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Advancements in Venous Thromboembolism Management: Insights from Diverse Interventions and Patient Populations—An Integrative Review

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Abstract

Introduction: Venous thromboembolism (VTE), encompassing deep vein thrombosis (DVT) and pulmonary embolism (PE), poses a significant health burden worldwide, leading to considerable morbidity and mortality. Effective prevention and management strategies for VTE are critical, especially given the associated risk factors and implications, including those linked with COVID-19. Timely diagnosis and intervention play pivotal roles in mitigating the impact of VTE on patient outcomes. **Method:** This integrative review aimed to synthesize findings from studies investigating interventions for VTE prevention and management. A comprehensive search strategy was employed to identify relevant literature, and data analysis involved descriptive statistics, comparative analysis of intervention effectiveness, and qualitative synthesis to identify common themes and trends across studies. **Results:** The review included studies examining diverse interventions for VTE prevention and management. These interventions ranged from routine duplex ultrasound screening to novel mechanical compression devices and oxygen therapy in intermediate-risk acute PE. Through the studies, interventions demonstrated efficacy in reducing VTE rates, improving compliance, and enhancing patient outcomes. Notable findings included the significant reduction in VTE rates with fondaparinux combined with intermittent pneumatic compression compared to IPC alone and the improved compliance with mechanical prophylaxis using novel mechanical compression devices. **Conclusion:** The review underscores the importance of diverse interventions in the prevention and management of VTE. While the evidence supports the effectiveness of these interventions, further research,

including larger-scale trials, is warranted to validate findings and optimize patient care. This multidisciplinary approach to VTE management reflects a continued commitment to improving outcomes and addressing the global burden of this condition.

Keywords

COVID-19, Interventional Strategies, Patient Outcomes, VTE Management

1. Introduction

Advancements in the management of venous thromboembolism (VTE) have significantly improved outcomes through a combination of effective prevention strategies and treatment modalities [1]. VTE, encompassing deep vein thrombosis and pulmonary embolism, is a major cause of morbidity and mortality, particularly among cancer patients [2]. The chronic inflammatory nature of conditions like inflammatory bowel disease contributes to the development of VTE due to endothelial dysfunction, stasis, and hypercoagulability [3]. Furthermore, VTE is a common complication in patients undergoing orthopedic surgeries like total knee or hip arthroplasty [4]. Anticoagulant therapies, including direct oral anticoagulants (DOACs), have revolutionized the management of VTE and related conditions like atrial fibrillation (AF) and pulmonary hypertension [5]. These advancements have led to a shift away from traditional treatments like vitamin K antagonists towards more effective and safer options [5]. However, the use of anticoagulants in patients with pulmonary hypertension requires careful consideration due to the risk of hemorrhage [5]. In the context of cardiopulmonary resuscitation (CPR), there is ongoing research on the use of fibrinolytic and adjunctive antithrombotic treatments to improve outcomes in out-of-hospital cardiac arrest cases of assumed cardiac origin [6]. While the effectiveness and safety of antithrombotic treatments in elderly patients with AF are being investigated, the balance between reducing the risk of VTE and increasing the risk of bleeding remains a critical consideration [7].

Antithrombotic treatment during CPR is crucial in improving outcomes for patients experiencing cardiac arrest. Research has explored various interventions and their impact on CPR success rates. For instance, studies have investigated the use of fibrinolytic agents and adjunctive antithrombotic treatments during CPR in out-of-hospital cardiac arrest cases, aiming to enhance survival chances [6]. Additionally, the implementation of bystander-focused public health interventions, such as dispatch-assisted CPR and training programs for CPR, has been associated with increased rates of bystander CPR and improved survival outcomes [8] [9]. In specific clinical scenarios, such as cardiac arrest due to hyperkalemia, interventions like prolonged CPR along with hemodialysis have shown success in restoring spontaneous heartbeat [10].

Moreover, the continuous use of antithrombotic medications during procedures like endoscopic submucosal dissection has been studied to manage postoperative bleeding effectively [11]. These findings highlight the importance of tailored interventions based on the underlying cause and patient population. Furthermore, the adherence to antithrombotic therapy in various patient populations, such as those with atrial fibrillation, has been a subject of investigation [12]. Understanding the factors influencing adherence can help optimize treatment outcomes and reduce the risk of thromboembolic events. Additionally, studies have explored the impact of pre-injury antithrombotic agents on outcomes in traumatic brain injury cases, emphasizing the need for personalized approaches in managing patients on antithrombotic therapy [13].

The objective of this integrative literature review is to synthesize existing evidence on interventions for the prevention and management of venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary embolism (PE) and antithrombotic treatment during cardiopulmonary resuscitation.

2. Materials and Methods

The data analysis involved several steps to synthesize findings across the included studies. First, descriptive statistics such as mean, median, standard deviation, minimum, and maximum were calculated for key variables, including publication year, sample size, and main outcomes.

Then, a comparative analysis was conducted to compare the effectiveness of different interventions for VTE prevention or management. This involved examining differences in outcomes, such as VTE rates, between intervention groups and control groups within each study.

Additionally, qualitative synthesis was performed to identify common themes, trends, and patterns across the included studies. This included summarizing the main findings, conclusions, and implications of each study.

Furthermore, knowledge gaps and areas needing further research were identified based on the limitations and inconsistencies observed across the included studies. This helped guide recommendations for future research directions.

The synthesis of data revealed several key findings: routine duplex ultrasound screening in trauma patients was associated with a lower rate of symptomatic or fatal pulmonary embolism (PE) compared to no surveillance; fondaparinux combined with intermittent pneumatic compression (IPC) was more effective than IPC alone for preventing VTE after major abdominal surgery, although it was associated with an increased bleeding risk; intermittent pneumatic compression (IPC) significantly reduced the occurrence of asymptomatic venous thrombosis in high-risk surgical patients compared to standard prophylaxis alone; the use of a novel mechanical compression device showed improved compliance with mechanical prophylaxis in trauma patients compared to IPC; and oxygen therapy in patients with intermediate-risk acute pulmonary embolism (PE) showed a potential trend towards improvement in echocardiographic parameters, although further research

with larger sample sizes is needed for definitive conclusions.

Overall, the synthesis of data provided insights into the effectiveness of various interventions for VTE prevention and management across different patient populations and clinical settings (Table 1).

Table 1. Search queries for integrative review on venous thromboembolism.

Database	Search Query
Pubmed	(("Deep Vein Thrombosis" [Mesh]) OR ("Pulmonary Embolism" [Mesh]) OR ("Venous Thromboembolism" [Mesh])) AND ("Diagnosis" [Mesh] OR "Management" [Mesh] OR "Therapeutics" [Mesh] OR "Epidemiology" [Mesh])
	("Deep Vein Thrombosis" OR "DVT" OR "Venous Thrombosis") AND ("Pulmonary Embolism" OR "PE" OR "Pulmonary Thromboembolism") AND ("Diagnosis" OR "Management" OR "Therapeutics" OR "Treatment" OR "Epidemiology")
	(("Deep Vein Thrombosis" OR "DVT" OR "Venous Thrombosis") AND ("Pulmonary Embolism" OR "PE" OR "Pulmonary Thromboembolism")) AND ("Diagnosis" OR "Management" OR "Therapeutics" OR "Treatment" OR "Epidemiology")
SciELO	(("Deep Vein Thrombosis" [Mesh]) OR ("Pulmonary Embolism" [Mesh]) OR ("Venous Thromboembolism" [Mesh])) AND ("Diagnosis" [Mesh] OR "Management" [Mesh] OR "Therapeutics" [Mesh] OR "Epidemiology" [Mesh])
	("Deep Vein Thrombosis" OR "DVT" OR "Venous Thrombosis") AND ("Pulmonary Embolism" OR "PE" OR "Pulmonary Thromboembolism") AND ("Diagnosis" OR "Management" OR "Therapeutics" OR "Treatment" OR "Epidemiology")
Web of Science	TS = ("Deep Vein Thrombosis" OR "Pulmonary Embolism" OR "Venous Thromboembolism") AND TS = ("Diagnosis" OR "Management" OR "Therapeutics" OR "Epidemiology")
	TS = ("Deep Vein Thrombosis" OR "DVT" OR "Venous Thrombosis") AND TS = ("Pulmonary Embolism" OR "PE" OR "Pulmonary Thromboembolism") AND TS = ("Diagnosis" OR "Management" OR "Therapeutics" OR "Treatment" OR "Epidemiology")
	TS = ("Deep Vein Thrombosis" OR "DVT" OR "Venous Thrombosis") AND TS = ("Pulmonary Embolism" OR "PE" OR "Pulmonary Thromboembolism")) AND TS = ("Diagnosis" OR "Management" OR "Therapeutics" OR "Treatment" OR "Epidemiology")

3. Results

From an initial pool of 60 articles, only five survived the rigorous selection process based on our stringent inclusion and review criteria. Through this meticulous winnowing process, characterized by discerning judgment, we ensured that only the most relevant and credible studies were included for our meticulous scrutiny.

Firstly, a 2024 (Table 2) study explored the efficacy of routine duplex ultrasound (DUS) screening among trauma patients. The findings suggested that trauma patients undergoing DUS surveillance had a reduced incidence of symptomatic or fatal pulmonary embolism (PE) compared to those without surveillance. This implies that implementing a selective DUS protocol could lead to fewer in-hospital PE cases among trauma patients, although larger-scale trials are warranted for conclusive evidence.

Table 2. Summary of studies on venous thromboembolism (VTE) interventions.

Study	Year	Population	Intervention	Primary Outcome	Conclusion
Trauma patients undergoing routine duplex ultrasound screening	2024	Trauma patients	Duplex ultrasound surveillance vs. no surveillance	Lower rate of symptomatic or fatal pulmonary embolism (PE)	Implementation of selective routine DUS protocol associated with fewer in-hospital PE cases.
Fondaparinux + IPC vs. IPC alone for VTE prevention after major abdominal surgery	2005	Major abdomina l surgery patients	Fondaparinu x + IPC vs. IPC alone	Significant reduction in VTE rate with Fondaparinux + IPC compared to IPC alone	Fondaparinux + IPC more effective than IPC alone for preventing VTE after major abdominal surgery.
IPC in addition to standard prophylaxis vs. standard prophylaxis alone in high-risk surgical patients	2021	Patients with Caprini score ≥ 11 undergoing major surgery	IPC + standard prophylaxis vs. standard prophylaxis alone	Significantly lower occurrence of asymptomatic venous thrombosis with IPC compared to control	IPC significantly reduced occurrence of asymptomatic venous thrombosis in high-risk surgical patients. Suggests potential benefit of adjunctive IPC in preventing VTE.
Evaluation of a novel mechanical venous thromboembolism compression device in trauma patients	2024	Trauma patients	MAC system vs. IPC device	Improved compliance with mechanical prophylaxis with MAC device compared to IPC	MAC device may improve compliance with mechanical prophylaxis in trauma patients. Further research needed to validate findings and assess long-term effectiveness/safety.
Oxygen therapy in patients with intermediate-risk acute pulmonary embolism	2023	Patients with intermediate-risk acute PE	Supplemental oxygen vs. ambient air	Trend towards improvement in echocardiographic RV size normalization with oxygen therapy	Oxygen therapy showed potential improvement in echocardiographic parameters. Further research with larger sample size needed for definitive conclusions.
Thrombolysis post-cardiopulmonary resuscitation in myocardial infarction with abdominal pain as the first presentation	2022	Myocardial infarction patients	Thrombolysis post-cardiopulmonary resuscitation	Return of autonomic circulation	Thrombolysis post-cardiopulmonary resuscitation following ST-segment elevation myocardial infarction diagnosis can lead to the return of autonomic circulation.
Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism increases 30-day	2019	Out-of-hospital cardiac arrest patients	Thrombolysis during resuscitation for pulmonary embolism	Increased 30-day survival	Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism has been associated with improved 30-day survival rates.
Successful recovery after prolonged cardiopulmonary resuscitation and rescue thrombolytics in a patient with cardiac arrest	2021	Patients with cardiac arrest	Rescue thrombolytics	Successful recovery after prolonged CPR	Rescue thrombolytics post-prolonged cardiopulmonary resuscitation can aid in successful recovery from cardiac arrest due to massive pulmonary embolism.

Continued

Fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest may increase survival chances	2021	Out-of-hospital cardiac arrest patients	Fibrinolytic and antithrombotic treatment during CPR	Increased survival chances	Fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest may increase survival chances.

Note: Studies on VTE interventions, including year, population, intervention, primary outcome, and conclusion. Source: Authors (2024).

Secondly, a study from 2005 investigated the effectiveness of fondaparinux combined with intermittent pneumatic compression (IPC) versus IPC alone in preventing VTE following major abdominal surgery. Results indicated a significant decrease in VTE rates with fondaparinux combined with IPC compared to IPC alone. Thus, fondaparinux combined with IPC emerges as a more effective strategy for VTE prevention post-major abdominal surgery, with a low bleeding risk in line with previous research.

The third study, conducted in 2021, focused on adding IPC to standard prophylaxis versus standard prophylaxis alone in high-risk surgical patients. It observed a notable reduction in asymptomatic venous thrombosis occurrence with IPC compared to the control group. This highlights IPC's efficacy in reducing asymptomatic venous thrombosis among high-risk surgical patients, suggesting a potential adjunctive role in VTE prevention.

In another 2024 study, a novel mechanical compression device for VTE prophylaxis in trauma patients was evaluated. The results demonstrated enhanced compliance with mechanical prophylaxis using the MAC device compared to IPC. This suggests the MAC device's potential to enhance compliance with mechanical prophylaxis among trauma patients. However, further validation through additional research is necessary to confirm these findings and assess their long-term efficacy and safety.

Lastly, a 2023 study investigated oxygen therapy versus ambient air in intermediate-risk acute pulmonary embolism (PE) patients. While preliminary results indicated a trend towards improved echocardiographic parameters with oxygen therapy, conclusive evidence necessitates further research with larger sample sizes.

Three studies were identified that investigated the use of thrombolytic and antithrombotic treatments during cardiopulmonary resuscitation (CPR) for out-of-hospital cardiac arrest, particularly focusing on cases related to pulmonary embolism (PE).

In 2019, a study conducted on out-of-hospital cardiac arrest patients examined the effects of thrombolysis during resuscitation for pulmonary embolism. The study found a significant increase in 30-day survival rates among patients who received thrombolysis during resuscitation for PE. This suggests that thrombolysis during CPR may play a crucial role in improving short-term survival outcomes in cases of out-of-hospital cardiac arrest secondary to pulmonary embolism.

In 2021, two separate studies further explored the use of thrombolytic and an-

tithrombotic treatments during CPR for out-of-hospital cardiac arrest. One study focused on patients with cardiac arrest and investigated the use of rescue thrombolytics. It reported successful recovery after prolonged CPR in cases of presumed massive pulmonary embolism, indicating that rescue thrombolytics may contribute to successful outcomes in such scenarios.

Similarly, another study conducted in 2021 examined the effects of fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest patients. The findings suggested a potential increase in survival chances associated with the use of these treatments during CPR. This highlights the importance of considering fibrinolytic and antithrombotic therapies as part of the resuscitative efforts in out-of-hospital cardiac arrest situations.

Overall, these results underscore the potential benefits of thrombolytic and antithrombotic treatments during CPR for out-of-hospital cardiac arrest, particularly in cases related to pulmonary embolism. Further research and clinical trials are warranted to validate these findings and determine the optimal protocols for incorporating these treatments into resuscitation efforts.

Five studies were reviewed, each focusing on different interventions and patient populations. In 2024, a study examined the efficacy of routine duplex ultrasound screening in trauma patients, revealing a significant difference in the pulmonary embolism (PE) rate between the surveillance and no-surveillance groups. Similarly, a 2005 study compared fondaparinux with intermittent pneumatic compression (IPC) versus IPC alone for VTE prevention after major abdominal surgery, showing a notable reduction in VTE rate with fondaparinux, despite an increased bleeding risk.

In 2021, another study evaluated IPC in addition to standard prophylaxis versus standard prophylaxis alone in high-risk surgical patients, highlighting a significant decrease in asymptomatic venous thrombosis occurrence with IPC. Meanwhile, a 2024 study investigated a novel mechanical compression device in trauma patients, demonstrating improved compliance with mechanical prophylaxis using the MAC device.

Lastly, a study from 2023 explored oxygen therapy in patients with intermediate-risk acute pulmonary embolism, suggesting potential improvements in echocardiographic parameters, although the trial was stopped prematurely, and the VTE rate was not specified.

One such study, conducted in 2022, titled "Thrombolysis post-cardiopulmonary resuscitation in myocardial infarction with abdominal pain as the first presentation", focused on myocardial infarction patients. It investigated the efficacy of thrombolysis post-cardiopulmonary resuscitation, revealing that such intervention could facilitate the return of autonomic circulation in these patients.

Another notable study, conducted in 2019, titled "Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism increases 30-day survival", explored the impact of thrombolysis during resuscitation for pulmonary embolism on the 30-day survival of out-of-hospital cardiac arrest patients.

The findings indicated an association between thrombolysis during resuscitation and increased 30-day survival rates among individuals experiencing out-of-hospital cardiac arrest due to pulmonary embolism.

Similarly, the study titled "Successful recovery after prolonged cardiopulmonary resuscitation and rescue thrombolytics in a patient with cardiac arrest secondary to presumed massive pulmonary embolism" in 2021 investigated the efficacy of rescue thrombolytics in patients with cardiac arrest secondary to presumed massive pulmonary embolism. The research highlighted the potential for successful recovery after prolonged cardiopulmonary resuscitation with the administration of rescue thrombolytics, particularly in cases attributed to massive pulmonary embolism.

Furthermore, another study from 2021, titled "Fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest may increase survival chances", explored the effects of fibrinolytic and antithrombotic treatment during

Table 3. Overview of studies on interventions and primary outcomes in venous thromboembolism management.

Study	Intervention	Primary Outcome
Trauma patients undergoing routine duplex ultrasound screening	Duplex ultrasound surveillance vs. no surveillance	Lower rate of symptomatic or fatal PE
Fondaparinux + IPC vs. IPC alone for VTE prevention after major abdominal surgery	Fondaparinux + IPC vs. IPC alone	Significant reduction in VTE rate
IPC in addition to standard prophylaxis vs. standard prophylaxis alone in high-risk surgical patients	IPC + standard prophylaxis vs. standard prophylaxis alone	Significantly lower occurrence of asymptomatic venous thrombosis with IPC compared to control
Evaluation of a novel mechanical venous thromboembolism compression device in trauma patients	MAC system vs. IPC device	Improved compliance with mechanical prophylaxis with MAC device compared to IPC
Oxygen therapy in patients with intermediate-risk acute pulmonary embolism	Supplemental oxygen vs. ambient air	Trend towards improvement in echocardiographic RV size normalization with oxygen therapy
Thrombolysis post-cardiopulmonary resuscitation in myocardial infarction with abdominal pain as the first presentation	Thrombolysis post-cardiopulmonary resuscitation	Return of autonomic circulation
Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism increases 30-day survival	Thrombolysis during resuscitation for pulmonary embolism	Increased 30-day survival
Successful recovery after prolonged cardiopulmonary resuscitation and rescue thrombolytics in a patient with cardiac arrest secondary to presumed massive pulmonary embolism	Rescue thrombolytics	Successful recovery after prolonged CPR
Fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest may increase survival chances	Fibrinolytic and antithrombotic treatment during CPR	Increased survival chances

Note: Study interventions and outcomes. Source: Authors (2024).

CPR on the survival chances of out-of-hospital cardiac arrest patients. The findings suggested that such treatment modalities may contribute to increased survival chances in individuals experiencing out-of-hospital cardiac arrest.

Trauma patients undergoing routine duplex ultrasound screening (2024): This study evaluated the effectiveness of duplex ultrasound surveillance in traumatized patients, demonstrating a reduction in the incidence of symptomatic or fatal pulmonary embolism with selective duplex ultrasound protocol.

Fondaparinux + IPC vs. IPC alone for VTE prevention after major abdominal surgery (2005): Fondaparinux plus intermittent pneumatic compression was compared to intermittent pneumatic compression alone for preventing VTE after major abdominal surgery, resulting in a significant reduction in VTE rate.

IPC in addition to standard prophylaxis vs. standard prophylaxis alone in high-risk surgical patients (2021): The addition of intermittent pneumatic compression to standard prophylaxis versus standard prophylaxis alone was evaluated in high-risk surgical patients, showing a significant decrease in the occurrence of asymptomatic venous thrombosis with intermittent pneumatic compression.

Evaluation of a novel mechanical venous thromboembolism compression device in trauma patients (2024): The use of a mechanical venous compression system was investigated compared to an intermittent pneumatic compression device in traumatized patients, demonstrating an improvement in compliance with mechanical prophylaxis.

Oxygen therapy in patients with intermediate-risk acute pulmonary embolism (2023): The effect of oxygen therapy in patients with intermediate-risk acute pulmonary embolism was examined, showing a trend towards normalization of right ventricular size in echocardiography.

Thrombolysis post-cardiopulmonary resuscitation in myocardial infarction with abdominal pain as the first presentation (2022): Thrombolysis post-cardiopulmonary resuscitation in myocardial infarction patients with abdominal pain as the first presentation was investigated, demonstrating the potential for the return of autonomic circulation.

Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism increases 30-day survival (2019): This study found an association between thrombolysis during resuscitation and increased 30-day survival in patients with out-of-hospital cardiac arrest due to pulmonary embolism.

Successful recovery after prolonged cardiopulmonary resuscitation and rescue thrombolytics in a patient with cardiac arrest secondary to presumed massive pulmonary embolism (2021): A case of successful recovery after prolonged cardiopulmonary resuscitation and rescue thrombolytics in a patient with cardiac arrest secondary to presumed massive pulmonary embolism was described.

Fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest may increase survival chances (2021): This study suggested that fibrinolytic and antithrombotic treatment during CPR in out-of-hospital cardiac arrest patients may increase survival chances.

An overview of studies on interventions and primary outcomes in venous thromboembolism management is shown in Table 3.

4. Discussion

This integrative review synthesizes current evidence on interventions for the prevention and management of venous thromboembolism (VTE) and antithrombotic treatment during cardiopulmonary resuscitation (CPR). The findings elucidate several efficacious strategies across diverse patient populations and clinical scenarios, contributing valuable insights to the evolving landscape of thromboprophylaxis and therapeutic interventions.

The implementation of routine duplex ultrasound (DUS) screening in trauma patients emerged as a significant preventive measure, with evidence suggesting a marked reduction in the incidence of symptomatic or fatal pulmonary embolism (PE) compared to patients without surveillance [1]. This observation underscores the potential value of selective DUS protocols in high-risk trauma settings, although larger-scale trials with robust methodological designs are warranted to establish definitive evidence-based guidelines. The early detection of deep vein thrombosis through systematic surveillance may facilitate timely intervention, potentially interrupting the pathophysiological cascade that leads to life-threatening PE.

Regarding pharmacological interventions, the combination of fondaparinux with intermittent pneumatic compression (IPC) demonstrated superior efficacy compared to IPC alone for VTE prevention following major abdominal surgery [2]. This combined approach resulted in a statistically significant reduction in VTE rates, suggesting a synergistic effect between pharmacological and mechanical prophylaxis modalities. However, the increased bleeding risk associated with fondaparinux administration necessitates careful patient selection and vigilant monitoring, particularly in surgical populations with elevated hemorrhagic risk profiles. The risk-benefit ratio must be meticulously evaluated on an individual basis, considering both thrombotic and hemorrhagic propensities.

The efficacy of mechanical prophylaxis was further substantiated by evidence showing that IPC, when added to standard prophylaxis in high-risk surgical patients, significantly reduced the occurrence of asymptomatic venous thrombosis [3]. This finding reinforces the value of mechanical prophylaxis as an adjunctive measure in comprehensive VTE prevention strategies, particularly in patients where pharmacological options may be contraindicated or require supplementation. The non-invasive nature of mechanical prophylaxis renders it an attractive option for patients with elevated bleeding risk, providing a complementary mechanism of action through enhancement of venous return and reduction of stasis.

Innovation in mechanical prophylaxis devices also demonstrates considerable promise, as evidenced by improved compliance with a novel mechanical compression device compared to traditional IPC in trauma patients [4]. Enhanced compliance represents a critical determinant of prophylaxis effectiveness, as suboptimal adherence to prescribed regimens may compromise outcomes regardless of theo-

retical efficacy. The development and implementation of more ergonomic, user-friendly, and comfortable devices may therefore contribute significantly to VTE prevention through improved patient acceptance and sustained adherence throughout the at-risk period.

In the context of established PE, oxygen therapy in patients with intermediate-risk acute pulmonary embolism showed a trend toward improved echocardiographic parameters, although definitive conclusions require further investigation with adequately powered studies and larger sample sizes [5]. This preliminary finding suggests potential benefits of supplemental oxygen beyond conventional respiratory support, possibly through mechanisms involving reduced pulmonary vascular resistance, improved ventilation-perfusion matching, or enhanced right ventricular function. The physiological rationale for oxygen therapy in this context merits further exploration through mechanistic studies.

The management of cardiac arrest potentially related to thrombotic events represents another critical area illuminated by this review. Thrombolysis during resuscitation for out-of-hospital cardiac arrest due to pulmonary embolism was associated with significantly increased 30-day survival rates [6], suggesting that targeted antithrombotic interventions during CPR may improve outcomes in selected cases. Similarly, rescue thrombolytics demonstrated potential benefit in cardiac arrest secondary to presumed massive pulmonary embolism [7], while fibrinolytic and antithrombotic treatments during CPR for out-of-hospital cardiac arrest showed promise for increasing survival chances [8].

These findings collectively suggest that the integration of antithrombotic strategies into resuscitation protocols may represent an important advancement in the management of cardiac arrest with suspected thrombotic etiology. The pathophysiological basis for this approach lies in the potential to rapidly restore pulmonary perfusion through thrombus dissolution, thereby facilitating return of spontaneous circulation and mitigating end-organ damage. However, the risk-benefit profile of such interventions requires careful consideration, particularly regarding hemorrhagic complications in the setting of CPR, where traumatic injuries may be sustained during chest compressions.

The adherence to antithrombotic therapy represents another critical dimension in VTE management, as highlighted by research examining compliance patterns among patients attending multidisciplinary thrombosis services [9]. Understanding factors influencing adherence—including medication complexity, patient education, socioeconomic determinants, and healthcare system factors—can inform strategies to optimize treatment outcomes and reduce thromboembolic event risk through improved medication compliance. The implementation of structured education programs, simplified dosing regimens, and regular follow-up may enhance adherence and, consequently, therapeutic efficacy.

Additionally, the impact of pre-injury antithrombotic agents on outcomes in traumatic brain injury cases emphasizes the complexity of managing patients on antithrombotic therapy who experience trauma [10]. While these agents may predict

intracranial hemorrhagic progression, their association with clinical outcomes appears more nuanced, underscoring the need for personalized approaches in this challenging patient population. The delicate balance between hemorrhagic and thrombotic risks in these patients necessitates individualized management strategies informed by comprehensive risk assessment.

Several methodological limitations must be acknowledged in interpreting these findings. The heterogeneity of study designs, interventions, outcome measures, and follow-up periods complicates direct comparisons across studies and limits the potential for meta-analytical approaches. Additionally, the relatively small number of studies meeting inclusion criteria for this review constrains the generalizability of conclusions to broader clinical contexts. Furthermore, the premature termination of some trials and variable follow-up periods may impact the robustness and long-term validity of reported outcomes. Selection bias in the included studies may also influence the observed effect sizes and directional trends.

Future research directions should encompass larger, multicenter randomized controlled trials with standardized outcome measures and adequate statistical power to strengthen the evidence base for VTE prevention and management strategies. Particular attention should be directed toward optimizing combined pharmacological and mechanical prophylaxis regimens, developing more effective and user-friendly mechanical devices, and refining protocols for antithrombotic interventions during CPR. Additionally, investigation of patient-specific factors influencing treatment response and risk profiles would facilitate more personalized approaches to VTE management, potentially through risk stratification algorithms incorporating clinical, laboratory, and genetic parameters.

5. Conclusion

The review underscores the importance of diverse interventions in the prevention and management of venous thromboembolism (VTE), demonstrating their efficacy in reducing VTE rates, improving compliance, and enhancing patient outcomes. However, it is essential to acknowledge the inherent limitations of the reviewed studies. Firstly, the heterogeneity among the included studies may limit the generalizability of the findings. Additionally, many studies had relatively small sample sizes, which could compromise the robustness of the conclusions. Other limitations include potential selection bias and the predominant focus on pharmacological and mechanical interventions, excluding other possible modalities. Therefore, it is crucial to interpret the results cautiously and recognize the pressing need for further research, including larger-scale randomized prospective studies and investigations into alternative intervention approaches. Such studies are critical for validating the findings and enhancing the quality of care provided to patients with VTE.

6. Limitations and Future Directions

Despite the valuable insights provided by the reviewed studies, there are limitations

to consider. The included studies vary in terms of sample sizes, study designs, and outcome measures, which may affect the generalizability of the findings. Additionally, some studies lacked specific data on VTE rates or had incomplete follow-up periods, limiting the robustness of the conclusions drawn. Furthermore, the focus on specific patient populations and interventions may restrict the applicability of the findings to broader clinical settings.

Future research should aim to address these limitations by conducting larger-scale, prospective studies with standardized protocols and longer follow-up periods. Moreover, comparative effectiveness studies and cost-effectiveness analyses could help guide clinical decision-making and resource allocation. Additionally, investigations into novel interventions and strategies for VTE prevention and management are warranted to further enhance patient care and outcomes.

Overall, while the reviewed studies offer valuable insights into current practices and interventions for VTE, ongoing research is essential to advance our understanding and optimize the prevention and management of this significant medical condition.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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