

RESEARCH ARTICLE

Clinical neurophysiology and cerebrospinal liquor analysis to detect Guillain-Barré syndrome and polyneuritis cranialis in COVID-19 patients: A case series

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Abstract

We report a case series of five patients affected by SARS-CoV-2 who developed neurological symptoms, mainly expressing as polyradiculoneuritis and cranial polyneuritis in the 2 months of COVID-19 pandemic in a city in the northeast of Italy. A diagnosis of Guillain-Barré syndrome was made on the basis of clinical presentation, cerebrospinal fluid analysis, and electroneurography. In four of them, the therapeutic approach included the administration of intravenous immunoglobulin (0.4 g/kg for 5 days), which resulted in the improvement of neurological symptoms. Clinical neurophysiology revealed the presence of conduction block, absence of F waves, and in two cases a significant decrease in amplitude of compound motor action potential compound muscle action potential (cMAP). Four patients presented a mild facial nerve involvement limited to the muscles of the lower face, with sparing of the forehead muscles associated to ageusia. In one patient, taste assessment showed right-sided ageusia of the tongue, ipsilateral to the mild facial palsy. In three patients we observed albuminocytological dissociation in the cerebrospinal fluid, and notably, we found an increase of inflammatory mediators such as the interleukin-8. Peripheral nervous system involvement after infection with COVID-19 is possible and may include several signs that may be successfully treated with immunoglobulin therapy.

KEYWORDS

COVID-19, cranial polyneuritis, immunoglobulin, interleukins, polyradiculoneuritis

1 | INTRODUCTION

Since December 2019, the novel coronavirus (SARS-CoV-2) has rapidly spread worldwide, causing an increased number of hospitalization and intensive care admissions, due to severe respiratory distress. Even though respiratory symptoms play a critical role in the clinical picture, in the last few weeks a variety of systemic manifestations has been increasingly described, including neurological symptoms. Neurological complications reported so far in patients

affected by new coronavirus infectious disease (COVID-19) suggest a possible neurotropism of the virus and its potential ability to induce auto-immunity reactions. Several neurological complications have been described, including cerebrovascular accidents, polyradiculoneuritis (Guillain-Barré syndrome), and other inflammatory diseases.¹ Among the peripheral nervous system manifestations, the most frequently observed are hyposmia, hypogeusia, and Guillain-Barré syndrome (GBS).^{2,3} GBS is a heterogeneous condition with several variant forms: the most common presentation is the

progressively ascending tetraparesis (acute inflammatory demyelinating polyneuropathy), but other localized clinical variants are also recognized. Miller-Fisher syndrome (MFS), a regional variant characterized by the triad of ophthalmoplegia, ataxia, and areflexia, has also been linked to COVID-19.⁴ According to a new classification, autoimmune neuropathies can also include forms with central nervous system involvement (Bickerstaff brainstem encephalitis).⁵ About 60% of the above-mentioned autoimmune syndromes can be infection-related by humoral and cellular cross-reactivity,^{6,7} most frequently gastrointestinal (*Campylobacter jejuni*) or respiratory tract infections, including flu syndrome and pneumonia.^{8,9} Clinical neurophysiology represents a fundamental tool for the diagnosis of acute inflammatory neuropathies. Neurophysiological investigations, however, require close contact with the patient and may result in an increased risk of infection, therefore, only partial data have been collected so far in COVID-19 patients.

Here we report a case series of five patients affected by COVID-19 who developed a spectrum of autoimmune polyneuropathies during hospitalization. We describe their clinical features, laboratory testing as well as treatment response. Particular attention has been paid to neurophysiological findings and cerebrospinal fluid analysis.

2 | MATERIALS AND METHODS

This case series described five patients admitted to the hospital affected by bilateral pneumonia due to SARS-CoV-2 infection from March to April 2020. Symptoms on admission were fever and cough, and in four out of five patients significant impairment of taste and smell was also reported (Table 1). Due to respiratory failure patients were admitted in the COVID-19 protected areas of the University Hospital of Trieste. COVID-19 diagnosis was then confirmed by means of nasopharyngeal swab. COVID-19 management included a variety of treatments, including antiviral drugs (Lopinavir/Ritonavir, Darunavir), hydroxychloroquine, antibiotic therapy, and oxygen support (Table 1). Two patients received Tocilizumab, a monoclonal antibody targeting the interleukin (IL)-6 receptor. Two out of the five patients remained in COVID-dedicated internal medicine units, whereas three of them required mechanical ventilation in the intensive care unit (ICU) for a prolonged time (from 11 to 20 days).

Patients developed progressive weakness of the upper and lower limbs, in a distoproximal fashion; the latency between the onset of the respiratory symptoms and neurological involvement ranged from 14 to 30 days. However, the longest latency (30 days) has been observed in a patient who came under prolonged sedation in ICU, therefore it is likely that symptoms appeared earlier in the course of the disease, but were not assessable at that time.

All the patients received neurological examination at symptoms development, routine blood chemistry analyses, and a panel of antiganglioside antibodies, including anti-GM1, -GM2, -GM3, -GD1a, -GD1b, -GT1b, and -GQ1b, were performed according to

standard procedures. Cerebrospinal fluid (CSF) was collected and processed for standard analyses including pressure, cell count, proteins, and glucose. CSF culture and polymerase chain reaction (PCR) for possible organisms, such as bacteria, *Mycobacterium tuberculosis*, fungi, Herpes viruses, Enteroviruses, Japanese B virus, and Dengue viruses, were performed, including analysis for SARS-CoV-2.

2.1 | Clinical neurophysiology

Motor and sensory nerve conduction studies were performed in the upper and lower limbs following standard international guidelines. The neurophysiological evaluation included electroneurography (ENG) and electromyography (EMG) that were performed in the COVID-dedicated area for all the patients. F waves were recorded from lower and upper limbs. Facial nerve conduction velocity was studied by using as recording points the Orbicularis Oris and the Orbicularis oculi muscles and using as stimulation point the tragus on both sides. A blink reflex testing was also carried out to the patient with suspect MFS. Needle EMG was performed in four patients. The physician and the technician wore personal protective equipment including appropriate masks, face shields, gowns, and gloves following the guidelines American Association of Clinical Neurophysiology website has guidance (<https://www.acns.org/practice/covid-19-resources>).

3 | RESULTS

Neurological examination revealed a flaccid paresis in four patients, with variable lower or upper limb predominance; interestingly, in these patients, we observed a unilateral mild facial nerve involvement limited to the muscles of the lower face, with sparing of the forehead muscles. Two patients also reported paresthesia, described as tingling or a sense of "tight bandage" located at the lower extremities. Deep tendon reflexes were diffusely absent. The fifth patient developed a slightly different clinical picture, characterized by bilateral ophthalmoplegia, hypoaesthesia in the territory of maxillary and mandibular trigeminal branches, mild right lower facial nerve palsy, and limb ataxia. Generalized areflexia was also present. All patients have been complaining of taste and smell impairment since the beginning of the respiratory symptoms. In the latter patient described we performed a taste assessment which showed right-sided ageusia of the tongue, ipsilateral to the mild facial palsy (Figure 1).

In all patients the results of routine blood chemistry tests, human immunodeficiency virus, Hepatitis B Virus, Hepatitis C Virus, as well as a panel of serological tests for autoimmune disorders were unremarkable. A panel of antiganglioside antibodies, including anti-GM1, -GM2, -GM3, -GD1a, -GD1b, -GT1b, and -GQ1b, was negative. In four out of five patients. CSF analysis revealed clear

TABLE 1 Demographic, clinical, and laboratory features of the patients

Patient	1	2	3	4	5
Age	72 Y	72 Y	49 Y	94 Y	76 Y
Sex	Male	Male	Female	Male	Male
Early symptoms of COVID-19	Fever, dyspnea, hyposmia, and ageusia	Fever, cough, dyspnea, hyposmia, and ageusia	Fever, cough, dyspnea, hyposmia, and ageusia	Fever, cough, gastrointestinal symptoms,	Fever, cough, dysuria, hyposmia, and ageusia
Need for mechanical ventilation	Yes	Yes	No	No	Yes
Latency of neurological symptoms ^a	18 d	30 d ^b	14 d	33 d	22 d
Neurological signs and symptoms	Flaccid tetraparesis, with proximal upper limb predominance	Flaccid tetraparesis with lower limbs predominance	Ophthalmoplegia with diplopia in the vertical and lateral gaze, limb ataxia	Lower limbs weakness	Proximal weakness of lower and upper limb, with upper limb predominance
Deep tendon reflexes	Diffusely absent	Diffusely absent	Diffusely absent	Diffusely weak	Diffusely absent
Sensory disturbances	Tingling of distal lower extremities	Sense of having a tight bandage on legs and feet	Right-sided hypoesthesia of the face	Unassessable due to agitation status	None
Cranial nerve involvement	Mild right-sided lower face facial weakness, with sparing of the forehead muscles	None	Bilateral ophthalmoplegia; Hypoesthesia in the territory of maxillary and mandibular trigeminal branches; Mild right-sided lower facial deficit	None	Mild left-sided lower facial deficit; Reported mild transient diplopia fully recovered at the time of evaluation
CSF findings	Protein level 52 mg/dL; 1 cell/mm ³	Normal protein level (40 mg/dL); 1 cell/mm ³	Protein level 72 mg/dL; 5 cells/mm ³	Not performed	Protein level 53 mg/dL; 2 cell/mm ³
Antiangiostoid antibodies	PCR for SARS-CoV-2: negative	PCR for SARS-CoV-2: negative	PCR for SARS-CoV-2: negative	PCR for SARS-CoV-2: negative	PCR for SARS-CoV-2: negative
Serum interleukin level ^c	Negative	Negative	Negative	Not performed	Negative
	IL-1 β : 0.2 pg/mL \uparrow	IL-1 β : 0.5 pg/mL \uparrow	Not performed	Not performed	IL-1 β : 0.2 pg/mL \uparrow
	IL-6: 113.0 pg/mL $\uparrow\uparrow$	IL-6: 9.8 pg/mL \uparrow	Not performed	Not performed	IL-6: 32.7 pg/mL $\uparrow\uparrow$
	IL-8: 20.0 pg/mL \uparrow	IL-8: 55.0 pg/mL $\uparrow\uparrow$	Not performed	Not performed	IL-8: 17.8 pg/mL \uparrow
	TNF- α : 16.0 pg/mL \uparrow	TNF- α : 16.0 pg/mL \uparrow	IL-2R: 1203.0 pg/mL IL-10: 4.6 pg/mL IP-10: 94.8 pg/mL INF- γ : 0.8 pg/mL	Not performed	TNF- α : 11.1 pg/mL
CSF interleukin level ^d	IL-1 β : 0.12 pg/mL IL-6: 9.6 pg/mL	IL-1 β : 0.1 pg/mL IL-6: 1.4 pg/mL	Not performed	Not performed	IL-1 β : 0.52 pg/mL IL-6: 5.9 pg/mL

TABLE 1 (Continued)

Patient	1	2	3	4	5
	IL-8: 22.7 pg/mL TNF- α : 0.3 pg/mL	IL-8: 96.0 pg/mL TNF- α : 0.7 pg/mL	IL-2R: 24.6 pg/mL IL-10: 0.55 pg/mL IP-10: 60.8 pg/mL INF- γ : 0.63 pg/mL		IL-8: 42.6 pg/mL TNF- α : 0.25 pg/mL
IL-8 CSF/serum ratio	1.1	1.74	Not performed	Not performed	2.39
Brain MRI	Not performed	Normal findings	Normal findings	Not performed	Not performed
Treatment of the neurological syndrome	IVIg cycle (0.4 g/kg for 5 d)	IVIg cycle (0.4 g/kg for 5 d)	IVIg cycle (0.4 g/kg for 5 d)	Methylprednisolone 60 mg for 5 d	IVIg cycle (0.4 g/kg for 5 d)
Other therapies	COVID-19 management included administration of hydroxychloroquine, oseltamivir, darunavir, methylprednisolone, and tocilizumab	COVID-19 management included administration of hydroxychloroquine, lopinavir-ritonavir, methylprednisolone	COVID-19 management included administration of hydroxychloroquine, lopinavir-ritonavir, methylprednisolone	COVID-19 management included administration of methylprednisolone	COVID-19 management included administration of hydroxychloroquine, oseltamivir, darunavir, methylprednisolone, Tocilizumab, meropenem, linezolid, clarithromycin, doxycycline and fluconazole
Outcome	Improvement of tetraparesis	Improvement of weakness	Progressive improvement	Stationary	Progressive improvement

Abbreviations: CDF, cerebrospinal fluid; IL, interleukin; PCR, polymerase chain reaction; TNF, tumor necrosis factor.

^aDays between early respiratory symptoms and neurological syndrome onset.

^bIt is possible that symptoms appeared earlier in the course of disease but were not evident as the patient was intubated and sedated.

^cLaboratory reference values for serum interleukins—IL- β : <0.001 pg/mL; IL-6: 0.8–6.4 pg/mL; IL-8: 6.7–16.2 pg/mL; TNF- α : 7.8–12.2 pg/mL; IL-2R: 440.0–1435.0 pg/mL; IL-10: 1.8–3.8 pg/mL; IP-10: 37.2–222.0 pg/mL; INF- γ : <0.99 pg/mL.

^dReference values for CDF interleukins were assumed equal to serum values, as standardized cut-off values are not yet recognized.

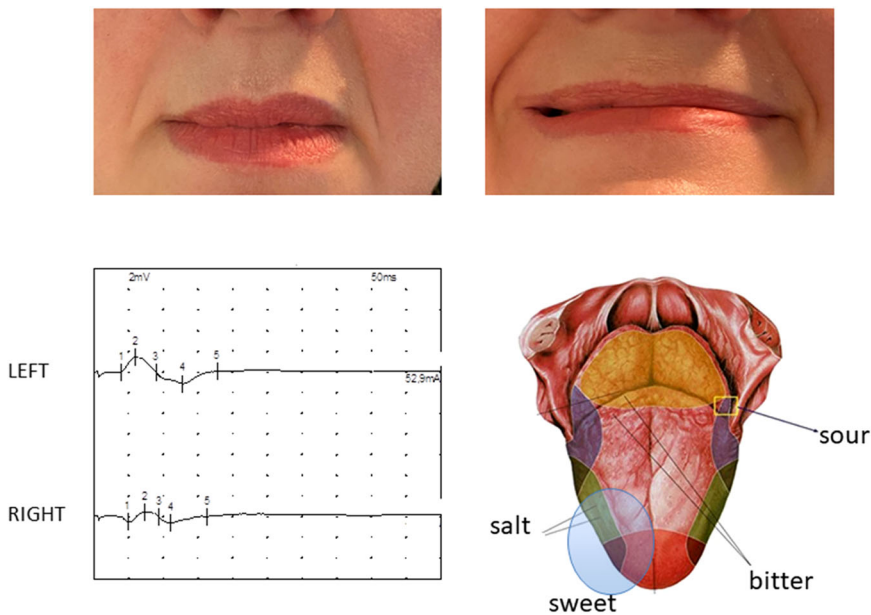


FIGURE 1 a 50-year-old female with initial ophthalmoplegia and diplopia, left upper arm cerebellar dysmetria, generalized areflexia, mild defect in right lower branch of facial nerve. The facial defect persisted after the general improvement with immunoglobulins therapy. Asymmetry of the latency and amplitude of facial nerve conduction of the right lower branch was associated with asymmetrical ageusia for salt and sweet taste on the right side of the tongue

CSF, normal pressure, and no blood cells (Table 1). The CSF/serum glucose ratio was normal in all patients. In three of them, CSF revealed a mild albumin-cytologic dissociation (ranging from 52 to 72 mg/dL of proteins; normal protein level <45 mg/dL). CSF culture and PCR for possible organisms yielded negative results. PCR for SARS-CoV-2 was also carried out and resulted in negative in all the patients tested. A remarkable increase of ILs (mainly IL-8) was found in three patients suggesting an active inflammatory process inside the cerebrospinal fluid (Table 1).

3.1 | Clinical neurophysiology

Three patients showed the presence of conduction block mainly in lower limbs, two of them mainly in the upper limbs (Table 2). All the patients showed either an increase in latency of F wave or the dispersion and the decrease in amplitude of F wave. In two of them, we noted the presence of denervation signs related to the marked decrease amplitude of peroneal and tibial nerve suggesting axonal damage. In particular, the patients had a decrease in amplitude of the facial nerve conduction recorded from orbicularis oris and stimulated from the tragus site ipsilateral to the facial weakness. Notably, the nerve conduction recorded from orbicularis oculi was normal. The blink reflex was performed in one patient and was normal.

Based on the clinical presentation, neurophysiological and CSF findings, intravenous immunoglobulins (IVIg) therapy was initiated in four patients at a dose of 0.4 g/kg for 5 days. The neurological symptoms improved and partially resolved after the initiation of IVIg treatment in four of the patients. No side effects were reported after the use of IVIg therapy.

4 | DISCUSSION

The clinical presentation, the neurophysiology findings, and CSF analysis showing albumin-cytological dissociation suggested a diagnosis of GBS in these patients during and after COVID-19 infection. The neurophysiology examination, although complicated by the protective equipment and protocols to reduce the risk of infection, was extremely useful to detect subclinical findings, better defining the diagnosis and encouraging the start of the appropriate therapy with IVIg, as previously suggested.⁵ In fact, during COVID-19 infection the weakness of the upper and lower limbs could be underestimated and misdiagnosed, especially in the first phase of the disease, when the emergency and the high risk of infection in COVID-19 dedicated areas are the overriding concern. In our experience, ENG was mandatory for the correct diagnosis despite being complicated to perform in COVID-19 areas, to respect the protocols of security and protection.¹⁰ In two of our patients, the ENG has documented the presence of conduction block and increase in latency and dispersion of F waves typical of GBS, while in the other two cases a significant decrease in amplitude in distal and proximal compound muscle action potential as previously reported in axon motor acute neuropathy.⁵ In contrast, the ENG in the fifth patient was able to clearly detect the facial involvement.

In this study, we observed an increase in serum ILs, particularly IL-6 and IL-8 in three patients; these findings are consistent with the current evidence that the overproduction of inflammatory cytokines may lead to severe forms of COVID-19, increased risk of multiorgan failure, and eventually death.¹¹ Indeed, in three of our patients, mechanical ventilation was required due to the acute respiratory distress syndrome, while two received Tocilizumab to block the inflammatory cascade. As such, the autoimmune polyneuropathies

TABLE 2 Neurophysiological study of patients

Patients	Nerve	Stimulation point	Record point	Distal latency, ms	Amplitude, mV	Velocity, m/s	F wave minimal latency, ms
1	Motor NCS						
	Median (L)	Elbow	Wrist	13.70	4.10	45.0	26.6
	Median (R)	Elbow	Wrist	8.80	5.30	67.0	31.3
	Ulnar (L)	Elbow	Wrist	6.56	3.60	...	34.4
	Ulnar (R)	Elbow	Wrist	7.38	4.20	67.0	29.5
	Tibial (L)	Ankle	Adb hal	6.17	2.30	...	67.0
	Peroneal (L)	Ankle	EDB	4.42	1.80	...	62.0
		Head of fibula	Ankle	4.60	1.10	34.4	73.0
	Peroneal (R)	Ankle	EDB	5.21	1.05	...	...
		Head of fibula	Ankle	16.10	0.13	34.0	...
	Antidromic sensory NCS						
	Median (R)	Wrist	2rd Digit	3.80	8.50	...	...
	Ulnar (R)	Wrist	5th Digit	3.70	7.20	...	...
Sural (L-R)	Lateral malleolus	Calf	...	...	...	...
2	Motor NCS						
	Median (L)	Wrist	APB	3.74	1.31	...	39.0
		Elbow		8.20	0.69	23.7	...
	Median (R)	Wrist	APB	5.37	2.00	...	29.0
		Elbow		11.30	0.88	23.7	...
	Ulnar (L)	Wrist	ADM	5.85	1.93	...	34.0
		Elbow		11.30	1.62	49.5	...
	Peroneal (L)	Ankle	EDB	6.69	0.18	...	Absent
		Head of fibula		8.54	0.13	10.8	...
	Peroneal (R)	Ankle	Abd hal	25.90	0.60	...	Absent
		Knee		24.10	0.54	...	...
		Head of fibula	Ankle	27.10	0.06	...	...
	Antidromic sensory NCS						
Median (L)	Wrist	2nd Digit	3.79	15.40	...	...
Median (R)	Wrist	2nd Digit	4.18	4.80	...	...
Ulnar (R)	Wrist	5th Digit	3.36	13.10	...	...
Sural (L)	Lateral malleolus	Calf	7.65	15.00	24.8	...	
3	Motor NCS						
	Median (R)		2nd Digit	4.51	9.10	54.0	25.5
	Ulnar (R)		5th Digit	4.32	8.20	55.1	27.4
	Peroneal R			4.70	9.50	50.2	40.3
	Facial (L)	Postauricular	Orbicular oris	3.88	1.60	...	...
			Orbicular oculi	2.88	1.50	...	...
	Facial (R)	Postauricular	Orbicular oris	4.85	0.50	...	...
			Orbicular oculi	3.25	1.60	...	...
	Antidromic sensory NCS						
	Median (R)			3.50	11.30	...	...
Ulnar (R)			3.80	12.00	...	...
Sural (R)			6.30	20.00	...	...
4	Motor NCS						
	Peroneal (L)	Ankle	Abd hal	23.60	1.50	...	Absent
	Peroneal (R)	Ankle	EDB	7.90	0.10	...	Absent
		Ankle	EDB	15.70	0.16	...	Absent
		Head of fibula	Ankle	17.50	0.75	...	...
				4.50	...	...

(Continues)

TABLE 2 (Continued)

Patients	Nerve	Stimulation point	Record point	Distal latency, ms	Amplitude, mV	Velocity, m/s	F wave minimal latency, ms
	Facial (R)	Postauricular	Orbicular oris	5.73	1.10	...	...
	Facial (L)	Postauricular	Orbicular oris	4.50	1.99	...	...
	Antidromic sensory NCS						
	Not tested						
5	Motor NCS						
	Median (R)	Wrist	APB	Not detectable	...	...	...
	Ulnar (R)	Wrist	ADM	Not detectable	...	...	...
	Tibial (L)						49.8
	Tibial (R)						50.7
	Peroneal (L)	Ankle		3.00	0.76	...	47.6
		Head of fibula	EDB	9.13	0.74	45.7	...
		Knee	Ankle	11.50	0.79	46.4	...
	Peroneal (R)	Ankle		3.32	1.07	...	49.9
		Head of fibula	EDB	9.44	0.62	46.6	...
		Knee	Ankle	11.30	0.68	43.0	...
	Facial (R)	Postauricular	Orbicular oris	2.10	3.40	...	...
	Facial (L)	Postauricular	Orbicular oris	2.70	1.10	...	...
	Antidromic sensory NCS						
	Not tested						

Note: "... " = not measured.

Abbreviations: Abd Hal, abductor hallucis; ADM, abductor digiti minini; APB, abductor pollicis brevis; EDB, extensor digitorum brevis; L, left side of the body; NCS, nerve conduction study; R, right side of the body.

observed in our patients may be considered as part of a systemic overactive inflammatory response, namely "cytokine storm." Moreover, in two out of three patients tested, IL-8 resulted markedly increased also in CSF, with a CSF/serum ratio more than 1, suggesting the presence of an acute inflammatory process specifically targeting the nervous system. Previous studies showed that the CSF/serum IL-8 ratio was increased in GBS as compared to chronic neuropathies such as the chronic inflammatory demyelinating polyneuropathy, thus it has been proposed as a possible biomarker of acute immune reaction against the nervous system.^{12,13}

Neurological complications are common following respiratory infections,⁸ therefore, a cross-reactivity for SARS-CoV-2 was also speculated and reported.^{3,14} This note is in agreement with other studies reporting GBS and cranial polyneuritis during the SARS-CoV-2 pandemic as neurological clinical complications of COVID-19. We did not find the presence of any antiganglioside antibody as anti-GM1, -GM2, -GM3, -GD1a, -GD1b, -GT1b, and -GQ1b. The GQ1b and other glycoproteins are located at the paranodal sites of the peripheral nerves, Ia-afferent neurons of the spinal dorsal horn cells, proximal segments of the cranial nerves controlling ocular motion, muscle spindle afferents, cerebellar vermis, and hypothalamic nuclei, usually explaining the symptoms of the disease.^{5,15} However, in some cases of MFS (10%-15%) and MFS/GBS overlap syndrome (22%) negative results for anti-GQ1b tests have been reported.^{16,17}

Despite the exact mechanisms linking SARS-CoV-2 infection to neurological symptoms need further investigation, it is not possible

to exclude a direct penetration of the virus in the peripheral and central nervous system.^{18,19} In our patients, an autoimmune mechanism may be speculated, for the typical features of clinical neurophysiology, the albuminocytologic dissociation in CSF, and mainly for the significant response to immunoglobulins. A peculiar note is the rapid onset of neurological symptoms of neuropathy in these cases after the onset of COVID infection, indicative of a rapid and dramatic inflammatory reactivity not common in the typical GBS.⁵ The timing of neurological signs in one of our patients seemed too rapid to imply a typical heterologous immune reaction to a first viral exposure and it could rather resemble a form of acute parainfectious paralysis that has already been associated with some viruses, such as ZIKV.^{20,21} This paralysis usually develops from 5 to 10 days after infection and has higher morbidity, more frequently with cranial neuropathies and concurrent immune-mediated disorders such as thrombocytopenic purpura⁹; antiglycolipids antibodies typically involved in cross-reactive mechanisms are not common.^{9,21} The hypothesis of neurological manifestations of COVID-19 is supported by the evidence of neurotropic and neuroinvasive characteristics of coronaviruses in humans¹⁹; moreover, other strains of human coronaviruses have already been involved with peripheral nervous system manifestations^{3,14} and with pediatric cases of GBS.²²

A novelty of this study is represented by the subclinical involvement of facial nerve detected by ENG in patients associated with ageusia. Facial nerve involvement is intriguing and should be considered as the real novelty of this study since its implication aligns with other

cranial nerves involvement in these forms of GBS. Detecting facial nerve impairment with the ENG underlines the importance of clinical neurophysiology as a precious tool to detect mild demyelinating nerve damage; it also helps us investigate the mechanism behind ageusia, as direct involvement of facial nerve and not only as central dysfunction. In particular, the patient presenting a unilateral involvement with ageusia affecting the same side confirms this hypothesis, already described in some other cases.^{22,23} Finally, IVIG therapy was found to be effective and safe to treat the reported peripheral neurological symptoms, with a good recovery in most of the patients. Most patients with COVID-19 and lower /upper limbs related weakness are still not recognized or are not investigated by ENG and do not receive any specific treatment, therefore increasing the risk of permanent damage. In conclusion, this study describes the clinical and neurophysiological characteristics of GBS polyneuropathy in patients affected by COVID-19, and the clinical responses to IVIG therapy, encouraging the use of clinical neurophysiology to better detect abnormalities, define the diagnosis, and promote the use of specific therapies, such as IVIG, to treat these important neurological symptoms.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTION

PM contributed to conceptualization, study design, data collection, wrote the draft and approved the final version of the manuscript. GB contributed to study design, data collection, manuscript draft, and approved the final version of the manuscript. LD contributed to study design, data collection, reviewed the manuscript, and approved the final version. VT contributed to data collection and reviewed the manuscript, and approved the final version. MF contributed to data collection and reviewed the manuscript, and approved the final version. AS and LB contributed to data collection and reviewed the manuscript, and approved the final version. AB contributed to data analysis, wrote the draft, and approved the final version of the manuscript. VP contributed to conceptualization, study design, data collection, reviewed, and approved the final version of the manuscript.

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