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The Use of ECMO in Acute Respiratory Failure: Analysis of Advantages, Clinical Challenges, and Long-Term Outcomes in Critically III Patients

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ABSTRACT

A systematic review was conducted on the production and publication of studies related to the use of ECMO, acute respiratory failure, clinical challenges, and the management of critically ill patients, covering the period from 2020 to 2023 and using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach. The objective of this analysis was to identify the main characteristics of the publications registered in the Scopus and WoS databases, as well as to evaluate their contribution to the study of the variables raised. In a first phase, a total of 61 publications were identified. Subsequently, the search was refined by introducing keywords on both platforms, such as digital strategies, ICT, education and Latin America, which allowed the sample to be reduced to 24 documents, after the exclusion of duplicates and those that did not meet the inclusion criteria. Among the most relevant findings, it is highlighted that the use of ECMO in the management of acute respiratory failure has proven to be fundamental, especially during the COVID-19 pandemic, where it has been crucial to improve the survival of critically ill patients with acute respiratory distress syndrome.

Keywords: *ECMO, acute respiratory failure, clinical challenges, critical patients.*

1. INTRODUCTION

Acute Respiratory Failure (AKI) represents one of the main causes of morbidity and mortality in critically ill patients, especially in intensive care settings. This condition, characterized by the inability of the lungs to perform adequate gas exchange, can result from multiple etiologies, such as Acute Respiratory Distress Syndrome (ARDS), severe pneumonia, sepsis, or chest trauma. In many cases, conventional treatments, such as invasive mechanical ventilation, are not sufficient

to maintain oxygenation and ventilation of the patient, leading to the need for advanced therapeutic strategies. In this context, Extracorporeal Membrane Oxygenation (ECMO) has emerged as a crucial life-sustaining intervention. ECMO allows for extracorporeal oxygenation and carbon dioxide removal, acting as a bridge during recovery of lung and/or heart function, or until definitive treatment can be implemented. Despite its efficacy in improving the survival of patients with refractory AKI, ECMO also entails significant clinical challenges, such as the management of bleeding complications, the need for constant anticoagulation, and the high costs associated with its implementation and maintenance.(Mamani Encalada, 2022)(Rodríguez Perón & Rodríguez Izquierdo, 2021)(Moreno, Medina, Rivas, & Romero, 2021)

The use of ECMO has gained special relevance in the management of patients during the COVID-19 pandemic, where its use has been extensively documented in cases of severe ARDS. However, its effectiveness and long-term outcomes in different patient groups are still being debated within the medical community. This is due to the variability in patient selection, management protocols, and the availability of specialized hospital resources for safe and efficient application.(Alexander, y otros, 2024)

Given the growing interest in ECMO as a therapeutic tool in acute respiratory failure, a thorough analysis of the available evidence is necessary to evaluate its advantages, clinical challenges, and long-term outcomes in critically ill patients. A systematic review is especially valuable in this context, as it allows for the synthesis and analysis of scientific literature in a rigorous manner, identifying trends, knowledge gaps, and areas for future research. Therefore, the present study aims to conduct a systematic review using the PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) methodology, to provide a comprehensive view on the use of ECMO in patients with acute respiratory failure. Through this approach, we will seek to evaluate the effectiveness of ECMO in improving the survival and quality of life of patients, identify the factors that influence the success of the treatment and analyze the complications associated with its use. This will provide evidence-based guidance for clinical decision-making in the management of critically ill patients with AKI who could benefit from this treatment.

2. GENERAL OBJECTIVE

To analyze, from a bibliometric and bibliographic perspective, the production of research papers on the variables Acute Respiratory Failure, Clinical Challenges, and Critical Patients published in high-impact journals indexed in the Scopus and Wos databases during the period 2020-2023.

3. METHODOLOGY

The present research is qualitative, according to Hernández, et al., qualitative approaches correspond to research that carries out the procedure of obtaining information to review and interpret the results obtained in such studies; for this, it searched for information in the Scopus and Wos databases through the words Acute Respiratory Failure, Clinical Challenges, and Critical Patients. (2015)

3.1 Research design

The design of the research proposed for this research was the Systematic Review that involves a set of guidelines to carry out the analysis of the data collected, which are framed in a process that began with the coding to the visualization of theories. On the other hand, it is stated that the text corresponds to a descriptive narrative since it is intended to find out how the levels of the variable affect; and systematic because after reviewing the academic material obtained from scientific journals, theories on knowledge management were analyzed and interpreted. (Strauss & Corbin, 2016) (Hernández, Baptista, & Fernández, 2015)

The results of this search are processed as shown in Figure 1, through which the PRISMA technique for the identification of documentary analysis material is expressed. It was taken into account that the publication was published during the period between 2020 and 2023 without distinction of country of origin of the publication or area of knowledge, as well as any type of publication, namely: Journal Articles, Reviews, Book Chapters, Book, among others.

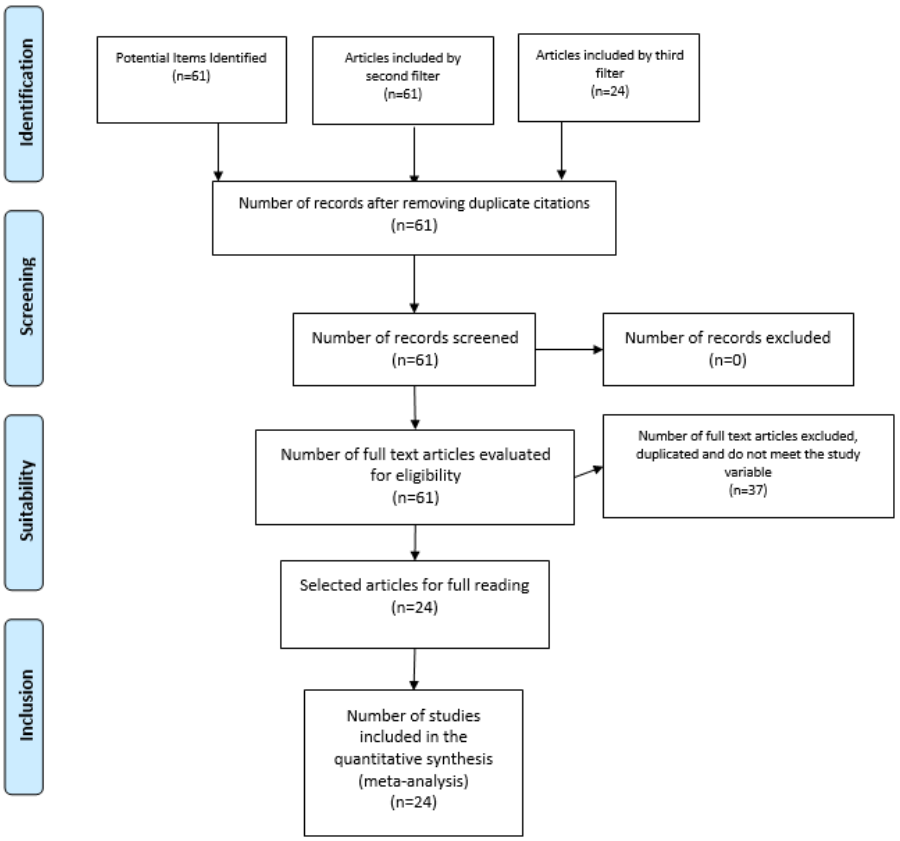

Figure 1. Flowchart of a systematic review carried out under the PRISMA technique (Moher, Liberati, Tetzlaff, Altman, & Group, 2009)

Source: Authors; Based on the proposal of the Prisma Group (Moher, Liberati, Tetzlaff, Altman, & Group, 2009)

4. RESULTS

Table 1 shows the results after applying the search filters related to the methodology proposed for this research, after recognizing the relevance of each of the referenced works.

Table 1. List of articles analyzed

No.	RESEARCH TITLE	AUTHOR/YEAR	COUNTRY	TYPE OF STUDY	INDEXING
1	*Evolving outcomes of extracorporeal membrane oxygenation during the first 2 years of the COVID-19 pandemic: a systematic review and meta-analysis*	Ling, R. R., Ramanathan, K., Sim, J. J. L., Wong, S. N., Chen, Y., Amin, F., ... & Brodie, D. (2022).	SINGAPORE, UNITED STATES, CANADA	QUALITATIVE	SCOPUS

2	*Neurological complications during veno-venous extracorporeal membrane oxygenation: Does the configuration matter? A retrospective analysis of the ELSO database*	Lorusso, R., Belliato, M., Mazzeffi, M., Di Mauro, M., Taccone, F. S., Parise, O., ... & Herr, D. (2021).	NETHERLANDS, ITALY, UNITED STATES, BELGIUM,	QUALITATIVE	SCOPUS
3	*Reduced anticoagulation strategy is associated with a lower incidence of intracerebral hemorrhage in COVID-19 patients on extracorporeal membrane oxygenation*	Hofmaenner, D. A., Furfaro, D., Wild, L. C., Wendel-Garcia, P. D., Baedorf Kassis, E., Pannu, A., ... & BonHanZA study group. (2023).	SWITZERLAND, UNITED STATES, GERMANY,	QUALITATIVE	SCOPUS
4	*Risk Factors of Acute Kidney Injury in ECMO Patients: A Systematic Review and Meta-Analysis*	Mou, Z., Guan, T., & Chen, L. (2022).	CHINA	QUALITATIVE	SCOPUS
5	*A high gas transfer efficiency microfluidic oxygenator for extracorporeal respiratory assist applications in critical care medicine*	Gimbel, A. A., Hsiao, J. C., Kim, E. S., Lewis, D. J., Risoleo, T. F., Urban, J. N., & Borenstein, J. T. (2021).	UNITED STATES	QUANTITATIVE	SCOPUS
6	*Modern approaches to the diagnostics, treatment and prevention of severe community-acquired pneumonia in adults: a review*	Avdeev, S.N., Belotserkovsky, B.Z., Dehnich, A.V., ... Yakovlev, S.V., Yaroshetsky, A.I. (2021)	RUSSIA	QUALITATIVE	SCOPUS
7	*Effect of convalescent blood products for patients with severe acute respiratory infections of viral*	Shao, S., Wang, Y., Kang, H., & Tong, Z. (2021).	CHINA	QUALITATIVE	SCOPUS

	etiology: A systematic review and meta-analysis				
8	*Extracorporeal membrane oxygenation as a bridge to advanced heart failure therapies*	Acharya, D., Manandhar-Shrestha, N., Leach, M., Rajpraire, I., William, P., Kajui, T., ... & Loyga-Rendon, R. (2023).	UNITED STATES	QUANTITATIVE/QUALITATIVE	SCOPUS
9	*; Non-invasive Mechanical Ventilation in Acute Respiratory Failure. Clinical Practice Guidelines; [S2k-Leitlinie Nichtinvasive Beatmung als Therapie der akuten respiratorischen Insuffizienz]*	Westhoff, M., Neumann, P., Geiseler, J., ... Walterspacher, S., Windisch, W. (2024)	GERMANY	QUALITATIVE	SCOPUS
10	*Membrane oxygenator for extracorporeal blood oxygenation*	Ratnaningsih, E., Aryanti, P. T. P., Himma, N. F., Wardani, A. K., Khoiruddin, K., Kadja, G. T. M., ... & Wenten, I. G. (2021).	INDONESIA	QUALITATIVE	SCOPUS
11	*Bridge to second double lung transplant with an extracorporeal carbon dioxide removal system in situs inversus patient*	Furukawa, M., Chan, E. G., & Sanchez, P. G. (2022).	UNITED STATES	QUALITATIVE	SCOPUS
12	*Extracorporeal Membrane Oxygenation (ECMO) in Critically Ill Patients with Coronavirus Disease 2019 (COVID-19) Pneumonia and Acute Respiratory Distress Syndrome (ARDS)*	Ma, X., Liang, M., Ding, M., Liu, W., Ma, H., Zhou, X., & Ren, H. (2020).	CHINA	QUALITATIVE	WOS

13	*Early prediction of extracorporeal membrane oxygenation eligibility for severe acute respiratory distress syndrome in adults*	Bohman, J. K., Hyder, J. A., Iyer, V., Pannu, S. R., Franco, P. M., Seelhammer, T. G., ... & Schears, G. J. (2016).	UNITED STATES	QUANTITATIVE	WOS
14	*Neurological monitoring in ECMO patients: current state of practice, challenges and lessons*	Aboul-Nour, H., Jumah, A., Abdulla, H., Sharma, A., Howell, B., Jayaprakash, N., & Gardner-Gray, J. (2023).	UNITED STATES	QUANTITATIVE	WOS
15	*Placental pathology in a pregnant woman with severe COVID-19 and successful ECMO treatment: a case report*	Rosner-Tenerowicz, A., Fuchs, T., Zimmer-Stelmach, A., Pomorski, M., Trzeszcz, M., Zwierzchowski, J., & Zimmer, M. (2021).	POLAND	QUANTITATIVE	WOS
16	*Nutrition Implications and Challenges of the Transplant Patient Undergoing Extracorporeal Membrane Oxygenation Therapy*	Ulerich, L. (2014).	UNITED STATES	QUALITATIVE	WOS
17	*How I Select Which Patients With ARDS Should Be Treated With Venovenous Extracorporeal Membrane Oxygenation*	Bullen, E. C., Teijeiro-Paradis, R., & Fan, E. (2020).	CANADA	QUANTITATIVE	WOS

18	*Spontaneous breathing during veno-venous extracorporeal membrane oxygenation*	Crotti, S., Bottino, N., & Spinelli, E. (2018).	ITALY	QUANTITATIVE	WOS
19	*Challenges and pitfalls of extracorporeal membrane oxygenation in critically-ill pregnant and peripartum women with COVID-19: a retrospective case series*	Piwowarczyk, P., Porzak, M., Szczukocka, M., Miturski, A., Kaziród, K., Kwaśniewski, W., ... & Boris, M. (2023)	POLAND	QUANTITATIVE	WOS
20	*Predictors of insufficient peak amikacin concentration in critically ill patients on extracorporeal membrane oxygenation*	Touchard, C., Aubry, A., Eloy, P., Bréchot, N., Lebreton, G., Franchineau, G., ... & Schmidt, M. (2018).	FRANCE	QUANTITATIVE	WOS
21	*Predictors associated with successful weaning of veno-venous extracorporeal membrane oxygenation and mortality in adult patients with severe acute lung failure: Protocol of a pooled data analysis of cohort studies*	Ning, Y., He, L., Pan, K., Zhang, W., Luo, J., Chen, Y., ... & Wang, D. (2024).	CHINA	QUANTITATIVE	WOS
22	*Mobile Extracorporeal Membrane Oxygenation for Covid-19 Does Not Pose Extra Risk to Transport Team*	Javidfar, J., Labib, A., Ragazzo, G., Kurtzman, E., Callahan, M., Heinsar, S., ... & Covid-19 Critical Care Consortium. (2022).	UNITED STATES, QATAR	QUANTITATIVE	WOS

23	*Severe COVID-19 Pneumonia in a 30-Year- Old Woman in the 36th Week of Pregnancy Treated with Postpartum Extracorporeal Membrane Oxygenation*	Takayama, W., Endo, A., Yoshii, J., Arai, H., Oi, K., Nagaoka, E., ... & Otomo, Y. (2020).	JAPAN	QUANTITATIVE	WOS
24	*Anticoagulation and Bleeding during Veno-Venous Extracorporeal Membrane Oxygenation Insights from the PROTECMO Study*	Martucci, G., Giani, M., Schmidt, M., Tanaka, K., Tabatabai, A., Tuzzolino, F., ... & Arcadipane, A. (2024).	ITALY, UNITED STATES, SPAIN	QUALITATIVE	WOS

Source: *Own elaboration*

4.1 Co-occurrence of words

Figure 2 shows the relationship between the keywords used to search for the study material for the elaboration of the systematic analysis proposed for this research.

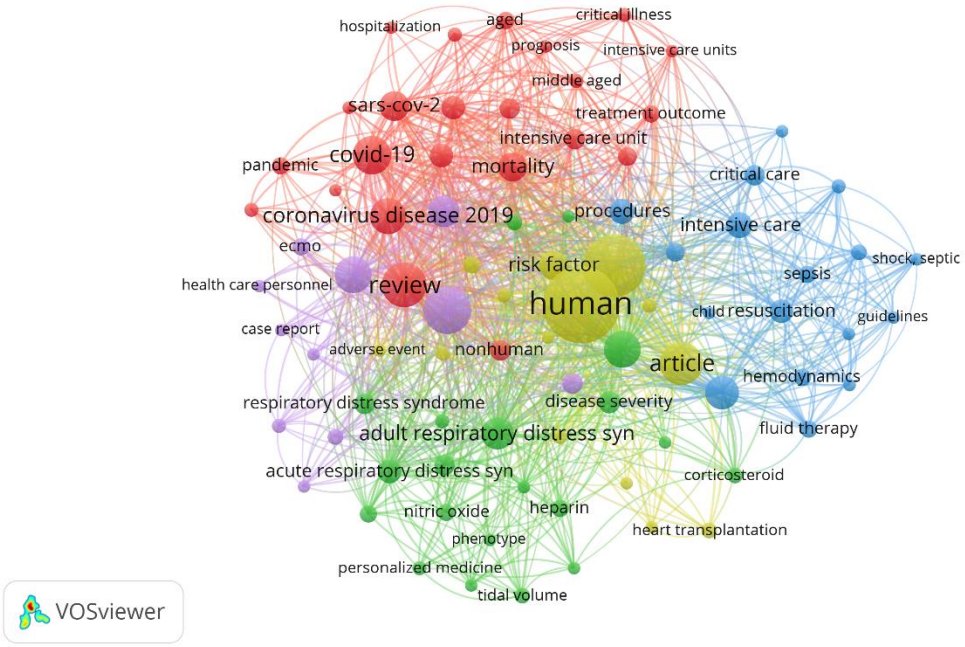

Figure 2. Co-occurrence of keywords.

Source: *Own elaboration*

The figure shows an analysis of the co-occurrence of terms related to the use of ECMO in the context of "ACUTE RESPIRATORY FAILURE". The terms are grouped by proximity and relatedness, indicating how often they appear together

in the scientific literature. Larger, closer nodes such as "CORONAVIRUS DISEASE 2019," "SARS-COV-2," "COVID-19," and "HOSPITALIZATION," suggest that much of the recent research has focused on the impact of the pandemic on ECMO use, especially in patients with "ADULT RESPIRATORY DISTRESS SYN."

In the center of the figure, the term "HUMAN" stands out, which is connected to other keywords such as "MORTALITY", "INTENSIVE CARE UNITS" and "CRITICAL ILLNESS". This indicates a predominant focus in studies focused on the survival and clinical outcomes of human patients in intensive care. The terms "MORTALITY" and "PROGNOSIS" are also strongly connected, highlighting the literature's concern about long-term outcomes in patients receiving ECMO support and variables that affect recovery, such as "DISEASE SEVERITY" and "RISK FACTORS".

Another part of the network shows the relationship of ECMO with terms such as "HEPARIN", "HEMODYNAMICS" and "FLUID THERAPY", reflecting the clinical challenges associated with the management of anticoagulation and hemodynamic stability in critically ill patients. This is crucial, as the implementation of ECMO requires constant monitoring and rigorous handling to avoid complications. In addition, terms such as "SEPSIS" and "SHOCK SEPTIC" connected to "CRITICAL CARE" underline the complexity of the cases in which ECMO is used, evidencing the need for comprehensive and personalized management.

Finally, the groups of terms related to "REVIEW" and "ARTICLE" indicate the existence of a large number of review studies on the topic, suggesting a sustained interest in the scientific community to synthesize and evaluate the evidence on ECMO. The presence of terms such as "CASE REPORT" and "ADVERSE EVENT" suggests that in addition to systematic studies, there is an interest in analyzing individual cases and the complications that may arise, providing a more detailed and specific view of clinical experiences with the use of ECMO in different contexts, especially during the pandemic.

4.2 Discussion

Analysis of studies on the use of ECMO in the context of acute respiratory failure reveals a wide range of methodological and geographic approaches, as well as a diversity of results that highlight both the advantages of the procedure and its clinical challenges. Ling et al. (2022), in a systematic review and meta-analysis focused on the evolution of ECMO outcomes during the "COVID-19" pandemic, underline the importance of this life support to improve survival in patients with severe "COVID-19". By involving data from multiple countries such as Singapore, the United States and Canada, the global relevance of the topic and the need to understand the efficacy of ECMO in different clinical contexts is evident. This study, being indexed in Scopus, adds a level of reliability and depth that enriches the discussion on the use of ECMO during global health emergency situations.

The study by Lorusso et al. (2021), which analyzes neurological complications during venovenous ECMO through a retrospective analysis of the "ELSO" database, provides crucial evidence on the risks inherent in the procedure, especially when it comes to patients with complex support configurations. The inclusion of countries such as the Netherlands, Italy, the United States and Belgium reinforces the importance of a multicultural perspective to understand variations in clinical practice and their implications for patient outcomes. This qualitative research, also indexed in Scopus, allows us to identify relevant patterns in neurological complications that should be considered in clinical decision-making, thus providing a basis for future management guidelines.

In a context of optimizing patient safety, Hofmaenner et al. (2023) address the relationship between reduced anticoagulation strategies and the lower incidence of intracerebral hemorrhage in patients with "COVID-19" receiving ECMO. This research, conducted in Switzerland, the United States and Germany, offers valuable insight into the need to balance the risk of thrombosis and bleeding in critically ill patients. The findings of this study are particularly relevant to clinical practice, as they suggest potential improvements in ECMO management protocols that could reduce severe complications in patients with "COVID-19". The qualitative approach of this work, together with its indexing in Scopus, reinforces its relevance and applicability in the context of the pandemic.

The study by Mou et al. (2022), a systematic review and meta-analysis on risk factors for acute kidney injury in patients with ECMO, highlights the critical relationship between extracorporeal support and renal dysfunction. Research from China offers a comprehensive view of how ECMO can influence patients' kidney function and what the main predictors of damage are. This qualitative study, indexed in Scopus, underscores the importance of close monitoring of renal function and the implementation of preventive strategies to mitigate the risk of renal complications in patients requiring this type of support. This contribution is essential to develop more effective management protocols in intensive care units.

In terms of technological innovation, Gimbel et al. (2021) explore the development of a high-efficiency microfluidic oxygenator for extracorporeal respiratory support in critical medicine. This quantitative study, conducted in the United States and also indexed in Scopus, emphasizes the importance of improving the efficiency of ECMO devices to reduce complications and improve the quality of support provided to patients. The research not only contributes to the field of bioengineering applied to medicine, but also offers a perspective on how technological innovation can be a catalyst for the advancement of treatments in critically ill patients, especially those with severe respiratory failure.

Finally, studies focused on the application of ECMO in particular clinical situations, such as that of Furukawa et al. (2022),

which analyzes the use of a carbon dioxide removal system in patients with double lung transplantation, offer specific evidence on the benefits of ECMO as a therapeutic bridge. This qualitative research, developed in the United States and indexed in Scopus, illustrates how ECMO can be adapted to complex clinical scenarios, maximizing the chances of survival in patients with specific pathologies. The ability of ECMO to be used as a bridge in advanced therapies reinforces its value as a versatile and essential tool in the management of critically ill patients with unique respiratory support needs.

5. CONCLUSIONS

The analysis of studies on the use of ECMO in the management of acute respiratory failure highlights its crucial role, especially during the COVID-19 pandemic, where it has become a fundamental tool to improve the survival of critically ill patients with acute respiratory distress syndrome. ECMO offers advanced life support that allows for better oxygenation and gives time for recovery of lung function in cases where other treatments have failed. However, its use involves facing several important challenges, such as the risk of complications, including intracerebral hemorrhages and renal dysfunction, which requires specialized management and constant monitoring. In addition, the availability of ECMO is limited to health facilities that have specialized resources and trained personnel, restricting access in certain countries and regions. Despite these challenges, technological innovation has led to the development of more efficient and safer devices, which has improved the quality of support provided and opened up new possibilities for use in critical medicine. However, significant variability in clinical practice and lack of standardization of use protocols still persist, which can lead to inconsistent results. This underscores the need to develop clear evidence-based guidelines to optimize their application, ensuring that the benefits of ECMO can be maximized in different clinical and geographic contexts. In addition, although some studies show promising results in the short and medium term, it is essential to continue investigating the long-term effects of this treatment to better understand its impact on patients' recovery and quality of life.

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