Catarina Morais

A REHABILITATION NURSING APPROACH TO THE CARE OF EXTRACORPOREAL MEMBRANE OXYGENATION PATIENTS
AN INTERNSHIP REPORT

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Porto

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AN INTERNSHIP REPORT

Ana Catarina Carvalho Morais

Internship report in the scope of the Master's Degree in Rehabilitation Nursing, guided by Professor Catarina Ribeiro, co-guided by Professor Pedro Barbosa and presented to the Escola Superior de Saúde de Santa Maria.

May 2023

Porto

A man's dream will never die!

Eiichiro Oda

To Ian and Olivia (fictitious names), for allowing me to be part of such a fragile phase of your lives. Olivia, you are a force of nature! Ian, for those who read this, you will never be forgotten, and you were never just a patient. To both, on behalf of all the patients and families who go through the ICU, especially patients on ECLS, who have inspired me to strive to be better.

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E, em último, mas sempre em primeiro na minha vida, à família, aos pais e irmã. É por vocês e para vocês. Nunca poderei compensar a eterna gratidão que sinto por serem vocês, Francisco, Teresa e Cláudia, a assumirem este papel na minha vida.

KEY TO ABBREVIATED TERMS AND ACRONYMS

ADL	Activities of Daily Living
BiVAD	Biventricular Assist Device
CPAx	The Chelsea Critical Care Physical Assessment Tool
ECLS	Extracorporeal Life Support
ECMO	Extracorporeal Membrane Oxygenation
HF	Heart Failure
ICU	Intensive Care Unit
ICU-AW	Intensive Care Unit acquired weakness
LVAD	Left Ventricular Assist Device
MBS	Borg Modified Scale For Dyspnoea
MCS	Mechanical Circulatory Support
MMSE	Mini-Mental State Examination
MRC	Medical Research Council
RASS	Richmond Agitation Sedation Scale
ROSC	Return of Spontaneous Circulation
RPE	The Borg Rating of Perceived Exertion
RVAD	Right Ventricular Assist Device
SpO_2	Peripheral Oxygen Saturation
VAD	Ventricular Assist Device
VA-ECMO	Venoarterial Extracorporeal Membrane Oxygenation
VF	Ventricular Fibrillation
VO_2	Peak Oxygen Uptake
VT	Ventricular Tachycardia
VV-ECMO	Venovenous Extracorporeal Membrane Oxygenation

ABSTRACT

Extracorporeal Life Support devices are utilized as an advanced management strategy for cardiorespiratory failure. It is not a treatment but rather a replacement of heart and/or lungs function while the organs are healing. During this period, patients are typically confined to the Intensive Care Unit and are at risk of complications related to critical care stay and limited body movement. Rehabilitation nursing has been shown in the literature to play an essential role in preventing complications and improving the clinical status of critically ill patients. However, the literature is limited regarding the role of rehabilitation nursing in patients implanted with Extracorporeal Life Support devices. The overall objective of this report is to reflect if rehabilitation nursing has the same positive outcomes in patients with Extracorporeal Life Support devices and what interventions are best to provide optimal conditions for their clinical improvement.

To achieve the objective of this report, firstly, we conducted a general search on major considerations regarding Extracorporeal Life Support implanted patients. Then, we conducted an integrative review of the literature using two reference databases: EBSCO and PubMed. We applied this knowledge to a practical field and conducted a case study on a Biventricular Assist Device implanted patient, following the Care Guidelines. We finalize this report with a reflection on the specific competencies of the specialist nurse in rehabilitation nursing and how they were developed during the internship.

Through this work, we have discovered that rehabilitation nursing has a significant impact on these patient's pathway, including increased muscular strength, reduced duration of mechanical ventilation, and shortened hospital length of stay with almost no adverse events reported. However, since the literature on this subject is scarce, we understand that rehabilitation nursing work is just beginning, and more research should be done and published on these complex patients.

KEYWORDS: Rehabilitation Nursing, Critical Care, Extracorporeal Membrane Oxygenation, Competency-Based Education.

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INTRODUCTION

This internship report was completed as part of the Master's degree in Rehabilitation Nursing program at the Escola Superior de Saúde de Santa Maria. It was conducted within the framework of the Internship Report unit. The report is the culmination of a reflection initiated during an internship that took place from the 2nd of November to the 1st of December 2022 at an Extracorporeal Membrane Oxygenation (ECMO) reference centre in the United Kingdom. The internship was carried out under the guidance and supervision of Master Catarina Ribeiro and Master Pedro Barbosa, who acted as advisor and co-advisor of this report, respectively.

In the face of adversity, humans tend to adapt and find ways to cope with challenges. ECMO was developed to address a challenge related to the need of buying time while the body is healing with the aid of a multidisciplinary approach. ECMO devices became more popular on pandemic times, and people became more familiar with them specially in the COVID-19 pandemic. However, as said before, ECMO is not a cure, but rather a device used to buy time. During this time, rehabilitation, among other therapies, plays an important role in providing optimal conditions to lessen the time bought (Abrams et al., 2022; Ferreira et al., 2019).

Rehabilitation has been shown to be effective in reducing complications during ICU stays, including decreasing the incidence of ICU-Acquired Weakness, improving functional capacity, decreasing the number of ventilator days, and increasing the discharge to home rate for patients with critical illnesses (Zhang et al., 2019). Rehabilitation is also safe, feasible, and cost-effective in the ICU setting (Chiarici et al., 2019). Hence, it becomes imperative to inquire whether rehabilitation interventions yield similar positive outcomes for Extracorporeal Life Support (ECLS) implanted patients.

To comprehend what should be expected from specialist nurses in the field of rehabilitation nursing, to provide optimal care for ECLS implanted patients and contemplate upon the most effective strategies for achieving improved outcomes, several objectives were formulated:

- Understanding the patient alongside the ECMO device, what should we be aware of, and what considerations should be addressed in the treatment of these patients;

- Describing and analysing the existing scientific literature about rehabilitation in ECMO patients, with the aim of identifying the benefits of rehabilitation and weighing them against possible adverse events;
- Comparing the results of the literature review to what is done in practice at the internship placement;
- Understanding the role of the specialist nurse in rehabilitation nursing in the care of ECMO implanted patients and exploring how we can develop and improve our practice with the available information.

To answer these goals, this internship report is divided into three parts.

The first part provides a conceptual framework for the report, including a brief history of ECMO, clarifying some concepts about ECMO and Biventricular Assist Device (BIVAD) devices, discussing the major complications that occur in these patients, and identifying important considerations when rehabilitating these patients.

The second part of the report details the methodological process and addresses the second and third goals. This section comprises two chapters, both of which have been written following the article framework, with the intention of submitting them as separate articles for publication in scientific journals. The first chapter is an integrative review that analyses and identifies rehabilitation programs discussed in the literature, their benefits, and reported adverse events. This integrative review complied with the recommendations of Toronto and Remington (2020) and the Preferred Reporting Items for Systematic Reviews and MetaAnalyses: The PRISMA Statement (Moher et al., 2010). The second chapter is a practical standpoint of a rehabilitation program applied during the internship to a BiVAD implanted patient. This was operationalized with a case report following the recommendations of CARE clinical case reporting guidelines (Gagnier et al., 2013).

In the third part of this report, the focus shifts from the patient to the specialist nurse in rehabilitation nursing. This section reflects on the specific competencies of this role and how they were addressed during the internship. It also suggests how they can be improved in the critical care setting.

Lastly, the report concludes with Final Remarks, wherein we contemplate and synthesize the key points discussed throughout the report. We also put forward recommendations for future practice based on the knowledge acquired during the

internship and the construction of this report, aiming to potentially apply them in future endeavours.

1. PART I - THE ECMO PATIENT

In this chapter, we review the principles and the existing literature on the Extracorporeal Membrane Oxygenation (ECMO) device, ECMO patients' profile and the rehabilitation practices on these patients. So, we take a brief look into the history of ECMO, explain the existing types of ECMO and do a resume on the major considerations of rehabilitating an ECMO patient.

To tell a story, it's important to start from the beginning. Therefore, to comprehend all the concepts related to ECMO, it is important to understand how and why it all began.

1.1. A BRIEF LOOK INTO HISTORY OF ECMO

The first glimpse of what ECMO would be started in the late 1930s when John Gibbon, a cardiothoracic surgeon, hypothesized that an effective circuit supporting cardiorespiratory function would allow complex surgical procedures. Then, he began to experiment with extracorporeal blood-flow circuits (Patel et al., 2019).

After two decades of experimentation, in 1953, Gibbon was able to successfully perform the first successful surgery using an extracorporeal device, which is why the invention of the first heart-lung machine is credited to him (Bauer & Tchantchaleishvili, 2018). With this machine and other similar oxygenators of the same era, there were issues related to the requirement of contact between blood and gas, which increased the risk of haemolytic, bleeding and emboli issues. Therefore, the use of the machine was limited to a few hours (Shah et al., 2021).

Since then, efforts were made to create a membrane that would allow blood oxygenation without requiring contact between blood and gas (Patel et al., 2019). By the late 1960s, ECMO technology had been improved and began to be used in the organ support of neonates, during surgeries. Only ten years later was reported the first successful use of ECMO in a neonate in an ICU setting by the hand of whom would be permanently known as the father of ECMO, the cardiothoracic surgeon Robert Bartlett (Patel et al., 2019). In regard to adult patients, by that time, published studies had shown no survival

benefits, so the use of this technology in the adult population significantly slowed during decades (Shah et al., 2021).

In 1989, the Extracorporeal Life Support Organization was formed with the aim of organizing and spreading knowledge about ECMO and, consequently, increasing the use of this technique (Meireles et al., 2021). Thus, despite early disappointments in adult critical care, ECMO therapy continued to develop with improved materials and evolved mechanisms.

When the H1N1 influenza pandemic occurred in 2009, a new era was born when ECMO was successfully used in the treatment of severe respiratory failure (Sakurai & Singhal, 2022). Due to COVID-19 pandemic in 2020, a substantial number of studies were published demonstrating the effectiveness, safety, and feasibility of ECMO therapy, confirming that this complex therapy is here to stay. Although in both pandemics, there was an emphasis on ECMO as a substitute for respiratory function, it is important to note that ECMO serves multiple functions, depending on the type of ECMO.

1.2. TYPES OF ECMO

To provide a comprehensive understanding of the different types of ECMO, it is important to clarify certain concepts. Mechanical Circulatory Support (MCS) devices are advanced instruments designed to compensate for the impaired heart function of a patient with heart failure (HF). A variety of MCS devices are available for patients with HF (Rateesh et al., 2015). These devices may be either extracorporeal, such as the Extracorporeal Life Support (ECLS) devices used for HF, or intracorporeal, like the total artificial heart (Salter et al., 2023). For the purposes of this report, we will focus solely on the extracorporeal branch of MCS.

Despite being often mistaken as synonyms, ECMO is not the same as ECLS. As a matter of fact, ECLS, by definition, means Extracorporeal Life Support and includes several types of life support devices, one of which is ECMO (Meireles et al., 2021).

ECMO is an advanced therapy used in the management of cardiorespiratory critically ill patients. This complex therapy is used when respiratory and/or cardiovascular failure is refractory to conventional management (Sakurai & Singhal, 2022).

Depending on the ECMO configuration, it can replace the lung and/or heart function, while buying time to reverse the underlying disease processes or causes (Worku et al., 2023). If a resolution is no longer possible, ECMO can be used as a bridge to transplant (Keshavamurthy et al., 2021).

Three major components make up the ECMO: cannulas, a centrifugal pump, and a blood oxygenator. The cannulas are connected to the body and are responsible for draining blood out of a vein and returning it after going through the circuit. If it returns to another vein, then it is a Venovenous Extracorporeal Membrane Oxygenation (VV-ECMO) and its objective is to replace the lung function; if it returns to an artery, then it is a Venoarterial Extracorporeal Membrane Oxygenation (VA-ECMO) and it provides cardiorespiratory support, replacing the left heart function (Duinmeijer et al., 2023; Meireles et al., 2021; Sakurai & Singhal, 2022).

The centrifugal pump provides negative pressure to remove the blood in the drainage cannula and positive pressure to return the blood in the return cannula after oxygenation (Duinmeijer et al., 2023; Meireles et al., 2021; Sakurai & Singhal, 2022). The oxygenator is composed of a polypropylene or polymethylpentene membrane, where gas is exchanged to remove CO2 and oxygenate blood. The oxygenated blood is, then, returned to the vascular system (Duinmeijer et al., 2023; Meireles et al., 2021; Sakurai & Singhal, 2022).

Apart from the ECMO configuration, it's important to distinguish between central or peripheral ECMO. Therefore, central and/or peripheral ECMO refers to the location where the cannulas are introduced. When it's central ECMO, it indicates that one or more cannulas are introduced in a major vessel (e.g. the aorta artery) or in a heart chamber (e.g. the atrium or ventricle) through a thoracic incision (Radakovic et al., 2021). The peripheral configuration, however, refers to the insertion of one or more cannulas into a blood vessel outside the thoracic or abdominal cavity (Oliveira et al., 2021; Radakovic et al., 2021). The introduction sites and flow circuit direction are based on several factors, including the type of ECMO (VA or VV) and the patient's age or condition (e.g. pregnancy or obesity which can increase abdominal pressure) (Oliveira et al., 2021).

The most commonly used blood vessels are the femoral and jugular ones (Oliveira et al., 2021). When both the return and drainage cannulas are located in the femoral vessels, it's called femoro-femoral cannulation (Burrell et al., 2018). When the drainage

cannula is located in the femoral vein/artery and the return cannula is located in the jugular vein, it's called femoro-jugular cannulation (Crivellari & Pappalardo, 2018).

There is one exception to this rule, where two site cannulation is not necessary – the dual lumen cannula. Although it's not very commonly used, the dual lumen cannula has two interior lumens, in which one is used for drainage and the other for return (Ngai et al., 2018; Oliveira et al., 2021).

The design of the rehabilitation program should consider the cannulation sites and the type of ECMO, keeping in mind the particularities and limitations of each kind of ECMO, cannulation and all dimensions of the patient (Eden et al., 2017).

1.3. THE BIVAD

Initially, this report was intended to focus solely on ECMO patients. However, due to various reasons related to the internship, including the absence of awake rehabilitating ECMO implanted patients at the time that the internship took place, the scope of the report was expanded to include Biventricular Assist Device (BiVAD) implanted patients as well.

In the case of biventricular failure requiring MCS, the typical initial approach is VA-ECMO. However, it presents its own set of challenges, including increased left ventricular afterload and consequently, worsening native cardiac function, the requirement of systemic anticoagulation which can lead to increased bleeding complications, and the use of an oxygenator, which is unnecessary in some patients (Weber et al., 2022). Modern temporary Ventricular Assist Devices (VADs) can address these issues and provide comparable hemodynamic support (Salter et al., 2023).

In the extracorporeal branch of MCS, one of the modern temporary VADs is the Left Ventricular Assist Device (LVAD), an extracorporeal device that provides support to the left ventricular function of patients with end-stage HF (DeFilippis et al., 2019). Following LVAD support, around 40% of patients develop right ventricular failure (Stephens et al., 2021). Currently, if pharmaceutical therapies fail, there are no durable implantable Right Ventricular Assist Devices (RVADs) commercially available. Thus, clinical teams have been using LVADs as an RVAD to provide simultaneous biventricular support (Stephens et al., 2021). Biventricular support is achieved with

BiVAD, which combines both the LVAD and RVAD, providing MCS to both systemic and pulmonary circulations (Gregory et al., 2018). However, using an LVAD for RVAD purposes presents potential hazards, because the pulmonary and systemic circulations have different physiological components, including type of blood, pressures, and volume of circulation. Clinicians must reduce speed or restrict RVAD outflow to decrease outlet pressure for pulmonary support, which carries risks, including the incidence of thrombogenesis around mechanical bearings or in cannula folds (Gregory et al., 2018).

We hope that the development of a reliable and effective BiVAD continues, at the same time as clinical experience improves and more investigation is published concerning other conditions to improve survival rates and quality of life such as rehabilitation of these critically ill patients. In this sense, further on, we will describe a case report regarding a rehabilitation program in a BiVAD implanted patient.

1.4. THE PATIENT IN ECMO – WHAT'S AT RISK?

To achieve positive results, clinical team aims to provide optimal conditions for the recovery of the patient. In this context, it's important to have present the most common complications, as well as most frequent causes of death while on ECMO to prevent them as much as possible.

Since the interaction of blood and the biomaterial surface of the ECMO circuits provokes a state of hyperinflammation prone to thrombosis, anticoagulation is required to prevent thrombosis of the circuit (Kumar & Maskey, 2021). On the other hand, the administration of anticoagulation has to balance the haemorrhagic risks for the patient (Kumar & Maskey, 2021) and it's not easy to achieve this equilibrium. So, it's not a surprise that, according to Treml et al. (2022), the most frequent adverse events during ECMO support was haemorrhage and thrombosis. This is particularly important when the manufacturers' advise for length of stay of the ECMO device, including the cannulas, is a maximum of 30 days (Oliveira et al., 2021). However, recent literature shows that, in some cases, the duration of the ECMO has been successful beyond that time, reaching periods of 100 or more days (Xu et al., 2021).

Still related to haemorrhage and thrombosis, other complications are common, including respiratory complications (pulmonary haemorrhage and pulmonary embolism), gastrointestinal haemorrhage, cerebral haemorrhage or stroke (Oliveira et al., 2021).

Besides anticoagulation complications, being in the ICU entails, per se, a risk of infection higher than general in-patient hospital population (Dasgupta et al., 2015). The risk factors associated with nosocomial infections in the ICU patients are often present in ECMO patients as well, including immunosuppressive therapy, surgical operation site, disturbance of consciousness, blood transfusion, multiple organ dysfunction syndrome, treatment with three or more antibiotics and invasive procedures like mechanical ventilation, tracheostomy, nasogastric catheter, urinary catheter, and central venous catheter (Wang et al., 2023). In ECMO patients, the risk for nosocomial infections is even more increased due to the presence of cannulas in continuing open wounds, especially if we're talking about femoral cannulas (Oliveira et al., 2021). This is especially significant, considering that patients with nosocomial infections have prolonged lengths of stay in ICU and hospital, increased hospitalization, antibacterial drug costs and mortality in the ICU compared to those without nosocomial infections (Wang et al., 2023). Mortality has a particularly high weight in ECMO patients, reaching percentages of 50%-70% in VA-ECMO adult patients (Makhoul et al., 2021) and 39% in VV-ECMO, according to Extracorporeal Life Support Organization registry reports (Friedrichson et al., 2021).

Looking at the patients in a holistic perspective means looking at their surroundings, including their family. Tramm et al. (2017) published a study where they perform a semi-structured interview to family members of ECMO patients to find out more about their experiences and their needs while their loved one was going through ICU hospitalization and ECMO implantation. This study reports several stress factors related to the clinical condition of the patient and their own role in the situation. Related to the clinical condition, when the patient was sedated or delirious, family members felt that the stress continued for them whereas it stopped for the patient and this stress was particularly related to the prolonged risk of dying, the ICU environment, changes in the condition or complications. The waiting in itself, for news, for the improvement of the patient or even for seeing the patient while in the waiting room was a stressor (Tramm et al., 2017). Related to their role in the situation, family members struggled to perform multiple roles as Tramm et al. (2017) describes: the decision maker (while the patient was

unable to make life affecting decisions); the carer (since family members stayed with the patient throughout the day during hospitalization); the manager (while they stayed with the patient, they also had to manage their own lives, their work, look after dependents and perform house duties, all at the same time) and the recorder (since most family members kept a diary or photos of the time patient spent in the ICU but they were conflicted about sharing that with the patient and reminisce about those hard times as, at the same time, the diary kept them sane and helped cope with the journey they went through). Tramm et al. (2017) confirm that nurses, and other healthcare professionals involved in the care and treatment of ECMO patients, "must pay attention to individual needs of the family and activate all available support systems to help them cope" (Tramm et al., 2017, p. 3).

When the ECMO patients are 'Awake', besides the challenges concerning their own clinical situation and their family, the patients in themselves present their own challenges. There is a risk of unsupervised body movements which can result in invasive device displacement, which is why close vigilance is important in these patients. In addition, the 'Awake' condition raises more concerns related to patient discomfort, pain, and anxiety, which must be attended (Langer et al., 2016). Having said that, it's important to acknowledge that having the patient awake has its own advantages, particularly concerning the ability to actively collaborate with the rehabilitation specialists and follow a rehabilitation program (Langer et al., 2016).

Considering the risk of complications and the high mortality rate in ECMO patients, it's important to investigate how it can be prevented and what role does rehabilitation have in providing the best outcomes for the patient.

Furthermore, we consider that investigation regarding ECMO management should prioritize the individual needs, clinical condition, and environmental dynamics of patients undergoing ECMO treatment. Understanding these aspects is crucial, as we discovered a scarcity of literature on this subject. By conducting further research in this area, we can enhance our understanding of how ECMO affects patients and tailor care accordingly.

1.5. REHABILITATING THE PATIENT IN ECMO – IMPORTANT CONSIDERATIONS

The rehabilitation of an ECMO patient is relatively recent in the same way as the 'Awake' ECMO patient is (Yu et al., 2021). Formerly, the ECMO device was only used after failure of mechanical ventilation, so most patients were highly sedated and paralysed, making it difficult to perform rehabilitation sessions. However, in recent years, the treatment course has been changing and ECMO is often started earlier, or sedation has been redrawn as soon as possible to avoid detrimental effects of mechanical ventilation (Langer et al., 2016), facilitating early ambulation and rehabilitation, expectedly improving both short- and long-term outcomes (Yu et al., 2021).

Prior to design a rehabilitation program specific for the ECMO patient and before every rehabilitation session, specialists recommend performing pre-treatment checklists, having present experienced staff with the appropriate knowledge and skills. Furthermore, it's important to recognize that any team member present during the session can stop it at any time if concerns arise. The principal concern of the rehabilitation team must be related to the safety of the patient and, so, safety pre, during and after session checklists are advised (Eden et al., 2017).

Preceding the beginning of the session, specialists advise to plan what's the aim of the session, how it's going to be accomplished and what role and responsibility every member of the team has (Eden et al., 2017). Additionally, before the session, patient should have the blood pressure, heart rate, peripheral haemoglobin oxygen saturation or ECMO flows monitored to establish a pattern. These parameters should continue to be monitored during session to identify any major shifts and responded to appropriately, and after session to detect any delayed adverse response to exercise (Eden et al., 2017). Every change in the parameters should be addressed, but it does not necessarily warrant an immediate termination of the session. Due to increase cardiac output, oxygen consumption and carbon dioxide production during exercise, changes in the parameters could just mean a need for increasing ventilation or ECMO support (Eden et al., 2017; Salna et al., 2020). If the patient continues to exhibit the identified adverse change despite basic interventions, such as an increase in FiO_2 in the mechanical ventilation, an increase

in ECMO sweep gas flow or blood flow, then it is necessary to terminate the rehabilitation session (Eden et al., 2017).

Apart from monitoring parameters, as talked about, there is a risk of cannula displacement, bleeding from cannulation sites or kinks and bends in cannulas, so staff should confirm if cannulas are well-secured and should continue monitoring blood flow and line pressures (Salna et al., 2020).

After addressing the safety measures, a question arises on which rehabilitation interventions are effective and must be part of a rehabilitation program for ECMO patients. The following chapter addresses this question, exploring which interventions are being implemented in published rehabilitation programs.

As previously stated, the rehabilitation of an ECMO patient is relatively recent so the scientific literature concerning this topic is scarce. So, unlike previous references, the data collection for the integrative review did not consider publication date in order to include as much information as possible.

2. PART II – METHODOLOGICAL PROCESS

This chapter provides a formal description of the investigative process undertaken in this report. As previously mentioned, this report is related to an internship conducted at an ECMO reference centre in the United Kingdom. The main goal of the internship was to gain an understanding of and report on the specificities and benefits of rehabilitation in patients implanted with ECLS. In order to fully comprehend and achieve the potential of the internship, a thorough analysis of relevant literature about rehabilitation of ECMO patients is conducted in this chapter through an integrative review. This integrative review complied with the recommendations of Toronto and Remington (2020) and the Preferred Reporting Items for Systematic Reviews and MetaAnalyses: The PRISMA Statement (Moher et al., 2010).

Throughout the duration of the internship, the progress of a BiVAD implanted patient was closely monitored, and a study case was produced, which is outlined in the second part of this chapter. The case report was operationalized following the recommendations of CARE clinical case reporting guidelines (Gagnier et al., 2013). To ensure consistency and maintain referential integrity throughout the report, all references cited in the articles are consolidated at the end of the report along with other references. The formatting of the integrative review and the case report adheres to the specified guidelines and orientations of the report.

2.1. REHABILITATION OF EXTRACORPOREAL MEMBRANE OXYGENATION IMPLANTED PATIENTS: AN INTEGRATIVE REVIEW

Abstract

Background: ECMO is an advanced management strategy used in acute cardiac, pulmonary, or cardiopulmonary failure patients. It enables patients to remain awake and actively participate in their treatment. Consequently, this presents an opportunity for patients to engage in a rehabilitation program that could hold the potential to influence the post-ECMO trajectory in a positive manner.

Objective: To identify and analyse the scientific literature pertaining to rehabilitation programs implemented in ECMO patients, their interventions, and potential outcomes.

Methods: We retrieved studies from EBSCO Host aggregator of databases for articles since inception until October 7, 2022, according to the recommendations of Toronto and Remington (2020) and the Preferred Reporting Items for Systematic Reviews and MetaAnalyses: The PRISMA Statement (Moher et al., 2010).

Results: Sixteen studies, representing 560 patients implanted with ECMO devices, were included. The findings from these studies demonstrated that rehabilitation programs led to enhancements in muscle strength, preservation of physical condition before hospitalization, decreased duration of mechanical ventilation, shortened hospitalization period, and reduced length of stay in the Intensive Care Unit (ICU) for ECMO patients undergoing rehabilitation, with minimal to no adverse events reported.

Conclusion: The findings of the present review support the hypothesis that rehabilitation is safe and can bring positive outcomes to patients on ECMO when being treated with an experienced team.

Keyword: Extracorporeal Membrane Oxygenation; Rehabilitation Nursing; Practice Patterns, Nurses'

2.1.1. Introduction

Life expectancy in evolved countries has been increasing in the last decades (Roser et al., 2019). One of the most important reasons is the scientific and technological advances in healthcare and the improvement of treatments and management strategies. Among these strategies, one of the most advanced used in ICU is the ECMO device (Ferreira et al., 2019). ECMO is an advanced management strategy used in acute cardiac, pulmonary, or cardiopulmonary failure patients who didn't respond to conventional treatment (Haji et al., 2021). Initially, the use of ECMO was accompanied by high levels of sedation and immobilization, resulting in issues such as Intensive Care Unit acquired weakness (ICU-AW) (Bohman et al., 2022) and prolonged ICU stay, which increases the risk of infection beyond that of the general in-patient hospital population (Dasgupta et al., 2015), particularly associated with devices such as nasogastric catheter, mechanical ventilation, urinary catheter, and central venous catheter (Wang et al., 2023).

Data shows that around 20-50% of critically ill patients experience ICU-AW and that reduces health-related quality of life and increase mortality after discharge (Zhang et al., 2019). Currently, ECMO provides the possibility of sedation and mechanical ventilation weaning since it replaces the function of the organ until full recovery while the rest of organs remain functional (Haji et al., 2021). This allows for early rehabilitation to be treated as priority which can hugely impact the post-ECMO course as it does for non-ECMO critically ill patients (Abrams et al., 2022). The benefits of rehabilitation in non-ECMO critically ill patients range from improvements in patient delirium rates to functional outcomes and initial studies on rehabilitation in ECMO patients has been associated with improvements on patients' functional capacity, muscle strength and prevention of immobility associated complications (Cerier et al., 2022). Whilst there is limited data on the long-term effects of rehabilitation after intensive care discharge, awareness of rehabilitation in ECMO patients is increasing (Naz et al., 2021).

The aim of this integrative review is to identify and analyse the scientific production related to the rehabilitation programs applied in ECMO patients, its interventions and identify its potential outcomes.

2.1.2. Methods

This integrative review comprises studies describing rehabilitation programs in ECMO implanted patients. We retrieved studies from Elton B. Stephens Company (EBSCO) Host aggregator of databases, including Complementary Index; Medical Literature Analysis and Retrieval System Online (MEDLINE) Complete; Academic Search Complete; The Cumulative Index to Nursing and Allied Health Literature (CINAHL) Complete; OpenAIRE; Directory of Open Access Journals; ScienceDirect; ClinicalTrials.gov; MedicLatina; OAIster; Nursing Reference Center Plus; Oxford Medicine Online; OpenDissertations; Networked Digital Library of Theses & Dissertations; SwePub; SciELO. References sections of the retrieved citations and other reviews were also screened. The search went from database inception until October 7, 2022 and this review complied with the recommendations of Toronto and Remington (2020) and the Preferred Reporting Items for Systematic Reviews and MetaAnalyses: The PRISMA Statement (Moher et al., 2010).

The present study was conducted to answer a question according to PICO mnemonic (Population; Intervention; Comparison; Outcome). The PICO question for this study is “What rehabilitation programs offer clinical benefits when applied to adult patients on ECMO?" and is available for consultation in Table 1.

Table 1.

PICO Question

Population	ECMO adult patients
Intervention	Rehabilitation Programs
Comparison	---
Outcome	Clinical benefits

2.1.2.1. Search Strategy

We conducted a search using indexed terms (MeSH) and synonyms, in combination using Boolean operators (AND and OR). The indexed terms were 'Extracorporeal Membrane Oxygenation' (entry terms used: 'ECMO*'; 'ECLS' and 'Extracorporeal Life Support') and 'rehabilitation nursing' and Practice Patterns, Nurses'. Terms related to the outcomes of interest, population or the type of study were not included to increase the results. Given the specificity of the topic and the lack of scientific evidence, the date of publication was not considered in the search results.

For this review, we used the Boolean sentence to search titles, abstracts, and keywords with the purpose of obtaining the maximal number of citations without overly restricting a search that was already confined to a very selective topic.

2.1.2.2. Eligibility Criteria

We searched for studies that reported patients on ECMO, regardless of the type of cannulation, who underwent on rehabilitation programs during ECMO support. According to PICO question, since the elected population is ECMO adult patients, we excluded any paediatric reports (patients aged ≤ 18 years old); since the intervention is rehabilitation programs, we excluded studies who weren't clear about the applied rehabilitation program or did rehabilitation only after ECMO decannulation; since the outcomes were clinical benefits, we excluded studies that didn't measure the outcomes of said program.

For abroad inclusion, all study types were included despite of publication date. We excluded all studies written outside of English, Portuguese or Spanish language and any studies without full text access.

2.1.3. Results

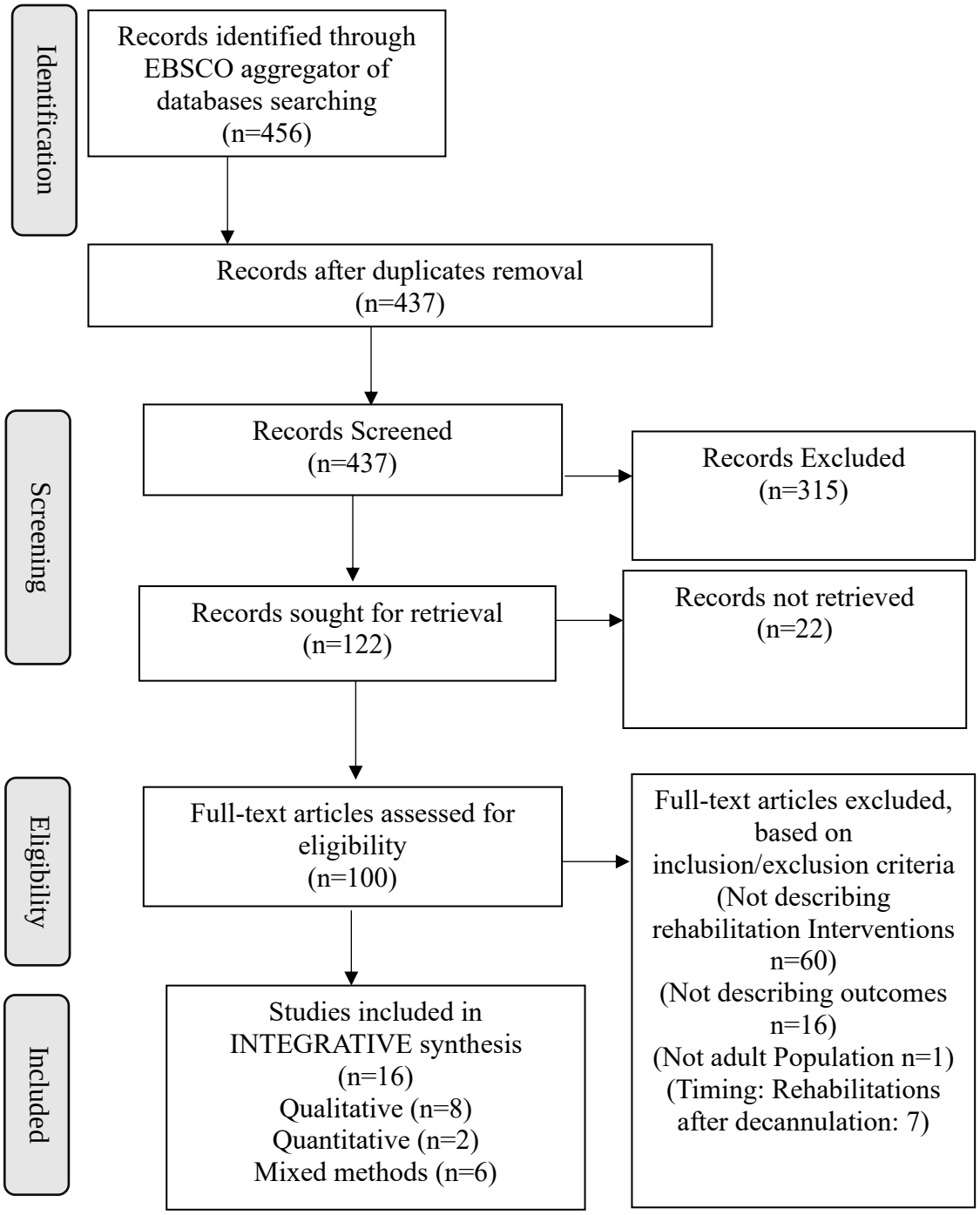
2.1.3.1. Data Analysis

Upon conducting a search using the Boolean sentence, a total of 456 articles were identified. Subsequently, after eliminating duplicates, the number of reports available for screening reduced to 437. Following an analysis of the titles and abstracts in accordance with the PICO question, 315 articles were excluded: 72 articles did not meet the population criteria, 199 articles did not meet the intervention criteria, 16 articles did not meet the outcome criteria, and 28 articles were excluded for other reasons (8 were conference presentations, 12 were letters to the editor and 8 were inaccessible). As a result of excluding these 315 articles, 122 articles remained for retrieval. Of these, 22 couldn't be retrieved so they were excluded; 100 full-text articles were analysed and 84 were excluded (1 article was not conducted in adult population; 60 articles were excluded due to not describing rehabilitation interventions;16 articles did not describe outcomes and 7 performed rehabilitation interventions only after ECMO decannulation).

As shown in Figure 1, 16 studies were included in our final revision. Data on the author and year of publication, study design or source of information, number and characteristics of the study populations, comparison groups (when available) and rehabilitation protocols were extracted. Additionally, we extracted data on patient outcomes, feasibility, safety, hospital outcomes, and mortality.

Figure 1.

PRISMA Flow-Chart



2.1.3.2. Characterization of included studies

For the total of 16 studies included in this review, 8 of them were qualitative studies (6 single case studies and 2 case series); 2 were quantitative studies (1 retrospective cohort study and 1 pilot randomised control trial) and 6 studies had a mixed methods design, all of them retrospective observational cohort studies. No case series included more than three subjects, and the largest study included 167 subjects. Since the included studies are very heterogeneous, it became impossible to analyse data through a statistical point of view. Therefore, the extracted data were analysed qualitatively.

The majority of studies were conducted in the United States of America (7 studies) and then Republic of Korea (2), and each one of the following countries contributed with one study: Italy, United Kingdom, Australia, Germany, China, Canada and Japan.

Of the 16 studies included, data were provided and analysed on 560 patients, including 400 patients who underwent a rehabilitation program and 160 patients who didn't, during ECMO support.

To ensure clear organization, we divided the results of the studies into five categories. The first category focuses on the rehabilitation program and its interventions, the second category pertains to the assessment tools used in the included studies, the third category relates to the benefits of the program, the fourth category addresses any adverse effects found in the studies related to the rehabilitation program, and the fifth category pertains to considerations about the type of cannulation. All the results presented in the categories can be viewed in Table 2.

2.1.3.3. Rehabilitation Programs

All 16 studies performed rehabilitation under a gradually-phase program, with different techniques depending on patient tolerance and capacity (Abrams et al., 2014; Andersen et al., 2022; Bonizzoli et al., 2019; Chavez et al., 2015; Cork et al., 2014; Han et al., 2022; Hayes et al., 2021; Hermens et al., 2015; Ko et al., 2015; Li et al., 2022; Mark et al., 2021; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018). Studies used different techniques and exercises:

- 10 studies included passive range of motion exercises during sedation weaning and clinical stability (Abrams et al., 2014; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Wells et al., 2018);
- 11 studies included active-assisted range of motion exercises (Abrams et al., 2014; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Mark et al., 2021; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018);
- 5 studies included active-resisted range of motion exercises (Hayes et al., 2021) including leg press, squats (Hermens et al., 2015) or bed bike (Hermens et al., 2015; Li et al., 2022), leg lifts, ankle rolls, and arm lifts (Turner et al., 2011) and elastic band (Ko et al., 2015);
- 13 studies included sitting on the edge of bed (Abrams et al., 2014; Andersen et al., 2022; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Li et al., 2022; Mark et al., 2021; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018);
- 5 studies included transfer to sitting in chair (Abrams et al., 2014; Bonizzoli et al., 2019; Han et al., 2022; Hermens et al., 2015; Rickelmann & Knoblauch, 2018);
- 14 studies included sit to stand up (Abrams et al., 2014; Andersen et al., 2022; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Li et al., 2022; Mark et al., 2021; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018);
- 7 studies included marching in place (Abrams et al., 2014; Bonizzoli et al., 2019; Han et al., 2022; Ko et al., 2015; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Wells et al., 2018);
- 11 studies included ambulation (Abrams et al., 2014; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018);
- 2 studies included respiratory exercises, including sputum clearance (Cork et al., 2014; Hermens et al., 2015) and ventilator hyperinflation (Cork et al., 2014).

2.1.3.4. Assessment Tools

According to Toronto and Remington (2020), the primary goal of integrative reviews is to facilitate the process of accessing and analysing diverse sources of information in order to gain a comprehensive understanding of a topic through synthesis. To achieve this, one of the challenges is to organize that information coming from different sources and using different methodologies. In these included studies, the assessment tools differ. One of the most common assessment tools was the maximum activity achieved throughout the program (Abrams et al., 2014; Andersen et al., 2022; Bonizzoli et al., 2019; Chavez et al., 2015; Hayes et al., 2021; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Rickelmann & Knoblauch, 2018; Wells et al., 2018); some studies utilized distinct parameters, such as mechanical ventilation duration and ECMO duration (Bonizzoli et al., 2019; Han et al., 2022), length of stay and ICU mortality (Bonizzoli et al., 2019; Turner et al., 2011); muscle strength evaluation (Chavez et al., 2015; Han et al., 2022; Hermens et al., 2015; Nakanishi et al., 2020) that was evaluated through Medical Research Council (MRC) scale (Han et al., 2022; Hermens et al., 2015; Nakanishi et al., 2020); respiratory parameters such as Chest radiography, respiratory rate, maximum tidal volume (Cork et al., 2014; Hayes et al., 2021; Nakanishi et al., 2020), and one study used the Mini-Mental State Examination (MMSE) (Han et al., 2022).

2.1.3.5. Benefits of Rehabilitation Programs

Studies used different variables to express their results concerning rehabilitation sessions. Eight studies registered level of mobility from bed-level assisted exercises to ambulation, depending on clinical stability and tolerance (Abrams et al., 2014; Andersen et al., 2022; Chavez et al., 2015; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Rickelmann & Knoblauch, 2018; Wells et al., 2018) with 34 patients reaching ambulation level of mobility. The studies included in this review showed benefits of rehabilitation such as lower duration of ECMO support (Andersen et al., 2022; Bonizzoli et al., 2019; Han et al., 2022); improvement in lung compliance (Cork et al., 2014); lower noradrenaline dosage, less sedation and lower ECMO fresh gas flow linked to higher mobility levels (Hayes et al., 2021); improved muscle strength (Han et al., 2022; Hermens

et al., 2015) or maintenance of physical condition before hospitalization (Nakanishi et al., 2020); lower duration of mechanical ventilation (Bonizzoli et al., 2019), and reduced length of stay (Bonizzoli et al., 2019; Turner et al., 2011).

2.1.3.6. Adverse Events

Most patients included in the studies didn't present any complications (Abrams et al., 2014; Bonizzoli et al., 2019; Cork et al., 2014; Hayes et al., 2021; Nakanishi et al., 2020). Nonetheless, some studies reported punctual complications related to hemodynamic and respiratory stability (Andersen et al., 2022; Rickelmann & Knoblauch, 2018; Wells et al., 2018), complaints from patients such as fatigue and breathlessness (Mark et al., 2021) and circuit events namely obstructing thrombus and large haematomas (Hermens et al., 2015). One study (Chavez et al., 2015) mentioned hemodynamic instability but it wasn't specific about the event; four studies didn't mention any patient or circuit-related complications or the lack of them (Han et al., 2022; Li et al., 2022; Munshi et al., 2017; Turner et al., 2011). One study reported three potential safety events (one tachycardia and two tachypnoea) during rehabilitation but a fast recovery and no clinically significant adverse events secondary to that (Ko et al., 2015). All these events are available in detail in Table 3 for consultation.

2.1.3.7. Type of Cannulation

Bonizzoli and colleagues (2019) compared the type of cannulation and concluded that, despite increased risk of exteriorising the cannula, there is no difference with the progression of the program between patients with femorofemoral cannulas or dual-lumen jugular ones. Another study had a total of seven out of eight patients with femoral cannulation, reporting that three of them achieved standing throughout 11 sessions and one patient walked (Ko et al., 2015). Wells and colleagues (2018) published a study where they report that mobilization including ambulation was accomplished in patients with femoral cannulation, from which 13 of them had bifemoral cannulation sites with no reported adverse events. However, one study showed concerns of rehabilitating patients with femoral insertion of cannulas, since they had complications in one patient with a

large rectus haematoma and another one with an obstructing thrombus in the return cannula, both with bi-femoral cannulation (Hermens et al., 2015).

Table 2.

Characteristics Of The Studies Included In The Review

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
Abrams et al. (2014)	Quantitative Retrospective cohort study	100 patients receiving ECMO, from which 35 participated in active physical therapy.	1. No mobilization or passive range of motion of extremities. 2. Turning in bed (including active-assisted range of motion of extremities). 3. Sitting in bed with the head of bed elevated. 4. Sitting on the edge of the bed with feet on floor. 5. Out of bed sitting in a chair. 6. Standing out of bed. 7. Marching in place. 8. Ambulating.	Max Activity: 11 patients achieved bed-level active-assisted range of motion; 2 patients - sitting in bed; 1 patient - sitting at the edge of the bed; 3 patients – standing; 18 patients – ambulation.	No patient-related or circuit-related complications reported.
Andersen et al. (2022)	Qualitative Single Case Study	1 patient	While on ECMO: 1. Consulted with nursing; patient to chair via ceiling lift 2. Initial evaluation including sitting edge of bed; 3. Sit-to-stand with 3-person assistance.	Patient progressed to standing with assistance from 3 staff members while on full mechanical ventilation on rehabilitation day 6 and was successfully decannulated from ECMO on rehabilitation day 8, with a total of 6 rehabilitation sessions.	Patient faced desaturations of Peripheral Oxygen Saturation (SpO_2) to 75% during activity, respiratory rate increased from 25 to 50 breaths/min, heart rate increased from 110 to 150

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
					beats/min and prolonged recovery (5-8 minutes).
Bonizzoli et al. (2019)	Mixed Methods Retrospective observational study	101 ECMO patients with refractory ARDS	To record the level of mobilization achieved, this ordinal scale was used: 1. No mobilization or passive range of motion of extremities. 2. Turning in bed (including active-assisted range of motion of extremities). 3. Sitting in bed with the head of bed elevated. 4. Sitting on the edge of the bed with feet on floor. 5. Out of bed sitting in a chair. 6. Standing out of bed. 7. Marching in place. 8. Ambulating.	Early physiotherapy (within the first week) was associated with lower duration of ECMO support, mechanical ventilation, and length of stay. In-ICU mortality was not different between the two subgroups. At first physiotherapy session, most patients were able to perform exercise in bed, while at discharge 37.3% were able to actively participate in physiotherapy.	No patient-related or circuit-related complications reported.
Chavez et al. (2015)	Qualitative Case Series	2 patients	1. Chair position in bed (Range of Motion; Raise Head Of Bed; Raise Head Of Bed; Progress to bed in chair). 2. Sitting at edge of bed (sit upright at the edge of bed with feet on floor or a platform; test lower extremity strength). 3. Stand/pivot to chair.	Patient A wasn't considered since he wasn't on ECMO support. Patient B gained strength to hold trunk upright in a sitting position for 40 seconds in the first days of rehabilitation. Then, progressed and gained strength to tolerate sitting at the edge of the bed for 10	Mobility progression was gradually due to hemodynamic instability, not clear in the article.

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			4. Ambulation (goal of 200+ feet 2-3x per day).	minutes, 2 times per day over consecutive days. The patient had significant gains in static and dynamic sitting, demonstrating an increase in trunk stabilization, and by admission day 26, he was standing for 45 seconds 3 times per day. Mobility to the point of ambulation is a feasible clinical expectation when patients present with substantial acute respiratory and cardiac failure and are managed with MCS.	
Cork et al. (2014)	Qualitative Single Case Study	1 patient	Chest Physiotherapy: Positioned in supine, 10° head down; Ventilator hyperinflation (increase in set inspiratory pressure to 30 cmH2O in pressure-controlled mode); optimally timed expiratory chest wall shaking to maximize expiratory flow without increasing peak pressure; Secretions were removed with closed circuit suctioning plus	These interventions were well tolerated by the patient with no physiological disturbances observed. The patient's chest radiography improved with subsequent improvement in lung compliance, and sedation was reduced to allow spontaneous breathing. Ventilatory mode was then switched to pressure support,	No physiological disturbances observed.

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			saline lavage (5 ml per cycle of CPT). The cycle was repeated until minimal secretions were obtained by suction (typically 3–6 cycles lasting 30 minutes in total). Treatment was performed two to three times daily for the following 13 days.	and TVs of 400ml were achieved.	
Han et al. (2022)	Qualitative Single Case Study	1 patient	1. No mobilization or passive range of motion of extremities 2. Turning in bed including active-assisted range of motion of extremities 3. Sitting in bed with the head of bed elevated 4. Sitting on the edge of the bed with feet on floor 5. Sitting in a chair 6. Standing 7. Marching in place 8. Ambulation	Initial MRC sum score was 30, and improved to 60 at discharge; Initially had severe agitation with a Richmond Agitation Sedation Scale (RASS) score of +4 but recovered to a RASS score of 0 through rehabilitation. Further, the MMSE score improved from 13 to 28 points within a month. Total ECMO support time was shorter than expected.	No mention of patient-related or circuit-related complications.
Hayes et al. (2021)	Quantitative Pilot randomised controlled trial	Total 15 patients (7 in intervention group; 8 in control group)	The control group received care from physiotherapy staff not involved in the early, intensive rehabilitation program. early intensive rehabilitation program:	No difference between the groups for the primary respiratory, haemodynamic parameters or sedation scores.	There were no adverse events related in both groups.

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			1. Passive range of motion exercises for the upper and lower limbs until stability and sedation weaning; 2. Resistance and active range of motion exercises for the upper and lower limbs when RASS was of -1 to +1 3. Sitting on the edge of the bed, standing, and, ultimately, ambulation, if medical stability allowed.	Higher mobility levels (IMS) were associated with respiratory rate, maximum tidal volume during physiotherapy, lower noradrenaline dosage, less sedation, longer exercise duration, and lower ECMO fresh gas flow. The early intensive rehabilitation group spent more time exercising per session than the standard care group. Three patients in the intensive rehabilitation group, versus none in the standard care group, mobilised out of bed whilst on ECMO. Patients in the intensive rehabilitation group achieved standing sooner 15 days than patients in the standard care group.	
Hermens et al. (2015)	Mixed Methods Retrospective cohort study	9 patiens	1. Extensive sputum mobilisation 2. Muscle training of the lower extremities which entailed dynamic quadriceps training by	In all surviving patients, mobilisation was successful and improved lower body muscle strength (mean MRC score before training was	Complications during mobilisation were only observed with bi-femoral cannulation and included one patient with a large

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			leg press, bed bike or squats from sitting position 3. Bed-to-chair mobilisation.	3.75 and mean MRC 1-day pre-Lung Transplant was 4.25). Of the non-surviving patients, only one patient was physically able to perform muscle training but gained no improvement on muscle strength.	rectus haematoma and a separate case with an obstructing thrombus in the return cannula.
Ko et al. (2015)	Mixed Methods Retrospective cohort study	8 patients	1. Passive range of motion (PROM) of extremities and electrical muscle stimulation (EMS) in supine 2. Sitting in reclined bed with the head and trunk upright or on the edge of the bed 3. Strengthening using elastic band in sitting position 4. Standing out of bed or marching in place with or without device 5. Walking with assistance	Seven patients had femoral venous ECMO cannula, of which three patients achieved 11 sessions while standing, one patient completed one session while walking.	Only three potential safety events (one tachycardia and two tachypnoea) occurred during standing or marching in place but they were recovered within 2 minutes after interrupting the rehabilitation sessions. There was no clinically significant adverse event in patients.
Li et al. (2022)	Qualitative Single Case Report	1 patient	1. Seated position on the edge of his hospital bed for at least 30 minutes while undergoing physical therapy; 2. As the patient improved, he began using a modified cycle;	The patient obtained a Physical Function ICU Test score of 3 on the first day he received the rehabilitation program and score of 10 (stepped 98 steps/min) after 17 days of physical therapy	No mention of patient-related or circuit-related complications.

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			3. After six days of physical therapy intervention, the patient could hold a standing position for 10 seconds.	intervention. He was successfully removed from ECMO support after 20 days of treatment in the ICU.	
Mark et al. (2021)	Qualitative Single Case Report	1 patient	1. In-bed, active-assisted, range-of-motion exercises, sitting at the edge of bed and standing; 2. Achieved standing at the bedside with improved duration of stance, strength of standing force, and performance of pre-gait exercises; 3. Trial of ambulation prior to her expected decannulation from VV ECMO that afternoon.	The patient was successful ambulating approximately 3m space twice. Out-of-bed mobility is feasible with a limited treatment team of 4 staff members if the team is highly experienced in performing early mobility interventions. Early mobility interventions are feasible during ECMO with COVID-19, and physical therapist-delivered treatments, including in-room ambulation, may facilitate discharge to home.	Out-of-bed activity was held one day because of concerns for preterm labour. Besides one episode of transient hypotension, mild dyspnoea and light-headedness following the walk and complains of fatigue after standing, no other adverse physiologic or equipment events occurred.
Munshi et al. (2017)	Mixed Methods Retrospective cohort study	50 ECMO patients with ARDS	According to ICU Mobilization Scale: 0. No mobilization 1. Passive range of motion 2. Active range of motion 3. Sitting in bed 4. Sitting at edge of bed 5. Standing	39% of patients' best IMS score on ECMO was ≥ 2 (sitting in bed/exercises in bed) and 17% of patients' best IMS score on ECMO was ≥ 4 (actively sitting over the side of the bed)	No mention of patient-related or circuit-related complications.

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			6. Ambulating	Intensive care and in-hospital mortality was 22% amongst those who underwent ICU physiotherapy compared to 64% amongst those who did not.	
Nakanishi et al. (2020)	Qualitative Single Case Study	1 patient	Day 2 - Passive range of motion; Day 3 - Active mobilization: The patient was mobilized with sitting on the edge of bed and standing; Day 4 - Standing two times in a day; Day 5 - Foot stepping was added to standing; Day 6 - After the separation from ECMO, the patient was transferred from the bed to the chair with minimum assistance.	Diaphragm thickness remained unchanged during five days of mechanical ventilation. MRC score was maintained at 58-60 during ECMO support. Physical function was maintained during the ICU stay. The patient did not experience ICU-acquired weakness.	During mobilization in the ICU, the patient did not experience any hemodynamic, ventilatory, or cannulation trouble.
Rickelmann and Knoblauch (2018)	Mixed Methods Retrospective Cohort Study	12 patients	0-1. No mobilization or passive range of motion; Turning in bed (including passive and active range of motion); Sitting in bed with the head of the bed elevated; Sitting on the edge of the bed with the feet on the floor; Sitting in a chair; Standing. 2. Marching in place; Ambulation with assistance.	1 patient achieved walking in the hallway up to 200 ft on numerous occasions; 1 patient was out of bed with an overhead lift, and 1 patient was able to dangle at the bedside. In 2 patients, the highest level of mobility achieved was standing at the edge of the bed.	7 patients did not progress past PROM due to: an unstable cannula and respiratory and hemodynamic instability. No report of events of desaturation episodes, falls, increased bleeding at the cannula sites, and dislodgement of cannulas

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			3. Ambulation independently (ECMO patients will not achieve phase 3)		or lines related to mobility.
Turner et al. (2011)	Qualitative Case Series	3 patients	Twice-daily interactions. 1. Strengthening and reconditioning exercises in the supine position (ankle pumps, heel slides, upper extremity stretching, and range of motion exercises); 2. Sitting position on the edge of the bed to strengthen the torso, upper extremities, and lower extremities (leg lifts, ankle rolls, and arm lifts); 3. Standing position; 4. Ambulation.	In these three patients, the posttransplant hospital lengths of stay represent a substantial improvement when compared to the four previous transplant survivors who required ECMO in our institution before lung transplantation.	No mention of patient-related or circuit-related complications.
Wells et al. (2018)	Mixed Methods Retrospective Cohort Study	254 ECMO patients, from which 167 were included in the study	1 - Therapeutic exercises: Range of motion, stretching and strengthening exercises, muscle endurance, breathing exercises 2 - Bed mobility: Rolling, supine to sit transfer training, and bridging activities 3 - Edge of bed activities: Sitting balance, posture, pre-standing activities, breathing and coughing	The patients who received early PT scored higher on the IMS while on ECMO and after decannulation when compared with patients receiving therapy after decannulation. Mobilization including ambulation was accomplished in the presence of femoral cannulation with	Three minor events occurred requiring the mobility activity to be terminated for further medical assessment: an episode of hypotension in a patient when elevating the head of the bed to a sitting position in preparation for edge of bed transfer; one patient

Author(s) / Year	Method	Sample	Rehabilitation Plan	Outcome	Adverse Events
			4 - Sit to stand transfer activities: Sit to standing transfers and functional strengthening using sit to stand from the bed or chair 5 - Stand pivot transfers: Patient completing pivot or taking small steps from the bed or chair with purpose to transfer to another surface 6 -Standing activities: Standing balance and tolerance, strengthening, preambulation activities such as weight shifting, marching, and stepping in place 7 – Ambulation: Gait training, gait speed, and ambulation tolerance	13 patients with bifemoral cannulation sites. Increase in functional mobility while on ECMO and after decannulation resulted in more patients progressing to ambulation and being discharged home with family.	experienced two episodes of no sustained ventricular tachycardia (VT) during standing activities.

Table 3.

Studies With Reported Adverse Events

Study	Total of patients	Adverse events
(Rickelmann & Knoblauch, 2018)	7 patients	Unstable cannulas and respiratory and hemodynamic instability
(Andersen et al., 2022)	1 patient	Episodes of desaturation during activity, increased respiratory rate, increased heart rate and prolonged recovery
(Hermens et al., 2015)	1 patient	Large rectus haematoma, in a bi-femoral cannulation
(Hermens et al., 2015)	1 patient	Obstructing thrombus in the return cannula, in a bi-femoral cannulation
(Wells et al., 2018)	1 patient	An episode of hypotension when elevating the head of the bed to a sitting position
(Wells et al., 2018)	1 patient	Two episodes of no sustained VT during standing activities
(Mark et al., 2021)	1 patient	An episode of transient hypotension, mild dyspnoea and light-headedness and complains of fatigue after standing and one held session due to concerns of preterm labour.

2.1.4. Discussion

The present review describes the existing literature about rehabilitation of adult patients on ECMO. Most studies included in this review were case reports evidencing a lack of literature publish in this area with a higher sample size. This is consistent with other reviews in the same topic, like the one published by Polastri and colleagues (2016),

where they report that all studies included in their review had limited number of subjects. For the sake of organization, the discussion will be divided into five categories, same as in results session: rehabilitation programs and its interventions; assessment tools; benefits of the program; adverse effects and type of cannulation.

2.1.4.1. Rehabilitation Program

Only two studies in this review reported respiratory interventions as part of the rehabilitation program on patients in ECMO (Cork et al., 2014; Hermens et al., 2015). In the study conducted by Hermens and colleagues (2015), all subjects had respiratory conditions like cystic fibrosis. One of the main characteristics of cystic fibrosis is the build-up of sticky sputum and difficulty in clearing it (NHS, 2021). Therefore, the first intervention of their program is focused on lung clearance. Regarding the study conducted by Cork and colleagues (2014), their primary focus was on respiratory improvement. The study's findings indicated that chest physiotherapy significantly contributes to promoting secretion clearance and enhancing lung function in patients undergoing ECMO. The systematic review conducted by Polastri and colleagues (2016) is aligned with the evidence found in this review, since they refer that a transition from respiratory interventions to motor ones should be considered along the progression of clinical status, suggesting that respiratory enhancement should be first priority. Another systematic review found that rehabilitation could have a potential beneficial effect in secretions clearance, pulmonary recovery, and overall improvement in respiratory function (Ferreira et al., 2019). Polastri and colleagues (2016) also refer that in-bed positioning and postural exercises are a key component to respiratory improvement since these interventions promote lung ventilation and removal of secretions. Even though, only two studies focused on the respiratory component of rehabilitation, all other rehabilitation programs included in this review started with in bed-positioning and postural exercises, which, as said before could lead to respiratory improvement and could serve as a preventative activity (Polastri et al., 2016). Some studies report that they couldn’t advance past in-bed positioning and passive range of motion exercises due to clinical instability and high dosage of sedation, but it’s clear in the evaluated studies that this is a starting point of the rehabilitation program (Abrams et al., 2014; Bonizzoli et al., 2019; Chavez et al., 2015;

Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Nakanishi et al., 2020; Rickelmann & Knoblauch, 2018; Wells et al., 2018).

Ambulation has reportedly positive effects in terms of cervical spine mobility and muscle strengthening so walking in the ICU is an important goal for critically ill patients (Polastri et al., 2016). For most studies included in this review, ambulation is the epitome of the rehabilitation program (Abrams et al., 2014; Bonizzoli et al., 2019; Chavez et al., 2015; Han et al., 2022; Hayes et al., 2021; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Rickelmann & Knoblauch, 2018; Turner et al., 2011; Wells et al., 2018), since it involves the activation of both physical and neurological functions (Polastri et al., 2016). Hayes and colleagues (2022) conducted a scoping review where they report that ambulation was the most commonly reported intervention in their evaluated studies but, before that stage, patients need to acquire sufficient muscle strength, balance and improved duration of stance (Mark et al., 2021). So, before reaching ambulation, patients started doing active-assisted and active-resisted range of motion exercises, sitting on the edge of bed, transfer to sitting in chair, sit to stand up, marching in place and, finally, ambulation, as exposed on results section.

2.1.4.2. Assessment tools

Depending on the outcomes, the authors of the included studies selected the assessment tools they deemed most suitable to address the proposed objectives. Consequently, the assessment tools employed varied across studies, reflecting the specific objectives of each study. For instance, in the study by Cork et al. (2014) that focused on respiratory outcomes, assessment tools based on respiratory parameters, including chest radiography, respiratory rate, and maximum tidal volume, were utilized. In contrast, Hermens and colleagues (2015) incorporated both respiratory and motor rehabilitation in their program, leading them to adopt a broader evaluation approach without specific respiratory assessment tools. Instead, they assessed outcomes from another perspective using the muscle strength evaluation via the MRC scale. The MRC scale was consistently employed across all studies assessing muscle strength, facilitating data standardization in this review.

Given that most studies emphasized mobilization parameters and evaluated outcomes based on mobility, it is not surprising that the most commonly utilized assessment tool was the maximum activity achieved throughout the program (Abrams et al., 2014; Andersen et al., 2022; Bonizzoli et al., 2019; Chavez et al., 2015; Hayes et al., 2021; Ko et al., 2015; Mark et al., 2021; Munshi et al., 2017; Rickelmann & Knoblauch, 2018; Wells et al., 2018). In addition to maximum activity achieved, Bonizzoli et al. (2019) also considered the duration of ECMO support, mechanical ventilation, length of stay, and mortality as indicators of the rehabilitation program's benefits. Other studies employed different assessment tools to examine the outcomes of their programs. For instance, Han et al. (2022) utilized the duration of ECMO support along with the RASS score, the MRC sum score, and the MMSE score to assess cognitive function. Studies focusing on the impact of a mobility program in ICU patients employed additional assessment tools that could offer valuable insights to the included studies in this review. For example, Schujmann et al. (2020) employed sit-to-stand and 2-minute walk tests, as well as Barthel Index scores, in their randomized controlled trial involving ICU patients. They also evaluated Barthel Index scores of these patients three months after ICU discharge. Evaluating the patients after discharge could provide insights into the long-term benefits of rehabilitation in ECMO implanted patients' post-discharge.

2.1.4.3. Benefits of Rehabilitation Programs

Ferreira and colleagues (2019) discovered that, despite a limited number of controlled studies, rehabilitation yields several benefits. These benefits include reduced hospital stays, healthcare costs, duration of mechanical ventilation, myopathy, morbidity, and mortality, alongside an increase in physical capacity. In this present review, similar benefits were identified, as the included studies reported improvements in muscle strength (Han et al., 2022; Hermens et al., 2015) and maintenance of physical condition prior to hospitalization (Nakanishi et al., 2020). Additionally, a decrease in the duration of mechanical ventilation (Bonizzoli et al., 2019) and a shortened length of stay (Bonizzoli et al., 2019) were observed. Hayes and colleagues (2021) also reported a shorter ICU stay for ECMO patients who underwent rehabilitation; however, they cautioned that the

differences were not statistically significant and, similar to this study, the sample sizes were small, preventing definitive conclusions from being drawn.

2.1.4.4. Adverse Events

One of the most frequent concerns reported by studies in this area is the safety of rehabilitating a patient while on ECMO support. In this review, most patients (330 patients) did not present any complication or adverse events; however, as it is visible in Table 3, some studies reported punctual complications related to hemodynamic and respiratory stability that reversed once sessions stopped. This goes in line with the review published by Kourek and colleagues (2022), since they report that the most frequently reported events in their investigation were oxygen desaturation and hemodynamic instability.

Only two patients in all included studies faced major adverse events, one related to a thrombus obstructing the return cannula and one large haematoma. This data was collected from 12 of the 16 studies since 4 of them didn't mention any patient or circuit-related complications or the lack of them (Han et al., 2022; Li et al., 2022; Munshi et al., 2017; Turner et al., 2011). Hayes and colleagues (2021) presented similar findings since they report that most adverse events found were minor, self-limiting, and solved with the cessation of exercises. In the same paper, 50% of studies reported no potential adverse events during rehabilitation, which concurs with the findings of this review. Another side adverse brought to attention by Kourek and colleagues (2022) is the dislocation of ECMO cannulas, which can cause disturbances in the ECMO flow, decannulation and severe bleeding. Even though there is no reported literature in this topic, it's something that health professionals involved in the rehabilitation of ECMO patients must be aware of.

2.1.4.5. Type of Cannulation

Since cannula dislocation is a major concern in the rehabilitation of ECMO patients, some studies compared the use of dual-lumen cannulas in contrast with femoral ones. In the studies included in this review, although there is an increased risk of exteriorising the cannula, femoral configuration is not a contraindication for rehabilitation

and there is no difference with the progression of the program between patients with femorofemoral cannulas or dual-lumen jugular ones (Bonizzoli et al., 2019; Ko et al., 2015; Wells et al., 2018). Double lumen cannulas could facilitate rehabilitation exercises since it reduces problems in the lower limbs (Ferreira et al., 2019; Polastri et al., 2016). Nonetheless, rehabilitation in patients with femorofemoral cannulas has been reported as feasible and safe since there is reports of rehabilitating ECMO patients with femoral configuration without any cannula-associated complications (Bonizzoli et al., 2019; Ko et al., 2015; Kourek et al., 2022; Wells et al., 2018).

2.1.5. Limitations

This review has limitations worth mentioning. The low number of patients enrolled in the included studies (mostly case reports) and the non-randomised nature of studies limits the drawing of conclusions. In addition, since studies were published in larger experienced ECMO centres, with experienced staff, the results and lack of adverse events in rehabilitation of ECMO patients cannot be generalized into a wider context. Other limitation is related to the retrospective nature of most included studies, since these studies depend on past medical records registered by different personnel, which can affect the accuracy of the information. The use of different patient outcomes measures and measurement instruments limits the wider interpretation of results and comparison between studies. Studies show limitations with separating results from rehabilitation programs alone and the improvement of clinical condition and alertness of patients.

Future studies should focus on randomised controlled trials and experimental studies with larger samples. In future studies, we recommend analysing mortality of ECMO patients on and off rehabilitation; financial costs of rehabilitation; facilitators to the rehabilitation on ECMO; difference of outcomes based in VV or VA type of ECMO and individual patient needs; safety criteria to monitor patient while performing rehabilitation; a more individualized concept of rehabilitation programs, designed with the collaboration of the patient and his family specifically for that patient with his limitations and particularities. Furthermore, as evident from this integrative review, all the included studies focused exclusively on rehabilitation programs that targeted motor and cardiorespiratory aspects. In order to adopt an holistic approach to patient care, it is

crucial to explore additional dimensions of rehabilitation, such as neurological aspects, environmental considerations, preparation for post-discharge life, family coping mechanisms, and other similarly impactful factors on the patient's well-being.

2.1.6. Conclusion

This review showed that rehabilitation programs can be composed of different interventions but all of them start gradually depending on patient’s tolerance and collaboration. Despite the limited number of studies with low sample sizes, the findings of the present review seem to support the hypothesis that rehabilitation can bring positive outcomes to patients on ECMO when being treated with an experienced team. This hypothesis is supported by evidence indicating that rehabilitation interventions in ECMO patients lead to benefits such as increased muscular strength, reduced duration of mechanical ventilation, and shortened hospital length of stay.

Most patients included in this review did not face any adverse events or complications due to rehabilitation interventions and most adverse events reported were considered minor and promptly solved with cessation of the session, demonstrating that rehabilitation in ECMO patients is safe.

Since the paradigm of having highly sedated patients is changing to more and more awake patients, we are confident that rehabilitation in ECMO patients is an emerging area of investigation, and we hope this review can be a motto for the development of more knowledge in this area.

2.2. REHABILITATION OF A PATIENT WITH BIVENTRICULAR ASSIST DEVICE IMPLANTATION – A CASE REPORT

Abstract

Background & Objective: Research shows that rehabilitation plays an important role on providing the best outcome after hospitalization and preventing immobility complications in critically ill patients. The purpose of this case study is to report a rehabilitation program that focused on respiratory function, muscle strength and mobility and describe his results in a BiVAD implanted patient.

Case Presentation: This case reports a 63-year-old English man admitted after a myocardial infarction and following heart failure to do a BIVAD implantation. Throughout hospitalization, the patient experienced multi-organ dysfunctions, which delayed rehabilitation and worsened his health condition. Thus, the rehabilitation program was set up according to three goals: enhancing respiratory function, improve muscle strength and promote mobility. The results of this program were monitored in three phases of the patient's pathway to recovery. The respiratory function was monitored with the aid of The Borg modified scale for dyspnoea and The Borg Rating of Perceived Exertion; as for the muscle strength through the MRC Scale for Muscle Strength and mobility was evaluated by the Intensive Care Mobility Scale (IMS). To sum up all results gathered, we used the Chelsea Critical Care Physical Assessment Tool (CPAx).

Conclusion: The results showed a favourable progression in all monitored parameters, with an improvement in patient's clinical condition. Throughout the rehabilitation program, the patient didn't face any major adverse events or complications.

Keyword: Biventricular assist device; Rehabilitation nursing; critical care

What is already known about the topic?

• Exercise training is highly recommended in Heart Failure due to its beneficial effects on functional capacity and prognosis.

• Early mobilization and exercise training have been proven to improve functional capacity, exertional ventilatory response and quality of life despite limited data and published articles.

• Although limited evidence and small study populations, all data produced support the feasibility, safety, and potential for benefit.

What this paper adds

• These findings corroborate the literature about the feasibility and safety of mobilising BiVAD patients since no adverse effects were reported.

• The patient in this case report presented positive outcomes regarding respiratory status and mobilization during the rehabilitation program.

• Since few studies are published regarding rehabilitation in BiVAD patients, we hope to shine a light in its safety and promote a more focused approach in these patients.

2.2.1. Background

The World Health Organization reports HF as the leading cause of death worldwide (WHO, 2020). The mechanical VAD is an advanced management strategy for HF utilised when other conventional methods have not been successful (Takayama et al., 2011). Depending on the cardiac condition, various types of VADs exist, each having distinct criteria and objectives. The BiVAD is a device that supports both pulmonary and systemic circulation and generally serves as a bridge to transplant for patients with end stage HF (Wells, 2013). Frequently, patients with this device must remain in ICU until the condition is treated or a transplant is available. Since BiVAD replaces cardiac function, in this type of patients the focus is maintaining the rest of organs and muscles in the best shape possible to provide the best outcome after discharge. Due to risk of exteriorising cannulas, the mobility of BIVAD patients is often conditioned so they are

often subject to immobility-related damages such as cardiorespiratory and muscular weakness and functional impairment (Schujmann et al., 2020; Vanhorebeek et al., 2020). As a result, the focus relies on enhancing respiratory function, muscle strength and physical function.

Rehabilitation plays an important role to prevent immobility complications and provide the best outcome after transplant (Wells, 2013). Studies have shown that rehabilitation improves functional capacity, exertional ventilatory response and an overall positive impact in quality of life (Adamopoulos et al., 2019; Grosman-Rimon et al., 2019). Although limited evidence and small study populations, all data published so far show that rehabilitation is feasible, safe and has potential for benefit in VAD patients (Adamopoulos et al., 2019).

Thus, the purpose of this study is to describe a rehabilitation program with a focus on enhancing respiratory function, muscle strength and mobility in a BiVAD implanted patient.

This case report complied with the recommendations of CARE clinical case reporting guidelines (Gagnier et al., 2013).

2.2.2. Case Presentation

A 63-year-old male English patient presented to a local hospital with back pain and numbness in both legs after cycling. He was known to have type 2 diabetes mellitus with no end organ complications. At the local hospital, he was diagnosed with a ST-Elevation Myocardial Infarction and programmed for a Primary Angioplasty and implantation of a stent in the occluded left anterior descending coronary artery. The procedure was complicated by early Ventricular Tachycardia (VT) and Ventricular Fibrillation (VF) leading to an arrest in the catheter lab, with prompt resuscitation with a rapid Return Of Spontaneous Circulation (ROSC). Transthoracic echocardiography showed Left Ventricular Ejection Fraction of 18% but no severe mitral regurgitation, ventricular septal defect, or other issues.

He was transferred to a leading national specialist cardiothoracic centre, for HF management and transplant assessment. Shortly after, patient went into VF arrest with ROSC after cardiopulmonary resuscitation. Initially CentriMag LVAD was implanted but

due to incessant VT/VF, it was converted to a BiVAD with cannulas of drainage on right atrium and left ventricle.

During his admission in the specialist cardiothoracic centre, the patient experienced multi-organ dysfunction complications and multiple infections, which delayed extubation and the progression of rehabilitation. One of the major complications was a left middle cerebral artery and bilateral cerebellar infarction.

After that, he continued to participate in rehabilitation sessions and his condition started to improve. On Day 97 of hospitalization, he had a step back and almost a reset of all the improvement so far - he was again intubated and sedated due to tachypnoea, secretions, and worsening lung findings. Hospitalization day 97 marks day 1 (D1) of the rehabilitation program stated in this study.

2.2.2.1. Data Collection

Ethical concerns to protect the patient were discussed with the university and hospital administration department. Every necessary data collected was explained previously to the patient as well as to the next of kin and an informed consent was signed to authorise data collection during rehabilitation sessions along with data from medical records. This consent is available for consultation in ANNEX I.

For the data collection, the assessment tools used were scales: Borg Modified Scale For Dyspnoea (MBS); The Borg Rating Of Perceived Exertion (RPE); MRC Scale for Muscle Strength; Intensive Care Mobility Scale and the CPAx.

The scales used were applied in the beginning, 8 days after start of the program and 20 days after daily rehabilitation sessions.

2.2.2.2. Rehabilitation Program

The program focused on two main dimensions – respiratory improvement and functional enhancement as it’s visible on Table 4. Our emphasis was not on cardiac rehabilitation due to the patient's condition of end-stage HF, their position in the potential bridge-to-transplant trajectory and, simultaneously, the BiVAD assumed nearly all cardiac functioning.

On the respiratory dimension, the goals were airway clearance, prevention of respiratory complications and promoting tracheostomy weaning. To accomplish the first goal, interventions included bronchial drainage techniques, cough techniques and suction when required.

Regarding the second goal, after several trials that resulted in aspiration of oral secretions and increasing frequency of chest infections/pneumonia, the multidisciplinary team decided to avoid cuff deflation. For this reason, speech therapy implemented above cuff vocalization to do phonation training and keeping lungs clear of aspiration at the same time. Difficult weaning from tracheostomy is closely associated with respiratory muscle weakness (Vanhorebeek et al., 2020). Therefore, interventions aimed at addressing this goal include techniques focused on enhancing muscle strength.

Regarding functional enhancement, the objectives encompass the prevention of complications associated with prolonged bed rest, the improvement of functional mobility, the enhancement of tolerance of activity, and the promotion of muscular strength and body balance. The interventions consisted of gradual mobilization starting with sitting on the edge of the bed, then standing, preambulatory exercises and ambulation. The level of mobilization was set according to patient's tolerance and compliance. Each rehabilitation session included airway clearance interventions followed by exercises and mobilization, according to the daily needs of the patient.

The progress of mobilization depended on several monitored factors related to the patient and to the BiVAD. Patient related observations included hemodynamic parameters: heart rate, systolic, diastolic, and mean arterial pressures measured through an intra-arterial line and respiratory parameters such as SpO_2 and respiratory rate recorded from the intensive care monitor. These vital signs were monitored before, during and after sessions. Besides objective values, during the session, patient would be encouraged to evaluate dyspnoea and exertion through Borg modified scales and asked if he needed to stop or rest. In terms of BiVAD precautions, nurses specially trained in extra-corporeal circuit management were present throughout all the sessions to ensure the cannulas were fixed and the flows were always monitored. Any major change in vital signs, exertion complaints from the patient or BiVAD events were considered, and the session would be paused or ended depending on the event and resolution.

Table 4.

Timeline Of Rehabilitation Progression And Goals Achieved

<table>
<tr><td>Rehabilitation Program Goals</td><td>Rehabilitation Program Interventions</td></tr>
<tr><td>Airway Clearance</td><td rowspan="3">D1 - Bronchial drainage techniques
D1 and on (when needed) – Suction (SOS)
D3 and on (when needed) - Cough techniques – Huff
D3 and on (when needed) - Forced expiratory technique

D9 – Speech Therapy commenced above cuff vocalization to keep tracheostomy cuff inflated.</td></tr>
<tr><td>Prevention of respiratory complications</td></tr>
<tr><td>Promote tracheostomy weaning</td></tr>
<tr><td>Prevent complications of bed rest</td><td rowspan="5">Gradual mobilization
D5 – SOEOB with nurse on Endotracheal Tube.
D9 - Started 2xday sessions. SOOB, transfer to chair in the morning. Pedals in afternoon 10min.
D10 – Morning SOEOB with Ao2; 4x STS with Ao2 and transfer to chair. Walked for 22 steps with RF. Afternoon 3x STS.
D15 - Transferred to SOEOB with Ao2; STS to RF with Ao1 and Ao1 on frame; Manage to walk 52 steps with 3 resting stops with RF and Ao1 with patient and Ao1 with frame.
D16 – First time walking out of the room for a total of 95 steps and 1 stop rest and 4 STS.
D18 - Walked out of the room for a total of 160 steps and 1 stop rest.
D22 – Walked 40 meters with RF and Ao1 with patient and Ao1 with frame. Only 1 rest and performing a total of 286 steps.</td></tr>
<tr><td>Increase functional mobility</td></tr>
<tr><td>Increase in Activity Tolerance</td></tr>
<tr><td>Promote Muscular Strength</td></tr>
<tr><td>Promote Body Balance</td></tr>
<tr><td colspan="2">Legend: D – Day or rehab session; SOEOB - Sitting On Edge Of Bed; SOOB - Stand Out Of Bed; STS – Sit To Stand-up; Ao2 – Assistance of 2; RF – Rollator frame</td></tr>
</table>

2.3.1 Results

In total, from D1 to D22, 25 sessions were implemented. Focusing on the purpose of this study, results are showed divided in the three dimensions evaluated. As far as respiratory function implies, patient was encouraged to use the MBS and the RPE as a tolerance and stop criteria and respiratory function was also evaluated through Chest X-Ray. There were no adverse events during rehabilitation program, hemodynamic parameters kept stable throughout all sessions and all the rest stops were at patient command mostly because of muscle fatigue (RPE ≥ 5). As it's visible in the timeline, the mobilization was taking further as sessions goes by and the rest stops were fewer. On first day, there were no active mobilization of patient due to high doses of sedation and the Chest X-ray is visible in Figure 2; on D9, patient was able to SOOB, transfer to chair in the morning and pedalling in the afternoon for 10min; on D22, patient walked 40 meters with RF with only 1 rest and performing a total of 286 steps. A Chest X-Ray of improved lungs in D15 is visible in Figure 2 comparing the two stages of the rehabilitation program. Patient dyspnoea was always controlled with MBS around 0 and peak of 3.

To evaluate muscle strength, the assessment tool applied was MRC scale for muscle strength and the results are showed in Table 5. For mobility purposes, the assessment tool was the Intensive Care Mobility Scale showed in Table 5.

An overall picture of the patient improvement is given by CPAx scale visible in Figure 3 with comparisons of D1, D9 and D22.

Figure 2.

Chest X-Ray: Left – November 7th; Right – November 21st

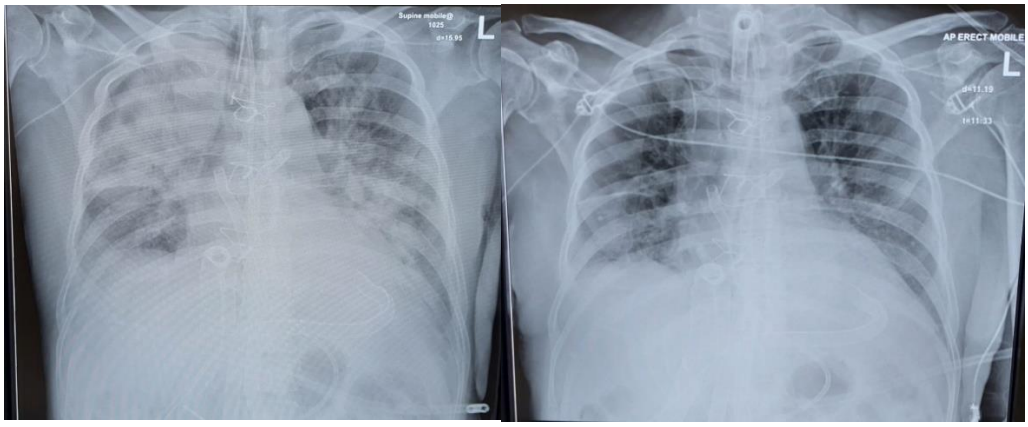


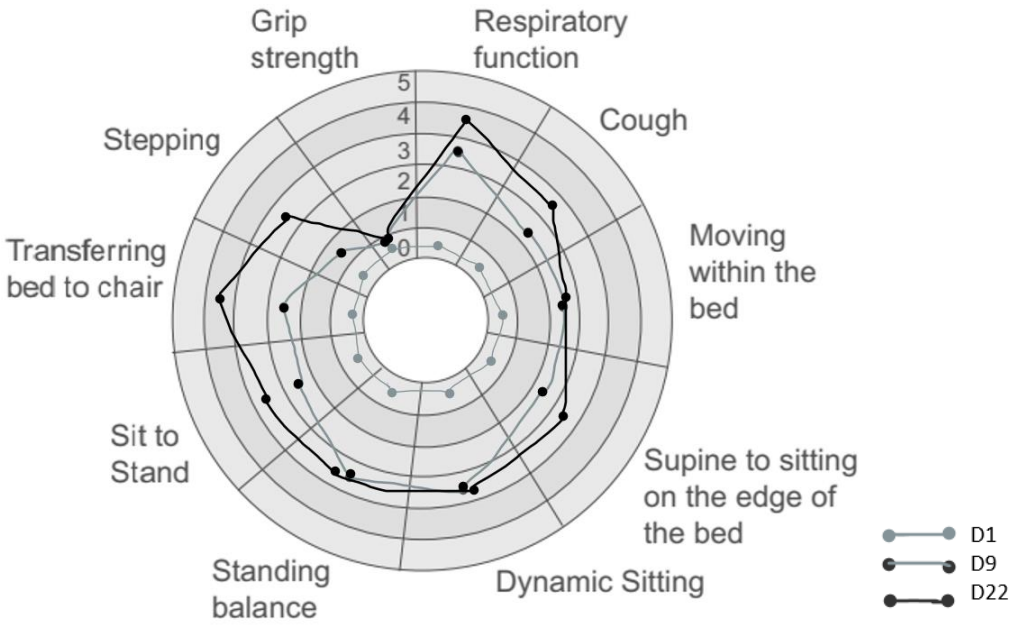
Table 5.

Evaluation Of MRC Scale For Muscle Strength And Intensive Care Mobility Scale On D1, D9 And D22

MRC scale for Muscle Strength	D1	D9	D22
Left Arm: Proximal	1	3	3
Left Arm: Distal	1	3	4
Right Arm: Proximal	1	3	3
Right Arm: Distal	1	3	4
Left Leg: Proximal	1	3	4
Left Leg: Distal	1	3	4
Right Leg: Proximal	1	4	4
Right Leg: Distal	1	4	4
Intensive Care Mobility Scale	0	4	7

Figure 3.

Evaluation Of CPAX Scale



Final Score: 28/50

2.3.2 Discussion

Rehabilitation sessions started in the beginning of hospitalization. However, because of complications that patient experienced, the pathway of rehabilitation was not smooth, with a lot of steps back and forward. On hospitalization day 97, patient was intubated, sedated and the rehabilitation interventions were limited, focusing solely on airway clearance, and preventing additional respiratory complications. Upon initiation of sedation weaning, rehabilitation sessions were resumed to enhance motor and functional status through progressive mobilization.

It is crucial to comprehend that this approach followed a multidisciplinary framework, encompassing a team consisting of bedside nurses, ECMO-specialist nurses, physiotherapists, speech and language therapists, occupational therapists, and physicians. Each one had a role on promoting well-being and recovery of the patient. Decker and colleagues (Decker et al., 2019) published a retrospective study about mobilising patients on MCS greater than 50 days. In this study, the authors refer the importance of involving an interdisciplinary team in promoting a safe ambulation with these patients.

Studies published related to exercise training in VAD patients have shown benefits in terms of pulmonary compliance (Adamopoulos et al., 2019; Alswyan et al., 2018; Grosman-Rimon et al., 2019). Most studies evaluated respiratory function through measuring Peak Oxygen Uptake (VO_2) after exercise sessions (Adamopoulos et al., 2019; Alswyan et al., 2018). A systematic review focused on exercise training in patients with cardiac implanted devices showed that, on average, for VAD patients, the difference in VO_2 between exercise and control groups after completion of exercise was 2.2 mL/kg/min, which reports a significantly difference in contrast with usual care (Alswyan et al., 2018). In this case report, VO_2 wasn't evaluated but a respiratory and patient tolerance improvement is visible since exercise training was taking further as sessions goes by and the rest stops were fewer, showing that patient tolerated, from a respiratory point of view, pushing further in each session. Another factor to this argument is the comparisons between Chest X-rays D1 vs D15. The first X-ray shows bilateral patchy opacifications, particularly on the right upper lung with extensive consolidation and air bronchogram sign, suggesting pneumonia and right costophrenic angle blunting,

suggesting pleural effusion, in contrast with second one which shows a clear improvement in opacities.

As it's visible on Table 5, muscle strength and mobility were evaluated throughout the process. In the beginning, muscle strength was very limited, without any movement due to high doses of sedation. When the patient was no longer sedated, the muscle strength was more visible and his upper and lower limbs showed grossly a 3/5 (MRC scale for muscle strength), indicating movement against gravity with potential to improve. At the end of the evaluation, D22, the patient presented a muscle strength of 4/5, being able to do movement against gravity and resistance. Studies show that mobilisation prevents the complications of muscle deconditioning (Adamopoulos et al., 2019). A study has shown that a higher muscle strength could improve the likelihood of avoiding rehospitalization after discharge (Kobayashi et al., 2022) and a shorter ICU stay for recovering patients (Schujmann et al., 2020). However, in this instance, the length of stay or rehospitalization cannot be utilized as a clinical outcome measure, as it primarily relies on the patient's eligibility for the transplant waiting list and the availability of donor organs, factors beyond the control of the ICU team and the patient. Nonetheless, there is still evident improvement in muscle strength observed between D9 and D22. More studies would be important to understand what this data could mean for the outcome of this patient.

The mobility was evaluated throughout sessions with the Intensive Care Mobility Scale. It shows that, at first, the patient didn't have any activity, so was scored as lying in bed and at D9 he was able to stand out of bed. His mobility continued to improve and by the end of the month (D22), he was able to walk with assistance of two people and a rollator frame for a total of 286 steps. Lammers and colleagues (Lammers et al., 2017) published a case report about a BiVAD patient with peak ambulation distance of 400 feet after seven rehabilitation sessions on a first phase after almost four weeks of bed rest with no major BiVAD complications. Although, in this case, the peak ambulation was 286 steps after 22 days of daily rehabilitation sessions in this case, considering more than three months of hospitalization and multiple complications, it is still a positive result that surpasses expectations.

The CPAx evaluation gives an overall picture of the improvement throughout the rehabilitation sessions and it's possible to see that, in the beginning all the dimensions evaluated on the CPAx scale were on level 0 and started to improve reaching higher levels

in almost all of them except Grip Strength that wasn't evaluated due to lack of resources. This scale provides the whole picture of improvements that the patient was able to accomplish, improving on respiratory function, cough techniques, moving within the bed, supine to sitting on the edge of the bed, dynamic sitting, standing balance, sit to stand transferring from bed to chair and stepping. McGarrigle and Caunt (2016) presented a case series study concerning rehabilitation for patients receiving CentriMag Short-Term VAD Support. In their study, the authors evaluated the improvement of the patients using CPAx. On D1, the median CPAx score was 0 in contrast to the peak CPAx score of 39. The results of that study are in line with this case report, considering that on D1 of the program, the patient started with a score of 0 in every parameter and by the end he finished with a total score of 28, suggesting a similar improvement.

Senduran and colleagues (2011) published a BiVAD patient case report where they described the rehabilitation throughout 15 sessions. The physical therapy program was very similar in terms of respiratory exercises, airway clearance techniques, motor exercises and gradual mobilization. The difference lied on the start of rehabilitation since they started an early physical program on the second postoperative day after BIVAD implantation, corresponding to the first day after extubation. In this case, the patient had a tracheostomy throughout the entire duration of the rehabilitation sessions, making airway clearance and respiratory techniques crucial components of the program. Senduran and colleagues (2011) focused on analysing results through hemodynamic responses. The reason for this decision lies on the literature findings, in which it states that the first criteria to start rehabilitation sessions in the ICU is ensuring hemodynamic and/or physiological stability (Stiller, 2007). Thus, Senduran and collaborators (2011) emphasizes that safety of the treatments is usually investigated via measuring vital signs during the interventions. While in this case we found important monitoring hemodynamic parameters to promote a safe and feasible program, the improvement of the patient was evaluated through muscle strength, mobility, and respiratory status.

All the analysed studies didn't report any adverse events. This is in line with this case report, since no significant adverse events occurred during the 25 rehabilitation sessions of the program.

2.3.3 Limitations

Regarding the BiVAD, we assume that the program did not lead to an excessive stress to cardiac muscle or to BiVAD as we detected no significant alarms during the sessions or poor changes on clinical findings during all rehabilitation sessions. The hemodynamic parameters were considered to provide a safe and feasible program but not to objectively record the outcomes of the patient.

One of the primary limitations in this study pertains to the assessment tools employed. Muscle strength was measured through the ordinal scale of the MRC sum score and this scale limits the sensitivity to detect more subtle changes in muscle function and improvements. To use the CPAx scale to the best of its performance, we should have recorded the grip strength and analyse his results throughout the rehabilitation program. Additionally, the study lacks the inclusion of other objective measures, such as the recording of VO_2 and cardiac output related to the BiVAD's pump function.

Future studies should consider including a larger sample of participants with single-centre and multi-centre studies; ongoing monitoring of vital signs and description of interventions down to time, intensity, frequency, and the occurrence of adverse events is recommended to understand the safety and feasibility of a rehabilitation program; measurement of costs and patient-centred outcomes; link between patient compliance and adherence to treatment impacting outcome.

This program was possible because it was applied in a leading national specialist cardiothoracic centre with a very experienced and specialised multidisciplinary team. Implications to the practice should include specializing more healthcare professionals and preparing them to take care of BiVAD patients, their specific needs, and interventions with scientifically proven results to provide best practice for these patients in other centres and to provide opportunity for more studies to be published.

2.3.4 Conclusion

The patient presented positive outcomes regarding respiratory status and mobilization during the rehabilitation program. Although this is a case report, there were no significant adverse effects reported, which could contribute to the likelihood of

demonstrating that this rehabilitation program is safe and feasible on a long-term BiVAD patient.

Given the case study nature of this article, no general conclusions can be drawn. Nonetheless, since few studies are published regarding rehabilitation in BiVAD patients, we hope to shine a light in its safety and promote a more focused approach in these patients.

3. PART III - SPECIFIC COMPETENCIES AND OBJECTIVES – A REFLECTION ON THE INTERNSHIP

Ordem dos Enfermeiros (2010) has outlined a regulation regarding the specific competencies of the specialist nurse in rehabilitation nursing. In said regulation, three specific competencies are explicitly stated. In this chapter, these specific competencies will be addressed, including their description, units of competency, evaluation criteria, and a reflection on their development during the internship period.

Furthermore, prior to the start of the internship, specific objectives were defined based on the specific competencies already stated. In this chapter, the initial objectives defined for the internship are compared to what was accomplished during the internship period.

3.1. SPECIFIC COMPETENCIES OF THE SPECIALIST NURSE IN REHABILITATION NURSING

Considering that the competencies and regulations are written in Portuguese, and to avoid altering information from official documents, the competencies, their descriptions and units of competency that will be directly quoted from the official document will be written in Portuguese.

3.1.1. “Cuida de pessoas com necessidades especiais, ao longo do ciclo de vida, em todos os contextos da prática de cuidados.”

(Diário da República, 2019, p. 13566)

According to Ordem dos Enfermeiros (2010), this competency is described as follows:

Identifica as necessidades de intervenção especializada no domínio da enfermagem de reabilitação em pessoas, de todas as idades, que estão impossibilitadas de executar actividades básicas, de forma independente, em resultado da sua condição de saúde, deficiência, limitação da actividade e restrição de participação, de natureza permanente ou temporária. Concebe, implementa e avalia planos e programas

especializados tendo em vista a qualidade de vida, a reintegração e a participação na sociedade. (Ordem dos Enfermeiros, 2010, p. 3)

UNIT OF COMPETENCY: Regarding this specific competency, the first mentioned unit of competency is as follows: “Avalia a funcionalidade e diagnostica alterações que determinam limitações da atividade e incapacidades.” (Diário da República, 2019, p. 13566)

ANALYSIS: In this context, to assess the functionality of the person prior to the start of the rehabilitation program, a data collection form was established, with appropriately validated assessment instruments that can be consulted in APPENDIX I. This form was used to collect data prior to the initiation of the rehabilitation program, at an intermediate phase, and at a final phase for the development of the case study presented in this report.

The described form assessed all dimensions of functionality proposed by this competency unit, including motor, sensory, cognitive, cardiac, and respiratory aspects, as well as nutrition, elimination, along with the person's functional capacity to perform Activities of Daily Living (ADLs) prior to hospitalization and the current situation. These data were analysed to establish diagnoses, objectives, and intervention needs for optimizing and rehabilitating motor, sensory, cognitive, cardiac, respiratory, nutritional, elimination functions and independence in the ADLs.

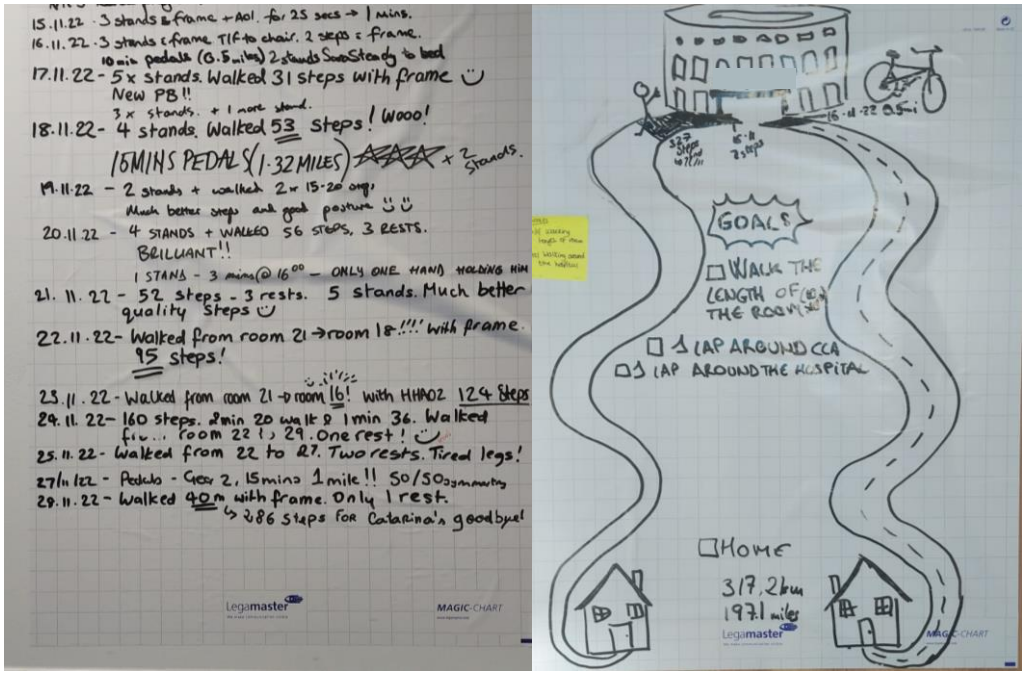
The aforementioned form encompassed all the necessary topics for data collection. However, only a selected few significant data points were utilized in constructing the case report. This approach was taken to ensure that the case report was presented in a clear and objective manner focused on the patient's progress, thereby including only essential data. Furthermore, certain aspects of the form were not applicable for evaluation due to the patient's clinical condition.

UNIT OF COMPETENCY: The second competency unit is as follows: “Concebe planos de intervenção com o propósito de promover capacidades adaptativas com vista ao autocontrolo e autocuidado nos processos de transição saúde/doença e ou incapacidade.” (Diário da República, 2019, p. 13567)

ANALYSIS: Based on the data collected from the form, an intervention plan was developed in collaboration with the client and next of kin. In this regard, strategies were established to improve the client's clinical condition and set goals for self-motivation, quality of life, and autonomy. Occasionally, these goals were established with visual aid, as evidenced in Figure 4, where a customized chart was used to record the distance from the hospital to the client's home via two routes - one for walking and the other for cycling - to create awareness in the patient that their effort could bring them closer to home.

Figure 4.

Tracking Chart Of Patient Goals



UNIT OF COMPETENCY: The third competency unit is as follows: “Implementa as intervenções planeadas com o objetivo de optimizar e/ou reeducar as funções aos níveis motor, sensorial, cognitivo, cardíaco, respiratório, da eliminação e da sexualidade.” (Diário da República, 2019, p. 13567)

ANALYSIS: The rehabilitation program, developed in collaboration with the patient and their next of kin, prioritized respiratory and motor function (Table 4). As evident in the case study, this program was implemented over several sessions, taking

into consideration the patient's tolerance and capacity. The same program included safety criteria assessed through monitoring of the patient's hemodynamic status, parameters of the BiVAD, and evaluation scales such as the BORG Modified Scale for Dyspnea and Exertion.

UNIT OF COMPETENCY: The fourth competency unit is described as follows: “Avalia os resultados das intervenções implementadas.” (Diário da República, 2019, p. 13567)

ANALYSIS: As previously mentioned, the evaluation form was implemented at three distinct moments throughout the rehabilitation program. The aim of its implementation was to assess the effectiveness of the interventions, reflect on the need to reformulate the intervention plan, as well as record the health gains achieved through the program in terms of patient respiratory function, muscle strength and mobility in order to promote patient’s empowerment, autonomy, and overall quality of life.

3.1.2. “Capacita a pessoa com deficiência, limitação da atividade e/ou restrição da participação para a reinserção e exercício da cidadania.”

(Diário da República, 2019, p. 13566)

According to Ordem dos Enfermeiros (2010), this competency is described as follows:

Analisa a problemática da deficiência, limitação da atividade e da restrição da participação na sociedade atual, tendo em vista o desenvolvimento e implementação de ações autónomas e/ou pluridisciplinares de acordo com o enquadramento social, político e económico que visem a uma consciência social inclusiva. (Ordem dos Enfermeiros, 2010, p. 4)

UNIT OF COMPETENCY: Regarding this specific competency, the first mentioned unit of competency is as follows: “Elabora e implementa programa de treino

de AVD’s visando a adaptação às limitações da mobilidade e à maximização da autonomia e da qualidade de vida.” (Diário da República, 2019, p. 13566)

ANALYSIS: Regarding this competency unit, it is recognized that its implementation was limited to the context of the internship and the characteristics of the patients encountered. In an ICU where the target population of this study is patients implanted with ECLS devices and respiratory and/or cardiac failure, the performance of specific ADL exercises has limitations. Another factor is the temporary nature of their current clinical condition, with the expectation that the person will achieve maximum independence after resolution of the clinical condition or organ transplantation. The patient's independence is mainly limited by the use of the ECLS device, particularly the existence of cannulas and the need for hemodynamic monitoring.

During the hospitalization period, the patient is encouraged to perform all possible ADL exercises autonomously or with assistance instead of substitution. The clinical team encourages the presence of their next of kin during the entire daytime period, considering it as a facilitating factor for the patient's adhesion to the rehabilitation program. In this case, the patient and their next of kin inquired about what they could do during the rest periods of the rehabilitation program to improve upper limb muscle strength. In this sense, a document with several exercises that the patient could do autonomously with the supervision or assistance of their family member was elaborated, with a focus on improving upper limb muscle strength. This document was handed over to the patient in the presence of their next of kin, and the exercises were taught, instructed, practiced, and questions were clarified. The mentioned document is available for reference in APPENDIX II.

UNIT OF COMPETENCY: The second competency unit is as follows: “Promove a mobilidade, a acessibilidade e a participação social.” (Diário da República, 2019, p. 13567)

ANALYSIS: This competency unit was challenging to approach since the internship took place in a foreign country with unfamiliar policies regarding community health and resources.

The internship was conducted at a specialized tertiary hospital in the United Kingdom, which primarily caters to cardiac and respiratory patients and is recognized as an ECMO reference centre. In addition to that, they offer a community-based cardiac rehabilitation program that is led by a multidisciplinary team. The cardiac rehabilitation program consists of four phases: Phase I, Phase II, Phase III and Phase IV.

During Phase I, the cardiac rehabilitation nurses visit the patients who are nearing discharge from the hospital and discuss their support at home. They provide a booklet titled "Returning to Fitness after Heart Attack" that contains information on medication, driving restrictions, and heavy weight activities, including reference to the cardiac rehabilitation centre in the patient's residential area.

In Phase II, the nurses conduct a phone call assessment to inquire about the patients' symptoms, lifestyle changes, and overall well-being. They also schedule a face-to-face consultation for the beginning of Phase III.

In Phase III, during the first consultation, the patients undergo physical tests such as the 6-Minute Walking Test, Timed Up and Go Test, Incremental Shuttle Walk Test, Chester Test, and Treadmill Test (which has three difficulty levels: Noughton Protocol, Modified Bruce, and Full Bruce). Arterial pressure, heart rate, and Exertion Borg Scale are monitored during the tests, and exercises are stopped if any significant changes occur. Following the tests, a 12-week lifestyle change program begins, where patients visit the hospital once a week for exercise and education sessions. They also receive YouTube videos from the hospital for home exercises. In addition to the hospital-based sessions, patients are expected to perform exercise sessions at home two to three times a week. After six weeks, a re-evaluation is conducted, and patients are encouraged to continue the program at home. At nine weeks, the cardiac rehabilitation nurses conduct a follow-up phone call to assess progress, address any questions, and provide clarification. At the end of the 12 weeks, patients return for a final consultation to perform the same exercises as in the initial assessment and compare results.

Phase IV, the long-term cardiac rehabilitation program, is optional but available for patients who are interested. It involves exercise and education sessions at a leisure centre, in a support group setting with other patients who have similar conditions.

During the internship, an analysis was conducted in the ICU to identify architectural barriers that may impede the implementation of the rehabilitation program,

specifically concerning out-of-room ambulation. As a recently constructed facility, the hospital boasts modern infrastructure that has been designed taking into account the input from various hospital staff, including the rehabilitation team, during its construction. As a result, the doors of the isolated rooms in the ICU are wide enough to allow passage for walking aids, clinical staff, and ECLS devices, and the corridors are spacious enough for walking.

Furthermore, the clinical staff not directly involved in the rehabilitation sessions are experienced and aware of rehabilitation interventions. They proactively make way for patients to pass through without the need for verbal communication.

3.1.3. "Maximiza a funcionalidade desenvolvendo as capacidades da pessoa."

(Diário da República, 2019, p. 13567)

According to Ordem dos Enfermeiros (2010), this competency is described as follows:

Interage com a pessoa no sentido de desenvolver atividades que permitam maximizar as suas capacidades funcionais e assim permitir um melhor desempenho motor, cardíaco e respiratório, potenciando o rendimento e o desenvolvimento pessoal. (Ordem dos Enfermeiros, 2010, p. 4)

UNIT OF COMPETENCY: Regarding this specific competency, the first mentioned unit of competency is as follows: "Concebe e implementa programas de treino motor, cardíaco e respiratório." (Diário da República, 2019, p. 13568)

ANALYSIS: The primary objective of this report was to ascertain the advantages of a rehabilitation program for patients with ECMO devices. However, it was not possible to closely monitor a rehabilitation program progress in these patients for two main reasons: firstly, patients were highly sedated and sedation withdrawal only occurred after decannulation; secondly, patients only needed ECMO device for a short period of time.

Nevertheless, I was fortunate to be involved in the rehabilitation program of a patient implanted with a BiVAD device. As indicated in the case report, the only viable solution for this patient was to be included in the heart transplant list. Therefore, the program primarily emphasized motor and respiratory enhancements to optimize their physical condition for entry into the list and subsequent recovery following the transplant surgery. Given the patient's multiple setbacks and complications, the rehabilitation program was tailored and adapted based on their day-to-day condition and clinical status. The rehabilitation team also sought the patient's input on the most suitable time for the daily sessions, empowering the patient to have a say in their own care despite being hospitalized in the ICU.

Furthermore, I had the opportunity to shadow the hospital's transplant team for a day, gaining insight into the intricacies of heart transplant surgery and its implications. On that day, the transplant team was called upon to retrieve a heart and lungs of a donor with circulatory arrest from a local hospital. In such cases, the heart is retrieved and preserved using an Organ Care System for heart, a device not yet available in Portugal. This device enables near-physiological conditions (including temperature, muscle contraction, and irrigation) for organ storage and monitoring during transportation (Alomari et al., 2022). Although not directly related to rehabilitation, witnessing an organ retrieval procedure, and gaining a comprehensive understanding of its intricacies, provided valuable insight into the critical importance of patients being in optimal physical condition for successful surgery and recovery.

UNIT OF COMPETENCY: Regarding this specific competency, the second mentioned unit of competency is as follows: “Avalia e reformula programas de treino motor, cardíaco e respiratório em função dos resultados esperados.” (Diário da República, 2019, p. 13568)

ANALYSIS: The monitoring of interventions and their results during the rehabilitation program was assessed using the evaluation form available in APPENDIX I. This form was utilized not only for initial data collection, but also during an intermediate phase to monitor the patient's progress and adjust as needed, and during a final phase to evaluate the effectiveness of the interventions. In addition to the evaluation

form, the patient's clinical status was reviewed daily, and prior to each session, the patient was assessed to ensure he was in a suitable condition to participate in the planned interventions. As evident in the case study, the rehabilitation program commenced with respiratory enhancement, and motor interventions were initiated only when the patient met specific criteria such as sedation weaning, ventilator weaning, stability of clinical condition, and assurance of safety conditions.

3.2. INTERNSHIP GOALS

This planning arose with the purpose of defining objectives that align with maximizing the learning opportunities associated with the internship site. The internship occurred between the 2nd of November and the 1st of December 2022. In this regard, the following specific objectives were established:

3.2.1. To acquire knowledge about the organization and dynamics of the internship site, the methodology of work employed, and rehabilitation care practice.

Strategies/Activities:

- Meeting with the clinical educator's team and the physiotherapist service leader to understand the organization and functioning dynamics of the clinical departments, existing material and human resources, and the projects and activities in which the hospital is involved;
- Familiarization with the multidisciplinary team (team composition, roles of different team members, and working methodology);
- Research through consultation of documents such as clinical departments manuals and protocols, procedural norms, and existing rehabilitation projects;
- Identification of existing physical and human resources used for various dimensions of rehabilitation in ECMO patients;
- Identification of clinical and support areas, and the patient's pathway from admission to discharge/relocation;
- Comprehending the dynamics of communication with patients, families, and caregivers during the illness and recovery process;

- Integration in the multidisciplinary team;
- Seeking clarification of doubts from the supervisor (s).

Evaluation:

- Familiarizes oneself with the clinical department, its organization, and dynamics, identifying the resources used for rehabilitation interventions;
- Obtains the necessary information for appropriate rehabilitation interventions, considering the uniqueness and complexity of the situation;
- Demonstrates good interpersonal relationships and a sense of cooperation with the multidisciplinary team;
- Participates in different activities of the clinical department, including meetings and/or shift handovers;
- Assists and collaborates in nursing care plans in accordance with the functioning and dynamics of the clinical department;
- Acts in accordance with the norms and protocols of the clinical department;
- Demonstrates initiative and interest in promoting the development of specialized practice.

ANALYSIS: This objective was focused on the first week of the internship. During this first week, I took the time to meet the staff I would be working with throughout the entire month, become familiar with the norms, protocols, and health policies of the country. To achieve this objective, a placement timetable was created by the institution to ensure maximum exposure to different experiences. This timetable can be found in ANNEX II. Focused on the rehabilitation of ECLS patients, I engaged in a different activity every day and accompanied rehabilitation sessions for specific patients whose cases I was following. The rehabilitation department at the hospital is composed of a multidisciplinary team comprising cardiac rehabilitation nurses, physiotherapists, occupational therapists, nutritionists, and speech therapists. Weekly meetings are held to discuss patients' progress and what is expected for the upcoming days.

One of the major difficulties I experienced in establishing a relationship with the multidisciplinary team was the language barrier. Despite speaking English, I am not a native speaker, and therefore, I found it difficult to understand when personnel spoke too

fast. However, over time, this difficulty was mitigated as all personnel were very sensitive to my needs and spoke slowly, repeating information when necessary. On the other hand, the Portuguese training was advantageous for my integration into the team. Based on what I observed and read about the National Health System in England, I concluded that there is highly partitioned knowledge, where each person knows their role and interventions, sometimes at the expense of losing the holistic perspective of the patient. In Portugal, however, the education is focused on a holistic perspective, allowing me to participate in every meeting, providing feedback on all dimensions of the patient. They were surprised by how much we knew, from neurological to cardiorespiratory, gastrointestinal, elimination and motor dimensions of rehabilitation. The fact that I could read and understand Complementary Methods of Diagnosis and Therapy, such as X-rays or computed tomography scans, was unexpected to them since most professionals (except for doctors and physiotherapists) do not have access to them because they do not feel the need to analyse this information. Every day that I spent with different personnel, they were impressed by how much I could contribute to the conversation, allowing me to establish a fast and productive relationship for both sides.

I also spent some time with ICU nurses and learnt about their role in patient care, their hierarchy, and resources. In the ICU, nurses have different roles depending on their salary band. These roles can vary depending on the department and institution. I will provide a brief description based on my observations and discussions with nurses in the ICU where I completed my internship.

Bedside nurses, who are responsible for the direct care of patients, fall under Band 5. There are different types of bedside nurses, depending on their training, including newly graduated nurses and trained nurses in specific patients, such as BiVAD trained nurses or ECMO trained nurses. Only trained nurses in these specific patients can be responsible for their care.

Band 6 nurses are Nursing Specialists or Senior Nurses. In the ICU, they have different roles depending on their training, such as ECMO specialist or BiVAD specialist nurses. The ECMO or BiVAD specialist nurses are responsible for taking clinical decisions, including prescribing medication, changing oxygenator circuits with a doctor's assistance, walking with ECMO or BiVAD patients outside of the room, and floating (trading places with trained nurses on patients care so they can have their breaks). In the

ICU, the nurse-to-patient ratio is 1:1, so whenever a bedside nurse needs to leave the patients' unit, another nurse must replace them. They can also be part of a clinical educators teaching team, which is responsible for training nurses in specific interventions and discussing errors and devising plans to prevent them (from training nurses personally in every room, handing out flyers, or even be part of discussions regarding country health-specific policies).

Band 7 nurses are Advanced nurses or Nurse Practitioners. In the ICU, they perform management roles as team leaders, distribute workload, clarify doubts in less experienced nurses, identify training gaps, and are present in multidisciplinary meetings. They are responsible for the overall running of the unit.

Lastly, Band 8 Nurses are the Chief Nurses. They are the overall chief in charge of nursing staff and are involved in administrative roles, participating in administrative meetings and being part of specific committees. In this ICU, the chief in charge is responsible, besides management duties, for the ECLS training and course, co-authoring one of the books used for ECMO training worldwide.

3.2.2. Develop skills in providing rehabilitation nursing care to patients on ECMO and their families, aiming at patient autonomy and quality of life.

Strategies/Activities:

- Mobilization of knowledge acquired in complementary curricular units, supplemented with bibliographic research, protocols, and clinical teaching norms;
- Use of the patient's clinical process, data collection, and diagnostic complementary exams;
- Assessment of the patient's functional capacity and rehabilitation potential at sensory-motor and cognitive levels, using the most appropriate evaluation tools for the situation;
- Development and implementation of individualized rehabilitation nursing intervention plans based on the identified needs of the ECMO patient, aiming at reducing limitations, promoting autonomy, and improving quality of life.

Evaluation:

- Mobilizes the theoretical and practical knowledge acquired throughout the master's course;
- Knows and uses the norms and procedures of clinical departments;
- Demonstrates a therapeutic and safe attitude during the application of rehabilitation nursing interventions;
- Identifies the potentialities of the person and involves their family in the process of illness and recovery, through client interview and family interview, using appropriate assessment tools;
- Elaborates and revises a rehabilitation nursing intervention plan that is suitable for the needs of the person and their family, considering the individuality and complexity of the situation;
- Develops rehabilitation nursing interventions based on scientific evidence, aiming at the improvement of care.

ANALYSIS: This objective was designed to focus on developing the specific competencies of specialist nurses in rehabilitation nursing. To apply the theoretical and practical knowledge acquired throughout the Master's course, I followed the rehabilitation pathway of ECLS patients and collaborated in their sessions, discussing the care plan with patients, their families, and rehabilitation professionals. Unfortunately, I had fewer opportunities than I had expected to participate in the rehabilitation programs and observe progress in different ECLS patients. This was because all ECMO patients in the ICU at that time had a short ECMO duration and remained sedated throughout, and other BiVAD patients had been in ICU for months by then, waiting for a transplant and remained stable, so the rehabilitation care plan focused on maintaining their clinical situation. Although, there was one patient, a BiVAD patient, who had gone through several complications and was restarting a rehabilitation program. I followed and collaborated with the rehabilitation program of this patient from the beginning, having the opportunity to discuss his plan with the patient, his next of kin, and the rehabilitation team involved in his treatment. From this patient's rehabilitation path, a study case was produced, which is available in PART II.

To identify the potentialities of the patient, an evaluation form was developed and is available in APPENDIX I. This form covers every dimension of rehabilitation that made sense in the patient's actual condition and was completed through patient and family interviews, data collection from the clinical process, and assessment tools applied to the patient. From data analysis of the evaluation form, a rehabilitation plan was elaborated in conjunction with the patient, their next of kin, and the rehabilitation team responsible for the patient's care. This plan is available in the study case present in this report.

In order to share the knowledge acquired during the treatment of this patient, a poster was submitted for presentation at the 11th EuroELSO congress, and it is available for consultation in APPENDIX III. This poster was subsequently honoured with the Young Investigator Award for the year 2023.

3.2.3. Promote person's autonomy with mobility impairment, with a focus on promoting mobility, accessibility, and social participation.

Strategies/Activities:

- Develop strategies for identifying factors, situations, or resources that may facilitate or inhibit the transition of the individual and their family;
- Assess the level of awareness, expectations, and involvement of the individual and their family in the process of illness and recovery;
- Implement rehabilitation nursing interventions to promote the involvement of the patient and family in the process of illness and recovery;
- Characterize the transitions experienced by the individual and family in the process of illness and recovery;
- Identify the rehabilitation potential of the individual in the process of illness and recovery;
- Develop rehabilitation nursing strategies for empowering and maximizing the autonomy and quality of life of the individual in the process of illness;
- Propose suggestions for mobilizing critically ill patients on ECMO to prevent mobility limitations due to neuro-muscular impairments developed during intensive care hospitalization.

Evaluation:

- Collaborates in providing rehabilitation care as part of a multidisciplinary team, based on scientific evidence, and aimed at improving quality of care;
- The rehabilitation nursing interventions developed are tailored to the needs of the patient and family;
- The individual in the process of illness and recovery has regained partial functionality, or has acquired appropriate alternatives;
- Has sought scientific evidence to support the developed rehabilitation nursing interventions;
- Develops rehabilitation nursing intervention plans, implementing them according to the individuality and rehabilitation potential of the patient;
- Evaluates the effectiveness of planned interventions, reformulating or adapting them as necessary.

ANALYSIS: During my intervention with the case report patient and their next of kin, they were regularly updated on the patient's progress, expectations were discussed and formed based on daily assessments of the patient's clinical condition. They were also involved in the rehabilitation process and inquire about the program and other aspects they could do to improve patient’s condition, resulting in the development of a pamphlet about exercises for upper limb muscle strength to be performed out of rehabilitation sessions (available in APPENDIX II).

In the ICU, the multidisciplinary team involves patients and their next of kin in all aspects related to their health. For instance, with patients waiting for a transplant, they inform them of every organ retrieval call they receive that is compatible with the patient, even if they are unsure whether they will be able to retrieve the organ and perform the transplant.

In the case of the patient in the case report, he was previously informed that he did not meet the requirements to remain on the transplant list and was subsequently removed. After his condition improved, he was informed that he still had a long recovery process ahead of him but could potentially fulfil the conditions required to be put back on the transplant list. The patient and their next of kin were asked to reflect on the possibility

of not fully recovering and remaining with permanent tracheostomy, nasogastric tube feeding, and walking limitations, and whether they still wanted to pursue a transplant. The patient and next of kin ultimately decided to enter the transplant awaiting list.

During the rehabilitation program, the patient made positive progress, so the program did not require significant changes. However, due to an increasing frequency of chest infections/pneumonia, a change was made to the rehabilitation program. Instead of weaning off the tracheostomy, it was decided to stop the weaning process and continue with nasogastric tube feeding to prevent food aspirations. Additionally, above cuff vocalization was introduced for phonation training.

The effectiveness of the rehabilitation program was evaluated through the initial evaluation form and comparisons of results were made since the beginning of the program in an intermediate phase and final phase. As outlined in the case report, the patient made positive progress in all evaluated parameters. While not all credit can be attributed to the rehabilitation program, it was a gratifying feeling to know that the patient was put back on the transplant list by the end of the internship.

FINAL REMARKS

As highlighted in this report, rehabilitation programs can have a positive impact on the outcomes of ECLS-implanted patients. However, to achieve these important benefits, it is crucial to have an experienced and skilled team that not only understands the rehabilitation interventions, but also knows how to respond to adverse events and how to prepare for them.

As nurses, we are trained to advocate for our patients and to discuss clinical decisions with them. To have effective discussions and provide clarification to patients, it is important to understand the device that has been implanted and to be aware of major concerns such as haemorrhagic issues, thrombosis, or cannula displacement, as well as how to manage these issues. Every member of the multidisciplinary team should be experienced and aware of their role during rehabilitation sessions. Roles should be discussed and assigned prior to the session, with the patient present. Additionally, a checklist should be implemented to ensure that it is safe to initiate the rehabilitation process and after session to ensure that the patient can safely rest.

Regarding rehabilitation in ECMO patients, the integrative review shows that the literature describes benefits such as increased muscular strength, reduced duration of mechanical ventilation, and shortened hospital length of stay. In comparison to the occurrence of adverse events, it was concluded that most studies showed that patients did not experience any adverse events or complications due to rehabilitation interventions. In the minority of studies that described the occurrence of adverse events, they were minor and promptly solved. However, it is important to consider this evidence with caution, as the available literature was limited, with no uniformity in data collection, in different ECMO centres with different personnel experience. Moreover, most studies had a small number of patients. Nevertheless, weighing the pros and cons, rehabilitation should be more widely investigated, and applied in ECMO patients.

This report covers not only ECMO patients but also BiVAD patients. Both BiVAD and ECMO devices provide extracorporeal life support, and, so, they share some similarities. However, the differences between them have prompted this author to delve into the existing literature and include important considerations about rehabilitation in both types of complex patients.

During the internship, I had the opportunity to accompany the rehabilitation process of a BiVAD implanted patient and witnessed his journey from deep sedation to walking outside of the room. Most BiVAD implanted patients reported in the literature do not face any complications since the beginning of ECLS support until recovery or transplant, and they are awake, and rehabilitating smoothly. However, in this case, the patient had long-time sedation and faced a lot of complications involving multiple organs. Thus, the rehabilitation program focused on improving the affected dimensions of the body, especially cardiorespiratory and motor dimensions, with a focus on autonomy and independence. I was fortunate to witness the improvements from bed rest, little to no movement, and secretions suction to chair, sit-to-stands, cough, and finally ambulating outside of the room. Witnessing this patient's journey was a memorable experience.

On a specific competency of the specialists in rehabilitation nursing level, as shown, all the specific competencies could be developed in various contexts, including the unique context of critical patients, particularly those implanted with ECMO and BiVAD devices. This reflection led to the development of recommendations for future practice that aims to increase health gains for these specific patients.

Based on the specific competencies, the recommendations for future practice rests on the following topics:

- Training:
  - Develop and implement a basic training program for new professionals specifically focused on patients implanted with ECLS. This program will discuss the general outlines of how the device works, the general characteristics of the patient, potential adverse events and complications, and how to respond to them. It will also address the nurse's role in caring for these complex patients, including integrating the family into their care;
  - Develop and implement an advanced training program for more experienced professionals specifically focused on patients implanted with ECLS. This program will cover more advanced topics, such as the decision-making process for treating these patients, involving the family and individual in this process, the specificities of different types of circulatory support systems, managing emergency situations, and the role of the generalist nurse and other specialist nurses in collaborating with the rehabilitation nursing specialist in the rehabilitation program for these patients.

- Develop and implement a health education session, aimed at the family and patient, with a focus on raising awareness of the current health situation, promoting knowledge and the capability of the individual and family, and empowering the individual to participate effectively and committedly in their health project.

- Integration of Evidence-Based Practice:
- Design of a Rehabilitation Nursing Program:
  - Based on current scientific evidence;
  - Flexible for application according to the expressed needs of the patient and family as well as identified by Rehabilitation Nursing Specialists;
  - Properly structured for uniform data collection, to produce knowledge with scientific rigor and clarity of discussion.
- Production, Sharing, and Dissemination:
- Production of scientific knowledge based on the collection and analysis of data related to the results of the previously mentioned Rehabilitation Nursing Program;
- Sharing the achieved results among peers as a vehicle for motivation to continue the program and openness to suggestions for improvement, based on the experience gained;
- Dissemination of acquired knowledge to the scientific community in order to discuss better strategies of action and optimization of Rehabilitation Nursing care.

On a final remark about this report, reflecting on the history of ECMO, it is important to note that the first results were so poor that investigation was scarce for several decades. Having this into consideration, it is possible that the history of ECMO could have taken a completely different course, and ECMO may not have existed.

With that in mind, according to EuroELSO, until March 2023, 16,716 confirmed Covid-19 patients have been treated with ECMO, with a total mortality rate of 47% for patients who initiated ECMO at least 90 days ago (EuroELSO, 2023). By being in ECMO, 8,859 out of 16,716 patients (53%) have survived Covid-19.

This report began with a quote about how dreams never die. The dreams of those who envisioned ECMO and other therapeutic measures for ECMO patients have made it possible for 8,859 people to not die.

I would like to conclude this report on a personal note, as this journey has been as much a personal experience as a professional one for me. The cluster of scientific investigation and practical experiences that this journey brought has enriched my clinical eye, helping me to understand that knowledge is not static but rather a turmoil of experiences, late-night and early morning readings, experimentation, connection, and love. It is a journey of love - love for what we do, love for the growing results we see, love for the stories we've heard and the patients we touch, love-sharing and love-receiving. What a beautiful, memorable way of living.

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ANNEXES

ANNEX I – Patient Consent for Data collection

ORIGINAL

Informed Consent Form

According to the "Declaration of Helsinki" from the World Medical Association (Helsinki 1964; Tokyo 1975; Venice 1983; Hong Kong 1989; Somerset West 1996, Edinburgh 2000; Washington 2002, Tokyo 2004, Seoul 2008, Fortaleza 2013) – when applied.

Rehabilitation of critically ill patients with Extracorporeal Membrane Oxygenation: Intervention of Nurse Specialist in Rehabilitation Nursing

Title of investigation

I, _____ [INSERT FULL NAME]
have been informed that thisresearch study is intended to understand and describe the rehabilitation process of a critically ill patient on ECMO, to propose suggestions for an effective practice of Rehabilitation Nursing in this situation.
By signing this form, I confirm that:

- I know that a case report is planned in this study, having been explained to me what it consists of.
- I authorize access to my personal health information (medical record) as explained in this form.
- I was assured that all data relating to the identification of study participants is confidential.
- I have been informed that I do not have to participate in this case report or that I can stop participating in the study at any time, without any penalty for this fact.
- The case report has been fully explained to me, I understood the information given to me and all my questions have been answered to my satisfaction
- I voluntarily agree to participate in thisstudy.
- Iauthorize divulgation of scientific results, guaranteeing confidentiality, and I have been informed of the risks and benefits of allowing my information to be used in this case report.

16 / 11 / 2022 | _____
Date | Signature

Lead Investigator: Ana Catarina Carvalho Morais, +351 916 944 807

16 / 11 / 2022 | _____
Date | Signature

[redacted]

le)

Consent form in relation to photography/interview/filming

You have been given this form as you have indicated that you are happy to be either photographed, filmed or interviewed in order to help promote the work of [redacted] Hospital NHS Foundation Trust to wider audiences.

Please read it carefully and only sign it if you understand what granting this consent means for you.

Delete as appropriate: ***I am a Patient / Relative of a Patient / Member of the Public / Volunteer***

How we will use your story

At [redacted], we want to raise awareness of our work with our staff, patients, partners and the general public. Patient stories can help us to show how the hospital is helping to provide excellent care and research new treatments in heart and lung medicine.

If you consent for us to do so, we may share your photo, case study, interview or footage of your procedure in the following ways:

- On our website or social media channels
- In the media (eg in a newspaper, on TV or radio or a media outlet's website and social media channels)
- With our partners, for use on their website, social media channels or printed literature

We can only share case studies where the individuals concerned are willing for us to do so and are happy to share information about their experience of, or their role in, the care and treatment of patients at [redacted].

Section 1

Name of staff member: [redacted]

Job title: CCA Physiotherapy Team Lead. on behalf of Catarina ~~Horcas~~ Morais, critical care nurse on placement from Portugal.

Section 2 – Description of photography/interview/filming and where it will be used*

Video of walking with BiVAD during rehabilitation session.
It will be used for presentation in a conference and to present on clinical meetings in Portugal to improve rehabilitation with patients on Extracorporeal membrane support.

*Also include here if the case study/photo/video will be used by a media agency for commercial purposes

Section 3 – Consent

By signing below, I agree to being filmed/photographed/interviewed for the purposes indicated above in Section 2, including the use of any information relevant to my activity or treatment at [redacted] and I confirm as follows:

- I am 18 years old or older and am providing this consent of my own accord;
- I have read through this form and understand the consequences of signing it;
- I understand that once an image/video/news story is in the public domain we have no control over how it is used or shared by individuals who can access it;
- I am happy to be contacted by the hospital's Communications team if and when another media opportunity arises in future as a result of this story;
- Any provision of information in relation to, and participation in, any filming/photography/interview is voluntary;

Please note: We can only hold and share this information if you consent for us to do so. We will hold your photos, story or video footage indefinitely until you ask us to stop using it, at which point we will remove any data we hold about you. Email [redacted]@nhs.net to withdraw your consent at any time.

Section 4 – Future media/publicity requests

Occasionally, after seeing an initial story in the media, we receive requests from other media outlets to feature your story. If this happens, we will contact you and ask for your verbal permission over the phone or written permission via email. We will record any future opportunities on this consent form.

Date	**Opportunity**	**Verbal/email consent**

Signature	[redacted]	Date	28/11/2022

Once signed, the original signed form should be sent to the Communications Team at Communications Team ([redacted]@nhs.net).

If you have completed this form electronically and are returning to us via email, we will keep a copy of the email as evidence of consent instead of having an ink signature on the form.

ANNEX II – Placement Timetable

CATARINA MORAIS MASTERS PLACEMENT 2ND NOVEMBER – 1ST DECEMBER 2022

Daily 8am ICU meeting in doctors office

ICU ward daily – 9am in North and South.

Tues and Thursday 12:30 MDT meeting in ICU doctors office

Monday Tx meeting Teams 12:30 – 13:30

ICU rehab huddle Monday 1-2 – Rehab Seminar room in the Therapies area

Surgical floor long term patient meeting Tuesdays 3-4 – 5th floor 5 North day room

ICU complex patients Tuesday 4-5 (access MS Teams in ICU education team office)

ICU Training Tuesday (access MS Teams in ICU education team office)

ICU Mortality and Morbidity meeting Wednesdays 4-5:30 (access MS Teams in ICU education team office)

Other MDT – transplant, PPCI/ cardiology service, theatres, outpatient/ cardiac support nurses/ preadmission clinic, respiratory medicine

Monday	Tuesday	Wednesday	Thursday	Friday
		02/11/22 8-9:30 with [redacted], bespoke induction - access card, hospital tour, contact other teams. With Allaina ICU M&M 4-5	03/11/22 ([redacted] day off) Rehab/Comms Study Day Ground Floor meeting rooms 1&2 09:00-17:00	04/11/22 ([redacted] on leave afternoon) With Physio team

Monday	Tuesday	Wednesday	Thursday	Friday
07/11/22 With [redacted] in OT ICU rehab huddle Monday 1-2 – Rehab Seminar room	08/11/22 With ICU teaching team Training Tuesday ICU complex patients Tuesday 4-5	09/11/22 Heart Failure/ Transplant Study Day Ground Floor 1&2 (08:00- 17:00)	10/11/22 ([redacted] day off) With 5th floor Physio/ OT team	11/11/22 Own time for data collection
14/11/22 With physio team ICU rehab huddle Monday 1-2 – Rehab Seminar room	15/11/22 With ICU teaching team Training Tuesday ICU complex patients Tuesday 4-5	16/11/22 With [redacted] SaLT – AM Physio team PM ICU M&M 4-5	17/11/22 ([redacted] day off) CR treadmill test 8am - lunchtime Own time for data collection	18/11/22 With ICU teaching team
21/11/22 With physio team ICU rehab huddle Monday 1-2 – Rehab Seminar room 15:30-16:30 – Trust tracheostomy group meeting – Rehab seminar room 5-6 ECMO M&M (access MS Teams in ICU education team office)	22/11/22 With ICU teaching team Training Tuesday ICU complex patients Tuesday 4-5	23/11/22 Pain nurse 07:00-09:00, bleep 848. With cardiac rehab all day ICU M&M 4-5	24/11/22 ([redacted] day off) Own time for data collection 1-2 Trust delirium meeting (MS Teams)	25/11/22 ([redacted] on leave all day) With ICU teaching team

Monday	Tuesday	Wednesday	Thursday	Friday
28/11/22 With Physio team ICU rehab huddle Monday 1-2 – Rehab Seminar room	29/11/22 With ICU teaching team Training Tuesday ICU complex patients Tuesday 4-5	30/11/22 With physio team ICU M&M 4-5	01/12/22 ([redacted] day off) Last day Own time for data collection	02/12/22

ANNEX III – Ethics committee report

Comissão de Ética - Parecer CE2022/64

AM António Mesquita Montes

Para: ANA CATARINA CARVALHO MORAIS

qua, 01/03/2023 08:26

Ex.mo(a) Sr.(a),

Sendo que V. Ex.a se encontra identificada como Investigador Principal, incumbe-me a Presidente da Comissão de Ética da ESSSM de informar que foi emitido um parecer favorável à realização do projeto de investigação.

Mais informo que, posteriormente, receberá um documento comprovativo com o respetivo parecer. Para efeitos de identificação deste parecer no estudo de investigação é suficiente mencionar o código CE2022/64.

Com os melhores cumprimentos,

Escola Superior Saúde Santa Maria

ANTÓNIO MESQUITA MONTES | PT, MSc, PhD

PROFESSOR ADJUNTO

Travessa Antero de Quental, 173 - 175 | 4049-024 Porto

+351 225 098 664 santamariasaude.pt

APPENDICES

APPENDIX I - Evaluation Form

EVALUATION FORM

Date:

Consent__

Group I: Personal Information

Person

RGM/Colour code: Age:

Schooling Level: Marital Status:

Profession:

Gender:

Previous condition before hospitalization:

Do you live alone?

Group II: Clinical Information

Days in ICU overall: Days in ECMO:

Type of ECMO:

Data from ECMO: RPM/BF/Sweep

Cannula Insertion locals:

Last oxygenator change:

Medical Diagnosis: (Gagnier et al., 2013)

Diagnostic testing (such as PE, laboratory testing, imaging, surveys)

Medical History:

Relevant past interventions with outcomes:

Allergies:

Timeline of the disease:

Conscience Level

Without sedation: Glasgow Score: (Mehta et al., 2019)

Eye Opening: Verbal Response: Motor Response:

Orientation: Time: Space: Person:

With Sedation: RASS Scale: (Wesley et al., 2003)

Table 1. The Richmond Agitation-Sedation Scale (RASS)

Score	Term	Description	
+4	Combative	Overtly combative, violent, immediate danger to staff	
+3	Very agitated	Pulls or removes tube(s) or catheter(s); aggressive	
+2	Agitated	Frequent nonpurposeful movement, fights ventilator	
+1	Restless	Anxious but movements not aggressive or vigorous	
0	Alert and calm		
−1	Drowsy	Not fully alert, but has sustained awakening (eye opening/eye contact) to voice (>10 seconds)	Verbal stimulation
−2	Light sedation	Briefly awakens with eye contact to voice (<10 seconds)	
−3	Moderate sedation	Movement or eye opening to voice (but no eye contact)	
−4	Deep sedation	No response to voice, but movement or eye opening to physical stimulation	Physical stimulation
−5	Unarousable	No response to voice or physical stimulation	

Procedure for RASS Assessment

1. Observe patient
   - Patient is alert, restless, or agitated. — Score 0 to +4
2. If not alert, state patient's name and say to open eyes and look at speaker.
   - Patient awakens with sustained eye opening and eye contact. — Score −1
   - Patient awakens with eye opening and eye contact, but not sustained. — Score −2
   - Patient has any movement in response to voice but no eye contact. — Score −3
3. When no response to verbal stimulation, physically stimulate patient by shaking shoulder and/or rubbing sternum.
   - Patient has any movement to physical stimulation. — Score −4
   - Patient has no response to any stimulation. — Score −5

Pain:

Sleep Schedule: Sleep Difficulty:

Sedative Medication: Sleep Medication:

Respiratory System:

Intubated: Tracheostomy:

Ventilation parameters: Mode/FiO_2/RR/Volumes/PEEP/PS

Non intubated:

Oxygen Need: Oxygen device:

Cough Reflex:

Cough: Dry/Productive/Irritative (In)Effective

Sputum: Expelled?

Characteristics: Colour: Quantity: Type: Fluid/Thick/Spumes

Auscultation Characteristics:

Circulatory System:

Heart Rate:

Blood Pressure:

Tissue Perfusion:

Vasopressor medication:

Regulatory System:

Body Temperature:

Medication:

Gastrointestinal system

Diet:

Feeding tube? Nasogastric/Gastric/Jejunal

Blood Glucose Status:

Sphincter Control: Last dejection: Abnormal characteristics:

Medication:

Urinary System:

Sphincter Control: Bladder Probe:

Quantity: Stimulation:

Abnormal characteristics:

Medication:

Integumentary System:

Skin Characteristics: Intact/Dry/Macerated

Wounds:

Pressure Ulcers:

Oedema:

Positioning Timing: Any non-tolerated lying positioning?

GROUP III – Assessment Tools

Dyspnoea:

BORG modified Scale for Dyspnea (Hareendran et al., 2012)

	Shortness of Breath	At Rest	During Activity
0	Nothing at all		
0.5	Very, very slight (just noticeable)		
1	Very slight		
2	Slight		
3	Moderate		
4	Somewhat severe		
5	Severe		
6			
7	Very severe		
8			
9	Very, very severe (almost maximal)		
10	Maximal		

Respiration Rate: At Rest: During Activity:

Muscle Strength: Medical Research Council (MRC) Scale for Muscle Strength (Kleyweg et al., 1991)

MRC scale for muscle strength (0-5)

Grade 5: Normal

Grade 4: Movement against gravity and resistance

Grade 3: Movement against gravity over (almost) the full range

Grade 2: Movement of the limb but not against gravity

Grade 1: Visible contraction without movement of the limb (not existent for hip flexion)

Grade 0: No visible contraction

MRC grade for each muscle given in full numbers: (4+/4.5 =4) (4- =3) (5- = 4)

Left Arm: Proximal:___ Distal:___

Right Arm: Proximal:___ Distal:___

Left Leg: Proximal:___ Distal:___

Right Leg: Proximal:___ Distal:___

The Short Physical Performance Battery (SPPB) (Welch et al., 2021) – Available on electronic patient record

Intensive care Unit Mobility Scale: (Hodgson et al., 2014)

	Classification	Definition
0	No activity, lying in bed	Passively rolled or passively exercised by staff, but not actively moving
1	Sitting in bed, exercises in bed	Any activity in bed including rolling, bridging, active exercise, cycling
2	Passively moved to chair (no standing)	Hoist, passive lift or slide transfer to the chair with no standing or sitting on the edge of the bed
3	Sitting over edge of bed	May be assisted by staff, but involves actively sitting over the side of the bed with some trunk control
4	Standing	Weight-bearing through the feet in standing position with or without assistance
5	Transfer to chair	Able to step or shuffle through standing to the chair. This involves actively transferring weight from one leg to another to move to the chair.
6	Marching in place (at bedside)	Able to walk in place by lifting alternate feet (at least 4 times, twice on each foot), with or without assistance
7	Walking with assistance of 2 or more people	Walks at least 15 feet with assistance of 2 or more people
8	Walking with assistance of 1 person	Walks at least 15 feet with assistance of 1 person
9	Walking independently with gait aid	Walks at least 15 feet with assistance of gait aid. If wheelchair bound, wheels chair at least 15 feet independently
10	Walking independently without a gait aid	Walks at least 15 feet without any assistance

(Hodgson et al., 2014; Tipping et al., 2016)

Contraindications to Mobility:

Significant dose of vasopressors for hemodynamic instability
Mechanically ventilated with FiO2 >.8 and/or PEEP >12, acutely worsening respiratory failure
Neuromuscular blockers
Acute neurologic event (CVA, SAH, ICH, SDH) with worsening mental status and/or ICP >20
Unstable spine or extremity fractures
Poor prognosis with plan to transition to comfort care
Open abdomen, at risk for dehiscence
Active bleeding

Indications for Physical Therapy Evaluation

Stable extremity fractures
Spinal fractures requiring a brace
Spinal cord injury
Moderate to severe traumatic brain injury
Baseline disability/fall from standing
Poor tolerance of activity with nursing staff

Functional Independence Measure (Black et al., 1999)

FIM™ instrument

Functional Independence Measure

LEVELS		
	7 Complete Independence (Timely, Safely) 6 Modified Independence (Device)	**NO HELPER**
	Modified Dependence 5 Supervision (Subject = 100%+) 4 Minimal Assist (Subject = 75%+) 3 Moderate Assist (Subject = 50%+) **Complete Dependence** 2 Maximal Assist (Subject =25%+) 1 Total Assist (Subject = less than 25%)	**HELPER**

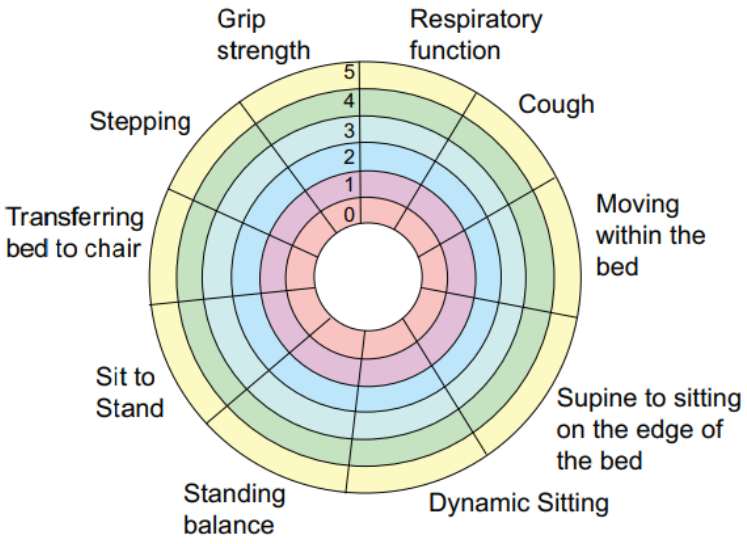
	ADMISSION	DISCHARGE	FOLLOW-UP
Self-Care			
A. Eating	☐	☐	☐
B Grooming	☐	☐	☐
C. Bathing	☐	☐	☐
D. Dressing - Upper Body	☐	☐	☐
E. Dressing - Lower Body	☐	☐	☐
F. Toileting	☐	☐	☐
Sphincter Control			
G. Bladder Management	☐	☐	☐
H. Bowel Management	☐	☐	☐
Transfers			
I. Bed, Chair, Wheelchair	☐	☐	☐
J Toilet	☐	☐	☐
K. Tub, Shower	☐	☐	☐
Locomotion			
L. Walk/Wheelchair	☐ ☐ (W Walk, C Wheelchair, B Both)	☐ ☐ (W Walk, C Wheelchair, B Both)	☐ ☐ (W Walk, C Wheelchair, B Both)
M. Stairs	☐	☐	☐
Motor Subtotal Score	☐	☐	☐
Communication			
N. Comprehension	☐ ☐ (A Auditory, V Visual, B Both)	☐ ☐ (A Auditory, V Visual, B Both)	☐ ☐ (A Auditory, V Visual, B Both)
O. Expression	☐ ☐ (V Vocal, N Nonvocal, B Both)	☐ ☐ (V Vocal, N Nonvocal, B Both)	☐ ☐ (V Vocal, N Nonvocal, B Both)
Social Cognition			
P. Social Interaction	☐	☐	☐
Q. Problem Solving	☐	☐	☐
R. Memory	☐	☐	☐
Cognitive Subtotal Score	☐	☐	☐
TOTAL FIM Score	☐	☐	☐

NOTE: Leave no blanks; enter 1 if patient not testable due to risk

Observations:

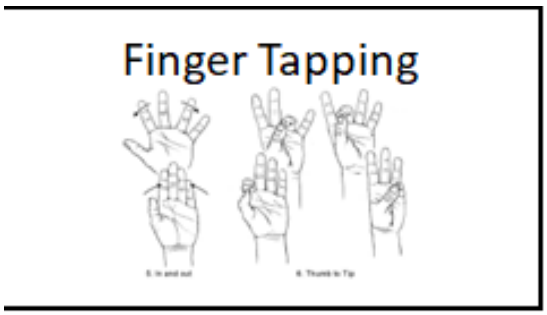
CPAx (Corner et al., 2013)

Aspect of physicality	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Respiratory function	Complete ventilator dependence. Mandatory breaths only. May be fully sedated/ paralysed	Ventilator dependence. Mandatory breaths with some spontaneous effort	Spontaneously breathing with continuous invasive or non-invasive ventilatory support	Spontaneously breathing with intermittent invasive or non-invasive ventilatory support or continuous high flow oxygen (>15 l)	Receiving standard oxygen therapy (<15 l)	Self-ventilating with no oxygen therapy
Cough	Absent cough, may be fully sedated or paralysed	Cough stimulated on deep suctioning only	Weak ineffective voluntary cough, unable to clear independently (e.g. requires deep suction)	Weak, partially effective voluntary cough, sometimes able to clear secretions (e.g. requires Yankauer suctioning)	Effective cough, clearing secretions with airways clearance techniques	Consistent effective voluntary cough, clearing secretions independently
Moving within the bed (e.g. rolling)	Unable, maybe fully sedated/ paralysed	Initiates movement. Requires assistance of two or more people (maximal)	Initiates movement. Requires assistance of at least one person (moderate)	Initiates movement. Requires assistance of one person (minimal)	Independent in ≥3 seconds	Independent in <3 seconds
Supine to sitting on the edge of the bed	Dynamic Unable/unstable	Initiates movement. Requires assistance of two or more people (maximal)	Initiates movement. Requires assistance of at least one person (moderate)	Initiates movement. Requires assistance of one person (minimal)	Independent in ≥3 seconds	Independent in <3 seconds
Dynamic sitting (i.e. when sitting on the edge of the bed/unsupported sitting)	Unable/unstable	Requires assistance of two or more people (maximal)	Requires assistance of at least one person (moderate)	Requires assistance of one person (minimal)	Independent with some dynamic sitting balance (i.e. able to alter trunk position within base of support)	Independent with full dynamic sitting balance (i.e. able to reach out of base of support)
Standing balance	Unable/unstable/bedbound	Tilt table or similar	Standing hoist or similar	Dependant on frame, crutches or similar	Independent without aids	Independent without aids and full dynamic standing balance (i.e. able to reach out of base of support)
Sit to stand (starting position: ≤ 90° hip flexion)	Unable/unstable	Sit to stand with maximal assistance (standing hoist or similar)	Sit to stand with moderate assistance (e.g. one or two people)	Sit to stand with minimal assistance (e.g. one person)	Sit to stand independently pushing through arms of the chair	Sit to stand independently without upper limb involvement.
Transferring from bed to chair	Unable/unstable	Full hoist	Standing hoist or similar	Pivot transfer (no stepping) with mobility aid or physical assistance	Stand and step transfer with mobility aid or physical assistance	Independent transfer without equipment
Stepping	Unable/unstable	Using a standing hoist or similar	Using mobility aids and assistance of at least one person (moderate)	Using mobility aid and assistance of one person (minimal)	Using mobility aid or assistance of one person (minimal)	Independent without aid
Grip strength (predicted mean for age and gender on the strongest hand)	Unable to assess	<20%	<40%	<60%	<80%	≥80%



APPENDIX II – Upper limb exercises

EXERCISES FOR UPPER LIMB MUSCLE STRENGTH



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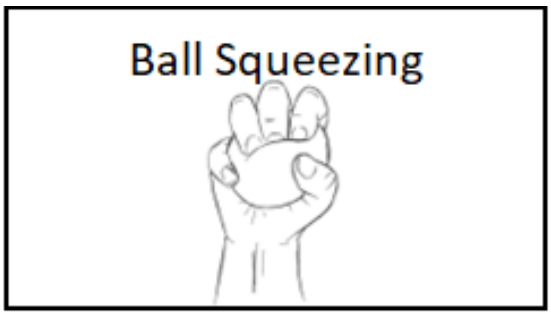

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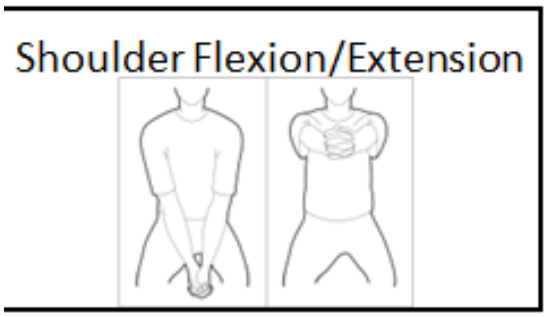

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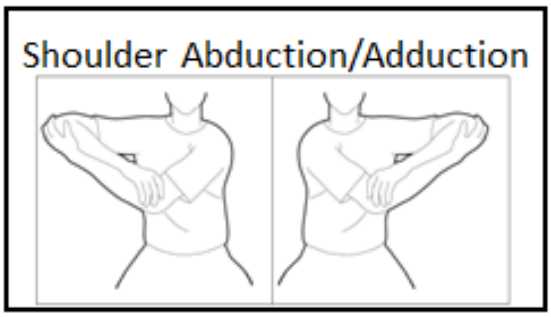

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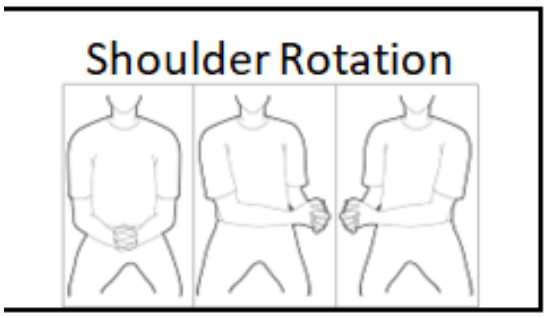
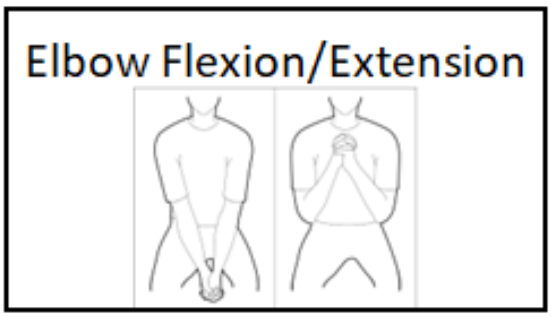
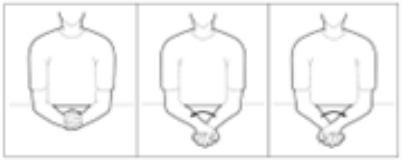


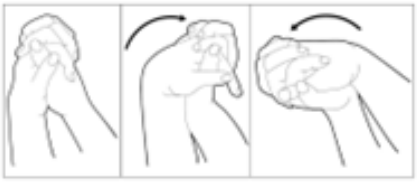


Elbow Rotation



7

Wrist Flexion/Extension



8

Wrist Abduction/Adduction

9

APPENDIX III – EuroELSO Poster

The Dynamic Role Of Rehabilitating A Patient With Biventricular Assist Device Implantation – A Case Report

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Background: Recent literature has emphasized the importance of rehabilitation in preventing immobility complications and providing optimal conditions for the best outcome after hospitalization in critically ill patients (1, 2).

Purpose: The purpose of this case study is to report on a rehabilitation program for a patient with a BiVentricular Assist Device (BiVAD), focusing on respiratory function, muscle strength and mobility.

Methods: The case report was conducted according to CARE clinical case reporting guidelines.

CASE PRESENTATION

A 63-year-old man underwent BiVAD implantation after suffering from a myocardial infarction and heart failure. Complications during hospitalization impeded his rehabilitation progress. The rehabilitation program focused on improving respiratory function, muscle strength, and mobility, and outcomes were evaluated using assessment tools at three stages of recovery.

Respiratory Goals

- Airway Clearance
- Prevention of Respiratory Complications
- Promote Tracheostomy Weaning

Interventions

- Bronchial drainage techniques
- Above cuff vocalization

Mobilization Goals

- Prevention of Immobility Complications
- Increase Functional Mobility
- Increase in Activity Tolerance
- Promote Muscular Strength
- Promote Body Balance

Interventions

Gradual mobilization:

- Sit on the Edge of Bed
- Stand Out Of Bed
- Walking with Rollator Frame

Figure I. – Rehabilitation session

RESULTS

Figure II. – Evaluation of CPAx scale (3)

Figure III. – Chest X-Ray: Above - D_1; Below – D_9

CONCLUSION

The patient presented a positive progression in all the evaluated parameters. The rehabilitation program was well-tolerated in this case without significant complications or adverse events.

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