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Original Research

Prehospital Blood Glucose Testing as a Predictor of Impending Hypotension in Adult Trauma Patients

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A B S T R A C T

Objective: Stress-induced hyperglycemia has been found to increase hemorrhagic shock, morbidity, and mortality in the trauma patient. The purpose of this study is to evaluate whether prehospital point-of-care glucose is an independent predictor of hypotension in the adult trauma patient transported by air ambulance to the receiving trauma center.

Methods: This retrospective chart review evaluated adult, nondiabetic trauma patients transported by air ambulance at 3 programs in the Midwest for the calendar year 2018. A total of 107 patients met the inclusion criteria. The primary analysis was the determination of an optimal cutoff for the blood glucose diagnostic for predicting a hypotensive outcome followed by chi-square incidence comparison.

Results: The optimal diagnostic cutoff point using Youden's index (J) was determined to be a blood glucose value of 220 mg/dL or greater. Initial glucose values were associated with an increased relative risk of a hypotension outcome ($P = .040$). Glucose dichotomy was also associated with a mean decrease in systolic blood pressure during transport ($P = .016$).

Conclusion: The findings in this study indicate a point-of-care glucose measurement greater than 220 mg/dL should prompt prehospital clinicians to initiate aggressive balanced resuscitation before arrival at the receiving trauma center in order to prevent worsening hypotension and hemorrhagic shock.

Hyperglycemia appears secondary to a hypermetabolic state that occurs in patients suffering critical illness, stress, or injury.[1] This state is characterized by excessive gluconeogenesis, glycogenolysis, and insulin resistance.[2-6] The neuroendocrine response to this stress causes increased activation of the adrenal gland.[1-6] Because of this activation and release of a multitude of proinflammatory markers, there is an excess of counter-regulatory hormones such as glucagon, cortisol, and catecholamines.[7-9] Insulin is found in lower concentrations in plasma, indicating a relative deficiency.[3,10] The insulin that is present in the plasma fails to suppress gluconeogenesis from the liver despite elevated plasma glucose levels.[11,12] In addition, there is impaired glucose uptake into the skeletal muscle.[11,12] The result is an elevated blood glucose level, and this phenomenon has been studied under various names including stress-induced hyperglycemia (SIH), stress hyperglycemia, acute glucose elevation, or early hyperglycemia.[3,10,13-16] For this study, we have elected to use SIH.

Studies have shown that SIH is a predictor of morbidity and mortality in the critically ill and injured patient.[3,14,17,18] Specifically, trauma patients appear to be more prone to poor outcomes with an elevated admission blood glucose compared with other critically ill patients.[14,19-22] Admission hyperglycemia has been found to independently predict increased hospital length of stay and mortality in the trauma population.[17,20] Laird et al[3] showed a significant relationship between the Injury Severity Score, Glasgow Coma Scale (GCS), and mortality with an admission plasma glucose $\geq$ 150.[3] Two studies also found that patients with severe injury and a plasma glucose > 200 mg/dL were associated with higher rates of infection and mortality.[3,23] This finding was found to be independent of the severity of injury or the associated shock.[3,23] Kreutziger et al[22] described that patients who died in hemorrhagic shock had the highest blood glucose levels on hospital admission compared with other critically ill patients. A systematic review concluded after reviewing 17 articles

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that met the inclusion criteria that there is strong evidence that early hyperglycemia is correlated with a worse prognosis in trauma patients.[16]

Despite this growing body of literature, there are no published studies evaluating prehospital blood glucose as a predictor of hypotension before arrival at the receiving trauma center. Prehospital emergency clinicians provide an important role in trauma care by initiating and continuing lifesaving stabilization and resuscitation. Because trauma is the fourth leading cause of death overall for all ages in the United States, prehospital providers commonly encounter these patients, and early prediction of hypotension has the potential to impact resuscitation.[24] The purpose of this proposed retrospective chart review is to evaluate whether prehospital point-of-care glucose is an independent predictor of hypotension in the adult trauma patient transported by air ambulance to the receiving trauma center. Identifying a rapid, point-of-care parameter that indicates impending hypotension would allow for optimization of prehospital care of trauma patients. Prehospital point-of-care glucose may provide valuable information to the prehospital provider and the receiving trauma center in the evaluation and treatment of these trauma patients.

Methods

This retrospective chart review was conducted in air medical programs within the United States. This study was approved by the institutional review board with exempt status because of its retrospective design.

A detailed chart review was performed using the data of trauma patients that were transported by air ambulance from the selected programs. All trauma transports were collected for the year 2018, which totaled 1,623 patients. Each patient contact was reviewed by the authors. Patients were manually excluded if they were diabetic (n = 103), were less than 18 years of age (n = 184), were pregnant (n = 3), patient contact was made but patient was not transported (n=13), no point-of-care glucose was documented (n = 210), no final systolic blood pressure was documented (n = 2), or they had a point-of-care blood glucose less than 200 (n = 1,003). The point-of-care glucose used for the inclusion criteria was 200 mg/dL. This value was selected based on the discussion in multiple studies, which indicated 200 mg/dL as the definition of SIH.[3,14,23] Inclusion criteria included trauma patients who were 18 years of age or greater, had no documented past medical history of diabetes, and had point-of-care glucose > 200 mg/dL. The final sample size was 107 patients.

A systolic blood pressure of less than 90 mm Hg was used as the definition of hypotension in this study.[25] Data collected included the initial heart rate (beats/min), final heart rate (on landing), initial blood pressure (mm Hg), final blood pressure, GCS, point-of-care glucose, sex, age, and past medical history. If more than 1 point-of-care glucose measurement or GCS was documented, the initial value was included as the data point. Because of the variability in the patient presentation and condition, the precise timing of the point-of-care glucose could not be captured.

The data were imported into SPSS Version 25.0 software (IBM Corp, Armonk, NY) for evaluation. The primary study objective was to determine if the point-of-care glucose measurement was predictive of hypotension before arrival at the trauma center. Those transports meeting the inclusion criteria had tabular data summaries for patient physiologic parameters, GCS, and personal characteristics with appropriate descriptive statistics. In addition, the time from dispatch to arrival at the medical facility was segmented in an attempt to describe the timing of glucose measures. The segments summarized were the average time from dispatch to on-scene arrival, the average time at scene from arrival to departure, and the average transport time to medical facility. The primary analysis determined the maximum Youden's J index value to define an optimal glucose cutoff score for predicting hypotensive outcome. Relative risk was calculated along with a Pearson chi-square test to determine both the significance of the relationship and the strength of the effect. Finally, the diagnostic cutoff was evaluated for predictive significance for the change in systolic blood pressure during transport via the Student *t*-test.

Results

A total of 107 patients met the inclusion criteria. The demographic data including the mean and standard deviation are included in Table 1.

The primary outcome variable was the systolic blood pressure measurement on arrival at the receiving trauma center. The final mean for the systolic blood pressure for our population was 122.5 mm Hg with a standard deviation of 35.4 mm Hg. The sample yielded 22 (20.6%) patients who had a final systolic blood pressure below 90 mm Hg. The blood pressure cutoff is an objectively measured outcome and is not subject to any interpretative bias because this criterion is a physiologic parameter. Table 2 provides the individual variables that were evaluated for their ability to predict hypotension.

The area under the receiver operating characteristic curve for a hypotensive outcome based on blood glucose was 0.581 with a standard error of 0.068 corresponding to a *P* value of .243 for a test of equivalence to 0.5. The optimal diagnostic cutoff point using Youden's index (*J*) was determined to be a blood glucose value of 220 mg/dL or greater corresponding to a sensitivity of 0.864 with a 1-specificity value of 0.635. Nineteen of the 22 hypotensive patients (86%) were found to be hypotensive with a point-of-care glucose of greater than or equal to 220 mg/dL. There were 3 (14%) who were hypotensive with a point-of-care glucose below the cutoff of 220 mg/dL.

Table 3 illustrates that patients with initial glucose values of 220 mg/dL and above had significantly greater mean decreases in systolic blood pressure (SBP) ($P = .016$). Patients with glucose below the 220 mg/dL threshold experienced no significant changes in SBP. Post hoc testing revealed that GCS was not associated with any significant changes in SBP either ($P > .05$).

Table 4 provides the mean for 3 segmented times from dispatch to arrival at the medical facility. The first describes the mean time from dispatch to the arrival of the air ambulance clinicians at the bedside. The second describes the time the clinicians were with the patient at the scene or hospital before departure. The third describes the time from departure to the arrival at the trauma center, which reflects the actual air ambulance transport time. These data indicate that the glucose values were obtained between 26.9 minutes and 69 minutes postdispatch on average.

Discussion

Previous studies have shown that admission plasma blood glucose levels were strongly associated with increased mortality, increased length of stay, hemorrhagic shock, and increased infection rates.[3,13,14,16,17,19,20,22,23] Kreutziger et al[20,22] showed that admission blood glucose indicated the presence or development of hemorrhagic shock during the initial hospitalization more precisely than other

Table 1
Demographics and Baseline Characteristics

Variable/Statistic	Study Cohort (N = 107) Mean (SD)
Age (years)	52.3 (22.61)
GCS score	9.6 (5.23)
Initial systolic BP (mm Hg)	131.6 (39.02)
Initial diastolic BP (mm Hg)	77.1 (22.06)
Initial heart rate	103.3 (22.22)
Male	66 (62%)
Female	41 (38%)

BP = blood pressure; GCS = Glasgow Coma Scale; SD = standard deviation.

Table 2
Predictor of a Hypotensive Outcome

Variable/Statistic		Not Hypotensive (n = 85)	Hypotensive (n = 22)	*P* Value
GCS total	Median (IQR)	13 (4-15)	3.5 (3-12.5)	.008
Initial systolic BP (mm Hg)	Median (IQR)	138 (104-162.5)	103.5 (85.25-128.75)	<.001
Glucose (mg/dL)	Median (IQR)	235 (213-282)	247.5 (223.75-318)	.243
Glucose dichotomy, n (%)	Glucose ≥ 220	54 (74.0)	19 (26.0)	.04
	Glucose < 220	31 (91.2)	3 (8.8)	

BP = blood pressure; GCS = Glasgow Coma Scale; IQR = interquartile range.

Table 3
Change in Systolic Blood Pressure (BP) Outcome

Variable/Statistic	Mean (SD) Change in Systolic BP (N = 107)	*P* Value
Glucose dichotomy, n (%)		.016
Glucose ≥ 220	−13.5 (36.18)	
Glucose < 220	0.26 (21.57)	

Table 4
Transport Summary

Variable/Statistic	Study Cohort (N = 107)
Time from dispatch to patient (minutes)	
Mean (SD)	26.9 (12.78)
Time from arrival to patient to departure/lift (minutes)	
Mean (SD)	20.9 (11.89)
Time from departure to facility (minutes)	
Mean (SD)	21.2 (12.63)

SD = standard deviation.

laboratory measurements including hemoglobin, lactate, standard base excess, pH, and bicarbonate.[20,22] The data from this retrospective chart review show a sensitivity of .86 when associated with glucose of 220 and above; however, there was a high false-positive rate of .635. GCS is often a predictor of severity of injury in the prehospital environment. In this study, GCS was not related to significant changes in blood pressure; however, glucose values greater than 220 were associated with large decreases in SBP. The calculated glucose cutoff is better than GCS at predicting rapid decreases in systolic blood pressure and impending hemorrhagic shock on arrival at the receiving trauma center.

Although the results of this study are promising, there are a number of limitations worthy of discussion. The study is a retrospective chart review, and trauma patients were evaluated in 1 area of the United States over a single calendar year. This led to a small sample size of patients. The inclusion criteria eliminated pediatric, obstetric, and diabetic patients. Therefore, these results cannot be generalized to the larger more inclusive population. The small sample size also reduced our statistical toolbox, and a nonparametric test was used. A multivariate analysis could not be conducted, and adjustments could not be made for GCS, mechanism of injury, and length of transport. In addition, adjustment for sex was not evaluated and based on the article by Mohr et al[26] may be significant because of the variability of glucose predictability between men and woman. Because of the critical condition of these patients, there is the possibility that the medical history did not include diabetes or patients may not have an official diagnosis, again adding bias to this study. Multiple patients were missing data including the point-of-care glucose measurement and final systolic blood pressure on arrival and therefore were not included within the study. A bias because of missing data is possible and must be considered. Patients who were not transported by the prehospital air ambulance were eliminated from the study population. The 2 most common reasons for lack of transport were patient refusal and the patient died secondary to their traumatic condition. These 2 conditions also confer bias. We included transports for both scene and interfacility air ambulance transports. Because of variation in the time and duration of the initial resuscitation at the sending centers, this could impact the results. The point-of-care glucose may have been completed at any time during the transport, and this could affect the findings because of this variance. Finally, because of this study being confined to the prehospital transport of these patients, there is no hospital laboratory or outcomes data including morbidity, mortality, and length of hospital stay. Correlation with these variables would also be of benefit in future studies and would allow for comparison with other studies that did evaluate these variables. In order to determine if a more aggressive resuscitation strategy is beneficial in patients with elevated prehospital glucose measurements, it will be important to evaluate all of these elements in future studies. This may include a more robust retrospective prehospital study limiting the transport to scene transports, including a larger geographic area, and/or a prospective design evaluating outcomes.

This retrospective chart review study showed that point-of-care glucose measured in the prehospital air ambulance environment predicted the development of hypotension before arrival to the receiving trauma center. The relative risk of the development of hypotension was 2.95 times greater with a point-of-care glucose measurement of ≥ 220. This inexpensive, rapid, and reliable measurement is an indicator of hypotension in the trauma patients meeting the inclusion criteria reviewed in this study. This finding is consistent with the previous studies that evaluated admission glucose measurements in the prediction of hemorrhagic shock. Based on these findings, a point-of-care glucose measurement greater than 220 mg/dL should prompt prehospital clinicians to initiate aggressive balanced resuscitation before arrival at the receiving trauma center in order to prevent worsening hypotension and hemorrhagic shock.

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