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COMPLICATIONS RELATED TO EXTRACORPORAL MEMBRANE OXYGENATION (ECMO): NURSING DIAGNOSES BASED ON THE NANDA TAXONOMY 2021 – 2023

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Abstract: Goal: Identify complications related to extracorporeal membrane oxygenation in the literature and map the nursing diagnoses in the face of this problem. **Methodology:** An integrative review study with a descriptive approach, where studies published in the last 10 years were searched in Medline and LILACS databases via the PuBMEd portal and in the Virtual Health Library (BVS), respectively, using the terms "Oxygenation by extracorporeal membrane" OR "ECMO" AND "Complications". **Results:** A total of 7,218 studies were identified, after screening and application of inclusion and exclusion criteria, only 9 studies were included in the review. No studies on nursing diagnoses in patients with ECMO were identified. Categorically, the most frequent complications identified were: hemorrhagic, vascular, renal, infectious and mechanical complications. **Conclusion:** The nursing diagnoses suggested by the authors are promising, as they enable critical thinking to identify real or potential problems, helping nurses' clinical practice.

Keywords: Extracorporeal membrane oxygenation, complications, Nursing diagnoses.

INTRODUCTION

O uso de oxigenação por membrana extracorpórea (ECMO) vem sendo bastante requisitado no suporte a pacientes com insuficiência cardíaca and/or severe respiratory problems that do not respond to conventional clinical treatments, especially nowadays in the context of the Covid-19 pandemic (1,2). International statistical data released by the Extracoporal Life Support Organization (ELSO) report an overall survival of 54% of patients undergoing ECMO, including all age groups, adults, pediatrics and neonates, as well as all indications, cardiac and pulmonary. Thus, ECMO appears to be a very promising life support strategy for patient survival. (1)

However, despite its benefits, it must be clear that patients undergoing such support are not exempt from complications, since it is an extremely invasive support. Regardless of the indication or modality of ECMO, categorically the most frequent complications are: hemorrhagic, vascular, infectious and renal complications, in addition to mechanical problems related to the ECMO circuit and devices. (3) Therefore, the clinical and scientific understanding of these complications by nurses is necessary, and the Nursing Diagnoses (ND) are one of the stages of the nursing process (NP) essential in this context.

The nursing process consists of a methodological instrument that guides nursing practice in an organized and scientific manner, being essential in patient care. The resolution of the Federal Nursing Council (COFEN) No. 358 states that the NP is organized into five interrelated, interdependent and recurrent stages, namely: data collection, Nursing Diagnosis, Planning, Implementation and Nursing Assessment (4). For the elaboration of nursing diagnoses, the focus of this study, the taxonomy of the North American Nursing Diagnoses Association (NANDA) is used, which provides the basis for their formulation. (5)

The elaboration of nursing diagnoses involves analysis and clinical judgment regarding data collected after initial investigation of the patient, whether through primary or secondary sources. Therefore, through the interpretation of the responses of the person, family or community, it is possible to identify real or potential problems, which will be the basis for planning and interventions to be adopted. (4)

For the elaboration of the ND, some structures must be taken into account, namely: The defining characteristics, which refer to the signs and symptoms identified

in the data collection; Related factors refer to the cause, etiology or conditions that are related to the diagnosis; and risk factors, which express situations that increase the vulnerability or susceptibility of the person, family or community to a disease, whether biological or environmental factors. [5]

In view of the frequent complications related to ECMO, this study is justified by the importance of the use of nursing diagnoses, as a strategy that allows the early identification, as well as the resolution of these complications by the Nurse, as he is an active agent that is found if on the front line in this context. As a result, the following guiding question is asked: What Nursing Diagnoses are relevant and appropriate in the face of complications related to extracorporeal membrane oxygenation?

GOAL

Identify ECMO-related complications in the literature and develop nursing diagnoses in the face of this problem.

METHODOLOGY

This is an integrative, qualitative descriptive systematic review. The literature search was carried out between November and December 2021, in the Medline and Lilacs databases via the PubMed portal and the Virtual Health Library (BVS), respectively. The following terms were used in the databases: "Extracorporeal Membrane Oxygenation", "ECMO", "Complications". Along with the terms described, the Boolean operators were used: OR and AND. The search strategy used was: "Extracorporeal membrane oxygenation" OR "ECMO" AND "Complications" (via pubmed); ("Extracorporeal membrane oxygenation") OR ("ECMO") AND ("complications") (via VHL). The references of some studies found were also searched as a way to identify potentially eligible articles. As inclusion criteria, only complete online articles of free access, published in the last 10 years, without language restriction were included. Articles with primary results were chosen, such as prospective or retrospective cohort studies. Only articles that addressed the research question were carefully included. Narrative and integrative review articles, abstracts of articles, monographs, theses, repeated articles, as well as studies with less than 10 participants were excluded. The initial search and screening process of the studies was performed by only one researcher, in which the inclusion and exclusion criteria were applied. The pre-selected articles had their titles and abstracts read, and then those that met the eligibility criteria of the study were read in full, with the last process carried out by three researchers independently, who finally reached consensus.. To present the results, two tables were constructed. Table 01 presents relevant data on ECMO patient complications, as well as the main characteristics of the included studies, being structured as follows: Author and year of publication, title, type of study, objectives and results. Table 02 presents the Nursing Diagnoses based on NANDA, in which they were structured as follows: Domain/classes, Nursing Diagnoses including their related factors. For the elaboration of the Nursing diagnoses, a clinical reasoning method was used based on the main complications and clinical findings identified in table 01. The organization of the search and selection of literature data is presented in the adapted flowchart based on the prism guidelines - Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (6).

RESULTS

The electronic literature search resulted in a total of 7,218 studies, most of which were identified in the Medline database

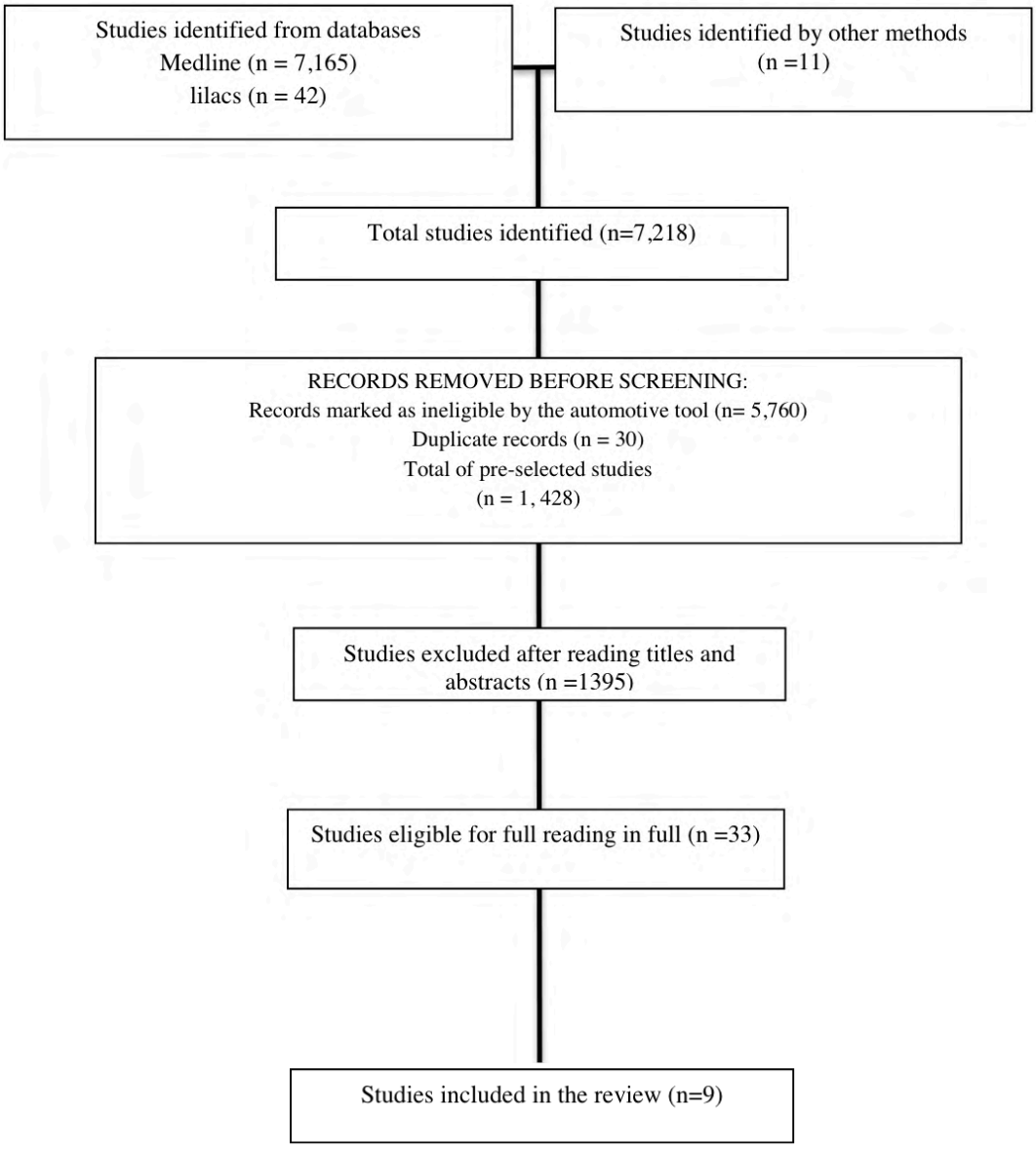

Figure 1. Flowchart of the study identification and selection process. Adapted from PRISMA.

(n=7,165), and only (n=42) studies in Lilacs. After exclusion by automation tools and elimination of duplicates, 1,428 studies eligible for reading titles and abstracts were pre-selected. Of these, 33 were eligible for full reading, and 9 studies were included in the review.

Table 01 presents the most relevant data on ECMO patient complications, obtained from the analysis of each study. After analysis, as expected, the main events identified were: hematological complications (hemolysis, embolism/thrombosis, bleeding), vascular complications (lower limb ischemia, vascular trauma,compartmentsyndrome),neurological events (intracranial hemorrhage, ischemic stroke, seizure), infectious complications (bloodstream, respiratory tract, urinary tract, and surgical wound infections), renal complications, and mechanical complications (pump and membrane oxygenation failure). [7, 8, 9, 10, 11, 12, 13, 14, 15]

In view of the complications and clinical findings identified in the literature, the possible nursing diagnoses were primarily elaborated, listed in table 2. Thus, there were a total of 16 nursing diagnoses, of which 13 focused on the problem and 3 risk diagnoses, as well as like, 4 domains and 6 distinct classes.

Author (year)	Study title	Type of study	objective	Main findings
LEHLE et al. (7) (2015)	Technique-induced hemolysis in patients with respiratory failure supported by veno-venous ECMO - Prevalence and Risk Factors.	Retrospective Cohort	To explore the prevalence and risk factors for technique-induced hemolysis in adults with veno-venous extracorporeal membrane oxygenation (VV-ECMO) and to analyze the effect of hemolytic episodes on outcome.	Higher levels of free hemoglobin were associated with blood flow velocity, patients with renal failure requiring continuous veno-venous hemodialysis (CVVHD), increased need for erythrocytes.
BISDAS et al. (8) (2011)	Vascular complications in patients undergoing femoral cannulation to support extracorporeal membrane oxygenation.	cohort Retrospective	Specifically assess short- and medium-term vascular complications and associated risk factors.	Clinical manifestations in the veno-arterial cohort were acute embolism/thrombosis, common femoral artery dissection, postoperative false aneurysm, groin hematoma, femoral artery perforation, and compartment syndrome.
KAUFELD et al. (9) (2019)	Risk factors for critical limb ischemia in patients undergoing femoral cannulation by extracorporeal veno-arterial membrane oxygenation: is distal limb perfusion a mandatory approach?	Retrospective Cohort	Distinguish the presence or absence of perfusion of the distal limb in relation to the incidence of ischemia of the distal limb.	Poor ipsilateral distal perfusion was identified as the main risk factor for limb ischemia.
AUBRON et al. (10) (2016)	Predictive factors of bleeding events in adults undergoing extracorporeal membrane oxygenation.	Retrospective Cohort	To describe bleeding complications in critically ill patients undergoing ECMO and to identify risk factors for bleeding events.	Higher PTT values, in addition to higher APACHE III and ECMO scores after surgery, as well as lower recorded temperature, were factors associated with bleeding events.

CAVAYAS et al. (11) (2020)	Early change in PaCo2 after initiation of extracorporeal membrane oxygenation is associated with neurologic complications	Retrospective Cohort	To determine whether magnitude of PaCo2 in the first 24 hours of ECMO initiation is associated with an increased incidence of neurological complications.	Patients with a large relative decrease in Pa_{CO2} (>50%) showed an increased incidence of neurological complications compared to those with a smaller reduction (9.8% vs. 6.4%; P < 0.001).
SANDERS JÖÖ et al. (12) (2017)	Predictors of intracranial hemorrhage in adult patients on extracorporeal membrane oxygenation	observational cohort	To identify predictors of intracranial hemorrhage in adult patients treated with Ecmo.	Pre-admission antithrombotic therapy, high pre-cannulation sofa coagulation score, spontaneous extracranial hemorrhage, thrombocytopenia, patients on dialysis, septic shock, and amount of packed red blood cells administered were risk factors for ICH.
AYYILDIZ et al. (13) (2017)	Evaluation of nosocomial infections in pediatric patients supported by extracorporeal membrane oxygenation.	Retrospective Cohort	To determine the incidence, risk factors, and causal organisms related to acquired infections and to assess survival rates of ECMO patients with nosocomial infections.	The main factor associated with infection was prolonged ECMO support.
LEE et al. (14) (2015)	Risk factors for acute kidney injury and hospital mortality in patients receiving extracorporeal membrane oxygenation	Retrospective Cohort	Explore risk factors for AKI and in-hospital mortality in patients receiving ECMO support	The initial ECMO pump speed was associated with in-hospital mortality and AKI. Elevated RDW may be suggested as a risk factor for severe AKI in these patients.
LUBNOW et al. (15) (2014)	Technical complications during veno-venous extracorporeal membrane oxygenation and their relevance in predicting a system change - retrospective analysis of 265 cases.	Retrospective Cohort	Identify technical complications and predictive factors that indicate switching systems in ECMO.	The formation of clots in the OM and in the pump head, represented 85% of the technical complications, implying in the transfer of gases and coagulation disorders as well as hemolysis. In addition, mechanical failure of pumps suspected of circuit infection was pointed out.

Table 1 - Main complications and clinical findings in the patient on ECMO.

Source: Reis, T. S, et al., (2021).

Domains/Classes	Nursing Diagnoses
Activity/Rest Cardiovascular/pulmonary responses	Risk of impaired peripheral tissue perfusion related to excessive hemolysis
Activity /Rest Cardiovascular/pulmonary responses **Safety / Protection** Physical injury	Ineffective peripheral tissue perfusion related to intravascular femoral artery cannula insertion procedure, evidenced by signs of poor episilateral perfusion Risk of impaired skin integrity related to impaired lower limb blood circulation. Risk of vascular trauma related to vascular cannula insertion
Security / Protection physical injury **Security / Protection** thermoregulation	Risk of Bleeding related to higher value of APTT, ECMO post-surgery and low temperature. Hypothermia characterized by core body temperature below normal diurnal parameters related to failure of thermoregulatory mechanisms;
Activity/Rest Answers cardiovascular/pulmonary **Security / Protection** physical injury	Risk of ineffective brain tissue perfusion related to pharmaceutical agent; Bleeding risk associated with antithrombotic therapy and thrombocytopenia;
Activity/Rest Answers cardiovascular/pulmonary	Risk of ineffective cerebral tissue perfusion related to marked variations in PaCo2 and/or PaO2.
Security / Protection Infection **Security / Protection** physical injury	Risk of Infection at the surgical site related to improper handling of the surgical wound Risk of infection related to invasive procedures and breach of aseptic techniques Shock risk associated with infection by pathogenic microorganisms.
Nutrition Hydration	Risk of electrolyte imbalance
Elimination and Exchange Respiratory function **Security / Protection** physical injury **Activity/Rest** Answers cardiovascular/pulmonary	Impaired gas exchange related to the formation of clots in the oxygenating membrane, as evidenced by an increase in post-OM PCO2 and a decrease in post-OM PO2; Risk of bleeding related to clotting disorders induced by blood contact in the ECMO circuit; Risk of ineffective peripheral tissue perfusion associated with mechanical failure of ECMO devices.

Table 2 - Nursing Diagnoses suggested to the patient on ECMO.

Source: Reis, T. S, et al., (2021).

DISCUSSION

In this research, it was observed that most of the studies were cohort, unicentric and multicentric, reflecting a higher level of evidence for the research in question. In addition, there was little production about the proposed objective, and no study on nursing diagnoses in ECMO patients, which may be related to nurses' lack of knowledge about ECMO, as well as low involvement in research. Therefore, a critical analysis was carried out in a descriptive way, seeking to elucidate the Nursing diagnoses suggested by the authors.

Hemolysis is an important complication in patients on ECMO, occurring secondary to several mechanisms, with free hemoglobin (FHB) being an important predictor of mortality (16). In a retrospective analysis of the incidence and possible causes of hemolysis in 318 patients on VV-ECMO, it was observed that the flow velocity of the centrifugal pump was significantly associated with higher levels of free hemoglobin, interestingly with no change in lactate dehydrogenase (LDH). However, patients with renal failure (RI) requiring continuous veno-venous hemodialysis (CVVHD) before or during ECMO expressed higher levels of FHB and LDH compared to patients without IR. [7]

It is worth noting that lower (≤ 2.5 L/min) and medium (2.5-3.0 L/min) blood flows were associated with a lower level of FHB in relation to higher blood flow (≥ 3, 0 L/min) which resulted in a moderate increase in FHB. In this study, the type of pump used was not significantly associated with hemolysis. On the other hand, the use of a 24 Fr cannula induced significantly higher FHB levels (116 (94, 129) mg/L compared to 27 Fr (61 (40, 83) mg/L). [7]

It is speculated that centrifugal pumps result in less hemolysis than roller pumps, despite controversial experiments. In a clinical comparative study between the use of centrifugal and roller pumps, hemolysis was strongly associated with roller pumps, with higher levels of free hemoglobin in plasma being evidenced. (17) Excessive free hemoglobin in plasma can trigger a series of consequences, including cytotoxic effects, inhibition of nitric oxide and consequent vasoconstriction with hypoxia, resulting in reduced blood and oxygen supply to tissues. (18) Therefore, the diagnosis of impaired peripheral tissue perfusion risk was attributed to hemolysis.

On the other hand, the risk of impaired peripheral tissue perfusion may also be associated with other conditions as well as intravascular procedures. Lower limb ischemia is a potential complication in patients on ECMO via femoral cannulation. In a cohort including 307 patients on ECMO-VA, poor ipsilateral distal perfusion was identified as the main risk factor for limb ischemia, occurring in 7.49% of all patients in the study. In addition, a significant difference in poor perfusion was found between patients in the group without distal limb perfusion (DLP) compared to the group with DLP. [9]

In a retrospective analysis of 174 patients on ECMO-VA in femoral cannulation, the main risk factor for vascular complications was peripheral arterial disease, where at least one vascular complication manifested in 10% (n=17) of the patients. In this study, the main vascular events reported were: Acute embolism/thrombosis (n=6), common femoral artery dissection (n=2), postoperative pseudoaneurysm (n=2), groin hematoma (n=1), femoral artery perforation (n=1) and compartment syndrome (n=6). [8]

In the context of limb ischemia, it is necessary to understand that the cannula inserted in the femoral artery allows delivery of oxygenated blood to the patient, however, it reduces the vascular lumen, decreasing blood flow to the lower limbs, resulting in lower

tissue perfusion and consequent ischemia. Therefore, the following diagnoses must be considered: Ineffective peripheral tissue perfusion, and risk of impaired skin integrity related to decreased blood circulation in the lower limbs.

Unquestionably, bleeding complications are an important challenge for patients on ECMO, as they are associated with less favorable outcomes. A recent multicenter ELSO study reported the occurrence of 8,457 hemocompatibility-related adverse events (HRAE) in 5,285 of 11,984 patients (44.1%), where hemorrhages represented 5,256 events (62.1%). Patients who experienced HRAE had a higher mortality rate in contrast to those without HRAE (64.4% vs 54.6%). [19]

It must be made clear that the occurrence of bleeding in ECMO patients is due to several pathophysiological mechanisms, as well as clotting factor dysfunction, thrombocytopenia induced by blood contact on non-endothelial surfaces, anticoagulant therapy, in addition to underlying pathological conditions that may influence hemostatic disorders. [20–22]

The Dutch single-center retrospective cohort, including 164 participants, showed that 73 (45%) of the 164 patients evaluated had a bleeding complication, results that are associated with longer activated partial thromboplastin time aPTT, longer ECMO support, especially venous ECMO -arterial (ECMO-VA).[23] Another study with 149 patients showed similar results, where higher aPTT, higher APACHE III score, post-surgical ECMO, and lowest temperature recorded were considered as risk factors.[10] Taking into account these results, diagnoses of risk of bleeding related to higher APTT, post-surgery ECMO and low temperature were elaborated.

Neurological events such as intracranial hemorrhage, cerebrovascular accident and seizure can also manifest in ECMO patients, involving a variety of complex mechanisms. A large multicenter study with 11,972 adult patients enrolled in the ELSO registry sought to determine the relationship between the variation in partial pressure of carbon dioxide (paCo2) after initiation of ECMO and the occurrence of neurological complications. In this study, neurological complications occurred in 6.9% of patients, with an incidence of seizures in (1.1%), ischemic stroke (1.9%), intracranial hemorrhage (3.5%) and brain death in (1.6%).[11]

In the reported study, the authors showed that patients with a drop in PaCo2 > 50% had a higher incidence of neurological complications when compared to those with minimal changes in PaCo2 (PaCo2 < 50%). At the same time, another relevant result is that post-ECMO hypoxemia (PaO2 < 60mmHg) and hyperoxemia (PaO2 > 300mmHg) were significantly associated with a higher incidence of neurological complications.[11]

In contrast, the literature has also shown an association between hyperoxia and increased mortality in ECMO patients. (24) It must also be noted that both hypocapnia and hypercapnia are also associated with neurological complications, as they result in vasoconstriction and vasodilation, respectively, thus affecting brain parenchymal perfusion, among other physiological repercussions. [11]

With regard to neurological complications, intracranial hemorrhage (ICH) is a potentially life-threatening complication of ECMO patients, thus underscoring the need for early identification. In an observational cohort study with 253 patients, ICH manifested in 54/253 patients during ECMO support, representing 21%. In the comparative analysis between patients who developed ICH compared to those without ICH, pre-admission antithrombotic therapy, high coagulation score, precannulation sofa, spontaneous extracranial hemorrhage,

thrombocytopenia, patients on dialysis, septic shock and amount of packed red blood cells administered. [12]

In view of this, the following diagnoses were made: risk of ineffective brain tissue perfusion related to pharmaceutical agent, risk of ineffective brain tissue perfusion related to marked variations in PaCo2 and/or PaO2, and risk of bleeding associated with antithrombotic therapy and thrombocytopenia.

Undoubtedly, infectious events represent a complication commonly found in patients on ECMO, and may occur during or after support, regardless of age group and type of ECMO used. Within this spectrum, studies show that the main infectious events are bloodstream infections, respiratory tract infections, urinary tract infections and surgical wound infections, complications related to a range of factors. [25,26]

The incidence rates of infectious events are heterogeneous in the literature. However, in a cohort of 66 pediatric patients on ECMO in the ICU, the study reported that 28/66 (42%) patients had at least one infection during ECMO support, with 34 episodes of infecfions being idenfified. Bloodstream infections accounted for 13 episodes (37.2%), 10 (29.4%) respiratory tract infections, 9 (25.7%) urinary tract infections, and 2 (5.7%) episodes of sternal wound infections. [13]

In the aforementioned study, prolonged ECMO support was strongly associated with a higher risk for infections, with a nosocomial infection rate of 116.2/1000 ECMO days [13]. It is a fact that ECMO patients are critically ill, requiring venous access, all orotracheal, drains, catheters, in addition to surgical wounds, making them more susceptible to infections. In view of this, the diagnoses of risk of infection at the surgical site related to inadequate handling of the surgical wound, invasive procedures and breach of aseptic techniques, in addition to risk of shock associated with infection by pathogenic microorganisms, were elaborated.

Among the various events that occur, renal complications manifest themselves with a high incidence and impact with great magnitude patients on ECMO, since it is associated with unfavorable outcomes. This statement has been corroborated by a large meta-analysis with 10,212 patients, which showed that 62.8% of patients had acute kidney injury (AKI), of which 44.9% required renal replacement therapy (RRT). The study showed high mortality rates, with 62.0% and 68.9% for patients with AKI and AKI on RRT, respectively. [27]

The literature denotes a complex and multifactorial relationship between ECMO patients and the development of acute kidney injury (AKI). Studies speculate that AKI is associated with several factors, such as: Pre-ecmo management, hemodynamic disorders with changes in renal macro and microvasculature, ischemic processes, excessive hemolysis, oxidative stress, nephrotoxicity, immune responses such as the activation of inflammatory cytokines and chemokines that recruit inflammatory cells during AKI, among other factors not yet clarified and unknown. [28–32]

In addition to the factors already mentioned for AKI, the serum sodium level and SAPAS II are parameters that must be taken into account, since these variables in retrospective evidence covering 322 adult patients on ECMO were associated with higher mortality compared to the group of surviving patients.. In parallel, initial pump speed and red blood cell distribution amplitude (RDW) > 14.1% were significantly associated with AKI and in-hospital mortality. Thus, we take into account the diagnosis of risk of electrolyte imbalance related to renal dysfunction. [14]

Although clinical complications are of great importance, technical complications

are also worth mentioning, which, among other factors, are usually secondary to clotting disorders, especially with regard to clot formation. The formation of clots in the various parts of the ECMO circuit and devices results in a series of consequences, as well as pump operation and reduced transfer of O2 and CO2 gases in the oxygenating membrane (OM). [15]

In a retrospective analysis of 265 patients on VV-ECMO, about 88 (31%) of the patients required one or more ECMO system changes due to technical complications that occurred. In this study, the author reported mechanical failure of pumps, thrombosis in the pump head, acute thrombosis in the oxygenator, suspected circuit infection, and coagulation disorders as the main technical complications. Furthermore, clot formation in the OM and pump head accounted for 85% of technical complications.[15]

Therefore, in view of the findings, we considered the diagnoses of impaired gas exchange related to the formation of clots in the oxygenating membrane, evidenced by an increase in post-OM PCO2 and a decrease in post-OM PO2; Risk of bleeding related to clotting disorders induced by blood contact in the ECMO circuit; Risk of ineffective peripheral tissue perfusion associated with mechanical failure of ECMO devices.

The findings of this research especially provide Critical Care Nurses with clinical reasoning regarding ECMO patient complications, with a view to evidence-based practices, while it can support nurses in clinical practice in the elaboration of an individualized care plan, ensuring greater safety in the management of these patients. At first, it is emphasized that diagnostic hypotheses were raised, and there is also a need for studies on Nursing Interventions, which will be the objective of a later study.

It is emphasized that this research may have limitations due to the small number of studies included, a fact related to the eligibility criteria, in addition, there were few studies related to the topic in question.

CONCLUSION

The results presented and discussed were considered relevant, although there are limitations, since the nursing diagnoses listed in the study proved to be a very promising strategy in the management of patients on ECMO, because through them, it was possible to identify injuries and assume possible complications, which are essential for quality and systematized care. Furthermore, this study brought a reflection on the role of nurses in the context of patients on ECMO, since they are active agents in the management of these patients.

However, there was little scientific production involving nurses in this context of study, a fact that may be related to the lack of knowledge about the magnitude of complications in ECMO patients. Therefore, this study awakens the need for nurses to join as a research agent, thus contributing to the scientific community by providing evidence-based care.

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