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Preoperative Hemoglobin A_{1C}, Glycemic Status, and Postoperative Outcomes in General Surgery

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IMPORTANCE Dysglycemia is increasingly recognized as a major contributor to adverse surgical outcomes. However, the clinical utility of preoperative hemoglobin A_{1C} (HbA_{1c}) screening in general surgery remains unclear.

OBJECTIVE To determine whether elevated HbA_{1c} is associated with increased 30-day postoperative complications, readmissions, and mortality in patients undergoing general surgery procedures.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study used the American College of Surgeons National Surgical Quality Improvement Program database from 2021 to 2023. Multivariable logistic regression was used to evaluate associations between glycemic status and complications within 30 days after surgery. The multicenter database comprised more than 700 participating institutions worldwide, predominantly in the US. Participants included adult patients (18 years or older) undergoing general surgery procedures with available HbA_{1c} data.

EXPOSURES Glycemic status categorized by documented diabetes diagnosis and HbA_{1c} levels, ranging from normoglycemia to very poor glycemic control. Patients without a diagnosis but HbA_{1c} levels higher than 6.4% (to convert to proportion of total hemoglobin, multiply by 0.01) were considered to have undiagnosed diabetes.

MAIN OUTCOMES AND MEASURES Main outcomes included occurrence of any, surgical, and medical complications, as well as readmissions, reoperations, and mortality within 30 days after surgery.

RESULTS Among 282 131 patients (mean [SD] age, 60 [15] years), 36% had diagnosed diabetes, whereas 6.4% had HbA_{1c} values in the diabetes range but no diagnosis. In those patients with diabetes, risk of any complication increased progressively from near normal (HbA_{1c} level <6.0%; odds ratio [OR], 1.06; 95% CI, 1.00-1.11) to very poor glycemic control (HbA_{1c} level >9.0%; OR, 1.32; 95% CI, 1.25-1.39). Undiagnosed diabetes was also associated with higher risks of medical complications (OR, 1.11; 95% CI, 1.04-1.18) and mortality (OR, 1.24; 95% CI, 1.07-1.42).

CONCLUSIONS AND RELEVANCE Dysglycemia—both diagnosed and undiagnosed—is highly prevalent among general surgery patients and independently associated with increased risks of complications, readmissions, or mortality. A significant proportion of patients had HbA_{1c} levels in the diabetes range, despite lacking a diabetes diagnosis. These findings support routine preoperative HbA_{1c} screening and the adoption of individualized glycemic management strategies to optimize surgical risk assessment, reduce complications, and improve perioperative outcomes.

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Supplemental content

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General surgery (GS) encompasses a broad range of procedures performed on a diverse, often highly comorbid, patient population. Dysregulated glucose metabolism, ranging from prediabetes to poorly controlled diabetes, has become increasingly recognized as a critical determinant of surgical outcomes.[1-5]

Hemoglobin A_{1C} (HbA_{1c}) serves as a reliable marker of long-term glycemic control, reflecting chronic hyperglycemia.[6-8] While the relationship between elevated HbA_{1c} and adverse surgical outcomes is well documented in high-risk specialties, such as cardiac, orthopedic, and transplant surgery, its implications within GS remain insufficiently explored.[9-11]

This knowledge gap is particularly problematic given the considerable proportion of GS patients who present with undiagnosed dysglycemia, potentially overlooked without routine HbA_{1c} screening.[12,13] Undetected dysglycemia significantly elevates the risk of complications, such as surgical site infections, impaired wound healing, cardiovascular events, and extended hospital stays, thereby increasing morbidity, mortality, and health care resource utilization.[14-16] Current GS preoperative protocols rarely differentiate among varying degrees of glycemic control, and standardized HbA_{1c} thresholds for perioperative management are not clearly defined. Consequently, inadequate identification and management of glycemic abnormalities persist, undermining efforts to optimize patient outcomes.[17,18]

A recent large-scale study involving over 500 000 surgical patients across various specialties demonstrated a clear link between poor preoperative glycemic control and heightened postoperative complication risk.[2] To address the uncertainty of HbA_{1c} and its role specifically among GS patients, we conducted a retrospective cohort study using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. Our study aimed to quantify the prevalence of undiagnosed prediabetes and diabetes, evaluate the impact of varying glycemic control levels on postoperative outcomes, and identify areas for improving risk stratification and perioperative care pathways in GS patients.

Key Points

Question Is elevated hemoglobin A_{1C} (HbA_{1c}) associated with increased postoperative complications among general surgery patients?

Findings In this cohort study of 282 131 patients, elevated HbA_{1c} was independently associated with increased postoperative complications, readmissions, and mortality, with 6.4% of patients having undiagnosed diabetes; these associations were strongest in abdominal operations.

Meaning Routine preoperative HbA_{1c} screening and targeted glycemic management could significantly enhance perioperative risk stratification and patient outcomes in general surgery.

Methods

Data Source

The ACS-NSQIP is an initiative aimed at enhancing surgical care quality in over 700 hospitals worldwide. It gathers comprehensive, patient-specific data on outcomes following surgical procedures. These data are extracted from the medical records of randomly selected patients by trained surgical clinical reviewers. All patient information used was anonymized and the study received ethical approval from the Brigham and Women's Hospital in Boston, Massachusetts (2013P001244). This study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Patient Selection

The primary analysis was restricted to adult patients (18 years or older) undergoing GS procedures with documented HbA_{1c} values. Data were extracted from the ACS-NSQIP datasets between 2021 and 2023, with late 2020 admissions included if the surgical episode extended into subsequent years. A secondary analysis was performed to unveil a potential selection bias by comparing the aforementioned group to adult patients (18 years or older) undergoing GS without documented HbA_{1c} measurements.

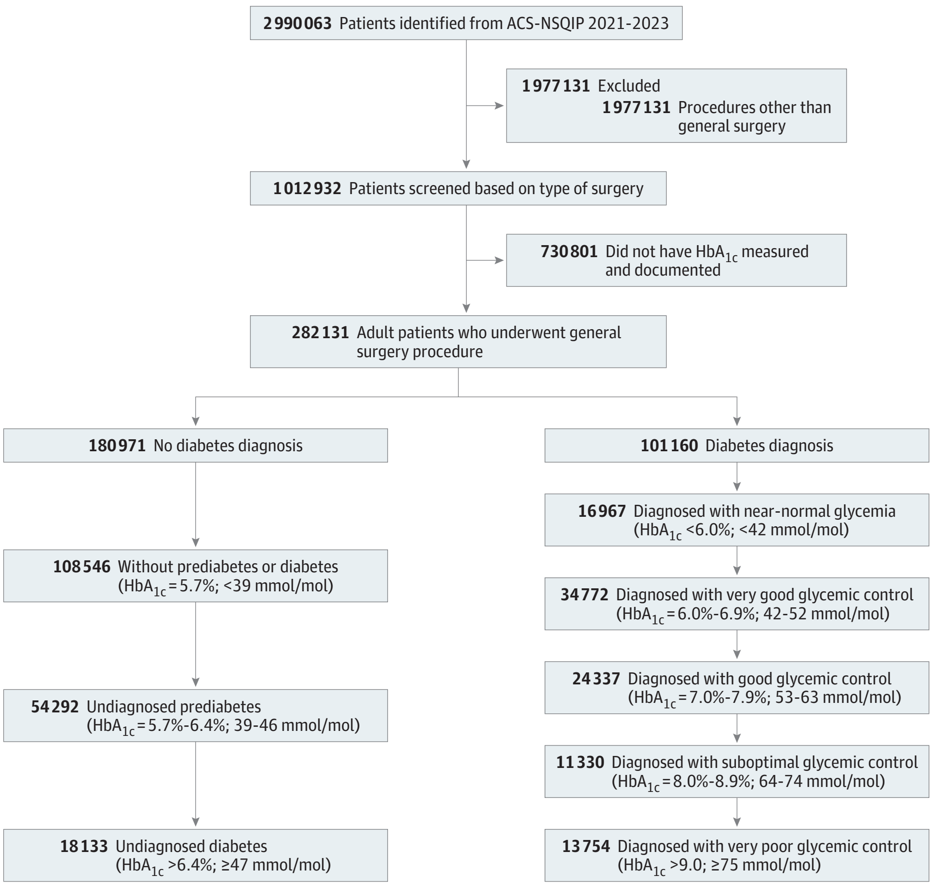
Patient Grouping

Patients were categorized into 8 groups based on diabetes status and HbA_{1c} levels. Diabetes status was determined from the ACS-NSQIP "diabetes" variable, with "insulin," "non-insulin," and "oral" indicating a documented diagnosis requiring treatment and "no" indicating its absence. The HbA_{1c} thresholds were selected based on prior research to capture potential nonlinear relationships with clinical outcomes.[2,19] Among those without a recorded diagnosis, individuals with HbA_{1c} levels lower than 5.7% (<39 mmol/mol; to convert from percentage of total hemoglobin to proportion of total hemoglobin, multiply by 0.01) were classified as healthy; those with HbA_{1c} levels 5.7% to 6.4% (39-46 mmol/mol) were classified as having undiagnosed prediabetes; and those with HbA_{1c} levels higher than 6.4% (≥47 mmol/mol) were deemed to have undiagnosed diabetes. In patients with a documented diabetes diagnosis, the subgroups were defined as near-normal glycemia (HbA_{1c} levels <6% [<42 mmol/mol]), very good glycemic control (HbA_{1c} 6.0%-6.9% [42-52 mmol/mol]), good control (HbA_{1c} 7.0%-7.9% [53-63 mmol/mol]), suboptimal control (HbA_{1c} levels 8.0%-8.9% [64-74 mmol/mol]), and very poor control (HbA_{1c} levels >9% [≥75 mmol/mol]).

Variable Extraction

A full set of extracted variables can be found in eTables 1 through 4 in Supplement 1. The primary outcome was a composit=e end point capturing the occurrence of any postoperative complication, defined as the presence of at least 1 of the following: mortality, reoperation, readmission (including unplanned readmission), surgical complication, or medical complication. Surgical complications included any event reported in the ACS-NSQIP dataset and observed in the study cohort, such as superficial or deep incisional infections, organ-space infections, wound dehiscence, and bleeding requiring transfusion. Medical complications encompassed pneumonia, unplanned intubation, pulmonary embolism, prolonged ventilator use (>48 hours), kidney

Figure 1. American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Data Extraction Flowchart



To convert hemoglobin A_{1c} (HbA_{1c}) from percentage of total hemoglobin to proportion of total hemoglobin, multiply by 0.01.

insufficiency, acute kidney failure, postoperative dialysis, urinary tract infection, stroke, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, deep vein thrombosis requiring treatment, sepsis, and septic shock.

Importantly, we assessed complications on a per-patient basis rather than by the total number of individual events. Thus, if a patient experienced both a return to the operating room and a medical complication, this was counted as a single complication case (n = 1).

Statistical Analysis

Raw data from the annual ACS-NSQIP datasets were processed into analyzable Microsoft Excel files (version 16; Microsoft) using IBM SPSS Statistics for Windows version 29 (IBM). All datasets were securely stored in an electronic laboratory notebook (LabArchives) and subsequently analyzed using Google Colab (Google).

Descriptive statistics were computed for all baseline, perioperative, and postoperative outcome variables across the 8 glycemic groups. Group comparisons were conducted using χ^2 tests for categorical variables, as well as independent *t* tests and 1-way analysis of variance for continuous variables.

Multivariate logistic regression models were used to assess the independent impact of glycemic status on any complication, surgical complication, medical complication, mortality, readmission, and reoperation and were adjusted for all available preoperative and baseline clinical variables that did not demonstrate multicollinearity.

Also, we conducted a descriptive analysis of postoperative morbidity rates in the 10 most frequently performed GS procedures, stratified by glycemic control. This procedure-specific approach was intended to explore potential trends and highlight variations in the magnitude of HbA_{1c}-associated risk across different surgical contexts. While not designed to test formal statistical interactions, this analysis provides insight into procedure-dependent patterns that may inform future studies focused on identifying clinically relevant interactions between glycemic status and surgical outcomes.

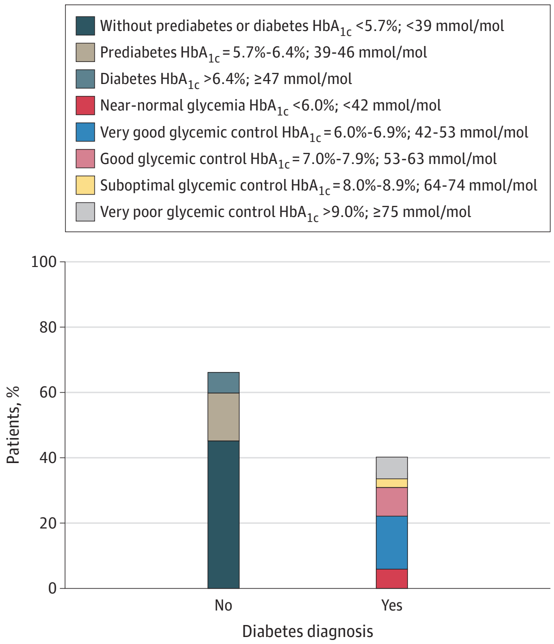
Results

Patient Cohort and Prevalence of Undiagnosed Diabetes

Among the 1 012 932 GS patients in the 2021 to 2023 database, 282 131 were GS cases with documented HbA_{1c} that were included in the analysis. (**Figure 1**)

Among GS patients with diabetes diagnosis (n = 101 160 [36%]), 17% (n = 16 967) exhibited near-normal glycemia

Figure 2. General Surgery Patients Stratified by Diabetes Diagnosis and Glycemic Groups



Percentages are provided with respect to status of diabetes diagnosis. To convert hemoglobin A_{1c} (HbA_{1c}) from percentage of total hemoglobin to proportion of total hemoglobin, multiply by 0.01.

(HbA_{1c} levels <6% [<42 mmol/mol]), 34% (n = 34 772) very good glycemic control (HbA_{1c} levels 6.0%-6.9% [42-52 mmol/mol]), 24% (n = 24 337) good glycemic control (HbA_{1c} levels 7.0%-7.9% [53-63 mmol/mol]), 11% (n = 11 330) suboptimal glycemic control (HbA_{1c} levels 8.0%-8.9% [64-74 mmol/mol]), and 14% (n = 13 754) very poor glycemic control (HbA_{1c} levels >9% [≥75 mmol/mol]).

Patients without a diabetes diagnosis (n = 180 971 [64%]) were classified as healthy (n = 108 546 [60%]) and HbA_{1c} levels lower than 5.7% (<39 mmol/mol), with undiagnosed prediabetes (n = 54 292 [30%]) and HbA_{1c} levels of 5.7% to 6.4% (39-46 mmol/mol), or undiagnosed diabetes (n = 18 133 [10%]) and HbA_{1c} levels higher than 6.4% (≥47 mmol/mol). (**Figure 2**). Therefore, 6.4% of the entire cohort had HbA_{1c} levels in the diabetes range despite having no documented diagnosis of diabetes.

When comparing preoperative characteristics of the 282 131 GS patients with the 730 801 without HbA_{1c} measurement, only minor effect sizes could be measured for body mass index (BMI) (Cohen d = −0.25), age (Cohen d = −0.37), or hematocrit (Cohen d = 0.11) (eTable 1 in Supplement 1).

Perioperative Characteristics

Mean (SD) age was lowest among healthy individuals (56 [16] years), with significant differences observed across groups (P < .001). Healthy patients exhibited the lowest mean (SD) BMI (calculated as weight in kilograms divided by height in meters squared) (30 [8.0]; P < .001). The proportion of female patients was highest in the healthy group (n = 63 539 [59%]) and lowest in those with diagnosed diabetes and suboptimal glycemic control (n = 5678 [50%]). Most patients self-identified as White, ranging from 67% (n = 72 283) in the healthy group to 59% (n = 8063) in the very poor glycemic control group. Full perioperative data are provided in eTables 2 and 3 in Supplement 1.

Outcomes and Multivariable Analysis

Stratification by diabetes diagnosis and glycemic groups revealed significant differences in postoperative complication rates (eTable 4 in Supplement 1) (**Figure 3**).

Multivariate logistic regression revealed that, compared with healthy individuals, patients diagnosed with diabetes had significantly higher odds of experiencing any complication. While those with very poor (odds ratio [OR], 1.32; 95% CI, 1.25-1.39; P < .001) and suboptimal (OR, 1.16; 95% CI, 1.09-1.22; P < .001) glycemic control were impacted most, patients were also affected despite expressing good (OR, 1.05; 95% CI, 1.00-1.10; P = .03) or even near-normal (OR, 1.06; 95% CI, 1.00-1.11; P = .03) glycemic control.

Similarly, patients diagnosed with diabetes with very poor (OR, 1.15; 95% CI, 1.09-1.23; P < .001) and even near-normal (OR, 1.10; 95% CI, 1.04-1.17; P < .001) glycemic control had increased risk of surgical complications.

Strikingly, patients without a diabetes diagnosis but HbA_{1c} levels in the diabetes range (undiagnosed diabetes) expressed significantly increased odds (OR, 1.11; 95% CI, 1.04-1.18; P = .002) of medical complications. This could also be observed in patients diagnosed with diabetes and suboptimal (OR, 1.15; 95% CI, 1.07-1.24; P < .001) or very poor (OR, 1.43; 95% CI, 1.34-1.52; P < .001) glycemic control.

Odds of readmission were significantly higher in patients with good (OR, 1.09; 95% CI, 1.02-1.16; P = .009), suboptimal (OR, 1.17; 95% CI, 1.08-1.27; P < .001), and very poor glycemic control (OR, 1.28; 95% CI, 1.19-1.37; P < .001) in patients diagnosed with diabetes.

Lastly, significantly elevated odds of mortality were found in patients with undiagnosed diabetes (OR, 1.24; 95% CI, 1.07-1.42; P = .003) (eTable 5 in Supplement 1; **Figure 4**).

Procedure-Specific Risk Patterns

To evaluate whether the observed associations varied by surgical procedure, subgroup analyses were performed on the 10 most frequent operations within the cohort, identified by their primary *Current Procedural Terminology* (*CPT*) codes. Across the cohort, procedures, such as laparoscopic cholecystectomy without visualization of the bile ducts (*CPT* code 47562; n = 28 878), laparoscopic appendectomy (*CPT* code 44970; n = 14 974), laparoscopic sleeve gastrectomy (*CPT* code 43775; n = 8818), laparoscopic partial colectomy with anastomosis (*CPT* code 44204; n = 10 997), laparoscopic partial colectomy with anastomosis and coloproctostomy (low pelvic anastomosis) with a colostomy (*CPT* code 44207; n = 10 020), laparoscopic partial colectomy with terminal ileum resection and ileocolostomy (*CPT* code 44205; n = 8727), laparoscopic cholecystectomy with intraoperative cholangiography (*CPT* code 47563; n = 7861), and repair of an initial reducible

Figure 3. Surgical Outcomes Among the Investigated Glycemic Groups

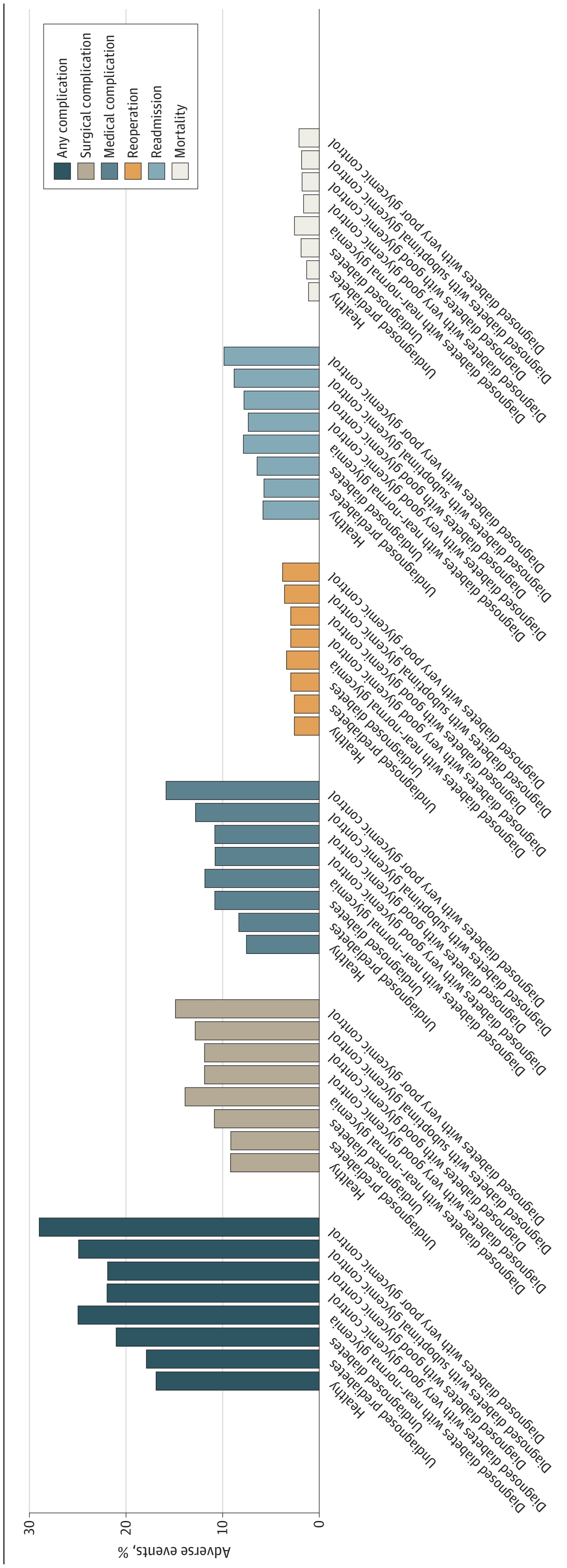
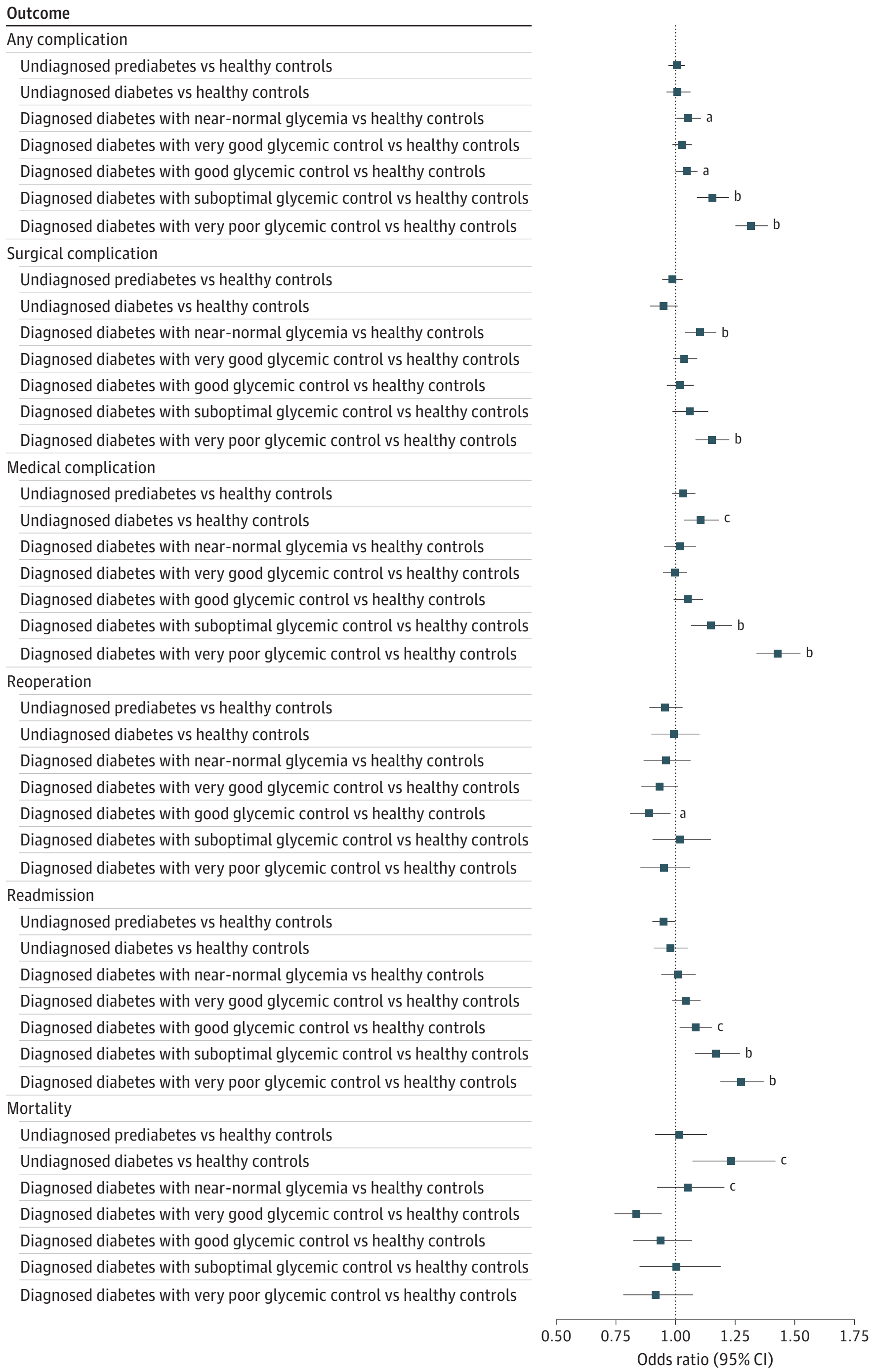


Figure 4. Visualized Results of the Multivariable Analysis



[a] $P < .05$

[b] $P < .001$

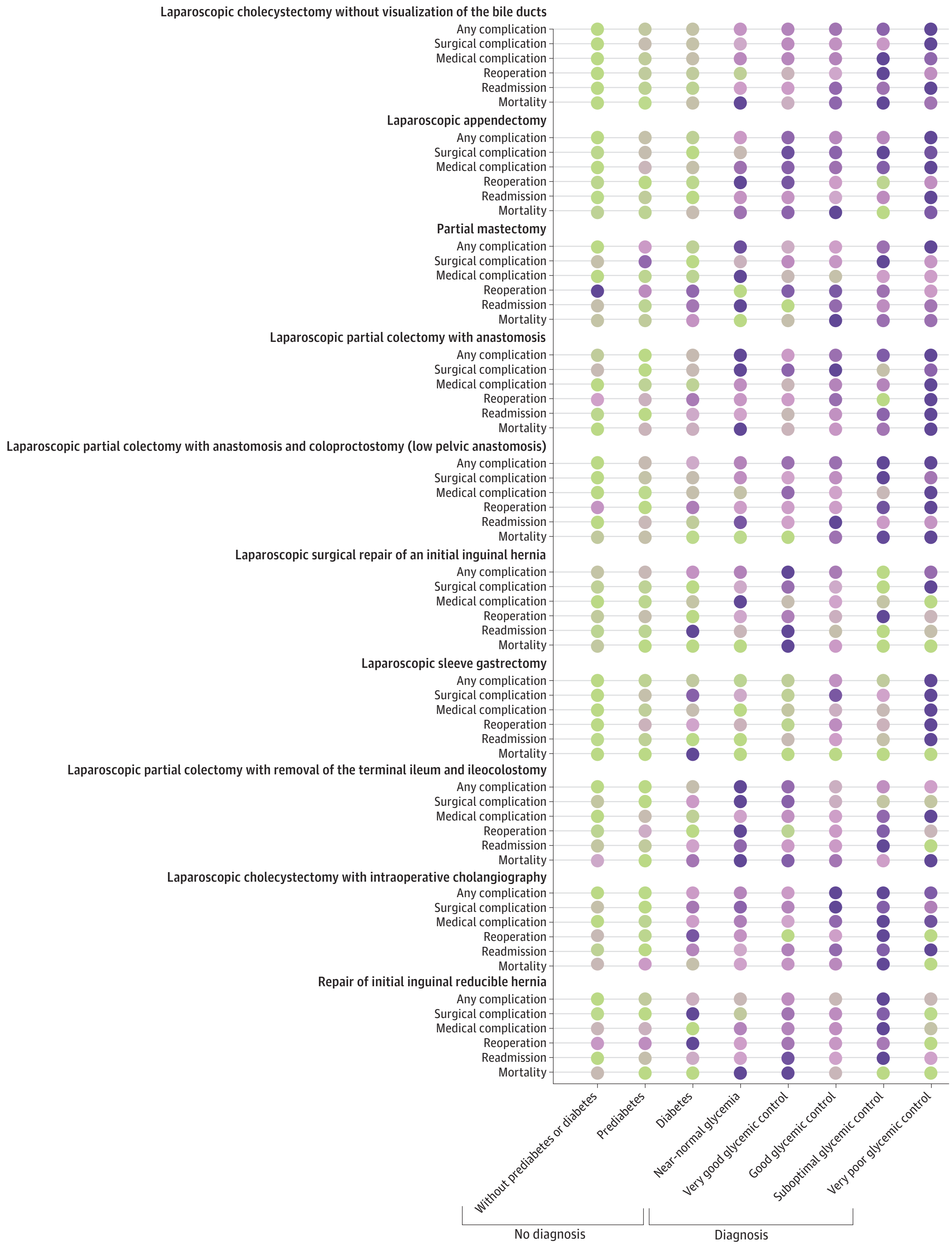
[c] $P < .01$

inguinal hernia (*CPT* code 49505; n = 7728) reflected the broader trend of increased complication risk with diabetes and worsening glycemic control. In contrast, partial mastectomy (*CPT* code 19301; n = 11 541) and laparoscopic repair of an initial inguinal hernia (*CPT* code 49650; n = 9363) did not follow the overall trend, showing no significant associations with glycemic status (eTable 6 in Supplement 1; **Figure 5**).

Discussion

The present study highlights a crucial, yet underexplored, aspect of perioperative risk stratification in GS: the influence of both diagnosed and undiagnosed dysglycemia on postoperative outcomes. Despite mounting evidence linking elevated HbA_{1c} levels with adverse events in many surgical

Figure 5. Graphically Illustrated Complication Frequency Within Specific Procedures Stratified by Glycemic Groups



The gradient from green to purple indicates lightest green = low complication rate and darkest purple = high complication rate.

specialties, our findings underscore the persistent gap in standardized glycemic risk assessment within GS.[20-22] The high prevalence of undiagnosed diabetes among surgical patients, combined with the lack of routine HbA_{1c} screening, calls for a reevaluation of current preoperative pathways to ensure better identification and management of metabolic risk.[2]

Multivariable regression analysis revealed that patients diagnosed with diabetes had significantly higher odds of experiencing any, surgical, and medical complications. Interestingly, patients with undiagnosed diabetes expressed significantly increased odds of medical complications. Furthermore, 6.4% of the overall study population—10% of patients without a documented diabetes diagnosis—had HbA_{1c} levels in the diabetes range, highlighting substantial burdens of previously unrecognized dysglycemia in surgical patients. Moreover, the increasing trend of complication risk with rising HbA_{1c} levels was consistent across multiple procedures, with some showing no clear association between glycemic status and complication rates, indicating procedure-specific variability.

The association between dysglycemia and surgical complications is well established. Elevated HbA_{1c} has been associated with increased rates of surgical site infections, wound dehiscence, and poor healing due to impaired leukocyte function, collagen synthesis, and microvascular perfusion.[4,14] In gastrointestinal and orthopedic surgery, moderate preoperative hyperglycemia has been shown to significantly increase the risk of deep incisional and organ-space infections.[23] Perioperative hyperglycemia has been associated with prolonged wound drainage and increased use of vacuum-assisted closure following procedures, such as mastectomy and hernia repair, emphasizing the importance of proactive glucose control in surgery.[15]

Medical complications, such as pneumonia, myocardial infarction, kidney insufficiency, and sepsis, were significantly more common in patients with both diagnosed and undiagnosed diabetes and increased with worsening glycemic control.[24-26] Notably, hyperglycemia promotes endothelial dysfunction, immune suppression, and a proinflammatory state, which together increase the risk of pneumonia, sepsis, and acute kidney injury.[11,27] In cardiac and abdominal operations, perioperative glucose elevations have been independently associated with major adverse events, including myocardial infarction and stroke.[15,28] Hyperglycemia has been implicated in increased risk of postoperative pulmonary complications and delayed ventilator weaning in both diabetes and nondiabetes populations undergoing major surgery.[27,29,30] This aligns with experimental models implicating hyperglycemia in endothelial dysfunction, immune dysregulation, and systemic inflammation.[2,15]

Similarly, perioperative hyperglycemia has consistently been associated with increased postoperative mortality across a wide range of surgical specialties.[31,32] This increased risk is thought to stem from detrimental effects of chronic hyperglycemia on immune and vascular function, which heighten vulnerability to life-threatening complications, such as sepsis and multiorgan failure.[33,34] In cardiac surgery, elevated preoperative HbA_{1c} has emerged as strong, independent predictor of both early and late mortality, with values above 8.6% correlating with a nearly 4-fold increase in risk.[35] Conversely, while some analyses have observed a trend toward higher mortality with increasing HbA_{1c} levels, these associations have not always remained significant after adjusting for confounding factors—highlighting the need for nuanced interpretation within specific surgical contexts.[36]

Moreover, the impact of diabetes and glycemic control on surgical outcomes varies by procedure. In sleeve gastrectomy, diabetes has been associated with increased risks of mortality and major complications.[37] In addition, each 1% increase in HbA_{1c} was associated with a 41% higher risk of severe postoperative complications, indicating a dose-dependent relationship.[38] In hernia surgery, open abdominal wall reconstruction has been associated with increased wound morbidity in patients with diabetes, reflecting the systemic impact of impaired glycemic control on healing capacity.[39] However, this risk is not consistent across approaches. Laparoscopic hernia repair has been associated with lower complication and readmission rates, suggesting that minimally invasive techniques may attenuate surgical risk in this population.[40] These findings underscore the procedural context as a key determinant of outcomes in patients with diabetes.

Beyond glycemic indices, obesity and hyperglycemia are closely linked components of metabolic syndrome, raising the possibility that BMI could be the main driver of the observed complications. However, our adjusted analyses accounted for BMI, and we further showed that BMI did not differ meaningfully between patients with and without HbA_{1c} measurements. Importantly, HbA_{1c} remained an independent predictor of complications, indicating risk beyond body composition alone. Nevertheless, obesity and dysglycemia likely act synergistically, underscoring the need for integrated preoperative assessment that considers metabolic syndrome as a whole rather than isolated factors.

In summary, the findings of this study highlight the critical role of preoperative glycemic assessment and optimization in GS. Given the high prevalence of undiagnosed dysglycemia and its independent association with increased surgical morbidity and mortality, routine HbA_{1c} screening should be considered in all GS candidates. Interdisciplinary collaboration involving endocrinology, anesthesia, and surgical teams may facilitate prehabilitation strategies, such as medical therapy adjustment, nutritional support, and glucose monitoring protocols. Importantly, these interventions should not be limited to patients with diagnosed diabetes; individuals with undiagnosed hyperglycemia may benefit equally from early identification and targeted optimization. Lastly, considering significant regional differences, routine HbA_{1c} testing would increase short-term costs ($5-$33 per test, or approximately $5-33 million annually per 1 million elective cases[41-43]); however, the potential savings from preventing complications, such as surgical site infections ($2800-$22 000 per case[44-49]), myocardial infarction ($11 000-$24 000 in acute care[50-52]), or stroke ($4400-$28 000 acutely, plus more than $44 000 per year[53-55]) suggest that routine screening could be both clinically beneficial and economically sustainable.

Limitations

Several limitations must be acknowledged, primarily due to the retrospective nature of the ACS-NSQIP dataset. While the database provides large volumes of standardized outcomes, its reliance on academic centers may introduce selection bias and limit generalizability to smaller institutions. Similarly, while HbA_{1c} values were only available for a subset of patients, comparison with those without measurements showed broadly comparable demographic and clinical characteristics, with only minor differences, thereby reducing but not fully eliminating the potential for selection bias (eTable 1 in Supplement 1). Although ACS-NSQIP requires participating sites to achieve 80% or more complete 30-day follow-up and excludes sites below this threshold from national reporting, a small proportion of patients may still be lost to follow-up within 30 days. Moreover, although all HbA_{1c} values were preoperative, the exact timing was not recorded, complicating interpretation in dynamic states, such as glycemic control in response to acute illness or interventions. The database also lacks details on diabetes duration, type, treatment regimen, perioperative interventions (eg, corticosteroid dosage, insulin management, glucose-altering medications) and preoperative nonpharmacologic measures, such as dietary changes or weight loss, all of which could confound associations. Similarly, anemia, particularly iron-deficiency anemia, may falsely elevate HbA_{1c} values and, thus, confound associations, especially in colorectal surgery patients; while we adjusted for hematocrit as a proxy, the absence of detailed hematologic parameters in ACS-NSQIP prevents comprehensive assessment of this effect. Given the large sample size, even modest ORs (eg, 0.9-1.2) may achieve statistical significance. Such findings, while robust statistically, likely represent clinically marginal effects and should be interpreted with caution in the context of absolute risk differences and clinical relevance. Moreover, ACS-NSQIP records only 30-day outcomes, excluding longer-term complications, delayed readmissions, and outpatient events, thereby potentially underestimating dysglycemia's true burden. Similarly, outpatient postoperative events not requiring readmission are not assessed. Lastly, because HbA_{1c} is not routinely measured in all surgical patients, the database must be interpreted within this limitation. These issues highlight the need for prospective studies with standardized preoperative HbA_{1c} collection and long-term follow-up to clarify glycemic control's role in surgical risk stratification.

Conclusions

This study demonstrates that both diagnosed and undiagnosed dysglycemia are independently associated with increased risks of postoperative complications, readmission, and mortality in GS patients. A total of 6.4% of the overall cohort and 10% of patients without a documented diabetes diagnosis had HbA_{1c} values in the diabetes range, revealing a substantial burden of unrecognized hyperglycemia. These findings support routine preoperative HbA_{1c} screening in all surgical candidates, regardless of diabetes history, and suggest that even moderate glycemic elevations may confer measurable perioperative risk. Integrating glycemic assessment into standard surgical-risk stratification could enable early identification, individualized optimization, and improved outcomes for the broad surgical population.

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