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Association of Elevated Perioperative Blood Glucose With Complications and Postoperative Outcomes Following Traumatic Spine Surgery

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ABSTRACT

Background: Perioperative blood glucose control has been demonstrated to influence outcomes following spine surgery, though this association has not been fully elucidated in patients with traumatic spine injuries. This study sought to determine the association between perioperative blood glucose levels and complications or outcomes in patients undergoing spine surgery due to injury.

Methods: A retrospective review was conducted to identify patients who underwent spine surgery due to traumatic injuries between 1 March 2020 and 29 September 2022 at a single academic institution. Descriptive factors, complications, and outcomes were compared between those with a postoperative blood glucose level of <200 mg/dL and those with a preoperative glucose of <200 mg/dL.

Results: Patients with a post- and preoperative blood glucose of ≥200 mg/dL had significantly higher odds of respiratory complications (OR = 2.1, 2.1, P = 0.02, 0.03), skin/wound complications (OR = 2.2, 2.8, P = 0.04, 0.03), and increased hospital length of stay (OR = 9.6, 12.1, P = 0.02, 0.03) compared with those with blood glucose of <200 mg/dL. Those with postoperative glucose ≥200 mg/dL also had significantly higher odds of inpatient mortality (OR = 4.5, P = 0.04) when controlling for confounding factors. Neither pre- nor postoperative blood glucose of ≥200 mg/dL was associated with an improvement in American Spinal Injury Association Impairment Scale score at the final follow-up when controlling for multiple confounding factors (P = 0.44, 0.06).

Conclusion: Elevated blood glucose both pre- and postoperatively was associated with an increased rate of postoperative complications and negative postoperative outcomes. However, there was no association between elevated blood glucose levels and neurological recovery following traumatic spinal injury.

Level of Evidence: 3.

Complications

Keywords: blood glucose, traumatic spine surgery, nonelective, complications, neurologic outcomes

INTRODUCTION

Traumatic spine injury is a major cause of morbidity and mortality within the United States, with approximately 13,600 cases per year in 2020, with an expected increase to 17,560 cases per year by 2050.[1] Given the increased number of patients experiencing these injuries and the associated morbidity, there has been an increase in research focused on postinjury interventions to minimize complications and negative postoperative outcomes following traumatic spine injuries.[2–4] One area of particular interest has been the influence of blood glucose control on outcomes in those with traumatic spinal cord injuries. Elevated blood glucose levels have been previously demonstrated to be associated with an increased risk of developing complications following spine surgery, in particular superficial skin infections.[5] Additionally, elevated blood glucose levels have been demonstrated in rat models to disrupt the blood-spine barrier.[6] Disruption of the blood-spine barrier allows inflammatory cells to enter the spinal cord following a traumatic spinal cord injury, resulting in a large inflammatory response, which can further worsen neurological injury.[7] Therefore, strict blood glucose control following traumatic spinal cord injury may help to mitigate further disruption to the blood-spine barrier and minimize damage to the spinal cord.

Previous studies have analyzed the effect of diabetes on infections and complications after spine surgery; however, these studies focused on elective spine surgery, and their results were conflicting.[8–15] The literature is even more limited regarding the effect of blood glucose abnormalities on neurological recovery in patients undergoing spine surgery, and the results are also conflicting.[16,17] The purpose of this study is to evaluate the effect of perioperative blood glucose parameters on complications, postoperative outcomes, and neurological recovery for traumatic spine surgery patients.

MATERIALS AND METHODS

Approval for this study was granted by the Institutional Review Board (approval number: 1960173–1) at our institution. Informed consent was not required due to the retrospective nature of the study; therefore, an exemption was granted by the Institutional Review Board at our institution. Upon Institutional Review Board approval, a retrospective review was conducted to identify a large cohort of patients who underwent surgery for cervical and/or thoracolumbar spine trauma. Patients aged 18 years or older who underwent traumatic spine surgery (Current Procedural Terminology codes: 22310, 22513, 22325, 22326, 22514, and 22585) between 1 March 2020 and 29 September 2022 were identified. Patients were excluded from this study if they had an elective spine surgery. Demographic data collected from patients included age, race, gender, ethnicity, body mass index (BMI), insurance status, and Charleson Comorbidity Index (CCI). Perioperative blood glucose variables, such as hemoglobin A1c (HbA1c), highest glucose reading before surgery taken after injury, highest glucose reading within 72 hours postoperatively, whether the blood glucose level was ≥200 mg/dL pre- and postoperatively, and how many times the postoperative blood glucose reading was ≥200 mg/dL were also collected. Perioperative blood glucose control medication regimens were managed by the primary admitting team based on a patient's medical factors and clinical condition. As such, there was no standardized blood glucose regimen for patients perioperatively. Additional data collected included blood alcohol concentration, drug screen results, use of supplemental oxygen in the emergency department, injury mechanism, preoperative American Spinal Injury Association Impairment Scale (ASIA) scores, postoperative complications, days spent in the hospital, days spent in the intensive care unit (ICU), days spent using a ventilator, and disposition status. Finally, ASIA scores were collected postoperatively both within 1 week of injury and at the most recent follow-up.

Continuous variables were tested for normality using the Shapiro-Wilk normality test along with histograms. Continuous data were expressed as mean ± SD, while nominal data were expressed as frequency (percentage). Simple logistic and linear regression models were created to evaluate the odds ratio and Wald confidence intervals for categorical and continuous variables. χ^2 test was used to compare the nominal data of the different groups in the study. Univariate linear regression was utilized to determine significant predictors for our primary outcome: an increase in ASIA score at the most recent follow-up. Factors that were noted to be significant predictors of an increase in ASIA score were then included in our multivariable linear analysis to determine whether elevated preoperative or postoperative blood glucose were independent predictors for an increase in ASIA score at the most recent follow-up when controlling for confounding variables. Student's t test was used to compare the means of the groups, and P values were considered significant if ≤0.05.

RESULTS

A total of 410 patients were included in the final analysis, with an average postoperative follow-up time of 17.6 months (range: 3–34 months). Demographic information is presented in Table 1. The highest glucose readings both before and within 72 hours after surgery ranged from 63 to 671 (average: 139.2) and from 83 to 547 (average: 163.1) mg/dL, respectively. The average HbA1C was 6.3% (range: 4.6%–12.6%). Of the 153 patients with a recorded HbA1C, 49 (32%) had an HbA1c of 6.5%. Patients spent an average of 22.9 days in the hospital (range: 1–281 days), 6.7 days in the ICU (range: 0–103 days), and 4.6 days on a ventilator (range: 0–117 days). There were 12 (2.9%) inpatient mortalities, with 6 (50%) due to acute respiratory failure secondary to acute respiratory distress syndrome, 2 (16.7%) due to myocardial infarction, 1 (8.3%) due to anoxic brain injury, and 3 (25%) due to unknown causes. The average ASIA scores preoperatively, within 1 week of injury, and at the most recent follow-up were 3.9, 4.0, and 4.4, respectively.

Patients were separated into 2 cohorts: those who had a postoperative glucose level <200 mg/dL ($n = 333$) and those who had a postoperative glucose level ≥200 mg/dL ($n = 68$, Table 2). Patients in the postoperative glucose ≥200 mg/dL group were significantly more likely to be older (61.99 vs 50.66, $P < 0.01$), be White/Caucasian (64.7% vs 48.6%, $P = 0.04$), have higher CCI scores (3.4 vs 1.5, $P < 0.01$), have a diagnosis of diabetes mellitus (69.1% vs 9.91%, $P < 0.01$), and have a higher BMI (30.48 vs 27.65, $P = 0.01$) when compared with patients with postoperative glucose <200 mg/dL. Additionally, it was found that patients with postoperative glucose ≥200 mg/dL had higher rates of respiratory complications (23.5% vs 12.9%, $P = 0.02$) and

Table 1. Descriptive variables—all patients.

Factor	Mean (SD)	Minimum	Maximum
Patient variables			
Age	52.4 (19.0)	18	94
Gender, n (%)			
Female	96 (23.4)	-	-
Male	314 (76.6)	-	-
Race, n (%)			
White	206 (50.5)	-	-
Black	174 (42.7)	-	-
Other	28 (6.9)	-	-
Body mass index	28.2 (7.5)	12.4	63
CCI	1.8 (2.0)	0	9
Clinic/ED variables			
BAC	61.5 (101.2)	0	417
ED O_2 saturation	96.0 (4.1)	69	100
ED Glasgow Coma Scale	13.8 (3.1)	3	15
ISS	17.8 (12.6)	4	75
TRISS	0.9 (0.2)	0.01	0.99
Quantity of complication variables			
Cardiac	0.0 (0.2)	0	2
Deep vein thrombosis	0.1 (0.3)	0	2
Genitourinary	0.2 (0.6)	0	5
Nervous system	0.2 (0.4)	0	2
Oropharynx	0.1 (0.4)	0	2
Postoperative infection	0.1 (0.4)	0	3
Respiratory	0.2 (0.6)	0	4
Skin/wound	0.1 (0.4)	0	4
Total complication categories affected	1.2 (1.4)	0	7
Total individual complications	1.4 (1.8)	0	11
Glucose and other outcome variables			
HbA1C	6.2 (1.6)	4.6	12.6
Highest glucose reading prior to surgery	139.2 (56.4)	63	671
Highest glucose reading within 72 h postoperative	163.1 (67.7)	83	547
If postoperative glucose was >200 mg/dL, how many times?	0.8 (2.8)	0	22
Total hospital days	22.9 (31.8)	1	281
Total ICU days	6.7 (9.9)	0	103
Total ventilator days	4.6 (13.3)	0	117
ASIA grade at most recent follow-up	4.4 (1.1)	1	5
Best ASIA grade within 1 wk of injury postop	4.0 (1.2)	1	5
Preoperative ASIA grade	3.9 (1.2)	1	5

Abbreviations: ASIA, American Spinal Injury Association Impairment Scale; BAC, blood alcohol concentration; CCI, Charlson Comorbidity Index; ED, emergency department; ICU, intensive care unit; ISS, Injury Severity Score; TRISS, Trauma Score and Injury Severity Score.
Note: Data presented as mean (SD) unless otherwise noted.

skin/wound complications (16.2% vs 8.1%, *P* = *0.04*), with these patients having significantly higher odds of developing a respiratory (OR = 2.08, *P* = *0.03*) and skin/wound complication (OR = 2.19, *P* = 0.04) compared with those with postoperative glucose <200 mg/dL (Table 3). It was also found that patients with postoperative glucose ≥200 mg/dL had longer hospital lengths of stays (30.85 vs 21.24 days, *P* = 0.01), more time spent in the ICU (7.92 vs 6.44 days, *P* = 0.02), and more time on a ventilator (6.89 vs 3.91 days, *P* = 0.01). Those with postoperative glucose ≥200 mg/dL had significantly higher odds of having an increase in the length of hospitalization (OR = 9.6, *P* = 0.02); however, this was not demonstrated for days spent in ICU (*P* = 0.26) or days spent on a ventilator (*P* = 0.09). Finally, patients with postoperative glucose ≥200 mg/dL were more likely to suffer inpatient mortality (7.4% vs 2.1%, *P* = 0.04) with an unadjusted OR of 3.7 (*P* = 0.03) and an OR of 4.5 (*P* = 0.04) when controlling for confounding variables, such as age, race, BMI, and CCI.

Patients were additionally separated into groups based on whether their preoperative blood glucose levels were <200 mg/dL (*n* = 374) or ≥200 mg/dL (*n* = 34). Those with a preoperative glucose ≥200 mg/dL were more likely to be older (56.74 vs 52.01, *P* < 0.01), be White/Caucasian (73.5% vs 48.7%, *P* = *0.01*), have a diagnosis of diabetes mellitus (61.8% vs 16.0%, *P* < *0.*01), and have higher BMIs (32.4 vs 26.2, *P* < 0.01) than patients with a preoperative glucose <200 mg/dL. Patients with preoperative glucose ≥200 mg/dL were also more likely to develop respiratory complications (29.4% vs 13.6%, *P* = 0.03) and to develop skin/wound complications (20.6% vs 8.6%, *P* = 0.03). The odds of developing a respiratory and skin/wound infection were 2.1 (*P* = 0.02) and 2.8 (*P* = 0.01) times higher for those with a preoperative blood glucose of ≥200 mg/dL, respectively. Additionally, patients with preoperative glucose ≥200 mg/dL had longer hospital lengths of stays (34.06 vs 21.93 days, *P* < *0.01)*, more time spent in the ICU (9.18 vs 6.46 days, *P* = 0.01), and more time spent on a ventilator (5.82 vs 4.46, *P* = 0.01). Those with preoperative glucose ≥200 mg/dL had significantly higher odds of having an increase in the length of hospitalization (OR = 12.1, *P* = 0.03); however, this was not demonstrated for days spent in the ICU (*P* = 0.12) or days spent on a ventilator (*P* = 0.57).

Univariate linear regression analysis was utilized to find significant predictive factors for an increase in ASIA scores at the most recent follow-up (**Table 4**). Postoperative glucose ≥200 mg/dL (OR = –0.4, *P* = 0.048), Emergency Department Glasgow Coma Scale (OR = 0.08, *P* < 0.01), Injury Severity Score (OR = –0.05, *P* < 0.01), total days hospitalized (OR = –0.02, *P* < 0.01), total days in the ICU (OR = –0.06, *P* < 0.01), total days on a ventilator (*P* = –0.04, *P* < 0.01), preoperative ASIA score (OR = 0.76, *P* < 0.01), positive alcohol screen (OR = –0.45, *P* < 0.01), use of emergency room oxygen supplementation (OR = –0.61, *P* < 0.01), incidence of postoperative infection (OR = –0.59, *P* = 0.03), incidence of respiratory complication (OR = –0.92, *P* < 0.01), incidence of nervous system complication (OR = –0.6, *P* = 0.01), and incidence of skin/wound complication (OR = –1.6, *P* < 0.01) were all found to be significant predictive factors for an increase in ASIA score at most recent follow-up. These

Table 2. Categorical/continuous variable comparison—postoperative glucose <200 and ≥200 mg/dL and preoperative glucose <200 and ≥200 mg/dL.

Factor	Postoperative Glucose <200 mg/dL (*n* = 333)	Postoperative Glucose ≥200 mg/dL (*n* = 68)	*P*	Preoperative Glucose <200 mg/dL (*n* = 374)	Preoperative Glucose ≥200 mg/dL (*n* = 34)	*P*
Age, y, mean (SD)	50.7 (19)	62 (15.9)	<0.01	52 (19.4)	56.7 (3.2)	<0.01
Gender, *n* (%)						
Female	81 (24.3)	14 (20.6)	0.51	88 (23.5)	8 (23.5)	>0.99
Male	252 (75.7)	54 (79.4)		286 (76.5)	26 (76.5)	
Race, *n* (%)						
Black or African American	145 (43.8)	22 (32.4)	0.04	164 (43.9)	8 (23.5)	0.02
Caucasian	161 (48.6)	44 (64.7)		182 (48.7)	25 (73.5)	
Other Race	25 (7.6)	2 (2.9)		28 (7.5)	1 (2.9)	
BMI, mean (SD)	27.7 (7.2)	30.5 (8.3)	0.01	27.7 (7.4)	32.4 (7.2)	<0.01
Diagnosis of Diabetes, *n* (%)						
No	300 (90.1)	21 (30.9)	<0.01	314 (83.9)	13 (38.3)	<0.01
Yes	33 (9.9)	47 (69.1)		60 (16)	21 (61.8)	
Respiratory Complication, *n* (%)						
No	290 (87.1)	52 (76.5)	0.02	324 (86.6)	24 (70.6)	0.03
Yes	43 (12.9)	16 (23.5)		51 (13.6)	10 (29.4)	
Skin/wound Complication, *n* (%)						
No	306 (91.9)	57 (83.8)	0.04	342 (91.4)	27 (79.4)	0.03
Yes	27 (8.1)	11 (16.2)		32 (8.6)	7 (20.6)	
CCI, mean (SD)	1.5 (1.9)	3.4 (2.1)	<0.01	1.8 (2.0)	2.8 (2.3)	<0.01
Total Hospital Days, mean (SD)	21.2 (28.5)	30.9 (43.6)	0.01	21.9 (31.9)	34.1 (29.3)	<0.01
Total ICU Days, mean (SD)	6.4 (10.2)	7.9 (7.7)	0.02	6.5 (10)	9.2 (8.2)	0.01
Total Ventilator Days, mean (SD)	3.9 (11.6)	6.9 (16.9)	0.01	4.5 (13.7)	5.8 (8.3)	0.01
ASIA Grade at most recent follow-up, mean (SD)	4.4 (1)	4 (1.4)	0.15	4.4 (1.1)	4.3 (0.91)	0.17
Best ASIA grade within 1 week of injury postop, mean (SD)	4 (1.2)	3.7 (1.4)	0.17	4 (1.2)	4 (0.95)	0.48
Preop ASIA Grade, mean (SD)	3.9 (1.2)	3.7 (1.5)	0.59	3.9 (1.3)	3.9 (1.0)	0.91
Discharge Status, *n* (%)						
Alive	326 (97.9)	63 (92.7)	0.04	362 (96.8)	34 (100)	0.61
Dead	7 (2.1)	5 (7.4)		12 (3.2)	0 (0)	

Abbreviations: ASIA, American Spinal Injury Association Impairment Scale; BMI, body mass index; CCI, Charleson Comorbidity Index; ICU, intensive care unit.

factors were included in our multivariable linear regression analysis, which found that neither postoperative no preoperative glucose ≥200 mg/dL was associated with an increase in ASIA scores at the most recent follow-up (*P* = 0.06, 0.44, respectively, **Table 5**).

DISCUSSION

The effect of perioperative blood glucose control on postoperative complications and neurological recovery has previously been studied for elective spine surgery, but the data are limited regarding its effect following spine surgery for trauma. The results of the current study demonstrated that patients with preoperative or postoperative glucose ≥200 mg/dL had increased odds of developing respiratory complications (OR = 2.05, 2.08, *P* = 0.02, 0.03) and skin/wound complications (OR = 2.84, 2.19, *P* = 0.01, 0.04) compared with patients with glucose <200 mg/dL. Patients with pre- or postoperative glucose ≥200 mg/dL also had higher odds of an increase in hospital length of stay (OR = 9.6, 12.1, *P* = 0.02, 0.03). Patients with postoperative glucose ≥200 mg/dL had 4.5 times higher odds of inpatient mortality (*P = 0.04*) when compared with patients with glucose <200 mg/dL, even when controlling for confounding variables. Finally, a multivariable linear analysis revealed neither pre- nor postoperative blood glucose ≥200 mg/dL was associated with an increase in ASIA score at the most recent follow-up when controlling for confounding factors (*P* = 0.06, 0.44, respectively).

When considering a patient for a surgical procedure, a surgeon must evaluate the risk of postoperative

Table 3. Unadjusted odds ratios and Wald CIs for comparisons of postoperative and preoperative glucose levels.

Comparison	OR (95% CI)	*P*
Postoperative glucose ≥200 compared with <200 mg dL		
Respiratory complication, yes vs no	2.1 (1.1–4)	0.03
Skin/wound complication, yes vs no	2.2 (1–4.7)	0.04
Increase in hospital length of stay, d	9.6 (1.4–17.9)	0.03
Increase in ICU stay, d	1.5 (−1.1–4.1)	0.26
Increase in time on ventilator, d	2.9 (−0.39–6.4)	0.09
Discharge status, dead vs alive	3.7 (1.1–12)	0.03
Preoperative glucose ≥200 compared with <200 mg dL		
Respiratory complication, yes vs no	2.1 (1.1–3.8)	0.02
Skin/wound complication, yes vs no	2.8 (1.4–5.7)	0.01
Increase in hospital length of stay, d	12.1 (0.97–23.3)	0.03
Increase in ICU stay, d	2.7 (−0.75–6.2)	0.12
Increase in time on ventilator, d	1.4 (−3.3–6.1)	0.57

Abbreviation: ICU, intensive care unit.

Table 4. Univariate linear regression analysis for increase in ASIA score.

Factor	OR (95% CI)	*P*
Postoperative glucose ≥200 mg/dL	−0.4 (−0.81 to −0.01)	0.048
Preoperative glucose ≥200 mg/dL	−0.13 (−0.65–0.38)	0.61
Age	0.004 (−0.003–0.01)	0.28
Female gender	−0.08 (−0.41–0.24)	0.62
CCI	0.02 (−0.07–0.1)	0.7
ED GCS	0.08 (0.03–0.12)	<0.01
BMI	−0.01 (−0.03–0.02)	0.59
ISS	−0.05 (−0.06 to −0.04)	<0.01
TRISS	0.06 (−0.2–0.33)	0.63
Total ventilator days	−0.04 (−0.05 to −0.03)	<0.01
Total ICU days	−0.06 (−0.07 to −0.04)	<0.01
Total hospital days	−0.02 (−0.02 to −0.01)	<0.01
Preoperative ASIA grade	0.76 (0.69–0.83)	<0.01
Caucasian race	0.1 (−0.19–0.39)	0.5
Black race	−0.08 (−0.37–0.21)	0.59
Positive alcohol screen	−0.45 (−0.74 to −0.16)	<0.01
ED supplemental O_2	−0.61 (−0.97 to −0.26)	<0.01
History of smoking	0.12 (−0.18–0.42)	0.42
Chronic steroid use	0.44 (−0.55–1.4)	0.39
Pulmonary embolism	−0.58 (−1.6–0.4)	0.25
Infection	−0.59 (−1.1 to −0.04)	0.03
Cerebrovascular complication	0.03 (−0.96–1.0)	0.95
Respiratory complication	−0.92 (−1.3 to −0.57)	<0.01
Nervous system complication	−0.6 (−1.1 to −0.13)	0.01
Postoperative shock	0.13 (−1.4–1.7)	0.87
Skin/wound complication	−1.6 (−2.0 to −1.2)	<0.01
Preoperative steroids	−0.31 (−0.69–0.07)	0.11

Abbreviations: ASIA, American Spinal Injury Association Impairment Scale; BMI, body mass index; CCI, Charleson Comorbidity Index; ED, emergency department; GCS, Glasgow Coma Scale; ICU, intensive care unit; ISS, Injury Severity Score; TRISS, Trauma Score and Injury Severity Score.

complications. The literature has cited diabetes to be associated with postoperative complications for spine surgery, but the results are conflicting. Worley et al found an increased rate of pneumonia, urinary tract infection, unplanned intubations, and wound complications for diabetic patients when compared with nondiabetics.[13] Additionally, Chen et al, Xing et al, Peng et al, and Hwang et al all found an increased rate of postoperative infections in those with diabetes, and by extension elevated HbA1c, but they did not examine

Table 5. Multivariate linear regression analysis for increase in ASIA score.

Factor	OR (95% CI)	*P*
Postoperative glucose ≥200 mg/dL	−0.27 (−0.52–0.01)	0.06
Preoperative glucose ≥200 mg/dL	0.13 (−0.19–0.44)	0.44
ED GCS	−0.01 (−0.05–0.03)	0.6
ISS	−0.01 (−0.01–0.01)	0.39
Total ventilator days	−0.01 (−0.02–0.003)	0.16
Total ICU days	−0.01 (−0.02–0.01)	0.62
Total hospital days	−0.001 (−0.005–0.002)	0.42
Preoperative ASIA grade	0.65 (0.55–0.74)	<0.01
Positive alcohol screen	−0.02 (−0.21–0.17)	0.84
ED supplemental O_2	−0.001 (−0.03–0.02)	0.91
Infection	−0.02 (−0.38–0.34)	0.92
Respiratory complication	−0.19 (−0.45–0.07)	0.15
Nervous system complication	0.28 (−0.03–0.58)	0.08
Skin/wound complication	−0.3 (−0.65–0.06)	0.1

Abbreviations: ASIA, American Spinal Injury Association Impairment Scale; ED, emergency department; GCS, Glasgow Coma Scale; ICU, intensive care unit; ISS, injury severity score.

other complications.[9,10,12,15] However, Khan et al found no significant increase in postoperative complications between diabetics and nondiabetics.[14] This study did not focus on diabetes but instead evaluated postoperative and preoperative blood glucose levels, as it was felt this would represent a clearer picture of whether elevated blood glucose was related to an increase in postoperative complications. The results of this study brought some clarity to the topic and added to the available literature, demonstrating that both postoperative and preoperative blood glucose of ≥200 mg/dL was associated with increased odds of developing respiratory complications and skin/wound complications. These findings generally support the results of previous studies, suggesting that elevated blood glucose both post- and preoperatively increases the odds of developing postoperative complications.

Hospital length of stay, especially if that time is spent in the ICU or on a ventilator, can be an important marker of a patient's overall clinical status. Additionally, this variable has the potential to be expensive for a hospital system, and identifying patients at risk for longer and more extensive hospital stays may be valuable for their treatment. Guzman et al and Worley et al both found an increased length of hospitalization in those with diabetes mellitus compared with those without.[11,13] In contrast, Khan et al found no significant difference in length of hospital stay for those with diabetes compared with those without.[14] The findings of this study concur with the former studies, as both elevated post- and preoperative blood glucose were found to be associated with significantly higher odds of an increase in the length of hospital stay. These findings suggest that preventing high blood glucose levels for patients in the preoperative and postoperative period for traumatic spine surgery may help decrease the overall time spent admitted to the hospital. Therefore, blood glucose control may not only help patients' treatment plans but may also potentially reduce the overall costs of medical care to the patient and the hospital. Given this, surgeons may want to focus on maintaining strict blood glucose control in patients undergoing traumatic spine surgery to decrease their overall length of admission.

An interesting finding in this study was the relationship between postoperative glucose and the odds of inpatient mortality. There was found to be a significant increase in the odds of suffering inpatient mortality for patients with postoperative blood glucose of ≥200 mg/dL compared with those with postoperative blood glucose of <200 mg/dL, even when controlling for confounding variables. The results of this study are supported by Guzman et al and Furlan et al, who also found an increase in inpatient mortality in patients with diabetes undergoing spinal surgery compared with those without.[11,18] A potential reason for the discrepancy between the post- vs preoperative groups could be that, while blood glucose may be elevated preoperatively secondary to the physiological stress of the injury, elevated postoperative blood glucose may more definitively and specifically indicate a systemic derangement of internal regulatory systems, leading to an increased likelihood of suffering inpatient mortality.

A well-studied and reliable marker of a patient's neurological function after a spinal cord injury is the ASIA score.[19–23] Despite the importance of this score, to our knowledge, no other study has focused on how blood glucose levels affect ASIA scores and the patient's subsequent neurological recovery following traumatic spine injury. Additionally, previous studies that focused on neurological recovery following spinal injury in hyperglycemic patients noted conflicting results.[18,24] Furlan et al and Tokai et al found that hyperglycemia was associated with worse neurological outcomes following spinal surgery for traumatic spinal cord injury and cervical myelopathy, respectively, while Cassinelli et al did not find diabetes to be a significant risk factor for worse outcomes or complications following spinal surgery.[18,24,25] This study brought some clarity to this topic while taking a novel approach to evaluating ASIA scores, demonstrating that neither postoperative nor preoperative glucose ≥200 mg/dL was associated with a decreased rate of neurological recovery when controlling for multiple potential confounding variables. The results of this study suggest that strict blood glucose control both pre- and postoperatively may not influence the rate of neurological recovery following traumatic spinal injury.

There are several limitations to this study. First, although we had a large cohort of 410 patients in this study, only 285 of these patients had preoperative ASIA scores, and 231 had postoperative ASIA scores at their most recent follow-up. This is due to our health system transitioning electronic medical record systems on 1 February 2021, with some patient information being lost during the transition that has not since been recovered. This smaller sample size may limit the ability of our results to be generalizable for this surgical cohort regarding neurological recovery as this patient drop-off may mask confounding variables and has the potential to skew our results. Also, a significant percentage of our patient population may have undiagnosed diabetes, which may serve as a confounding factor we are unable to adequately control, thereby limiting the validity of our results. Next, traumatic injury in general may result in dysregulation of physiological glucose levels, which, given the nature of the study, we are unable to adequately control for in our analysis. In addition, the postoperative blood glucose control protocol was not standardized to all patients, which limits our ability to generalize our findings. Additionally, the majority of our study population was male (76.6%) and white (50.5%), which similarly may limit our ability to generalize our results to other racial and gender groups. Finally, we are unable to determine from our results whether perioperative hyperglycemia affects neurological recovery in the form of ASIA scores, or if worse presenting ASIA scores affect perioperative hyperglycemia, thereby limiting the validity of our results. Despite these limitations, our study is one of the first of its kind to examine how postoperative complications, postoperative outcomes, and neurological recovery are related to pre- and postoperative blood glucose levels.

CONCLUSION

The current study found that elevated post- and preoperative blood glucose levels were associated with an increased odds of respiratory complications, skin/wound complications, and hospital length of stay. Elevated postoperative glucose was also associated with an increased odds of inpatient mortality when controlling for confounding variables. Neither elevated pre- nor postoperative blood glucose was associated with a decrease in neurological recovery following surgery for a traumatic spine injury. Tighter blood glucose control may help prevent complications, decrease hospital and patient costs, and ultimately decrease patient morbidity and mortality. Further study in a prospective fashion is necessary to fully elucidate the relationship between perioperative hyperglycemia and postoperative outcomes.

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