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COMPARISON OF THE PROGNOSIS OF THE VENO VENOUS AND VENO-ARTERIAL ECMO: A SYSTEMATIC REVIEW

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ABSTRACT

Extracorporeal membrane oxygenation (ECMO) is a life-saving technique used in critical care settings to support patients with severe respiratory or cardiac failure. This systematic review examines the prognostic outcomes associated with Veno-venous (VV) and Veno-arterial (VA) extracorporeal membrane oxygenation (ECMO), focusing on survival rates, complications, and long-term consequences. A comprehensive literature search was conducted using PubMed, Embase, and Scopus, targeting studies published between 2014 and 2024. Inclusion criteria encompassed studies reporting survival, mortality, complications, and long-term outcomes in adult populations (≥18 years). Data from 42 eligible studies were extracted, synthesized, and assessed for quality using standardized tools. The review highlights a higher mortality rate for VA ECMO compared to VV ECMO, attributed to the severity of conditions treated, such as acute myocardial infarction and refractory cardiogenic shock. Factors including age, comorbidities, and complications such as infection and acute kidney injury significantly influenced outcomes. Dynamic prognostic models incorporating variables like lactate levels, pH, and bicarbonate offered superior predictive accuracy over static scoring systems. In contrast, VV ECMO demonstrated more favorable outcomes, especially in younger patients and trauma cases. Scoring systems such as SAVE and RESP provided valuable prognostic insights, while early intervention and effective management of complications, such as bleeding and severe acute kidney injury, were crucial in improving survival. Long-term survival and quality-of-life assessments indicated high return-to-work rates among ARDS patients treated with VV ECMO. This study underscores the importance of multidisciplinary teams, dynamic prognostic models, and refined treatment protocols to enhance ECMO outcomes. Future research should prioritize optimizing patient selection, improving the management of complications, and developing advanced predictive tools for tailored interventions.

KEYWORDS: Veno-venous ECMO, Veno-arterial ECMO, Prognosis, Survival rates, Complications, Long-term Outcomes, Acute kidney injury, ARDS, Dynamic prognostic models, SAVE score, RESP score.

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) is a widely used, intensive life-support therapy for patients with severe respiratory or cardiac failure, providing critical cardiopulmonary support rather than directly addressing the underlying disease.[1] Technology and ICU care advances over the past decade have significantly increased the number of patients receiving ECMO and their survival rates.[2] ECMO operates in two main modes, each tailored to specific medical needs. The Extracorporeal Life Support Organization (ELSO) recommends Veno-arterial ECMO (VA-ECMO) for patients experiencing refractory cardiogenic shock due to conditions like acute myocardial infarction, fulminant myocarditis, cardiotoxic drug reactions, end-stage cardiomyopathy, hypothermia with circulatory instability, massive pulmonary embolism, or transplant-induced cardiogenic shock. In VA-ECMO, the ECMO circuit functions parallel with the heart and lungs, redirecting blood flow to bypass these organs and reintroducing it to the arterial system through peripheral cannulation.[3]

Veno-venous ECMO (VV-ECMO), on the other hand, is indicated for severe, acute respiratory failure that doesn't respond to optimal medical treatment but does not require cardiac support.[4] This mode involves venous cannulation, typically performed through a single cannula in the right internal jugular vein or dual cannulas in the common femoral vein and right internal jugular or femoral vein, facilitating oxygenation while allowing the heart to function independently.[5]

Although ECMO is a critical, life-saving intervention, studies have shown that mortality rates vary significantly depending on the patient's condition and the type of ECMO used. Mortality rates have been reported as high as 76% in patients requiring both ECMO and dialysis, while a mixed cohort of Veno-venous (VV) and Veno-arterial (VA) ECMO patients had a lower mortality rate of 37%. Data from the ELSO registry, spanning 1989 to 2014, reported mortality rates of 57% for respiratory ECMO and 41% for cardiac ECMO cases.[6]

However, ECMO is not without risks. The procedure is highly invasive and can lead to severe complications, any of which may cause substantial morbidity.

Additionally, ECMO requires considerable time and resources, making it a complex and demanding intervention with potential challenges in both execution and patient management.[7]

Various predictive models are available to help assess outcomes in critically ill patients undergoing ECMO.

Initially, general scoring systems were developed for critically ill patients and were later applied to ECMO populations to evaluate their predictive accuracy. Notable examples include the Sequential Organ Failure Assessment (SOFA) score.[8] and the Acute Physiology and Chronic Health Evaluation II (APACHE II) score.[9]

However, these models have shown mixed results in terms of accuracy and calibration. For instance, Hilder et al.[10] Found that the SOFA score provided better predictive accuracy for patients on VV-ECMO than some ECMO-specific scores.

Conversely, Fisser et al[11] Reported that general ICU scores performed better for VA-ECMO patients but were less effective for those on VV-ECMO. In response to these limitations, ECMO-specific scoring models have been developed to improve predictive capabilities. Although these models have shown a slight advantage in survival prediction compared to general ICU risk scores, there is a consensus that their support in clinical decision-making remains limited.[9] Given this context, a focused evaluation of these newer ECMO-specific scores, including an analysis of their statistical strengths, limitations, and practical applicability, could provide valuable insights.

The use of Veno-arterial extracorporeal membrane oxygenation (VA ECMO) for managing cardiocirculatory failure is increasingly common, especially in cases of cardiogenic shock, refractory cardiac arrest, post-cardiotomy cardiac failure, and post-cardiac arrest syndrome.[12] Despite its growing use, VA ECMO is a technically complex therapy, and monitoring hemodynamics to achieve optimal resuscitation remains challenging without standardized guidelines.[13]

Key objectives typically include ensuring adequate oxygen delivery (by regulating flow rate and oxygenation) and maintaining sufficient perfusion pressure to critical organs, with these parameters tailored to each patient's specific needs.

However, conventional hemodynamic parameters and markers of oxygen metabolism do not always reliably indicate effective resuscitation.[14]

Lactate is often used to guide therapy and serves as a prognostic marker in shock. Elevated lactate levels, while indicative of anaerobic metabolism, can be misleading as they may result from impaired clearance in liver or kidney failure or increased glycolysis triggered by high doses of adrenaline.[15] Another important measure is the partial pressure gradient of CO_2 between venous and arterial blood, or the PCO_2 gap, which is used to assess peripheral hypoperfusion in cases of septic or cardiogenic shock.[16] Recently, a more specific metric, the ratio of the PCO_2 gap to the arteriovenous oxygen difference (PCO_2 gap/Da–vO_2), has been identified as a more accurate marker of anaerobic metabolism, with a ratio above 1 proving more informative than the PCO_2 gap alone.[17]

METHODOLOGY

Study Design

This study was conducted as a systematic review comparing the prognosis of Veno-venous (VV) and Veno-arterial (VA) extracorporeal membrane oxygenation (ECMO). The review aimed to synthesize available evidence on survival rates, complication profiles, and long-term outcomes associated with each modality to identify key prognostic differences.

Literature Search Strategy

A comprehensive literature search was conducted using PubMed, Embase, and Scopus. Keywords and Medical Subject Headings (MeSH) terms included combinations of venovenous ECMO, Veno-arterial ECMO, prognosis, survival rate, mortality, complications, cardiac failure, and respiratory failure. The search focused on studies published in English from 2014 to 2024 to ensure relevance to current ECMO practices.

Inclusion and Exclusion Criteria

- **Inclusion Criteria**
  - Studies specifically reported on survival, mortality, complications, or long-term outcomes of VV and VA ECMO.
  - Studies that included adult populations (18 years and older).
  - Randomized controlled trials, cohort studies, retrospective studies, and systematic reviews.
- **Exclusion Criteria**
  - Case reports, editorials, and commentaries.
  - Studies focusing exclusively on pediatric populations or neonatal ECMO.
  - Studies lacking specific outcome data on prognosis (e.g., survival rates, complications) for VV and VA ECMO.

Data Extraction

Data were extracted by two independent reviewers to minimize bias. Key data points collected from each study included:

- **Patient demographics**: Age, gender, and primary indication for ECMO.
- **ECMO modality**: VV or VA ECMO.
- **Outcomes**: Survival rates, mortality rates, incidence and type of complications, and long-term outcomes (e.g., functional status post-ECMO).
- **Study design and quality**: Type of study, sample size, and potential sources of bias.

Quality Assessment

The methodological quality of the included studies was assessed using appropriate tools, such as the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias Tool for randomized controlled trials. Studies were rated as high, moderate, or low quality based on these assessments, and sensitivity analyses were conducted where necessary to evaluate the impact of study quality on findings.

Data Synthesis and Analysis

A narrative synthesis was conducted, with quantitative synthesis where appropriate. For studies providing survival rates and complication rates, pooled estimates were calculated. Heterogeneity was assessed using the I^2 statistic. If significant heterogeneity was present, subgroup analyses were performed based on factors such as indication (e.g., respiratory vs. cardiac failure) and patient characteristics.

Reporting

The systematic review was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A PRISMA flow diagram illustrated the study selection process, and key findings were summarized in tables comparing prognosis, survival rates, and complications between VV and VA ECMO.

RESULTS

Study selection

The research identified 2,784 records through database searches, with an additional 12 records from other sources (Fig.1). After removing 1,753 duplicates, 1,031 records were screened, resulting in the exclusion of 157 irrelevant records, and 179 full-text articles were assessed for eligibility. Based on the exclusion criteria, 137 articles were excluded due to inappropriate study design, a lack of relevant outcome data, or a population mismatch. Ultimately, 42 studies were included in the qualitative synthesis, with a subset included in the quantitative synthesis where applicable.

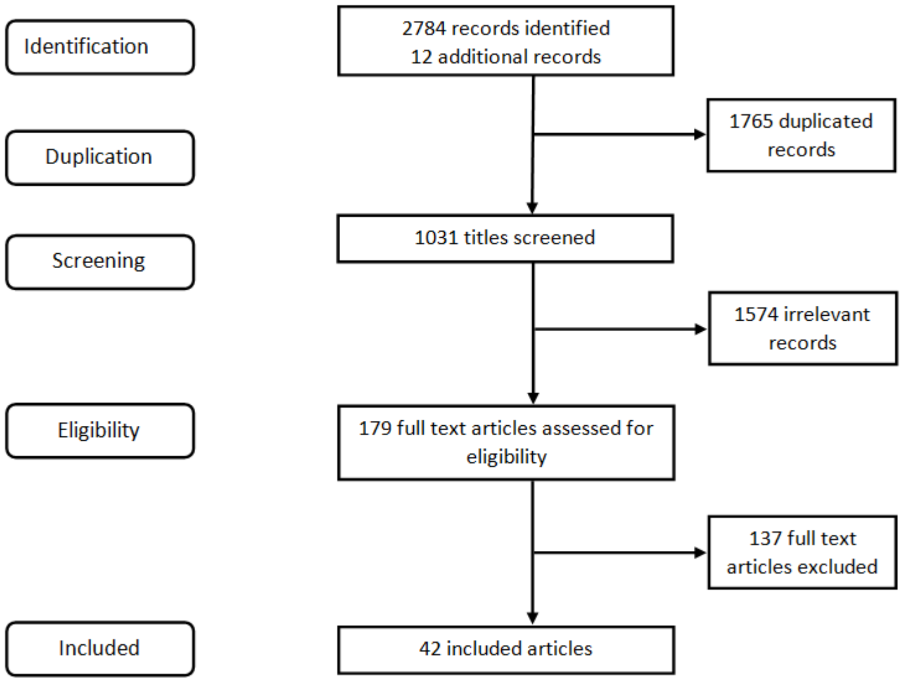

Figure 1: Follow the diagram of the study selected.

Study characteristics

The following table (table 1) the prognosis of patients treated with Veno-Venous (VV) and Veno-Arterial (VA) ECMO across various studies. VA ECMO has higher mortality rates, especially with complications like IFD and AKI. Factors like age, heart failure type, and comorbidities affect outcomes. Dynamic models and specialized teams improve survival predictions and rates. VV ECMO shows better outcomes in younger patients and trauma cases, with age and liver failure impacting mortality. Early intervention and specific scores like SAVE and RESP help predict survival. Overall, ECMO duration and complications influence patient outcomes.

Table 1: Prognosis of Veno-Venous (VV) and Veno-Arterial (VA) ECMO with ECMO.

No.	Type of ECMO	Key Findings on Prognosis	Mortality Rate/Survival	Notes	References
1	VA	IFD linked to higher mortality; no difference after matching	In-hospital mortality: 94% for IFD patients	The severity of the disease and renal issues was predictive of IFD.	[18]
2	VA	APACHE-II, SOFA scores predictive of mortality	Higher scores linked to mortality	APACHE-II > 27 and SOFA > 14 were significantly predictive.	[19]
3	VV	Age negatively impacts survival	6-month survival: 76.7% (<65), 60.9% (65-74), 52.9% (75+)	Older age groups showed lower survival rates.	[19]
4	VA	Demographic factors affect survival	Survival to discharge: 44%	Increased survival odds with age, decreased with prior cardiac arrest.	[20]
5	VA	High complication and mortality rates	Common complication: Bleeding	ECMO was mostly for AMI, meaning ECMO support: 7.8 days.	[21]
6	VA	Advanced age was not as predictive of hospital mortality as expected	Hospital mortality: 60-68%	Age was more relevant during follow-up.	[22]
7	VV	Severe AKI linked to poor outcomes	90-day mortality: 72% for KDIGO 3	AKI significantly impacts the mechanical ventilation weaning rate.	[23]
8	VA	Type of heart failure affects outcomes	90-day survival: 51%	Isolated LV failure predicts 90-day mortality.	[24]
9	VA	SAVE score critical in survival comparison	No significant survival difference	ECMO vs. Impella showed similar ICU and long-term survival rates.	[25]
10	VA	Dynamic prognostic model outperforms static scores	AUC for 12-hour PREDICT: 0.839	The model uses lactate, pH, and bicarbonate levels for prediction.	[26]
11	VA	Dynamic models provide better mortality prediction	AUC for 6-hour score: 0.823	Based on lactate, pH, and standard bicarbonate concentration.	[27]
12	VA	Comorbidities significantly affect long-term mortality	Hospital mortality: 39%	Higher age and immunocompromised state linked to mortality.	[28]
13	VA	Central and peripheral cannulation outcomes comparable	Mortality: Central 54%, Peripheral 58%	Axillary cannulation reduces local infections and ischemia but increases stroke risk.	[29]
14	VA	Risk factors include lactate levels and CRRT	In-hospital survival: 68.2%	High pre-ECMO lactate concentrations linked to mortality.	[30]
15	VA	Nadir lactate levels predict mortality	30-day survival: 44%	24- and 48-hour nadir lactate levels are significantly different between survivors and non-survivors.	[31]
16	VV/VA	VV-VA switch used for complex cases	5 out of 10 patients survived	Reasons for switching include hemodynamic instability.	[32]
17	VA	Neurological outcomes and long-term survival assessed	In-hospital survival: 63%	EQ-5D-5L scores are comparable to the general population.	[33]
18	VV	Prolonged ECMO does not increase mortality	Mortality: 69.3%	Age correlated with survival probability.	[34]
19	VA	Machine learning models predict in-hospital mortality	AUC: 0.70 (small set), 0.71 (comprehensive set)	Dynamic predictions using various variables.	[35]
20	VV	Cardiac arrest during VV-ECMO linked to poor prognosis	Survival to discharge: 13%	ROSC was achieved in 86% of cardiac arrests.	[36]
21	VV	RESP score predicts outcomes in VV-ECMO for ARDS	1-year survival: 58.6%	A higher RESP score correlates with better survival.	[37]
22	VA	NCAD as a key mortality predictor in AMI-related RCS	100-day survival: 43.5%	Multivariate analysis highlights NCAD's impact on mortality.	[38]
23	VV	Age and liver failure predict mortality	In-hospital mortality: 37.6%	80% of patients resumed employment post-ECMO.	[38]
24	VA	ECMO configuration affects HT outcomes	HT survival: Peripheral 63%, Central 83%	The conversion group had a lower cumulative incidence of HT.	[39]

25	VV/VA	The younger age group shows better outcomes	30-day survival: VV 56.1%, VA 52%	Higher SAPS II and noradrenaline use linked to mortality.	[40]
26	VA	Age and comorbidities influence long-term survival	5-year survival: 27.7%	PC-ECMO score was effective in predicting survival.	[17]
27	VA	PCO2 gap and PCO2 gap/Da–vO2 ratios predict mortality	Higher PCO2 gap linked to early mortality	These markers were useful in VA-ECMO management.	[41]
28	VV/VA	AKI recovery rates compared between VA and VV ECMO	In-hospital mortality: VA 64%, VV 49%	RRT was more frequent in the VV ECMO group.	[42]
29	VV	Trauma patients on VV ECMO show high survival rates	Survival to discharge: 78%	Early intervention improves outcomes.	[43]
30	VA	TIMI-3 flow grade and early ECMO initiation critical	In-hospital mortality: 50%	A higher TIMI-3 flow grade is associated with better survival.	[44]
31	VA	Early oxygen debt repayment linked to survival	Mortality: 67.9%	Higher oxygen debt is linked to poorer outcomes.	[45]
32	VA	Rapid disease progression linked to poor outcomes in PE	In-hospital mortality: 47.6%	Cardiac arrest is a significant poor prognosis indicator.	[46]
33	VA	Longer ECMO duration impacts survival	Median ECMO duration: 4 days	Survival decreases after 4 days of ECMO.	[47]
34	VV	High long-term survival and quality of life in ARDS patients	5-year survival: 68.5%	High HRQL and return-to-work rates were reported.	[48]
35	VA	Specialized ECMO team improves survival	In-hospital mortality: Pre-team 54.2%, Post-team 33.9%	Multidisciplinary teams significantly reduce mortality.	[49]
36	VA	ECMO used for refractory cardiac arrest	Survival to discharge: 73%	68% achieved good neurological outcomes.	[50]
37	VA	Axillary cannulation reduces complications but increases stroke risk	90-day mortality: 53%	Lower infection and ischemia rates with axillary cannulation.	[51]
38	VA	VAC linked to longer ICU stays	ICU stay: VAC 18 days, non-VAC 12 days	The VAC group required more blood transfusions.	[52]
39	VA	No significant mortality difference due to cannulation complications	Complications: 32%	No increase in mortality with cannulation complications.	[53]
40	VV	Early ECMO use in trauma linked to better outcomes	Survival rate: 68% overall, 94% for trauma patients	PaO2/FiO2 ratio and pH criteria used for ECMO initiation.	[54]
41	VA	Antegrade cannulation improves outcomes	In-hospital mortality: 50%	Antegrade cannulation is associated with better perfusion and lower mortality.	[55]
42	VA	PC-ECMO score predicts long-term survival	5-year survival: 27.7%	Older age significantly reduces long-term survival.	[56]

The abbreviations used in the table: VA (Veno-Arterial), VV (Veno-Venous), ECMO (Extracorporeal Membrane Oxygenation), IFD (Infectious Disease), AMI (Acute Myocardial Infarction), AKI (Acute Kidney Injury), APACHE-II (Acute Physiology and Chronic Health Evaluation II), SOFA (Sequential Organ Failure Assessment), SAPS II (Simplified Acute Physiology Score II), RRT (Renal Replacement Therapy), ROSC (Return of Spontaneous Circulation), PREDICT (Prognostic Evaluation and Dynamic Intervention for Cardiac Therapies), RESP (Respiratory ECMO Survival Prediction Score), PCO2 (Partial Pressure of Carbon Dioxide), PC-ECMO (Peripheral Cannulation Extracorporeal Membrane Oxygenation), PASI (Psoriasis Area and Severity Index), TIMI-3 (Thrombolysis in Myocardial Infarction 3), VAC (Ventilator-Associated Complications), EQ-5D-5L (EuroQol 5-Dimension 5-Level Scale), KDIGO (Kidney Disease: Improving Global Outcomes), and SCO2 (ScvO2, central venous oxygen saturation).

DISCUSSION

The study's findings provide a comprehensive overview of the prognostic outcomes associated with Veno-Venous (VV) and Veno-Arterial (VA) extracorporeal membrane oxygenation (ECMO), highlighting critical insights into patient survival, complications, and predictive factors. Below, we discuss key aspects of the results of the existing literature. VA ECMO demonstrates higher mortality rates compared to VV ECMO, a trend consistent with the complexity of conditions it addresses, such as acute myocardial infarction (AMI) and refractory cardiogenic shock. Several studies, including those by Poth et al. (2024) and Sudarsanan et al. (2024), highlight factors like the severity of illness (as indicated by APACHE-II and SOFA scores), which significantly predict mortality. The mortality rate among VA ECMO patients with complications such as infection and acute kidney injury (AKI) remains alarmingly high, reinforcing the importance of early detection and management of these complications.[57] Dynamic prognostic models, such as those developed by Yu et al. (2019) show promise in predicting outcomes by incorporating variables like lactate levels, pH, and bicarbonate. These models outperform static scoring systems, offering a more accurate prediction of survival and aiding clinical decision-making.[58] VV ECMO outcomes are generally more favorable, particularly in younger patients and those with trauma-related conditions. This aligns with findings from Turgeon et al. (2018), which emphasize the importance of early intervention and tailored criteria for initiation, such as the PaO2/FiO2 ratio and pH. However, age and liver failure are significant predictors of mortality, as demonstrated by Fernando et al. (2023).[59, 60]

Specific scoring systems like SAVE and RESP provide valuable prognostic insights into VV ECMO, with higher scores correlating with improved survival rates. These findings support the adoption of standardized scoring tools to optimize patient selection and treatment strategies.[61] The duration of ECMO support significantly impacts survival. M. Smith et al. (2017) noted a decline in survival rates with prolonged ECMO, emphasizing the need for timely weaning strategies. Complications such as bleeding, as reported by Olson et al. (2021), and severe AKI, highlighted by Thongprayoon et al. (2019), further exacerbate mortality risks. These findings highlight the need for specialized teams and protocols to manage complications effectively.[62-64] Long-term survival and quality of life are vital considerations. J. Rilinger et al. (2021) reported high survival rates and return-to-work rates among ARDS patients on VV ECMO, suggesting that ECMO can have a positive impact beyond immediate survival. However, factors like age and comorbidities continue to influence long-term outcomes.[65]

CONCLUSION

This review highlights the complexity of ECMO therapy, where outcomes are shaped by various factors like patient demographics, existing health conditions, and complications. VA ECMO tends to have higher mortality rates due to the severity of the conditions it treats, while VV ECMO generally shows better results, especially with early intervention and specific scoring systems. Dynamic models and multidisciplinary teams play a crucial role in improving survival predictions and patient management. Future research should aim to refine prognostic tools, optimize cannulation techniques, and better manage complications to improve ECMO outcomes.

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Authors' Contributions

Mohamed Hassan Mohamed Gafow: Conceptualization, methodology, and original draft writing.
Naima Omar Adan: Data collection, analysis, and critical manuscript review.
Ahmed Abdirahman Ibrahim: Literature review and data interpretation.
Said Abdirahman Adan: Statistical analysis and writing review.
Liu Hao: Support in methodology and drafting sections of the manuscript.
Zhou Jun: Supervision, project administration, and final approval of the version to be published.

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Not applicable

Declarations

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Competing Interests
The authors declare that they have no competing interests related to this study.

REFERENCES

1. Ali, J. and A. Vuylsteke, Extracorporeal membrane oxygenation: indications, technique, and contemporary outcomes. Heart, 2019; 105(18): 1437-1443.
2. Hayes, K., et al., Physical function after extracorporeal membrane oxygenation in patients pre or post-heart transplantation–An observational study. Heart & Lung, 2016; 45(6): 525-531.
3. Lorusso, R., et al., ELSO interim guidelines for venoarterial extracorporeal membrane oxygenation in adult cardiac patients. ASAIO journal, 2021; 67(8): 827-844.
4. Tonna, J.E., et al., Management of adult patients supported with venovenous extracorporeal membrane oxygenation (VV ECMO): guideline from the extracorporeal life support organization (ELSO). ASAIO journal, 2021; 67(6): 601-610.
5. Makdisi, G. and I.-w. Wang, Extra Corporeal Membrane Oxygenation (ECMO) review of lifesaving technology. Journal of Thoracic Disease, 2015; 7(7): E166.
6. Giordano, L., et al., Predictive models in extracorporeal membrane oxygenation (ECMO): a systematic review. Syst Rev, 2023; 12(1): 44.
7. Zhang, H., et al., Narrative review of neurologic complications in adults on ECMO: prevalence, risks,

outcomes, and prevention strategies. Frontiers in Medicine, 2021: 8: 713333.
8. Magoon, R., et al., SOFA scoring in VA-ECMO: plenty to ponder! Journal of Cardiothoracic and Vascular Anesthesia, 2020; 34(10): 2844-2845.
9. Ng, W.T., et al., An audit of mortality by using ECMO specific scores and APACHE II scoring system in patients receiving extracorporeal membrane oxygenation in a tertiary intensive care unit in Hong Kong. Journal of Thoracic Disease, 2019; 11(2): 445.
10. Hilder, M., et al., Comparison of mortality prediction models in acute respiratory distress syndrome undergoing extracorporeal membrane oxygenation and development of a novel prediction score: the PREdiction of Survival on ECMO Therapy-Score (PRESET-Score). Crit Care, 2017; 21(1): 301.
11. Fisser, C., et al., Validation of Prognostic Scores in Extracorporeal Life Support: A Multi-Centric Retrospective Study. Membranes (Basel), 2021; 11(2).
12. Kowalewski, M., et al., Venoarterial extracorporeal membrane oxygenation for postcardiotomy shock—analysis of the extracorporeal life support organization registry. Critical care medicine, 2021; 49(7): 1107-1117.
13. Tsangaris, A., et al., Overview of veno-arterial extracorporeal membrane oxygenation (VA-ECMO) support for the management of cardiogenic shock. Frontiers in Cardiovascular Medicine, 2021; 8: 686558.
14. Patel, B., M. Arcaro, and S. Chatterjee, Bedside troubleshooting during venovenous extracorporeal membrane oxygenation (ECMO). Journal of Thoracic Disease, 2019; 11(Suppl 14): S1698.
15. Yang, L., et al., Blood lactate as a reliable marker for mortality of pediatric refractory cardiogenic shock requiring extracorporeal membrane oxygenation. Pediatric Cardiology, 2019; 40: 602-609.
16. McDonald, C.I., et al., Elevated venous to arterial carbon dioxide gap and anion gap are associated with poor outcome in cardiogenic shock requiring extracorporeal membrane oxygenation support. ASAIO Journal, 2021; 67(3): 263-269.
17. Ellouze, O., et al., Prognosis value of early veno arterial PCO2 difference in patients under peripheral veno arterial extracorporeal membrane oxygenation. Shock, 2020; 54(6): 744-750.
18. Poth, J.M., et al., Prevalence and prognostic relevance of invasive fungal disease during veno-arterial ECMO: A retrospective single-center study. Journal of Critical Care, 2024; 83: 154831.
19. Sudarsanan, S., et al., Comparison of four intensive care scores in prediction of outcome after Veno-Arterial ECMO: A single center retrospective study. medRxiv, 2024: p. 2024.08. 12.24311770.
20. Jones, A., et al., Prognostic Factors of Survival in Veno-Arterial ECMO Patients: A Multivariable Logistic Regression Analysis. International Journal of Medical Students, 2023; 11(4): 285-293.
21. Koerner, M.M., et al., Adult cardiac veno-arterial extracorporeal life support (VA-ECMO): prevention and management of acute complications. Annals of cardiothoracic surgery, 2019; 8(1): 66.
22. Provaznik, Z., et al., Outcome after veno-arterial extracorporeal membrane oxygenation in elderly patients: A 14-year single-center experience. Artificial Organs, 2023; 47(4): 740-748.
23. Delmas, C., et al., 3-month prognostic impact of severe acute renal failure under veno-venous ECMO support: Importance of time of onset. Journal of Critical Care, 2018; 44: 63-71.
24. den Uil, C.A., et al., Isolated left ventricular failure is a predictor of poor outcome in patients receiving veno-arterial extracorporeal membrane oxygenation. European journal of heart failure, 2017; 19: 104-109.
25. Schiller, P., L. Hellgren, and P. Vikholm, Survival after refractory cardiogenic shock is comparable in patients with Impella and veno-arterial extracorporeal membrane oxygenation when adjusted for SAVE score. European Heart Journal: Acute Cardiovascular Care, 2019; 8(4): 329-337.
26. Wengenmayer, T., et al., Development and validation of a prognostic model for survival in patients treated with venoarterial extracorporeal membrane oxygenation: the PREDICT VA-ECMO score. European Heart Journal: Acute Cardiovascular Care, 2019; 8(4): 350-359.
27. Enger, T.B., et al., Long-term survival in adult patients with severe acute lung failure receiving veno-venous extracorporeal membrane oxygenation. Critical Care Medicine, 2017; 45(10): 1718-1725.
28. Kalampokas, N., et al., Postcardiotomy veno-arterial extracorporeal membrane oxygenation: does the cannulation technique influence the outcome? Frontiers in Cardiovascular Medicine, 2021; 8: 658412.
29. Gao, S., et al., Outcomes from adult veno-arterial extracorporeal membrane oxygenation in a cardiovascular disease center from 2009 to 2019. Perfusion, 2022; 37(3): 235-241.
30. Hu, R.T., et al., 30-day outcomes post veno-arterial extracorporeal membrane oxygenation (VA-ECMO) after cardiac surgery and predictors of survival. Heart, Lung and Circulation, 2020; 29(8): 1217-1225.
31. Ius, F., et al., Veno-veno-arterial extracorporeal membrane oxygenation for respiratory failure with severe hemodynamic impairment: technique and early outcomes. Interactive cardiovascular and thoracic surgery, 2015; 20(6): 761-767.
32. Cankar, T., et al., Long-Term Survival and Quality of Life in Non-Surgical Adult Patients Supported with Veno-Arterial Extracorporeal Oxygenation. Journal of Clinical Medicine, 2022; 11(21): 6452.
33. Flinspach, A.N., et al., Therapy and outcome of prolonged venovenous ECMO therapy of critically

Ill ARDS patients. Journal of Clinical Medicine, 2023; 12(7): 2499.
34. Braun, J., et al., Predicting Survival for Veno-Arterial ECMO Using Conditional Inference Trees—A Multicenter Study. Journal of Clinical Medicine, 2023; 12(19): 6243.
35. Booke, H., et al., Cardiopulmonary resuscitation in veno-venous-ECMO patients—A retrospective study on incidence, causes and outcome. PLoS One, 2023; 18(8): e0290083.
36. Song, J.H., et al., Outcome of veno-venous extracorporeal membrane oxygenation use in acute respiratory distress syndrome after cardiac surgery with cardiopulmonary bypass. Journal of Thoracic Disease, 2016; 8(7): 1804.
37. Kim, H.S., et al., Predictors of survival following veno-arterial extracorporeal membrane oxygenation in patients with acute myocardial infarction-related refractory cardiogenic shock: clinical and coronary angiographic factors. Journal of Thoracic Disease, 2020; 12(5): 2507.
38. Neumann, E., et al., Predictors associated with mortality of veno-venous extracorporeal membrane oxygenation therapy. Journal of Thoracic Disease, 2023; 15(5): 2389.
39. Marie, B., et al., Impact of age on outcomes of patients assisted by veno-arterial or veno-venous extra-corporeal membrane oxygenation: 403 patients between 2005 and 2015. Perfusion, 2020; 35(4): 297-305.
40. Narotsky, D.L., et al., Short-term and longer-term survival after veno-arterial extracorporeal membrane oxygenation in an adult patient population: does older age matter? Perfusion, 2016; 31(5): 366-375.
41. Thyagarajan, B., et al., Renal recovery in critically ill adult patients treated with venovenous or veno-arterial extracorporeal membrane oxygenation: a retrospective cohort analysis. The Journal of Critical Care Medicine, 2021; 7(2): 104-112.
42. Menaker, J., et al., Veno-venous extracorporeal membrane oxygenation (VV ECMO) for acute respiratory failure following injury: outcomes in a high-volume adult trauma center with a dedicated unit for VV ECMO. World Journal of Surgery, 2018; 42: 2398-2403.
43. Yonezu, K., et al., Determinants of survival and favorable neurologic outcomes in ischemic heart disease treated by veno-arterial extracorporeal membrane oxygenation. Heart and Vessels, 2018; 33: 25-32.
44. Kurniawati, E., et al., Oxygen debt repayment in the early phase of veno-arterial extracorporeal membrane oxygenation: a cluster analysis. BMC Cardiovascular Disorders, 2022; 22(1): 363.
45. Chen, Y.-Y., et al., Clinical course and outcome of patients with acute pulmonary embolism rescued by veno-arterial extracorporeal membrane oxygenation: a retrospective review of 21 cases. Journal of Cardiothoracic Surgery, 2020; 15: 1-9.
46. Chen, W.-C., et al., The modified SAVE score: predicting survival using urgent veno-arterial extracorporeal membrane oxygenation within 24 hours of arrival at the emergency department. Critical care, 2016; 20: 1-7.
47. Smith, M., et al., Duration of veno-arterial extracorporeal life support (VA ECMO) and outcome: an analysis of the Extracorporeal Life Support Organization (ELSO) registry. Critical care, 2017; 21: 1-9.
48. Rilinger, J., et al., Long-term survival and health-related quality of life in patients with severe acute respiratory distress syndrome and veno-venous extracorporeal membrane oxygenation support. Critical Care, 2021; 25: 1-11.
49. Hong, D., et al., Multidisciplinary team approach in acute myocardial infarction patients undergoing veno-arterial extracorporeal membrane oxygenation. Annals of Intensive Care, 2020; 10: 1-11.
50. Sun, T., et al., Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) for emergency cardiac support. J Crit Care, 2018; 44: 31-38.
51. Vale, J.D., et al., Femoro-axillary versus femoral-femoral veno-arterial extracorporeal membrane oxygenation for refractory cardiogenic shock: A monocentric retrospective study. Perfusion, 2024: p. 2676591241261330.
52. Singh, V., et al., Vascular access complications in patients undergoing veno-arterial ECMO and their impact on survival in patients with refractory cardiogenic shock: A retrospective 8-year study. Ann Card Anaesth, 2022; 25(2): 171-177.
53. Wong, J.K., et al., Cannulation-Related Complications on Veno-Arterial Extracorporeal Membrane Oxygenation: Prevalence and Effect on Mortality. Artif Organs, 2017; 41(9): 827-834.
54. Lee, J.J., et al., Efficacy of veno-venous extracorporeal membrane oxygenation in severe acute respiratory failure. Yonsei Med J, 2015; 56(1): 212-9.
55. Zhong, Z., et al., Veno-Arterial Extracorporeal Membrane Oxygenation Support in Patients Undergoing Aortic Surgery. Artif Organs, 2017; 41(12): 1113-1120.
56. Biancari, F., et al., Five-year survival after post-cardiotomy veno-arterial extracorporeal membrane oxygenation. Eur Heart J Acute Cardiovasc Care, 2021; 10(6): 595-601.
57. Ostermann, M. and N. Lumlertgul, Acute kidney injury in ECMO patients. Crit Care, 2021; 25(1): 313.
58. Yu, H.Y., et al., Effect of the interplay between age and low-flow duration on neurologic outcomes of extracorporeal cardiopulmonary resuscitation. Intensive Care Med, 2019; 45(1): 44-54.
59. Turgeon, J., et al., Long-term outcomes of patients supported with extracorporeal membrane oxygenation for acute respiratory distress syndrome: a systematic review and meta-analysis. Intensive Care Med, 2024; 50(3): 350-370.

60. Fernando, S.M., et al., Age and associated outcomes among patients receiving venoarterial extracorporeal membrane oxygenation-analysis of the Extracorporeal Life Support Organization registry. Intensive Care Med, 2023; 49(12): 1456-1466.
61. Pratt, E.H., et al., Ability of the respiratory ECMO survival prediction (RESP) score to predict survival for patients with COVID-19 ARDS and non-COVID-19 ARDS: a single-center retrospective study. J Intensive Care, 2023; 11(1): 37.
62. Smith, M., et al., Duration of veno-arterial extracorporeal life support (VA ECMO) and outcome: an analysis of the Extracorporeal Life Support Organization (ELSO) registry. Crit Care, 2017; 21(1): 45.
63. Olson, S.R., et al., Thrombosis and Bleeding in Extracorporeal Membrane Oxygenation (ECMO) Without Anticoagulation: A Systematic Review. Asaio j, 2021; 67(3): 290-296.
64. Thongprayoon, C., et al., Incidence and Impact of Acute Kidney Injury in Patients Receiving Extracorporeal Membrane Oxygenation: A Meta-Analysis. J Clin Med, 2019; 8(7).
65. Rilinger, J., et al., Long-term survival and health-related quality of life in patients with severe acute respiratory distress syndrome and veno-venous extracorporeal membrane oxygenation support. Crit Care, 2021; 25(1): 410.