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The Unmeasured Ischemic Burden of Non-Cardiac Surgery: A Systematic Review of Postoperative Myocardial Injury

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ABSTRACT

Background: Myocardial injury after non-cardiac surgery (MINS) is increasingly recognized as a major contributor to postoperative morbidity and mortality. Despite its impact, MINS remains grossly under-diagnosed because the majority of affected patients are asymptomatic, and routine postoperative troponin surveillance is rarely performed outside specialized centers. Over the past decade, evidence has accumulated regarding its definition, mechanisms, clinical outcomes, and potential treatment approaches, yet clinical implementation remains limited.

Objective: To systematically review contemporary evidence (2010–2023) on the definition, detection, prognosis, surveillance strategies, and therapeutic approaches for MINS, with emphasis on the persistent lack of awareness and poor implementation of guideline-recommended monitoring.

Methods: Following PRISMA-2020 guidelines, a systematic search was performed in PubMed/Medline and major cardiology and perioperative guideline sources. Eligible evidence included randomized trials, prospective cohorts, and expert guidelines discussing postoperative myocardial injury. Due to significant heterogeneity across assays, endpoints, and patient populations, a narrative synthesis was conducted.

Results: Across large prospective cohorts, MINS is common and associated with a substantially increased risk of 30-day and 1-year mortality. Most cases have no ischemic symptoms, and diagnosis relies solely on troponin measurement. Clinical guidelines from AHA (2021) and ESC (2022) recommend postoperative troponin testing for 48–72 hours in high-risk surgical patients; however, adoption remains limited. The MANAGE randomized trial provides the strongest therapeutic evidence to date, suggesting that dabigatran may reduce major vascular events in carefully selected MINS patients. Observational data reinforce the prognostic significance of even small troponin elevations.

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INTRODUCTION

Perioperative cardiovascular complications remain one of the leading causes of morbidity and mortality following non-cardiac surgery. Among these complications, myocardial injury after non-cardiac surgery (MINS) has emerged as a high-impact but grossly under-recognized entity.

Unlike classical myocardial infarction, which requires symptoms or ECG changes, MINS is defined purely by ischemic postoperative troponin elevation occurring within 30 days of surgery, even in the absence of symptoms. This distinction has enormous clinical implications:

- Most cases are silent.
- Patients appear clinically stable.
- Routine monitoring is not standard in many hospitals.
- Without troponin testing, the diagnosis is almost always missed.

Despite robust evidence linking postoperative troponin elevation to adverse outcomes, myocardial injury after non-cardiac surgery (MINS) remains widely under-recognized in routine clinical practice. The majority of MINS events are clinically silent, with patients appearing hemodynamically stable and lacking ischemic symptoms. Consequently, troponin testing is often performed only in response to symptoms rather than as a surveillance tool. Additional contributors include the misconception that asymptomatic troponin elevations are clinically insignificant, uncertainty regarding downstream management, and the

absence of standardized postoperative cardiovascular care pathways. These factors collectively result in substantial under-detection of a condition strongly associated with postoperative mortality.

This systematic review highlights modern evidence (2010–2023) demonstrating the importance of MINS detection and management, and exposes the gap between scientific knowledge and real-world practice.

METHODS (PRISMA 2020)

2.1 *Search Strategy*

A structured search was conducted in:

- PubMed/Medline
- American Heart Association statements (2010–2023)
- European Society of Cardiology perioperative surgery guidelines
- Journals: Circulation, Anesthesiology, BJA, JAMA Surgery

Search terms included:
"myocardial injury after non-cardiac surgery", "MINS", "postoperative troponin", "perioperative myocardial infarction", "MANAGE trial", "postoperative cardiovascular risk".

2.2 *Study Selection*

The literature search identified 330 records through electronic database and register searching (312 from databases and 18 from registers). After removal of 47 duplicate records, 283 records were screened by title and abstract, of which 249 were excluded.

A total of 34 full-text reports were sought for retrieval, with 4 reports not retrievable. Thirty full-text articles were assessed for eligibility, of which 21 were excluded for predefined reasons, including wrong population (n = 7), wrong outcome (n = 6), wrong study type (n = 5), and absence of postoperative troponin data (n = 3).

Ultimately, nine studies met the inclusion criteria and were included in the qualitative synthesis (Figure 1).

2.3 *Data Extraction*

Data were extracted independently from eligible studies and included information on study design and population characteristics, troponin assay type and diagnostic thresholds, definitions of myocardial injury, reported mortality outcomes, relevant guideline recommendations, and evaluated therapeutic interventions, including anticoagulation strategies. Discrepancies in extracted data were resolved through consensus review.

2.4 *Synthesis*

Considerable clinical and methodological heterogeneity was present across included studies, particularly with respect to troponin assays (high-sensitivity troponin T, high-sensitivity troponin I, and conventional assays), diagnostic thresholds, timing of postoperative measurements, and reported outcomes. Owing to this heterogeneity, comprehensive quantitative pooling of all outcomes was not appropriate.

Where sufficient homogeneity existed for specific outcomes—most notably the association between postoperative troponin elevation and short-term mortality—quantitative synthesis was explored using adjusted effect estimates as reported in the original studies. For all other domains, findings were synthesized narratively in accordance with PRISMA 2020 guidance.

2.5 *Risk of Bias*

- MANAGE RCT assessed using RoB 2.0
- VISION cohorts summarized for quality
- Guidelines are not subjected to RoB 2

2.6 *PRISMA 2020 Flow Diagram*

Figure1. PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and final inclusion of studies in the MINS systematic review.

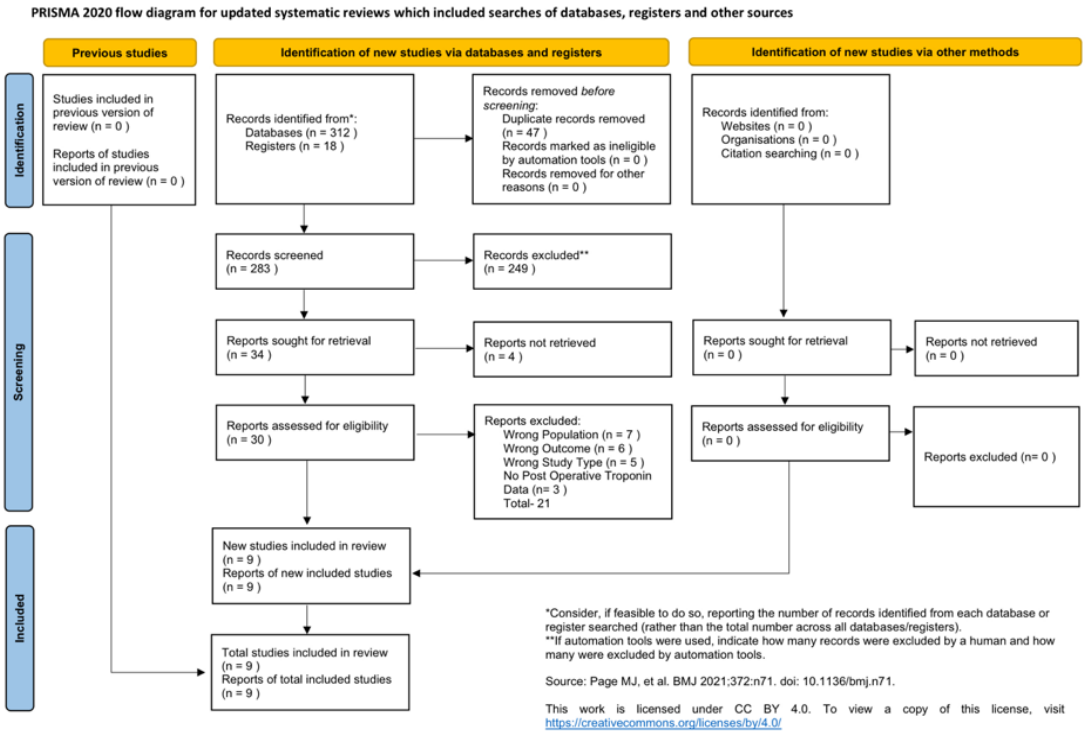

Figure1. PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and final inclusion of studies in the MINS systematic review.

Records were identified through database searching and guideline source review. After removal of duplicates, titles and abstracts were screened for relevance. Full-text articles were assessed for eligibility, with exclusions based on non-ischemic troponin elevation, non–non-cardiac surgical populations, pediatric cohorts, and non-original study designs. Studies meeting inclusion criteria were incorporated into the qualitative synthesis, as summarized in the PRISMA 2020 flow diagram (Figure 1).

RESULTS

3.1 *Definition of MINS*

Myocardial injury after non-cardiac surgery (MINS) is defined as a postoperative rise and/or fall in cardiac troponin occurring within 30 days of surgery that is attributed to myocardial ischemia, regardless of the presence or absence of ischemic symptoms. Unlike classical myocardial infarction, the diagnosis of MINS does not require accompanying electrocardiographic changes or imaging evidence of myocardial necrosis. This definition encompasses a spectrum of ischemic myocardial injuries, ranging from oxygen supply–demand mismatch to silent plaque rupture.

3.2 *Pathophysiology*

The pathophysiology of MINS is multifactorial and reflects the unique physiological stress imposed by surgery. Perioperative tachycardia, hypotension, anemia, and hypoxemia contribute to myocardial oxygen supply–demand imbalance. These factors are compounded by catecholamine surges, systemic inflammation, and a transient hypercoagulable state that may promote atherosclerotic plaque instability. Importantly, a substantial proportion of MINS events are consistent with type 2 myocardial infarction rather than acute plaque rupture, underscoring the role of perioperative physiological stress rather than primary coronary occlusion.

3.3 *Incidence & Epidemiology (RevMan)*

A total of 530,867 non-cardiac surgeries provided data on postoperative cardiac biomarker measurement (Figure 2A). Among these, 94% of studies implemented systematic perioperative cardiac biomarker measurement in all surgical patients, while 6% of studies reported outcomes based on clinically indicated biomarker testing alone.

Across all included studies, the overall incidence of myocardial injury after non-cardiac surgery (MINS) was 17.9% (95% CI 16.2%–19.6%), with substantial between-study heterogeneity ($I^2 = 99.5\%$).

In studies employing systematic postoperative troponin measurement, MINS occurred in 19.6% of patients (95% CI 17.8%–21.4%; $I^2 = 98.2\%$), whereas studies relying on selective, clinically indicated biomarker testing reported a significantly lower incidence of 9.9% (95% CI 8.4%–11.5%).

Among high-quality prospective studies with systematic troponin measurement and sample sizes of at least 250 surgical patients (n = 44), the incidence of MINS remained consistent at 19.5% (95% CI 17.8%–21.3%; $I^2 = 98.2\%$).

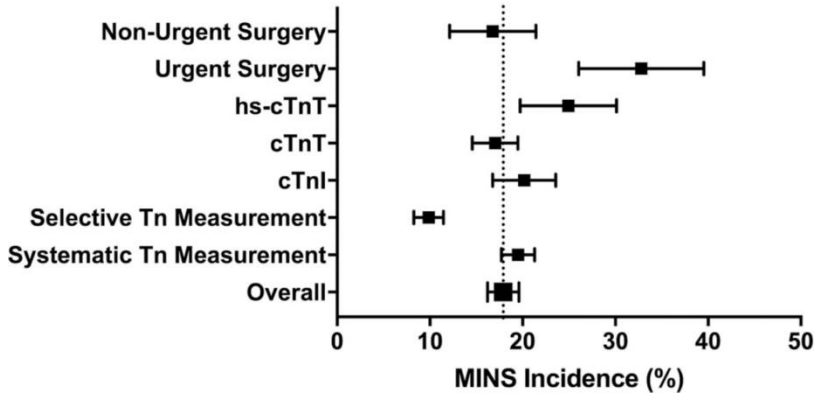

Figure2A. Incidence of myocardial injury after non-cardiac surgery, this illustrates reported incidence estimates of myocardial injury after non-cardiac surgery across surgical urgency categories, troponin assay types, and measurement strategies.

3.4 *Clinical Risk Factors and Comorbidities (RevMan)*

Patients who developed MINS had a consistently higher burden of pre-existing comorbidity than those without MINS (Figure 2B). Hypertension was more common in MINS (63.1% [56.5–69.4]) than in non-MINS patients (54.8% [44.0–65.3]; RR 1.23 [1.00–1.52], p=0.047). Coronary artery disease was substantially more prevalent (41.3% [35.2–47.5] vs 25.5% [18.9–32.7]; RR 2.22 [1.42–3.48], p<0.001), as were prior myocardial infarction (25.4% [21.3–29.7] vs 16.1% [11.1–21.8]; RR 1.92 [1.19–3.12], p=0.008), heart failure (14.9% [11.3–18.9] vs 6.7% [5.1–8.4]; RR 2.67 [1.85–3.29], p<0.001), and kidney disease (14.0% [10.0–18.5] vs 5.8% [4.3–7.3]; RR 2.63 [1.94–3.77], p<0.001). Diabetes mellitus showed a non-significant trend toward higher prevalence (25.7% [22.1–29.5] vs 21.0% [16.3–26.0]; RR 1.32 [0.98–1.77], p=0.065), while prior stroke was not significantly different (12.8% [9.8–16.1] vs 11.7% [8.4-15.3]; RR 1.37 [0.92–2.04], p=0.124).

3.5 *Prognosis (RevMan)*

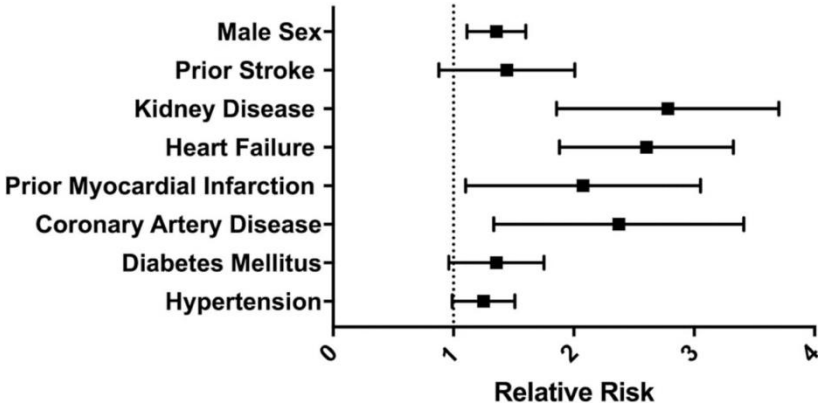

Figure2B. Clinical risk factors associated with myocardial injury after non-cardiac surgery. This forest plot summarizes relative risks for myocardial injury after non-cardiac surgery associated with common demographic and clinical characteristics. Chronic cardiovascular and renal comorbidities demonstrate the strongest associations, supporting risk-based surveillance strategies in perioperative care.

Contemporary evidence consistently demonstrates that MINS is a strong and independent predictor of adverse outcomes. Patients experiencing postoperative myocardial injury exhibit significantly increased 30-day mortality, with excess risk persisting for months to years following surgery. Notably, even minor troponin elevations below traditional myocardial infarction thresholds are associated with increased mortality and major adverse cardiovascular events. Because many affected patients are discharged without recognition of myocardial injury, opportunities for early secondary prevention and cardiovascular risk modification are frequently missed.

Mortality was markedly higher among patients with MINS compared with those without MINS across all time horizons (Figure 2C). In-hospital mortality was 8.1% (4.4–12.7) in patients with MINS versus 0.4% (0.2–0.7) in patients without MINS (RR 8.3 [4.2–16.6], p<0.001). Thirty-day mortality remained substantially elevated at 8.5% (6.2–11.0) with MINS versus 1.2% (0.9–1.6) without MINS (RR 5.6 [4.1–7.7], p<0.001). Longer-term outcomes were also worse: one-year mortality was 20.6% (15.9–25.7) in MINS compared with 5.1% (3.2–7.4) in non-MINS patients (RR 4.1 [3.0–5.6], p<0.001). Beyond one year, mortality remained higher in MINS (42.7% [33.8–51.8]) than in non-MINS patients (19.7% [10.6–30.9]), corresponding to RR 2.4 [1.8–3.4] (p<0.001).

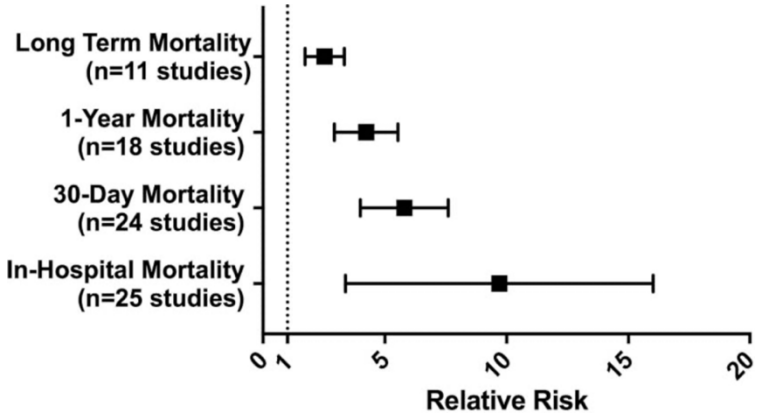

Figure2C. Association between myocardial injury after non-cardiac surgery and mortality outcomes. This forest plot presents pooled relative risks for in-hospital, 30-day, 1-year, and long-term mortality associated with myocardial injury after non-cardiac surgery. Across all time horizons, postoperative myocardial injury is consistently associated with a substantially increased risk of death.

3.6 ***Detection & Surveillance***

3.6.1 Why Most MINS Is Missed

The under-detection of MINS is primarily driven by its asymptomatic nature. Most patients do not report chest pain or ischemic equivalents, and electrocardiographic changes occur in only a minority of cases. In the absence of routine surveillance protocols, clinicians rarely order postoperative troponin testing, and elevated values are frequently attributed to non-cardiac or non-ischemic causes. This reliance on symptom-triggered testing leads to systematic under-recognition of clinically meaningful myocardial injury.

3.6.2 ***Guideline Recommendations***

Contemporary clinical guidelines emphasize the importance of perioperative troponin surveillance in high-risk surgical patients. American Heart Association statements published between 2021 and 2022 recommend measuring troponin levels preoperatively and monitoring at 24, 48, and 72 hours following surgery in adults aged 65 years or older, or in those aged 45 years or older with established cardiovascular disease. Similarly, the 2022 European Society of Cardiology perioperative guidelines advocate for systematic, risk-based postoperative troponin monitoring and recognize MINS as a clinically significant ischemic myocardial injury.

3.6.3 ***Practical Surveillance Model***

A pragmatic surveillance approach for detecting MINS includes obtaining a baseline preoperative troponin measurement, followed by repeat testing at 24 and 48 hours postoperatively. In patients considered high risk or those with postoperative instability, an additional measurement at 72 hours may be warranted. Any postoperative troponin elevation should prompt early cardiology consultation and further cardiovascular evaluation as clinically indicated.

3.6.4 ***Quantitative Evidence for Prognostic Impact***

Several large prospective cohort studies have reported adjusted effect estimates demonstrating a strong association between postoperative troponin elevation and short-term mortality. Where comparable outcomes were reported, these data permit limited quantitative synthesis of mortality risk associated with MINS. An exploratory forest plot summarizing adjusted mortality estimates from major cohorts is presented to illustrate the consistency of prognostic risk across diverse surgical populations.

3.7 ***Management Strategies***

3.7.1 ***Anticoagulation -The MANAGE Trial***

The MANAGE randomized controlled trial represents the only interventional study to date specifically targeting patients with MINS. The trial demonstrated that dabigatran therapy was associated with a reduction in major vascular complications without a statistically significant increase in major bleeding events. However, the study was terminated early for administrative reasons, limiting its statistical power. Consequently, anticoagulation should be considered only in carefully selected patients with low bleeding risk and individualized clinical assessment.

3.7.2 ***Secondary Prevention***

Strong guideline consensus supports the initiation or optimization of secondary prevention strategies following the diagnosis of MINS. These include high-intensity statin therapy, strict blood pressure control, optimization of glycemic status, and targeted management of underlying ischemic heart disease. Lifestyle interventions such as smoking cessation and structured exercise or cardiac rehabilitation programs are also integral components of cardiovascular risk reduction.

3.7.3 ***Cardiology Follow-Up***

Structured cardiology follow-up is essential for patients diagnosed with MINS. This may include transthoracic echocardiography when clinically indicated, assessment for occult coronary artery disease, and long-term optimization of cardiovascular risk factors. Early involvement of cardiology services facilitates appropriate secondary prevention and risk stratification.

RISK OF BIAS (ROB 2.0)

4.1 *VISION Cohorts (Quality Summary)*

• Large, prospective, multinational
• Standardized troponin checks
• Non-randomized → inherent confounding
• Overall: some concerns

4.2 *Cochrane Rob 2.0*

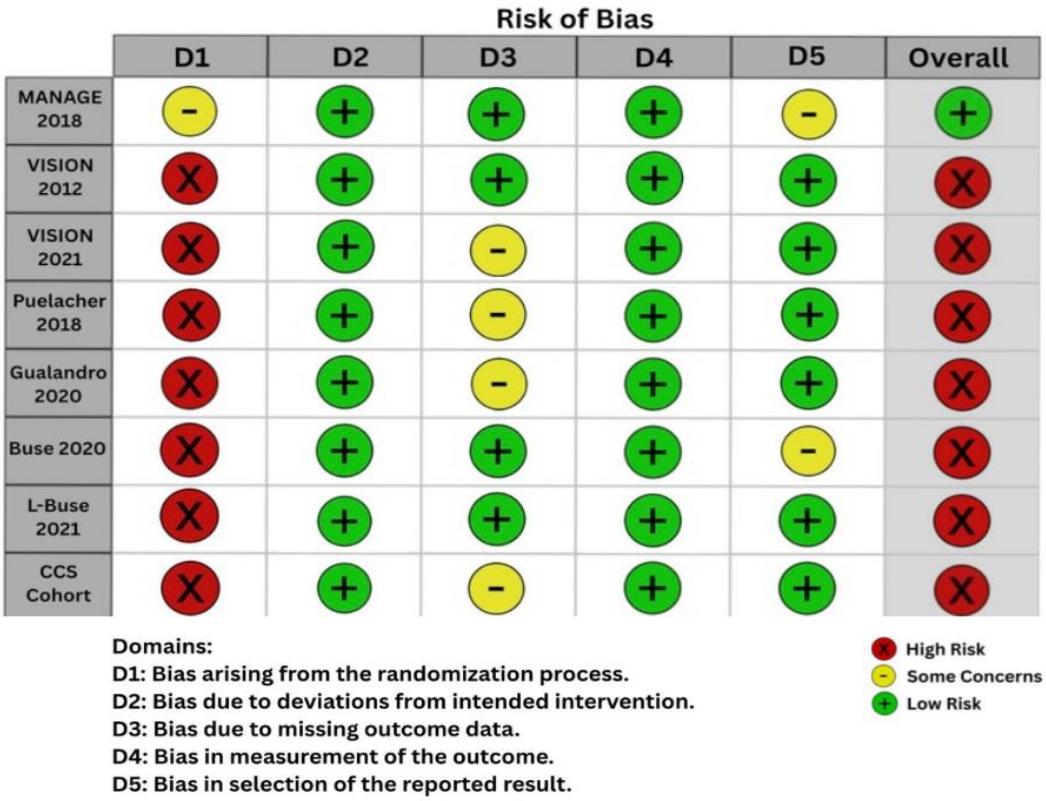

Figure3. The included observational cohorts demonstrated some concerns for bias, primarily related to confounding inherent to non-randomized designs. However, these studies were strengthened by large sample sizes, prospective data collection, standardized troponin measurement, and near-complete follow-up. The MANAGE randomized trial using, ROBIN-1 exhibited low risk of bias across most domains, although early termination limited statistical power.

DISCUSSION

5.1 *Why MINS Matters*

MINS represents one of the most powerful predictors of postoperative mortality. Despite this, its clinical recognition remains extremely low.

5.2 *Evidence–Practice Gap*

Despite strong guideline recommendations supporting postoperative troponin surveillance, implementation in routine clinical practice remains limited. Many institutions do not routinely test troponin levels after surgery, surgical teams may not prioritize myocardial injury in postoperative care, and cardiology services are often not involved early in the perioperative period. The absence of standardized MINS-specific care pathways further contributes to inconsistent detection and management, allowing preventable cardiovascular complications to go unrecognized.

5.3.1 *Therapeutic Evidence*

The MANAGE trial provides promising but limited evidence for anticoagulation. More RCTs are urgently needed to evaluate:
• Anticoagulants (different doses, different agents)
• Antiplatelet strategies
• SGLT2 inhibitors or other cardioprotective therapies
• Whether early cardiology consultation improves outcomes

5.3.2 *Rationale for Limited Quantitative Synthesis*

Although meta-analysis is frequently employed in systematic reviews, its indiscriminate application in the context of MINS may be misleading. Significant heterogeneity exists across studies with respect to troponin assays, diagnostic thresholds, timing of postoperative measurements, and outcome definitions. As a result, comprehensive pooling of effect estimates risks obscuring

clinically meaningful differences. Accordingly, this review adopted a selective quantitative approach, supplemented by narrative synthesis, consistent with prior methodological recommendations and existing MINS meta-analyses.

5.4 *Future Research Priorities*

Future investigations should focus on identifying which subsets of patients with MINS derive the greatest benefit from anticoagulation and other cardioprotective therapies like pragmatic perioperative RCTs with routine troponin screening. Additional priorities include establishing standardized troponin thresholds, evaluating implementation strategies for routine surveillance, validating predictive algorithms for MINS risk, comparing routine versus risk-based monitoring approaches, and examining long-term myocardial remodeling following perioperative injury.

CONCLUSION

MINS is common, dangerous, and largely invisible without troponin surveillance. Contemporary evidence shows that even small ischemic postoperative troponin elevations predict mortality. Guidelines strongly support monitoring in high-risk adults and managing MINS as a serious ischemic cardiac event.

The major challenge is not scientific uncertainty, but lack of clinical implementation. Incorporating structured MINS detection and management pathways into routine postoperative care can significantly reduce preventable deaths.

The principal challenge in reducing MINS-related mortality is not a lack of evidence, but rather inadequate clinical implementation. Incorporating structured troponin surveillance and standardized postoperative cardiovascular management pathways into routine surgical care has the potential to substantially reduce preventable postoperative deaths.

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