated with it. COVID-19 is not only a respiratory disease, as the virus may also attack internal organs, including the brain, causing neurological and/or psychiatric problems. The problem is all the more serious because, to date, there exists no complete data capturing the long-term effects of the disease and its many mutations. In addition, the disease may present differently from patient to patient, with its symptoms ranging from mild, flu-like ones to severe cases that lead to death. The findings by Hu et al. (2021) confirm that the receptors that make it easier for the coronavirus to enter organisms are present in numerous tissues. It has been suspected that the symptoms of the virus, such as headaches, changes to the sense of taste, anosmia (Carod-Artal, 2020), semantic disfluency, and problems with word retrieval, pose a threat to the nervous system; but the fact that they may persist for a long time has not been taken into account. A report published in 2021 confirmed that a patient with COVID-19 had developed confusion, tremor, cerebellar ataxia, behavioral alterations, aphasia, pyramidal syndrome, coma, cranial nerve palsy, dysautonomia, and central hypothyroidism (Perrin et al., 2021). Such symptoms are characteristics of neurodegenerative diseases: multiple sclerosis (MS), Alzheimer's disease, and dementia. Taquet et al. (2021) have also reported that one in eight people diagnosed with COVID-19 received their first psychiatric or neurological diagnosis within six months of being diagnosed with COVID-19.

There are concerns among doctors that in some survivors, the psychological effects of the disease may be permanent. In other COVID-19 patients – as indicated by many neurologists – strokes may occur as the most severe and common neurological complication. These may occur even in very young people who do not suffer from any coexisting diseases. The so-called COVID strokes (Sagris et al., 2021) can be revealed in comparative studies that screen for differences in the course of the disease in COVID-19 patients. Many patients do not show the typical symptoms of a respiratory disease, and it is only a test result that confirms that they are positive. Vogrig et al. (2021) showed that strokes in COVID-19 patients were directly related to increased clotting in the patients' blood (Wool & Miller, 2021). CT and fMRI images of patients who have suffered a COVID stroke confirm a diffuse course of the disease (disseminated angiopathy). In addition, the case of a patient treated by the first author shows that the brain can be attacked from both sides, leading to a stroke that is both left-hemispheric (aphasia) and right-hemispheric (pragnosia), as well as a brainstem stroke.

Researchers are constantly studying the long-term effects of COVID-19. It has been documented that it can cause neurological damage, psychosis, and the so-called brain fog. Among the neurological problems are voice deficits such as voiceless speech, stuttering, as well as dysphagia (Mohapatra & Mohan, 2020). Chang et al. (2019) explain that while stress and anxiety do not cause stuttering, fluent speech depends on a well-functioning brain. In a so-called cytokine storm, which may be the result of an extremely strong immune system response, it is not only pathogenic cells that are attacked, but also healthy ones; and an immune attack on synaptic connections in the brain can lead to changes in its functioning. Patients complain of problems with memory, association-making, and concentration. Some experience increased anxiety and depression; others may develop psychotic behavior. These are complex neurological deficits that may require prolonged treatment. Concentration disorders, problems with working memory and understanding are classified in ICD-10 as F06.7 – mild cognitive impairment (MCI). These disorders are characterized by impaired memory, learning difficulties, and a diminished ability to concentrate on a task for more than a short period of time. Often, patients experience a marked feeling of mental fatigue when attempting to perform mental tasks.

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In order to fully describe the health status of a COVID-19 patient, a range of various data is necessary. These may include data related to the patient's neurological and neuropsychological health but also various data on the patient's general health, their linguistic ability, and communication deficits. All of these types of data provide a multifaceted picture of heterogenous pathology, in which speech and its impairment are crucial from a speech therapist's point of view.

It is worth considering the issue of speech as well as communicative behavior of COVID-19 survivors from the analytical (linguistic competence and skills) and functional (communicative competence and skills) aspects. A particularly important question is that of what speech and communication disorders accompany COVID-19 and what speech therapy procedures and speech rehabilitation methods should be applied to support patients' communication in the early period after recovery, especially since post-disease symptoms sometimes do not desist spontaneously or are significantly prolonged over time. To this end, a study was carried out using a group of 30 patients with COVID-19 confirmed by a positive test result. The aim of the study was to diagnose what types of speech (and memory) disorders occur in COVID-19 survivors. Additionally, the study also aimed to investigate how long the speech disorders last and whether or not they seem transient or permanent at this stage. Finally, the study also aimed to determine whether there was any correlation between the patient's age and their score in each of the categories of the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scale.

METHODOLOGICAL CHALLENGES IN INVESTIGATING THE IMPACT OF COVID-19 ON VOICE, SPEECH, AND LANGUAGE

Clinical practice documents several types of disorders including speech disfluency (Furlanis et al. 2023), voice quality disorders (Asiaee et al. 2020) and memory loss (amnesia) (Keijsers 2022); the latter being an example of a functional cognitive disorder. Also worth mentioning are emotional and motivational disorders and symptoms, such as apathy, depression, reduced interest in the outside world, and increased fatigability (McCracken et al. 2020). The individual and clinical characteristics of the person being diagnosed determine the method as well as outcome of a diagnosis. The individual differences are the result of the individualized structure and function of the central nervous system, which results in inter-individual (i.e., individual differences in cognitive competence profiles, see Prat, 2011) and intra-individual variability (i.e., different parts of the brain may be involved in a task, see Jodzio, 2014).

Individual variables such as gender, age, education, personality traits, cultural and environmental characteristics as well as interactions between them determine human behavior. Individual differences in COVID-19 survivors affect the depth, type, and persistence of neuropsychological symptoms, language disorders, and their manifestation. The lateralization of brain function is also not irrelevant for language organization and post-COVID disorders. These issues are important, but a particularly significant factor among the variables in COVID-19 seems to be age. With age, the efficiency and quality of mental processes as well as overall fitness change, and the risk of dementia as well as of having coexisting conditions (diabetes, hypertension, circulatory disorders, visual and hearing defects) is increased. These factors may also affect the course of Sars-Cov-2 infection. Certain skills (e.g., episodic memory and alternating attention) may be altered, with others (e.g., semantic memory), being compensated. Particularly acute are changes in language and communication skills, such as word retrieval, sentence comprehension, and complex sentence formation; however, one can also notice difficulties in discourse

comprehension (Thornton & Light, 2006). As shown by Stern (2009) and Robertson (2014), the way symptoms manifest themselves may be determined by individual characteristics.

To investigate the impact of COVID-19 on speech, voice, and language, a comprehensive methodology is required. A full examination of language functions, as in the case of differential diagnosis used in neurodevelopmental diseases, may be carried out by using a procedure suggested for clinical speech pathology by Kluj-Kozłowska (2018, pp. 137-159). This procedure is very much like the approach developed for neuropsychology, as it includes:

- spontaneous speech (especially descriptions and dialogic speech),
- verbal fluency (especially semantic and phonemic fluency),
- naming (confronting names with their referents, the pictures they refer to, etc.)
- comprehension (understanding single words, understanding messages varying in length and grammatical complexity)
- repetition (with variation of linguistic material; attempts to repeat syllables, words, syllable sequences, word sequences, sentences)
- writing and reading (especially reading-aloud tasks, reading comprehension tasks; in terms of writing, assessment of the ability to produce an independent written narrative, dictated writing).

It is equally useful to assess various dimensions of interaction in order to identify typical communication changes and disorders in the post-COVID period. While doing so, various variables should be taken into account, such as individual differences, the onset of pathological phenomena, their severity, and the type of these phenomena in patients. The scope of the assessment and the focus of the examination should therefore encompass:

- Assessment of systemic linguistic abilities (Preserved or compromised). A typical indication here is language disorders concerning lexis, for example, naming, word retrieval problems, with a rather insignificant decline in grammatical skills (concerning syntax or inflection), and a good level of production skills (prosodic features);
- Evaluation of dialogue and monologue skills (Preserved or not). An indication here may be difficulties concerning the content of speech and the ordering of the information conveyed;
- Assessment of linguistic social skills (The patient knows who they are talking to and is aware of the relationship between them and the interlocutor; they know where they are and what they are doing). Difficulties may include recognition of the interlocutor and the relationship between them and the patient, as well as the patient's ability to recognize where they are and what their role there is);
- Assessing situational language skills (Does time and place determine the patient's behavior? Do they know where they are and what time it is?). Difficulties may relate to indicating the time and place where the patient is, to their personal temporal perspective, to stating their own age or period of life, and to the coherence of their temporal perspective (now/before/sometimes);
- Assessing pragmatic skills (Testing the intentionality of utterances). Difficulties exhibited by patients may concern conveying information, readiness to take action and interest in doing so, and communicating emotions to their interlocutors. Assessing basic dimensions of interactions is crucial when determining treatment. Standardized diagnostic tests, for

example, those used in the diagnosis of aphasia[c], may also be helpful in this respect. However, the fullest identification of the patient's capabilities and limitations in terms of language communication can be carried out on the basis of an interview and the patient's responses, for example, through dialogues with the patient in which various topics of everyday life and monologues (in which stories, descriptions, etc., are produced).

To capture the complexity of the impact of COVID-19 on speech, voice, and language, our study employed a methodology that is described in the next section.

METHODOLOGY

The current study took place at the St. John Paul II Mazovian Voivodeship Hospital in Siedlce, Poland between December 2020 and February 2021. A total of 30 people aged between 30 and 60 years (15 men and 15 women) participated in this study. Prior to hospitalization, they had been economically active. None of them had suffered the so-called COVID stroke[d] and all of them had developed transient speech disfluency and memory impairment between 1 month and 12 months after recovery. Soon after being discharged, they had begun outpatient rehabilitation.

The participants' speech was evaluated using the analytical approach. The speech evaluation was conducted using 4 types of tests:

- a test of spontaneous speech (speech samples were elicited from the participants by the first author in guided interviews which took place in a speech therapy room; the participants were asked questions about their interest and their speech was recorded);
- a test of repetition of words and sentences (the participants were asked to repeat words and sentences consisting of 2 to 5 words.);
- a monologue (the participants were asked to talk freely about a topic that they chose themselves);
- a series of automated word sequences (the participants were asked to list the days of the week, months, and count to 20).

In addition, the perceptual evaluation of the patients' speech was carried out by means of the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scale. To determine the correlations between the patient's age and their assessment using the GRBAS scale, Spearman's rho was calculated for the patients' age and each of the criteria on the GRBAS scale separately.

The assessment of language communication skills in people who have suffered from COVID-19 differs from that in people who have coexisting neurodegenerative diseases such as Alzheimer's disease or dementia. For the purposes of postdiagnostic examination (of COVID-19

[c] *As mentioned above, there are no appropriate diagnostic tools designed for post-COVID patients; however, due to the effect of the virus on the brain, one may attempt to use tests specific to the study of aphasia, cf: Boston Diagnostic Aphasia Examination, BDAE, (Goodglass & Kaplan 1972), Minnesota Test for Differential Diagnosis of Aphasia, MTDDA, (Schuell 1965), Multilingual Aphasia Examination, MAE, (Benton, Hamsher & Sivan 1978), Aachen Aphasia Test, AAT, (Huber et al. 1983); for the assessment of language functions one may use: Communication Activities of Daily Living, CADL (Holland 1980), Functional Communication Profile, FCP, (Taylor-Sarno 1969), Edinburgh Functional Communication Profile, EFCP, (Skinner et al. 1984); for screening one may use: The Halstead-Wepman Aphasia Screening Test (Halstead & Wepman 1949), Western Aphasia Battery, WAB, (Kertesz 1979), Frenchay Aphasia Screening Test (Enderby, Wood, and Wade 1987), The Aphasia Screening Test, (Whurr 1996); for comprehension one may use: The Token Test (De Renzi & Vignolo 1962), the Cracow Neurolinguistic Battery of Aphasia Examination (Pąchalska, Kaczmarek, and Knapik 1995), the Boston Naming Test (Kaplan et al. 2001), and others. These procedures are not always appropriate or accurate, but they can be used to assess so-called "extreme cases". Walsh, co-author of the term "extreme case method," advocates that differential diagnosis training programs for psychologists should begin with extreme cases, i.e., cases that display the largest number of characteristics differentiating between diagnostic categories (Walsh 1985, 1998).*

[d] *Attempts to diagnose a person with a stroke have been unsuccessful because of the high mortality of stroke patients, mainly due to comorbidities.*

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survivors) with an existing diagnosis of neurological problems, the procedures and neuropsychological diagnosis used in dementia diseases (i.e., a comprehensive assessment of cognitive functions as well as language functions) were applied. The diagnosis included both a full neuropsychological examination and a speech examination. The latter consisted in the assessment of the patients' communicative skills in the context of the history of the disease and the therapy (planned or to be implemented). In the diagnostic aspect, an undoubted barrier is the lack of appropriate diagnostic tools specifically designed for post-COVID patients, which have yet to be developed in speech therapy worldwide.

RESULTS AND DISCUSSION

SPEECH DISFLUENCY

We found that some patients produced disrupted speech, suspended a phrase, and kept repeating words, parts of words or whole phrases, with the symptoms sometimes deviating from those found in typical cases of stuttering. The results are given in the form of the percentage of disfluency episodes in the speech sample of each patient (See Appendix A for the dataset). The intensity of disfluency turned out to be highly varied in the studied group and ranged from 10% to 20%. Revisions (corrections) and interjections were a particularly frequent symptom of disfluency and made up 20% and 23% of all disfluency cases, respectively. These were followed by repetitions of:

- whole words (20%), for example, *tutaj, tutaj* (*tutaj* means 'here');
- parts of words (10%), for example, *dob, dobre* ('good');
- phrases (10%), for example, *to są dobre buty, to dobre buty* ('these are good shoes, these good shoes');
- parts of phrases (6%), for example, *lubię lody waniliowe, lody waniliowe* ('I like vanilla ice cream, vanilla ice cream').

Interestingly, occasional repetitions of vowels and their prolongation also occurred, for example, (the prolonged vowel is underlined) *d<u>o</u>bre lody* ('good ice cream'), *j<u>a</u>błka* ('aples'), pi<u>e</u>niądze ('money'). The observed difficulties were not permanent and pathological in nature; nor did they show features of well-established logophobia. Rather, they were signs of a semantic disfluency, characterized by difficulties in formulating speech at its first stage, the conceptual stage (also known as the ideation stage), in which an awareness is formed of the content of the message to be conveyed. According to Luria (1959), this stage involves the subject's feeling of the need to communicate his or her own thoughts to the environment. Meyer and Damasio (2009) and Gläscher et al. (2009) explain this in terms of the presence of neuronal maps in our brain, which our mind transforms into mental images that represent the external and internal world, feelings, facts, circumstances.

Disfluencies were found in the speech of all subjects at different times after the resolution of the disease symptoms. The intensity of disfluency, defined as the total number of disfluency episodes per 100 syllables, varied between 5% and 20%. Importantly, the subjects exhibited disfluency only in some runs of the examination while in others they did not show it at all. While disfluency in spontaneous speech was common, only 1/3 of the subjects showed symptoms of it in the repetition test and only 5 subjects showed it in the test of automated word sequences. Emotional components (interjections), revisions, repetitions of whole words and parts of words, and

repetitions of phrases were found in the speech of patients (mainly females, with 2/3 of the female subgroup affected). There were broken phrases in the speech of 17 subjects, emphases (prolonged vowel durations) in 10, filler vowels in 10, and incomplete words in 5. The symptoms identified do not entirely match those typical of stuttering. The participants more often made mistakes in the first words in a sentence, with the initial vowels and syllables of words, and they experienced more difficulty with lexemes than with grammatical categories, which is characteristic of stuttering. Yet, most disfluencies involved the use of interjections and revisions as well as the repetition of whole words, which does not fit the clinical picture of this diagnosis. Moreover, it was found that patients made more errors in single-syllable words or short words in general than in other words, a symptom atypical for stuttering.

Based on the data, it appears that disfluency and working memory impairment commonly affect people with brain fog. It is not possible to unambiguously classify all post-COVID symptoms as stuttering or pseudo-stuttering. They form a set of diverse symptoms that intensify in some individuals and subsist in others. According to Branson's (1981) hypothesis, there is evidence of a link between disfluency and difficulties with word retrieval, but this is still not confirmed by current research. This would also have a logical justification in the occurrence of working memory impairment. Further research is needed to establish to what extent disfluency is caused by dysfunctions of a cortical or even pragmatic nature (through conversational analysis, speech act analysis[e]) or by other CNS dysfunctions (neurodegeneration).

SPEECH THERAPY TREATMENT

Just as there is no single theory explaining the origin of stuttering, there is no single approach to therapy for stuttering. Acquired stuttering may arise at different ages and its course may be equally atypical. COVID-19 confirms that the list of causes of speech disfluency is still not closed. When diagnosing speech disfunctions, the variability of stuttering symptoms should be taken into account. The severity of stuttering symptoms often changes over time and shows a high dependence on the elements of social interaction, namely, the person, their interlocutor, the situation, as well as the purpose and type of speech. Time plays an important role in speech disfluency resulting from the disease; we observe a gradual subsistence of stuttering symptoms in relation to the onset of its first symptoms. This means that patients regain complete fluency within a short or long period after the illness. To facilitate this process, various methods can be used, such as motor-verbal exercises accompanied by music, group reading of a text, slowing down the pace of speaking, prolonged pronunciation of certain sounds, singing, rhythmic speech cuing, improving the movement of articulators, adjusting muscle tension, echo correction (delayed auditory feedback, or DAF), relaxation, pharmacotherapy, and others.

PSEUDOAPHASIA

Another type of symptom characteristic of the post-COVID patients in this study is the impairment of cognitive functions and memory processes found in most subjects. These include characteristic language difficulties resulting from focal brain damage located within the “speech area” in the dominant hemisphere. Such an understanding of these disorders corresponds to the classic definition of aphasia, understood as a set of symptoms characteristic of language disorders caused by cerebral pathology (Mierzejewska 1977, Styczek 1983, Jakimowicz 1987, Prusiński 1989,

[e] *It is worth investigating whether some of the numerous interjections are due to mislearned conversational rules.*

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Brain & Bannister 1992, Kaczmarek 1995, Pąchalska 1999). In this sense, the word *aphasia* is used in speech therapy settings. Meanwhile, in the clinical practice of treating post-COVID patients, one tends to encounter cases of characteristic, but not progressive aphasia-type disorders of verbal communication. which are accompanied by temporary memory lapses, periphrases, and problems with word retrieval. Due to their pathomechanism, language symptoms and their dynamics, these disorders require separate diagnostic and therapeutic procedures (Panasiuk 2012). Such disorders seem to result from damage to the cortical speech centers, manifested by temporary (albeit of varying length) impairment of competence and/or impaired production skills. Symptoms in the post-COVID patients tend to resemble neurodynamic symptoms that are not the result of permanent damage to the speech area, but of temporary inactivation of certain brain structures, leading to temporary language disorders, called pseudoaphasia by A. Luria (1967). Post-COVID changes impede the work of the brain at various levels of its activity, including language and thought processes. Sometimes these changes produce symptoms that suggest a loss of cognitive skills or loss of some speech-related activities in patients who had previously demonstrated these activities (Maruszewski 1966: 98). To date, the specific nature of post-COVID language disorders has not been clearly distinguished from other speech disorders due to the scant research in this area and the still ongoing pandemic period, preventing a complete view of the pathomechanism, location, impaired functioning or coexisting neuropsychological deficits. The extent of concomitant language disorders, which may include permanent (partial or total) nosological units, has not been investigated yet. However, it seems reasonable to suggest that the repetitions, periphrases, and revisions that frequently occur in the spontaneous speech of the patients usually stem from great difficulties in retrieving words, similar to those found in aphasia. After preliminary studies, it can be concluded that the symptoms of post-COVID speech disorders indicate a probable cortical mechanism of speech disorders and impaired neurotransmitter functionality. It is also worth investigating further aspects of language, such as categorization, the formation of superordinate concepts, abstraction and generalization in order to assess thought operations, and the ability to identify relationships between words in relation to oneself and to the external world.

SPEECH THERAPY TREATMENT

Due to the lack of conclusive evidence or data on the effectiveness of linguistic therapy in the early post-COVID-19 period, it would be advisable to start speech therapy as early as possible in order to rehabilitate lost functions fairly quickly. Post-COVID disorders can be multi-modal in nature, affecting skills such as comprehension, reading, speaking, and writing. These deficits usually have a different configuration in terms of elements of language and its subsystems and may negatively affect other cognitive functions. It is essential to recognize the symptoms and quickly start cognitive rehabilitation as soon as a period of their spontaneous absence is noticed. The rate at which specific language deficits subside varies between patients. Some of the COVID survivors recover spontaneously; some do not experience a full improvement of their functioning with respect to higher mental functions for as long as 6 months after the end of the treatment and complete recovery (i.e., they experience problems with word retrieval, suffer from comprehension deficits, or from anomic aphasia). It should be mentioned that in addition to language problems (word retrieval, memory, etc.), patients may face medical and psychological difficulties that further complicate the picture of post-COVID disorders. These include visual, auditory, sensory disorders, dysphagia, depression, etc. Post-COVID patients may also suffer from anxiety disorders, apathy, lack of physical strength, emotional lability (emotional episodes that do not match the situational context).

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Every COVID survivor is different because their language disorders are related to the different location of the viral impact, other symptoms, the time that has elapsed since recovery, as well as the patient's age, previous language experience, level of cognitive functions, lateralization of language functions and even lifestyle. This diversity, profiled by time and the compensatory capacities of the brain and the body, is accompanied by deficits in such cognitive functions as memory, attention, concentration, visual and auditory gnosis, executive functions, and non-verbal speech. The assessment of linguistic functions such as naming, forming logical and sensible sentences, and understanding utterances does not always allow for an unequivocal recognition of the patient's linguistic deficits due to the varying degree of their intelligence and previous social functioning. Speech activities have a complex and hierarchical character, and their functioning is conditioned by many elementary abilities, which may be impaired in a selective way. For example, word retrieval is possible when the referent is shown, but impaired when instead of the referent, the definition of the concept corresponding to the given name is presented. Moreover, the structures of language are complex in various ways, so that in the same activity, for example, repetition or comprehension the patient's performance, can vary depending on the difficulty of the language material. Speech therapy measures require a detailed individual therapy plan to be formulated, taking into account any co-existing disorders (dysphonia, semantic disfluency, etc.), diagnostic hypotheses to be verified, and the therapy plan to be modified depending on the patient's progress. Speech therapy should aim to help patients regain disturbed language functions. This involves a precise definition of the defect, but it always has to be based on the preserved elements of the dynamic "speech chain" (Panasiuk 2015: 909).

The methods of speech therapy are furthermore dependent on the pace at which the disease symptoms subside. The variability of the picture of language disorders resulting from the course of the disease, the patient's compensatory abilities, rehabilitation activities, the patient's clinical condition, his/her well-being, etc. make it necessary to carry out multiple speech therapy diagnoses (initial, control, final) and to verify previous assumptions and therapeutic strategies.

DYSPHONIA / APHONIA

Phoniatricians report that post-COVID changes observed soon after the disease has subsided may include a change in the quality of the voice. COVID-19 survivors may report hoarseness, coughing, pain on swallowing, the feeling of a foreign body in their throat and voiceless speech. The quality of a patient's voice depends not only on the condition of the larynx, but also on the function of the resonators and articulators. The quality of the voice may be affected by the general state of health, the hydration level of the body, mental state, eating habits, diseases of the digestive system (reflux). An important symptom is the presence of dyspnoea (i.e., breathing discomfort), even intermittent dyspnoea, but with a noticeable stridor.[f] Such symptoms occurring together with COVID-19 cannot be overlooked. The etiology of dysphonia (i.e., hoarseness) may be complex and individual, involving pathological changes in voice characteristics, without primary, organic changes in the vocal folds.

The 30 participants in this study were examined using the GRBAS scale, which describes perceptual voice disorders using 5 parameters: G (grade of hoarseness), R (roughness), B (breathiness), A (asthenia), S (strain). Each parameter has 4 degrees of severity: 0 – normal, 1– mild, 2 – moderate, 3 – severe. After a phoniatric examination, we found that the majority of patients (25 out of 30) used excessive force to produce voice, with an average phonation time

[f] *A high-frequency sound produced in the larynx during inhalation due to narrowing of the glottis.*

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markedly shortened[g] (M = 15.0, SD = 5.8; M_{men} = 15.6, SD_{men} = 6.0; M_{women} = 14.4, SD_{women} = 5.7). On the basis of several tests, it was established that the shortest phonation time in 7 patients was below 10 seconds, which indicated a marked pathology in voice production. In more than half of the subjects (17 patients), the presence of noise sensations was also detected with the phonendoscope, suggesting the presence of false air between the vocal folds. In the assessment of vocal performance, the maximum intensity and dynamic modulation of the voice, that is, the ability to increase its intensity, were also taken into account. These parameters are 50 dB for whisper, 65 dB for ordinary speech, and 90 dB for screaming (with the microphone placed at a distance of 30 cm away from the participant's mouth). The results of the study showed a marked weakening of the ability to produce voice immediately after the disease in all subjects. The records showed that post-COVID patients were able to use voice with a maximum intensity of up to 90 dB (M = 62.0, SD = 15.7; M_{men} = 60.0, SD_{men} = 16.0; M_{women} = 64.3, SD_{women} = 15.7), and an increase in these parameters resulted in significant voice fatigue and dysphonia of varying severity, with one patient developing aphonia (defined as the inability to produce voiced sound). Spearmann's correlation coefficient was used to calculate the correlation between the patient's age and individual scores on the GRBAS scale as all the scores on the GRBAS scales were ordinal. Spearmann's correlation coefficient and the corresponding p values were found to be: r_s = 0.010, p = 0.959; r_s = 0.003, p = 0.989; r_s = –0.062, p = 0.744; r_s = 0.196, p = 0.300; r_s = 0.057, p = 0.763. None of these correlations were found to be significant.

The examination seems to indicate changes with a phononeurotic profile, which are the result of impaired mental processes (Pruszewicz 1992) linked to phonasthenia, that is, disturbed coordination of breathing, phonation, articulation and resonance, resulting from the discoordination or weakening of the muscles involved in these processes.

SPEECH THERAPY TREATMENT

The ability to use one's voice is part of the overall communicative functioning of a person; the realization of individual sounds, speech segments, and language depends on it. Voice quality is related to the linguistic, paralinguistic, and extralinguistic functions of speech. The treatment of voice disorders requires close cooperation with a phoniatrician who evaluates the progress of rehabilitation throughout its different stages. Sometimes treating a patient requires the involvement of other specialists, such as a physiotherapist or psychotherapist. Multi-specialist rehabilitation of voice disorders aims to develop correct breathing, phonation, resonation, articulation mechanisms and to improve the biomechanics and coordination of these activities. The effect of the therapy should be an effortless ability to use a resonant voice, without the feeling of discomfort, in all the communicative activities in which the patient participates. The therapy should also focus on muscle tension regulation (relaxation in autogenic training, progressive relaxation, elements of music therapy and visualization) and on the use of different voice intensities (expanding the range of the voice in singing and speaking).

[g] *The normal phonation time is about 20 to 25 seconds in healthy individuals.*

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CONCLUSIONS

Preliminary studies of post-COVID patients' speech clearly indicate the need for post-COVID speech rehabilitation in COVID-19 survivors whose symptoms persist over an extended period of time. The results of these studies may still be incomplete and contradictory until the mechanisms and a full range of deficits caused by various COVID-19 mutations are known. This raises the need for long-term longitudinal studies, during which a range of abnormalities in the course of transient and longer-lasting speech disorders should be monitored despite the absence of disease symptoms. Diagnostic dilemmas may relate to subsequent manifestations of the disease and symptoms such as L2 decline, insomnia, powerlessness, inability to take action, disorientation, mental chaos, symptoms reminiscent of anxiety-depressive disorders (post-traumatic stress disorder), which may be further compounded by imposed isolation. All this raises the question: How far can a speech pathologist intervene without the help of a psychologist, a psychiatrist, a neurologist, or an internist?

Establishing the diagnostic and therapeutic procedure for a variety of speech disorders, formulating the goals of therapy, its stages, strategies, methods, and techniques when working with a post-COVID patient requires a thorough methodological knowledge of many specialists; but above all it requires further observation of existing speech and communication deficits. The complex consequences of post-COVID brain damage and the speech disorders associated with it create the need for comprehensive rehabilitation of patients, with a significant role to be played by clinical speech pathologists. Speech therapy does not have the capacity to physically interfere with the anatomical structures of the body; it can only affect its physiology by applying appropriate therapeutic procedures. These should include activities related to the sphere of biological functioning of the voice, psychological activities of a higher order (such as thought processes), and activities in the field of social communication. In other words, the definition of post-COVID speech and language disorders should simultaneously be based on at least several types of criteria: anatomical, physiological, psychological, and linguistic. Systematic and quickly-undertaken therapy conducted by many specialists may bring satisfactory results, which may be facilitated by the regression of the disease (in many cases patients fully recover) and by high motivation on the part of patients to participate in therapy.

REFERENCES

Asiaee, M., Vahedian-azimi, A., Atashi, S.S., Keramatfar, A., & Nourbakhsh, M. (2022). Voice Quality Evaluation in Patients With COVID-19: An Acoustic Analysis. *Journal of Voice*. *36*(6), 879.e13-879.e19. https://doi.org/10.1016/j.jvoice.2020.09.024

Brain, R. & Bannister, R. (1992). *Brain and Bannister's clinical neurology*. Oxford: Oxford University Press.

Branson, C. (1981). *Speech and language characteristics of children with Prader-Willi syndrome*. In: V.A. Holm, S. Sulzbacher, P.L. Pipes (Eds.), *The Prader-Willi Syndrome*. (pp. 179–183). Baltimore, MD: University Park Press.

Carod-Artal F. J. (2020). Neurological complications of coronavirus and COVID-19. Complicaciones neurológicas por coronavirus y COVID-19. *Revista de neurologia*. *70*(9), 311–322. https://doi.org/10.33588/rn.7009.2020179

Chang, S. E., Garnett, E. O., Etchell, A., & Chow, H. M. (2019). Functional and Neuroanatomical Bases of Developmental Stuttering: Current Insights. *The Neuroscientist: a review journal*

bringing neurobiology, neurology and psychiatry. *25*(6), 566–582. https://doi.org/10.1177/1073858418803594

Furlanis, G., Busan, P., Formaggio, E., Menichelli, A., Lunardelli, A., Ajcevic, M., Pesavento, V., & Manganotti, P. (2023). Stuttering-Like Dysfluencies as a Consequence of Long COVID-19. *Journal of Speech, Language, and Hearing Research*. *66*(2), 415–430. https://doi.org/10.1044/2022_JSLHR-22-00381

Gläscher, J., Tranel, D., Paul, L. K., Rudrauf, D., Rorden, C., Hornaday, A., Grabowski, T., Damasio, H., & Adolphs, R. (2009). Lesion mapping of cognitive abilities linked to intelligence. *Neuron*. *61*(5), 681–691. https://doi.org/10.1016/j.neuron.2009.01.026

Hu Ben, Hua Guo, Peng Zhou, Shi Zheng-Li (2021). Characteristics of SARS-CoV-2 and COVID-19. *Nature reviews. Microbiology*. *19*(3), 141–154. https://doi.org/10.1038/s41579-020-00459-7

Jakimowicz, W. (1987). *Neurologia kliniczna w zarysie*. Warszawa: PZWL.

Jodzio, K. (2014). *Neuropsychologia różnic indywidualnych w świetle badań klinicznych*. In E. Łojek, A. Bolewska, H. Okuniewska (Eds.), *Studia z neuropsychologii klinicznej*. *Na 45-lecie pracy zawodowej Profesor Danuty Kądzielawy* (pp. 71-96). Warszawa, Wydawnictwa Uniwersytetu Warszawskiego.

Keijsers, K., Broeders, M., Baptista Lopes, V., Klinkert, A., van Baar, J., Venrooij, N., & Kerckhoffs, A. (2022). Memory impairment and concentration problems in COVID-19 survivors 8 weeks after non-ICU hospitalization: a retrospective cohort study. *Journal of Medical Virology*. *94*(9), 4512–4517. https://doi.org/10.1002/jmv.27831

Kaczmarek, B. (1995). *Mózgowa organizacja mowy*. Lublin: Agencja Wydawniczo-Handlowa.

Kluj-Kozłowska, K. (2018). Rola neurologopedy w diagnostyce różnicowej chorób neurozwyrodnieniowych. *Biuletyn Logopedyczny*. *32*, 137–159.

Luria, A.R. (1959). The directive function of speech in development and dissolution. *Word*. *15*(3), 341–352. https://doi.org/10.1080/00437956.1959.11659703

Luria, A.R. (1967). *Zaburzenia wyższych czynności korowych wskutek ogniskowych uszkodzeń mózgu. Podstawy neuropsychologii*. Warszawa: Państwowe Wydawnictwo Naukowe.

Maruszewski, M. (1966). *Afazja: zagadnienia teorii I terapii*. Warszawa: Państwowe Wydawnictwo Naukowe.

McCracken, L., Badinlou, F., Buhrman, M., & Brocki, K. (2020). Psychological impact of COVID-19 in the Swedish population: Depression, anxiety, and insomnia and their associations to risk and vulnerability factors. *European Psychiatry*. 63(1), e81, 1–9. https://doi.org/10.1192/j.eurpsy.2020.81

Meyer, K., & Damasio, A. (2009). Convergence and divergence in a neural architecture for recognition and memory. *Trends in neurosciences*. *32*(7), 376–382. https://doi.org/10.1016/j.tins.2009.04.002

Mierzejewska, H. (1977). *Afatyczna dezintegracja fonetycznej postaci wyrazów*. Wrocław: Ossolineum.

Mohapatra, B., Mohan, R. (2020). Speech-Language Pathologists' Role in the Multi-Disciplinary Management and Rehabilitation of Patients with Covid-19. *Journal of rehabilitation medicine. Clinical communications*, *3*, 1–6. https://doi.org/10.2340/20030711-1000037

Panasiuk, J. (2012). Afazja a interakcja. TEKST – metaTEKST – konTEKST, Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.

Panasiuk, J. (2015). Postępowanie logopedyczne w przypadku afazji. In S. Grabias, J. Panasiuk, T. Woźniak (Eds.), *Logopedia. Standardy postępowania logopedycznego* (pp. 869–919). Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.

Pąchalska, M. (1999). *Afazjologia*. Kraków: Wydawnictwo Naukowe PWN.

Perrin, P., Collongues, N., Baloglu, S., Bedo, D., Bassand, X., Lavaux, T., Gautier-Vargas, G., Keller, N., Kremer, S., Fafi-Kremer, S., Moulin, B., Benotmane, I., & Caillard, S. (2021). Cytokine release syndrome-associated encephalopathy in patients with COVID-19. *European journal of neurology*. *28*(1), 248–258. https://doi.org/10.1111/ene.14491

Prat, C.S. (2011), The Brain Basis of Individual Differences in Language Comprehension Abilities. *Language and Linguistics Compass*, 5, 635–649. https://doi.org/10.1111/j.1749-818X.2011.00303.x

Prusiński, A. (1989). *Podstawy neurologii klinicznej*. Warszawa: Państwowy Zakład Wydawnictw Lekarskich.

Pruszewicz, A. (Ed.) (1992). *Foniatria kliniczna*. Warszawa: Państwowy Zakład Wydawnictw Lekarskich.

Robertson I. H. (2014). Right hemisphere role in cognitive reserve. *Neurobiology of aging*. *35*(6), 1375–1385. https://doi.org/10.1016/j.neurobiolaging.2013.11.028

Sagris, D., Papanikolaou, A., Kvernland, A., Korompoki, E., Frontera, J. A., Troxel, A. B., Gavriatopoulou, M., Milionis, H., Lip, G., Michel, P., Yaghi, S., & Ntaios, G. (2021). COVID-19 and ischemic stroke. *European journal of neurology*. *28*(11), 3826–3836. https://doi.org/10.1111/ene.15008

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia*. *47*(10), 2015–2028. https://doi.org/10.1016/j.neuropsychologia.2009.03.004

Styczek, I. (1983). *Logopedia*. Warszawa: Państwowe Wydawnictwo Naukowe.

Taquet, M., Geddes, J. R., Husain, M., Luciano, S., & Harrison, P. J. (2021). 6-month neurological and psychiatric outcomes in 236 379 survivors of COVID-19: a retrospective cohort study using electronic health records. *The Lancet. Psychiatry*. *8*(5), 416–427. https://doi.org/10.1016/S2215-0366(21)00084-5

Thornton R., Light L. (2006). *Language comprehension and production in normal aging*. In J.E. Birren, K.W. Schaie, R.P. Abeles, M. Gatz, T. Salthouse, (Eds.), *Handbook of the Psychology of Aging* (pp. 261–279). Oxford: Elsevier.

Vogrig, A., Gigli, G. L., Bnà, C., & Morassi, M. (2021). Stroke in patients with COVID-19: Clinical and neuroimaging characteristics. *Neuroscience letters*. *743*, 135564. https://doi.org/10.1016/j.neulet.2020.135564

Wool, G. D., & Miller, J. L. (2021). The Impact of COVID-19 Disease on Platelets and Coagulation. *Pathobiology: journal of immunopathology, molecular and cellular biology*. *88*(1), 15–27. https://doi.org/10.1159/000512007

Walsh, K., (1985). *Understanding brain damage. A primer of neuropsychological evaluation*. Edinburgh: Churchil Livingstone,

Walsh, K. (1998). *Neuropsychologia kliniczna*. Warszawa: Wydawnictwo Naukowe PWN.

DIAGNOSTIC TOOLS

The Aachen Aphasia Test [Huber, Poeck & Willmes 1983].
The Aphasia Screening Test [Whurr 1996].
Boston Diagnostic Aphasia Examination [Goodglass & Kaplan 1972].
The Boston Naming Test [Kaplan, Goodglass & Weintraub 2001].
Communication Activities of Daily Living [Holland 1980].
Cracow Neurolinguistic Battery of Aphasia Examinnation / Krakowska Neurolingwistyczna Bateria Diagnostyki Afazji [Pąchalska, Kaczmarek & Knapik 1995].
Edinburgh Functional Communication Profile [Skinner, Wirtz, Thompson & Davidson 1984].
Frenchay Aphasia Screening Test [Enderby, Wood & Wade 1987].
Functional Communication Profile [Taylor-Sarno 1969].
Minnesota Test for Differential Diagnosis of Aphasia [Schuell 1965].
Multilingual Aphasia Examination [Benton, Hamsher & Sivan 1978].
The Halstead-Wepman Aphasia Screening Test [Halstead & Wepman 1949].
The Token Test [De Renzi & Vignolo 1962].
The Western Aphasia Battery [Kertesz 1979].

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APPENDIX A

The Dataset Collected in the Study

No	Age	Education	sex	repeating words	repeating parts of words	repeating phrases	repeating parts of phrases	prolonging vowels (emphases)	broken phrases	filler vowels	incomplete words	G	R	B	A	S	phonation time	dB
1	30	university	F	yes	yes	no	no	yes	yes	yes	yes	1	1	0	1	0	20	70
2	37	university	F	yes	no	no	no	yes	yes	no	no	2	2	1	2	1	15	60
3	50	secondary school	F	no	no	no	no	no	no	yes	no	1	1	0	2	1	10	45
4	57	secondary school	F	no	no	no	no	no	yes	yes	no	1	1	0	2	1	9	55
5	60	vocational school	F	no	no	no	no	no	no	no	no	2	1	0	2	1	20	55
6	53	vocational school	F	no	no	no	no	no	no	no	no	0	0	0	0	0	9	90
7	45	vocational school	F	yes	yes	yes	no	yes	yes	yes	yes	2	3	1	2	3	6	40
8	42	university	F	no	no	no	no	no	no	no	no	0	0	1	0	0	25	90
9	59	university	F	no	no	no	no	no	no	no	no	1	0	1	1	0	15	70
10	60	secondary school	F	no	no	no	no	no	no	no	no	1	1	1	1	1	13	65
11	55	vocational school	F	no	no	no	no	no	no	no	no	1	0	1	0	0	20	80
12	39	university	F	no	no	no	no	no	no	no	no	1	1	1	1	1	20	70
13	48	university	F	no	no	yes	yes	yes	no	no	yes	3	2	2	2	2	10	65
14	35	university	F	no	no	no	no	no	no	yes	no	2	1	1	2	1	10	45
15	60	vocational school	M	no	no	no	no	no	no	no	no	0	0	1	0	0	20	80
16	60	secondary school	M	no	no	no	no	no	no	no	no	2	2	0	2	1	12	50
17	56	secondary school	M	no	no	no	no	no	no	yes	no	2	1	0	2	1	17	55
18	57	vocational school	M	yes	no	yes	no	yes	yes	no	no	1	1	1	2	1	12	60
19	49	vocational school	M	no	no	no	no	no	no	no	no	0	1	0	1	0	18	65
20	52	university	M	no	no	no	no	no	no	no	no	0	0	0	1	0	23	75
21	31	university	M	no	no	no	no	no	no	no	no	0	0	0	0	0	25	90
22	44	vocational school	M	yes	yes	no	yes	yes	yes	yes	no	2	2	2	2	2	12	30
23	45	vocational school	M	no	no	no	no	yes	yes	yes	yes	1	2	1	2	2	7	40
24	47	university	M	no	no	no	no	no	no	no	no	1	0	0	0	0	20	80
25	51	secondary school	M	yes	no	no	no	yes	yes	yes	no	1	2	1	2	1	8	55
26	33	university	M	no	no	no	no	no	no	no	no	1	0	0	0	0	9	70
27	48	university	M	no	no	no	no	yes	yes	yes	no	2	1	1	2	1	7	50
28	60	vocational school	M	no	no	no	no	yes	yes	no	no	1	2	1	2	1	18	60
29	58	vocational school	M	no	no	no	no	no	no	no	no	2	1	0	2	1	20	55
30	56	secondary school	M	no	no	no	no	no	no	no	yes	1	1	1	2	1	22	45

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