Review Article

Bull Emerg Trauma 2024;12(3):103-110.

Bulletin of Emergency And Trauma

A Systematic Review and Meta-analysis Unveiling the Pivotal Role of Extracorporeal Membrane Oxygenation (ECMO) in Drug Overdose Treatment Optimization

Hany A. Zaki[1], Yavuz Yigit[1], Mohamed Elgassim[1*], Eman E. Shaban[1], Amira Shaban[1], Stuart A Lloyd[1], Mazin Sharafeldien Elsayed Mohamed[1], Aftab Mohammad Azad[1]

[1]Department of Emergency Medicine, Hamad Medical Corporation, Doha, Qatar

***Corresponding author:** Mohamed Elgassim
Address: Department of Emergency Medicine, Hamad Medical Corporation, Doha, Qatar.
e-mail: moelgassim@gmail.com

Received: April 2, 2024
Revised: June 10, 2024
Accepted: June 18, 2024

ABSTRACT

Objective: The present study aimed to evaluate the clinical benefits and drawbacks of administering ECMO/ECLS therapies to drug-intoxicated patients.
Methods: From inception until April 30, 2024, an extensive search was performed on four main databases: PubMed, Web of Science, Cochrane Library, and EMBASE. There was no restriction on the search period. Only the studies that reported survival to hospital discharge rates, adverse events, and the utilization of ECMO/ECLS in the treatment of intoxicated patients were included. On the other hand, articles that did not report adverse events or hospital discharge rates as outcomes, as well as studies published in languages other than English, were excluded. The evaluated outcomes were the rate of survival to hospital discharge rate and the incidence of adverse events associated with ECMO therapy. The Newcastle Ottawa scale was employed to appraise each study to determine its methodological quality. The Comprehensive Meta-Analysis (CMA) software (version 3.0) for statistical analysis was used, with the random effects model (due to high heterogeneity among the studies) and a 95% confidence interval.
Results: From a total search of 2216 search results, only 10 studies were included. The pooled analysis from 10 studies indicated that ECMO therapies among drug-overdosed/poisoned patients were associated with a significant survival to hospital discharge rate of 65.6% ([95% CI: 51.5%-77.4%], p=0.030). However, the outcomes were highly heterogeneous (I^2=83.47%), which could be attributed to the use of several medicines by different studies. In contrast, ECMO therapies among drug-overdosed patients were associated with a significant incidence rate of adverse events of 23.1% ([95% CI: 12.3%-39.2%], p=0.002). However, the pooled analysis had a significant heterogeneity (I^2=70.27%).
Conclusion: Despite various health complications, extracorporeal membrane treatment enhanced survival to hospital discharge with good neurological outcomes. Hence, it was a viable, effective, and feasible alternative for managing drug-induced intoxication in patients.

Keywords: Extracorporeal treatment, ECMO therapies, ECLS, Drug-overdose, Poisoning.

Please cite this paper as:
Zaki HA, Yigit Y, Elgassim M, Shaban EE, Shaban A, Lloyd SA, Mohamed MSE, Azad AM. A Systematic Review and Meta-analysis Unveiling the Pivotal Role of Extracorporeal Membrane Oxygenation (ECMO) in Drug Overdose Treatment Optimization. *Bull Emerg Trauma*. 2024;12(3):103-110. doi: 10.30476/beat.2024.102203.1503.

Introduction

The National Poison Data System reported at least 2.10 million human toxicologic contact incidences in 2019, with over 2000 deaths in the United States [1]. The majority of serious cases were caused by pharmaceuticals, specifically analgesics, followed by cardiovascular prescriptions, sedatives, illicit narcotics, and antidepressants [1]. In 2021, pharmaceutical products accounted for 50.30% of all registered toxic exposures [2]. The data indicated that drug overdose resulting in poisoning is steadily intensifying. Therefore, drug poisoning caused by overdose is a global issue, contributing to a variety of morbidities and fatalities [3]. With the gradual increase in drug overdose, which leads to severe health consequences, there is a need to develop particular treatments and therapeutic modalities.

Despite advances in the specific poisoning exposure treatment, sympathetic and symptomatic care remains the primary therapy [4]. Among the most aggressive sympathetic mode is extracorporeal membrane oxygenation (ECMO) [4]. According to Wang *et al.,* ECMO, also known as extracorporeal life support (ECLS), is an external mechanism that provides supportive cardiovascular and respiratory functions such as oxygenation, carbon (IV) oxide removal, cardiac operations, and the maintenance of perfusion pressure in critically ill patients. The device is responsible for pumping hypoxic blood from the patient's body and running it through artificial lungs, which expel the accumulated Carbon (IV) oxide and facilitate the addition of oxygen [4]. Moreover, the machine warms the oxygenated blood to fulfill the physical requirements [5]. Thus, a temporary bypass is established, reducing blood flow to the heart and lungs, allowing these organs to effectively expel toxins and recover from the intoxication.

In contrast, nutrition and oxygenated blood delivery are maintained throughout the body [6]. The use of ECMO as a treatment modality for critically ill patients has increased during the past five decades [7, 8]. Consequently, studies showed that it is appropriate for delivering cardiac and respiratory functions when conventional therapy and treatment options have been deemed ineffective [7, 9].

The applicability of ECLS therapy in people has remained a clinical puzzle, based on the immediate administration of ECLS in animals following drug intoxication, which does not reflect the human toxification process [10]. However, a case study assessed the application of ECMO in individuals with acute drug intoxication with profound shock reveals much better outcomes than other therapies [10]. With an increase in ECMO treatments globally, there is a need to investigate the clinical benefits of this therapy modality among individuals intoxicated with drugs. Therefore, following this gap presented in the literature on the effectiveness of ECMO therapy in humans presenting with acute drug intoxication, we aimed to conduct a systematic review and meta-analysis of available data to provide a more comprehensive overview and offer more transparent and more concise medical outcomes on the role of ECMO or ECLS therapies to medical professionals and policymakers. Besides, this will be the first systematic review and meta-analysis that will pool data and focus explicitly on the role of ECMO therapy in enhancing survival among patients who have experienced a drug overdose. In this way, the primary aim of this study was to investigate the clinical benefits (survival rate) of ECMO/ECLS therapies in drug-intoxicated patients while also evaluating the drawbacks associated with the therapies.

Materials and Methods

Two reviewers determined the criteria for excluding and including the identified studies in this comprehensive review article. After assessing the topic and research objective, the two reviewers derived the following inclusion criteria:

a) Studies reported outcomes from patients admitted to healthcare facilities with acute drug intoxication, either intentionally or unintentionally.

b) Studies highlighted the use of ECMO/ECLS in acute intoxication treatments caused by drug administration or overdose to remove the poison.

c) Studies reported survival to hospital discharge rate, adverse events, or both.

In contrast, the reviewers devised the following exclusion criteria to determine the illegibility of the articles:

a) Studies that reported neither of the following outcomes: adverse events and survival to discharge rates.

b) Studies on alternative treatments for drug overdose, other than ECMO or ECLS.

c) Non-English, secondary content (reviews, letters to editors), or animal studies.

To determine relevant studies to this research objective, two search strategies: manual and electronic were applied. One reviewer was tasked with doing a literature search on the four main databases, including PubMed, Web of Science, Cochrane Library, and EMBASE, from inception to 30th April 2024. The reviewers used the following keywords and MeSH terms to identify the articles: (extracorporeal membrane oxygenation OR ECMO) OR (extracorporeal life support OR ECLS) AND (drug intoxication OR drug overdose or drug poisoning). There was no restriction on the publication year. Furthermore, the reviewer conducted a manual search by scanning the reference lists of identified articles for additional and relevant publications.

Two independent reviewers screened the studies included in the present review and collected the data required for statistical analyses. The acquired

data by these reviewers were tabulated and included author ID (the first author's surname and year of publication), study design, number of participants on ECMO, study duration, drug intoxication agents, and primary outcomes. The outcomes of this study included summary findings, survival to discharge rate, and adverse events. Any disagreements or controversies that arose during data extraction were referred to the chief author for settlement through resolution.

Given that studies in this review were retrospective, the methodological quality was assessed using the Newcastle-Ottawa quality assessment tool. A single reviewer independently carried out the quality appraisal process and grouped each included study into three categories: selection, comparability, and outcomes. The selection category used four assessment criteria, while comparability and outcomes had 1 and 3 assessment criteria, respectively. Rating scores were then assigned to each study based on the assessment criteria. A rating score of "1" was used for a fully addressed criterion, and "0" was used for a criterion that was either ambiguous or not entirely addressed. Studies with ratings of 0-2, 3-5, and >5 were classified as poor, moderate, and high methodological quality, respectively.

Statistical analyses were performed using the Comprehensive Meta-Analysis (CMA) software (version 3.0). Random effects models were utilized to estimate the pooled survival to hospital discharge rate and adverse events with the corresponding 95% confidence intervals (CI). The I^2 statistic was used to assess the heterogeneity of the study findings. The I2 value of ≥70%, ≤50%, or <25% indicated high, moderate, or low heterogeneity [11]. The dichotomous outcomes (events) of the included studies were combined to produce a pooled effect size. Funnel plots evaluated the publication bias across the studies eligible for statistical analysis. The symmetrical distribution of studies indicated the absence of publication bias, while the unsymmetrical distribution of studies in the funnel plot demonstrated publication bias [12].

Results

The database search yielded 2216 potential studies for inclusion. The first examination resulted in the removal of 1500 duplicates. Based on the title and abstract screening, 126 articles were excluded from 716 articles. The remaining 590 articles were sought for retrieval, and all were retrieved and assessed based on the predetermined eligibility criteria. Subsequently, only 10 studies were included, while 580 studies were excluded. The exclusion criteria included non-English (n=89), evaluated animal subjects (n=22), in-vitro (n=60), reviews (n=200), case studies (n=200), and letters to the editors (n=9) (Figure 1).

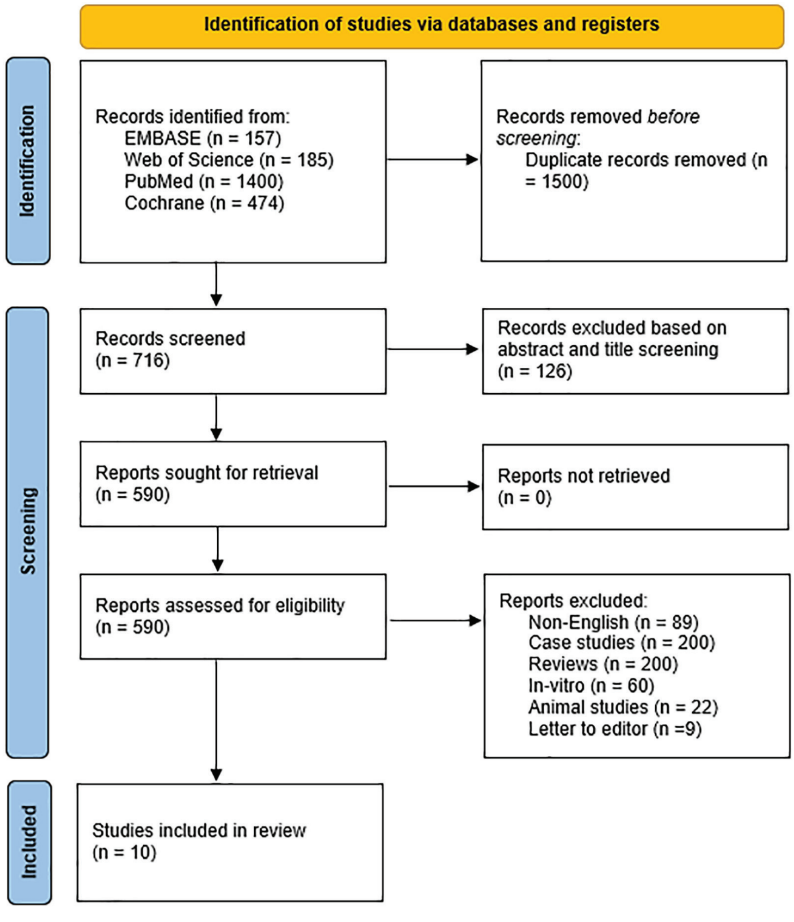

Fig. 1. A PRISMA flow diagram for the selection criteria

Table 1 summarizes the main findings extracted from the included studies. All of the included studies had retrospective designs [4, 5, 13-20]. The evaluated outcomes were survival to discharge rate and adverse events associated with ECMO/ECLS therapies. The types of ECMO therapies assessed among the included studies were beta-blockers, calcium channel inhibitors, cardiovascular agent opioids, cardiotoxins, membrane-stabilizing agents, antiarrhythmic and anti-malarial, analgesics, sedatives, antidiabetics, and antidepressants. Table 1 below provides detailed outcomes for ECMO/ECLS therapies in drug-intoxicated patients.

The quality assessment of the included studies showed that 6 out of 10 studies were of moderate quality, while 4 were of high quality (Table 2). Similarly, no study had a poor methodology quality.

Masson *et al.,* [16] compared ECMO to conventional therapies, and found that ECMO had a survival rate of 85.7% to hospital discharge rate, while conventional treatments had a rate of 47.9% [16]. Overall, the data from 10 studies indicated a significant survival rate for hospital discharge among patients administered with ECMO/ECLS at 65.6% ([95% CI: 51.5%-77.4%], p=0.030) (Figure 2). However, there was a significant heterogeneity among the 10 studies (I^2=83.47%, p<0.01). This heterogeneity could be attributed to different ECMO types used in these studies.

Six of 10 studies assessed the prevalence of adverse events, including cardiovascular complications, limb ischemia, brain death, stroke, hemolysis, and death, following ECMO therapy to treat drug-induced poisoning [5, 13, 14, 17, 18, 20]. The pooled analysis of the six studies showed that ECMO therapies administered among drug-overdosed patients were associated with a significant rate of adverse events of 23.1% ([95% CI: 12.3%-39.2%], p=0.002) (Figure 3). Besides, these findings indicated a statistically significant moderate heterogeneity (I^2=70%, p<0.005).

Table 1. A summary of characteristics of included studies

Study ID	Study design	Total ECMO group.	Duration (years)	Outcomes evaluated	Drug intoxication agents	Survival to discharge rate	Adverse events
Pozzi *et al.,* 2017 [13]	Retrospective cohort	12	5	Survival to hospital discharge, weaning rates, and complications.	Beta-blockers; calcium channel inhibitors	9	3
Pozzi *et al.,* 2022 [14]	Retrospective cohort	32	14	Survival to hospital discharge and complications	Cardiovascular agents, opioids	25	
Weiner *et al.,* 2020 [15]	Retrospective cohort	104	15	Survival to hospital discharge, weaning rates, and complications.	Cardiovascular agents, opioids	39	1
Masson *et al.,* 2012 [16]	Retrospective cohort	62	15	Survival to hospital discharge, weaning rates, and complications.	beta-blockers, calcium channel inhibitors	12	NC
Daubin *et al.,* 2009 [17]	Retrospective cohort	17	10	Survival to hospital discharge, weaning rates, and complications.	Cardiotoxins and membrane-stabilizing drugs	13	NC
Lewis *et al.,* 2019 [5]	Retrospective chart review	16	18	Survival to hospital discharge, adverse events	Cardiovascular drugs, beta-blockers, opioids	13	1
Cole *et al.,* 2020 [18]	Retrospective chart review	407	/	Survival to discharge, adverse events	Calcium channel blockers, Antiarrhythmic and anti-malarial; Opioids, Antidepressants	285	3
Wang *et al.,* 2016 [4]	Retrospective study	10	3	Survival to discharge	Analgesics, sedatives, antidiabetics, antidepressants, and cardiovascular drugs	8	122
Mégarbane *et al.,* 2007 [19]	Prospective cohort study	12	2	Survival to discharge after one year compared to conventional life support interventions	Analgesics and cardiovascular toxins	3	NC
Duburcq *et al.,* 2022 [20]	Retrospective cohort study	22	6	Survival to discharge	Analgesics and cardiovascular toxins	10	NC

Hemodynamic parameters (SBP: Systolic blood pressure; DBP: Diastolic blood pressure; and MAP: Mean Arterial Pressure), survival to discharge, defined as discharged home or to another hospital from the ECMO center, metabolic (acid/base) and ventilatory parameters, and complications related to VA-ECMO support; NC: not classified

Table 2. Methodological quality assessment outcomes using the Newcastle Ottawa scale for retrospective studies

Author ID	Selection (maximum 4)	Comparability (Maximum 1)	Outcome (Maximum 3)	Total score	Quality
Pozzi *et al.*, 2017 [13]	4	1	2	7	High
Pozzi *et al.*, 2022 [14]	2	1	3	6	Moderate
Weiner *et al.*, 2020 [15]	2	1	3	6	Moderate
Masson *et al.*, 2012 [16]	4	1	2	7	High
Daubin *et al.*, 2009 [17]	3	1	2	6	Moderate
Lewis *et al.*, 2019 [5]	4	1	2	7	High
Cole *et al.*, 2020 [18]	2	1	2	6	Moderate
Wang *et al.*, 2016 [4]	2	1	3	6	Moderate
Mégarbane *et al.*, 2007 [19]	2	1	3	6	Moderate
Duburcq *et al.*, 2022 [20]	4	1	2	7	High

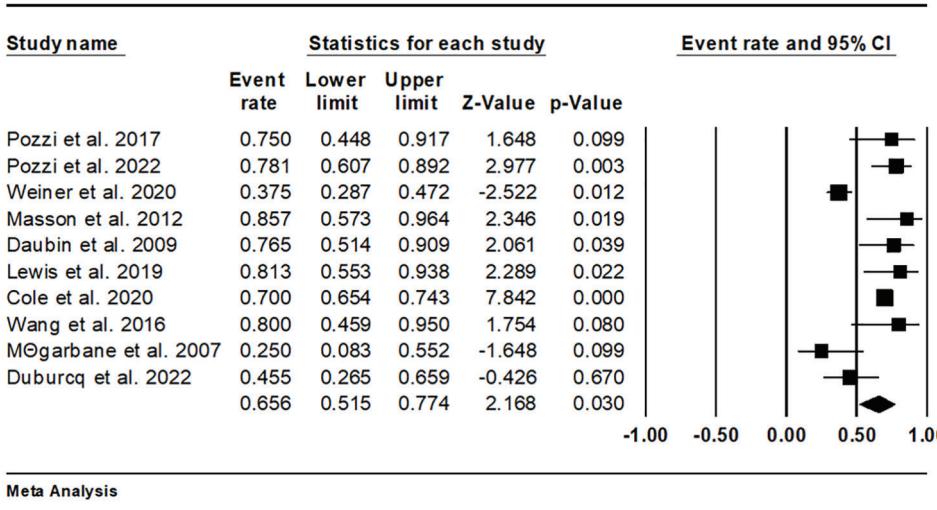

Fig. 2. A forest plot shows the survival to discharge rate when ECMO or ECLS is administered in patients experiencing a drug overdose.

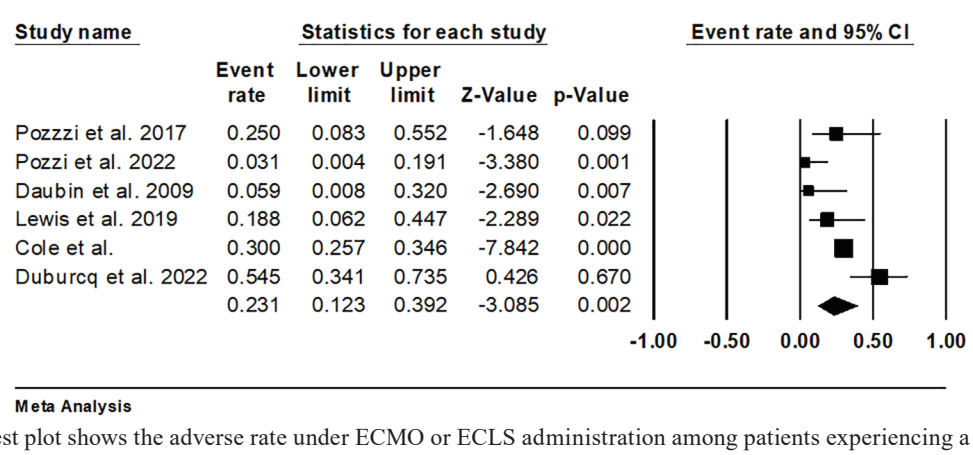

Fig. 3. The forest plot shows the adverse rate under ECMO or ECLS administration among patients experiencing a drug overdose.

The symmetrical funnel plot obtained by the 10 studies indicated a well-behaved dataset with improbable publication bias (Figure 4).

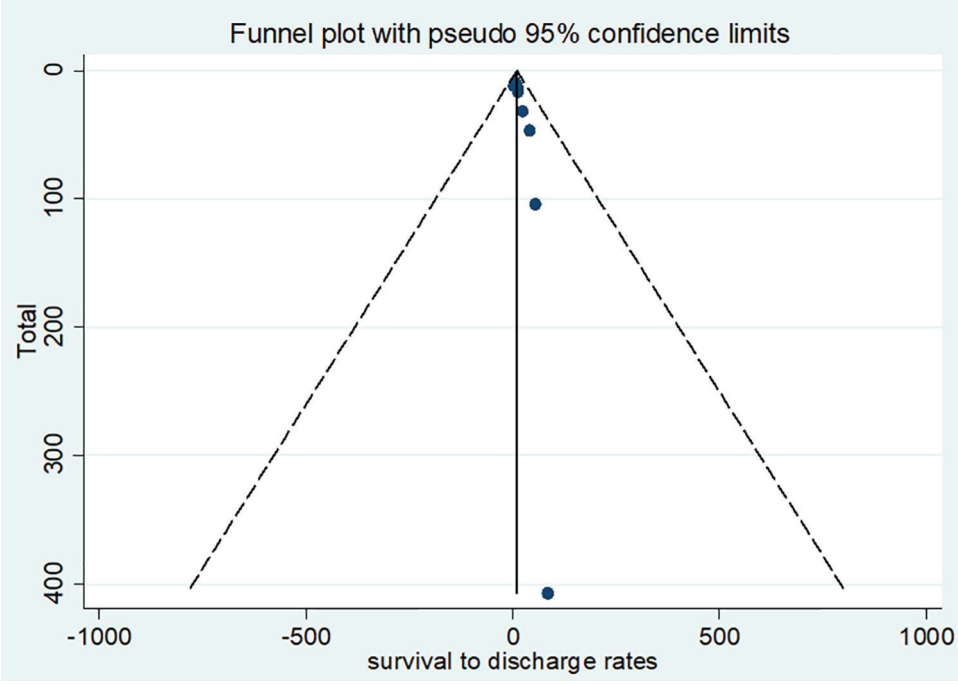

Fig. 4. The funnel plot determining the publication bias

Discussion

The primary objective of the present study was to discuss the role of extracorporeal membrane oxygenation in enhancing survival rates among drug-dosed patients. Consequently, the study evaluated the rate of incidences of adverse events and survival to hospital discharge rate from the intensive care unit (ICU) among drug-overdosed patients after receiving ECMO. According to the findings of this study, using ECMO reduced the length of stay in ICU by facilitating discharge; thus, enhancing their survival. The analysis showed that the survival rate to hospital discharge rate was 65.6% ([95% CI: 51.5%-77.4%]) p=0.030) when ECMO is utilized among the patients. Conversely, the incidence rate of adverse events was 23.1% ([95% CI: 12.3%-39.2%], p=0.002) when similar therapy mechanisms were used.

To the best of our knowledge, this is the first systematic review and meta-analysis that reported the role of ECMO in enhancing survival to discharge rate and incidences of adverse events among drug-overdosed patients using pooled data. However, it is worth mentioning that certain prospective and review studies have made significant efforts to evaluate the clinical importance of extracorporeal treatments in drug-induced adverse cardiovascular events [4, 21, 22]. The meta-analysis revealed favorable patient outcomes regarding survival to hospital discharge in poisoning patients who underwent extracorporeal membrane oxygenation due to drug-induced cardiogenic or refractory shock. Despite concerns such as shock and leg ischemia, Masson *et al.,* highlighted that ECMO is a viable alternative to other conventional treatment modalities in cardiogenic shock [16]. Compared to standard therapies, *Masson et al.,* revealed that ECMO therapies had significant survival importance in treating drug-intoxicated patients [16]. Therefore, the results of the present analysis on discharge rate were consistent with those of the Masson *et al*., study [16] and other previous studies [10, 23]. Similarly, Pozzi *et al.,* found that ECMO therapies were associated with greater survival to hospital discharge rate with promising neurological outcomes in handling drug-intoxicated-induced refractory shock [13].

In animal experiments with cardiogenic shock caused by lidocaine and amitriptyline overdoses, ECMO therapy was found to be more effective than typical cardiac life support interventions [24]. However, due to the differences in morphology and other characteristics between animals and humans, as well as the intention-to-treat parameters used in clinical testing, animal studies were excluded from this meta-analysis.

Despite the promising survival rate of hospital discharges when ECMO was used, this meta-analysis revealed the adverse events associated with the mechanism. The adverse events reported by studies in this review were limb ischemia, brain death, stroke, infection, death, cardiac complications, and hemolysis [13, 18]. Research showed this treatment modality was associated with risk factors and complications [13, 25, 26]. Some previous studies showed that the potential risk factors and adverse events were lower limb ischemia, cardiovascular diseases, bacterial pneumonia, and death incidences [25, 26]. Similarly, Cheng *et al.,* investigated the incidences of compartment syndrome, stroke, kidney failure, and infection [25]. Therefore, the findings of the present study on adverse events, such as

complications and morbidity resulting from ECMO usage among patients, were comparable with Cheng et al.'s analysis [25].

According to Wang *et al.,* extracorporeal treatment should be considered while examining poisoning patients to ensure efficiency and a higher survival rate [4]. These considerations were age, sex, comorbidities, specific drug or poisoning agent exposure, time of infusion, and previous incidence of cardiac events. Similarly, several studies assessed the feasibility of extracorporeal treatments in healthcare facilities [1, 27, 28]. According to Wang *et al.,* performing and managing ECMO treatments required a significant amount of effort and time [4]. Besides, De Lange and colleagues argued that although ECMO therapy's principal role was to keep poisoned patients alive, it also necessitated considerations to attain survival to discharge from the hospital [21]. Thus, under acceptable ethical requirements, ECMO application on drug-intoxicated patients could result in a higher survival rate to hospital discharge rate with better neurological outcomes [21, 27].

Overall, this meta-analysis and some previous studies [25, 26] found that ECMO utilization was associated with some risks of health complications, and death in some cases. However, patients who received this treatment modality had a high chance of surviving until they were discharged from the hospital. Based on this analysis and approvals from previous studies, ECMO should be considered a striking emergency resuscitative mechanism among critically ill drug-poisoned inpatients who barely respond to standard treatments.

Firstly, the retrospective study designs utilized by studies in these systematic reviews and meta-analyses presented a wide range of biases in the review, with reporting and selection biases identified as the primary contributors. Secondly, the datasets derived were primarily from the ELSO registry; thus, they were not subject to confirmation testing. Consequently, the data might have been subject to incomplete datasets and confounding outcomes. This limitation could result in overestimating or underestimating findings in the review. Therefore, controlled trials are required to assess the resuscitative value of ECMO on drug-intoxicated patients in the emergency department. Similarly, controlled trials could classify conditions in the emergency setting that are unresponsiveness to conventional therapies and ECMO indications.

The findings of this review revealed that extracorporeal membrane treatments were associated with significantly higher survival to discharge rates. Moreover, some adverse complications, such as hemolysis, death, limb ischemia, and brain death, were identified after extracorporeal treatment administration. Thus, it is recommended to use extracorporeal in drug-induced poisoning as an alternative, efficient, and feasible treatment in managing drug-induced acute poisoning.

Declaration

Ethics Approval And Consent To Participate: Ethical committees approval is not required as this is a systematic review and metanalysis.

Competing Interests: No competing interests were disclosed.

Funding: No instituational funding gained for this article.

Consent For Publication: As corresponding author and on behalf of all authors I provide the journal full publication rights to this journal.

Acknowledgments: Not applicable.

References

1. Upchurch C, Blumenberg A, Brodie D, MacLaren G, Zakhary B, Hendrickson RG. Extracorporeal membrane oxygenation use in poisoning: a narrative review with clinical recommendations. *Clin Toxicol (Phila)*. 2021;**59**(10):877-87.
2. Gummin DD, Mowry JB, Beuhler MC, Spyker DA, Rivers LJ, Feldman R, et al. 2021 Annual Report of the National Poison Data System(©) (NPDS) from America's Poison Centers: 39th Annual Report. *Clin Toxicol (Phila)*. 2022;**60**(12):1381-643.
3. Wahba MA, Alshehri BM, Hefny MM, Al Dagrer RA, Al-Malki SD. Incidence and profile of acute intoxication among adult population in Najran, Saudi Arabia: A retrospective study. *Sci Prog*. 2021;**104**(2):368504211011339.
4. Wang GS, Levitan R, Wiegand TJ, Lowry J, Schult RF, Yin S. Extracorporeal Membrane Oxygenation (ECMO) for Severe Toxicological Exposures: Review of the Toxicology Investigators Consortium (ToxIC). *J Med Toxicol*. 2016;**12**(1):95-9.
5. Lewis J, Zarate M, Tran S, Albertson T. The Recommendation and Use of Extracorporeal Membrane Oxygenation (ECMO) in Cases Reported to the California Poison Control System. *J Med Toxicol*. 2019;**15**(3):169-77.
6. Brent J, Burkhart K, Dargan P, Hatten B, Megarbane B, Palmer R. Critical care toxicology: Springer Berlin/ Heidelberg, Germany; 2016.
7. Sauer CM, Yuh DD, Bonde P. Extracorporeal membrane oxygenation use has increased by 433% in adults in the United States from 2006 to 2011. *Asaio j*. 2015;**61**(1):31-6.
8. Dominguez-Cherit G, De la Torre A, Rishu A, Pinto R, Ñamendys-Silva SA, Camacho-Ortiz A, et al. Influenza A (H1N1pdm09)-Related Critical Illness and Mortality in Mexico and Canada, 2014. *Crit Care Med*. 2016;**44**(10):1861-70.
9. MacLaren G, Combes A, Bartlett RH. Contemporary extracorporeal membrane oxygenation for adult respiratory failure: life support in the new era. *Intensive Care Med*. 2012;**38**(2):210-20.
10. Das Gupta J, Saavedra R, Guliani S,

Marinaro J, Rana MA. Decompressive laparotomy for a patient on VA-ECMO for massive pulmonary embolism that suffered traumatic liver laceration after mechanical CPR. *J Surg Case Rep*. 2018;**2018**(10):rjy292.
11. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002;**21**(11):1539-58.
12. Copas J, Shi JQ. Meta-analysis, funnel plots and sensitivity analysis. *Biostatistics*. 2000;**1**(3):247-62.
13. Pozzi M, Koffel C, Djaref C, Grinberg D, Fellahi JL, Hugon-Vallet E, et al. High rate of arterial complications in patients supported with extracorporeal life support for drug intoxication-induced refractory cardiogenic shock or cardiac arrest. *J Thorac Dis*. 2017;**9**(7):1988-96.
14. Pozzi M, Buzzi R, Hayek A, Portran P, Schweizer R, Fellahi JL, et al. Veno-arterial extracorporeal membrane oxygenation for drug intoxications: A single center, 14-year experience. *J Card Surg*. 2022;**37**(6):1512-9.
15. Weiner L, Mazzeffi MA, Hines EQ, Gordon D, Herr DL, Kim HK. Clinical utility of venoarterial-extracorporeal membrane oxygenation (VA-ECMO) in patients with drug-induced cardiogenic shock: a retrospective study of the Extracorporeal Life Support Organizations' ECMO case registry. *Clin Toxicol (Phila)*. 2020;**58**(7):705-10.
16. Masson R, Colas V, Parienti JJ, Lehoux P, Massetti M, Charbonneau P, et al. A comparison of survival with and without extracorporeal life support treatment for severe poisoning due to drug intoxication. *Resuscitation*. 2012;**83**(11):1413-7.
17. Daubin C, Lehoux P, Ivascau C, Tasle M, Bousta M, Lepage O, et al. Extracorporeal life support in severe drug intoxication: a retrospective cohort study of seventeen cases. *Crit Care*. 2009;**13**(4):R138.
18. Cole JB, Olives TD, Ulici A, Litell JM, Bangh SA, Arens AM, et al. Extracorporeal Membrane Oxygenation for Poisonings Reported to U.S. Poison Centers from 2000 to 2018: An Analysis of the National Poison Data System. *Crit Care Med*. 2020;**48**(8):1111-9.
19. Mégarbane B, Leprince P, Deye N, Résière D, Guerrier G, Rettab S, et al. Emergency feasibility in medical intensive care unit of extracorporeal life support for refractory cardiac arrest. *Intensive Care Med*. 2007;**33**(5):758-64.
20. Duburcq T, Goutay J, Preau S, Mugnier A, Rousse N, Moussa MD, et al. Venoarterial Extracorporeal Membrane Oxygenation in Severe Drug Intoxication: A Retrospective Comparison of Survivors and Nonsurvivors. *Asaio j*. 2022;**68**(7):907-13.
21. de Lange DW, Sikma MA, Meulenbelt J. Extracorporeal membrane oxygenation in the treatment of poisoned patients. *Clin Toxicol (Phila)*. 2013;**51**(5):385-93.
22. Bouchard J, Shepherd G, Hoffman RS, Gosselin S, Roberts DM, Li Y, et al. Extracorporeal treatment for poisoning to beta-adrenergic antagonists: systematic review and recommendations from the EXTRIP workgroup. *Crit Care*. 2021;**25**(1):201.
23. Mohan B, Singh B, Gupta V, Ralhan S, Gupta D, Puri S, et al. Outcome of patients supported by extracorporeal membrane oxygenation for aluminum phosphide poisoning: An observational study. *Indian Heart J*. 2016;**68**(3):295-301.
24. Larkin GL, Graeber GM, Hollingsed MJ. Experimental amitriptyline poisoning: treatment of severe cardiovascular toxicity with cardiopulmonary bypass. *Ann Emerg Med*. 1994;**23**(3):480-6.
25. Cheng R, Hachamovitch R, Kittleson M, Patel J, Arabia F, Moriguchi J, et al. Complications of extracorporeal membrane oxygenation for treatment of cardiogenic shock and cardiac arrest: a meta-analysis of 1,866 adult patients. *Ann Thorac Surg*. 2014;**97**(2):610-6.
26. Zangrillo A, Landoni G, Biondi-Zoccai G, Greco M, Greco T, Frati G, et al. A meta-analysis of complications and mortality of extracorporeal membrane oxygenation. *Crit Care Resusc*. 2013;**15**(3):172-8.
27. Lafç G, Budak AB, Yener A, Cicek OF. Use of extracorporeal membrane oxygenation in adults. *Heart Lung Circ*. 2014;**23**(1):10-23.
28. Uziel Y, Adler A, Aharonowitz G, Franco S, Fainmesser P, Wolach B. Unintentional childhood poisoning in the Sharon area in Israel: a prospective 5-year study. *Pediatr Emerg Care*. 2005;**21**(4):248-51.