Original Article

A study of mechanical ventilation in the ICU after cardiac surgery: a bibliometric analysis

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Background: After cardiac surgery, patients are often admitted to the intensive care unit (ICU) due to various preoperative factors and continue to receive mechanical ventilation. This study sought to conduct a bibliometric analysis to summarize studies on mechanical ventilation among postoperative ICU patients who had undergone cardiac surgery.

Methods: We searched the Science Citation Index Expanded (SCI-E) database using the following terms: "cardiac surgery (Topic)", "intensive care (Topic)" and "ventilation (Topic)". The search results were analyzed using R software. The analysis examined the number of publications of relevant articles and the annual change trend, the number of times an article was cited and the annual change trend, the distribution of countries conducting the research, the cooperation between countries and the citation frequency, the distribution of institutions conducting research, the cooperation between institutions, and the citation frequency, the number of published articles, the cooperation among researchers, and the citations frequency of researchers, the journals in which the articles were published, and the use of keywords.

Results: A total of 1,969 relevant research papers were included in this study. The main countries that conducted the relevant research included the United States (US), China, Germany, and Canada. The research institutions were mainly located in the US and Canada, and the main researchers were from research institutions in these countries. The most cited authors were Zappitelli, Hichey, and Wypij. According to Bradford's law, 9 core journals in this field were identified. The results of the keyword analysis showed that in the past 10 years, research has focused on the mortality of patients, but only a few related random controlled trials have been conducted.

Conclusions: More randomized controlled trials need to be conducted in this field to provide higher evidence-based medical evidence.

Keywords: Cardiac surgery; intensive care unit (ICU); mechanical ventilation; bibliometric analysis

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Introduction

According to previous statistics, more than 2 million patients worldwide undergo cardiac surgery every year (1,2). Common cardiac surgical procedures include coronary artery bypass grafts, heart valve replacements, cardiac trauma repairs, and the correction of congenital heart disease. Due to the special surgical site, severe conditions, and a high incidence of postoperative complications,

patients are often transferred to the intensive care unit (ICU) after surgery for continued observation (2,3). After cardiac surgery, patients are often affected by various preoperative factors (including the patient's basic condition, and cardiac function), various intraoperative factors that affect cardiac function, intraoperative cardiopulmonary bypass (CPB), the incomplete metabolic clearance of anesthetics, the incomplete recovery of spontaneous breathing, significant fluctuations in vital signs, and unstable hemodynamics, and mechanical ventilation may be required to help patients recover (4-6).

The current types of mechanical ventilation are invasive ventilation and non-invasive ventilation (7,8). Most patients undergoing cardiac surgery can be weaned from the ventilator 12–24 hours after surgery, but some patients have difficulty weaning and require prolonged mechanical ventilation due to factors such as severe underlying conditions, decreased cardiac function, or infection (9). To address this issue, researchers have carried out a great deal of research, especially on the risk factors leading to prolonged mechanical ventilation, preventive measures, and weaning strategies (10). Additionally, due to advancements in technology, non-invasive ventilation technology has gradually replaced invasive ventilation technology in patients with relatively mild illness, which greatly reduces the suffering of patients, the incidence of ventilator-associated pneumonia, and the weaning time (7). Researchers need to conduct further research on the respiratory and infection problems related to invasive ventilation (11,12).

Cardiac surgery patients often experience multiple organ insufficiencies, such as heart and lung dysfunction (13). Additionally, the operation time is long, and the establishment of extracorporeal circulation during surgery and various invasive operations in the perioperative period create potential risks for postoperative infection (14,15). Long-term mechanical ventilation leads to a high incidence of postoperative respiratory and related pneumonia, which affects the prognosis of patients (12). There are many studies on mechanical ventilation during intensive care after cardiac surgery, but the overall picture of research in this area is unclear.

Bibliometric research, which involves searching the relevant literature and conducting a statistical analysis, reveals the development of relevant research in different countries and institutions, the cooperation between these countries or institutions, and the main researchers and related journals, while a keyword analysis reflects the focus of the research and any changes. This study conducted a bibliometric analysis to summarize studies examining the use of mechanical ventilation during postoperative intensive care among patients who had undergone cardiac surgery.

Methods

Database

The search for this study was based on the Science Citation Index Expanded (SCI-E) database of the Web of Science Core Collection (WOSCC). The SCI-E database is currently the most commonly used database for bibliometric research and this database cover the most literatures for natural science.

Retrieval strategy

In this study, on the search page of the SCI-E database, we used the "Topic Terms" search, and used the following search terms: "cardiac surgery (Topic)" and "intensive care (Topic)" and "ventilation (Topic)". The publication time was not limited. The last search was conducted on December 19, 2021.

Th removal of duplicates from the literature records

Some of the publications, including articles published in advance, conference papers, conference abstracts, retractions, and corrections, were duplicates of formally published documents. Thus, before the analysis, we took the officially published documents as the standard version, and deleted other forms of duplicate articles.

Analysis method

After the retrieval was completed, all the records of the retrieval results and the cited references were exported in plain-text format to generate the source file for the analysis, and the bibliometric package of R software was used to analyze the related articles on mechanical ventilation in ICU patients after cardiac surgery. The analysis examined the number of publications of relevant articles and the annual change trend, the number of times an article was cited and the annual change trend, the distribution of countries conducting the research, the cooperation between countries and the citation frequency, the distribution of institutions conducting research, the cooperation between institutions, and the citation frequency, the number of published articles, the cooperation among researchers, and

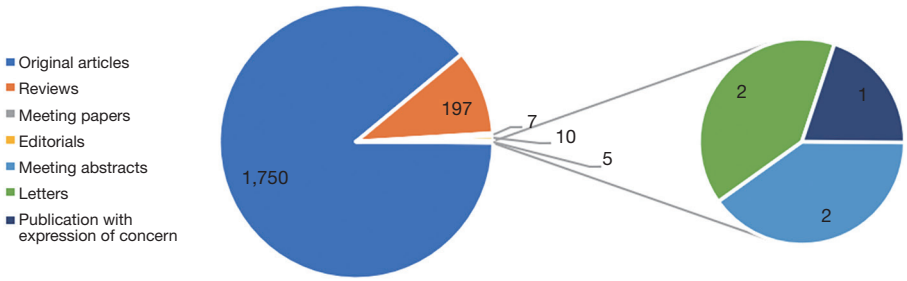

Figure 1 Types of articles (the number "5" includes 2 conference abstracts, 2 letters, and 1 expression of concern publication).

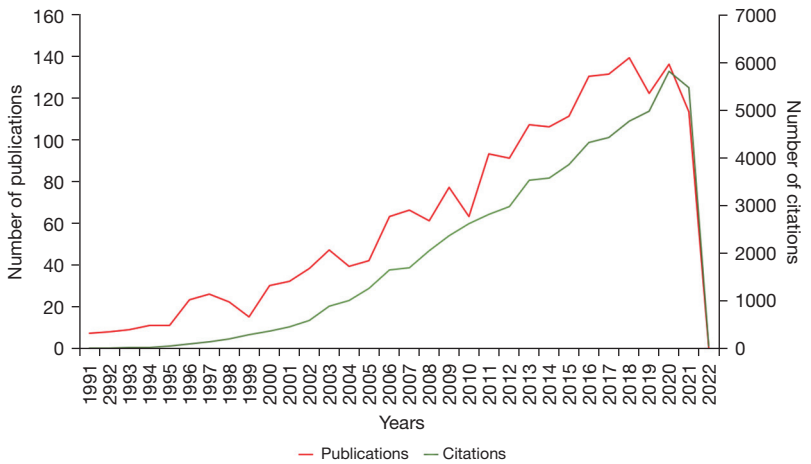

Figure 2 Annual publications and citations of articles.

the citations frequency of researchers, the journals in which the articles were published, and the use of keywords.

Statistical analysis

The data are expressed as numbers and percentages.

Results

General information

A total of 2,107 related research literature records were retrieved in this study, of which 138 were duplicate records. After deleting the duplicate records, the number of articles totaled 1,969. These articles were cited a total of 45,425 times. The average number of citations per article was 23.07, and the h-index was 103. The articles comprised 1,750 original articles (88.88%), 197 review articles (10.01%), 7 conference papers (0.36%), 10 editorial materials (0.51%), 2 conference abstracts (0.10%), 2 letters (0.10%), and 1 expression of concern publication (0.05%) (see *Figure 1*). There was a clear upward trend each year in the number of articles published and the number of citations of these articles (see *Figure 2*).

Countries

The analysis results showed that many countries around the world have conducted relevant research (see *Figure 3*); however, some Central Asian countries and most African countries have not carried out any research on this topic. The countries that conducted the most research included the United States (US), China, Canada, the United Kingdom, Belgium, Germany, France, and Italy. A further analysis showed that countries, including the US, China, Germany, Canada, and Australia, have cooperated extensively with other countries (see *Figure 4*). The country with the most citations for the research results was the US, followed by Belgium, Germany, Canada, and the United Kingdom (see *Figure 5*).

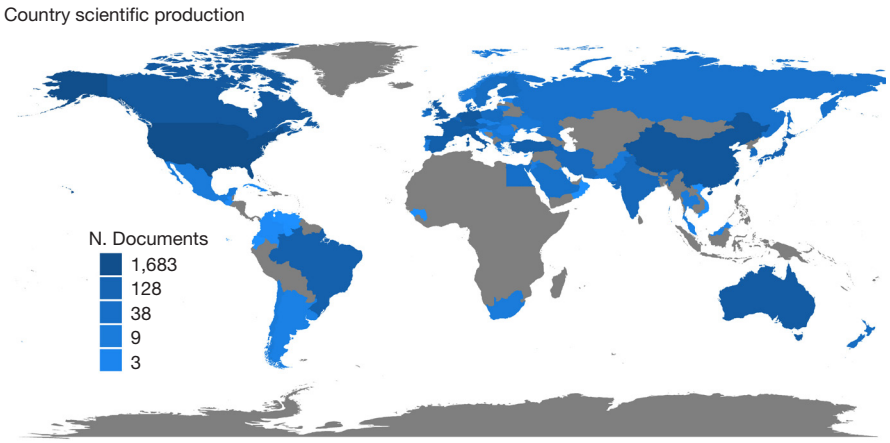

Figure 3 Distribution of the number of articles published by country.

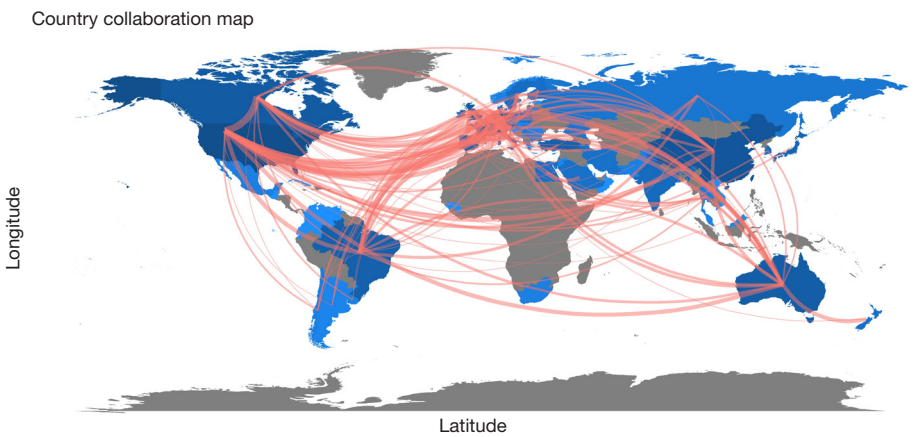

Figure 4 Cooperation between countries.

Institution

The institution that conducted the most research on this topic was the University of Toronto in Canada, followed by the University of Michigan, and Harvard University in the US. Among the top 20 research institutions with the largest number of published articles, most were from the US (see *Figure 6*), and these institutions also collaborated extensively among themselevs, especially the University of Toronto, the University of Michigan, and the University of Pennsylvania, which had the largest number of collaborations (see *Figure 7*).

Authors

The author with the largest number of publications was Landoni from Vita-Salute San Raffaele University, Italy, followed by his colleague Zangrillo, and Schultz from the University of Amsterdam, Netherlands (see *Figure 8*). As the visualization map in *Figure 9* shows, the collaborative relationships between the researchers were clearly clustered, which suggests that these collaborating researchers may belong to the same research institutions, and that they collaborate frequently. In terms of article citations, researchers from Europe and the US are often

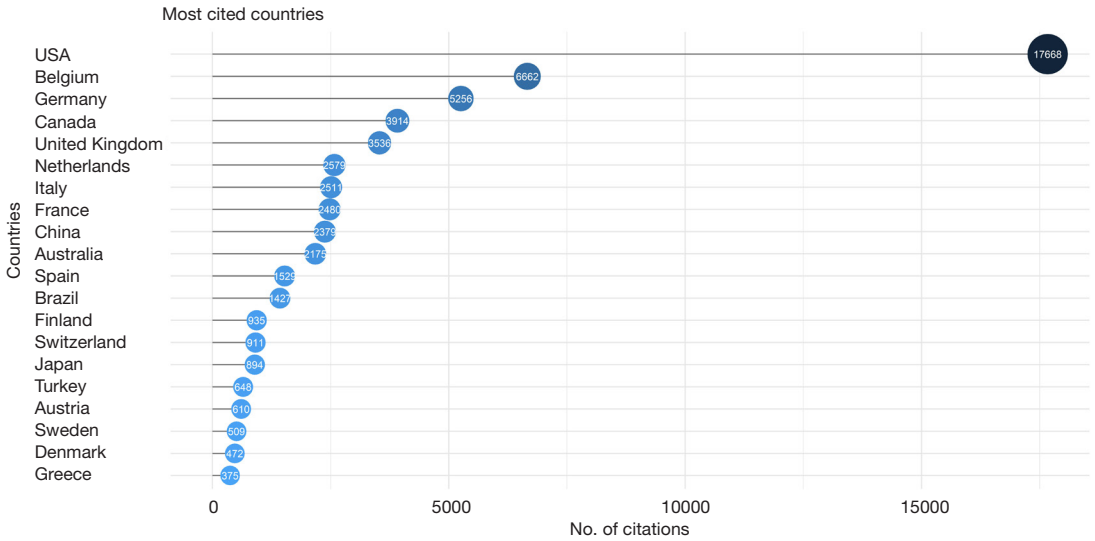

Figure 5 Number of articles published by countries.

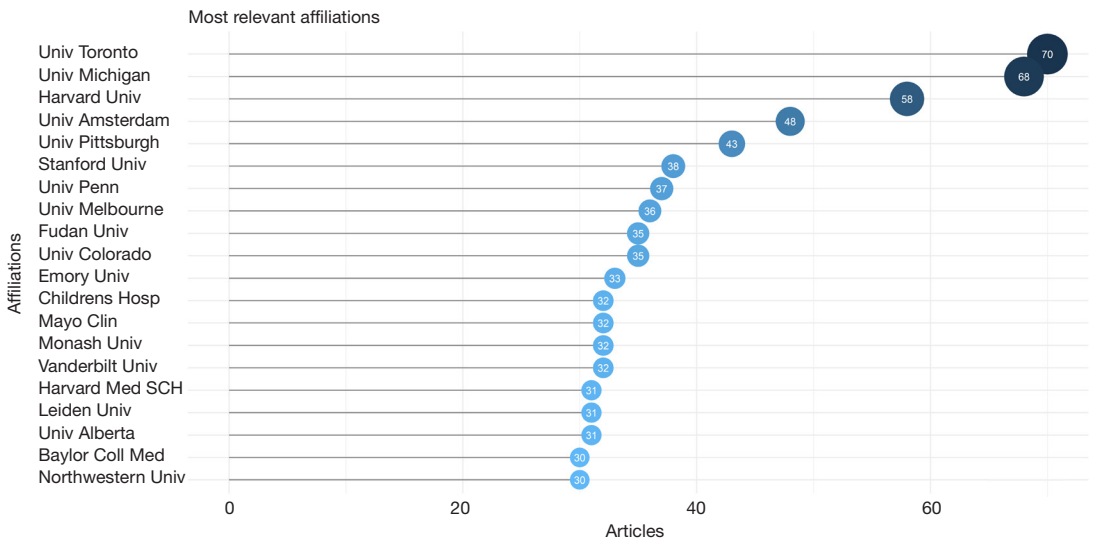

Figure 6 Top 20 institutions by number of publications.

cited. Among them, the most cited researcher, Zappitelli, was from Canada. Hichey and Wypij were from the US, but they were not the most published researchers, which suggests that their research work may be more significant in this field (see *Figures 10*,*11*).

Journals

The statistical results showed that the top 3 journals with the largest number of published articles were the *Journal of Cardiothoracic and Vascular Anesthesia*, *Critical Care Medicine*, and *Annals of Thoracic Surgery* (see *Figure 12*). The top 20 journals were all cardiac surgery, thoracic surgery, or top journals for critical care. According to Bradford's law, the core journals in this field were the *Journal of Cardiothoracic and Vascular Anesthesia*, *Critical Care Medicine*, *Annals of Thoracic Surgery*, *Journal of Thoracic and Cardiovascular Surgery*, *Pediatric Critical Care Medicine*, *European Journal of Cardiothoracic Surgery*, *Intensive Care Medicine*, *Anesthesia and Analgesia*, and *Pediatric Cardiology* (see *Figure 13*).

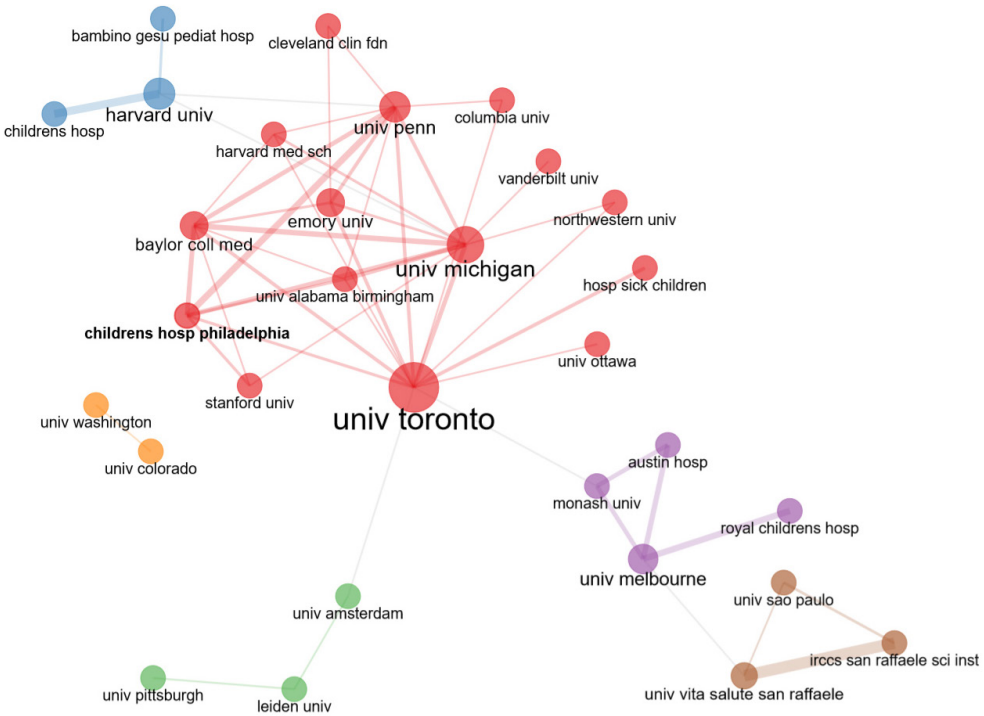

Figure 7 Institutional collaborations.

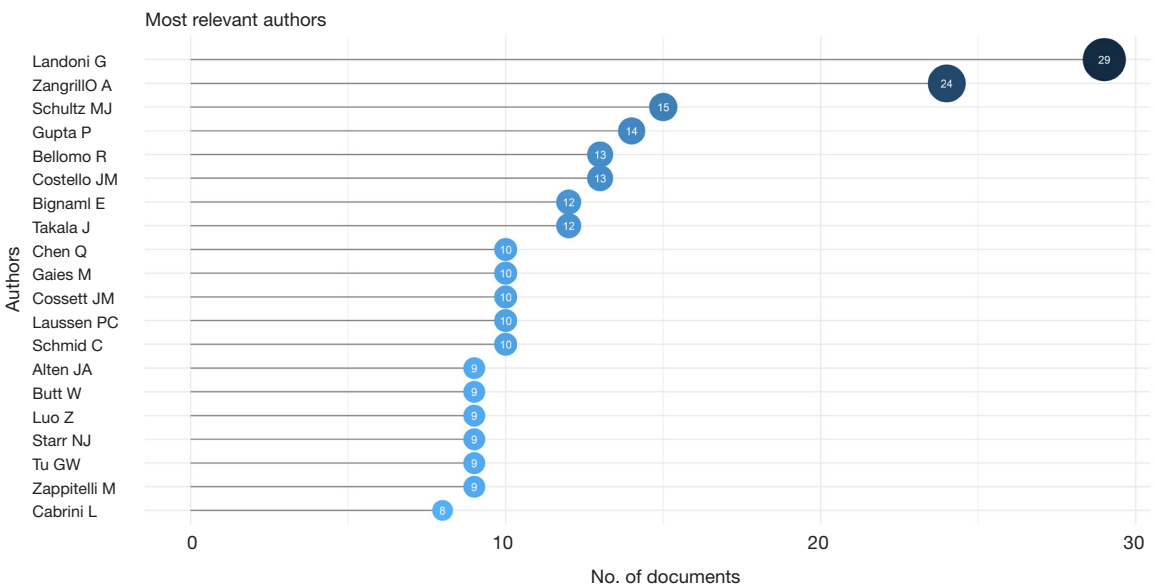

Figure 8 Number of publications by authors (top 20).

Keywords

The statistical results showed that the top 3 most commonly used keywords were cardiac surgery, morality, and cardiopulmonary bypass. The most studied patients in this field were those who had undergone coronary artery bypass grafting, and the main concern of the researchers was the death rate (see *Table 1*). In total, 3 keyword co-occurrence clusters were formed by the 3 keywords with the highest frequency of

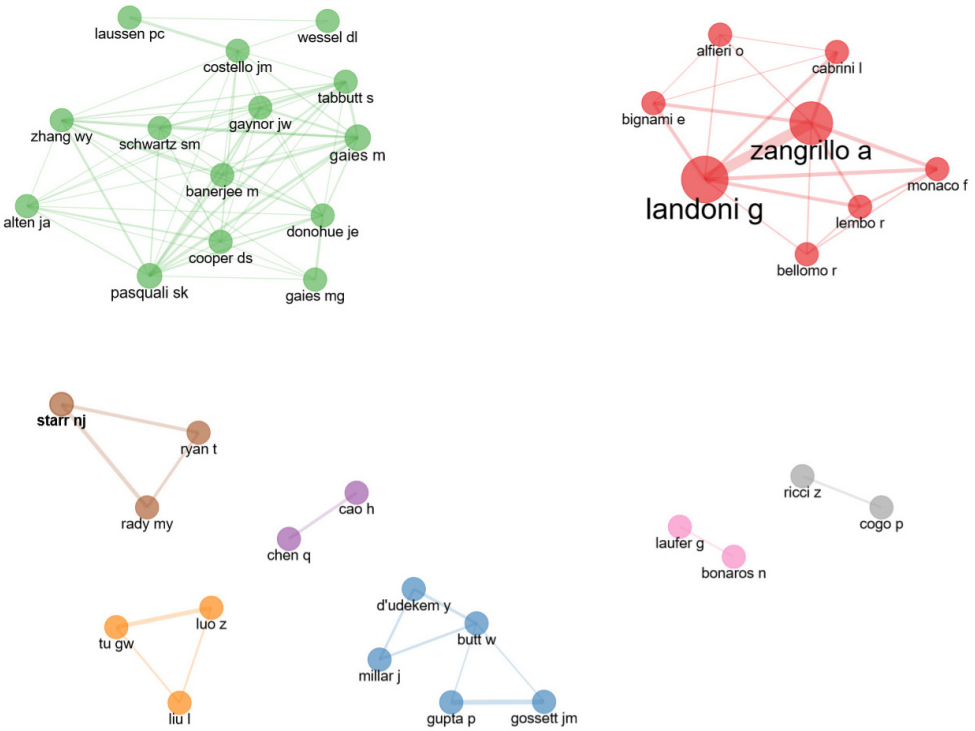

Figure 9 Author collaborations.

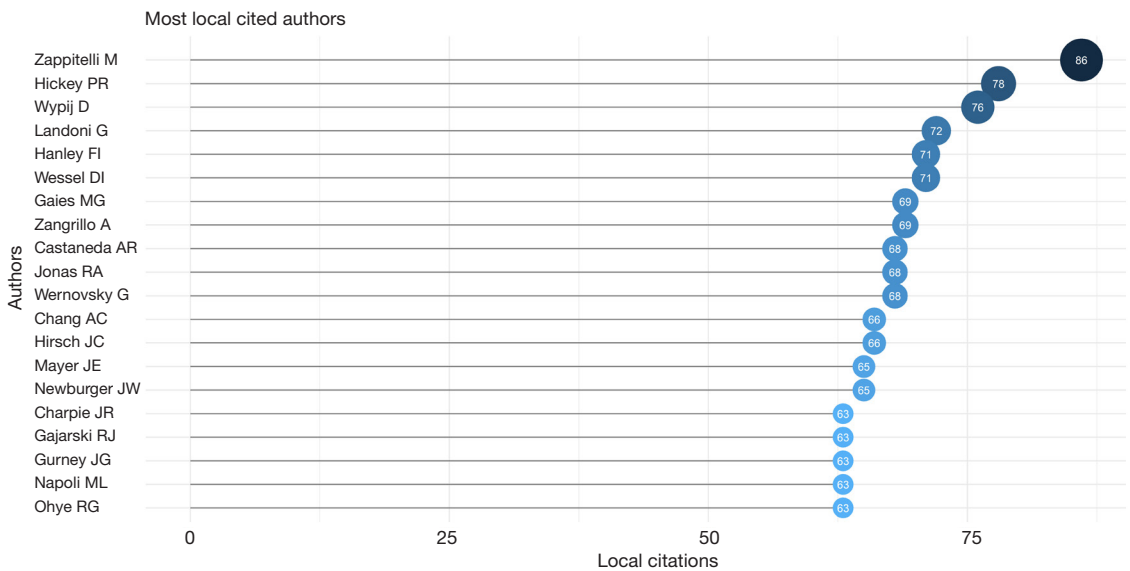

Figure 10 Author citations (Top 20).

use, which reveals the use of keywords in the literature (see *Figure 14* and *Table 2*). The use of keywords showed obvious temporal changes. In the last 10 years, the importance of morality has increased significantly (see *Figure 15*).

Discussion

In this study, a statistical analysis of 1,969 retrieved articles was conducted. The results revealed a significant increasing trend in the number of publications and the number of

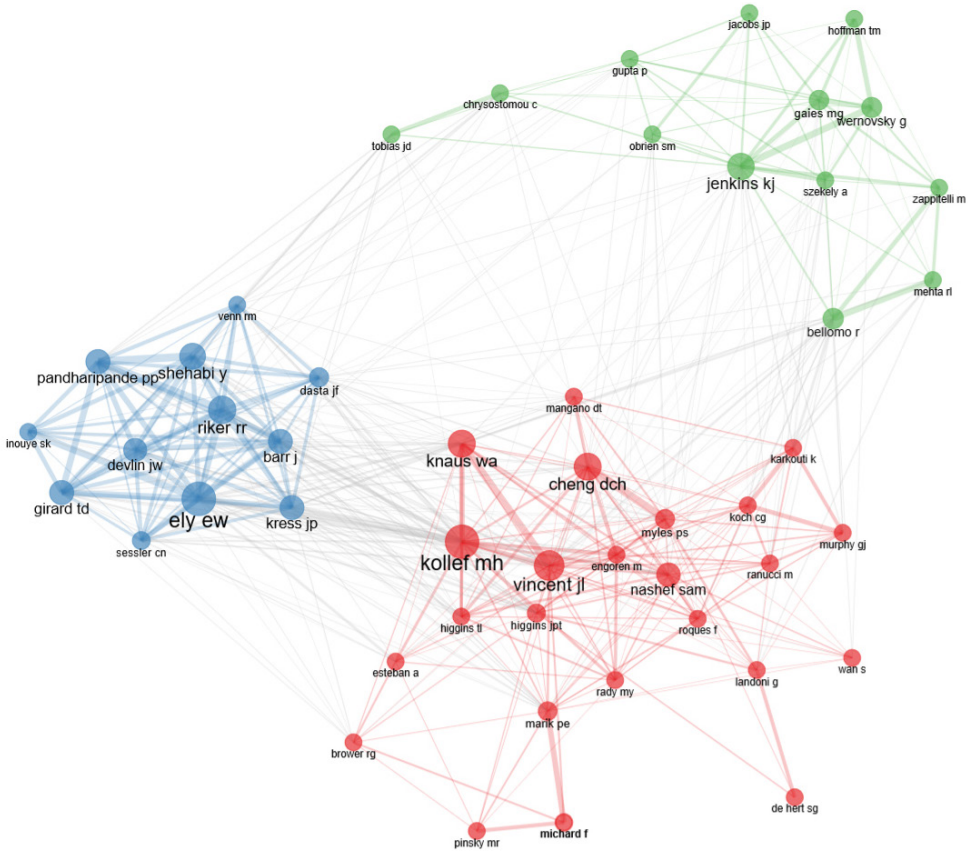

Figure 11 Author co-cited relationships.

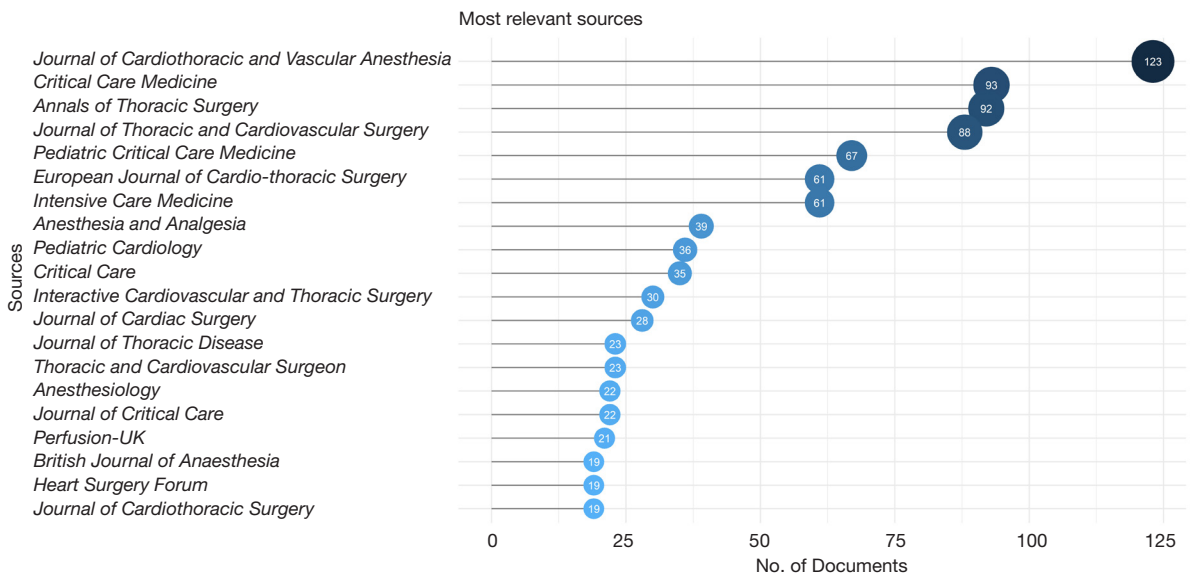

Figure 12 Number of articles published in Journals (top 20).

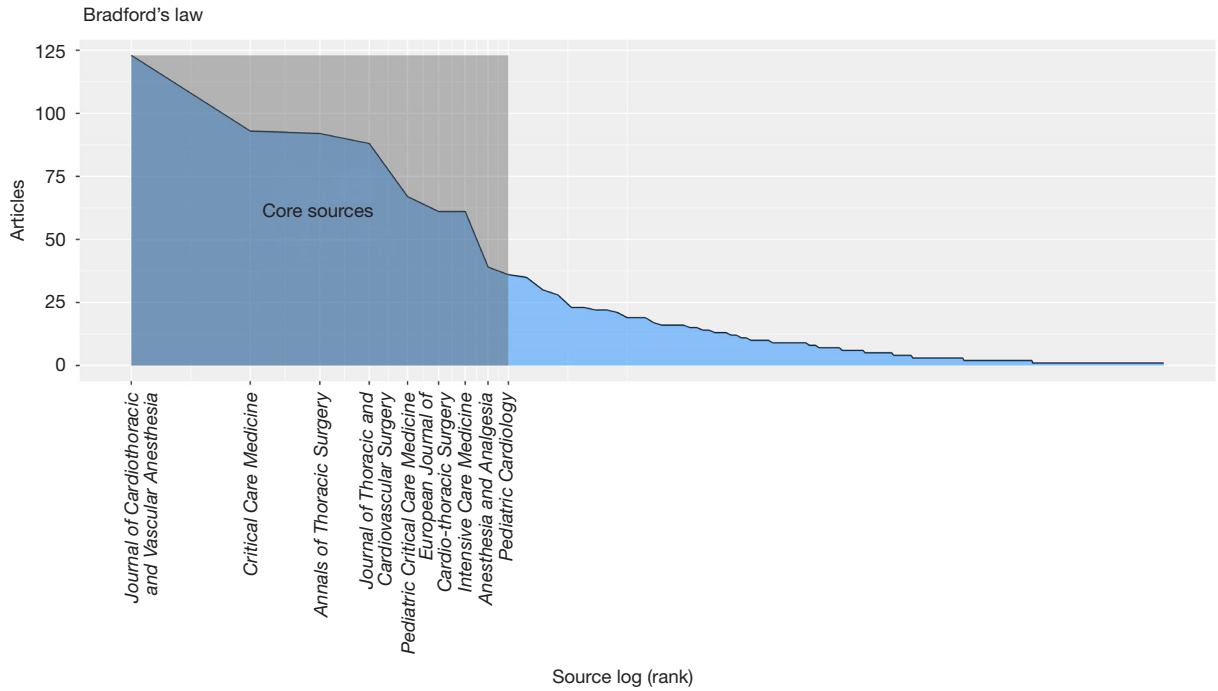

Figure 13 Bradford's law was used to determine the core journals on cardiac surgery and ventilation.

Table 1 The number of times the keywords are used (top 10)

Terms	Frequency
Cardiac surgery	546
Mortality	340
Cardiopulmonary bypass	310
Children	241
Mechanical ventilation	226
Intensive care unit	223
Outcomes	207
Surgery	207
Risk factors	203
Infants	170

citations of articles on the use of mechanical ventilation during ICU hospitalization after cardiac surgery. The countries involved in the research in this field were mainly the US, China, Canada, and several European countries, and these countries cooperated extensively. The research results of the US, Belgium, Germany, and other countries were more valued by researchers than those of other countries, and had been cited extensively in the literature. The countries with the largest number of published articles were mainly the US and Canada, but the 3 researchers with the most published articles were from Italy and the Netherlands, and the 3 most cited researchers were from Canada and the US. We also identified 9 core journals that are important in research in this area according to Bradford's law. The analysis results for keyword usage showed that the frequency of keyword usage has changed over time, and the issue that researchers have paid most attention to in the past decade was morality.

Most critically ill patients undergoing cardiac surgery require monitoring and adjuvant support to ensure they fully recover their cardiac and respiratory functions. The adjunctive support techniques used during surgery often continue to be used for a period after a patient has undergone cardiac surgery. Among them, mechanical ventilation technology is one of the most commonly used assisted support technologies. Non-invasive mechanical ventilation techniques are generally used in patients with relatively mild disease, and patients can often be weaned off this type of ventilation within 12–24 hours of surgery according to the treatment plan.

Preoperative cardiac function decline, myocardial infarction, and atrial fibrillation can lead to prolonged mechanical ventilation (PMV) after cardiac surgery. Other

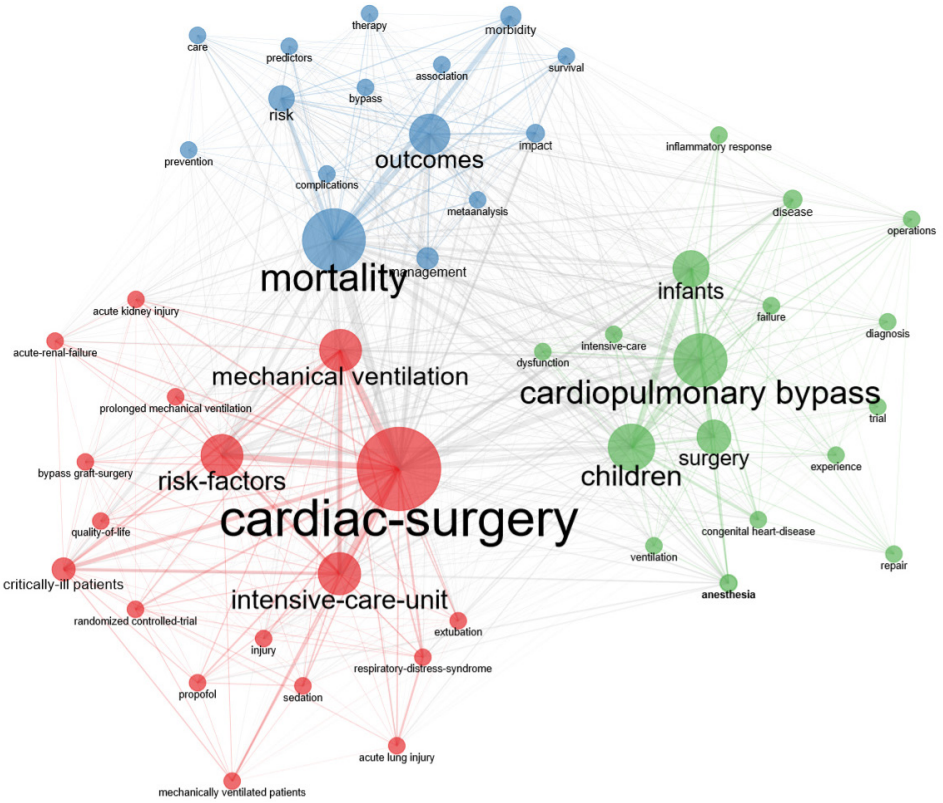

Figure 14 Use of keywords.

risk factors associated with PMV include emergency cardiac surgery, age, smoking, chronic obstructive pulmonary disease, pulmonary hypertension, chronic kidney disease, renal failure, and obesity. Additionally, many intraoperative factors are also related to PMV, including cardiopulmonary bypass time, aortic occlusion time, total operation time, a complicated operation, prolonged hypothermia, and excessive blood dilution, while postoperative factors include bleeding, delirium, acute kidney injury, respiratory, and related pneumonia. In response to these risk factors, researchers have adopted a variety of approaches to try to reduce the risk of PMV.

Tian *et al.* compared the effects of remifentanil and sufentanil/fentanyl on the postoperative mechanical ventilation time of cardiac surgery patients, and found that remifentanil significantly shortened the postoperative mechanical ventilation time and reduced myocardial injury (16). Some researchers have confirmed that the use of sedation, and sucralfate, and the appropriate use of antibiotics reduces the risk of respiratory and related pneumonia after patients are transferred to the ICU after surgery, thereby avoiding PMV (17). Other studies have found that the use of invasive and non-invasive sequential mechanical ventilation effectively reduces the time of mechanical ventilation and reduces the incidence of respiratory complications (18,19).

Most of the relevant studies used death as the primary endpoint, which is consistent with our findings on the change in the frequency of keyword usage (20,21). Suarez-Pierre *et al.* found that PMV after cardiac surgery was associated with a 50% increase in surgery-related mortality (20). Consistent with the study of Fernandez-Zamora *et al.*, their results showed that approximately 10–20% of cardiac surgery patients will develop PMV after surgery, and PMV is associated with increased mortality in the ICU (22). Petrou *et al.* analyzed the predictive value of the EuroSCORE in relation to postoperative mortality and PMV in cardiac surgery patients, and found that the area under the curve of the EuroSCORE for predicting death was 0.791, and that for predicting PMV was 0.711 (23).

As mentioned above, there are many relevant research areas and research directions. We conducted a statistical

Table 2 Keyword co-occurrence clusters

Rank	Node	Cluster	Betweenness	Closeness	PageRank
1	Cardiac surgery	1	166.36920	0.020000	0.088575
2	Mortality	2	54.39548	0.020000	0.065617
3	Cardiopulmonary bypass	3	43.69823	0.018868	0.050868
4	Children	3	28.70456	0.019231	0.046237
5	Intensive care unit	1	25.59164	0.018868	0.041325
6	Risk factors	1	23.69060	0.018519	0.042518
7	Mechanical ventilation	1	19.23191	0.017241	0.039635
8	Outcomes	2	17.52863	0.018868	0.039350
9	Surgery	3	16.38490	0.018182	0.028983
10	Infants	3	12.50087	0.017241	0.036247
11	Risk	2	6.44807	0.017241	0.024415
12	Critically ill patients	1	6.20841	0.016129	0.023012
13	Management	2	5.93259	0.018182	0.020427
14	Meta-analysis	2	3.05531	0.016129	0.016386
15	Dysfunction	3	2.94636	0.016129	0.016056
16	Impact	2	2.54880	0.016393	0.018111
17	Morbidity	2	2.33974	0.015152	0.021034
18	Respiratory distress syndrome	1	2.25714	0.014085	0.015091
19	Failure	3	1.73863	0.015152	0.017096
20	Survival	2	1.69216	0.015873	0.015839

analysis of the relevant literature to provide a rough overview of the current research situation in this field. Based on the results of this study, researchers now have a general understanding of which countries have more advanced research results, which research institutions and researchers have more research results, and which are the related core journals. Our findings have important reference value for literature searches, and should also facilitate academic exchanges. Based on the use of keywords, the current research focus can be grasped, and our findings also indicate which areas have not received enough attention. And our results also suggested that we should pay more attention to this topic in some developing countries to help people there to have better cardiac surgery service.

This study had some limitations. In the search for this study, "cardiac surgery" was used as the search term, and any articles that did not use this term as the topic term may have been missed, which may have affected the statistical results. Thus, we recommend that researchers and journal editors standardize the topic headings of the literature as much as possible. Second, this study did not include documents published in languages other than English that were not in the SCI-E database, including documents from several countries that conduct a great deal of medical research (e.g., Chinese-language documents, German-language documents, and French-language documents), and it is likely that some high-level studies have been conducted and related articles have been published in journals in these countries. In future bibliometric analyses, we intend to search multiple databases, and then merge the search results to ensure that the analysis results are more representative of the current research situation.

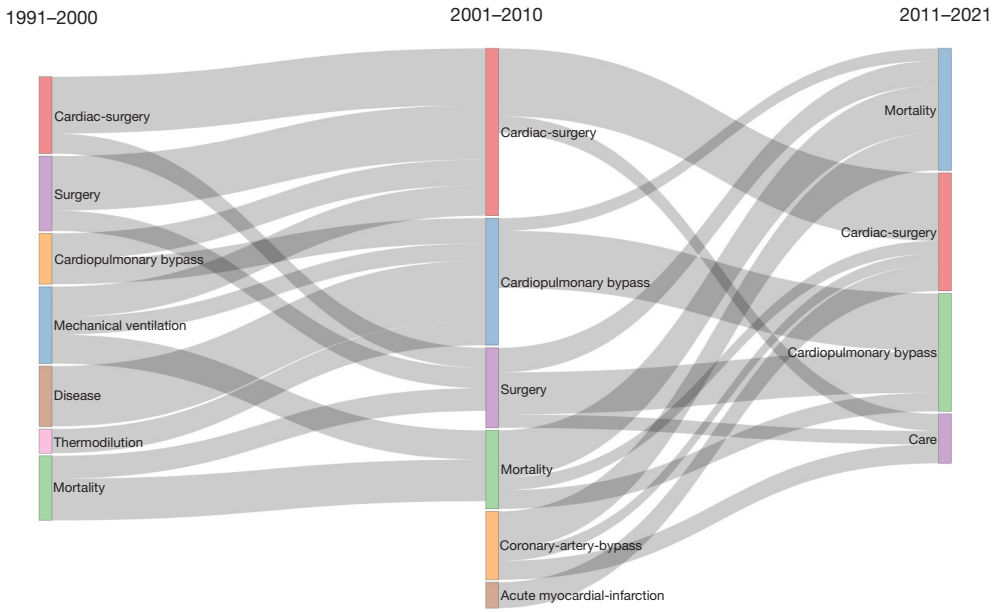

Figure 15 Temporal changes in keyword usage.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-233/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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