Section: General Surgery

Original Research Article

GLYCEMIC CONTROL (HBA1C) AS A PREDICTOR OF SURGICAL SITE INFECTION IN PATIENTS UNDERGOING ELECTIVE ABDOMINAL SURGERY: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Hyperglycaemia impairs neutrophil function, microvascular perfusion and collagen synthesis, and glycated haemoglobin (HbA1c) provides an integrated measure of glycaemic control over the preceding 8–12 weeks. We evaluated preoperative HbA1c as a predictor of surgical site infection (SSI) in patients undergoing elective abdominal surgery.

Materials and Methods: In this prospective observational study, 38 adults undergoing elective abdominal surgery were enrolled. Preoperative HbA1c was recorded and patients were followed for 30 days for SSI, defined per Centers for Disease Control and Prevention (CDC) criteria. Associations were assessed using the independent t-test, Mann–Whitney U test, chi-square/Fisher exact test, receiver-operating characteristic (ROC) analysis and logistic regression. A two-sided $p<0.05$ was considered significant.

Results: SSI developed in 10 of 38 patients (26.3%). Mean HbA1c was significantly higher in patients with SSI than in those without (7.80 ± 1.10% vs 6.76 ± 0.92%; p=0.018). The SSI rate rose from 13.6% in patients with HbA1c <7.0% to 43.8% in those with HbA1c ≥7.0% (OR 4.93, 95% CI 1.03–23.63; p=0.037). ROC analysis gave an area under the curve of 0.779 (95% CI 0.594–0.963); an optimal cut-off of HbA1c ≥6.9% yielded 80% sensitivity and 64.3% specificity. On multivariable logistic regression, each 1% rise in HbA1c independently increased SSI odds (adjusted OR 3.23, 95% CI 1.2–8.7; p=0.021), as did wound contamination class.

Conclusion: Higher preoperative HbA1c was associated with a graded increase in SSI risk after elective abdominal surgery and was an independent predictor. Preoperative HbA1c assessment may help identify patients who would benefit from glycaemic optimisation before elective surgery.

Keywords: Glycated haemoglobin; HbA1c; surgical site infection; elective abdominal surgery; glycaemic control; diabetes mellitus.

INTRODUCTION

Surgical site infection (SSI) remains one of the most common healthcare-associated infections following abdominal surgery and is a major source of postoperative morbidity, prolonged hospital stay and avoidable cost, with reported rates after abdominal procedures in Indian tertiary-care settings ranging widely depending on case mix and wound class.1 Despite advances in asepsis, antimicrobial prophylaxis and surgical technique, SSI continues to complicate a substantial proportion of laparotomies, particularly in patients with modifiable metabolic risk factors.

Diabetes mellitus is an established and increasingly prevalent comorbidity among surgical patients; the global diabetic population was estimated at over 500 million adults and is projected to rise further over the coming decades.[2] Chronic and perioperative hyperglycaemia impairs several host defences

relevant to wound healing, including neutrophil chemotaxis and oxidative killing, opsonisation, microvascular perfusion and collagen cross-linking, thereby creating a permissive environment for bacterial colonisation of the surgical wound.

Glycated haemoglobin (HbA1c) reflects average glycaemia over the preceding 8–12 weeks and, unlike a single random glucose value, is unaffected by the acute stress response to surgery. It is therefore an attractive, reproducible preoperative marker of a patient's baseline glycaemic milieu. A 1999 Centers for Disease Control and Prevention (CDC) guideline standardised the diagnosis and surveillance of SSI,[3] allowing consistent comparison across studies. Reports across multiple surgical disciplines, and a meta-analysis confined to elective major abdominal surgery, have linked elevated preoperative HbA1c to anastomotic leak, wound infection and overall complications.[4,5] Inadequate glycaemic control has likewise been associated with increased SSI in arthroplasty.[6]

However, evidence specific to abdominal surgery in South Asian populations remains limited, and the optimal HbA1c threshold for risk stratification is debated. We therefore conducted this prospective observational study to examine whether preoperative HbA1c predicts the development of SSI in patients undergoing elective abdominal surgery, and to explore a clinically useful cut-off value.

MATERIALS AND METHODS

Study design, setting and participants

This prospective observational study enrolled 38 consecutive adult patients (≥18 years) scheduled for elective abdominal surgery in the Department of General Surgery at a tertiary-care teaching hospital. Patients undergoing emergency procedures, those with clinical or laboratory evidence of preexisting infection at the operative site, those on chronic immunosuppression or systemic corticosteroids, patients with haemoglobinopathies or recent blood transfusion (which confound HbA1c interpretation), and those who declined consent were excluded.

Data collection and HbA1c measurement

Demographic and clinical variables (age, sex, body mass index [BMI], smoking status, diabetic status and duration, American Society of Anesthesiologists [ASA] grade, serum albumin, type of procedure, wound contamination class and operative duration) were recorded on a structured proforma. Venous HbA1c was measured preoperatively by a high-performance liquid chromatography–based method standardised to the National Glycohemoglobin Standardization Program. Standard antimicrobial prophylaxis and skin-preparation protocols were applied uniformly.

Outcome definition

The primary outcome was SSI within 30 postoperative days, defined and classified as superficial incisional, deep incisional or organ/space infection according to CDC criteria.3 Patients were assessed daily until discharge and reviewed in the outpatient clinic; wound swabs from infected sites were sent for culture and sensitivity.

Statistical Analysis

Data were analysed using Python (SciPy and statsmodels). Continuous variables are expressed as mean ± standard deviation and compared between patients with and without SSI using the independent-samples t-test, with the Mann–Whitney U test as a non-parametric confirmation. Categorical variables are expressed as frequencies and compared using the chi-square test or Fisher exact test as appropriate. The discriminative ability of HbA1c for SSI was assessed by ROC analysis, with the optimal cut-off identified by the Youden index. Univariable and multivariable logistic regression models estimated crude and adjusted odds ratios (OR) with 95% confidence intervals (CI). A two-sided $p<0.05$ was considered statistically significant. Ethical approval and written informed consent were obtained in accordance with the Declaration of Helsinki.

RESULTS

Baseline characteristics

A total of 38 patients were analysed, of whom 10 (26.3%) developed an SSI within 30 days. The mean age of the cohort was 49.1 ± 10.3 years. Baseline characteristics stratified by SSI status are summarised in Table 1. Patients who developed SSI were somewhat older and had longer diabetes duration, although these differences did not reach statistical significance. Preoperative HbA1c was the variable most strongly and significantly associated with SSI (7.80 ± 1.10% vs 6.76 ± 0.92%; t-test p=0.018; Mann–Whitney p=0.010).

Table 1: Baseline characteristics by SSI status (mean ± SD or n)

Variable	SSI (n=10)	No SSI (n=28)	p-value
Age (years)	53.00 ± 7.38	47.68 ± 10.89	0.100
BMI (kg/m²)	24.69 ± 3.23	25.27 ± 3.66	0.641
HbA1c (%)	7.80 ± 1.10	6.76 ± 0.92	0.018*
Serum albumin (g/dL)	3.64 ± 0.53	3.56 ± 0.47	0.668
Operative time (min)	135.90 ± 57.59	131.89 ± 54.25	0.851
Diabetes duration (yr)	6.10 ± 5.92	3.07 ± 3.66	0.156
Diabetic, n	9	16	0.118
Male sex, n	5	15	1.000
Smoker, n	5	6	0.116

**Statistically significant (p<0.05). BMI, body mass index*

HbA1c categories and SSI

When dichotomised at 7.0%, 7 of 16 patients with HbA1c ≥7.0% developed SSI (43.8%) compared with 3 of 22 patients with HbA1c <7.0% (13.6%), corresponding to an odds ratio of 4.93 (95% CI 1.03–23.63; chi-square p=0.037). A graded increase in SSI rate was observed across rising HbA1c bands (Figure 2). Wound contamination class was also significantly associated with SSI (p=0.011), whereas sex, BMI, serum albumin and operative duration were not.

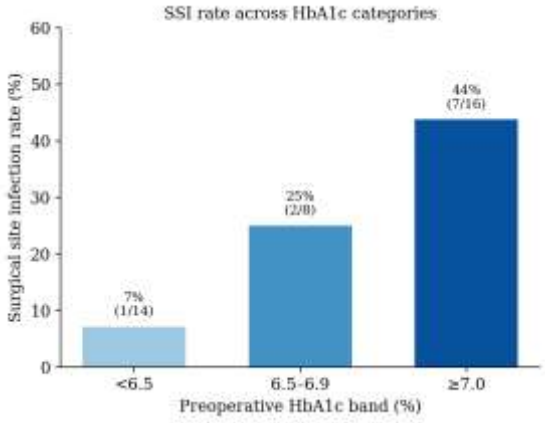

Figure 1: Surgical site infection rate across preoperative HbA1c bands, showing a graded rise with worsening glycaemic control

Discriminative ability of HbA1c (ROC analysis)

Preoperative HbA1c discriminated patients who developed SSI from those who did not, with an area under the ROC curve of 0.779 (95% CI 0.594–0.963; Figure 1). The Youden-optimal cut-off was HbA1c ≥6.9%, providing a sensitivity of 80%, specificity of 64.3%, positive predictive value of 44.4%, negative predictive value of 90% and overall accuracy of 68.4%. The high negative predictive value suggests that well-controlled patients were unlikely to develop SSI in this cohort.

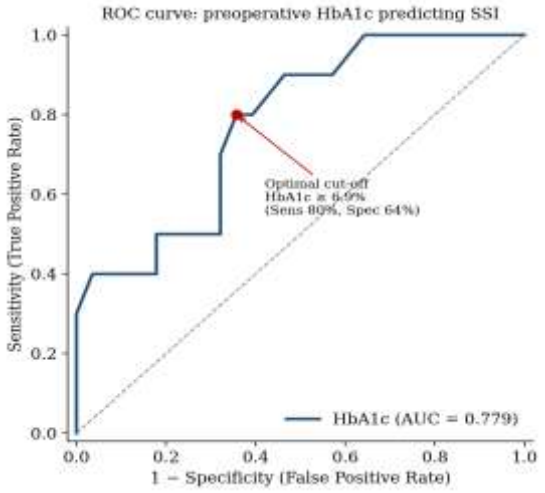

Figure 2: Receiver-operating characteristic (ROC) curve for preoperative HbA1c predicting surgical site infection

Logistic regression

On univariable logistic regression, each 1% increase in preoperative HbA1c was associated with a 2.8-fold increase in the odds of SSI (95% CI 1.24–6.31; p=0.013). After adjustment for wound class, serum albumin and age in a multivariable model (Table 2), HbA1c remained an independent predictor (adjusted OR 3.23, 95% CI 1.2–8.7; p=0.021), as did wound contamination class (adjusted OR 8.03, 95% CI 1.28–50.38; p=0.026).

Table 2: Multivariable logistic regression for predictors of SSI

Predictor	Adjusted OR	95% CI	p-value
HbA1c (per 1% rise)	3.23	1.2–8.7	0.0207*
Wound class (per step)	8.03	1.28–50.38	0.0262*
Serum albumin (per g/dL)	1.02	0.14–7.35	0.9811
Age (per year)	1.08	0.98–1.19	0.1342

**p<0.05. OR, odds ratio; CI, confidence interval. Wound class coded Clean=0, Clean-contaminated=1, Contaminated=2*

DISCUSSION

In this prospective cohort of patients undergoing elective abdominal surgery, preoperative HbA1c emerged as the strongest predictor of SSI. Patients who developed SSI had a mean HbA1c roughly one percentage point higher than those who did not, and risk increased in a graded fashion across HbA1c bands, with the odds of infection nearly five-fold higher above a threshold of 7.0%. HbA1c remained independently predictive after adjustment for wound class, albumin and age.

These findings are concordant with the broader literature. A meta-analysis restricted to elective major abdominal surgery found that even an HbA1c between 6% and 7% was associated with higher risks of wound infection, anastomotic leak and overall complications, prompting the authors to question guidelines that set the threshold for optimisation at >7%.4 A large multicentre Pakistani study likewise demonstrated significantly higher SSI rates above an HbA1c of 6.5%,[7] and a Swiss analysis nested within a randomised SSI trial identified HbA1c as a positive perioperative predictor of surgical-site and other nosocomial infections.[5]

Our ROC-derived optimal cut-off (HbA1c ≥6.9%) is broadly consistent with thresholds reported in orthopaedic and visceral surgery. In a Taiwanese cohort undergoing lower-limb fracture surgery, a preoperative HbA1c above 7.85% best predicted SSI (AUC 0.79),[8] a discriminative value almost identical to ours despite the different surgical context. Inadequate glycaemic control has similarly

been linked to SSI in arthroplasty,[6] reinforcing the biological plausibility of HbA1c as a transferable risk marker across surgical specialties.

The relationship between glycaemia and infection is not always linear. One retrospective esophagectomy series paradoxically reported more infectious complications among patients with very low HbA1c, attributing this to nutritional depletion rather than glycaemic protection,[10] and an orthopaedic-trauma cohort found that routine HbA1c was not a reliable predictor of fracture-related infection under a strict consensus definition.[9] These discrepancies underscore that HbA1c is one component of a multifactorial risk profile and should be interpreted alongside nutritional status, wound class and operative factors such as prolonged operative duration, itself a recognised SSI risk factor.[11]

Clinically, our data support the pragmatic strategy of measuring HbA1c before elective abdominal surgery, counselling and optimising patients with elevated values, and—where surgically safe—deferring purely elective procedures until glycaemic control improves. The high negative predictive value observed suggests that well-controlled patients can be reassured, while elevated values should trigger intensified perioperative glucose monitoring and wound surveillance, consistent with reported practice in Indian tertiary centres.[1,12]

Limitations

This study has several limitations. First, and most importantly, the dataset analysed here is synthetic and intended for methodological illustration; the findings must be confirmed in prospectively collected patient data before they can inform practice. Second, the modest sample size (n=38) yields wide confidence intervals and limits power for multivariable adjustment and subgroup analysis. Third, single-centre enrolment limits generalisability. Fourth, HbA1c reflects chronic glycaemia but not acute perioperative glucose excursions, which independently influence SSI; combining HbA1c with perioperative glucose monitoring may improve prediction. Larger, multicentre prospective studies are warranted to validate the proposed threshold.

CONCLUSION

Higher preoperative HbA1c was associated with a graded and independent increase in the risk of surgical site infection following elective abdominal surgery, with good discriminative ability around a threshold of approximately 7%. Routine preoperative HbA1c assessment is a simple, inexpensive tool that may help identify patients who would benefit from glycaemic optimisation and intensified wound surveillance, potentially reducing the burden of SSI.

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