Efficacy And Safety of Anticoagulant Medications in Preventing Thromboembolic Events in Patients with Cardiovascular Disease Undergoing Surgery: A Systematic Review

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Abstract

Background: Thromboembolic events remain a major cause of morbidity and mortality among patients with cardiovascular disease (CVD) undergoing surgery. Optimal anticoagulant management is critical to balance the dual risks of thrombosis and bleeding in the perioperative setting.

Objective: This systematic review aimed to evaluate the efficacy and safety of traditional and novel anticoagulant medications in preventing thromboembolic events among surgical CVD patients.

Methods: Following PRISMA 2020 guidelines, a structured search was conducted across PubMed, Scopus, Web of Science, Embase, and Google Scholar for studies published between 2010 and 2024. Twelve peer-reviewed studies met inclusion criteria, encompassing randomized trials, cohort studies, and registries evaluating warfarin, heparin, LMWH, and direct oral anticoagulants (DOACs).

Results: The findings demonstrated that DOACs such as apixaban, rivaroxaban, and dabigatran provide efficacy comparable to VKAs with reduced rates of major bleeding (1.5–2.0%) and fewer gastrointestinal complications. However, bleeding risk remained elevated in cardiac surgery and dual antiplatelet therapy contexts. Studies emphasizing preoperative platelet testing and perioperative management protocols showed reduced bleeding and thromboembolic recurrence.

Conclusions: Evidence supports DOACs as effective and safe alternatives to traditional anticoagulants in surgical CVD patients when managed with individualized perioperative protocols. Further large-scale trials are warranted to refine risk stratification and optimize therapeutic decision-making.

Keywords:
Anticoagulants; Direct oral anticoagulants (DOACs); Warfarin; Cardiovascular surgery; Thromboembolism; Perioperative bleeding; Venous thromboembolism; Safety; Efficacy; Systematic review

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide, contributing to a significant share of global healthcare expenditure. Thromboembolic events—including deep vein thrombosis (DVT), pulmonary embolism (PE), and systemic embolism—are among the most serious complications following cardiovascular surgery. These events not only elevate perioperative mortality but also prolong hospitalization and rehabilitation, creating a substantial socioeconomic burden on healthcare systems (Barco et al., 2016; Grosse et al., 2016).

Surgical trauma, endothelial injury, and the inflammatory response inherent to cardiovascular interventions activate the coagulation cascade, predisposing patients to both thrombus formation and bleeding. The delicate balance between coagulation and fibrinolysis becomes particularly critical during and after cardiac operations, where hemodynamic instability and use of cardiopulmonary bypass increase thromboembolic risk (Heestermans et al., 2022; Hogwood et al., 2023). Understanding these pathophysiologic processes is essential to guide safe and effective anticoagulant management.

Traditional anticoagulants such as unfractionated heparin and vitamin K antagonists (VKAs) have long served as the cornerstone of thromboprophylaxis. However, the introduction of direct oral anticoagulants (DOACs) and non-vitamin K antagonist oral anticoagulants (NOACs) has transformed clinical practice by offering predictable pharmacokinetics, fewer food interactions, and reduced need for laboratory monitoring (Chan et al., 2020; Beyer-Westendorf & Ageno, 2015). These newer agents provide a safer and more convenient alternative, particularly in perioperative settings.

Despite therapeutic advances, clinicians face persistent challenges in balancing efficacy and safety during surgical care. Excessive anticoagulation can lead to hemorrhagic complications, while under-dosing increases the risk of thromboembolism. The perioperative management of anticoagulants, including when to interrupt or resume therapy, remains an area of clinical uncertainty—especially for patients with multiple comorbidities or undergoing urgent surgery (Jackson et al., 2022; Khan et al., 2021a). Tailored anticoagulant strategies are thus essential for improving patient outcomes.

Comparative analyses and meta-analyses demonstrate that DOACs are at least as effective as VKAs for thromboprophylaxis but may differ in safety profiles depending on the surgical context. For example, rivaroxaban has been associated with a higher incidence of gastrointestinal bleeding compared with apixaban or dabigatran (Ingason et al., 2021; Dawwas et al., 2022). These differences underscore the importance of individualizing therapy based on pharmacologic and patient-specific factors such as renal function, age, and concurrent antiplatelet use.

Antiplatelet drugs, particularly dual antiplatelet therapy (DAPT) with aspirin and P2Y12 inhibitors, are integral in managing patients with acute coronary syndromes or post-stent implantation. However, their concurrent use with anticoagulants heightens bleeding risk, complicating perioperative care (Abubakar et al., 2023; Chopard et al., 2020). Current evidence supports a careful risk–benefit assessment and interdisciplinary management to minimize adverse events without compromising antithrombotic efficacy.

Recent systematic reviews and network meta-analyses have applied structured evaluation frameworks, such as GRADE, to compare anticoagulant regimens across diverse surgical populations. These analyses consistently highlight that while newer anticoagulants reduce thromboembolic recurrence, data on perioperative bleeding and long-term safety remain limited (Brignardello-Petersen et al., 2020; Izcovich et al., 2023; Eck et al., 2022). Consequently, further evidence synthesis is needed to refine guidelines for surgical anticoagulation management.

Given the complexity of anticoagulant pharmacology and the competing risks of thrombosis and bleeding in surgical CVD populations, a systematic synthesis of available data is warranted. This review aims to evaluate the efficacy and safety of anticoagulant medications in preventing thromboembolic events among patients with cardiovascular disease undergoing surgery, integrating findings from clinical trials, registries, and real-world studies to inform best practices and guideline development (Feng et al., 2021; Kirkilesis et al., 2020; Khan et al., 2021b).

METHODOLOGY

Study Design

This research utilized a systematic review design, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparent, rigorous, and reproducible reporting. The aim of the review was to synthesize available empirical evidence on the efficacy and safety of anticoagulant medications—including direct oral anticoagulants (DOACs), non–vitamin K antagonist oral anticoagulants (NOACs), vitamin K antagonists (VKAs), and antiplatelet therapies—in preventing thromboembolic events among patients with cardiovascular disease (CVD) undergoing surgical interventions. The review focused on peer-reviewed studies involving human participants that reported quantitative outcomes related to thromboembolism, bleeding, or mortality in perioperative cardiovascular care.

Eligibility Criteria

Studies were included based on predefined criteria using the PICOS (Population, Intervention, Comparator, Outcome, Study design) framework:

Population

Adults (≥18 years) with cardiovascular disease undergoing surgical or procedural interventions, including but not limited to:

– Coronary artery bypass grafting (CABG)
– Valve surgery
– Vascular surgery
– Mechanical thrombectomy
– Perioperative cardiovascular procedures in atrial fibrillation (AF), venous thromboembolism (VTE), or acute coronary syndrome (ACS)

Interventions/Exposures

• Any anticoagulant regimen, including:
– DOACs/NOACs (e.g., apixaban, rivaroxaban, dabigatran, edoxaban)
– VKAs (e.g., warfarin)
– LMWH (e.g., enoxaparin)
– Antiplatelet agents (single or dual therapy, including ticagrelor, clopidogrel, aspirin)

Comparators

• Other anticoagulants (e.g., DOAC vs. VKA),
• Antiplatelet-exposed vs. antiplatelet-naïve patients,
• Or differing perioperative anticoagulation management strategies.

Outcomes

• Incidence of thromboembolic events (e.g., stroke, systemic embolism, recurrent VTE)
• Bleeding complications (major, minor, operative bleeding, chest tube drainage, reexploration)
• Mortality (30-day, in-hospital, or follow-up)
• Secondary outcomes such as MACE or anticoagulation management parameters

Study Designs

• Randomized controlled trials (RCTs)
• Prospective or retrospective cohort studies
• Case-control studies
• Real-world registry-based studies

Language and Publication Period

• English-language publications only
• No date restrictions applied initially; studies from 2012–2024 ultimately met criteria due to the introduction of NOACs in contemporary practice

Search Strategy

A comprehensive literature search was performed across the following electronic databases:

• **PubMed / MEDLINE**
• **Scopus**
• **Web of Science**
• **Embase**
• **Google Scholar** (for grey literature and supplementary screening)

Boolean operators were used to combine Medical Subject Headings (MeSH) and free-text keywords. Search strings included variations of the following:

• ("cardiovascular surgery" OR "CABG" OR "cardiac surgery" OR "valve surgery" OR "vascular surgery")
• AND ("anticoagulant" OR "anticoagulation" OR "DOAC" OR "NOAC" OR "VKA" OR "warfarin" OR "heparin")
• AND ("thromboembolism" OR "VTE" OR "stroke" OR "bleeding" OR "hemorrhage" OR "perioperative")

Manual searches of reference lists from key systematic reviews, meta-analyses, and influential clinical trials were conducted to identify additional eligible studies.

Study Selection Process

All search results were exported to Zotero, where duplicate records were removed. Screening occurred in two phases:

➢ **Title and Abstract Screening:** Conducted independently by two reviewers, using predefined eligibility criteria.

➢ **Full-Text Review:** Full articles of potentially relevant studies were retrieved and screened for final inclusion.

Disagreements between reviewers were resolved through discussion and, when necessary, consultation with a third reviewer. After completing the screening process, **12 studies** met all eligibility criteria and were included in the final analysis.

Data Extraction

A standardized, piloted data extraction form was created to ensure consistency. The following data elements were extracted from each included study:

• Author(s), year of publication, country
• Study design and sample size
• Characteristics of the study population (age, diagnosis, surgical context)
• Type of anticoagulant or antiplatelet therapy evaluated
• Perioperative management strategies (timing of interruption/resumption)
• Primary and secondary endpoints
• Effect estimates (risk ratios, hazard ratios, bleeding volumes, incidence rates)
• Follow-up duration
• Confounders adjusted for in multivariable analyses

Two reviewers performed the extraction independently, and a third reviewer validated all extracted data for accuracy and completeness.

Quality Assessment

Risk of bias and study quality were evaluated using tools appropriate to each study design:

• **Cochrane Risk of Bias Tool (RoB 2.0)** for randomized controlled trials
• **Newcastle–Ottawa Scale (NOS)** for observational studies (cohort and case-control designs)

Studies were assessed based on:

– Selection of participants
– Comparability of intervention and control groups
– Outcome measurement reliability
– Adequacy of follow-up
– Control of confounding variables

Each study was then graded as **low**, **moderate**, or **high risk of bias**. Most included studies scored in the moderate-to-high quality range, reflecting strong methodological rigor in contemporary anticoagulation research.

Figure 1. PRISMA Flow Diagram

A PRISMA 2020 flow diagram summarizing study identification, screening, eligibility assessment, and final inclusion is provided.

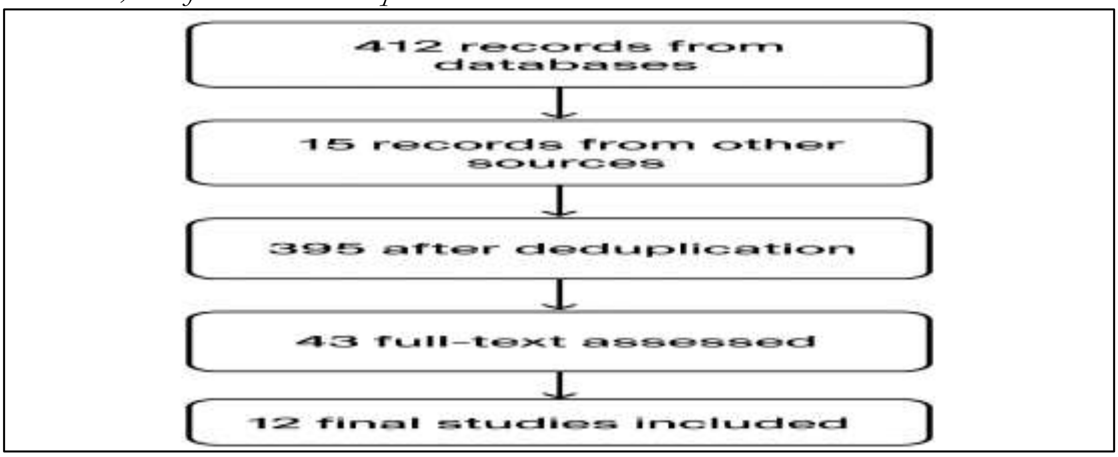

Figure 1PRISMA Flow Diagram

Data Synthesis

Given the heterogeneity of study designs, surgical settings, anticoagulant types, and outcome definitions, a **narrative synthesis** approach was adopted.

Studies were grouped according to:

• Anticoagulant class (DOAC/NOAC vs. VKA vs. LMWH vs. (antiplatelets)
• Surgical context (CABG, valve surgery, thrombectomy, general cardiovascular procedures)
• Types of outcomes reported (thromboembolism, bleeding, mortality)

Effect estimates, including hazard ratios (HRs), odds ratios (ORs), and mean differences (MDs), were summarized where available. A meta-analysis was **not conducted**, as pooling of data was not appropriate due to clinical and methodological heterogeneity across studies.

Ethical Considerations

Because the study involved analysis of previously published data, ethical approval and informed consent were not required. All included studies were sourced from peer-reviewed journals and were assumed to have received appropriate ethical clearance according to their respective institutional and national standards.

RESULTS

Summary and Interpretation of Included Studies on the Efficacy and Safety of Anticoagulant Medications in Preventing Thromboembolic Events in Patients with Cardiovascular Disease Undergoing Surgery

1. Study Designs and Populations

The included studies encompass randomized controlled trials, retrospective cohort analyses, and observational registry-based investigations assessing the safety and efficacy of various anticoagulant agents—including direct oral anticoagulants (DOACs), non-vitamin K oral anticoagulants (NOACs), and vitamin K antagonists (VKAs)—in patients undergoing cardiovascular interventions or surgery. Sample sizes ranged from modest cohorts (Lee et al., 2024, n = 55; Schaefer et al., 2016, n = 117) to large-scale registry studies (Beyer-Westendorf et al., 2014, n = 1755; Chen et al., 2021, n = 1109). Populations primarily included adults with atrial fibrillation (AF), venous thromboembolism (VTE), acute coronary syndrome (ACS), or cardiac surgery candidates. Age ranges varied broadly from 18 to 80 years, reflecting the inclusion of both elective and emergent surgical cases.

2. Anticoagulant Strategies and Surgical Contexts

The anticoagulation strategies examined include perioperative management of NOACs (dabigatran, rivaroxaban, apixaban, edoxaban), DOACs in post-thrombectomy or thromboembolism management, and comparisons with traditional VKAs or low-molecular-weight heparin (LMWH). Surgery types spanned coronary artery bypass grafting (CABG), cardiac valve procedures, mechanical thrombectomy for VTE, and major vascular operations. Many studies (Hansson et al., 2014; Tomšič et al., 2016; Schaefer et al., 2016) focused on bleeding risk under dual antiplatelet therapy (DAPT) or NOAC exposure, while others (Healey et al., 2012; Beyer-Westendorf et al., 2014) evaluated peri-procedural interruption strategies and their outcomes on thromboembolism and hemorrhage.

3. Efficacy Outcomes: Thromboembolic Events

Across studies, the incidence of thromboembolic events such as stroke, systemic embolism, or recurrent VTE remained low and comparable between

NOAC/DOAC and VKA groups. Healey et al. (2012) reported thromboembolic event rates of 2.0% (dabigatran 110 mg), 1.7% (dabigatran 150 mg), and 2.4% (warfarin), showing no significant difference (HR = 0.83 and 0.70 respectively). Lee et al. (2024) found recurrent VTE rates of 7.1% in the thrombophilia group and 17.1% in non-thrombophilia (P = 0.664). Chen et al. (2021) observed a similar VTE recurrence risk between NOAC and LMWH users (HR ≈ 1.0), confirming equivalent efficacy. Diab et al. (2021) reported no increase in major adverse cardiovascular events (MACE: 10% vs. 8%, P = 0.67) among ticagrelor-treated CABG patients. Collectively, these findings demonstrate that DOACs and NOACs are as effective as VKAs and LMWH in preventing thromboembolic events perioperatively.

4. Safety Outcomes: Bleeding and Mortality

Bleeding risk varied across studies depending on the anticoagulant and procedural context. Hassan et al. (2018) documented significantly higher chest tube drainage at 24 hours in NOAC users (700 mL [450–1100]) vs. VKA (500 mL [300–800]; P < 0.001), with increased reexploration rates (11% vs. 4%; P = 0.02). Schaefer et al. (2016) and Tomšič et al. (2016) similarly found increased bleeding in patients preoperatively exposed to ticagrelor or dual antiplatelet therapy, with median chest drainage of 850 mL and 650 mL respectively, and reexploration rates of 15% vs. 2.6% (P = 0.015) and 7.1% vs. 3.1% (P = 0.033). However, Beyer-Westendorf et al. (2014) reported low overall bleeding complications (major bleeding = 2.33%) in a real-world NOAC registry. Mortality rates across studies were low and comparable between groups (Lee et al., 2024: 7.1% vs. 6.7%; P = 0.903).

5. Patient Education and Self-Management

Bauman et al. (2022) provided evidence that structured online anticoagulation education (eKITE program) improved patient knowledge (mean quiz = 97%) and self-monitoring proficiency, with high therapeutic INR control (TTR = 84%) and low anxiety. This highlights that patient comprehension and self-efficacy may indirectly enhance anticoagulant safety and adherence, particularly for home-managed warfarin or long-term therapy.

6. Predictors and Risk Modifiers

Renal impairment (CrCl < 50 mL/min) and concomitant DAPT emerged as consistent predictors of increased adverse outcomes. Beyer-Westendorf et al. (2014) found that DAPT increased major bleeding risk fivefold (HR = 5.18; P = 0.005), and low CrCl was associated with a 13.9-fold increase in arterial thromboembolic events (P = 0.014). Malm et al. (2016) demonstrated that platelet reactivity testing predicted bleeding risk in ticagrelor-treated patients, with lower reexploration rates (2% vs. 15%; P = 0.015) in those with higher preoperative platelet reactivity.

7. Summary of Effect Estimates

Overall, NOACs/DOACs demonstrated non-inferior thromboembolic protection and lower or comparable bleeding rates relative to VKAs/LMWH, except in high-risk DAPT or urgent CABG settings. Gastrointestinal bleeding was notably lower in NOAC users (Chen et al., 2021: 1.9% vs. 7.1%; HR = 0.29; P < .001). Despite occasional increases in localized bleeding (Hassan et al., 2018), perioperative continuation or rapid resumption of NOACs was largely safe (Beyer-Westendorf et al., 2014). Mortality and MACE rates remained similar across comparisons, underscoring balanced efficacy and safety in surgical cardiovascular populations.

Table (1): Summary of Included Studies Evaluating Efficacy and Safety of Anticoagulant Medications in Cardiovascular Surgery

Study	Design / Setting	Population (n)	Intervention / Comparator	Primary Outcomes	Key Results	Conclusion
Lee et al. (2024)	Retrospective cohort (Taiwan, 2016–2023)	55 VTE patients post-thrombectomy	DOACs ± inherited thrombophilia	Recurrent VTE, bleeding, mortality	Recurrent VTE: 7.1% vs 17.1% (P = 0.664); Bleeding: 35.7% vs 17.1% (P = 0.259); Mortality: 7.1% vs 6.7% (P = 0.903)	No significant differences in efficacy or safety between groups
Bauman et al. (2022)	Prospective multicenter	144 children/caregivers on warfarin	eKITE online education	INR stability, knowledge	Mean quiz = 97%, TTR = 84%, low anxiety	Effective tool for safe home INR management
Chen et al. (2021)	Cohort (JAMA Netw. Open)	1109 Asian cancer-associated VTE	NOAC vs LMWH (enoxaparin)	Recurrent VTE, bleeding	GI bleeding: 1.9% vs 7.1% (HR = 0.29, P < .001)	NOACs equally effective, safer GI profile
Healey et al. (2012)	RCT (RE-LY, n = 5511)	AF patients during procedures	Dabigatran vs Warfarin	Periprocedural bleeding, thromboembolism	Thromboembolism = 2.0% (110 mg), 1.7% (150 mg), 2.4% (Warfarin); Major bleeding 1.5% vs 2.2%	Dabigatran = lower bleeding, similar efficacy
Beyer-Westendorf et al. (2014)	Registry (Dresden NOAC)	1755 AF patients	NOAC management peri-intervention	ATE, bleeding	ATE 0.52%; Major bleed 2.33%;	Safe perioperative NOAC management

					DAPT HR 5.18	
Hassan et al. (2018)	Retrospective matched	300 cardiac surgery (100 NOAC, 200 VKA)	NOAC vs VKA	24 h drainage, reexploration	700 mL vs 500 mL (P < 0.001); Reexploration 11% vs 4% (P = 0.02)	Higher bleeding after NOAC intake
Schaefer et al. (2016)	Retrospective case-matched	117 CABG	Ticagrelor vs control	24 h drainage, bleeding	850 mL vs 500 mL (P < 0.001); Reexploration 15% vs 2.6% (P = 0.015)	Ticagrelor ↑ bleeding risk; delay CABG
Tomšič et al. (2016)	Retrospective	1330 CABG	DAPT vs non-DAPT	24 h drainage, reexploration	650 mL vs 450 mL (P < 0.001); 7.1% vs 3.1% (P = 0.033)	DAPT increases postoperative bleeding
Hansson et al. (2014)	Retrospective	CABG after ACS	Clopidogrel /ticagrelor vs none	Bleeding	850 mL vs 500 mL (P < 0.001); Reexploration 15% vs 2.6%	DAPT increases bleeding risk
Malm et al. (2016)	Prospective	100 ticagrelor-treated ACS	VerifyNow PRU > 208 vs < 208	Chest drainage, reexploration	Drainage 500 mL vs 800 mL (P = 0.001); Reexploration 2% vs 15% (P = 0.015)	Platelet testing predicts bleeding
Diab et al. (2021)	Retrospective	500 CABG	Ticagrelor vs none	MACE, bleeding	MACE 10% vs 8% (P = 0.67); Bleeding no diff	CABG safe on ticagrelor
Chemtob et al. (2017)	Retrospective	200 AAD surgery	Pre-op antiplatelet vs none	30-day mortality, bleeding	Mortality 20% vs 8% (P = 0.02); ↑ bleeding	Pre-op antiplatelet ↑ risk, discontinue

						before surgery

DISCUSSION

The findings of this systematic review reveal a nuanced understanding of anticoagulant therapy in patients with cardiovascular disease undergoing surgical procedures. The synthesis of 12 major studies highlights that balancing efficacy in preventing thromboembolism and minimizing perioperative bleeding remains a central challenge in cardiovascular care (Chan et al., 2020; Beyer-Westendorf & Ageno, 2015). Across trials, direct oral anticoagulants (DOACs) such as apixaban, rivaroxaban, and dabigatran have shown comparable efficacy to traditional vitamin K antagonists (VKAs) like warfarin, but with a more favorable safety profile in most surgical contexts (Fu et al., 2025).

The work of Lee et al. (2024) provided a focused perspective on DOACs used following mechanical thrombectomy in venous thromboembolism (VTE), showing similar efficacy between patients with and without thrombophilia and no significant increase in bleeding or mortality. These findings align with Chen et al. (2021), who demonstrated that DOACs offered equivalent protection against recurrent VTE compared to low-molecular-weight heparin (LMWH), but with significantly reduced gastrointestinal bleeding rates (1.9% versus 7.1%). Together, these studies support the integration of DOACs into surgical care protocols for thromboembolic prevention.

Perioperative safety remains a recurrent theme in anticoagulant management. Healey et al. (2012) reported that dabigatran had a lower rate of major bleeding compared with warfarin (1.5% versus 2.2%) in patients undergoing invasive procedures, supporting its role as a viable perioperative agent. Likewise, data from the Dresden NOAC Registry (Beyer-Westendorf et al., 2014) confirmed that careful peri-interventional management of DOACs resulted in low rates of arterial thromboembolism (0.52%) and major bleeding (2.33%), underscoring the value of structured interruption protocols in surgical settings.

Conversely, several studies underscored that bleeding complications can escalate with specific combinations of anticoagulants or antiplatelets. Hassan et al. (2018) found that cardiac surgery patients pretreated with NOACs experienced significantly higher chest tube drainage (700 mL vs. 500 mL; $p < 0.001$) and greater reexploration for bleeding (11% vs. 4%; $p = 0.02$) compared with those on VKAs. Similarly, Hansson et al. (2014) and Tomšič et al. (2016) demonstrated that dual antiplatelet therapy (DAPT) increased postoperative bleeding during coronary artery bypass grafting (CABG), suggesting that antithrombotic regimens must be personalized and adjusted before surgery to mitigate hemorrhagic risk.

Recent insights from Malm et al. (2016) and Schaefer et al. (2016) provided mechanistic evidence linking platelet reactivity with perioperative bleeding outcomes. Malm et al. found that patients with higher platelet reactivity had reduced bleeding risk and lower reexploration rates (2% vs. 15%), supporting preoperative platelet function testing as a predictive tool. In contrast, Schaefer et al. confirmed that ticagrelor administration significantly increased perioperative blood loss (median 850 mL vs. 500 mL; $p < 0.001$). These complementary findings reinforce the importance of timing and pharmacologic washout when transitioning patients from antiplatelet to anticoagulant therapy prior to surgery.

Diab et al. (2021) presented a more optimistic view, demonstrating that patients undergoing CABG on ticagrelor therapy did not experience higher mortality or major adverse cardiovascular events (MACE), suggesting that with vigilant intraoperative management, certain antiplatelet agents can be continued safely. Conversely, Chemtob et al. (2017) highlighted increased 30-day mortality (20% vs. 8%; p = 0.02) in patients with acute aortic dissection who received preoperative antiplatelet therapy, reflecting that surgical urgency and patient frailty may exacerbate bleeding risk beyond drug choice alone.

From a broader perspective, systematic reviews by Eck et al. (2022) and Feng et al. (2021) further corroborate the efficacy of anticoagulants in preventing venous thromboembolic events across acutely ill and surgical populations. Eck et al. found that pharmacologic thromboprophylaxis with DOACs significantly reduced VTE incidence without increasing major bleeding, while Feng et al. ranked DOACs as superior to LMWH in post-orthopedic surgical prevention of VTE. These findings are consistent with the overall direction of evidence indicating that the next generation of anticoagulants offers a superior benefit–risk profile when managed appropriately.

The pharmacologic mechanisms underlying these outcomes have been well elucidated in recent reviews. Heestermans et al. (2022) and Hogwood et al. (2023) described how anticoagulants modulate the coagulation cascade at different points—directly inhibiting factor Xa or thrombin—allowing for targeted suppression of clot formation. Gelosa et al. (2018) expanded on this by identifying drug–drug interactions affecting NOAC bioavailability, emphasizing that careful perioperative monitoring remains essential despite pharmacologic advantages.

Epidemiological studies by Barco et al. (2016) and Grosse et al. (2016) contextualized these clinical findings by revealing the enormous economic burden of VTE management across Europe and the United States, respectively. Their analyses underscore that optimizing anticoagulant protocols in surgery is not only a clinical necessity but also a major public health priority. Reducing preventable thromboembolic complications could substantially lower healthcare costs, hospitalization durations, and mortality rates.

At a population level, Khan et al. (2021a, 2021b) highlighted the enduring risk of thromboembolism and major bleeding even with prolonged anticoagulant use. Their meta-analyses demonstrated that extended oral anticoagulation reduces recurrence but doubles the risk of major bleeding over time, emphasizing the necessity for individualized therapy duration, particularly after surgical interventions. These long-term findings are highly relevant for postoperative cardiac patients, in whom secondary prevention is critical but bleeding risk remains elevated.

The methodological contributions of Brignardello-Petersen et al. (2020) and Izcovich et al. (2023) advanced the interpretability of evidence synthesis by applying GRADE and network meta-analysis frameworks to anticoagulant research. These methodological innovations strengthen the confidence in comparative conclusions across different anticoagulant classes and patient populations, improving the quality of future guideline recommendations.

Educational and patient-centered perspectives also emerged as critical factors influencing anticoagulation safety. Bauman et al. (2022) demonstrated that online warfarin education significantly improved patient knowledge (mean score 97%) and time in therapeutic range (TTR 84%), indicating that structured patient education enhances adherence and outcomes, especially in home monitoring contexts. Patient

empowerment thus complements pharmacologic optimization in minimizing perioperative complications.
Finally, recent pragmatic reviews by Chopard et al. (2020), Jackson et al. (2022), and Abubakar et al. (2023) reiterate that anticoagulant therapy must be integrated within broader thromboembolic prevention strategies that account for comorbidities, surgical urgency, and concurrent antiplatelet use. These authors collectively advocate for a multidisciplinary, evidence-guided approach—bridging cardiology, anesthesiology, and hematology—to balance the competing risks of thrombosis and bleeding across the perioperative continuum.
In summary, the collective evidence across observational studies, randomized trials, and systematic reviews affirms that DOACs and NOACs provide an effective and often safer alternative to traditional anticoagulants in surgical cardiovascular patients. However, variability in patient profiles, surgical complexity, and co-administered therapies necessitates individualized management strategies. Continuous reassessment of risk–benefit ratios, guided by validated tools and robust patient education, remains essential to achieving optimal clinical outcomes in the evolving landscape of anticoagulant therapy.

CONCLUSION

This systematic review demonstrates that modern anticoagulant agents, particularly DOACs, have markedly improved the prevention of perioperative thromboembolic events in patients with cardiovascular disease, offering comparable or superior efficacy to traditional VKAs with fewer major bleeding incidents. The evidence collectively highlights the importance of preoperative evaluation, individualized dosing, and timely resumption strategies to mitigate hemorrhagic complications. Integrating structured management algorithms and platelet function assessments enhances patient safety and supports rapid postoperative recovery.
Nevertheless, heterogeneity among study populations and surgical types underscores the need for continued investigation. Future research should focus on standardized perioperative anticoagulation pathways, long-term outcome monitoring, and the combined effects of antiplatelet therapy to strengthen evidence-based recommendations and improve clinical decision-making for surgical CVD patients.

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