Original Article

Global research trends and hotspots in extracorporeal membrane oxygenation for cardiogenic shock: a bibliometric review and knowledge mapping approach (1990–2024)

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Background: Extracorporeal membrane oxygenation (ECMO) has emerged as a promising rescue strategy for patients with refractory cardiogenic shock (CS). However, comprehensive and quantitative insights into the global research landscape of ECMO in CS remain limited. This study aimed to address this gap by systematically mapping the global research landscape of ECMO in CS through bibliometric analysis and knowledge visualization.

Methods: A narrative synthesis was used to provide concise summaries of the key findings, highlighting emerging research frontiers and thematic shifts over time. Publications related to ECMO management in CS from 1990 to 2024 were retrieved from the Web of Science Core Collection. CiteSpace and VOSviewer were used to analyze publication patterns, co-authorship networks, keyword clustering, and citation metrics. High-impact authors, institutions, countries, and emerging research frontiers were identified.

Results: A total of 701 publications involving 4,433 authors from 1,105 institutions across 55 countries were analyzed. The United States led in both publication volume and citations, followed by Germany and China. Four major thematic clusters were identified: postcardiotomy shock, cardiac arrest, extracorporeal cardiopulmonary resuscitation (ECPR), acute myocardial infarction (AMI)-related mechanical circulatory support, and ECMO bridging to transplantation. Over time, research emphasis has shifted from general survival and mortality to protocol-driven care, predictive modeling, and long-term outcomes.

Conclusions: ECMO for CS is a rapidly expanding field, with bibliometric patterns suggesting increasing research consolidation and thematic diversification. Bibliometric analysis revealed a centralized and collaborative academic ecosystem with evolving themes suggestive of a shift toward precision support, multidisciplinary management, and clinical guideline development. These insights provide a roadmap for future research and health policy planning.

Keywords: Bibliometrics; cardiogenic shock (CS); critical care; extracorporeal membrane oxygenation (ECMO); mechanical circulatory support (MCS)

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Introduction

Cardiogenic shock (CS) represents one of the most severe syndromes of acute circulatory failure, commonly caused by acute myocardial infarction (AMI), myocarditis, or postcardiotomy complications (1,2). It is characterized by reduced cardiac output, leading to hypoperfusion and multi-organ dysfunction, and remains one of the most critical conditions in clinical practice (3). Despite advances in pharmacotherapy and mechanical circulatory support (MCS), mortality rates remain stubbornly high (4). In recent years, extracorporeal membrane oxygenation (ECMO) has been increasingly employed as an MCS strategy to stabilize hemodynamics and preserve end-organ perfusion in patients with CS (5,6).

Despite promising outcomes in selected cases, ECMO remains controversial due to complications, resource intensity, and heterogeneous clinical indications (7). Recent bibliometric analyses have explored various aspects of ECMO management in contexts such as respiratory failure (8), acute respiratory distress syndrome (ARDS) (9), corona virus disease 2019 (COVID-19) (10,11), pulmonary embolism (12), and out-of-hospital cardiac arrest (OHCA) (13). However, to our knowledge, no comprehensive knowledge mapping of ECMO in patients with CS has been conducted. This study aimed to fill this gap by systematically mapping the global research landscape of ECMO in CS through bibliometric analysis. It identifies publication trends, collaboration patterns, leading contributors, and thematic evolution with the goal of guiding future research in critical care. We present this article in accordance with the BIBLIO reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-aw-2072/rc).

Highlight box

Key findings

- Our bibliometric analysis included 701 publications on extracorporeal membrane oxygenation (ECMO) for cardiogenic shock (CS) from 1990 to 2024, involving 4,433 authors across 55 countries. The United States, Germany, and China were leading contributors; Columbia University and Capital Medical University ranked among the most productive institutions.
- Four major research clusters were identified: postcardiotomy shock, cardiac arrest and extracorporeal cardiopulmonary resuscitation, acute myocardial infarction-related mechanical circulatory support, and ECMO bridging to transplantation or ventricular assist devices. Research focus evolved from mortality and feasibility toward protocol-based management, risk prediction models, and long-term outcomes.

What is known and what is new?

- ECMO has been increasingly applied in refractory CS, but a comprehensive quantitative analysis of its global research landscape was lacking.
- This study is the first to delineate the global research landscape of ECMO in CS, highlighting evolving collaborations, emerging hotspots, and thematic transitions. The study highlights a thematic transition from empirical, case-based evidence to data-driven and standardized clinical algorithms supported by predictive scoring systems such as SAVE and ENCOURAGE.

What is the implication, and what should change now?

- Findings underscore the need to standardize ECMO indications, initiation timing, and patient selection to optimize outcomes.
- Future directions should include multi-center collaboration, integration of artificial intelligence for risk stratification, and economic evaluations to inform healthcare policy.
- Building internationally harmonized registries and guidelines will promote equitable access, improve resource utilization, and advance ECMO practice for CS worldwide.

Methods

Literature search strategies

A comprehensive literature search was conducted using the Web of Science database to identify relevant studies published between January 1990 and December 2024 with the aim of capturing key research developments in the 21st century. The search was performed on March 20, 2025 using the following query string: topic (TS) =((“Extracorporeal Membrane Oxygenation” OR “ECMO” OR “ECLS” OR “Extracorporeal Life Support”) AND (“Cardiogenic Shock” OR “Circulatory Shock” OR “Heart Failure Shock” OR “Acute Heart Failure” OR “Cardiac Shock”)) AND

Table 1 Summary of data source and selection

Category	Specific standard requirements
Research database	Web of Science core collection
Citation indexes	Science Citation Index Expanded and Social Sciences Citation Index
Searching period	January 1990 to December 2024
Language	English
Searching keywords	("Extracorporeal Membrane Oxygenation" OR "ECMO" OR "ECLS" OR "Extracorporeal Life Support") AND ("Cardiogenic Shock" OR "Circulatory Shock" OR "Heart Failure Shock" OR "Acute Heart Failure" OR "Cardiac Shock")
Publication types	Article
Data extraction	Exported with full records and cited references in plain text format
Sample size	701

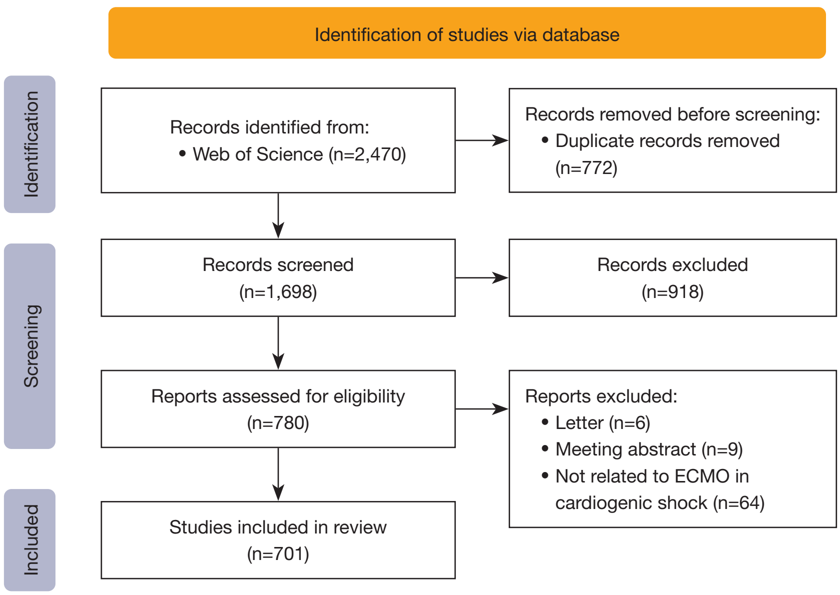


Figure 1 Flowchart of literature screening and research process. ECMO, extracorporeal membrane oxygenation.

DT=(Article) AND LA=(English). This query, which utilizes the TS field encompassing title, abstract and author keywords, yielded an initial pool of records. The keyword strategy was also summarized in *Table 1*.

Inclusion/exclusion criteria

Two independent researchers (S.C. and L.L.) screened the titles and abstracts of the retrieved articles (*Figure 1*). The inclusion criteria were: (I) studies directly related to ECMO applications in CS; (II) original research with complete bibliographic metadata; (III) full-text availability in English. The exclusion criteria were: (I) non-research articles such as editorials, letters to the editor, short communications, book chapters or conference abstracts; (II) duplicate or retracted studies. Disagreements were resolved by a third reviewer (S.L.). Following the completion of literature screening, three authors independently assessed the included records using the BIBLIO checklist, a standardized reporting guideline for bibliometric reviews of biomedical literature. This checklist evaluates reporting completeness, including bibliographic metadata integrity (authors, affiliations, keywords, references), document type eligibility, and database indexing consistency. The checklist was applied solely to confirm data suitability for bibliometric analysis and did not influence study inclusion, exclusion, or

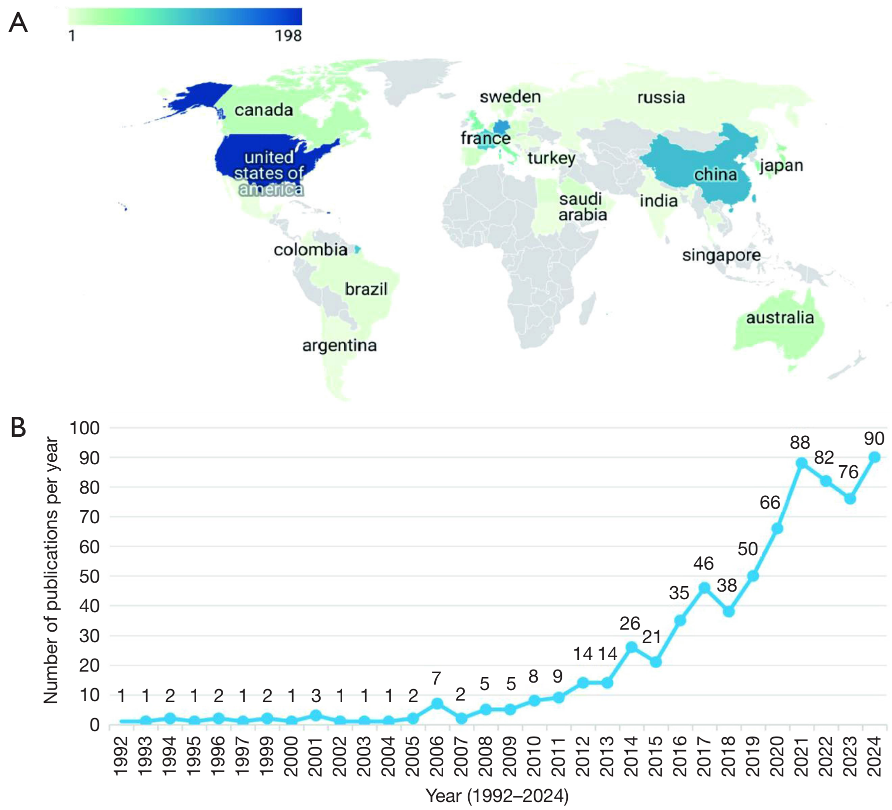


Figure 2 Global trends and geographic distribution of ECMO research in cardiogenic shock. (A) World map for the distribution of articles by country on cardiopulmonary resuscitation. (B) Trends in the growth of publications worldwide from 1992 to 2024. In the indicator given in the top left of the figure, productivity increases from light to dark. ECMO, extracorporeal membrane oxygenation.

weighting beyond the predefined eligibility criteria.

Tools and techniques for bibliometric analyses

CiteSpace and VOSviewer were used to analyze research trends, key authors, institutions, and geographic distributions. These tools provided visual representations of collaboration networks and emerging research hotspots. Data export and cleaning involved removing incomplete records, constructing co-authorship and keyword co-occurrence networks, and identifying trends and collaboration patterns. Detailed information on dataset access and software availability is provided in Appendix 1.

Results

Analysis of development trends

The study analyzed 701 papers from 55 countries, 1,105 institutions, and 4,433 authors, published across 158 journals, and cited 8,562 references from 1,457 journals. As shown in *Figure 2*, the annual number of publications on ECMO in CS has demonstrated a continuous upward trend since 1992, with a particularly rapid increase in the past decade, reflecting global expansion and growing interest in this field. *Figure 2A* shows the distribution of the number of articles by country. The data suggest that research on ECMO in CS will continue to grow, with publication volume expected to increase throughout the year.

Analysis of authors and research institutions

Identifying core authors

Using CiteSpace, we identified 10 core authors contributing 230 papers, accounting for 33% of the total publication volume, consistent with Price's Law. This indicates that the field is still evolving and is yet to form a stable group of authors. Among the leading contributors, Alain Combes ranked first with 28 publications and 2,454 citations, followed by Xiaotong Hou and Koji Takeda (*Table 2*). The

Table 2 Most important authors ranked by citations in ECMO in the CS research field

Rank	Author	Publications	Citations	ACI
1	Combes, Alain	28	2,454	87.64
2	Hou, Xiaotong	27	427	15.81
3	Takeda, Koji	26	464	17.85
4	Wang, Hong	24	424	17.67
5	Leprince, Pascal	23	2,337	101.61
6	Lebreton, Guillaume	23	857	37.26
7	Takayama, Hiroo	21	713	33.95
8	Wang, Liangshan	20	199	9.95
9	Naka, Yoshifumi	19	594	31.26
10	Brodie, Daniel	19	1,405	73.95

ACI, average citations per item; CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation.

average citations per item (ACI) is used to measure the impact of scientific work by quantifying the average number of citations received by a scholar, journal, or article. *Table 2* lists highly productive authors in this field with more than 19 publications, ranked by publication count.

Alain Combes leads with 28 papers and 2,454 citations. As one of the pioneers in ECMO research, his work has significantly influenced clinical practice, particularly in the application of veno-arterial extracorporeal membrane oxygenation (VA-ECMO) in CS (14) and in the development of clinical prognosis scoring systems (15). Although Pascal Leprince ranked fifth in publication count (23 papers), he demonstrated the highest ACI (101.61), indicating the significant impact and relevance of his individual contributions. His research often focuses on refractory CS (16) and long-term survival post-ECMO (17). Conversely, authors such as Xiaotong Hou and Hong Wang, despite having a high number of publications (27 and 24, respectively), show comparatively lower ACI values (15.81 and 17.67), suggesting a broader but perhaps less cited publication portfolio.

The collaborative network among core authors indicates strong partnerships, particularly among Alain Combes, Daniel Brode and Xiaotong Hou, highlighting their pivotal role in CS research. Central nodes such as Daniel Brodie, Alain Combes, and Xiaotong Hou serve as bridging scholars who connect multiple research networks, playing crucial roles in international collaboration and knowledge dissemination.

From *Figure 3A,3B*, a series of highly interconnected author clusters are evident, signifying the presence of research teams and cross-institutional collaborative projects. This visualization underscores the interdisciplinary nature of ECMO-CS research, integrating insights from cardiology, critical care, and surgery, and reveals the evolution from generalized shock management to specialized ECMO strategies over time.

Analyzing major research institutions

Similar to core author analysis, identifying principal research institutions involves evaluating their publication output, citation frequency, and collaborative networks. Columbia University, Capital Medical University, Sungkyunkwan University, and Sorbonne University were among the top research institutions. Columbia University leads in both the publication volume and citation impact, as shown in *Table 3*. This is closely followed by Capital Medical University, with 31 publications and 882 citations, and Sungkyunkwan University, with 20 publications and 557 citations. Both institutions are prominent in East Asia, particularly for their contribution to large-scale ECMO registries and retrospective clinical studies.

The institutional landscape illustrates a strong North America-East Asia-Europe triangular structure, with the USA, China, South Korea, Germany, and France forming the core of global ECMO-CS research. Their collaboration has significantly contributed to research advancements in this field.

Geographical distribution and analysis of international cooperation

The United States dominates ECMO-CS research with 198 papers and 6,780 citations, followed by Germany with 125 papers and France with 98 papers in *Table 4*, ranked by citation count. The distribution of publications across countries in this field is highly uneven, exhibiting a significant top-heavy effect. Notably, France had the highest ACI at 48.29, indicating the significant impact of its publications.

In *Figure 3C*, the node colors in the international collaboration network analysis represent different clusters, with larger nodes indicating a higher volume of publications. International collaborations are particularly strong among the USA, Germany, and France, indicating they are key hubs in global ECMO-CS research collaboration. This network map reveals a well-developed collaboration structure, with transatlantic and intra-European research ties forming the

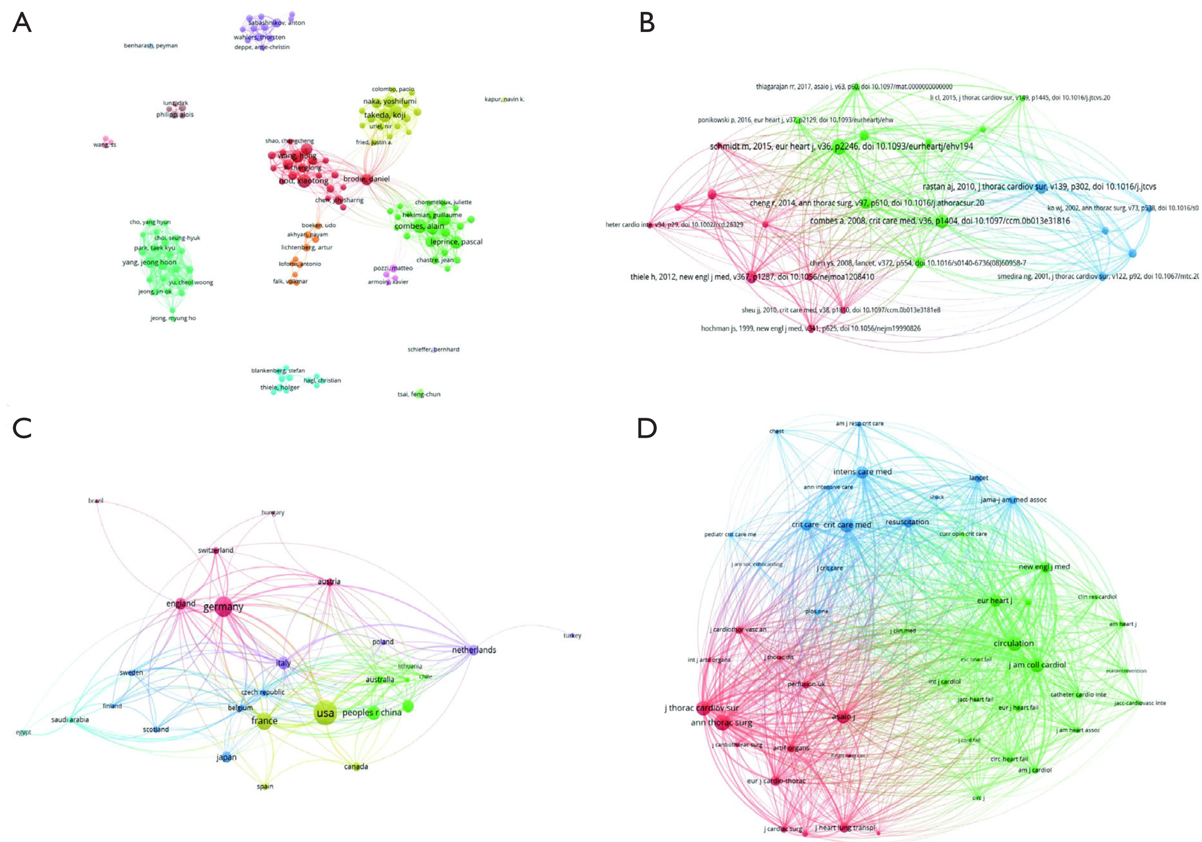


Figure 3 Collaboration and co-citation networks in ECMO research for cardiogenic shock. (A) Author collaboration network. Node size represents the number of relevant publications by the author; link strength represents the frequency of co-authorship between authors; node size reflects publication output. (B) Co-reference network. Node size represents the co-reference frequency of documents; link strength represents the co-reference association intensity between documents, reflecting connections of classic literature in this field. (C) Country collaboration network, showing international research cooperation. Node size corresponds to publication volume and link thickness indicates collaboration strength. (D) Journal co-citation network, highlighting the core journals and disciplinary distribution in this research field. Node size represents the co-citation frequency of journals; link strength represents the co-citation association intensity between journals. ECMO, extracorporeal membrane oxygenation.

Table 3 Top 10 organizations ranked by citations in ECMO in CS research field

Rank	Organization	Publications	Citations	ACI
1	Columbia University	41	1,071	26.12
2	Capital Medical University	31	882	28.45
3	Sungkyunkwan University	20	557	27.85
4	Sorbonne University	18	342	18.94
5	Harvard Medical School	15	667	44.47
6	National Taiwan University Hospital	15	747	49.80
7	Leipzig University	15	1,394	92.93
8	Mayo Clinic	15	400	26.67
9	Hôpital la Pitié Salpêtrière	13	421	32.38
10	Chang Gung University	13	509	39.15

ACI, average citations per item; CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation.

Table 4 Top 5 countries ranked by citations in ECMO in CS research field

Rank	Country	Publications	Citations	ACI
1	USA	198	6,780	34.25
2	Germany	125	4,286	34.29
3	China	106	2,923	27.58
4	France	98	4,733	48.29
5	Italy	49	1,637	33.41

ACI, average citations per item; CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation.

backbone of international ECMO-CS research. Cross-country collaboration has led to increased knowledge sharing and accelerated progress in the ECMO-CS domain.

Citation analysis: assessing the most influential articles, journals

Analysis of highly cited literature

As shown in *Table 5*, the top 10 most-cited publications are listed in descending order of citation count, emphasizing their academic influence and recognition within the field.

Table 5 Top 10 publications ranked by citations in ECMO in the CS research field

Rank	Author	Article title	Journal	Year	Type	Citation
1	Schmidt *et al.* (15)	Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial-ECMO (SAVE)-score	*European Heart Journal*	2015	Article	147
2	Combes *et al.* (16)	Outcomes and long-term quality-of-life of patients supported by extracorporeal membrane oxygenation for refractory cardiogenic shock	*Critical Care Medicine*	2008	Article	118
3	Rastan *et al.* (18)	Early and late outcomes of 517 consecutive adult patients treated with extracorporeal membrane oxygenation for refractory postcardiotomy cardiogenic shock	*The Journal of Thoracic and Cardiovascular Surgery*	2010	Article	110
4	Muller *et al.* (19)	The ENCOURAGE mortality risk score and analysis of long-term outcomes after VA-ECMO for acute myocardial infarction with cardiogenic shock	*Intensive Care Medicine*	2016	Article	81
5	Chen *et al.* (20)	Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis	*Lancet*	2008	Article	80
6	Smedira *et al.* (21)	Clinical experience with 202 adults receiving extracorporeal membrane oxygenation for cardiac failure: survival at five years	*The Journal of Thoracic and Cardiovascular Surgery*	2001	Article	65
7	Doll *et al.* (22)	Five-year results of 219 consecutive patients treated with extracorporeal membrane oxygenation for refractory postoperative cardiogenic shock	*Annals of Thoracic Surgery*	2004	Article	64
8	Hochman *et al.* (23)	Early revascularization in acute myocardial infarction complicated by cardiogenic shock. SHOCK Investigators. Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock	*The New England Journal of Medicine*	1999	Article	61
9	Thiagarajan *et al.* (24)	Extracorporeal Life Support Organization Registry International Report 2016	*ASAIO Journal*	2017	Article	50
10	Ko *et al.* (25)	Extracorporeal membrane oxygenation support for adult postcardiotomy cardiogenic shock	*Annals of Thoracic Surgery*	2002	Article	48

CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation; VA-ECMO, veno-arterial extracorporeal membrane oxygenation.

Table 6 Top 10 journals ranked by citations in ECMO in CS research field

Rank	Source	Publications	Citations	ACI
1	*Annals of Thoracic Surgery*	22	1,509	68.59
2	*Critical Care Medicine*	19	1,457	76.68
3	*Journal of Thoracic and Cardiovascular Surgery*	18	1,354	74.67
4	*ASAIO Journal*	40	952	23.80
5	*European Journal of Cardio-Thoracic Surgery*	23	703	30.57
6	*Artificial Organs*	28	445	15.89
7	*Interactive Cardiovascular and Thoracic Surgery*	18	376	20.89
8	*Journal of Cardiac Surgery*	17	291	17.12
9	*Perfusion-UK*	32	217	6.78
10	*Journal of Clinical Medicine*	28	161	5.75

ACI, average citations per item; CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation.

The most cited article is "Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial-ECMO (SAVE)-score", published in the *European Heart Journal*, with 147 citations. This study introduced the survival after veno-arterial ECMO (SAVE)-score, which predicts survival outcomes after VA-ECMO in patients with refractory CS. The second-most-cited work, by Combes *et al.* in *Critical Care Medicine*, focused on the long-term quality of life of patients treated with ECMO for refractory CS. Several other influential studies have been noted, including Muller *et al.*, who developed the prediction of cardiogenic shock outcome for AMI patients salvaged by VA-ECMO (ENCOURAGE) mortality risk score for patients (19), and Chen *et al.* (20), whose research in *Lancet* compared ECMO-assisted resuscitation with conventional methods in in-hospital cardiac arrest scenarios. Each of these publications contributes uniquely to the evidence base, whether by introducing clinical scoring systems, reporting long-term outcomes, or evaluating the comparative effectiveness of ECMO modalities.

Collectively, these articles represent a blend of retrospective cohort analyses, registry data evaluations, and prospective clinical studies. They serve not only as cornerstones in ECMO-related research but also guide ongoing clinical practices and future research directions.

Analyzing journal impact

The most influential journals in this field are *Annals of Thoracic Surgery* and *Critical Care Medicine* evaluated through citations as shown in *Table 6*. *ASAIO* ranks first in total publications, reflecting its prominent role as a core outlet for ECMO research. However, its ACI was 23.80, indicating moderate impact per article. In contrast, *Critical Care Medicine* exhibited the highest ACI at 76.68, despite having fewer articles, demonstrating its strong influence in the field. A similar trend was observed for the *Journal of Thoracic and Cardiovascular Surgery*, further emphasizing that journals with fewer but more impactful publications can exert significant academic influence. The co-citation network highlights the intellectual structure of ECMO-CS research in *Figure 3D*, highlights the intellectual structure of ECMO-CS research. These journals are central to disseminating research on ECMO in CS, playing a vital role in the academic community's understanding of the application of ECMO in clinical settings.

Analysis of research hot spots and frontier domains

Keyword co-occurrence analysis identifies research hot spots

To gain insights into emerging themes and evolving directions within the ECMO-CS research landscape, we conducted keyword co-occurrence and clustering analysis. As shown in *Table 7*, the most frequently occurring keywords include "cardiogenic shock", "extracorporeal membrane oxygenation", "survival", and "mortality", reflecting core thematic areas of the field. The overlay visualization (*Figure 4A*) highlights a temporal trend of research emphasis shifting from broad terms such as mortality and life-support in earlier years toward specific strategies such as

Table 7 Top 10 keywords in ECMO in CS research field

Rank	Keywords	Occurrences	Total link strength
1	Cardiogenic shock	321	918
2	Extracorporeal membrane oxygenation	246	730
3	Survival	190	635
4	Outcomes	187	590
5	Mortality	167	570
6	Mechanical circulatory support	148	453
7	Life-support	155	451
8	Cardiac arrest	88	312
9	Support	109	280
10	Extracorporeal life support	84	266

CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation.

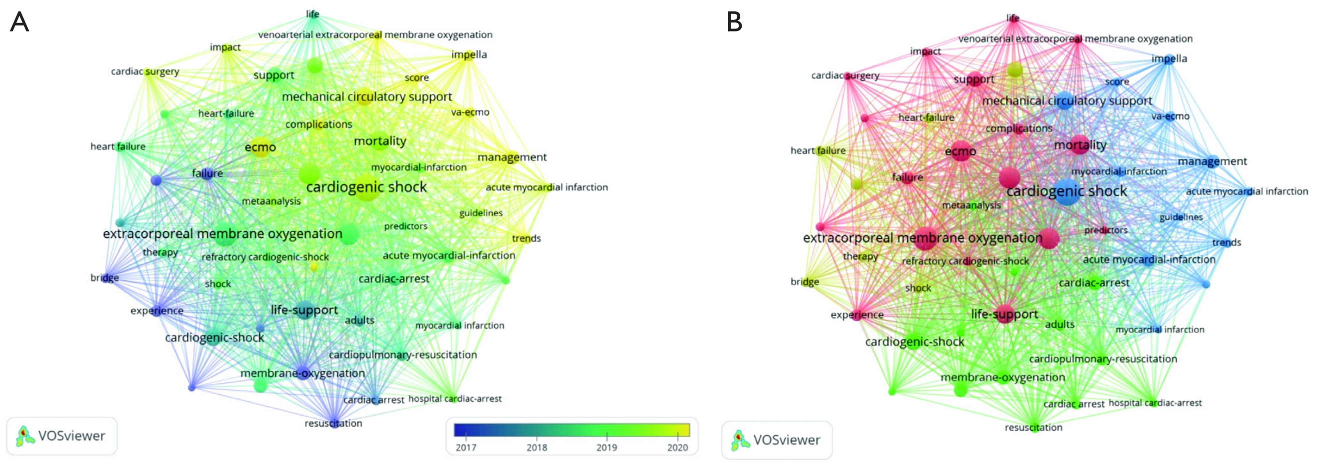


Figure 4 Visualization of keyword co-occurrence in ECMO research for cardiogenic shock. (A) The overlay visualization of the co-occurrence of keywords. Node size represents the co-occurrence frequency of keywords; link strength represents the co-occurrence association intensity between keywords; colors correspond to the publication year of keywords (the color bar from blue to green representing earlier to later years), showing the temporal evolution of research topics. (B) The network visualization of the co-occurrence of keywords, identifying major thematic clusters. Node size represents the co-occurrence frequency of keywords; link strength represents the co-occurrence association intensity between keywords. ECMO, extracorporeal membrane oxygenation.

MCS and cardiac arrest. Meanwhile, network visualization (*Figure 4B*) illustrates strong interlinkages among survival-related topics, indicating a persistent focus on prognostication and patient outcomes.

As illustrated in *Table 8*, keyword clustering resulted in four major thematic clusters. These discoveries offer a lucid perspective on research trends and core themes prevalent in the field.

Red cluster (part 1)

Evaluation of clinical outcomes in patients receiving ECMO for postcardiotomy CS is a mature and well-established domain. Keywords such as "adult patients", "postcardiotomy cardiogenic shock", "mortality", "complications", and "predictors" underscore the research focus on high-risk surgical populations. These patients often require ECMO as salvage therapy following cardiac

Table 8 Cluster of keywords in ECMO in CS research field

Cluster	Color	Label	Keywords
1	Red	Clinical outcomes in ECMO for postcardiotomy shock	Adult patients, cardiac surgery, complications, ECMO experience, extracorporeal membrane oxygenation, failure, impact, life, life-support, mortality, outcomes, postcardiotomy cardiogenic shock, predictors, refractory cardiogenic-shock, supports
2	Green	Cardiac arrest & resuscitation support	Adults, cardiac arrest, cardiogenic-shock, cardiopulmonary bypass, cardiopulmonary-resuscitation, circulatory support, ECLS, extracorporeal life support, hospital cardiac arrest, membrane-oxygenation, meta analysis, resuscitation
3	Blue	Mechanical circulatory support for cardiogenic shock in acute myocardial infarction	Acute myocardial infarction, cardiogenic shock, guidelines, Impella, management, mechanical circulatory support, myocardial infarction, percutaneous coronary intervention, score, trends, VA-ECMO
4	Yellow	Heart failure & VAD therapy	Bridge, extracorporeal membrane oxygenation, heart failure, shock, therapy, ventricular assist device

CS, cardiogenic shock; ECMO, extracorporeal membrane oxygenation; ECLS, extracorporeal life support; VA-ECMO, veno-arterial extracorporeal membrane oxygenation; VAD, ventricular assist device.

surgery when conventional weaning fails or low cardiac output syndrome persists. Several studies in this cluster have investigated short- and long-term mortality and identified factors associated with poor prognosis (26,27). Commonly examined predictors include pre-ECMO lactate levels, renal dysfunction, age, and cardiopulmonary bypass duration (28). Tools such as the SAVE score (15) and ENCOURAGE score (19) have been frequently applied to stratify patient risks and optimize selection criteria. This thematic area also emphasizes complication rates, particularly bleeding, thromboembolic events, infection, and neurological injury, all of which significantly affect patient outcomes (28,29). In recent years, there has been growing attention to weaning process predictors and long-term functional recovery, indicating a shift from survival alone to quality-of-life outcomes post-ECMO (30,31). Continuous refinement of risk stratification, prognostic modeling, and perioperative ECMO management strategies is essential to improve patient selection and therapeutic decision-making in ECMO treatment for postcardiotomy shock, thereby enhancing clinical outcomes.

Green cluster (part 2)

ECMO's expanding role, extending beyond traditional shock treatment into emergency and prehospital care, highlights its potential to redefine resuscitation strategies for refractory cardiac arrest. This significant thematic domain focuses on the use of ECMO in cardiac arrest, particularly in the context of extracorporeal cardiopulmonary resuscitation (ECPR) (32,33). Frequently occurring keywords in this cluster include "cardiac arrest", "resuscitation", "Extracorporeal Life Support (ECLS)", "cardiopulmonary bypass", and "hospital cardiac arrest", reflecting a growing interest in the role of ECMO as a life-saving intervention during refractory circulatory collapse. Research in this cluster primarily focuses on ECMO-assisted resuscitation strategies for patients experiencing either in-hospital cardiac arrest or OHCA (32,34,35), demonstrated improved survival and neurological outcomes in carefully selected patients receiving ECPR (36). Notable contributions in this area include the use of ECMO during ongoing Cardiopulmonary Resuscitation to maintain cerebral and myocardial perfusion, particularly in young patients with reversible etiologies and short low-flow duration (37). In recent years, the Extracorporeal Life Support Organization has provided compelling evidence supporting ECPR in selected cardiac arrest patients, prompting updated guidelines and increased adoption of ECMO-facilitated resuscitation in tertiary and quaternary care centers globally (38).

Blue cluster (part 3)

The use of MCS, which includes ECMO, in patients with AMI complicated by CS, represents a dynamic and evolving area of research. High-frequency keywords such as "acute myocardial infarction", "percutaneous coronary intervention", "mechanical circulatory support" and "Impella" indicate a strong focus on integrating advanced hemodynamic support in the management of CS. Studies have explored the role of ECMO as a bridge to recovery, transplant, or decision-making in patients undergoing revascularization through percutaneous coronary intervention (39,40). The interplay between early revascularization strategies and the timing of ECMO support has been frequently discussed (41). Furthermore, comparisons between different MCS devices, such as VA-ECMO, intra-aortic balloon pump and Impella, often assess their hemodynamic effects, survival rates, and complication profiles (42). While ECMO provides cardiopulmonary support, its use is frequently accompanied by risks such as bleeding and limb ischemia. This has prompted researchers to investigate optimal patient selection criteria and combined device strategies to mitigate these risks and enhance outcomes. Overall, the application of ECMO in acute coronary syndromes aims to improve both short-term stabilization and long-term outcomes in patients with AMI-related CS.

Yellow cluster (part 4)

A specialized and evolving research area represents the role of ECMO in end-stage heart failure and its function as a bridge to long-term support or transplantation. Representative keywords include “heart failure”, “ventricular assist device”, “bridge”, and “therapy”, pointing to ECMO’s transitional role in the continuum of advanced heart failure management. Studies in this cluster focus on ECMO as a temporary support measure in patients awaiting durable MCS, such as left ventricular assist device (LVAD), or heart transplantation (43,44). These patients often present with biventricular failure or postcardiotomy CS that is not amenable to immediate weaning (45). Furthermore, ECMO serves as a salvage support in patients who are initially deemed ineligible for transplant or LVAD but may recover end-organ function with short-term support (46). In essence, integration with ventricular assist device (VAD) and heart transplant considerations marks a frontier domain in ECMO research toward disease management and advanced heart failure care, highlighting its strategic importance as part of multistage treatment planning rather than solely as an emergency intervention.

Integrated evolutionary path of the literature

The timeline visualization generated by CiteSpace reveals the dynamic evolution of ECMO-related research in CS over the past two decades in *Figure 5A*. Initially, studies focused on foundational topics such as cardiopulmonary bypass and ECMO techniques, primarily as a last-resort therapy in pediatric and postcardiotomy patients. From 2013 to 2018, ECMO’s application expanded to adult CS and OHCA, with large-scale registries and multicenter studies shaping clinical protocols. Recent research has become more sophisticated, emphasizing optimized timing and patient selection, machine learning for risk stratification, and cost-effectiveness analysis. Cluster mapping highlights cardiac arrest and resuscitation, advanced heart failure and VAD bridging as rapidly growing domains. Overall, ECMO research has evolved from a reactive intervention to a strategic, multidisciplinary component of modern circulatory support.

Analysis of academic growth points

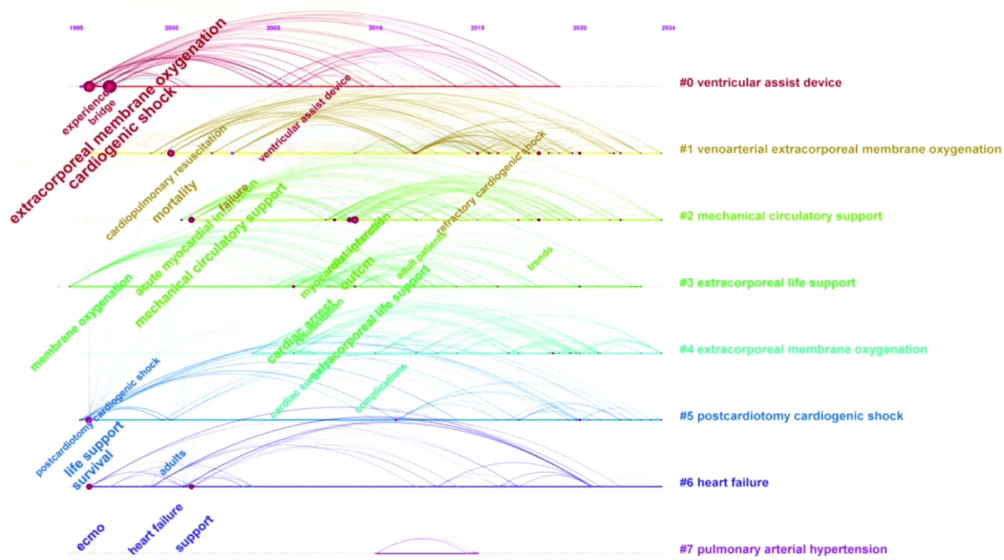
The burst term analysis in *Figure 5B* through CiteSpace identifies several high-impact terms in ECMO research, particularly in the context of CS, reflecting shifts in focus and emerging trends. Terms such as ECPR and MCS have surged in prominence, highlighting ECMO’s expanding role from post-surgical support to critical care rescue therapies, as well as hybrid approaches involving other devices. Cost-effectiveness has also emerged as a key term, emphasizing the need for economic assessments to guide resource allocation. Additionally, terms related to ECMO initiation timing, patient selection, and neurological outcomes indicate a growing emphasis on precision medicine. These burst terms highlight the evolving sophistication of ECMO research and its clinical applications, suggesting that ongoing advancements will be crucial for shaping future guidelines and improving patient outcomes in critical cardiac conditions.

Discussion

Summary of main findings

Through bibliometric analysis, our research highlights the evolving landscape of ECMO in the management of CS in *Figure 6*, capturing shifts in scholarly focus, geographic distribution, and institutional contributions. The upward trend in publication volume, particularly evident since 2010, reflects an increasing clinical interest in ECMO as an essential tool for the management of critically ill cardiac patients. The clustering and co-occurrence analysis of keywords in our study identified several core themes that have shaped ECMO-CS research over the past two decades. These include postcardiotomy shock, ECPR, and ECMO use in AMI, and its role as a bridge to recovery or advanced therapies. Such thematic concentration suggests a growing

A



B

Top 10 Keywords with the strongest citation bursts

Keywords	Year	Strength	Begin	End	2004–2024
Experience	2005	14.63	2005	2016	
Bridge	2005	7.97	2005	2015	
Failure	2006	4.51	2006	2010	
Cardiopulmonary bypass	2008	4.69	2008	2018	
Membrane oxygenation	2007	4.6	2009	2015	
Resuscitation	2007	6.01	2011	2017	
Adult patients	2012	5.26	2012	2018	
Refractory cardiogenic shock	2015	4.61	2016	2017	
Management	2009	6.21	2022	2024	
Veno-arterial extracorporeal membrane oxygenation	2020	4.72	2022	2024	

Figure 5 Evolution and citation bursts in ECMO research for cardiogenic shock. (A) Temporal evolution of keywords in ECMO research, showing the changing prominence of topics over time. Curves represent the occurrence timeline and thematic evolution connections of keywords; different colors correspond to thematic clusters divided; node size represents the occurrence frequency of keywords; this map shows the temporal distribution and evolution path of research themes in this field from 1990 to 2024. (B) Top 10 keywords with the strongest citation bursts, highlighting emerging research trends. The red segment in the color block represents the citation burst period, and the green segment represents the non-burst period, reflecting the fluctuation of research hotspots in different stages of this field. ECMO, extracorporeal membrane oxygenation.

recognition of ECMO not only as a rescue modality but also as an integral component of structured clinical algorithms (47). The increasing emphasis on score-based patient selection, such as the SAVE (15) and ENCOURAGE models (19), marks a critical transition from empirical to evidence-informed application, distinguishing the ECMO-CS literature from the broader, predominantly respiratory-focused ECMO research.

Comparison with prior bibliometric ECMO studies

Our findings resonate with prior bibliometric analyses in areas such as ARDS, OHCA, and pulmonary embolism, but they also highlight the distinct trajectory and

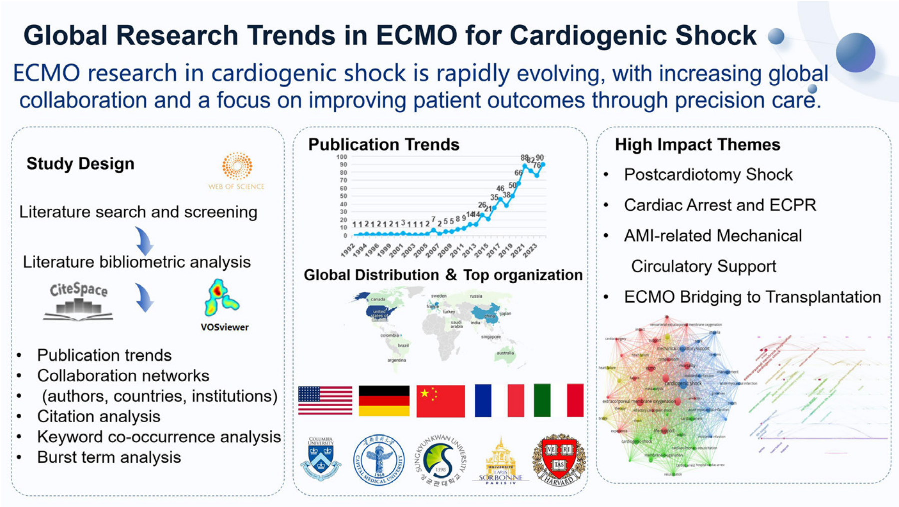


Figure 6 Global research trends in ECMO for cardiogenic shock. AMI, acute myocardial infarction; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation.

challenges associated with ECMO use in CS. Li *et al.* (48) highlighted ECMO's evolution in ARDS research using multidisciplinary and protocol-based practice models. The surge in ECMO-related publications during the COVID-19 pandemic (13) emphasized its central role in managing ARDS and the need for coordinated multidisciplinary care. In the context of OHCA (13), research has increasingly focused on guideline development and prognostic utility of ECPR, largely driven by a few high-output academic centers. Meanwhile, investigations into ECMO for respiratory failure have shifted toward more refined topics such as weaning protocols, patient selection, and its tailored use during viral pandemics (8). Similarly, emerging studies on ECMO in massive pulmonary embolism highlight its growing recognition as a life-saving modality integrated within structured clinical decision-making pathways (12).

Implications for clinical practice and research

Our results suggest a more centralized pattern of academic output in the CS domain. Leading institutions and researchers, such as those affiliated with Pitié-Salpêtrière Hospital and Columbia University, have produced a substantial proportion of high-impact work. This centralization indicates the importance of academic hubs and expert networks in advancing ECMO practice and research in CS. Moreover, the observed rise in keywords such as "guidelines", "prognosis" and "risk stratification" in recent years signals a shift in scholarly efforts from mere feasibility and survival reports toward optimizing outcomes and formalizing practice standards. Furthermore, the progression from descriptive case series to multi-center registry studies and risk-predictive modeling suggests a more mature research ecosystem, focused on refining patient selection and standardizing care. Clinically, the convergence of ECMO with broader cardiac arrest care pathways, particularly in the context of AMI and ECPR, underscores its expanding role across the continuum of critical cardiac care. These developments emphasize the necessity of multidisciplinary collaboration involving emergency services, cardiac surgery, intensive care, and perfusion specialists. Future research should aim to incorporate emerging technologies such as natural language processing and machine learning to identify latent thematic trends and hidden research patterns. The inclusion of non-English language literature and gray literature sources would enhance global comprehensiveness and contextual understanding. In parallel, large-scale collaborative studies are needed to validate existing prognostic tools and to investigate the cost-effectiveness of ECMO in CS under varying healthcare resource conditions. As ECMO indications expand, policy frameworks and training models must also evolve to ensure equitable access and optimal outcomes.

Limitations

Despite these advancements, several limitations of this study remain to be addressed. The exclusive reliance on the Web of Science Core Collection may have led to the omission of relevant studies indexed elsewhere, such as in Scopus or Embase, and no sensitivity analysis with additional databases was performed due to resource constraints. Additionally, citation-based indicators are subject to citation lag bias, which may favor older publications. The English-language restriction may introduce language bias, potentially underrepresenting regional research. Moreover, co-occurrence and clustering results may vary depending on software algorithms and parameter settings used in CiteSpace and VOSviewer.

Conclusions

Research on ECMO in CS has grown rapidly, with a shift toward standardized management, risk prediction, and integrated multidisciplinary care. Recent studies have increasingly emphasized long-term outcomes, patient selection, and cost-effectiveness, reflecting a move toward more precise and sustainable treatment strategies. Key challenges remain, including optimizing clinical protocols and improving outcome predictions. Future efforts should focus on refining treatment algorithms, strengthening evidence through large-scale studies, and enhancing collaboration across specialties to improve patient care.

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Footnote

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