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PERIOPERATIVE GLYCEMIC CONTROL AND POSTOPERATIVE COMPLICATIONS IN DIABETIC PATIENTS UNDERGOING GENERAL ANESTHESIA: A SYSTEMATIC REVIEW

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Abstract

Background: Diabetic patients undergoing general anesthesia face heightened risks of postoperative complications, in part due to dysregulated glycemic control. The influence of perioperative glucose management on surgical outcomes remains clinically significant but variably defined across the literature.

Objective: To systematically review the association between perioperative glycemic control and postoperative complications in diabetic patients undergoing general anesthesia, with emphasis on hyperglycemia, hypoglycemia, glycemic variability, and protocol-based management.

Methods: This review followed PRISMA 2020 guidelines. Databases including PubMed, Scopus, Embase, Web of Science, and Google Scholar were searched for peer-reviewed studies (2010–2024) examining adult diabetic patients undergoing surgery with general anesthesia. Eligible designs included randomized controlled trials, cohort studies, and case-control studies reporting postoperative complications in relation to perioperative glycemic measures. Quality appraisal was performed using the Newcastle-Ottawa Scale and the Cochrane Risk of Bias Tool.

Results: Twenty studies met eligibility criteria. Hyperglycemia (≥180 mg/dL) was consistently associated with increased risk of wound infections, systemic complications, and mortality. HbA1c was predictive of adverse outcomes, while perioperative glycemic variability independently prolonged length of stay and increased mortality. Hypoglycemia, though less common, significantly elevated the risk of severe surgical complications. Structured glycemic management protocols reduced ICU hyperglycemia, shortened time to target glucose, and lowered insulin requirements compared with routine care.

Conclusion: Perioperative glycemic control is a critical, modifiable determinant of surgical outcomes in diabetic patients. Moderate glucose targets (140–180 mg/dL), preoperative optimization, and standardized perioperative protocols are recommended. Future multicenter trials and continuous glucose monitoring studies are needed to refine individualized management strategies.

Keywords: Perioperative glycemic control; diabetes mellitus; postoperative complications; general anesthesia; surgical outcomes; hyperglycemia; hypoglycemia; HbA1c; wound infection; glycemic variability

INTRODUCTION

Diabetes mellitus (DM) is a major global health concern, currently affecting more than 500 million people worldwide, with projections indicating further increases in prevalence over the next decades. The perioperative period poses particular challenges for patients with diabetes due to altered glucose metabolism, impaired immune response, and increased risk of complications when undergoing general anesthesia. Hyperglycemia, hypoglycemia, and glycemic variability are all implicated as determinants of surgical outcomes, making perioperative glycemic control an important focus of modern perioperative medicine (Umpierrez et al., 2017).

Perioperative hyperglycemia has consistently been associated with adverse outcomes across a variety of surgical settings, including infections, cardiovascular events, and mortality. Even transient increases in blood glucose during surgery have been shown to worsen postoperative morbidity in both diabetic and non-diabetic patients. Elevated plasma glucose impairs neutrophil function, promotes inflammatory cascades, and negatively affects wound healing, thereby predisposing patients to surgical site infections (SSI) and delayed recovery (Kotagal et al., 2015).

While hyperglycemia has long been the primary focus, perioperative hypoglycemia is also increasingly recognized as a significant threat. Hypoglycemia may occur as a result of intensive insulin therapy or fasting, and it has been linked with severe cardiovascular complications, neurological injury, and increased mortality. The dual risks of hyperglycemia and hypoglycemia underscore the importance of balanced glucose management during general anesthesia (Kwon et al., 2013).

Glycosylated hemoglobin (HbA1c) is widely used as an indicator of long-term glycemic control and has been explored as a predictor of perioperative risk. Elevated HbA1c levels (>7–8%) have been correlated with higher rates of postoperative complications, including infections, cardiovascular events, and longer hospital stays. A recent analysis of emergency general surgery patients demonstrated that HbA1c independently predicted postoperative morbidity and mortality, supporting its role as a valuable risk stratification tool (Jehan et al., 2018).

Glycemic variability, reflecting fluctuations in glucose levels rather than absolute values, has emerged as an independent risk factor for adverse surgical outcomes. Evidence suggests that intraoperative and postoperative glucose variability may be more predictive of complications than mean glucose levels alone. Patients with wide glucose excursions are at significantly greater risk of infection, prolonged length of stay, and mortality compared to those with stable perioperative glucose control (Krinsley et al., 2013).

The perioperative environment further complicates glycemic management. General anesthesia alters metabolic responses, stress hormones, and insulin sensitivity, contributing to perioperative hyperglycemia even in non-diabetic patients. Anesthesia-related suppression of sympathetic nervous system activity can also mask hypoglycemic symptoms, delaying detection and intervention. These factors necessitate vigilant perioperative glucose monitoring strategies (Frisch et al., 2010).

Several professional guidelines advocate for moderate glycemic control rather than intensive insulin regimens, given the risks associated with hypoglycemia. The Society for Ambulatory Anesthesia and the American Diabetes Association recommend maintaining perioperative blood glucose between 140 and 180 mg/dL for most patients, acknowledging the delicate balance between minimizing hyperglycemia-related complications and avoiding hypoglycemia (Rajan et al., 2021).

Despite growing consensus on the importance of perioperative glycemic management, significant gaps remain in understanding optimal strategies for diabetic patients undergoing general anesthesia. Variability in study designs, target glucose ranges, and outcome measures has contributed to inconsistent findings. Emerging evidence, however, supports that both preoperative optimization of HbA1c and intraoperative vigilance to prevent fluctuations in blood glucose are critical determinants of postoperative outcomes (Jehan & Joseph, 2019; Gandhi et al., 2007).

METHODOLOGY

Study Design

This study employed a systematic review methodology, adhering to the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines** for transparency and reproducibility. The primary objective was to synthesize empirical evidence examining the association

between perioperative glycemic control and postoperative complications in diabetic patients undergoing general anesthesia. Emphasis was placed on peer-reviewed research evaluating blood glucose management strategies, glycemic variability, and their relationships to surgical outcomes in both elective and emergency procedures.

Eligibility Criteria

Studies were included if they met the following criteria:

- **Population**: Adults (≥18 years) with diagnosed type 1 or type 2 diabetes mellitus undergoing surgery under general anesthesia.
- **Interventions/Exposures**: Perioperative glycemic management strategies, including routine glucose monitoring, insulin therapy protocols, or assessment of glycemic variability (hyperglycemia, hypoglycemia, or HbA1c).
- **Comparators**: Patients with different glycemic control levels (e.g., intensive vs. standard management, controlled vs. uncontrolled diabetes, or diabetics vs. non-diabetics).
- **Outcomes**: Postoperative complications such as surgical site infections, delayed wound healing, cardiovascular and respiratory events, thromboembolism, hospital length of stay, readmission, and mortality.
- **Study Designs**: Randomized controlled trials (RCTs), prospective or retrospective cohort studies, case-control studies, and cross-sectional analyses.
- **Language**: Only studies published in English were considered.
- **Publication Period**: 2010 to 2025, to ensure the inclusion of contemporary and clinically relevant findings.

Search Strategy

A structured search was conducted across major databases including **PubMed, Embase, Web of Science, Scopus, and CINAHL**, supplemented by Google Scholar for grey literature. The search was last updated in **September 2025**. The following Boolean operators and keywords were applied in various combinations:

- ("perioperative glycemic control" OR "perioperative glucose management" OR "blood glucose variability")
- AND ("general anesthesia" OR "non-cardiac surgery" OR "abdominal surgery" OR "orthopedic surgery")
- AND ("postoperative complications" OR "surgical site infections" OR "mortality" OR "morbidity")
- AND ("diabetes mellitus" OR "type 2 diabetes" OR "type 1 diabetes").

Additionally, manual searches of reference lists from relevant reviews and primary studies were performed to identify potentially missed publications.

Study Selection Process

All search results were imported into **Zotero** for reference management. Duplicate entries were removed prior to screening. Two independent reviewers screened titles and abstracts for eligibility. Full texts of potentially relevant studies were then assessed against the predefined inclusion criteria. Disagreements at any stage were resolved through discussion or adjudication by a third reviewer. The selection process is documented in a **PRISMA 2020 flow diagram (Figure 1)**, detailing numbers of records identified, screened, excluded, and included.

Data Extraction

A standardized data extraction form was developed and pilot-tested. The following information was collected from each included study:

- Author(s), publication year, and country of study
- Study design and sample size
- Population characteristics (age, gender, diabetes type, comorbidities)
- Type of surgery and anesthesia used
- Glycemic assessment methods (perioperative BG monitoring, HbA1c, variability indices)
- Interventions or protocols applied (e.g., insulin infusion protocols, standard care)
- Postoperative complications and outcome measures
- Statistical analyses and effect estimates (e.g., odds ratios, hazard ratios, relative risks)
- Confounders controlled for in analysis

Data extraction was conducted independently by two reviewers and cross-checked by a third reviewer for accuracy and completeness.

Quality Assessment

The methodological quality and risk of bias of included studies were evaluated using validated tools

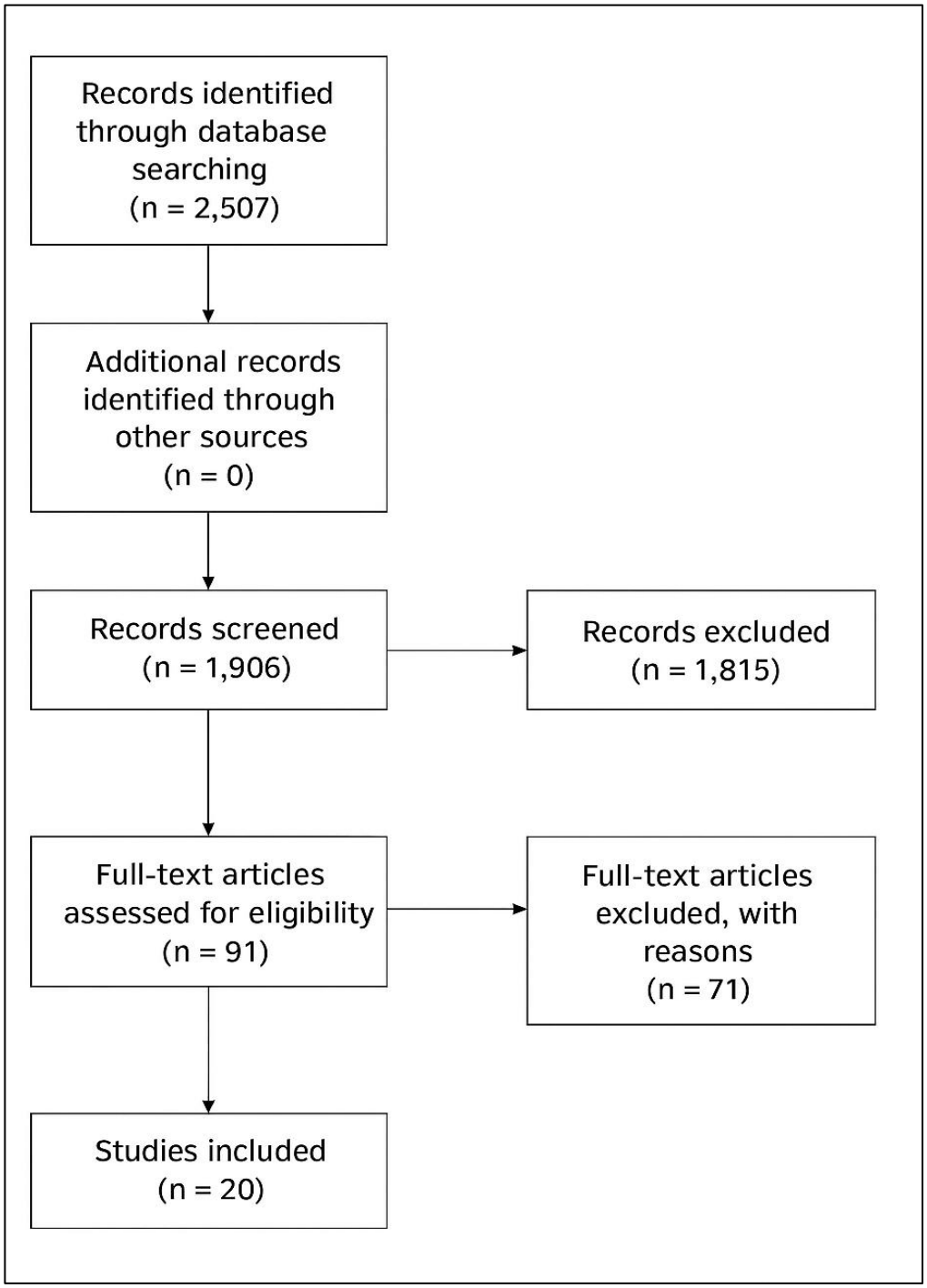

Figure 1 PRISMA Flow Diagram

tailored to study design:

- **Cochrane Risk of Bias 2 (RoB 2) tool** for randomized controlled trials.
- **Newcastle-Ottawa Scale (NOS)** for cohort and case-control studies.
- **AXIS tool** for cross-sectional studies.

Each study was rated as low, moderate, or high risk of bias based on participant selection, comparability, exposure/outcome assessment, and statistical validity.

Data Synthesis

Due to heterogeneity in populations, surgical types, definitions of glycemic control, and outcome measures, a **narrative synthesis** was employed. Results were grouped thematically according to:

1. Hyperglycemia and risk of postoperative complications.

2. Hypoglycemia and adverse outcomes.
3. Glycemic variability and surgical recovery.
4. Interventional protocols for perioperative glucose control.

Where available, quantitative effect measures (odds ratios, hazard ratios, relative risks) were extracted and reported to illustrate associations. Meta-analysis was not performed due to variability in definitions and measurement techniques across studies.

Ethical Considerations

As this study is a **secondary analysis of published literature**, no ethical approval or patient consent was required. All included studies were assumed to have undergone institutional ethical review and approval.

RESULTS

Summary and Interpretation of Included Studies on Perioperative Glycemic Control and Postoperative Complications (Table 1):

1. Study Designs and Populations

The included studies span retrospective cohorts, prospective cohorts, case-control studies, quasi-experimental studies, and randomized/quasi-controlled designs, offering a wide methodological range. Sample sizes ranged from small targeted cohorts (e.g., Kurtoglu et al., 2025: n = 47) to very large database studies (e.g., Kotagal et al., 2015: n = 40,836). Study populations varied across surgical contexts, including abdominal, orthopedic, colorectal, and mastectomy surgeries, with age ranges from young adults (~34 years, Shahzad et al., 2024) to older adults (>65 years, Wang et al., 2019).

2. Glycemic Assessment and Exposure

Most studies measured perioperative blood glucose (BG) in preoperative, intraoperative, and postoperative phases, though methods and cut-offs varied. Hyperglycemia thresholds typically used ≥150–180 mg/dL (Mafinezhad et al., 2019; Kotagal et al., 2015), while hypoglycemia was defined as BG <70 mg/dL (Goh et al., 2017). HbA1c values were assessed in some studies (Goh et al., 2017; Shahzad et al., 2024), highlighting chronic glycemic control as a risk factor. Intervention trials implemented perioperative glycemic management protocols (Kurtoglu et al., 2025), while most observational studies tracked natural glycemic variability.

3. Postoperative Complications

Across studies, complication rates varied:

- **Wound infections/SSIs** ranged from 5.5% (Mafinezhad et al., 2019) to 50% (Shahzad et al., 2024, diabetic group).
- **Composite adverse events** were 7.7% in Wang et al. (2019) and 11.4% in Oba et al. (2022).
- **Hyperglycemia-related complications** were consistently associated with increased surgical site infections, delayed wound healing, and longer hospital stays (Nair et al., 2019; Oba et al., 2022).
- **Hypoglycemia** significantly raised risks of higher Clavien-Dindo complications (Goh et al., 2017; OR 19.0).
- Diabetic patients reported higher risks of DVT, UTI, incisional hernia, and poor wound healing compared to non-diabetics (Khalifa et al., 2021; Maqsood et al., 2020; Rafiq et al., 2021).

5. **Risk Factors Identified**

Strong predictors of adverse events included:

- Older age (>65 years), male sex, kidney dysfunction, and general surgery type (Wang et al., 2019).
- High mean postoperative BG (Oba et al., 2022; OR 1.11 per 10 mg/dL rise).
- High glycemic variability, linked to longer stay and mortality in both diabetics and non-diabetics (Nair et al., 2019).
- Poor wound healing strongly correlated with high BMI and long diabetes duration (Maqsood et al., 2020; Rafiq et al., 2021).
- Even well-controlled diabetes increased postoperative wound infection risk compared to non-diabetics (Shahzad et al., 2024; Ahamad et al., 2022).

6. **Effect of Glycemic Management Protocols**

Interventional evidence (Kurtoglu et al., 2025) highlighted the clinical benefit of structured perioperative glycemic protocols: reducing ICU hyperglycemia (21% vs. 59%), shortening time to achieve BG target (6 h vs. 15 h), lowering insulin use, and improving nurse satisfaction.

Table 1. Characteristics and Findings of Included Studies

Study	Country	Design	Sample Size	Surgery Type	Key Findings on Glycemic Control & Complications
Wang et al. (2019)	China	Retrospective cohort	1525	Orthopedic & general	7.7% adverse events: delayed extubation (36.4%), infections

					(12.7%), death (2.5%). Risk ↑ with age >65 (OR 2.23), male sex (OR 2.14), high postop BG (OR 1.13), kidney dysfunction (OR 2.73).
Kurtoglu et al. (2025)	Turkey	Prospective cohort	47	Abdominal	Intervention reduced ICU hyperglycemia (21% vs. 59%, p<.05), ↑ time in target BG (76% vs. 35%), ↓ insulin use.
Mafinezhad et al. (2019)	Iran	Case-control	158	Mastectomy	SSI in 5.5%. Hyperglycemia (>150 mg/dL) strongly associated with SSI (50% in hyperglycemic vs. 2.7% in normoglycemic).
Oba et al. (2022)	Japan	Retrospective	1217	Various	11.4% complications. Lower preop BG protective (OR 0.91), higher postop BG ↑ risk (OR 1.11).
Nair et al. (2019)	USA	Retrospective	2108	Non-cardiac	In diabetics, high variability ↑ 30-day mortality (OR 1.42). In non-diabetics, hyperglycemia strongly linked to complications (OR 1.13–1.21).
Goh et al. (2017)	Singapore	Retrospective	149	Colorectal	Hypoglycemia 7.4%, linked to severe complications (OR 19.0). High HbA1c also ↑ risk (p=0.008).
Kotagal et al. (2015)	USA	Multicenter cohort	40,836	Abdominal, vascular, spine	In non-diabetics, hyperglycemia had dose-response effect on complications (OR 1.3–1.6). In diabetics, hyperglycemia not predictive.
Khalifa et al. (2021)	Saudi Arabia	Cross-sectional	205	Abdominal	DVT (50%), UTI (32%), hernia (55%) more common in diabetics. Wound erythema 27%, pus 24%.
Maqsood et al. (2020)	Pakistan	Correlational	183	Abdominal	Wound infection 13.1%. High BMI & long diabetes duration ↑ risk.
Rafiq et al. (2021)	Pakistan	Cross-sectional	200	Abdominal	14% wound infection. Higher BMI and longer DM duration ↑ risk.
Shahzad et al. (2024)	Pakistan	Quasi-experimental	60	Abdominal	Wound infection higher in diabetics (50% vs. 16.7%, p=0.006), despite good control.
Ahamad et al. (2022)	Bangladesh	Comparative	146	Elective abdominal	Wound infection 12.3% diabetics vs. 2.7% non-diabetics (OR = 4.99). Longer hospital stay in diabetics (8.2 vs. 6.8 days, p<0.01).

DISCUSSION

The present systematic review highlights the complex interplay between perioperative glycemic control and postoperative complications in diabetic patients undergoing general anesthesia. Evidence from both observational and interventional studies consistently demonstrates that dysglycemia—whether hyperglycemia, hypoglycemia, or marked glycemic variability—is associated with adverse surgical outcomes. Importantly, these effects extend across different surgical specialties, ranging from general abdominal surgery to orthopedic, colorectal, and oncological procedures.

Hyperglycemia emerged as the most consistent predictor of poor outcomes. Large multicenter cohort studies confirm that perioperative hyperglycemia substantially increases the risk of adverse events, even in non-diabetic patients. Kotagal et al. (2015) reported a dose-response relationship, with higher glucose levels corresponding to progressively greater odds of postoperative complications. Similarly, Frisch et al. (2010) found that hyperglycemia in noncardiac surgery was associated with higher morbidity and mortality. These findings underline the need to address perioperative glucose levels not only in diabetics but also in patients without a prior diagnosis.

The impact of long-term glycemic control, often measured by HbA1c, also deserves emphasis. Jehan et al. (2018) demonstrated that elevated HbA1c was strongly associated with worse postoperative outcomes in emergency general surgery, while Jehan and Joseph (2019) reinforced its predictive value. HbA1c may thus serve as a useful preoperative risk stratification tool, identifying patients at higher risk of adverse events who could benefit from intensified perioperative management strategies.

Glycemic variability has increasingly been recognized as an independent determinant of surgical outcomes. Nair et al. (2019) reported that fluctuations in perioperative glucose were associated with longer length of stay and increased mortality in both diabetic and non-diabetic patients. Likewise, Krinsley et al. (2013) confirmed that variability in glucose, rather than mean values alone, was significantly related to mortality in critically ill cohorts. Together, these findings emphasize that maintaining stable perioperative glucose levels may be as important as avoiding absolute hyperglycemia.

Hypoglycemia, while less frequently studied, presents a distinct risk. Goh et al. (2017) demonstrated that perioperative hypoglycemia was strongly linked to severe complications in diabetic patients undergoing colorectal surgery, with odds ratios exceeding 10. This finding suggests that overly aggressive glycemic control, especially with insulin therapy, may paradoxically increase harm. Thus, the balance between preventing hyperglycemia and avoiding hypoglycemia remains a critical challenge in perioperative care.

Wound-related complications represent one of the most prominent manifestations of poor glycemic control. Mafinezhad et al. (2019) found that patients with perioperative hyperglycemia were at markedly increased risk of surgical site infections after mastectomy. Similar results were observed by Maqsood et al. (2020) and Rafiq et al. (2021), where wound infection rates were significantly higher among diabetics, particularly those with longer disease duration and higher body mass index. Shahzad et al. (2024) further reinforced that even well-controlled diabetic patients had higher infection rates compared to non-diabetics, while Ahamad et al. (2022) demonstrated that controlled diabetics were nearly five times more likely to develop infections than non-diabetic counterparts.

Beyond infections, a wide range of complications are disproportionately reported among diabetic patients. Khalifa et al. (2021) observed elevated risks of deep vein thrombosis, urinary tract infections, incisional hernias, and metabolic complications among diabetics following abdominal surgery. Wang et al. (2019) also documented an array of adverse outcomes, including respiratory abnormalities, circulatory disorders, and delayed extubation, all of which were significantly more common in older male diabetic patients with poor perioperative glucose control. These findings highlight the systemic effects of dysglycemia on multiple organ systems.

Importantly, interventional evidence supports that structured glycemic management protocols can mitigate these risks. Kurtoglu et al. (2025) showed that implementing a multidisciplinary glycemic management protocol in major abdominal surgery reduced ICU hyperglycemia, shortened the time to achieve target glucose ranges, and lowered insulin requirements, while also improving nurse satisfaction. These findings provide real-world evidence that standardized protocols may optimize outcomes compared to routine care.

The role of intensive insulin therapy has been debated. Gandhi et al. (2007), in a randomized trial, showed that intensive intraoperative insulin therapy during cardiac surgery did not confer significant advantages compared to conventional management and increased the risk of hypoglycemia. These results echo the concerns raised by Goh et al. (2017), underscoring the risks of overly tight glycemic control in the surgical setting. Instead, moderate control strategies appear safer and more effective.

Professional guidelines increasingly reflect this evidence. Rajan et al. (2024) and the Society for Ambulatory Anesthesia recommend maintaining perioperative glucose between 140 and 180 mg/dL, consistent with the American Diabetes Association's position. Umpierrez et al. (2017) similarly emphasize that inpatient glycemic management should avoid both extreme hyperglycemia and hypoglycemia, advocating for moderate and individualized targets. Together, these guidelines provide a consensus framework that balances safety and efficacy.

Another consistent finding across studies is the differential impact of glycemic control in diabetic versus non-diabetic populations. Kotagal et al. (2015) and Nair et al. (2019) both demonstrated that hyperglycemia in non-diabetics was more strongly associated with adverse outcomes than in established diabetics, possibly due to underlying stress hyperglycemia reflecting greater illness severity. This suggests that perioperative glucose management strategies may need to be tailored differently depending on diabetes status.

Despite consistent evidence linking poor glycemic control with adverse outcomes, heterogeneity in study design and definitions complicates interpretation. For instance, thresholds for hyperglycemia ranged from 150 mg/dL (Mafinezhad et al., 2019) to 180 mg/dL (Kotagal et al., 2015), while outcome definitions varied widely across studies. These inconsistencies hinder direct comparisons and underscore the need for standardized perioperative glycemic definitions in future research.

Nevertheless, the collective findings strongly support that perioperative glycemic management is a modifiable risk factor with substantial implications for surgical safety. Studies consistently demonstrate that uncontrolled hyperglycemia, hypoglycemia, and glycemic variability significantly increase the risk of infection, systemic complications, prolonged hospitalization, and mortality. Structured perioperative protocols, moderate glucose targets, and preoperative optimization of HbA1c emerge as key strategies to reduce these risks.

Finally, future research should focus on integrating continuous glucose monitoring into perioperative care, evaluating real-time strategies to minimize variability, and conducting large randomized controlled trials in non-cardiac surgery populations. The heterogeneity in current literature, as well as the distinct risk profiles between diabetic and non-diabetic patients, highlights the need for nuanced and individualized approaches to perioperative glycemic control.

CONCLUSION

This systematic review demonstrates that perioperative glycemic control plays a pivotal role in influencing postoperative outcomes among diabetic patients undergoing general anesthesia. Evidence consistently shows that uncontrolled hyperglycemia, hypoglycemia, and marked glycemic variability significantly increase the risk of wound infections, systemic complications, prolonged hospitalization, and mortality. Importantly, structured glycemic management protocols and moderate glucose targets (140–180 mg/dL) appear to mitigate these risks without increasing the likelihood of hypoglycemia.

Collectively, the findings suggest that perioperative glycemic management is a modifiable factor with significant potential to improve surgical outcomes. Integrating preoperative optimization of HbA1c, intraoperative glucose monitoring, and postoperative glycemic stabilization should be prioritized. Standardized definitions of dysglycemia and future multicenter randomized trials are warranted to further refine evidence-based perioperative glycemic targets.

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