—Case Reports—

Rapid Recovery in a Patient with Severe COVID-19 after a Low-Load, High-Frequency Rehabilitation Program Using an Ergometer in the Supine Position

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Background: Rehabilitation therapy for patients with severe coronavirus disease 2019 (COVID-19) is crucial; however, studies regarding rehabilitation strategies for intensive care unit (ICU) patients with COVID-19 are limited. We report a case of severe COVID-19 in an ICU patient whose physical function and basic movement ability rapidly improved after the initiation of active aerobic exercise in the supine position.

Case: A 70-year-old man with hypertension and obesity was admitted to the ICU and managed with a ventilator because of severe COVID-19. Physical therapy started on postadmission day 34. Problems encountered during physical therapy included low saturation of percutaneous oxygen (SpO_2; <90%), dyspnea with a light exercise load, advancing muscle weakness, and endurance decline. The rehabilitation program included getting out of bed and resistance training of the upper and lower limbs twice daily while maintaining SpO_2 at ≥90%. After ventilator weaning, we initiated aerobic training using a supine ergometer with varying load volume. On discharge from the ICU on postadmission day 45, the patient's physical function (handgrip strength, Medical Research Council score, and Borg scale) and basic movement ability (Functional Status Score for ICU) rapidly improved.

Conclusion: Rehabilitation therapy involving aerobic cycling training based on a quantitative load setting may be effective in treating COVID-19. (J Nippon Med Sch 2023; 90: 414–418)

Key words: coronavirus disease 2019, cycling ergometer in the supine position, physiotherapy, intensive care unit

Introduction

The primary cardiorespiratory symptoms of severe coronavirus disease 2019 (COVID-19) include severe exercise-induced hypoxemia and dyspnea associated with decreased lung diffusing capacity[1–3], all of which significantly limit physical activity. In addition to hypoxemia and dyspnea associated with pneumonia, severe COVID-19 may cause post-intensive care syndrome, which includes impaired motor, cognitive, and mental functions. These impairments pose a risk of persisting functional limitation and disability for several years[4,5]. Actually, a case report of the patient with severe COVID-19 showed poor respiratory function and exercise capacity even at follow-up after discharge[6].

Previous studies conducted in other countries[7,8] have reported the rehabilitation therapy for patients with severe cases of COVID-19 to improve exercise tolerance and increase muscle strength. Previous reports on COVID-19[9,10] recommend early rehabilitation therapy intervention. However, detailed intervention strategies for patients with severe COVID-19 remain unclear. Therefore, more evidence and case reports are needed regard-

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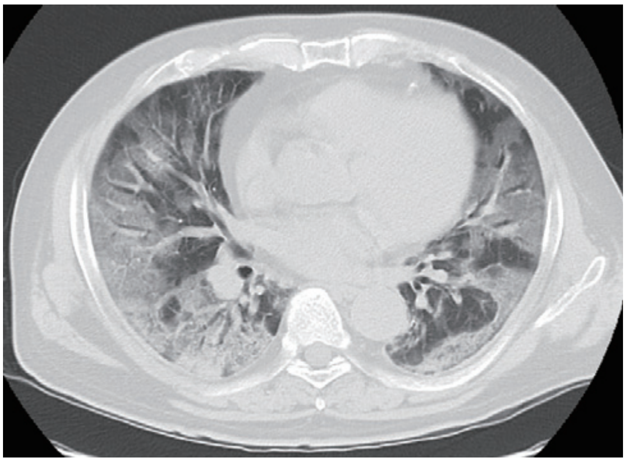

Fig. 1 Chest computed tomography showing multiple scattered ground-glass opacities with consolidation throughout the bilateral lung fields. Date of shooting: November 25 (Day 1).

ing rehabilitation therapy in Japanese and Asian patients with severe COVID-19.

This case shows the possibility of improvement of physical function and activities of daily living (ADL) in patients with COVID-19 through an acute rehabilitation therapy involving active aerobic cycling in the supine position.

Case

A 70-year-old Japanese male photographer with hypertension and obesity (body mass index: 27.3 kg/m^2) visited a clinic with a complaint of cough and dyspnea; he had hypoxemia. Polymerase chain reaction (PCR) was performed with his pharyngeal exudate because of a high suspicion of COVID-19 as apparent from the symptoms, and the patient tested positive for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). He was admitted to a university hospital and managed in a private room of the intensive care unit (ICU). Computed tomography imaging revealed multiple scattered ground-glass opacities throughout the bilateral lung fields (**Fig. 1**). On admission into the ICU, the level of consciousness was E4V5M6 on the Glasgow Coma Scale (GCS), C-reactive protein (CRP) level was 16.7 mg/L, and sialylated carbohydrate antigen KL-6 (KL-6) level was 964.1 U/mL. The patient was treated with favipiravir (Abigan®) 1.8 g enterally, dexamethasone sodium phosphate (Dexate®) 6.6 mg, and ceftriaxone sodium hydrate (ceftriaxone sodium for intravenous injection®) 2 g intravenously. However, the hypoxemia did not improve after oxygen administration, and he was placed on mechanical ventilation after intubation on postadmission day 1. During intubation, the ventilator settings were as follows: Assist/Control mode, pressure-controlled ventilation fraction of inspired oxygen (FiO_2) of 0.45, positive end expiratory pressure (PEEP) of 13 cmH_2O, and peak inspiratory pressure of 26 cmH_2O. The partial pressure of arterial oxygen/FiO_2 (PaO_2/FiO_2: P/F) ratio was 248 in these settings. On day 5, the patient's P/F ratio decreased to 120. Therefore, the patient was kept in the prone position from day 5 to 12. From days 8 to 20, 40 mg of methylprednisolone sodium succinate (Solmedol® for intravenous injection) was administered. As a result, the oxygenation temporarily improved and the patient proceeded with the spontaneous awakening trial[11]; however, a strong inspiratory effort was required. The patient had mediastinal emphysema on day 13 and underwent tracheostomy on day 14. Subsequently, mediastinal emphysema improved, CRP and KL-6 levels decreased, and the inspiratory effort reduced. Afterward, oxygenation improved, and ventilator weaning was started on day 24. PCR for SARS-CoV-2 was negative on postadmission day 30. Written consent was obtained from the patient for publication of this case report.

Initial Physical Evaluation and Therapy

Physical therapy was initiated on day 34 (**Fig. 2**), before which no rehabilitation had been attempted by the nurses, with usual care provided according to bed rest level. The ventilator settings were as follows: continuous positive airway pressure mode, FiO_2 0.3, PEEP 5 cmH_2O, and pressure support 8 cmH_2O. The level of consciousness was GCS score E4VTM6, muscle strength was 28 points (right/left; 2/2 shoulders, 2/2 elbows, 3/3 hands, 2/2 hip, 2/2 knees, and 3/3 ankle) based on the Medical Research Council (MRC) sum score, whereas the basic movement ability was 7 points based on the Functional Status Score for ICU (FSS-ICU). The motor score of Functional Independence Measure (FIM) was 13. **Table 1** shows the physical functions at the beginning of the rehabilitation therapy. The problems encountered in this case were exercise-induced hypoxemia and dyspnea; the saturation of percutaneous oxygen (SpO_2) decreased to 88% even with light load exertion. In addition, there were declines in central muscle strength and exercise tolerance. Therefore, all ADLs required assistance. The rehabilitation program included sitting on a bed, transferring to a reclining wheelchair, and upper and lower limb resistance training. Resistance training was performed with five repetitions, four sets, twice a day in the morning and afternoon while maintaining the SpO_2 above 90%. The exercise intensity was gradually increased while assess-

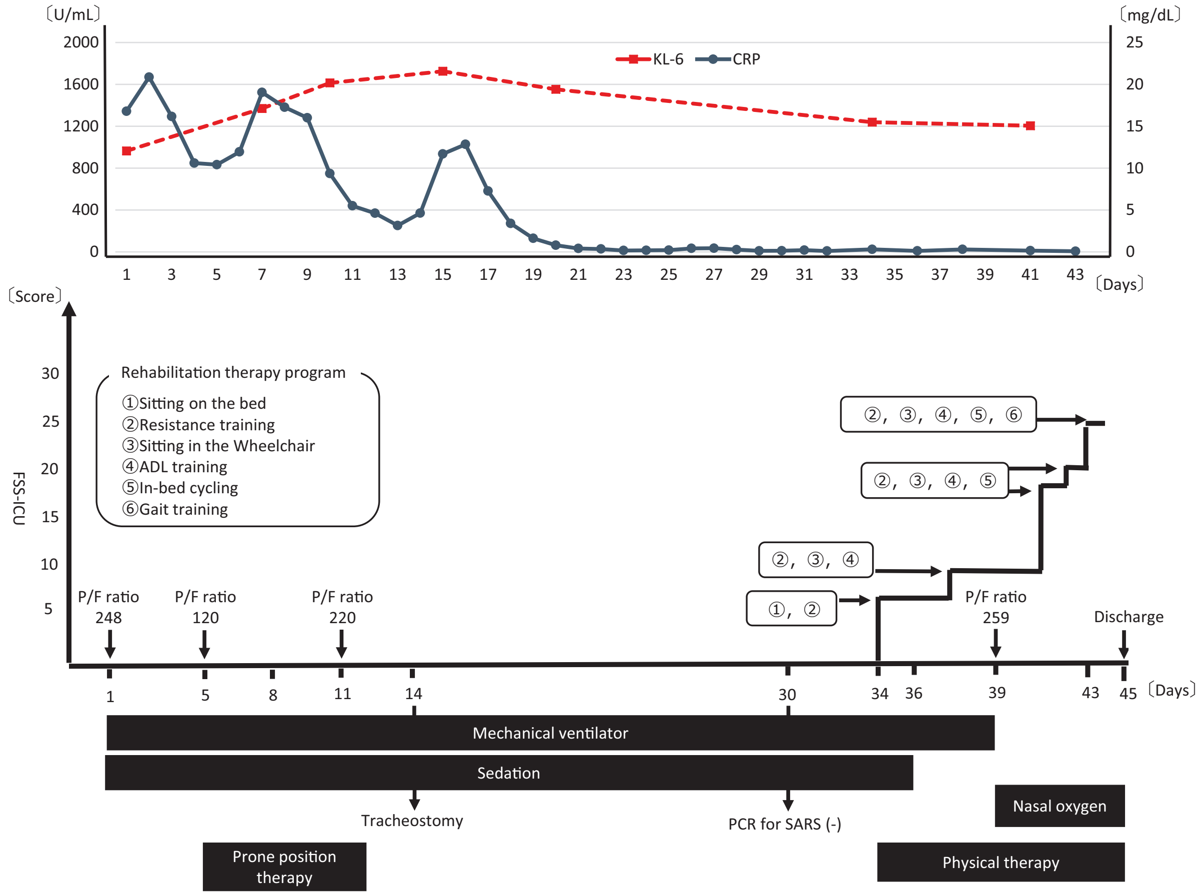

Fig. 2 Rehabilitation therapy program. Physical therapy was started after the polymerase chain reaction (PCR) for severe acute respiratory syndrome coronavirus was negative and the CRP and KL-6 peaked out.
KL-6: Left axis notation, indicated by broken line. CRP: Right axis notation, solid line.
Abbreviations: CRP: C-reactive protein, KL-6: Sialylated carbohydrate antigen KL-6, FSS-ICU: Functional Status Score for ICU, P/F ratio: Partial pressure of arterial oxygen/Fraction of inspired oxygen ratio

ing the patient's vital signs and dyspnea. In addition, on weekends when physical therapy could not be provided, ICU nurses transferred the patient to a reclining wheelchair, and extended the sitting time as long as possible.

Physical Evaluation and Therapy after Extubation

The patient was weaned from the ventilator on day 39. Postweaning oxygen therapy was managed with a flow rate of 3 L/min via an artificial nose for tracheal cannula. From day 41, rehabilitation therapy was performed under an oxygen flow rate of 3 L/min. In the morning, ADL exercises and resistance training were conducted. In the afternoon, the patient performed aerobic training using a supine ergometer with variable-load volume (Showa Denki Co., Ltd., Terasu Ergo II®) to improve endurance. This cycling exercise comprised warm-up and incremental exercises. Warm-up was performed at an intensity of 3 watts for 3 min. Afterward, the incremental exercise load was determined with a target of 10 min at an intensity of up to 20 watts, with constant monitoring of vital signs and dyspnea/lower limb fatigue using the Borg scale. In our patient, the resting heart rate was 119 bpm, whereas the respiratory rate was 24 breaths/min. After warm-up, the heart rate was 130 bpm, respiratory rate was 32 breaths/min, and the Borg scale rating was 15/16. During the aerobic exercise trial, SpO_2 was maintained at 90% or above to avoid hypoxemia. The ergometer exercise was continued for 6 days until the patient was transferred to a convalescent rehabilitation hospital.

The 6-day rehabilitation program and evaluation are shown in **Figure 2** and **Table 1**. The changes in physical function from the initiation of the program to discharge were <5.0/<5.0 kg to 8.0/7.7 kg in handgrip strength (right/left), 9.5/8.0 kg to 10.2/8.1 kg in lower limb muscle strength (right/left), and 28 to 42 points in MRC score. The changes in heart rate and Borg scale rating (from the initiation to discharge) at the end of the 3-min warm-up session were 130 bpm to 91 bpm and 15/16 to 12/12, respectively. From the initiation to discharge, SpO_2

Table 1 Laboratory data, body function, and body composition before and after the rehabilitation intervention

Laboratory Data	Entry (Day34)	Discharge (Day45)
C-reactive protein (mg/dL)	0.30	0.07
Lymph (%)	13.0	23.2
D-dimer (μg/mL)	1.8	0.8
KL-6 (U/mL)	1,239.3	1,204.9
Physical Function		
Hand grip (right/left) (kg)	<5.0/<5.0	8.0/7.7
Knee extensor muscle strength (right/left) (kg)	9.5/8.0	10.2/8.1
MRC sum score	28	42
FSS-ICU	10	25
Gait distance (meter)	0	15
Desaturation (%) *	82	86
Recovery time up to SpO2 90% (sec)	146	52
Borg scale (dyspnea / lower limb fatigue) **	15/16	12/12
Body Composition		
SMI (kg/m^2)	6.0	6.0
ECW/TBW	0.414	0.409
Whole body phase angle (φ)	2.9	3.5

Abbreviations: CRP, C-reactive protein; KL-6, Sialylated carbohydrate antigen KL-6; FSS-ICU, Functional Status Score for ICU; MRC sum score, Medical Research Council sum score; SMI, Skeletal muscle mass index; ECW/TBW, Extracellular Water/Total Body Water

*Measurement conditions: Three times after standing up from the wheelchair performed under 3 L oxygen

** Borg scale when 3 watts exercise load for 3 min with bedside cycling exercise and listen

values were improved from 90% to 93% with 3 L artificial nose for tracheal cannula. Furthermore, the FSS-ICU score improved from 7 points at entry to 25 points at discharge. The motor score of FIM improved from 13 at entry to 37 at discharge. The patient was able to walk 15 m with the aid of a circle walker after receiving 3 L/min of oxygen. There were no changes in skeletal muscle index measured using a bioelectrical impedance data acquisition system (Inbody S10®; Inbody Japan Inc, Tokyo, Japan) before and after the intervention; however, improvements were noted in the phase angle, which reflects the health of skeletal muscle cells and cell membranes. Although partial recovery of pulmonary and physical functions was observed, the patient required oxygen therapy and did not reach the prehospital functional level. On day 45, the patient was transferred to a rehabilitation hospital for further rehabilitation.

Discussion

This case of severe COVID-19 required long-term ventilator management. Immediately after weaning, aerobic exercise was initiated using a variable-load ergometer in the supine position to minimize oxygen desaturation. Subsequently, basic movement ability and limb muscle strength improved in a short period of rehabilitation intervention.

A previous study[12] has demonstrated the efficacy of a rehabilitation program using a bicycle ergometer in the ICU. Another study has shown that the use of a supine bicycle ergometer in addition to general physical therapy is effective in improving muscle strength and maintaining muscle morphology of the knee extensors and diaphragm in ICU patients[13]. These previous studies have also demonstrated the safety of the cycling exercise without adverse events. Similarly, in our case, no adverse events were observed with the variable-load ergometer, probably because of the comfortable position and careful monitoring of the vital signs for preventing exercise-induced hypoxemia. The FSS-ICU score improved after the initiation of ergometer use; this result supports the trend of a previous study[12,13]. Exercise therapy using a bicycle ergometer requires detailed vital sign monitoring and knowledge of exercise physiology. Therefore, it is preferable that a physical therapist prescribe the exercise regime. However, it is permissible for ICU staff to supervise aerobic exercise using a bicycle ergometer in accordance with the physical therapist's instructions.

A previous randomized controlled trial reported that respiratory and exercise therapies improved pulmonary function and exercise tolerance in elderly patients with COVID-19 compared with similar patients who did not receive these therapies[7]. Several academic societies recommend that exercise therapy for patients with COVID-19 should begin with low-intensity exercise of <3 metabolic equivalents (METs)[14,15]. However, few studies have discussed the effects of the existing specific rehabilitation programs, exercise intensity, and rehabilitation therapy in patients with severe COVID-19. In our study, we demonstrated the safety and efficacy of physical therapy, although it was a single case study. While increasing the number of rehabilitation sessions provided per day and monitoring oxygen saturation and dyspnea, various rehabilitation methods were tried, such as resistance training and aerobic exercise using a bicycle ergometer, and the content and intensity of the exercise therapy provided were modified according to the patient's condition. This case report can be used as a reference when planning rehabilitation therapy for patients with severe COVID-19; however, further studies are required to definitively establish the effectiveness of the rehabilitation therapy.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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