



## REVIEW

# Extracorporeal membrane oxygenation and rehabilitation in patients with COVID-19: A scoping review

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## Abstract

**Background and purpose:** The coronavirus diseases 2019 (COVID-19) pandemic posed severe difficulties in managing critically ill patients in hospital care settings. Extracorporeal membrane oxygenation (ECMO) support has been proven to be lifesaving support during the SARS-CoV-2 outbreak. The purpose of this review was to describe the rehabilitative treatments provided to patients undergoing ECMO support during the COVID-19 pandemic.

**Methods:** We searched PubMed and Scopus for English-language studies published from the databases' inception until June 30, 2021. We excluded editorials, letters to the editor, and studies that did not describe rehabilitative procedures during ECMO support. We also excluded those articles not written in English.

**Results:** A total of 50 articles were identified. We ultimately included nine studies, seven of which were case reports. Only two studies had more than one patient; an observational design analyzing the clinical course of 19 patients and a case series of three patients. Extracorporeal support duration varied from 9 to 49 days, and the primary indication was acute respiratory distress syndrome COVID-19-related. Rehabilitative treatment mainly consisted of in-bed mobilization, postural transfers (including sitting), and respiratory exercises. After hospital discharge, patients were referred to rehabilitation facilities. Physiotherapeutic interventions provided during ECMO support and after its discontinuation were feasible and safe.

**Conclusion:** The physiotherapeutic treatment of patients undergoing ECMO support includes several components and must be provided in a multidisciplinary context. The optimal approach depends on the patient's status, including sedation, level of consciousness, ECMO configuration, types of cannulas, and cannulation site.

## KEYWORDS

acute respiratory distress syndrome, COVID-19, ECMO, exercise, rehabilitation

## 1 | INTRODUCTION

Pathophysiological manifestations of coronavirus disease 2019 (COVID-19) are characterized by marked vascular suffrance that injures the vessels' endothelium; this specific feature distinguishes the COVID-19 acute respiratory distress syndrome (CARDS) from the traditional acute respiratory distress syndrome (ARDS).<sup>1</sup> Lymphopenia, over-activation of T cells, and increased concentration of highly pro-inflammatory cells are typical in COVID-19.<sup>2</sup>

Extracorporeal membrane oxygenation (ECMO) can be used to provide hemodynamic and respiratory support; in a recently published research conducted in a large cohort of 511 patients, 177 of whom received physiotherapy while on ECMO, it has been found that mobilization was feasible even for out-of-bed activities.<sup>3</sup> The use of ECMO, particularly in its veno-venous configuration, is an established practice in different clinical scenarios, particularly as a bridge to lung transplantation. It also represents a viable alternative to intubation in patients developing acute respiratory failure while waiting on the list to receive an organ.<sup>4-6</sup> As outlined in the 2021 updated guidelines from the Extracorporeal Life Support Organization, the role of ECMO for CARDS has become more apparent with the progressive development of evidence generated during the pandemic.<sup>7</sup> The 60-day mortality of patients with severe ARDS on ECMO support has been estimated to be about 35%,<sup>8</sup> not being substantially different in patients with COVID-19.<sup>9</sup> Not having a tracheostomy was an additional risk factor for death in an Italian series, thereby supporting the need for a radical ventilatory treatment enabling early spontaneous breathing.<sup>10</sup> Considering that ECMO can be used as a bridge to recovery, as in the COVID-19 pandemic, we would verify if rehabilitation is feasible even in such a context.

The purpose of this review was to describe the rehabilitative treatments provided to patients undergoing ECMO support during the COVID-19 pandemic.

## 2 | METHODS

This present research was a scoping review<sup>11</sup> of studies describing patients with COVID-19 undergoing ECMO support. In July 2021, we reviewed two primary databases, namely PubMed and Scopus, using the keywords "ECMO," "COVID-19," "rehabilitation" matched in a search string with the Boolean operator AND. The search adhered to the PRISMA guidelines<sup>12</sup> and went to the databases inception until June 30, 2021. References sections of the retrieved citations were also screened. A total of 50 articles were identified (Figure 1). We excluded editorials, letters to the editor, and studies that did not describe

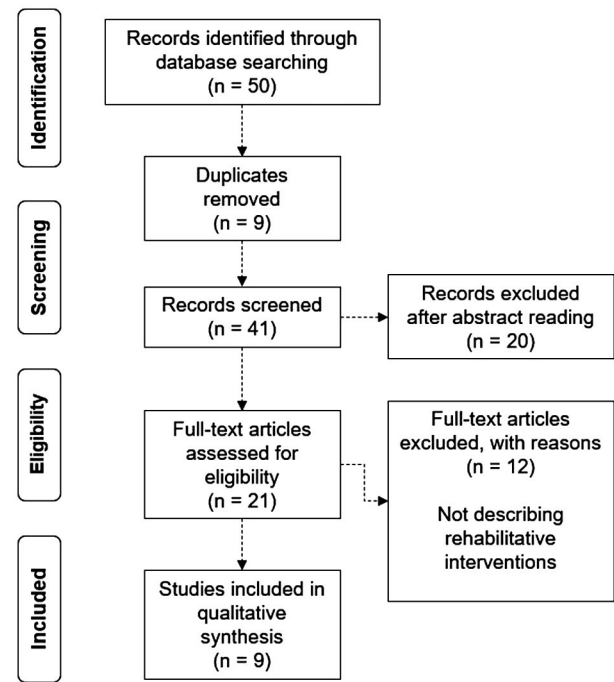


FIGURE 1 PRISMA flow-chart

rehabilitative procedures during ECMO support. We also excluded those articles not written in English. We ultimately included nine studies,<sup>13-21</sup> seven of which were case reports.<sup>14-19,21</sup> Only two studies had more than one patient; an observational design analyzing the clinical course of 19 patients,<sup>20</sup> and a case series of three patients.<sup>13</sup>

### 2.1 | ECMO in COVID-19

Complex clinical manifestations in patients with COVID-19 suggest that SARS-CoV-2 dysregulates the host response, triggering wide-ranging immuno-inflammatory, thrombotic, and parenchymal derangements. An increasing number of centers reported using ECMO to support severely ill patients with COVID-19, mainly developing ARDS.<sup>22-24</sup> The majority of those patients received veno-venous ECMO.<sup>22-25</sup> The use of veno-venous ECMO has been recognized as a preferred modality for patients with COVID-19<sup>26</sup> adopting a conservative transfusion strategy targeting hemoglobin at 7–8 g/dl to 10 g/dl in refractory cases.<sup>8</sup> Regarding the European experience, the most common reasons for cannulation were isolated hypoxemic respiratory failure followed by hypoxemia and hypercapnia.<sup>22,25</sup> In large cohorts of patients with COVID-19 who received ECMO, estimated mortality 90 days after ECMO and mortality in those with a final disposition of death or discharge were less than 40%.<sup>23,24</sup>

Although the importance of adequate gas exchange during veno-venous ECMO and the contribution of and



synergy between the native and membrane lung are well known, the optimal weaning strategy still remains unclear.<sup>27</sup> The tracheostomy is a frequently used procedure for the respiratory weaning of ventilated patients allowing sedation-free ECLS in awake subjects.<sup>28</sup> Tracheostomy can bridge to spontaneous breathing and awake-ECMO also in patients with COVID-19. Weaning from mechanical ventilation requires concomitant weaning from sedation.<sup>29</sup>

Important considerations should be made regarding middle-term survival after ECMO support in patients with CARDS. It has been found that 6-month mortality ranged between 33.3% and 65.9%, and the more frequent complications occurring during or immediately after ECMO were acute kidney injury, bloodstream infection, stroke, pulmonary embolism, and deep vein thrombosis.<sup>30</sup> At the same time, it should not be forgotten that COVID-19 could relapse several sequelae even after several months of its onset. In this regard, the long-COVID syndrome can be experienced by all age groups with wide-ranging symptoms, being fatigue the most reported.<sup>31</sup> Other physical and cognitive impairments require the planning of post-acute rehabilitation in such a population.<sup>32</sup>

## 2.2 | Paradigm change—Awake ECMO

A paradigm shift took place during the pandemic. The original recommendation to intubate patients as early as possible, receiving mechanical ventilation, turned out to be noninvasive forms of ventilation prior to endotracheal intubation, potentially selecting patients suffering self-inflicted lung injury. Prone position while awake under oxygen or high-flow oxygen support proved to be effective instead. This new trend presents to the bedside nurses and physiotherapists unique challenges. Breathing exercises, mobilization, and walking training are of particular importance in such a context. The use of the prone position in patients with post-COVID-19 respiratory failure has been widely used since the early stages of the pandemic, and it has been primarily adopted in intubated patients with severe hypoxemia showing benefits in terms of survival, while less clear are the results in moderate hypoxemia.<sup>33</sup> Prone position has been less frequently used in spontaneous-breathing patients, whether or not associated with noninvasive ventilation, and in patients supported by veno-venous ECMO, generally intubated and curarized.<sup>33–37</sup> In these latter cases, the real effectiveness of the prone position on the final prognosis is not clear as an increase in PaO<sub>2</sub> has not always translated into better survival. In fact, improvement in oxygenation has often been transitory, and in awake patients, the prone position has not always been well-tolerated, requiring significant sedation or its abandonment with therefore

final ineffectiveness of the treatment up to the patient's intubation.<sup>33,34,38–41</sup> In particular, in the case of patients supported with ECMO, the mechanisms by which pronation improves oxygenation are not well understood, and the risk of hemodynamic destabilization and complications related to cannulation sites are not negligible. All the cases reported in the literature were patients who needed curarization to tolerate the prone position. The practice of awake and pronated ECMO is not actually described in the literature, but it could be an exciting aspect to study in the future. The most minimally beneficial mechanism in these patients could be the increase in contractility of the diaphragm facilitated by its dorsal muscle component freer to contract in the prone patient with therefore a better distribution of muscular stress with benefit on the dorsal-basal atelectatic lung areas.<sup>33,34,42</sup> However, as in the other settings described, many important aspects are unclear such as the number of cycles to be performed, their duration, and which patients can benefit most from this cost-free but not free part of possible complications, particularly in patients in ECMO.<sup>33–36</sup> At the state of the art, the use of pronation in awake ECMO patients does not find published series, and in intubated patients, it is described by small numbers. In some small series, the pronated ECMO patients had higher mortality than those in non-pronated ECMO probably for a selection bias, the former were undoubtedly more severe patients. In all cases, pronation has improved oxygenation, but that does not correlate with better survival. Cases are reported where the patient in pronated veno-venous ECMO required a higher respiratory rate and a greater sweep gas flow, probably due to a significant increase in dead space and greater CO<sub>2</sub> retention.<sup>33,35,36,43</sup> Physiotherapeutic intervention for patients connected to the extracorporeal circulation via the large-lumen cannulas requires an enormous understanding of this complex therapy. Finally, physiotherapy on ECMO support has developed similar to sports teams; patient treatment cannot be provided exclusively by only one person. No substantial differences between patients with ARDS and CARDS have been found in a matched cohort of 44 subjects regarding sedation and participation in early physiotherapy.<sup>44</sup> Thus, even in patients with CARDS, one should expect they can attend an early rehabilitation program because the sedation status seems equivalent to those undergoing veno-venous non-COVID-19 ARDS.

In patients who are awake on ECMO, not intubated and cooperative, the post-transplant prognosis in the immediate postoperative and long-term phases may be significantly impacted.<sup>45–47</sup> Primary goals in critical care settings are avoiding pulmonary deconditioning, having patients participating in regular physiotherapy, and reducing the risk of ventilator-associated pneumonia.<sup>46–48</sup> These objectives, as recently highlighted, should be pursued even

in patients with COVID-19 on veno-venous ECMO support.<sup>49,50</sup> Several factors contribute to maintaining patients conscious and not intubated, such as the severity and etiology of the respiratory failure, the initial patient's conditions, the experience of the multidisciplinary team. Certain technical measures (shown in Table 1), such as the choice of the device, type of cannulae, and site of cannulation, play a crucial role when implementing an efficient rehabilitation and psychological support program. In the veno-venous configuration, choosing a device that can be properly used as a pure extracorporeal CO<sub>2</sub> removal and full ECMO for effective oxygenation is important. It is beneficial if cannulation is performed percutaneously, avoiding scalpel incision, and using only vascular dilators to avoid bleeding from the cannulation site, especially during patient mobilization and reduce the risk of infection and sepsis from the entry points of the cannulae. Cannulas and circuits should be heparin coated to minimize the need for anticoagulants; heparin may also be added for priming. Upper body veno-venous accesses via bi-lumen or coaxial cannulas are preferred to facilitate patients' mobilization and assisted walking. The beneficial site for this configuration is the right jugular vein, which is simple to obtain, has a low risk of complications, and best supports effective mobilization.

Recently, to enhance patients' mobility, many innovations in cannula design have been introduced.<sup>51,52</sup> Even if single cannulation (using a coaxial cannula) is not an available option and a double cannulation site is needed, the beneficial configuration that still permits a certain degree of mobilization is the femoral/atrial-jugular. In that case, the cannula introduced into the femoral vein prevents patients from walking but does not preclude other forms of mobilization and rehabilitation. Eventually, femoral/cava-femoral/atrial venous cannulation is another option, which may be the simplest. This configuration, which certainly prevents patient's mobilization, is characterized by a high degree of recirculation and an increased risk of infection at the inguinal cannulation site, especially when used for long-term support, as observed in patients with CARDS.<sup>53,54</sup> Similar to acute fibrinous organizing pneumonia (AFOP),<sup>55</sup> some aspects of the pathophysiology of COVID-19 are of crucial importance from the point of view of ECMO support.<sup>56</sup> Clinical manifestations of AFOP might include associate alterations of cardiac function<sup>57</sup> requiring different ECMO configurations, namely veno-venous and veno-arterial. In AFOP, ECMO cannulation is generally femoro-femoral. Keeping the patient awake and mobilization are two challenging goals difficult to pursue under such a specific condition. Renal function is also often impaired. Therefore, the risk of renal failure in patients undergoing ECMO support increases compared to what we are used to seeing in ARDS of other origins.<sup>58</sup>

TABLE 1 Risk profile and rehabilitation perspectives in relation to different cannulation modalities during VV-ECMO

Type of support	Number of cannulas	Venous drainage	Arterialized return	Cannulation risk	Recirculation	Infective risk	Mobilization	Risk of cannulae dislocation
ECCO2-R	Single dual-lumen <sup>a</sup>	SVC	RA	++	++	+	++++	+
VV ECMO	Single dual-lumen <sup>b</sup>	SVC	RA	++	+++ <sup>c</sup>	+	++++	+++
VV ECMO and/or RVAD	Single dual-lumen <sup>b</sup>	SVC/RA	PA	+++	-	+	+++	++
VV ECMO	Two cannulas configuration <sup>d</sup>	IVC	SVC/RA	++	++	+++	++	++
VV ECMO	Two cannulas configuration <sup>e</sup>	IVC	RA	+	++++ <sup>c</sup>	++++	+	+

Note: +, minimum; ++, low; +++, medium; +++++, high.

Abbreviations: ECCO2-R, extracorporeal carbon dioxide removal; ECMO, veno-venous extracorporeal membrane oxygenation; IVC, inferior vena cava; RA, right atrium; RVAD, right ventricular assistance device; SVC, superior vena cava; VV.

<sup>a</sup>Subclavian vein or jugular vein

<sup>b</sup>Jugular vein

<sup>c</sup>In particular at high-flow

<sup>d</sup>Jugular-femoral

<sup>e</sup>Femoro-femoral.



Not less important, bradykinin-dependent angioedema and alterations of the vascular endothelium determine—together with other factors not yet known—a state of hypercoagulability of the pulmonary microcirculation. ECMO might be associated with thrombotic complications and, consequently, with challenges in maintaining an adequate level of anticoagulation during support, often resulting in frequent circuits replacement and onset of oxygenator thrombus phenomena much more frequently than usual—even with very high flows.<sup>59,60</sup> Under such conditions, in-bed patient's mobilization might play a crucial role in avoiding thrombotic complications, especially in the venous district of the lower limbs.

### 2.3 | Rehabilitation while on ECMO support

Early mobilization and lower limb exercise in critically ill patients are increasingly recognized as safe and feasible and a potential means of optimizing outcomes in the intensive care setting. With the rapidly expanding use of ECMO for severe cardiopulmonary failure, there is a growing interest in early mobilization and full rehabilitation to this patient population. Early mobilization is beneficial in maintaining physical conditioning, which may be an essential component for a proper patient's full recovery. The ability to engage critically ill patients in active physiotherapy and early mobilization necessarily involves minimization of sedation and is often further facilitated by a strategy that favors endotracheal extubation. Whether an awake, extubated, and mobile strategy can be applied in any given patient is often dictated by the severity of the underlying disease and the amount of extracorporeal support required.<sup>61</sup> Additionally, whether this approach is superior to usual care, which patients might benefit or be harmed, and which patient characteristics are most likely to predict the success of this strategy are areas of an ongoing investigation.

Additionally, cannulation strategies focusing on jugular vessels with the double lumen cannulae and minimized ECMO devices with integrated pumps and membranes opened significant advances in patient mobility. While portable ECMO devices might have the most significant impact on the simplified inter-hospital transport, they simultaneously include early mobilization and lower limb exercises. We assume that patient's mobilization while on ECMO may reduce the risk of clotting formations both in the patient's venous vessels and ECMO system components, providing venous blood drainage, vigorous systemic blood antegrade circulation, and avoiding blood stasis. All the above may even reduce the rate of pulmonary embolism and other thromboembolic events,

which are typically related to coagulation disorders and the absence of full early mobilization.

In the present review, 29 patients were described in the included studies, as shown in Table 2. Among those studies, one reported that rehabilitation was provided with the patient on ECMO support.<sup>17</sup> In that study by Mark and colleagues, the patient was approached on ECMO day 5, initiating an in-bed range of motion exercises progressing toward increased mobility and walking on ECMO.<sup>18</sup> In another study by Oh and colleagues, the patient was waiting for lung transplantation. Even in that case, rehabilitation commenced while on ECMO and was prosecuted after lung transplantation.<sup>18</sup> From these two experiences, it can be gathered that rehabilitation is feasible and possible in patients with COVID-19 and ECMO support. A crucial message is that mobility and ECMO can coexist exclusively in a multidisciplinary environment where various professionals preside different aspects during mobilization. Furthermore, in Tran et al's study, a patient who underwent veno-venous ECMO was able to ambulate autonomously after 35 days of support, although it was not clear if physiotherapy was initiated before or after decannulation.<sup>21</sup> Eventually, in another case study by Rajdev and colleagues, although it has been reported the patient underwent aggressive rehabilitation during hospitalization, it was not clear if the authors implemented the rehabilitative treatment with the patient on ECMO support.<sup>19</sup>

Further consideration should be made on the patient's consciousness; it has already been clarified that awake ECMO can facilitate rehabilitative activities enhancing patients' outcomes.<sup>48</sup> In the two cases included in this review, in which rehabilitation has been provided while on ECMO, patients were awake (Table 2). The primary interventions reported in the included studies were mobilization—including in-bed passive and active range of motion exercises—elastic band exercises, and postural transfers.

Another essential aspect that must be considered when mobilizing patients while on ECMO support is the ineludible necessity to have several professionals available, each taking care of a given part of the treatment, including physiotherapists, nurses, intensive care physicians, perfusionists, ECMO specialists. Eden and colleagues previously highlighted the crucial importance of the interdisciplinary approach.<sup>62</sup>

### 2.4 | Rehabilitation after ECMO decannulation

As emerged from the present review, most patients ( $n = 24$ ) attended a rehabilitation program once being decannulated from ECMO, as described in Table 2. Two of them underwent lung transplantation to treat the COVID-19 sequelae,

TABLE 2 Studies describing rehabilitation activities in patients with COVID-19 on ECMO support

Source	Design and patients	ECMO support	Rehabilitative procedures
Chen et al <sup>13</sup>	<p>Case series</p> <p>Study timeline: February 10 to March 10, 2020 (first pandemic wave)</p> <p>3 patients with a median age of 66 yrs (100% males). All patients underwent LTx for the treatment of ARDS-related irreversible post-COVID-19 pulmonary fibrosis. 1 patient died during LTx because of intraoperative cardiac complications</p>	<p>Pre-LTx ECMO mode: 2 VV, 1 VAV</p> <p>Intraoperative ECMO mode: 3 VA</p>	<p>2 patients initiated postoperative rehabilitation on POD 2 and 3, respectively. Rehabilitative activities included limbs movements, sitting, in-bed cycling, respiratory muscle training, and muscle strength exercises. Rehabilitative activities were provided after ECMO decannulation</p>
Firstenberg et al <sup>14</sup>	<p>Case report</p> <p>Study timeline: March 6 to April 9, 2020 (first pandemic wave)</p> <p>A 51-year-old woman with intractable hypoxemic respiratory failure</p>	<p>VV support lasted 11 days</p>	<p>Able to walk short distances and maintaining a standing position. Not specified if patient was referred to physiotherapy during the hospital stay. The patient was discharged to a rehabilitation facility on hospital day 28</p>
Guo et al <sup>15</sup>	<p>Case report</p> <p>A 66-year-old woman with intractable hypoxemic respiratory failure and heart failure</p> <p>Study timeline: February to May, 2020 (first pandemic wave)</p>	<p>VV support lasted 49 days</p>	<p>Commenced respiratory and cardiac rehabilitation 3 months after ECMO decannulation</p>
Mao et al <sup>16</sup>	<p>Case report</p> <p>A 66-year-old woman with intractable hypoxemic respiratory failure underwent LTx</p> <p>Study timeline: the patient data were available until POD 112 (first pandemic wave), from February 2020 onward</p>	<p>ECMO mode not specified</p> <p>ECMO support lasted 15 days</p>	<p>Rehabilitative activities were provided after ECMO decannulation. Early postoperative rehabilitation commenced on POD 4 after LTx. The rehabilitation program consisted of mobilization, in-bed cycling, respiratory exercises including airway clearance techniques, posture management</p>
Mark et al <sup>17</sup>	<p>Case report</p> <p>A 27-year-old pregnant woman with hypoxemic respiratory failure</p> <p>Study timeline: manuscript submitted June 2020 (first pandemic wave)</p>	<p>VV support lasted 9 days</p>	<p>Rehabilitation started on ECMO day 5 consisting of in-bed mobilization and postural transfers (sitting at the edge of the bed and standing with two operator assistance) having the patient awake. On ECMO days 7 and 8 the patient was able to maintain a standing position with improved duration. Rehabilitation continued until hospital discharge on day 14 and the patient was referred to an out-patient rehabilitative setting being able to walk a distance of ~18 m on the day of hospital discharge</p>
Oh et al <sup>18</sup>	<p>Case report</p> <p>A 55-year-old woman with refractory CARDS underwent LTx</p> <p>Study timeline: not specified (manuscript submitted on March 21, 2021 and patient hospital stay was 176 days: first or second pandemic wave)</p>	<p>VV lasted 49 days prior to LTx</p>	<p>The patient initiated a rehabilitation program while on ECMO and awake. Despite being sedated and bedridden for more than 60 days, she was able to reach a standing position after three weeks of rehabilitative training. Following LTx, the rehabilitation program resumed on POD 4 and the patient was discharged to home three months after LTx</p>



TABLE 2 (Continued)

Source	Design and patients	ECMO support	Rehabilitative procedures
Rajdev et al <sup>19</sup>	Case report A 32-year-old man with refractory hypoxemia Study timeline: manuscript submitted on July 7, 2020 (first pandemic wave)	VV support lasted 17 days	The patient attended a rehabilitation program while hospitalized (not specified if already during ECMO support)
Tran et al <sup>21</sup>	Case report A 39-year-old man with severe CARDS Study timeline: late April 2020 (first pandemic wave)	VV support lasted 35 days	The patient received intense daily physiotherapy and occupational therapy (not specified if already during ECMO support)
Riera et al <sup>20</sup>	Observational study (retrospective) 19 patients with refractory hypoxemia. 4 patients died Study timeline: 15 March to 15 June 2020 (first pandemic wave)	Mean VV support lasted 10.7 (2–33) days	Patients did not attend a rehabilitation program while in charge at the ECMO center, but 13 out of 15 were discharged to a rehabilitation facility

Abbreviations: ARDS, acute respiratory distress syndrome; CARDS, COVID-19 acute respiratory distress syndrome; COVID-19, coronavirus disease 2019; ECMO, extracorporeal membrane oxygenation; LTx, lung transplantation; POD, postoperative day; VA, veno-arterial; VAV, veno-arterial-venous; VV, veno-venous.

and they received postoperative rehabilitation after surgery.<sup>13,16</sup> In their case, ECMO support was used as a bridge to transplantation. However, it also appears clear that the rehabilitative practice was not directly provided during ECMO support, and consequently, it cannot be intended as a novel contribution to the expected standards. Nevertheless, physiotherapy played a crucial role in the sub-acute phase, restoring physical function following ECMO decannulation.

The outcome measures used to detect clinical improvements directly related to rehabilitation were primarily linked to the patient's ability to cooperate, muscle strength, physical function, performance in activities of daily living, and dyspnea intensity.<sup>16</sup> These variables, taken together, can express the capacity of patients to pursue realistic outcomes in critical settings and can direct the team efforts toward a feasible therapeutic pathway. Thus, the studies describing rehabilitative activities not expressly provided during ECMO support have furnished an interesting algorithm to be used when planning or investigating rehabilitation in patients on or weaned off ECMO support.<sup>16</sup>

Another consideration should be made on the utility of calculating the patients' walked meters reported in one study.<sup>17</sup> It is a simple method allowing clinicians to evaluate the quality and feasibility of a given physical treatment and the residual physical capacity of patients. In this regard, increased distances detected following physiotherapeutic intervention can be strictly related to it and can provide valuable insights into therapeutic progression. At the same time, the ability to walk a given distance without the intervention of a physiotherapist can be the expression of a residual patient's physical capacity.

All the studies included in the present review have been conducted during the so-called first pandemic wave that

occurred between January and June 2020, a moment in which the knowledge of the disease was scarce. It would be interesting to repeat the current research in the next future to understand if ECMO support has been used with the same intentions during both the second pandemic wave and the further recrudescence that occurred between October—December 2020 and February—April 2021, respectively.

## 2.5 | Challenges faced in COVID-19 settings

Physiotherapy plays a crucial role in enhancing the recovery of patients in critical care settings, and it is well known that patients attending rehabilitative activities in intensive care units can gain significant improvements.<sup>63–68</sup> Nevertheless, at the beginning of the COVID-19 pandemic, very little information was available on the physiotherapeutic regimen to be safely adopted in such a population.<sup>69</sup> All those professionals involved in the rehabilitation field were supported in their practice by general recommendations issued in order to face such an unprecedented situation.<sup>70</sup> In the beginning, primary concerns were represented by the availability of personal protective equipment and prevention of healthcare workers' infection<sup>71,72</sup> as vaccines were not available yet. These conditions contributed to the increase in the perception of the burden of work.<sup>73,74</sup> Once the COVID-19 pandemic entered different phases and knowledge increased, healthcare workers had to deal with demanding shifts and harsh working conditions because of wearing their protective equipment for many hours a day. In addition, all the internal hospitals' procedures, including dressing and undressing, have been passed through a substantial remodeling, further increasing



the perception of fatigue and frustration in COVID-19 settings at all levels. From a certain point of view, all the above can be considered limitations of the present study because we have analyzed data from an unprecedented situation. As such, we cannot extend our assumption to a broader context. In this regard, we also highlight that our findings are based on the analysis of case reports; thus, they should be considered cautiously. However, we are confident having illustrated which are—at the time of writing—the initial rehabilitative experiences provided to patients on ECMO support during the COVID-19 outbreak.

### 3 | CONCLUSIONS

Although COVID-19 has challenged hospital settings to manage critical patients, rehabilitative interventions in those who have undergone awake ECMO support to treat COVID-19-related respiratory failure have contributed to improving outcomes, as emerged from the present review. Among the included papers, in three of them<sup>13,17,18</sup> patients gained significant functional improvements precisely because they were involved in early rehabilitation. It should be also highlighted that the findings of the present review seem to support the same hypotheses generated in a previously published research where rehabilitation for patients on awake ECMO was feasible and safe.<sup>48</sup> As a consequence, it seems that there are no substantial differences between rehabilitative practices for patients on ECMO with or without COVID-19. Nevertheless, COVID-19 imposes specific protective measures that represent, per se, a new different, and further challenging operative context. When feasible, ECMO support can be enhanced by physiotherapeutic interventions directed at improving patients' mobility, autonomy, and active participation in the recovery pathway.

#### CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

#### AUTHOR CONTRIBUTIONS

*Concept/design:* Andrea Dell'Amore, Massimiliano Polastri. *Data collection:* Massimiliano Polastri, Antonio Loforte. *Data analysis/interpretation:* Massimiliano Polastri, Justyna Swol, Antonio Loforte. *Drafting article:* Massimiliano Polastri, Justyna Swol, Andrea Dell'Amore. *Critical revision of article:* Justyna Swol. *Approval of article:* Massimiliano Polastri, Justyna Swol, Antonio Loforte, Andrea Dell'Amore.

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