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# Rehabilitative management of post-acute COVID-19: clinical pictures and outcomes

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## Abstract

This study aimed to detect patients' characteristics who suffered severe and critical COVID-19 pneumonia admitted to the post-acute COVID-19 rehabilitation clinic in Ankara City Hospital, Physical Medicine and Rehabilitation Hospital and to share our experiences and outcomes of rehabilitation programmes applied. This study was designed as a single-centre, retrospective, observational study. Severe and critical COVID-19 patients, admitted to the post-acute COVID-19 rehabilitation clinic, were included in patient-based rehabilitation programmes, targeting neuromuscular and respiratory recovery. Functional status, oxygen ($O_2$) requirement and daily living activities were assessed before and after rehabilitation. Eighty-five patients, of which 74% were male, were analysed, with the mean age of $58.27 \pm 11.13$ and mean body mass index of $25.29 \pm 4.81$ kg/m$^2$. The most prevalent comorbidities were hypertension (49.4%) and diabetes mellitus (34.1%). Of the 85 patients, 84 received antiviral drugs, 81 low-molecular-weight heparin, 71 corticosteroids, 11 anakinra, 4 tocilizumab, 16 intravenous immunoglobulin and 6 plasmapheresis. 78.8% of the patients were admitted to the intensive care unit, with a mean length of stay of $19.41 \pm 18.99$ days, while those who needed $O_2$ support with mechanic ventilation was 36.1%. Neurological complications, including Guillain–Barré syndrome, critical illness-related myopathy/neuropathy, cerebrovascular disease and steroid myopathy, were observed in 39 patients. On initial functional statuses, 55.3% were bedridden, 22.4% in wheelchair level and 20% mobilised with $O_2$ support. After rehabilitation, these ratios were 2.4%, 4.7% and 8.2%, respectively. During admission, 71 (83.5%) patients required $O_2$ support, but decreased to 7 (8.2%) post-rehabilitation. Barthel Index improved statistically from $44.82 \pm 27.31$ to $88.47 \pm 17.56$. Patient-based modulated rehabilitation programmes are highly effective in severe and critical COVID-19 complications, providing satisfactory well-being in daily living activities.

**Keywords** COVID-19 · Inpatient rehabilitation · Neurological manifestations · Patient outcome · Rehabilitation

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## Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged in Wuhan, China, on December 31, 2019, and then spread rapidly worldwide, causing the COVID-19 pandemic [1, 2]. As of August 19, 2021, there have been 6,138,452 confirmed cases and 4,392,322 deaths around the world. In Turkey, there hve been 309,236,105 confirmed cases and 53,675 deaths, which continue to increase [3]. COVID-19 infection expresses a respiratory involvement, an interstitial pneumonia and the major sign of disease. Initial symptoms include fever, dry cough, fatigue, headache, muscle pain, etc. [4]. The severity of disease can be categorised into three groups based on the severity of the infection: asymptomatic, mild and severe COVID-19. While the majority of cases are characterised as asymptomatic or

mild symptoms which do not need hospitalisation, severe patients need hospitalisation for the treatment of respiratory or several other issues [5].

Our main efforts were preventing the spread of infection and disease treatment while struggling with mortalities in the pandemic's early days. We are now in a period of disease, where we encounter compelling outcomes of the infection, especially among patients who recovered from severe (pneumonia requiring $O_2$ support) and critical COVID-19 (pneumonia requiring mechanical ventilation), accounting for about one-fifth of all cases [6–8]. The damaging effects of the virus are not only in the pulmonary system, but also in the cardiac, haematological and neuromuscular systems [7, 9]. The consequences of long-term immobilisation in intensive care units (ICU), impaired pulmonary function and multisystem involvement increased the demand for the rehabilitation of these patients [10–14]. In Ankara City Hospital, Physical Medicine and Rehabilitation Hospital, a specialised inpatient rehabilitation clinic was set to follow up discharged patients from COVID-19 clinics or from ICU with functional impairments.

This study aimed to detect the characteristics of patients who suffered from severe and critical COVID-19 pneumonia and admitted to the post-acute COVID-19 rehabilitation clinic in Ankara City Hospital, Physical Medicine and Rehabilitation Hospital and to share our experiences and outcomes of rehabilitation programmes applied.

## Materials and methods

This study was conducted in a single-centred, retrospective design between December 2020 and June 2021 at a newly set and organised post-acute COVID-19 rehabilitation clinic. Referred patients were admitted after consultation with their follow-up doctors in COVID-19 ICU or services in terms of eligibility. Inclusion criteria include (1) being $\geq 18$ years old and (2) COVID-19 diagnosis with at least one SARS-CoV-2 PCR-positive nasopharyngeal swab. Exclusion criteria include (1) cardiovascular and haemodynamic instability signs; (2) resting blood oxygen saturation ($SatO_2$) $< 90\%$, requiring nasal $O_2 > 4$ L per minute; and (3) inability to participate in the specified rehabilitation programme due to cognitive impairment. All patients signed a written informed consent form. This study was approved by a local ethical committee (E2-21-453) and conducted in accordance with the Helsinki Declaration.

Neurological involvement in addition to respiratory problems was considered as the determinant factor affecting the rehabilitation programme. Electroneurophysiological evaluation was performed in patients with muscle weakness or sensory impairment and no cerebrovascular event. Since the patients' clinical pictures varied widely, individualised rehabilitation programme was applied to each one as follows:

For bedridden patients' neuromuscular rehabilitation, head up by 10° per hour, progressive daily tilt table lifting at tolerance limit, venous compression stocking use, range of motion exercises (passive if available active-assisted, active or resisted), in-bed mobilisation and bridge and trunk exercises were performed. After developing adequate trunk stability for wheelchair-level patients, bedside sitting, standing and balance coordination; walking in the parallel bar and the hall; step climbing; strengthening exercises and progressive resistance training were performed. Functional electrical stimulation (FES) cycling was carried out for weak muscles on the upper and lower extremities.

For respiratory functioning of patients requiring $O_2$ supply, breathing and thoracic chest expansion exercises, respiratory muscle training, breath perception therapy, air clearance techniques for secretion mobilisation and evacuation, high-frequency chest wall oscillation devices (the Vest), respiratory muscle endurance and strength therapy and arm cycle ergometer (20–30 min for 5 days at least 3 weeks) were performed. The exercising load was set between 40 and 60% of patients' maximal loading capacity. Exercises progressed based on patients' physical conditioning.

All patients' heart rate and exercising $SatO_2$ parameters were monitored. The exercise was interrupted in the case of $SatO_2$ decrease below 88% or a four-point decrease from baseline $SpO_2$, Borg dyspnoea score $> 3$ and tachypnoea development ($> 30$ breaths per minute) [15–18].

The functional status was assessed using the Barthel Index (BI). The index is used for the measurement of limitations in daily living activities in patients with neuromuscular and musculoskeletal conditions. The total score ranges from 0 to 100. Scores of 0–20 indicate "complete" dependence, scores of 21–60 indicate "severe" dependence, scores of 61–90 indicate "moderate" dependence, and scores of 91–99 indicate "mild" dependence. [19].

Speech and swallowing therapy and nutritional and psychological support were considered according to clinical examination. For swallowing evaluation, 30 ml water swallowing test was applied to each patient. Patients were evaluated with video fluoroscopic swallow studies in case of inability to drink the full amount, withholding from drinking, or coughing during or immediately after drinking. The aspiration was defined as the passage of material into the airway below the level of the vocal cord. Afterwards, appropriate diets and exercise programmes were determined [20]. Voice therapy was also performed concurrently with swallowing therapy.

### Statistical analysis

Statistical Package for Social Sciences (SPSS) 23 for Windows was used for the statistical analysis. General descriptive statistics were summarised for continuous variables as mean, median, standard deviation and minimum and maximum values and numbers and percentages (%) for categorical variables. Student's *t* test/Mann–Whitney *U* test was used for continuous variables and Chi-square test for comparing the groups. Measurement results before and after treatment were evaluated using analysis of variance in repeated measurements. The results were evaluated with 95% confidence interval and $p < 0.05$ significance level.

## Results

There were 85 patients analysed in this study with the mean age of $58.27 \pm 11$, of which 74% were male, 40.0% university graduates and 50.6% actively working. The mean body mass index was $25.29 \pm 4.81$ kg/m$^2$. The most prevalent comorbidities were hypertension (49.4%) and diabetes mellitus (34.1%). Examining the comorbid rheumatological diseases revealed that three (3.5%) patients had rheumatoid arthritis, one (1.2%) had Wegener's vasculitis and one (1.2%) had gout arthritis. The most common COVID-19 initial symptoms were fatigue, cough, myalgia and arthralgia.

Of the 85 patients, 84 received antiviral drugs, 81 low-molecular-weight heparin (LMWH), 71 corticosteroids, 11 anakinra, 4 tocilizumab, 16 intravenous immunoglobulin (IVIG) and 6 plasmapheresis. 78.8% of patients needed intensive care, with mean length of stay of $19.41 \pm 18.99$ days, and 36.1% needed mechanical ventilation. It was noted that five patients with comorbid rheumatological diseases needed intensive care, but none of them required mechanical ventilation. The mean COVID-19 service hospitalisation was $16.16 \pm 12.11$ days. All 85 patients had severe pneumonia that needed hospitalisation for at least nasal $O_2$ support for respiratory symptoms. $O_2$ support with mechanic ventilation was needed by 36.1% of the patients and nasal $O_2$ by 90.6%. Forty-six (54.1%) of them were admitted to the rehabilitation clinic because they could not wean from $O_2$ support, while the other 39 also needed neuromuscular rehabilitation. Hypotension (28.2%), tachycardia (10.8%), pulmonary embolism (5.9%), pneumothorax (1.2%), deep vein thrombosis (1.2%), myocarditis (1.2%) and myocardial infarction (1.2%) were noted in cardiovascular system involvement.

A significant proportion of the patients had neurological involvement and were diagnosed with Guillain–Barré syndrome (GBS), critical illness-related myopathy/neuropathy (CRIMYNE), cerebrovascular disease, and steroid myopathy. Diagnoses were made based on the cerebrospinal fluid analysis (CSF), neurophysiological assessments and radiological examinations. CSF was available in 11 patients with albumino-cytological dissociation. Electroneuromyographic assessment was available in all patients diagnosed with GBS, CRIMYNE and steroid myopathy. In one patient, steroid myopathy was considered due to the rapidly developing weakness in the proximal muscles after high-dose IV prednisolone and oral dexamethasone treatment in the ICU. His blood creatinine kinase levels, motor and sensory nerve conduction studies and electromyographic features were normal. Among the accompanying complications, we observed hypotension, pressure ulcers, tachycardia and pulmonary embolism most frequently. Patient demographic and clinical characteristics are given in Table 1.

The male gender was dominant among patients with neurological complications (74.4%), with the mean age of $58.02 \pm 12.64$. Patients with neurological complications had longer ICU and post-acute rehabilitation stays, needing mechanical ventilators in ICU more than those without. Comparing comorbidities between groups, hypertension and chronic obstructive pulmonary disease (COPD) had statistically significant differences. Demographic and comorbidity characteristics of patients with and without neurological complications are given in Table 2.

During the rehabilitation process, rehabilitation-assisting applications were also used. Treatments applied to patients [i.e., FES cycling, arm/limb ergometer, high-frequency chest wall oscillation (the Vest)] are shown in Table 3.

Patients' initial functional statuses were as follows: 55.3% bedridden, 22.4% in wheelchair level and 20% mobilised with $O_2$ support. After rehabilitation, these ratios were 2.4%, 4.7% and 8.2%, respectively. Seventy-one (83.5%) patients required $O_2$ support during admission, which decreased to 7 (8.2%) at discharge. There was a statistically significant improvement of BI from $44.82 \pm 27.31$ to $88.47 \pm 17.56$. Functional status, oxygen requirement, and activities of daily living before and after rehabilitation are given in Table 4.

## Discussion

This study revealed the characteristics of 85 patients who recovered from severe and critical COVID-19 infection and admitted to post-acute COVID-19 rehabilitation clinic. Those with neurological complications, i.e. GBS, CRIMYNE, CVD and steroid myopathy, constitute a significant proportion of admitted patients. Among the patients, 83.5% were in need of $O_2$ support. All of them needed either $O_2$ support or assistive device during mobilisation before the specified rehabilitation intervention.

The results of our study draw attention to middle-aged male patients (74%), since the average age was 58 years. Moreover, the patients with neurological complications

**Table 1** Demographic and clinical characteristics of patients

| *Characteristics* | |
|---|---|
| Age (mean, ±) | 58.27 ± 11.13 |
| *Gender (n,%)* | |
| Female | 22 (25.9%) |
| Male | 63 (74.1%) |
| *Education status (n, %)* | |
| Primary school | 19 (22.4%) |
| High school | 32 (37.6%) |
| University | 34 (40.0%) |
| *Working status (n, %)* | |
| Working | 43 (50.6%) |
| Retired | 26 (30.6%) |
| Not working | 16 (18.8%) |
| *Smoking (n, %)* | |
| Active smoking | 13 (15.3%) |
| BMI (mean, ±), (median; min–max) | 25.29 ± 4.81 (24.2;17.7–46.7) |
| *Comorbidities (n, %)* | |
| Diabetes mellitus | 29 (34.1%) |
| Hypertension | 42 (49.4%) |
| Chronic obstructive pulmonary disease | 14 (16.5%) |
| Coronary artery disease | 14 (16.5%) |
| Thyroid disease | 10 (11.8%) |
| Chronic kidney disease | 1 (1.2%) |
| Malignancy | 2 (2.6%) |
| Rheumatic disorders | |
| Rheumatoid arthritis | 3 (3.5%) |
| Gout arthritis | 1 (1.2%) |
| Wegener vasculitis | 1 (1.2%) |
| *Initial COVID-19 symptoms (n, %)* | |
| Fatigue | 76 (89.4%) |
| Cough | 57 (67.1%) |
| Myalgia | 55 (64.1%) |
| Fever | 29 (34.1%) |
| Arthralgia | 24 (28.2%) |
| Headache | 18 (21.1%) |
| Nausea and vomiting | 6 (7.1%) |
| Loss of taste and smell | 1 (1.2%) |
| *Medical treatments (n, %)* | |
| Favipravir | 84 (98.8%) |
| Hydroxychloroquine | 28 (32.9%) |
| Colchicine | 32 (37.6%) |
| LMWH | 81 (95.3%) |
| Acetylsalicylic acid | 62 (72.9%) |
| Corticosteroid | 71 (83.5%) |
| Anakinra | 11 (12.9%) |
| Tocilizumab | 4 (4.7%) |
| IVIG | 16 (18.8%) |
| Plasmapheresis | 6 (7.1%) |
| Need for ICU (n,%) | 67 (78.8%) |
| Length of stay in ICU (mean, ±), (median; min–max) | 19.41 ± 18.99 (17; 0–120) |
| Length of stay in COVID-19 service (before admission, mean, ±), (median; min–max) | 16.16 ± 12.11 (14; 1–60) |

**Table 1** (continued)

| | |
|---|---|
| *Respiratory support for COVID-19 (n, %)* | |
| Nasal oxygen cannula | 77 (90.6%) |
| Reservoir mask | 53 (62.4%) |
| High flow oxygen therapy | 33 (38.8%) |
| Non-invasive ventilator | 5 (5.9%) |
| Mechanical ventilation | 31 (36.1%) |
| *Diagnosis for admission to the rehabilitation service (n, %)* | |
| GBS | 18 (21.2%) |
| AIDP | 13 |
| AMSAN | 5 |
| CRIMYNE | 11 (12.9%) |
| Acute cerebrovascular disease | 8 (9.4%) |
| Ischaemic | 8 |
| Haemorrhagic | 0 |
| Steroid myopathy | 1 (1.2%) |
| Sinus vein thrombosis | 1 (1.2%) |
| Pulmonary involvement | 48 (56.5%) |
| *Accompanying complications (n, %)* | |
| Pressure ulcers | 24 (28.2%) |
| Hypotension | 24 (28.2%) |
| Tachycardia | 10 (10.8%) |
| Pulmonary embolism | 5 (5.9%) |
| Swallowing and speech disorder | 5 (5.9%) |
| Pneumothorax | 1 (1.2%) |
| Deep vein thrombosis | 1 (1.2%) |
| Myocardial infarction | 1 (1.2%) |
| Myocarditis | 1 (1.2%) |
| Percutaneous endoscopic gastrostomy (PEG) | 2 (2.6%) |

*BMI* body mass index, *GBS* Guillain–Barré syndrome, *CRIMYNE* critical illness-related myopathy neuropathy, *LMWH* low-molecular-weight heparin (LMWH), *IVIG* intravenous immunoglobulin, *ICU* intensive care units, *AIDP* acute inflammatory demyelinating polyneuropathy, *AMSAN* acute motor–sensory axonal neuropathy

showed similar male dominancy and the same mean age. These results are concordant with Puchner et al.'s study [18] on their patient populations' age and gender similarity. In a recent multicentred study from Turkey, the mean age of patients diagnosed with COVID-19 was 53.7 years and the male sex ratio was 57.6%. However, when patients with severe COVID-19 were grouped separately, it was observed that the mean age increased to 60.3 and the male sex ratio increased to 60%. Our mean age in the patients we followed up after severe and critical COVID-19 is similar to Turan et al.'s study [21].

In the current study, it is noteworthy that the musculoskeletal system is frequently affected. The most common initial symptoms include fatigue (89.4%), myalgia (64.1%) and arthralgia (28.2%), similar to those patients referred to rheumatology outpatient clinics. As Ciaffi et al. reported in their meta-analysis, these initial symptoms are frequently reported in the literature [22]. In this case, COVID-19 diagnosis should be kept in mind even if there is no respiratory distress in patients who seek out rheumatologists during intense pandemic days.

Our findings indicate hypertension as the prevalent comorbidity (49.4%). In Liang et al.'s study [23], it was the most seen coexisting condition (16.7%). When we analysed comorbidities according to clinical involvement, we found that hypertension was preeminent in patients with neurologic involvement (61.5% and 38.5%, respectively), while COPD was preeminent (23.9% and 7.7%, respectively) in patients with pulmonary complication. These findings, in accordance with the study, reveal that COPD patients have increased risk for severe COVID-19 pneumonia [24]. Five (5.9%) of our patients had inflammatory rheumatic comorbid disease. Although these patients needed intensive care, none of them required mechanical ventilation. In a review, COVID-19 does not appear to be a risk factor for serious disease in rheumatoid arthritis patients. However, the inadequacy of studies on this subject draws our attention [25]. Although COVID-9 was not

**Table 2** Demographic and clinical characteristics of patients with and without neurological complications

| | Patients with neurological complications n:39 | Patients without neurological complications n:46 | *p* |
|---|---|---|---|
| Age (mean, ±) | 58.02 ± 12.64 | 58.47 ± 9.81 | 0.853 |
| *Gender (n, %)* | | | |
| Male | 29 (74.4%) | 34 (73.3%) | 0.963 |
| BMI (mean, ±), (median; min–max) | 24.35 ± 3.83 (23.4; 17.7–37.0) | 26.09 ± 5.42 (24.65; 18.5–46.7) | 0.098 |
| *Comorbidities (n, %)* | | | |
| Hypertension | 24 (61.5%) | 18 (39.1%) | *0.039 |
| Diabetes mellitus | 15 (38.5%) | 14 (30.4%) | 0.437 |
| Coronary artery disease | 7 (17.9%) | 7 (15.2%) | 0.735 |
| Chronic obstructive pulmonary disease | 3 (7.7%) | 11 (23.9%) | *0.041 |
| Rheumatoid arthritis | 1 (2.6%) | 2 (4.3%) | |
| *Smoking (n, %)* | 4 (10.3%) | 9 (19.6%) | 0.365 |
| Length of stay in ICU (mean, ±) (median; min–max) | 26.43 ± 22.92 (29; 0–120) | 13.45 ± 12.26 (11; 0–40) | *0.002 |
| Need of mechanical ventilation (median9; min–max) | 21 (67.7%) | 10 (32.3%) | *0.002 |
| Length of stay in post-acute rehabilitation clinic (mean, ±) (median; min–max) | 39.03 ± 17.71 (35; 21–90) | 29.63 ± 7.67 (30; 21–50) | *0.003 |

| | GBS *n* = 18 | CRIMYNE *n* = 11 | Acute cerebrovascular disease *n* = 9 | Steroid myopathy *n* = 1 | Without neurological complications n:46 |
|---|---|---|---|---|---|
| Age (mean, ±) | 58.44 ± 9.19 | 58.45 ± 15.92 | 58.66 ± 14.85 | 40 | 58.47 ± 9.81 |
| *Gender (n, %)* | | | | | |
| Male | 12, 66.7% | 9, 81.8% | 7, 77.8% | 1 | 34, 73.9% |
| BMI (mean, ±) | 24.13 ± 3.07 | 24.41 ± 5.02 | 25.01 ± 2.81 | 21.9 ± 3.8 | 26.09 ± 5.42 |
| *Comorbidities (n, %)* | | | | | |
| Hypertension | 12 (66.7%) | 7 (63.6%) | 5 (55.6%) | 0 | 18 (39.1%) |
| Diabetes mellitus | 8 (44.4%) | 2 (18.2%) | 5 (55.6%) | 0 | 14 (30.4%) |
| Coronary artery disease | 1 (5.6%) | 2 (18.2%) | 4 (44.4%) | 0 | 7 (15.2%) |
| Chronic obstructive pulmonary disease | 1 (5.6%) | 2 (18.2%) | 0 | 0 | 11 (23.9%) |

*ICU* intensive care units, *GBS* Guillain–Barré syndrome, *CRIMYNE* critical illness-related myopathy neuropathy, *BMI* Body Mass Index (kg/m$^2$)
*$p < 0.05$

**Table 3** Treatments applied to patients in post-acute COVID-19 rehabilitation clinic

| Treatments | *n*, % |
|---|---|
| Neuromuscular rehabilitation | 77 (85.4%) |
| FES | 43 (50.6%) |
| FES cycling | 29 (34.1%) |
| Arm/cycle ergometer | 44 (51.8%) |
| VEST | 10 (11.8%) |

*FES* functional electrical stimulation, *VEST* high-frequency chest wall oscillation devices

evaluated in rheumatic diseases, in our study, no mechanical ventilation needed in all five patients is in line with the literature in terms of the severity of COVID-9 in rheumatic diseases.

It should be emphasised that our study reveals determinants of patients with neurological and pulmonary complications.

In this study, neurological complications were recorded in 45.88% of the 85 patients followed up after severe and critical COVID 19 infections, of which 55.3% were bedridden. Curci et al. [26] studied 32 post-acute COVID-19 patients and reported that 56.3% of them were bedridden, similar to our study. However, they did not mention the information about the patients' neurological diagnoses. Puchner et al. [18] gave information on 23 patients they observed, of which 29% of them had muscle weakness. Mao et al. [27] described that 36.4%had neurologic manifestations. Unlike other studies, out study evaluated the patients' detailed neurological

**Table 4** Oxygen requirement, functional level, activities of daily living before and after rehabilitation

| | Before rehabilitation | After rehabilitation | *p* |
|---|---|---|---|
| Oxygen requirement (*n*, %) | 71 (83.5%) | 7 (8.2%) | |
| *Functional status (n, %)* | | | |
| Bedridden | 47 (55.3%) | 2 (2.4%) | |
| Wheelchair | 19 (22.4%) | 4 (4.7%) | |
| Mobilized with oxygen requirement | 17 (20.0%) | 7 (8.2%) | |
| Mobilized with assistive device | 2 (2.4%) | 19 (22.4) | |
| Mobilized with no requirement | 0 | 53 (62.4%) | |
| Barthel Index (mean, ±) (median; min–max) | 44.82 ± 27.31 (40; 0–95) | 88.41 ± 17.56 (92.5; 2–100) | < 0.001 |

manifestations and noted a relatively high rate of neurological involvement.

Pressure ulcers, hypotension, tachycardia and pulmonary embolism, which challenged us during the rehabilitation process, were encountered in substantial rates. It is noteworthy to emphasise that all patients with pulmonary embolism were receiving prophylactic antithrombotic treatment (LMWH). Poissy et al. [28] detected that the frequency of pulmonary embolism increased by two times in ICU patients; approximately 90% of them were under thromboprophylaxis treatment. They studied patients with acute COVID-19 pneumonia hospitalised in the ICU. Since we evaluated post-acute COVID-19 patients, we believe that our study will be valuable in showing that pulmonary embolism is a complication that should be kept in mind in the long-term follow-up of post-acute COVID-19 patients. Our findings may also support the theory that coagulopathy is one of the underlying factors in COVID-19 pathology [29].

Another issue which compelled us and we assume to be important in the follow-ups is the newly emerging dyspnoea unresponsive to $O_2$ support and medical treatment. Two of the patients developed dyspnoea dependent on post-intubation iatrogenic laryngeal stenosis and underwent surgical intervention. Extra attention should be paid to patients receiving mechanical ventilation in the ICU. It was shown that 45% of patients with COVID-19 with laryngeal injury due to intubation required procedural intervention [30].

Our findings revealed statistically significant increase in BI from 44.8 to 88.4. In Curci et al.'s study [26], BI was improved, but the difference was not statistically significant. They applied rehabilitation programme for 2–3 weeks. Puchner et al. [18] carried out 3- 4-week rehabilitation interventions and obtained better results in BI and 6-min walk test. However, they found out that residual pulmonary functional impairments still existed in the majority of the patients. Liu et al. [31] studied elderly patients with COVID-19 and implemented a 6-week respiratory rehabilitation programme. As a result, a significant difference was observed regarding pulmonary function and exercise capacity. In our study, rehabilitation time was extended from 3 to 12 weeks based on the patient's requirements. To obtain better results, prolonged rehabilitation sessions may be considered.

As suggested by previous studies, we recommend that specialised speech and swallowing therapists should be included in the rehabilitation team. Among those that we followed up were tracheostomy and percutaneous endoscopic patients. Those patients with dysphagia (5.9%) required swallowing and speech therapy. In the aetiology of dysphagia due to COVID-19, mechanical injuries (endotracheal intubation, mechanical ventilation and enteral nutrition), sensory disorders and peripheral or central nervous system involvement are considered [10, 32].

We collaborated with large multi-professional team and received support from nutritionist, occupational therapists and psychologist.

This study provides substantial practices regarding the characteristics of patients with neurological and pulmonary complications of severe and critical post-acute COVID-19 pneumonia and the rehabilitation outcomes of these patients.

The study's limitations are as follows: (1) pulmonary function tests could not be assessed since these tests were only available for patients who would undergo surgery during the pandemic; (2) grouping and comparing rehabilitation results depending on the main complication were difficult due to the wide variety of complications and outcomes of the disease; (3) there is a relatively small number of patients, preventing more definitive conclusions. The study's strength is that it is the first to represent the rehabilitation outcomes of both various neurological and respiratory complications of the infection.

## Conclusion

COVID-19 presents signs of widespread musculoskeletal symptoms both in the initial symptoms (fatigue, myalgia and arthralgia) and in the post-COVID-19 period (loss of muscle strength). In patients with severe COVID-19 infection, being aware of the signs of musculoskeletal system and neurological deficits, rehabilitation applications and

period adjusted according to the clinical priority of each patient for $O_2$ demand and functional losses and working with a multidisciplinary team can yield highly favourable and satisfactory results in the patients' pulmonary function and daily living activities.

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## Declarations

**Conflict of interest** The authors declare no conflict of interest.

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