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Abstract

Objective: Coronavirus disease 2019 (COVID-19) has dominated the attention of health care systems globally since January 2020. Various health disciplines including physical therapists are still exploring the best way to manage this new disease. The role and involvement of physical therapists in the management of COVID-19 are not yet well defined and are limited in many hospitals. This article reports a physical therapy service specially commissioned by the Health Commission of Sichuan

Province to manage COVID-19 during patients' stay in the intensive care unit (ICU) at the Public Health Clinical Center of Chengdu in China.

Methods: Patients diagnosed with COVID-19 were classified into 4 categories under a directive from the National Health Commission of the People's Republic of China. Patients in the "severe" and "critical" categories were admitted to the ICU irrespective whether mechanical ventilation was required. Between January 31, 2020, and March 8, 2020, a cohort of 16 patients was admitted to the ICU at the Public Health Clinical Center of Chengdu. The median (minimum to maximum) hospital and ICU stays for these patients were 27 (11–46) and 15 (6–38) days, respectively. Medical management included antiviral, immunoregulation and supportive treatment of associated comorbidities. Physical therapist interventions included body positioning, airway clearance techniques, oscillatory positive end-expiratory pressure, inspiratory muscle training, and mobility exercises. All patients had at least 1 comorbidity. Three of the 16 patients required mechanical ventilation and were excluded for outcome measures that required understanding of verbal instructions. In the remaining 13 patients, respiratory outcomes—including the Borg Dyspnea Scale, peak expiratory flow rate, $\text{PaO}_2/\text{FiO}_2$ ratio, maximal inspiratory pressure, strength outcomes, Medical Research Council Sum Score, and functional outcomes (including the Physical Function in Intensive Care Test score, De Morton Mobility Index, and Modified Barthel Index)—were measured on the first day the patient received the physical therapist intervention and at discharge.

Results: At discharge from the ICU, while most outcome measures were near normal for the majority of the patients, 61% and 31% of these patients had peak expiratory flow rate and maximal inspiratory pressure below 80% of the predicted value and 46% had De Morton Mobility Index values below the normative value.

Conclusion: The respiratory and physical functions of some patients remained poor at ICU discharge, suggesting that long-term rehabilitation may be required for these patients.

Impact: Our experience in the management of patients with COVID-19 has revealed that physical therapist intervention is safe and appears to be associated with an improvement in respiratory and physical function in patients with COVID-19 in the ICU.

In December 2019, a novel coronavirus was identified and named SARS-CoV-2, the seventh type of human coronavirus discovered. The pneumonia caused by this virus was subsequently named COVID-19.¹ Up to July 17, 2020, a total of 13,616,593 cases have been confirmed worldwide, with 585,727 deaths.² While antiviral and corticosteroids have been administered at different stages of COVID-19,³ to date there is no effective vaccine and the COVID-19 pandemic is ongoing.

In China, COVID-19 has been classified into 4 categories of severity: mild, general, severe and critical.⁴ Common symptoms in mild cases include fever, fatigue and dry cough. Most of the severe and critical cases experience hypoxemia and/or dyspnea after 1 week, and some of these patients progress rapidly to acute respiratory distress syndrome, septic shock, progressive metabolic acidosis and coagulation disorders, leading to multiple organ failure. Current clinical therapy for these patients focuses primarily on symptomatic supportive therapy since there is limited effective medication to cure the infected and no vaccine eradicating COVID-19.

Physical therapy is a recognized profession globally and the role of cardiorespiratory physical therapy in the management of acute and/or chronic respiratory conditions is well established.⁵ In response to the urgent need for clinical guidance for acute care of patients with COVID-19, a guideline for physical therapist practice in management of patients with COVID-19 in the acute hospital setting was published,⁶ but data indicating the COVID patient's response to physical therapist

intervention has not been published. West China Hospital is a hospital affiliated with Sichuan University in Chengdu and has an established multidisciplinary rehabilitation team with rehabilitation medical practitioners, rehabilitation nurses, physical therapists, respiratory therapists, speech therapists and occupational therapists. The Public Health Clinical Center of Chengdu (PHCCC) is the designated treatment center for all patients with COVID-19 in Chengdu, a large city with a population of 16.3 million. Between February 17, 2020, and March 8, 2020, a rehabilitation team from the West China Hospital, including medical doctors, nurses, physical therapists, and respiratory therapists, were temporarily transferred to the PHCCC to manage patients with COVID-19 in the intensive care unit (ICU). The present study reports the physical therapist management of 16 patients with COVID-19 (3 were classified as severe and 13 as critical)⁴ being managed in the ICU at PHCCC.

[H1] Public Health Clinical Center of Chengdu

This observational study was approved by the Biomedical Ethics Committee of West China Hospital of Sichuan University. The ICU at PHCCC has a total of 24 beds, with 10 standard-bed rooms, each with 2 beds, and 4 single-bed rooms. All rooms are equipped with negative-pressure facilities. There is a personal protective equipment (PPE) donning area at the entrance of the ICU and a doffing area in the ICU exit area.

Patients diagnosed with COVID-19 in Chengdu were admitted to the PHCCC. The diagnostic and classification criteria³ for COVID-19 is illustrated in the

Supplementary Figure. A total of 63 patients with COVID-19 were admitted to the PHCCC from January 23 to March 21, 2020, of whom 16 patients met the severe or critical diagnostic criteria³ and were admitted to the ICU. It should be noted that the COVID-19 classification criteria in China³ meant that patients admitted to the ICU might not require mechanical ventilation. The demographic data and selected relevant laboratory data for the 16 patients admitted to the ICU are displayed in Tables 1 and 2. The duration of hospital and ICU stays and the ventilation status are illustrated in Figure 1.

[H1]Physical Therapist Referral

As COVID-19 is a new infectious disease, the role of rehabilitation in these patients was unclear, particularly in circumstances where there was a shortage of PPE. Admission of patients with COVID-19 to the PHCCC commenced on January 23, 2020. It was soon considered that respiratory and physical rehabilitation for these patients was necessary. A rehabilitation team consisting of medical doctors, ICU nurses, physical therapists, and respiratory therapists was temporarily transferred from the West China Hospital to the ICU of PHCCC from February 17, 2020, until all patients with COVID-19 were discharged from the ICU (March 8, 2020). Physical therapist interventions were deemed appropriate provided the safety criteria for treatment were met (Suppl. Tab. 1).

[H1]Physical Therapist Interventions

Physical therapist interventions were delivered by 2 physical therapists. Both used PPE when performing physical therapist interventions. An additional full-face mask was used during respiratory physical therapy techniques as these were considered aerosol generating procedures. Proper hand hygiene was performed before and after treatment of each patient. There were 2 physical therapist shifts per day, including weekends. Each physical therapist was given 1 PPE suit per shift which lasted 4 h/d. All staff were required to wear PPE and allowed to move between patients in the ICU rooms (all patients in the ICU were proven to be COVID-19 infected).

Figure 2 displays the physical therapist management flow for patients with COVID-19 in the ICU. The aim of physical therapy focused on preventing sputum retention, maximize airway patency, respiratory and limb muscle strength and functional mobility. As COVID-19 was a new disease, rather than focusing on specific indications and identified problems in individual patients (as recommended by published guideline⁶), an approach that provided standardized treatment protocols to all patients was adopted (see below).

[H2]Maximization of Airway Patency and Prevention of Sputum Retention

All of the patients who were breathing spontaneously were placed in an upright position for 20 minutes daily. Those who required heavy sedation or were in an

impaired conscious state were placed with the head elevated at 30 degrees for 20 minutes, twice daily. All patients on mechanical ventilation were placed in the prone position for 12 hours each day until extubation. All of the patients who were breathing spontaneously were taught active cycle of breathing techniques and given an oscillatory positive expiratory pressure device (Acapella Portex; Smiths Medical, Ashford, Kent, United Kingdom) and asked to practice 8 breath sets (with rest between sets) for 10 minutes, 3 times per day, or anytime they felt an accumulation of pulmonary secretions. A video on how to conduct active cycle of breathing techniques was saved on an iPad, left in the ICU for use by nursing staff to remind patients to practice the breathing exercises when the physical therapists were off shift. Patients with moderate or a large amount of secretions were given percussion and vibration to alternate sides, twice each day.

The maximum inspiratory pressure (MIP) for each patient was measured and the percentage of the predicted value computed.⁷ All patients were given a threshold inspiratory muscle training (IMT) device (Digi IMT S2; XEEX Co Ltd, Xiamen, China) and practiced a standardized IMT protocol (4 sets of 8 breaths at a designated intensity with 2-minute rests)⁸ daily at a random allocation of either 30% or 50% MIP.

Two training intensity levels were adopted because, prior to the COVID-19 pandemic, the physical therapist team had launched research to compare the effects of training intensity levels. While the original project had to be suspended, the rehabilitation

team considered it appropriate to randomly allocate patients with COVID-19 to 2 IMT intensity groups. The sequence of randomization followed the order of patient admission. That is, the first patient referred to physical therapy would receive 30% MIP as the training intensity, the next one would receive 50%, the third one would receive 30%, and so on.

Patients on mechanical ventilation received a ventilator hyperinflation protocol⁹ delivered by the physical therapists with assistance from respiratory therapists. The ventilator hyperinflation protocol consisted of the following: volume control breaths at an inspiratory flow of 20 L/min; tidal volume was increased by 200 mL per breath until the peak airway pressure reached 40 cm of H₂O; 6 consecutive mechanical breaths were then delivered; and those 3 steps were repeated for 6 cycles. The aim of ventilator hyperinflation was to maintain and maximize lung recruitment.

[H2] Maximization of Mobility and Prevention of Functional or Neuromuscular Deconditioning

All 16 patients participated in a regimented sequence of mobility¹⁰: rolling over and moving on the bed regularly, sitting up in bed, sitting on the bedside, sitting on a chair, standing, and walking (along a 7-m walkway in the ICU). Only when each mobility stage was completed, was the next stage allowed. When physical therapists were off shift, nurses were encouraged to continue patient mobility activities by following the

recommendation of the physical therapists. The frequency and mode of activities were prescribed by the physical therapist on the basis of patient assessments. During mobility exercises, oxygen saturation (SpO₂) stability (above 90%) and rate of perceived exertion (Modified Borg Dyspnea Scale) were constantly monitored. Patients were encouraged to rest if their rate of perceived exertion was 4 or above.

[H1]Outcome Measures

Table 3 displays the following outcome measures which were recorded on the first day of referral to the physical therapist and then repeated when the patient was discharged from the ICU. Respiratory parameters included PaO₂/FIO₂ ratio, peak expiratory flow rate (PEFR) (peak flow meter; Spirit A1, Shanghai Sunny Instrument Co., Ltd., Shanghai, China), MIP (respiratory pressure meter (Micro RPM01; Micro-Medical Instrumente GmbH, Senftenberg, Germany), and resting dyspnea score (Modified Borg Dyspnea Scale).¹¹ Physical function parameters included the Medical Research Council Sum Score for muscle strength,¹² Physical Function in Intensive Care Test,¹³ De Morton Mobility Index (DEMMI),¹⁴ and Modified Barthel Index.¹⁵ Walking distance managed by the patient was also recorded. These data were available only from the 13 patients who were breathing spontaneously as these measurements cannot be undertaken when patients are mechanically ventilated.

[H1]Patient Progression in the ICU

Each patient received 2 sessions of physical therapy daily. Each session, including positioning, respiratory management and mobility exercise, lasted around 30-40 minutes. Treatment did not include donning and doffing time. None of the rehabilitation staff were contaminated with the SARS-CoV-2. No patients desaturated during or after either respiratory or mobility intervention and there were no adverse effects associated with physical therapist interventions. One patient (patient 1) with congestive heart failure experienced supraventricular tachycardia 4 hours after being placed in an upright position on 1 occasion. All hemodynamic and respiratory parameters were stable during all physical therapist interventions. One patient (patient 9) was admitted on February 12, 2020, but showed a significant increase in bilateral lesions on computerized tomography on February 20, 2020, with increased temperature and shortness of breath. High-flow nasal oxygenation commenced on February 20, 2020, as the patient was unable to tolerate noninvasive ventilation. Although not mechanically ventilated, he was placed in the prone position 12 h/d. His temperature returned to normal on February 23, 2020, and computerized tomography showed significant improvement on February 25, 2020.

[H2]Patients Who Were Spontaneously Breathing (n = 13)

Thirteen of the 16 patients were breathing spontaneously on high-flow nasal oxygenation or nasal cannulae) (Fig. 1). Ten patients produced a small amount of whitish sputum with the consistency of honey and 3 produced large amounts of

secretions. These 3 patients received percussion and vibration twice daily in addition to active cycle of breathing techniques and use of an Acapella device. Seven patients (patients 2, 4, 6, 8, 10, 13, and 16) received the IMT protocol at 30% MIP and the rest were trained at 50% MIP. All patients demonstrated an increase in MIP at ICU discharge (Tab. 3). Group analysis revealed that the median percentage increase in the 50% MIP training group was 21% (minimum–maximum = 17%–38%), which was higher than that in the 30% MIP training group (11% [9%–26%]) (Tab. 4). All except 2 patients had PEFr below 50% of the predicted value on the first day of physical therapy; all demonstrated improvement on the day of ICU discharge; and 10 of them (62%) still had PEFr of <80% of the predicted normal value (Tab. 3).

On day 1 of the physical therapist assessment, 12 of the patients who were breathing spontaneously were able to commence a walking program, which increased by 10 m each day. Patient number 16 was on renal dialysis and did not commence walking until February 29, 2020. The majority of patients required 2 or 3 short rest periods during walking. By the day of discharge from the ICU, all were able to walk either independently or with an assistant for 40 to 50 m. On the day of discharge from the ICU, 6 of these patients (46%) still had below-normal DEMMI values, and the Modified Barthel Index values for all patients were still categorized as moderately dependent. Individual patient performance on day 1 of the physical therapist intervention and at discharge from the ICU is illustrated in Table 3, and group performance is displayed in Table 4. Of these 13 patients, 11 were discharged to the

isolation ward on or before March 8 and to home later. Two of them were discharged directly from the ICU to the nursing home from which they originated. All patients discharged from PHCCC had to exhibit at least 2 consecutive negative nucleic acid tests for SARS-CoV-2.

[H2]Patients Who Were on Mechanical Ventilation (n = 3)

The 3 patients who required mechanical ventilation were 80 (81–87) years old, and all had multiple comorbidities (Tab. 1). Two of these patients were on assisted-volume control PEEP at 5 and 9 cm H₂O, 20 and 18 breaths per minute, and tidal volumes at 420 and 450 mL. The third patient received SIMV with 6 cm H₂O PEEP, 14 breaths per minute, and a tidal volume at 420 mL. Compared with the cohort of patients who were breathing spontaneously, they were older and had longer ICU and hospital stays (Suppl. Tab. 2) All 3 patients had difficulty in communicating. Two (patients 1 and 12) had Alzheimer disease, and 1 (patient 14) was unconscious. The low level of patient alertness meant that physical exercises were restricted to passive/assisted active limb mobility; however, all could (passively or actively with assistance) roll over and move on the bed and participated in body positioning, sitting on the bedside, transferring from the bed to the chair, and sitting on the chair. At the time of ICU discharge, patient 14 was able to sit in a chair, and patients 1 and 12 managed to stand by their beds. All 3 patients passed consecutive negative nucleic acid testing for SARS-CoV-2 on March 8 and were discharged to their respective nursing homes.

[H1]Discussion

This descriptive report aims to share with clinicians and physical therapists the response of patients with COVID-19 to physical therapist interventions provided at the ICU of PHCCC in Chengdu. Our cohort of patients with COVID-19 all showed impaired lung function as illustrated by computerized tomography, poor PEFR, and resting dyspnea score. As COVID-19 is a new disease, it was considered that a vigilant, preventative program to optimize respiratory and peripheral muscle strength and functional performance were necessary. To ensure maximal airway patency and ease of secretion mobilization, each patient who was breathing spontaneously was given an Acapella device. The majority of our patients did not have a large volume of secretions. As this is not a randomized controlled study, we are unable to determine whether the small number of patients with secretion problems is the natural course of COVID-19 or whether the use of the oscillatory positive end-expiratory pressure device helped to maintain airway opening and promote secretion expectoration. While the PaO₂/FiO₂ ratios, PEFR and MIP of our patients improved significantly at discharge, about one-third of the patients still generated an MIP below 80% of the predicted value and 62% had PEFR below 80% of the predicted normal values. The low PEFR of our patient cohort at ICU discharge is of concern. A reduced PEFR is associated with poor airway clearance ability.¹⁶ PEFR is correlated with peak cough rate in patients with chronic respiratory illness¹⁷ and an effective cough is essential for

airway clearance. This observational study therefore suggests that there is a need to follow up the respiratory function of discharged patients with COVID-19 to ensure respiratory muscle strength and optimal airway clearance ability is maintained.

PEFR has been shown to correlate with MIP¹⁸ in patients undergoing coronary artery bypass grafting. Analysis of our MIP data showed that the MIP of some of our patients with COVID-19 was significantly reduced (60% of the predicted value for people who were healthy and matched for age and sex) (Tab. 3) on admission to the ICU, and IMT training intensity at 50% MIP revealed a 20% increase in MIP, whereas the group with a training intensity of 30% MIP demonstrated only an 11% increase. We randomly allocated patients to 2 different training intensities to explore the value of high-intensity IMT in patients in the ICU and subsequently extended this study to the COVID-19 cohort. It appears that patients with COVID-19 have impaired respiratory muscle strength and that IMT at 50% training intensity benefits patients regaining respiratory muscle strength.

Our patients participated in a vigorous mobilization routine based on the reported impact of severe acute respiratory syndrome on pulmonary and functional capacity in survivors of severe acute respiratory syndrome.¹⁹ Pulmonary and functional impairments at 6 months after severe acute respiratory syndrome were comparable to those in patients after acute respiratory distress syndrome,¹⁹ and an individual exercise program was shown to improve the aerobic and exercise capacity of survivors of severe acute respiratory syndrome.²⁰ To optimize the respiratory and functional

capacity of patients with COVID-19 before signs of system dysfunction became apparent, we initiated interventions that included a wide range of functional/mobility tests (Physical Function in Intensive Care Test, DEMMI, and Modified Barthel Index) in our patients with COVID-19. We believe that mobility tests can be used as an incentive for exercise, as most patients responded well to an “objective” score after any exercise effort. Mobility exercises are essential for elderly patients as preexisting diseases in these patients make them more susceptible to COVID and they tend to develop severe and critical diseases,^{21,22} perhaps related to compromised immunity in these patients. Our data showed that patients with COVID-19 were associated with poor functional level, with low DEMMI and Modified Barthel Index scores. Our vigorous mobility regimen appeared to be successful in improving this score at discharge. This improvement is consistent with the reported recovery of patients after ICU stay.²³ However, it should be noted that about one-third of the patients at discharge had DEMMI scores below an indicative, age-matched, normal value,²⁴ and all patients were still categorized as having moderate dependency.¹⁵ This supports that post-discharge rehabilitation intervention will be necessary in patients who recover from severe COVID-19.²⁵

Physical therapy is a young and developing profession in China. While cardiopulmonary physical therapists are core members of the intensive care team, the opportunity for physical therapists to care for patients in acute care settings is very limited.²⁶ West China Hospital is one of the hospitals in China that provide

opportunities for cardiopulmonary physical therapy to develop. Being commissioned to specifically manage patients with COVID-19 in the ICU was a daunting and intimidating experience for the whole rehabilitation team. Physical therapy is considered an aerosol-generating procedure, and international guidelines suggest minimal intervention unless indicated otherwise.⁵ However, we adopted an aggressive, preventative approach in the management of COVID-19. PPE was available, and all patients underwent a standardized protocol of mobilization and outcome measures as described in the physical therapist intervention section above. The role that our physical therapists played in pulmonary management was different for patients with COVID-19 and patients without COVID-19. For patients without COVID-19, interventions were based on assessment findings; for patients with COVID-19, we adopted an aggressive prophylactic approach to minimize the risk of sputum retention and development of respiratory muscle weakness, through the prophylactic use of an oscillatory positive end-expiratory pressure device (Acapella) and IMT. This was a special strategy that we adopted for the management of COVID-19, a condition new to all of us.

The involvement of our team in the management of COVID-19 did not commence until February 17, 2020, and more information had become available by then. West China Hospital made special arrangements to support the staff involved in the management of patients with COVID-19. All members of the staff who were temporarily transferred were housed in a hotel next to the hospital as we were unable

to return to our homes between February 17, 2020, and March 8, 2020. Special meals were provided to ensure staff had sufficient nutrient input, shifts were reduced to 4 hourly per day to ensure sufficient rest time, debriefing/counseling sessions were organized every evening to immediately attend to any anxiety or other psychological problems. The opportunity to provide physical therapy to patients with COVID-19 increased our confidence in managing patients who were sick in an acute care hospital setting.

A summary of the lessons learned by our team includes the following 6 elements: importance of infection control and how to organize equipment use for prevention of contamination; use of an iPad to provide visual demonstrations of exercise techniques to patients; importance of collaborative teamwork with nursing staff for walking patients and conducting ventilator hyperinflation with respiratory therapists; apparent effectiveness of the prophylactic use of the Acapella device in minimizing the risk of secretion retention; apparent effectiveness of IMT at 50% MIP training intensity in improving respiratory muscle strength; and suggestion of the need for further investigation of the role of long-term rehabilitation in restoring the respiratory and functional capacity of patients with COVID-19 after discharge from the ICU.²⁵ Above all, we are pleased to see that physical therapist intervention in patients with COVID-19 is safe, and appears to assist in maintaining and improving their respiratory and mobility function.

This is a descriptive report and should be read in light of the following limitations. The number of patients is relatively small, and it was not ethical to have a ‘control’ group for comparison. All patients in the severe and critical categories were seen by our physical therapists and therefore no inference can be properly drawn as to whether patient recovery was natural or facilitated by rehabilitative intervention. Second, rehabilitation therapy was initiated in the middle phase of the disease and we are therefore unsure whether the absence of respiratory and mobility interventions in the early period of this disease influence the therapeutic efficacy of later physical therapist interventions in these patients. Another limitation of our report is that we were unable to compare and reflect on the differences between our cohort of patients with COVID-19 and ICU cohorts with pneumonia or influenza. Twelve of our 16 patients in the current study were identified as ‘critical’, but only 3 received mechanical ventilation. The majority of our patients did not demonstrate ICU acquired weakness, as illustrated by the high Medical Research Council Sum Score. This might be associated with our rigorous walking and battery of functional tasks applied, but also because these patients were not on mechanical ventilation and they were not sedated. However, the response of health care systems to the pandemic differs considerably in different countries, depending on the availability of human and equipment resources. To us, it is still a valuable lesson learned.

[H1]Conclusion

Our data support the pro-active implementation of physical therapy for patients with severe and critical illness caused by COVID-19 in maintaining airway clearance, and respiratory and functional capacity. Our data suggest that sputum retention and mobility was not a significant problem in the middle phase of the disease. However, PEFr, MIP, and functional mobility remained poor in some patients at discharge, suggesting that long-term pulmonary and functional rehabilitation requires further investigation. Finally, this report reveals that services provided by physical therapists proficient in pulmonary management are an integral component of a comprehensive plan of care for patients with COVID-19 in the ICU.

Author Contributions

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Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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Table 1.

Demographic Data for the 16 Patients at Admission to the ICU^a

| Patient | Sex | Age (y) | BMI | Comorbidity ^b | COVID Category | SOFA | On Admission to ICU | | | Pre admission Mobility Level | Smoking History ^c | Days in Hospital | Days in ICU | Days in MV ^d | Days on Mechanical Ventilation | Days of Physical Therapy | RASS | |
|---------|-----|---------|-------|--------------------------|----------------|------|---------------------|---|------------------|------------------------------|------------------------------|------------------|-------------|-------------------------|--------------------------------|--------------------------|------|----|
| | | | | | | | FIO ₂ | PaO ₂ /FI O ₂ Ratio | Pao ₂ | | | | | | | | | |
| 1 | F | 84 | 22.59 | 1-3, 9-11, 13 | Critical | 8 | 29 | 93 | 321 | Dependent on assistance | NS | 35 | 35 | 29 | 6 | 14 | 21 | -1 |
| 2 | F | 87 | 22.06 | 1, 3, 7, 8, 10, 16 | Critical | 1 | 29 | 79 | 276 | Dependent on assistance | NS | 24 | 9 | 0 | 0 | 3 | 9 | 0 |
| 3 | F | 78 | 21.11 | 4 | Severe | 1 | 29 | 130 | 450 | Independent | NS | 26 | 6 | 0 | 0 | 5 | 6 | 0 |
| 4 | M | 51 | 25.34 | 5 | Critical | 3 | 41 | 96 | 234 | Independent | NS | 27 | 17 | 0 | 0 | 10 | 7 | 0 |
| 5 | M | 44 | 22 | 5, 6 | Se | 2 | 2 | 6 | 20 | Inde | N | 33 | 1 | 0 | 0 | 12 | 5 | 0 |

| | | | | | | | | | | | | | | | | | |
|----|---|----|-----|-----------|----------|----|----|-----|-------------------------|----------------------|----|----|----|----|----|----|---|
| | | 7 | 4 | | ver | 9 | 0 | 7 | pen | S | | 0 | | | | | |
| | | | .80 | | e | | | | dent | | | | | | | | |
| 6 | F | 43 | 25 | 17 | Critical | 21 | 29 | 281 | Indep | N | 36 | 22 | 00 | 00 | 15 | 7 | 0 |
| | | | .32 | | | | | | dent | S | | | | | | | |
| 7 | F | 59 | 25 | 1 | Critical | 39 | 27 | 231 | Indep | N | 37 | 19 | 00 | 00 | 15 | 3 | 0 |
| | | | .81 | | | | | | dent | S | | | | | | | |
| 8 | M | 50 | 23 | 6 | Critical | 23 | 36 | 203 | Indep | FS | 30 | 12 | 00 | 00 | 9 | 3 | 0 |
| | | | .53 | | | | | | dent | | | | | | | | |
| 9 | M | 80 | 21 | 13 | Critical | 11 | 27 | 352 | Indep | FS | 22 | 22 | 00 | 00 | 5 | 17 | 0 |
| | | | .48 | | | | | | dent | | | | | | | | |
| 10 | F | 78 | 28 | 1,3,5,14 | Critical | 69 | 27 | 254 | Dependent on assistance | N | 24 | 24 | 00 | 00 | 3 | 21 | 0 |
| | | | .44 | | | | | | | S | | | | | | | |
| 11 | F | 84 | 18 | 13,18 | Sever | 29 | 27 | 268 | Dependent on assistance | N | 11 | 11 | 00 | 00 | 2 | 9 | 0 |
| | | | .07 | | e | | | | | S | | | | | | | |
| 12 | M | 87 | 15 | 1,7,11,15 | Critical | 49 | 23 | 452 | Dependent on | not available | 25 | 25 | 81 | 07 | 4 | 21 | 2 |
| | | | .6 | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|----|---|----|----|--------------------------------|------------------|---|----|----|-----|---|------------------|----|----|----|----|----|----|---|
| | | | 2 | | | | | | | assis tanc e | ab le | | | | | | | |
| 13 | M | 82 | 20 | 7 | Cri tic al | 4 | 41 | 65 | 159 | Inde pen dent | NS | 27 | 10 | 0 | 0 | 6 | 3 | 0 |
| 14 | M | 81 | 25 | 1, 7 | Cri tic al | 3 | 60 | 79 | 133 | Inde pen dent | FS | 46 | 38 | 17 | 29 | 32 | 21 | 4 |
| 15 | F | 80 | 18 | 1 | Se ver e | 3 | 21 | 56 | 268 | Dep ende nt on assis tanc e | FS | 27 | 6 | 0 | 0 | 6 | 5 | 0 |
| 16 | M | 50 | 21 | 1-3, 5, 10, 12, 17 | Cri tic al | 6 | 29 | 75 | 259 | Inde pen dent | S | 13 | 13 | 0 | 0 | 1 | 12 | 0 |

^aAll patients showed bilateral pulmonary changes on computerized tomography. Patients 1, 12, and 14 received mechanical ventilation (MV). BMI = body mass index; COVID = coronavirus disease; F = female; FIO₂ = fraction of inspired oxygen; ICU = intensive care unit; M = male; PaO₂ = partial pressure of oxygen, in mm Hg; RASS = Richmond Agitation-Sedation Scale; SOFA = sequential organ failure assessment.

^b1 = hypertension; 2 = congestive heart failure; 3 = atherosclerosis/ischemic heart disease; 4 = hypercholesterolemia; 5 = type 2 diabetes; 6 = fatty liver; 7 = emphysema/chronic obstructive pulmonary disease; 8 = bile stone; 9 = chronic renal ischemia; 10 = renal disease; 11 = Alzheimer disease; 12 = hypoproteinemia; 13 = ischemic stroke; 14 = breast cancer; 15 = prostate surgery; 16 = low thyroxine levels; 17 = anemia; 18 = dysphagia.

^cFS = formerly smoked; NS = never smoked; S = smoke.

^dDays until MV = number of days after hospital admission until MV commenced.

Table 2.Selected Laboratory Data for the 16 Patients at Admission^a

| Patient | White Cell Count (10 ⁹ /L) | Lymphocytes(%) | C-Reactive Protein (mg/L) | International Normalized Ratio | D-Dimers (µg/mL) | Prothrombin Time (s) | NT-proBNP (pg/mL) |
|---------|---------------------------------------|----------------|---------------------------|--------------------------------|------------------|----------------------|-------------------|
| 1 | 7.67 | 23.3 | 131.42 | NA | 1.43 | 21.7 | 5815 |
| 2 | 10.56 | 8.0 | 103.01 | NA | 1.33 | 14.2 | NA |
| 3 | 4.06 | 35.9 | 51.91 | NA | 4.36 | NA | NA |
| 4 | 4.33 | 19.2 | 47.01 | NA | 1.59 | NA | 93.77 |
| 5 | 3.61 | 14.1 | 14.14 | NA | NA | 13.7 | 63.1 |
| 6 | 3.71 | 15.1 | 33.76 | NA | 1.00 | NA | 52.2 |
| 7 | 3.74 | 23.4 | 18.21 | NA | NA | NA | NA |
| 8 | 13.52 | 4.2 | 8.65 | NA | NA | NA | 121.5 |
| 9 | 9.51 | 10.3 | 11.65 | NA | NA | NA | NA |
| 10 | 7.54 | 16.2 | 42.97 | 1.26 | 21.11 | 15.0 | NA |
| 11 | 7.75 | 17.0 | 2.20 | NA | NA | NA | NA |
| 12 | 2.66 | 16.2 | 120.13 | 1.08 | 1.82 | 13.0 | 815.8 |
| 13 | 5.92 | 13.0 | 57.94 | NA | 1.19 | 16.1 | 793.9 |
| 14 | 4.50 | 17.5 | 27.34 | 1.10 | 1.87 | 13.2 | NA |
| 15 | 5.61 | 15.9 | 20.65 | NA | NA | NA | NA |
| 16 | 7.63 | 8.4 | 15.14 | NA | 2.51 | NA | >35,000 |

^aPatients 1, 12, and 14 received mechanical ventilation. NA = not available; NT-proBNP = N-terminal prohormone of brain natriuretic peptide.

Table 3.

Measured Outcome Parameters for the 13 Patients Who Were Breathing Spontaneously at Day 1 of the Physical Therapist Intervention and at ICU Discharge^a

| Patient | Sex | Age (y) | PaO ₂ /FIO ₂ Ratio | | RAS Score | | Borg Dyspnea-Score | | MIP, cm H ₂ O, (% Predicted) | | | PEFR, L/min, (% Predicted) | | MRC -ss | | PFIT Score | | DEM MI | | MBI | | Walking Distance (m) | |
|---------|-----|---------|--|----|-----------|----|--------------------|----|---|----------|-----|----------------------------|------|---------|----|------------|----|--------|----|-----|----|----------------------|----|
| | | | D1 | I1 | D1 | I1 | D1 | I1 | D1 | IC1 | %G1 | D1 | IC1 | D1 | I1 | D1 | I1 | D1 | I1 | D1 | I1 | D1 | I1 |
| 2 | F | 87 | 27 | 30 | 00 | 00 | 5 | 2 | 54 | 68 | 25 | 12 | 25 | 5 | 5 | 7 | 9 | 2 | 3 | 5 | 7 | 5 | 4 |
| | | | 69 | | | | | | (82.7) | (104.13) | 3 | (41) | (82) | 4 | 6 | | | 7 | 9 | 4 | 2 | | 0 |
| 3 | F | 78 | 45 | 40 | 00 | 00 | 3 | 1 | 72 | 84 | 16 | 14 | 28 | 6 | 6 | 1 | 1 | 5 | 8 | 7 | 8 | 1 | 5 |
| | | | 09 | | | | | | (110.3) | (128.7) | 7 | (45) | (88) | 0 | 0 | 1 | 2 | 3 | 5 | 6 | 5 | 0 | 0 |
| 4 | M | 51 | 23 | 62 | 00 | 00 | 7 | 4 | 70 | 77 | 10 | 12 | 16 | 6 | 6 | 1 | 1 | 5 | 1 | 7 | 8 | 2 | 5 |
| | | | 44 | | | | | | (64.75) | (77.0) | 0 | (21) | (28) | 0 | 0 | 1 | 2 | 3 | 0 | 9 | 5 | 0 | 0 |
| 5 | M | 47 | 20 | 30 | 00 | 00 | 7 | 2 | 75 | 89 | 18 | 12 | 21 | 6 | 6 | 1 | 1 | 5 | 1 | 8 | 8 | 2 | 5 |
| | | | 70 | | | | | | (64.05) | (77.6) | 7 | (21) | (36) | 0 | 0 | 2 | 2 | 7 | 0 | 0 | 5 | 0 | 0 |
| 6 | F | 43 | 28 | 45 | 00 | 00 | 6 | 2 | 70 | 76 | 8 | 14 | 26 | 4 | 6 | 7 | 1 | 3 | 1 | 7 | 8 | 1 | 5 |
| | | | 12 | | | | | | (75.35) | (88.57) | 1.8 | (34) | (61) | 8 | 0 | | 1 | 9 | 0 | 8 | 5 | 0 | 0 |
| 7 | F | 59 | 23 | 40 | 00 | 00 | 7 | 2 | 69 | 83 | 20 | 13 | 20 | 6 | 6 | 1 | 1 | 5 | 1 | 8 | 8 | 4 | 5 |
| | | | 30 | | | | | | (81.2) | (102.2) | | (5) | (20) | 0 | 0 | 1 | 2 | 7 | 0 | 2 | 5 | 0 | 0 |

Modified Barthel Index; MRC-ss = Medical Research Council Sum Score; NA = not applicable; PEFr = peak expiratory flow rate; PFIT = Physical Function in Intensive Care Test; RASS = Richmond Agitation-Sedation Scale.

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Table 4.

Group Outcome Parameters for the 13 Patients Who Were Breathing Spontaneously on Day 1 of Physical Therapy and at ICU Discharge^a

| Parameter | Median (Minimum–Maximum) on: | |
|---------------------------|--|---------------------------|
| | Day 1 of Physical Therapist Intervention | Day of Discharge From ICU |
| P/F ratio | 206 (114–452) | 434.5 (236–624) |
| PEFR (L/min) | | |
| Actual value | 145 (120–205) | 250 (165–300) |
| % predicted | 35 (21–68) | 55 (28–100) |
| MIP (cm H ₂ O) | | |
| Actual value | 67 (54–76) | 77 (68–89) |
| % predicted | 83 (62–110) | 102 (68–118) |
| Increase in MIP | | |
| 30% MIP training (n = 7) | 8 (6–14) ^b | 11 (9–26) ^c |
| 50% MIP training (n = 6) | 14 (12–21) ^b | 21 (17–38) ^c |
| MRC-ss (0–60) | 60 (48–60) | 60 (56–60) |
| Borg Dyspnea score (0–10) | 6 (3–9) | 2 (0–5) |
| PFIT score (0–12) | 10 (7–12) | 12 (10–12) |
| DEMMI (0–100) | 41.5 (0–67) | 100 (53–100) |
| MBI (0–100) | 55 (0–70) | 75 (30–100) |

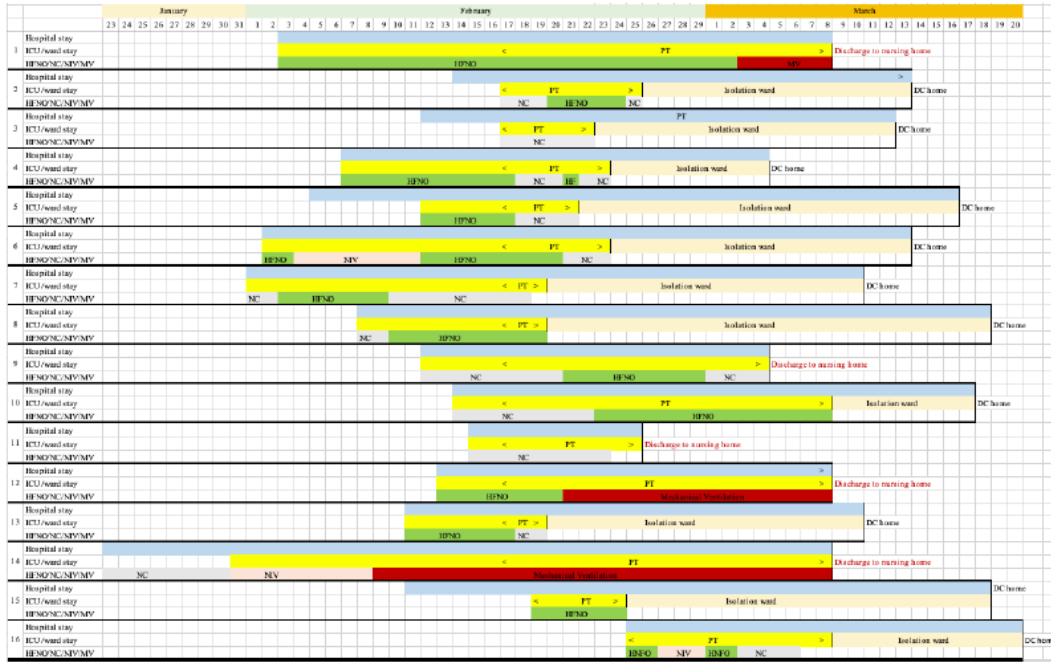
^aDEMMI = de Morton Mobility Index; ICU = intensive care unit; MBI = Modified Barthel Index; MIP = maximal inspiratory pressure; MRC-ss = daily Medical Research Council Sum Score; PEFR = peak expiratory flow rate; P/F = PaO₂/FIO₂; PFIT = Physical Function in Intensive Care Test.

^bReported as the absolute value (cm H₂O).

^cReported as the percentage increase.

Figure 1.

Duration of intensive care unit (ICU) stay, duration of hospital stay, ventilation and oxygenation status, and duration of physical therapy service for the 16 patients. HFNO = days on high-flow nasal oxygen; MV = mechanical ventilation; NC = days with nasal cannula; NIV = days on noninvasive ventilation; < PT > = duration of physical therapist intervention.

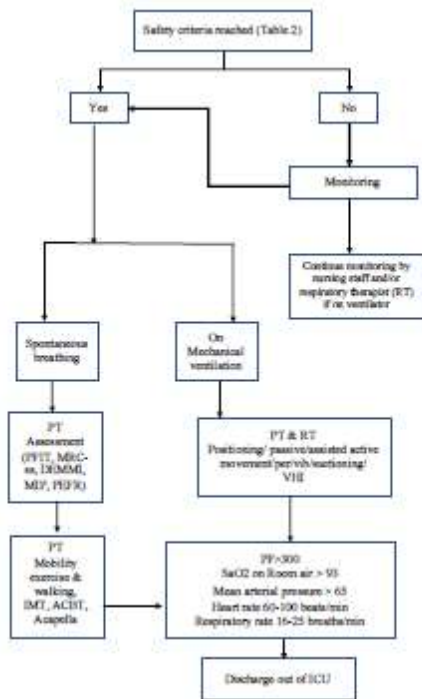


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Figure 2.

Flow diagram of physical therapist (PT) management of patients with coronavirus disease 2019 in the intensive care unit (ICU). OPEP = oscillatory positive-expiratory pressure device (Acapella Portex; Smiths Medical, Ashford, Kent, United Kingdom); = active cycle of breathing techniques; DEMMI = de Morton Mobility Index; IMT = inspiratory muscle training; MIP = maximal inspiratory pressure; MRC-ss = Medical Research Council Sum Score; PEFR = peak expiratory flow rate; per = ; P = percussion ; PFIT = Physical Function in Intensive Care Test; SaO₂ = arterial oxygen saturation; VHI = ventilator hyperinflation; vib =vibration .



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