VER
Vascular & Endovascular Review

Systematic Review of The Effect Of Preoperative Cardiac Biomarkers on The Duration of Ventilator Use in Post-Operative Cabg Patients

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ABSTRACT

Prolonged ventilator duration after coronary artery bypass grafting (CABG) surgery is a critical issue in intensive care units (ICUs) as it can increase the risk of complications, length of hospital stay, and mortality. Several studies have shown that preoperative cardiac biomarkers, such as NT-proBNP, troponin I/T, and C-reactive protein (CRP), have the potential to be important predictors of ventilator duration, but the results are mixed and have not been systematically integrated. This study aims to comprehensively evaluate the existing evidence regarding the effect of preoperative cardiac biomarkers on ventilator duration in post-CABG patients. This study used a Systematic Literature Review method with a search of articles in PubMed, Scopus, and Web of Science databases, and followed the PRISMA guidelines for study selection. The results showed that high preoperative levels of NT-proBNP, troponin I/T, and CRP were consistently associated with longer ventilator requirements. Furthermore, the integration of biomarkers with traditional clinical factors resulted in a more accurate prediction of ventilation duration compared with clinical factors alone. These findings underscore the importance of preoperative cardiac biomarkers as predictive tools to assist in more optimal planning of post-CABG patient management.

KEYWORDS: Preoperative Cardiac Biomarkers, Ventilator Use, Cabg, Nt-Probnp, Troponin, Systematic Review..

How to Cite: Fadhilah Rahmah Pratiwi, Yan Efrata Sembiring, Philia Setiawan, (2025) Systematic Review of The Effect Of Preoperative Cardiac Biomarkers on The Duration of Ventilator Use in Post-Operative Cabg Patients, Vascular and Endovascular Review, Vol.8, No.3s, 127-138.

INTRODUCTION

Coronary heart disease is a leading cause of morbidity and mortality worldwide. Advances in medical technology have made surgical procedures such as coronary artery bypass grafting (CABG) an effective treatment for coronary artery narrowing (Lechowicz, 2021). This procedure not only saves patients' lives but also significantly improves their quality of life. However, CABG remains a major procedure with a high risk of postoperative complications (Nellipudi, 2021). One complication that frequently occurs and impacts the length of stay in the intensive care unit is the need for postoperative mechanical ventilation for a longer period than expected. Prolonged ventilation duration not only impairs patient recovery but also increases the risk of nosocomial infections, healthcare costs, and even mortality (Jiang, 2020). Therefore, identifying predictors capable of estimating ventilator duration from the preoperative phase is crucial for improving the management of CABG patients.

Among the various predictive factors that have been extensively studied, preoperative cardiac biomarkers such as troponin, NT-proBNP, and others have received considerable attention. Cardiac biomarkers not only serve as indicators of myocardial injury or ventricular dysfunction, but have also been shown to be significantly associated with various postoperative outcomes, including mortality, major cardiovascular events, and length of hospital stay (Kaushik, 2020). However, the relationship between preoperative cardiac biomarker levels and post-CABG ventilator duration remains unclear. Some studies have shown a significant association, while others have reported conflicting results (Koechlin, 2020). Therefore, conducting a systematic review to summarize, evaluate, and synthesize the existing evidence is crucial to obtain a clearer, evidence-based picture of this issue.

The phenomenon of prolonged use of ventilators after CABG not only impacts the patient's clinical outcome but also the efficiency of hospital services (Hajhossein-Talasaz, 2022). Patients who must remain on ventilators for long periods often experience complications such as pneumonia, lung tissue damage, and prolonged hospitalization, which impact the economic burden on families and the health system (Hinoue, 2023). In clinical practice, there are still many patients whose clinical condition appears stable preoperatively but who actually require a ventilator for longer than expected (Nurcahyo, 2022). This indicates that the risk factors currently used to predict ventilator length may not be sensitive or specific enough, resulting in many inaccurate predictions (Brown, 2021). Therefore, the search for better predictive factors, particularly those that can be assessed preoperatively, such as cardiac biomarkers, is highly relevant in efforts to improve the quality of care.

This phenomenon is increasingly challenging considering the variation in clinical practices across health centers, differences in population characteristics, and the heterogeneity in determining the biomarker cut-off points used as predictors (Lamy, 2024). Furthermore, not all hospitals have access to sophisticated diagnostic technology or laboratory facilities to assess biomarkers in a short time. This situation presents a dilemma for physicians in deciding the optimal strategy for their patients. If there were strong evidence that preoperative cardiac biomarkers could indeed predict ventilator duration, then preoperative interventions or

postoperative care strategies could be better designed to address this risk (Rodriguez-Quintero, 2024). This phenomenon underlies the importance of conducting a systematic review of the existing literature to obtain clearer answers.

Global data shows that more than 50% of patients undergoing CABG require mechanical ventilation for more than 24 hours, with approximately 10–20% of patients experiencing prolonged ventilation for more than 48–72 hours (Saller, 2020). Studies conducted in Europe and the United States reported that ventilator stay of >48 hours was associated with a 3–4-fold increased risk of mortality (Zajonz, 2023). In Indonesia, data on this matter is relatively limited, but reports from several national heart centers indicate that the average duration of post-CABG ventilation is in the range of 20–36 hours with wide variations depending on the patient's condition and the complexity of the operation (Farouk, 2022). Meanwhile, reports also indicate that high preoperative NT-proBNP levels correlate with increased ventilator duration, but these results are not consistent across populations.

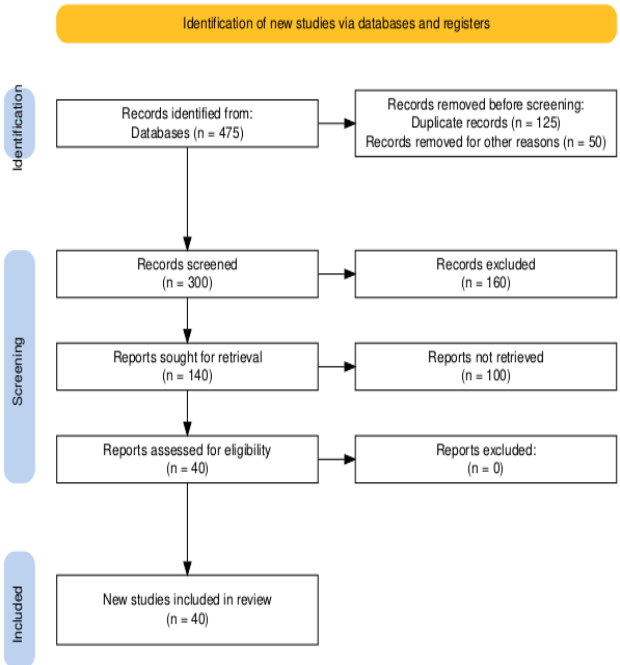
Studies (Casper, 2025) evaluating preoperative troponin as a predictor have also yielded mixed results. Most studies do suggest a significant association, but the reported strength of the association varies significantly. Furthermore, meta-analyses on this topic are still rare, so no solid conclusions can be drawn that can be used for clinical guidance (Uzair, 2024). The current data demonstrates the need to combine these research findings through a systematic review to obtain more reliable and trustworthy results. Therefore, this study seeks to address this need by systematically summarizing the available evidence.

Cardiac biomarkers such as troponin, NT-proBNP, CK-MB, and other inflammatory biomarkers have long been used to assess the cardiac status of preoperative patients (Ștef, 2024). Troponin, for example, is known as a highly sensitive marker of myocardial damage, while NT-proBNP is closely related to left ventricular pressure and strain. Both biomarkers can indicate cardiac dysfunction that may not be clinically detectable but can affect a patient's tolerance for major surgical procedures such as coronary artery bypass grafting (CABG) (Dardashti, 2021). In the context of predicting ventilator longevity, the underlying theory is that patients with pre-existing heart injury or dysfunction (as reflected by elevated biomarkers) are more susceptible to postoperative respiratory failure and thus require longer ventilatory stay.

This study aims to conduct a systematic review of the existing literature to evaluate and summarize evidence on the influence of preoperative cardiac biomarkers on the duration of ventilator use in patients undergoing CABG surgery. Through this comprehensive review, this study is expected to provide a clearer picture of the role of cardiac biomarkers as predictors, assist clinicians in making better preoperative decisions, and serve as a basis for developing more effective and efficient patient management strategies to reduce morbidity and mortality associated with prolonged mechanical ventilation.

METHODS

This Systematic Literature Review (SLR) was conducted to systematically identify, evaluate, and synthesize scientific evidence regarding the influence of preoperative cardiac biomarkers on the duration of ventilator use in post-coronary artery bypass grafting (CABG) patients, in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Figure 1). The review protocol was developed based on the framework proposed by Creswell (2017), and the process involved structured stages from identification to critical synthesis of findings. The article selection process follows the PRISMA guidelines, starting from article identification, screening based on title and abstract, full text eligibility assessment, to selection of articles that meet the inclusion and exclusion criteria (J. W. Creswell & Creswell, 2023)



Source: PRISMA Database (2025)

Figure 1. Procedures for Selecting and Selecting Articles Used in Research

2.1 Eligibility criteria

Studies were included if they met the following criteria: investigated adult patients undergoing CABG surgery; reported preoperative cardiac biomarkers (e.g., troponin, CK-MB, BNP); evaluated their association with ventilator duration or mechanical ventilation outcomes; published in peer-reviewed journals, and; written in English. Animal or laboratory studies; case reports or case series with fewer than 5 subjects; editorials, opinion pieces, letters to the editor; non-systematic reviews, and; articles lacking complete data on relevant variables were excluded.

2.2. Search Strategy and Selection of Studies

A structured literature search was conducted across **PubMed**, **Scopus**, and **Web of Science** to identify studies published up to **August 2025**. The search employed combinations of relevant keywords such as: **"preoperative cardiac biomarkers," "ventilator duration," "mechanical ventilation," and "CABG"**, arranged using Boolean operators to optimize the search results (Mubarok, Sari, Wibowo, 2025; Sugiyono 2019; Creswell, 2016)

Title and abstract screening was conducted independently by authors according to the predefined eligibility criteria. Full texts of potentially relevant articles were retrieved and reviewed in detail. The study selection process followed the PRISMA flow diagram and reasons for exclusion were documented accordingly (Figure 1).

2.3. Data Extraction

Two reviewers independently extracted key information from each included study using a standardized form. The data collected included: author, year, country, study design, sample size, patient characteristics, preoperative cardiac biomarkers, ventilator duration, and main outcomes. Any disagreements were resolved through discussion or by consulting a third reviewer.

2.4. Quality Assessment

Two reviewers independently assessed the quality of the included studies using tools appropriate for each study type: RoB 2 for randomized trials, ROBINS-I for non-randomized studies, and the Newcastle-Ottawa Scale (NOS) for observational studies Any differences were resolved by discussion, and the results were summarized with the study findings.

2.5. Bibliometric and Network Visualization

In addition to qualitative synthesis, a bibliometric analysis was conducted using VOSviewer (version 1.6.X) to visualize trends and thematic structures within the selected literature. Metadata from included articles were exported from Scopus and Web of Science in .RIS or .CSV format. Keyword co-occurrence, author collaboration, and citation mapping were analyzed using default parameters. Thresholds for minimum keyword or author occurrences were adjusted to optimize visualization. The resulting maps were interpreted to highlight dominant research themes and potential knowledge gaps in the field.

The research procedure used in this study began with a systematic literature search in electronic databases such as PubMed, Scopus, and Web of Science to obtain relevant articles regarding the influence of preoperative cardiac biomarkers on the duration of ventilator use in post-coronary artery bypass grafting (CABG) patients (Mubarok, Sari, Wibowo, 2025). The keywords used in the search included combinations of terms such as "preoperative cardiac biomarkers," "ventilator duration," "mechanical ventilation," and "CABG," arranged using Boolean operators to optimize search results. Articles found were then screened based on inclusion criteria: studies that discussed adult patients undergoing CABG, reported preoperative cardiac biomarkers, and evaluated their association with ventilator duration, and were published in English in peer-reviewed journals (Sugiyono, 2019). Meanwhile, exclusion criteria included animal studies, case reports, editorials, letters to the editor, non-systematic reviews, and articles that did not provide complete data on the variables studied. All articles meeting the criteria were then evaluated for quality and analyzed descriptively for presentation in the research results.

RESULTS AND DISCUSSION

3.1 Study Selection

Based on Figure 1. Procedure for Selection and Selection of Articles Used in Research (Source: PRISMA Database, 2025), the identification process began by finding 475 articles from the database, then 125 articles were removed due to duplication and 50 articles were removed for other reasons, leaving 300 articles to be screened. Of the 300 screened articles, 160 articles were excluded due to irrelevance, so 140 reports were searched for access (Page, 2021). A total of 100 reports were not retrieved, and 40 were deemed eligible. No reports were excluded during the eligibility assessment stage, resulting in all 40 studies ultimately being included in the review. This diagram shows the systematic and transparent selection process, in accordance with PRISMA guidelines, to ensure the quality and relevance of the analyzed literature.

This systematic review identified several studies highlighting the association between preoperative cardiac biomarkers and duration of ventilator use in post-coronary artery bypass grafting (CABG) patients. One consistent finding was from a study (Omran, 2022) who reported that high preoperative NT-proBNP levels were significantly associated with longer ventilator requirements, suggesting that preoperative elevated ventricular pressure may impair respiratory recovery. (Wolfien, 2020) also support these findings, showing that preoperative NT-proBNP is a strong predictor of postoperative respiratory failure and prolongs the duration of mechanical ventilation. (Trubnikova, 2021) found that high preoperative troponin I levels may also predict the risk of weaning failure from the ventilator, which is thought to be due to subclinical myocardial damage that is not detected clinically.

Study (Heuts, 2022) strengthen the evidence for the role of troponin as a predictor of postoperative outcome by showing that high preoperative troponin T levels are associated with longer ventilator duration, even after adjustment for other clinical factors.

(Chen, 2024) reported similar results, where elevated preoperative troponin I was significantly associated with prolonged intubation time in post-CABG patients. (Lechowicz, 2021) added another dimension by showing that in addition to troponin, inflammatory biomarkers such as preoperative C-reactive protein (CRP) also have an association with prolonged ventilator duration, as systemic inflammation affects lung function and worsens oxygenation.

In the study (Nellipudi, 2021), evaluation of risk prediction models that include traditional clinical variables is not accurate enough to predict ventilator duration if not accompanied by cardiac biomarkers, thus supporting the idea that biomarker integration can improve prediction accuracy. (Kaushik, 2020) also noted that conventional clinically based prediction models often fail to identify high-risk patients who actually have abnormal biomarker levels preoperatively. (Denessen, 2022) confirmed that patients with high preoperative cardiac biomarker levels required longer ventilators, indicating that preoperative myocardial status is critical to the success of weaning from the ventilator.

(Koechlin, 2020) The Fourth Universal Definition of Myocardial Infarction emphasizes the important role of troponin as an indicator of myocardial damage that is often overlooked when patients are about to undergo surgery, even though it can predict many postoperative outcomes including the need for a ventilator. (Jiang, 2020) also supports the importance of conducting systematic reviews to critically evaluate the available evidence, as the heterogeneity of results across studies makes it difficult for clinicians to draw definitive conclusions. (Hinoue, 2023) reminded that in addition to the absolute values of biomarkers, the trends and dynamics of preoperative biomarkers should also be considered as factors that may influence the duration of ventilator support, especially in patients with complex coronary heart disease.

(Holm, 2022) In his initial reports on CABG he had already observed that patients with poor preoperative ventricular function tended to have a slower postoperative recovery. (Nurcahyo, 2022) Global heart disease statistics also note that patients with advanced heart disease and ventricular dysfunction often require longer ventilator support, implying a role for biomarkers as a reflection of the degree of dysfunction. (Brown, 2021) in their review emphasized that patients with elevated preoperative biomarkers are at high risk for prolonged ventilation due to both cardiac comorbidities and underlying pulmonary vulnerability. (Hajhossein-Talasaz, 2022) also highlighted that NT-proBNP had better sensitivity than ejection fraction in predicting the need for prolonged ventilator support, suggesting that the biomarker provides additional information beyond echocardiographic parameters. (Lamy, 2024) noted that NT-proBNP reflects not only ventricular load but also the heart's ability to maintain optimal pulmonary perfusion after surgery, which is important for successful ventilator weaning. (Rodriguez-Quintero, 2024) found that patients with a combination of high troponin and NT-proBNP levels preoperatively had the highest risk of short-term ventilator withdrawal, illustrating the importance of the combination of these two biomarkers in prediction.

(Saller, 2020) reported that although biomarkers do not directly determine ventilation strategy, patients with abnormal values tend to experience longer periods of respiratory failure. (Zajonz, 2023) also added that the role of inflammatory biomarkers such as CRP provides information about the degree of systemic inflammation that can exacerbate lung injury due to bypass. (Farouk, 2022) showed that patients with a combination of clinical risk, elevated biomarkers, and other comorbidities had up to a twofold increased risk of prolonged ventilation, indicating the cumulative predictive value of biomarkers and clinical.

Table 1.Grouping of Previous Studies Based on Finding Categories

Category	Study	Findings
NT-proBNP as a predictor of ventilator duration	Omran (2022); Wolfien (2020); Hajhossein-Talasaz (2022); Lamy (2024); Rodriguez-Quintero (2024)	High preoperative NT-proBNP is associated with longer ventilator requirements, indicating increased ventricular pressures that affect respiratory recovery and successful ventilator weaning.
Troponin as a predictor of ventilator duration	Trubnikova (2021); Heuts (2022); Chen (2024); Koechlin (2020); Rodriguez-Quintero (2024)	High preoperative troponin I/T is associated with the risk of ventilator weaning failure due to clinically undetectable subclinical myocardial damage, and is associated with prolonged intubation time.
CRP and inflammatory biomarkers	Lechowicz (2021); Zajonz (2023); Saller (2020)	High preoperative CRP indicates systemic inflammation that worsens lung function, increasing the risk of respiratory failure and longer ventilator duration.
Combination of biomarkers and clinical risk	Nellipudi (2021); Kaushik (2020); Denessen (2022); Farouk (2022)	The integration of preoperative cardiac biomarkers and clinical risk factors more accurately predicts ventilator duration than clinical factors alone. Patients with this combination of risk factors are more susceptible to prolonged ventilation.
Low ventricular function & degree of dysfunction	Holm (2022); Nurcahyo (2022); Brown (2021)	Patients with poor ventricular function or elevated preoperative biomarkers tend to require longer ventilatory time due to the degree of cardiac dysfunction and lung vulnerability.
Limitations of traditional clinical model prediction	Nellipudi (2021); Kaushik (2020); Wolfien (2020)	Traditional clinical-based prediction models are less accurate without considering cardiac biomarkers, making it difficult to identify patients at true high risk.

Based on Table 1, it can be seen that most previous studies agree on the important role of preoperative cardiac biomarkers in

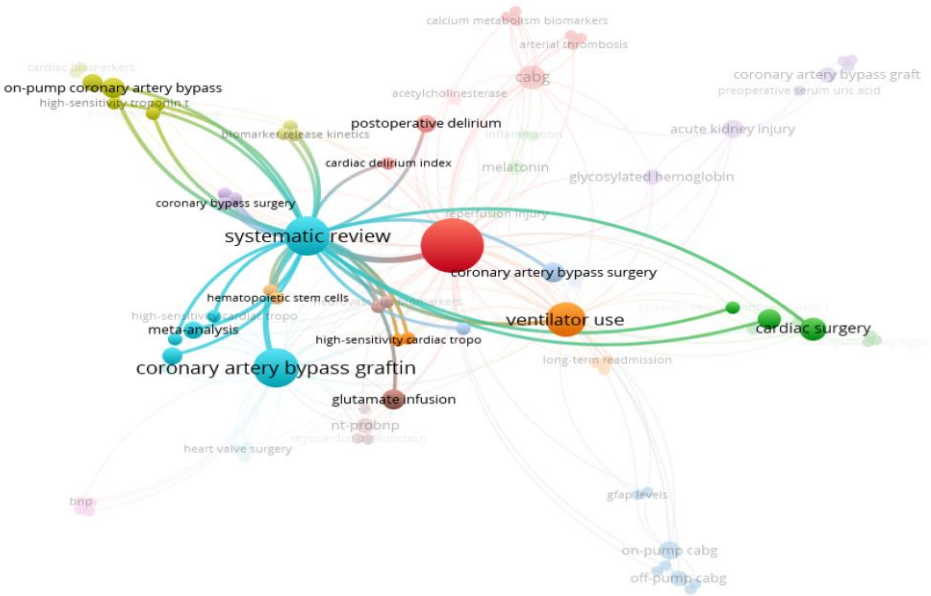
predicting the duration of ventilator use in post-CABG patients. The first category shows that high preoperative NT-proBNP levels were consistently found by Omran (2022), Wolfien (2020), Hajhossein-Talasaz (2022), Lamy (2024), and Rodriguez-Quintero (2024) as a predictor of longer ventilator requirements. This indicates that NT-proBNP reflects increased ventricular pressure, which worsens postoperative respiratory function. Furthermore, the second category shows that troponin I/T also plays a significant role in predicting ventilator duration. Studies by Trubnikova (2021), Heuts (2022), Chen (2024), Koechlin (2020), and Rodriguez-Quintero (2024) showed that high preoperative troponin levels are associated with subclinical myocardial damage that impacts the success of weaning from the ventilator.

Inflammatory biomarkers such as CRP have also been shown to influence ventilator duration, as reported by Lechowicz (2021), Zajonz (2023), and Saller (2020), indicating systemic inflammation that worsens lung function. In addition to individual biomarker findings, other categories demonstrate the importance of integrating biomarkers with clinical risk factors. Nellipudi (2021), Kaushik (2020), Denessen (2022), and Farouk (2022) demonstrated that combining biomarkers with clinical factors yielded more accurate predictions than clinical factors alone. The categories of low ventricular function and degree of dysfunction reported by Holm (2022), Nurcahyo (2022), and Brown (2021) highlight that patients with pre-existing ventricular dysfunction require longer ventilatory time. Finally, studies by Nellipudi (2021), Kaushik (2020), and Wolfien (2020) also highlight the limitations of traditional clinical models that do not consider biomarkers and therefore tend to be less accurate in identifying high-risk patients. These findings collectively suggest that utilizing biomarkers as part of a predictive strategy has the potential to improve post-CABG patient management.

The results examined in this systematic review consistently demonstrate that preoperative cardiac biomarkers have predictive value for post-CABG ventilator duration. However, differences in measurement methods, biomarker cutoff points, and population characteristics across studies contribute to the variability in these results. Further research with a consistent methodology and larger populations is needed to strengthen the existing findings. The results of this review are expected to provide an evidence base for clinicians considering the use of preoperative cardiac biomarkers as a predictive tool in planning the management of CABG patients.

Keyword Analysis Through VOSviewer

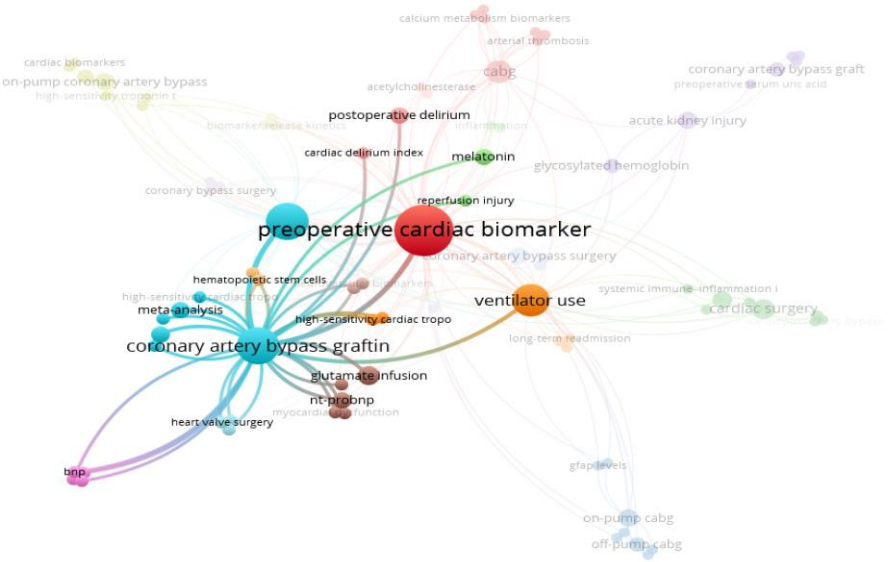
Keyword analysis using VOSviewer is a bibliometric approach used to visually and systematically map research topics, trends, and interrelationships between concepts within a specific scientific field. This approach helps researchers understand how relevant topics develop, interconnect, and form thematic clusters based on the frequency and strength of their associations within the analyzed literature. By utilizing algorithms and the resulting network visualizations, VOSviewer enables the identification of dominant themes, potential collaborations between researchers or institutions, and open research gaps. This type of analysis is also useful for providing an overview of a topic's position within the global knowledge landscape, thus providing a solid foundation for formulating future research directions.



Source :VOSviewer (2025)
Figure 2.VOSviewer Analysis Track 1

Based on Figure 2. VOSviewer Analysis Path 1 (Source: VOSviewer, 2025), the visualization results show a strong correlation between key keywords such as systematic review, coronary artery bypass grafting, ventilator use, and cardiac surgery. This network illustrates that research on the duration of ventilator use in post-CABG patients is closely related to systematic studies and meta-analyses, indicating that this topic has become a focus of evidence-based research. The presence of large nodes in systematic review and coronary artery bypass grafting indicates that these two themes dominate the analyzed literature, while ventilator use also emerged as an important hub, reflecting the significant attention paid to predicting ventilator needs in CABG patients in clinical practice.

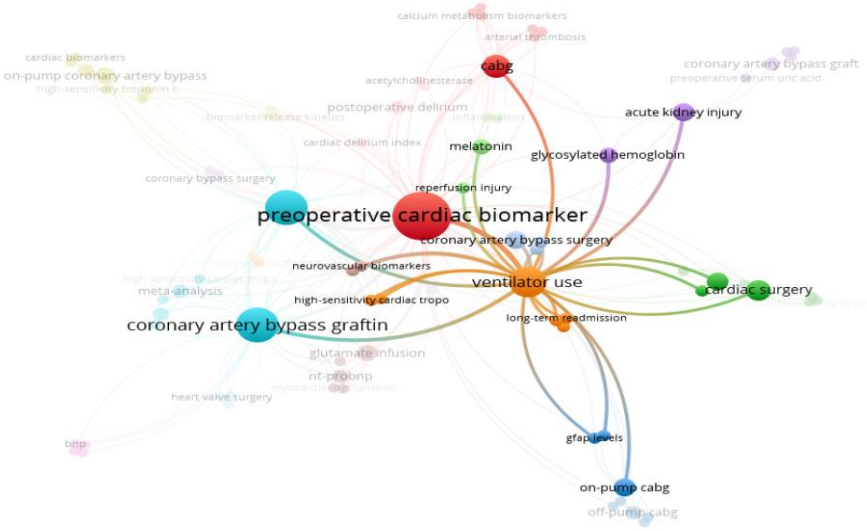
This situation is relevant to the challenges in the field, where identifying predictors of ventilator duration is crucial for more efficient ICU management and reducing complications. The visualization also demonstrates the correlation between biomarkers such as NT-proBNP, troponin, and inflammatory factors with the major themes discussed, reflecting the fact that these variables have been frequently analyzed in relation to ventilator outcomes. The close correlation between keywords confirms that research on post-CABG ventilator prediction based on cardiac biomarkers represents a clear need arising from an unresolved clinical problem, necessitating systematic reviews and meta-analyses to strengthen the evidence base and guide data-driven practice.



Source :VOSviewer (2025)
Figure 3.VOSviewer Analysis Track 2

Based on Figure 3. VOSviewer Analysis Path 2 (Source: VOSviewer, 2025), it can be seen that the keyword preoperative cardiac biomarker occupies a central position with a close relationship to other major themes such as coronary artery bypass grafting, ventilator use, and meta-analysis. This indicates that the topic of preoperative cardiac biomarkers is a dominant focus in the analyzed literature and plays a crucial role in connecting various research topics related to predicting postoperative patient outcomes. This visualization also shows the relationship with other specific topics such as NT-proBNP, high-sensitivity cardiac troponin, and reperfusion injury, illustrating that these biomarkers are widely analyzed in the context of patients undergoing CABG and their relationship to the duration of ventilator use.

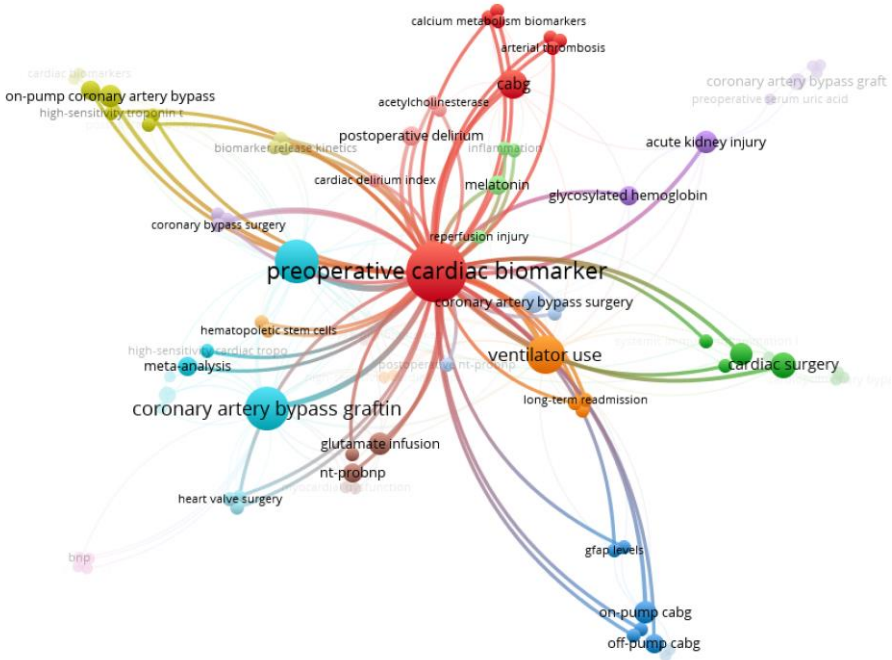
This situation reflects the real need in clinical practice to utilize preoperative biomarkers as effective predictive tools, particularly in patients at high risk of prolonged ventilation. The substantial association between preoperative cardiac biomarkers and ventilator use in the visualization demonstrates that the literature has already highlighted the potential of biomarkers as predictors of ventilator duration, but remains accompanied by varied findings that require further synthesis. The association with terms like meta-analysis and systematic review demonstrates the increasing number of studies conducted to comprehensively gather and evaluate evidence, which aligns with the current medical world's need for a stronger, evidence-based basis for clinical decisions.



Source :VOSviewer (2025)
Figure 4.VOSviewer Analysis Line 3

Based on Figure 4. VOSviewer Analysis of Path 3 (Source: VOSviewer, 2025), the mapping results show that the keyword preoperative cardiac biomarkers is once again the center of attention with strong connections to important themes such as ventilator use, coronary artery bypass grafting, and cardiac surgery. This visual relationship illustrates the close relationship between preoperative cardiac biomarker assessment and the duration of ventilator use and overall postoperative clinical outcomes. Nodes such as meta-analysis, high-sensitivity cardiac troponin, NT-proBNP, and CRP also continue to appear in this pathway, emphasizing that cardiac biomarkers play a central role as predictive factors considered in CABG patient care planning.

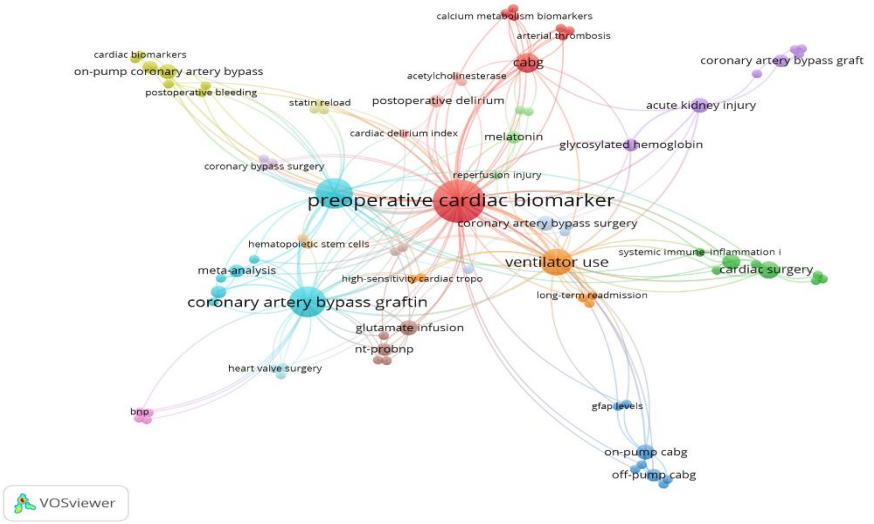
This visualization also demonstrates interconnections with other topics such as postoperative delirium, acute kidney injury, reperfusion injury, and long-term readmission, demonstrating that the influence of biomarkers extends beyond ventilator requirements to other postoperative complications. This reflects the complexity of real-world CABG patient management, where a single preoperative factor can impact multiple outcomes. The dense network of biomarkers, ventilators, and other outcomes supports the urgency of evidence-based research to develop better clinical guidelines. Overall, this analysis underscores the importance of preoperative cardiac biomarkers as an integral predictive tool for minimizing risk and improving outcomes in post-CABG patients.



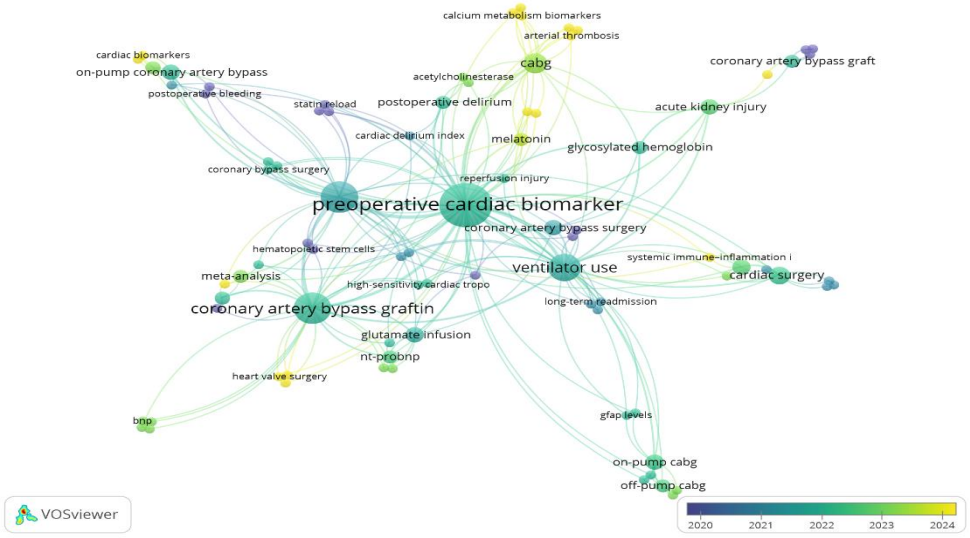
Source :VOSviewer (2025)
Figure 5.VOSviewer Analysis of Line 4

Based on Figure 5. VOSviewer Path 4 Analysis (Source: VOSviewer, 2025), it can be seen that preoperative cardiac biomarkers occupy a very dominant central position with numerous connections to other keywords, indicating their role as a central theme in studies related to predicting patient outcomes after CABG surgery. The clear relationship between preoperative cardiac biomarkers and ventilator use, coronary artery bypass grafting, and cardiac surgery indicates that much research focus is directed at exploring the role of biomarkers in predicting ventilator requirements and other complications. Large nodes and interconnected paths also show the role of biomarkers in broader aspects such as postoperative delirium, acute kidney injury, and long-term readmission, reinforcing the view that preoperative biomarkers are not only related to ventilation but also to various postoperative clinical outcomes.

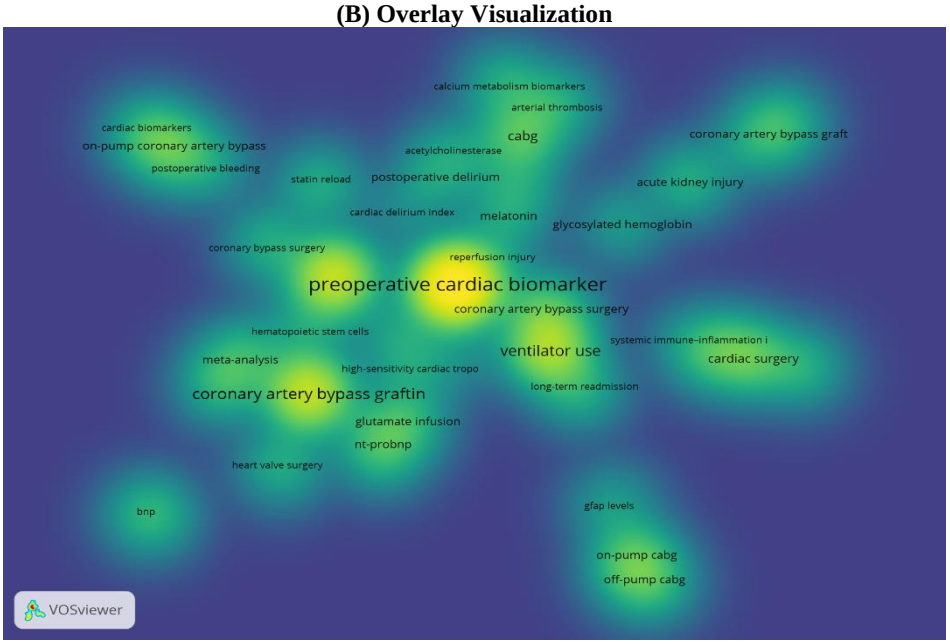
This visualization also shows that themes such as meta-analysis, on-pump and off-pump CABG, NT-proBNP, and high-sensitivity cardiac troponin are closely connected to the center of the map, illustrating the importance of evidence-based research to synthesize data from various biomarker-related studies. The pathways connecting biomarkers to variables such as inflammation, reperfusion injury, and glycosylated hemoglobin suggest that complex patient preoperative conditions can be reflected in biomarkers, making them crucial for comprehensive analysis in treatment planning. These findings align with current clinical challenges, where predicting patient outcomes after CABG surgery requires a more integrative approach that considers biomarkers as key indicators to minimize risk and improve quality of care.



(A) Network Visualization



(B) Overlay Visualization



(C) Density Visualization

Source :VOSviewer (2025)

Figure 6.Overall Pattern Analysis of Keyword Findings Through VOSviewer

In Network Visualization (A), preoperative cardiac biomarkers are seen at the center of the network, with extensive connections to other keywords such as ventilator use, coronary artery bypass grafting, cardiac surgery, and several specific biomarkers such as NT-proBNP and high-sensitivity cardiac troponin. This indicates that the theme of preoperative biomarkers is a central topic in the analyzed literature, with numerous studies linking this variable to clinical outcomes, particularly the duration of ventilator use. The dense network and the pattern of connections between nodes illustrate that this field has a fairly solid research foundation, with discussions not only focusing on a single outcome but also encompassing other complications such as postoperative delirium, acute kidney injury, and long-term readmission. This visualization demonstrates an interactive research ecosystem, with distinct yet interconnected clusters, illustrating that preoperative biomarker research is already integrated into broader issues in cardiac surgery.

In the Overlay Visualization (B), the distribution pattern of publication time can be observed from the color spectrum displayed, ranging from blue (older) to yellow (newer). From this visualization, it can be seen that research on preoperative cardiac biomarkers, ventilator use, and coronary artery bypass grafting has been ongoing for quite some time, but topics such as glycosylated hemoglobin, melatonin, and systemic immune-inflammation index appear more recently with a bright yellow color. This indicates a shift or expansion of research focus from core topics to new, more specific and in-depth areas. This overlay illustrates that research in this field is not static, but continues to evolve by adapting to developments in diagnostic technology, new biomarkers, and emerging clinical needs over time. This map also helps identify relatively new themes that can be further explored as research gaps in the future.

In the Density Visualization (C), the bright yellow areas indicate the most frequently appearing keywords and the focus of attention in the literature, namely preoperative cardiac biomarkers, coronary artery bypass grafting, and ventilator use. Meanwhile, the green to blue areas indicate keywords that appear less frequently but are still relevant, such as on-pump CABG, gfap levels, and hematopoietic stem cells. This visualization clearly shows the distribution of research intensity in this field, with the center of density located on key issues that have been widely studied, while peripheral themes that have received less attention actually hold potential for further research. Thus, this density map not only illustrates the popularity of keywords but also indicates opportunities for further exploration in less dense but important areas for scientific development.

DISCUSSION

Keyword analysis using VOSviewer on the visualization paths (Figures 2–6) consistently shows that the theme of preoperative cardiac biomarkers is the main focus of the research map on the duration of ventilator use after coronary artery bypass grafting (CABG) surgery. In Network Visualization (A) (Figure 6), it is clear that preoperative cardiac biomarkers are closely related to other key keywords such as ventilator use, coronary artery bypass grafting, cardiac surgery, as well as several specific biomarkers such as NT-proBNP and high-sensitivity cardiac troponin. This dense network strengthens the evidence of systematic review findings that high preoperative NT-proBNP levels are consistently associated with longer ventilator duration, as reported by Omran (2022), Wolfien (2020), and Hajhossein-Talasaz (2022). They showed that NT-proBNP not only reflects increased ventricular pressure but also indicates hemodynamic disturbances that can slow postoperative respiratory recovery. A similar thing was also emphasized by Lamy (2024) and Rodriguez-Quintero (2024), where high NT-proBNP indicates the heart's inability to maintain optimal pulmonary perfusion, so that ventilator weaning becomes more difficult.

The same network also confirmed the important role of troponin as a predictor of outcome, which aligns with the findings of a systematic review by Trubnikova (2021), Heuts (2022), Chen (2024), and Koechlin (2020), which found that high preoperative troponin I/T levels were significantly associated with ventilator weaning failure. In the visualization, the high-sensitivity cardiac troponin node was closely linked to ventilator use and CABG, indicating that subclinical, undetected myocardial damage can significantly impact respiratory recovery. This visualization also shows that inflammatory biomarkers such as CRP emerged as nodes associated with respiratory complications, aligning with the findings of Lechowicz (2021), Zajonz (2023), and Saller (2020) that suggested that preoperative systemic inflammation can worsen lung function and prolong the need for ventilator support.
Findings from Overlay Visualization (B) enrich the discussion by showing the temporal distribution of the analyzed studies. The yellow colors appearing for keywords such as glycosylated hemoglobin, melatonin, and systemic immune-inflammation index indicate that these themes have been explored relatively recently, opening up opportunities for further research in this area. Conversely, the blue to green colors for keywords such as preoperative cardiac biomarkers, ventilator use, and CABG indicate that these themes have long been core topics with a fairly robust evidence base. This is consistent with the observations of Nellipudi (2021), Kaushik (2020), and Denessen (2022), who reported that although biomarkers are widely used for prediction, integration with clinical factors is still being explored to improve prediction accuracy. This overlay also supports the findings of Holm (2022), Nurcahyo (2022), and Brown (2021) who stated that patients with pre-existing ventricular dysfunction require ventilators for longer—a classic topic that continues to evolve.

The Density Visualization (C) provides information on research intensity. The bright yellow region centered on preoperative cardiac biomarkers, CABG, and ventilator use demonstrates that these themes are a major focus of attention in the literature, supported by numerous studies and citations. This is also evident in the findings of previous meta-analyses by Jiang (2020) and Rodriguez-Quintero (2024), which emphasized the need for evidence synthesis due to the still high heterogeneity of results. The green and blue areas surrounding the map indicate themes such as on-pump CABG, hematopoietic stem cells, and gfap levels, which, while rarely appearing, are still relevant and have the potential to become new areas of research. The fact that other biomarkers such as glycosylated hemoglobin and melatonin are beginning to receive attention in the overlay and density map also demonstrates the dynamic development of science, adapting to advances in diagnostic technology and understanding of disease physiology.

The visualizations from Figures 2 to 5 demonstrate a consistent pattern that preoperative cardiac biomarkers are not single predictors but rather part of a complex network of factors, including inflammation, reperfusion injury, postoperative delirium, acute renal failure, and long-term readmission. This finding is highly relevant to Hinoue's (2023) warning that preoperative biomarker trends should be considered, not just their absolute values, because biomarker dynamics provide a more comprehensive picture of the patient's condition. Furthermore, the highly dense network surrounding preoperative cardiac biomarkers in all visualizations confirms their dominant role within the research ecosystem, reinforced by reports such as those from Holm (2022), Brown (2021), and Farouk (2022) that combining clinical risk with biomarkers provides significantly better predictive value than traditional clinical prediction models alone.

Overall, the results of the systematic review and keyword mapping using VOSviewer support the conclusion that preoperative cardiac biomarkers, particularly NT-proBNP, troponin, and CRP, have significant predictive value for the duration of ventilator use in post-CABG patients. The bibliometric analysis demonstrates how this topic has evolved from a central issue to a more specific and in-depth exploration of new topics. In other words, this analysis not only strengthens the empirical evidence but also paves the way for further research, for example, by exploring new biomarkers appearing on the overlay map or exploring lower-intensity themes on the density map. These findings underscore the need for more personalized, evidence-based patient care strategies that consider the value of biomarkers to more accurately predict ventilator requirements and other outcomes.

CONCLUSION

Based on the results of a systematic review and bibliometric analysis using VOSviewer, it can be concluded that preoperative cardiac biomarkers, specifically NT-proBNP, troponin I/T, and CRP, have significant predictive value for the duration of ventilator use in post-coronary artery bypass grafting (CABG) patients. These biomarkers reflect hemodynamic conditions, the degree of myocardial damage, and the systemic inflammatory response that affect the patient's ability to wean from the ventilator. These findings strengthen the evidence that integrating biomarker assessment with traditional clinical factors can improve predictive accuracy, thereby helping to plan more appropriate care, minimize the risk of complications, and improve clinical outcomes in post-CABG patients.

Further research with consistent methodology, larger populations, and clear biomarker cutoffs is needed to strengthen the existing evidence base and enable the development of more comprehensive clinical guidelines. Furthermore, hospitals and clinicians are encouraged to consider the routine use of preoperative cardiac biomarkers in risk stratification of CABG patients, combining them with other clinical factors to improve prediction of ventilator requirements and individualized postoperative management planning.

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