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Retrospective Analysis

Impact of Glycemic Control on Surgical Site Infections in Neuromodulation Pain Procedures: A Retrospective Analysis

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Background: Surgical site infections (SSIs) are common and preventable postoperative complications that contribute to increased morbidity, mortality, and health care costs. Diabetes mellitus (DM) is a known risk factor for SSIs across multiple surgical specialties, with poor perioperative glycemic control linked to higher infection rates. While neuromodulation procedures carry infection risks, optimal glycemic targets for these procedures remain unclear. Identifying an optimal glycemic threshold could improve infection rates and patient outcomes within this growing field of neuromodulation.

Objectives: To examine and compare the effects of Type 1 and Type 2 DM as well as those of hemoglobin A1c (HbA1c), perioperative glucose levels, DM status, and insulin use in association with neuromodulation pain management procedures.

Study Design: A single-center retrospective chart review.

Setting: This study was conducted at the University of Texas MD Anderson Cancer Center.

Methods: This retrospective study examined neuromodulation surgical cases between October 2019 to July 2024 to ascertain the postoperative infection factors. Among the variables studied were demographics, clinical factors, and surgical outcomes. After reviewing the charts of patients who had received qualifying procedures, the researchers investigated any infections that developed in those individuals.

Results: From the 297 surgical cases analyzed, 9 (3%) yielded SSIs. The rate of SSI was significantly higher in patients with Type 1 DM ($P = 0.0102$), HbA1c levels > 7 ($P = 0.0026$), perioperative glucose > 200 mg/dl ($P = 0.0088$), presence of DM ($P = 0.0111$), and insulin use ($P = 0.0244$). Data specifically showed a 6.23-fold increase in the odds of developing postoperative infections for DM patients, an 8.72-fold increase in the odds for those with type 1 DM in particular, and an 8.56-fold increase in the odds for patients with HbA1c > 7 over those with an HbA1c < 7.

Limitations: Due to the retrospective design of this study, the data eligible for collection were limited to what could be found within the charts available in the electronic medical record. Therefore, the data might have been susceptible to potential confounding and bias.

Conclusions: Patients with type 1 diabetes, HbA1c > 7, perioperative glucose > 200 mg/dl, presence of DM, and a history of insulin use demonstrated a significantly higher risk of developing postoperative infections after neuromodulation procedures. Identifying the variables that contribute to postoperative infection is important to further reduce surgical complications. Future research goals include establishing glycemic targets for patients who inquire about undergoing neuromodulation procedures to improve those patients' outcomes.

Key words: Diabetes, infection, chronic pain, neuromodulation, hemoglobin A1c, surgical site infection, dorsal root ganglion stimulation, peripheral nerve stimulation, spinal cord stimulation, hyperglycemia

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Surgical site infections (SSIs) are common yet highly preventable complications that occur after surgical procedures. SSIs have led to increased patient morbidity and mortality rates, are the costliest health care–associated infections, and prolong hospitalization times. These infections have been shown to occur in 1-5% of patients who have undergone inpatient surgery (1). Due to these concerns, the World Health Organization, Centers for Disease Control and Prevention, and Surgical Care Improvement Project have provided preventative guidelines to reduce further SSIs.

Diabetes mellitus (DM) has been found to be associated with SSIs across a multitude of surgical specialties. A substantial body of literature indicates that patients with poor long-term or perioperative glycemic control are more susceptible to postoperative infections. Specifically, higher rates of SSIs in diabetic patients with perioperative hyperglycemia have been found after surgeries of the orthopedic, cardiothoracic, vascular, and spinal varieties (2). Therefore, DM, glucose, and HbA1c monitoring remain critical for patients undergoing surgery.

Neuromodulation is a growing field within pain medicine that focuses on using minimally invasive surgical electrical treatments that are targeted to the nervous system. Most surgical procedures carry risks, and neuromodulation is no different. Among the spinal cord stimulator procedures, infection rates ranging from 2-5% were found, whereas that figure was recently discovered to be 0% in one place (3) after standardized infection prevention bundles were used. Intrathecal drug delivery systems (IDDS) were also found to be associated with similar infection rates of 2-5%. The Neurostimulation Appropriateness Consensus Committee (NACC) now recommends managing perioperative glucose levels and HbA1c in their guidelines for pain procedures.

The effects of DM have been described in various surgical fields. However, optimal HbA1c and glucose targets for neuromodulation pain procedures remain unclear. Our previous study based on preliminary findings indicated that DM was a risk factor for postoperative infection, suggesting that the discovery of an optimal target for glycemic control (HbA1c and perioperative glucose) could improve postoperative infection rate outcomes (2). In this retrospective study, we aim to examine whether a difference exists between Type 1 and Type 2 DM in terms of associated postoperative infection outcomes, as well as further explore how HbA1c, perioperative glucose, DM, and related variables influence the development of postoperative infections in patients undergoing neuromodulation procedures. Based on previous experience with postoperative infections in patients with poor perioperative glycemic control, we aim to determine whether diabetic patients with lower HbA1c levels show reduced postoperative complications and improved outcomes.

Methods

Data Collection

This retrospective study, approved by the institutional Quality Improvement Assessment Board with a waiver of consent, analyzed surgical cases seen in the Department of Pain Medicine between October 2019 and July 2024. Data gathered from the electronic medical record included trials, implants, revisions, and explants related to spinal cord stimulators (SCSs), intrathecal drug delivery systems (IDDSs), dorsal root ganglion stimulation (DRG-S), intrathecal implants, vertebral augmentation, and peripheral nerve stimulation (PNS).

Data Analysis

Patients' demographics, clinical characteristics, and surgical outcomes were summarized through descriptive statistics. Demographic characteristics were summarized at the patient level, while variables with multiple values collected at different time points (e.g., age, body mass index [BMI]) were averaged across all time points. Procedure-related variables (e.g., DM, HbA1c, perioperative glucose, surgery duration) were summarized at the procedure level, and procedures were assumed to be independent. Continuous variables (e.g., age) were summarized using means, medians, SD, and ranges, while categorical variables (e.g., gender) were summarized with frequencies and proportions. A generalized linear mixed model was used to associate the endpoint (SSIs) with the demographic and clinical factors, accounting for repeated procedures within each patient. For the categorical variables (e.g., "diabetic"), one level was selected as the reference, and other levels were compared to this reference. A 2-sided P-value < 0.05 was considered statistically significant. No adjustment for multiple comparisons was performed due to the exploratory nature of this study. Statistical analysis was conducted using SAS Version 9.4 (SAS Institute, Inc.) and R version 4.2.1 (R Foundation).

Results

A total of 297 surgical cases from 211 unique patients were analyzed. Nine surgical infections were present, with a mean HbA1c of 6.97% (SD = 1.49) and a mean glucose of 143 mg/dl (SD = 84). The postoperative infection rate was 3%.

Demographics

The patients' ages ranged from 21 to 89 years, with a median of 61 years. Of the patients, 45.5% were female. The median BMI was 28 kg/m^2, with a range from 14 kg/m^2 to 52 kg/m^2 (Table 1). No significant association was found between postoperative infections and gender (P = 0.5948), age (P = 0.1883), or BMI (P = 0.2901).

Surgical Details

The qualifying surgical procedures included trials, implants, revisions, and explants related to SCSs, IDDSs, DRG-S, intrathecal implants, vertebral augmentation, and PNS. The median surgery duration was 145 minutes, with a range from 55 to 400 minutes. No significant association was found between postoperative infections and surgery duration (P = 0.9167). Nine surgical cases (3%), each of which arose in a separate patient, developed SSIs. These cases included 2 intrathecal (IT) pump explants, one IT pump implant, one IT pump revision, 3 SCS implants, one SCS trial, and one kyphoplasty.

Type of DM

When associating types of DM with postoperative infections, we used nondiabetic patients as the control group and compared them with patients who had type 1 or type 2 DM. Accounting for the variability among individual patients, the association between postoperative infections and type 1 DM was statistically significant (P = 0.0102) (Table 2). Patients with type 1 DM had 8.72 times higher odds of developing postoperative infections than did nondiabetic patients (odds ratio [OR]: 8.72, 95% CI: 1.67, 45.54). This finding indicates that patients with type 1 DM are more likely to develop postoperative infections than are those without DM (OR > 1). However, there was no statistically significant association between type 2 DM and postoperative infections (P = 0.0581).

HbA1c

Among all procedures, 84.9% of patients had an HbA1c level < 7, whereas 15.1% had an HbA1c level > 7. Of the patients who had SSIs, 44.4% had an HbA1c level < 7, and 55.6% had an HbA1c level > 7. Patients with postoperative infections had a mean HbA1c level of 6.97%, compared to the mean of 5.94% seen in uninfected patients. A significant association between postoperative infections and HbA1c was found (P = 0.0026). Patients with an HbA1c > 7 had 8.56 times higher odds of developing postoperative infections than did those with an HbA1c level < 7 (OR: 8.56, 95% CI: 2.12, 34.6). This difference indicates that patients with HbA1c levels ≥ 7 are more likely to experience postoperative infections (OR > 1).

Table 1. *Table of demographic descriptions at patient level.*

Demographic Description Table	
	Overall (n =211)
Gender	
F	96 (45.5%)
M	115 (54.5%)
Age	
Mean (SD)	59.86 (14.25)
Median	61.00
Range	21.00-89.00
BMI	
Mean (SD)	29.44 (7.32)
Median	28.00
Range (kg/m^2)	14.00-52.00

Perioperative Glucose

Among all cases, 96.3% of the patients had a perioperative glucose level < 200 mg/dl, and 3.7% had a perioperative glucose level > 200 mg/dl. Of the patients with SSIs, 75% had a perioperative glucose level < 200 mg/dl, and 25% had a level > 200 mg/dl. The rate of postoperative infection was significantly higher among patients with a perioperative glucose level > 200 mg/dl (P = 0.0088).

Diabetes

Among patients who developed a postoperative infection, 66.7% had DM. To assess the association between DM and postoperative infections, we used nondiabetic patients as the control group. After variability among individual patients was accounted for, DM was significantly associated with an increased risk of postoperative infections (P = 0.0111) (Fig. 1). Diabetic patients had 6.23 times higher odds of developing postoperative infections than did nondiabetic patients (OR = 6.23, 95% CI: 1.52–25.56). This finding indicates that patients with DM are more likely to develop postoperative infections than are those without diabetes (OR > 1).

Table 2. *Comparison of postoperative infections.*

Comparison of Postoperative Infections								
Variable		**No (n = 288)**	**Yes (n = 9)**	**Total (n = 297)**	**OR**	**Low**	**Upper**	***P*-value**
Gender								
	F (ref)	134 (46.5%)	5 (55.6%)	139 (46.8%)				
	M	154 (53.5%)	4 (44.4%)	158 (53.2%)	0.6961	0.1832	2.6453	0.5948
Age								
	Mean (SD)	59.042 (13.808)	52.667 (23.701)	58.848 (14.186)	0.9701	0.9273	1.015	0.1883
	Median	60.000	47.000	60.000				
	Range	21.000 - 89.000	21.000 - 83.000	21.000 - 89.000				
BMI								
	Mean (SD)	29.615 (7.260)	26.978 (10.186)	29.536 (7.356)	0.9468	0.8556	1.0477	0.2901
	Median	28.350	26.000	28.000				
	Range	16.000 - 52.000	14.000 - 50.500	14.000 - 52.000				
Diabetic								
	No (ref)	218 (75.7%)	3 (33.3%)	221 (74.4%)				
	Yes	70 (24.3%)	6 (66.7%)	76 (25.6%)	6.2286	1.5179	25.5588	0.0111*
HbA1C								
	N-Miss	131	0	131				
	<7 (ref)	137 (87.3%)	4 (44.4%)	141 (84.9%)				
	>=7	20 (12.7%)	5 (55.6%)	25 (15.1%)	8.5625	2.1199	34.5842	0.0026*
Insulin								
	No (ref)	263 (91.3%)	6 (66.7%)	269 (90.6%)				
	yes	25 (8.7%)	3 (33.3%)	28 (9.4%)	5.26	1.2396	22.3202	0.0244*
Perioperative Glucose								
	N-Miss	135	1	136				
	< 200 (ref)	149 (97.4%)	6 (75.0%)	155 (96.3%)				
	≥ 200	4 (2.6%)	2 (25.0%)	6 (3.7%)	12.4167	1.8882	81.651	0.0088*
Surgery Duration								
	Mean (SD)	145.990 (50.803)	147.778 (46.241)	146.044 (50.600)	1.0007	0.9879	1.0136	0.9167
	Median	145.000	145.000	145.000				
	Range	55.000 - 400.000	75.000 - 215.000	55.000 - 400.000				
Type 1 or Type 2 Diabetes								
	no diabetes (ref)	218 (75.7%)	3 (33.3%)	221 (74.4%)				
	Type 1	25 (8.7%)	3 (33.3%)	28 (9.4%)	8.72	1.6697	45.5406	0.0102*
	Type 2	45 (15.6%)	3 (33.3%)	48 (16.2%)	4.8444	0.9471	24.7798	0.0581

*Indicates statistically significant *P*-value.

Insulin Use

Among all surgical cases, 9.4% of the patients (representing 19 unique individuals) were insulin-dependent at the time of surgery. The association between postoperative infections and insulin use was significant (*P* = 0.0244).

Discussion

Based on the findings of this study, DM and elevated HbA1c levels are significant risk factors for increased infection rates in neuromodulation pain procedures (*P* = 0.0111 and *P* = 0.0026, respectively). Diabetic patients demonstrated 6 times greater likelihood of developing

SSIs than did nondiabetic patients; individuals with type 1 DM showed an 8.72-fold increase in their odds of experiencing SSIs; and patients with HbA1c levels >7 appeared to have an 8.56-fold increase in those odds over those whose HbA1c levels were < 7. The overall postoperative infection rate was 3%, comparable to the 2.45% rate among patients who received SCSs (4). Patients with postoperative infections had a mean HbA1c level of 6.97%, compared to the mean of 5.94% in patients without infections. HbA1c is a reliable biomarker for long-term glycemic control, reflecting average blood glucose levels over the previous 2-3 months (5). Elevated HbA1c levels have been associated with impaired immune function, delayed wound healing, and increased infection susceptibility (6,7). These findings are consistent with existing literature across various surgical fields, in which patients with poorly controlled DM (HbA1c levels ≥ 7%) have been shown to run elevated risks of developing infections (2).

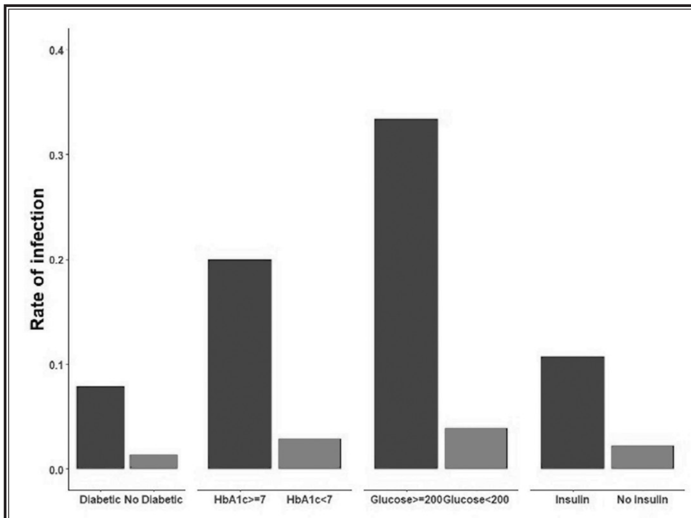

Fig. 1. *Comparison of rates of surgical site infections among diabetic risk groups.*

While HbA1c provides valuable information about long-term glucose control, it fails to capture short-term variations in blood glucose levels in perioperative settings. In this study, elevated perioperative glucose levels (> 200 mg/dl) were associated with postoperative infections ($P = 0.0088$). The data highlight the impact of high perioperative glucose levels on infection risk. Elevated glucose levels are well-documented risk factors for infections due to impaired neutrophil function and bacterial proliferation, which are particularly concerning in surgical procedures, such as neuromodulation, in which hardware implantation introduces additional risks of infection (6).

A significant association was seen between infections and type of DM ($P = 0.0102$), with the odds of developing postoperative infections 8.72 times higher for patients with type 1 DM than for patients who had no DM. The relationship between postoperative infection and insulin use was also significant ($P = 0.0244$). Insulin users' odds of developing postoperative infections were over 5 times higher than those of patients who did not use insulin. Among the 9 patients with postoperative infections, 3 (33.3%) were insulin users, compared to only 8.7% in the uninfected group. The hyperglycemia experienced by many DM patients and insulin users impairs both the adaptive and innate immune systems' abilities to combat infection effectively (8). This factor may contribute to the higher rates of postoperative infections evidenced in this study, since blood sugar levels are negatively correlated with leukocyte function (9). Further investigation into the causation among insulin use and high rates of postoperative infections is warranted because the deployment of insulin therapy to control glycemic levels is expected to improve incidences of infection.

The study found no significant association between gender ($P = 0.5948$), age ($P = 0.1883$), BMI ($P = 0.2901$), or surgery duration ($P = 0.9167$) and postoperative infections. Existing literature in similar fields has shown the influence of gender on infection rates to be primarily dependent on context, potentially affected by other variables such as immune function or hormone levels (10). Although the data indicate that age is not a reliable predictor of infection risk, age-related factors such as comorbidities and immunocompromised states could influence outcomes indirectly and warrant further investigation. Obesity has been associated with infections in general surgery, primarily due to impaired wound healing and immunodeficiency (11). That obesity lacks significance in this study may be attributed to the specific nature of neuromodulation procedures (e.g., smaller incision sites) or the small sample size of infected patients. Long durations of surgery are commonly linked to increased infection risks in other surgical fields because of prolonged tissue exposure and contamination risk (12). However, the absence of a significant relationship in this study suggests that duration alone may not be an essential factor in neuromodulation procedures.

Conclusion

This study underscores the multifactorial nature of postoperative SSIs that follow neuromodulation procedures. The findings highlight the significant role of DM and the type thereof, elevated HbA1c levels, and perioperative glucose control as critical factors influencing infection risk. Specifically, diabetic patients and those with poor glycemic control exhibit significantly higher odds of developing postoperative infections, with patients who have type 1 diabetes presenting the highest risk. Conversely, factors such as gender, age, BMI, and surgery duration showed no significant associations with infection rates in this study. This result suggests that metabolic and glycemic variables are more relevant predictors of infection.

These findings emphasize the importance of preoperative screening, individualized glycemic control strategies, and interdisciplinary care in minimizing SSI risks during neuromodulation procedures and improving their outcomes. Future research should establish specific glycemic thresholds, investigate the interplay of multiple risk factors, and assess the efficacy of targeted interventions in reducing SSIs.

Author Contributions

BKH, AH, SJ, and JM were involved in study conception. JM, XS, and JW contributed to data collection and analysis. JM, AH, JW, XS, SN, SJ, and BKH contributed to the drafting, revisions, and final approval of the manuscript.

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