Ann Med Res 2020;27(9):2298-305

Annals of Medical Research

DOI: 10.5455/annalsmedres.2020.05.451

Original Article

Stress hyperglycemia and glycemic control in critical neurosurgical patients: A retrospective study

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Abstract

Aim: The aim of this study was to determine the rate of stress hyperglycemia (SH) in non-diabetic critical neurosurgical patients and the effect of SH on patient outcomes, and to evaluate the glycemic control protocol applied in the neurosurgical intensive care unit (ICU).

Material and Methods: The sample of this retrospective study was the files of patients who had been admitted for at least three days to the neurosurgical ICU of a university hospital in Istanbul, Turkey, who were not diabetic, and who were aged 18 years or more. Data collection was performed with a data collection form developed by the researchers in line with the literature, and by examining the patients' files. Before commencing the study, permission was obtained from the ethics committee.

Results: The mean age of the patients was 55.74 years, and a majority (62.2%) was male. SH was seen in 47.7% of the patients. The rate of SH was significantly higher in those with a Glasgow Coma Scale (GCS) score of below 13 and in those with intracranial hematoma or traumatic brain injury ($p<0.05$). It was found that the blood glucose value of 91% of patients in the ICU remained within the target glycemic control range of 80-180mg/dl. It was found that 90% of patients who could not achieve glycemic control were patients who developed SH ($p<0.05$). In the ICU, hyperglycemia developed in 34.2% of patients (blood glucose>140 mg/dl), and in 73.7% of these were patients who developed SH ($p<0.05$). No correlation was found between SH developing in critical neurosurgical patients and hypoglycemia, infection, electrolyte imbalance, mortality or length of stay in the ICU ($p>0.05$).

Conclusion: The study showed that rates of SH are high in critical neurosurgical patients, and that in most of those developing SH, hyperglycemia continues while they are in the ICU.

Keywords: Critical patient; glycemic control; neurosurgical patient; stress hyperglycemia

INTRODUCTION

A temporary increase in blood glucose (BG) values as a response to acute physiological stress in patients without diabetes mellitus (DM) whose BG values are within normal limits is known as stress hyperglycemia (SH) (1-4). This hyperglycemia is in fact a metabolic response consisting of the secretion of steroid hormones (glucocorticoid and catecholamines) by the adrenal gland to stresses such as acute illness, trauma or surgery (1,2,5,6). The purpose of this metabolic response is to meet the energy needs of vital organs such as the brain (2,5). It has been reported that SH is common in critical neurosurgical patients, as in other critical patients, and that the incidence is in the range of 24.3-50.3% (7-9).

In the treatment and care of critical neurosurgical patients, it is important to prevent secondary brain injury in cases of acute brain injuries such as intracranial hematoma, traumatic brain injury (TBI) and aneurysmal subarachnoid hemorrhage (SAH) (9,10). It has been reported that SH developing in these patients causes secondary brain damage caused by a breakdown in the blood-brain barrier and an accumulation of lactic acid in the brain tissue, cerebral edema or recurrent bleeding (2,6,10). In some studies in the literature, it has been reported that SH makes neurological outcomes worse in critical neurosurgical patients (4,6,11,12) and increases mortality (4,8,13,14), while it is stated in others that SH is not correlated with a decline in neurological function and mortality (15,16). These conflicting conclusions show that there is insufficientevidence as to whether SH is harmful for non-diabetic critical neurosurgical patients (4,8). The same uncertainty continues on the subjects of how glycemic control is to be achieved in these patients and what the optimal BG level range should be (6,13,14,17).

Received: 08.05.2020 **Accepted:** 21.08.2020 **Available online:** 18.09.2020
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The first comprehensive study researching the effect of glycemic control in critical patients was performed in 2001 by Leuven. It showed that intensive glycemic control (IGC) with a BG level of 80-100mg/dl reduced infection and mortality (18). Following this study, it was established in meta-analysis studies performed with critical neurosurgical patients that IGC reduced the risk of infection and improved neurological outcomes (7) but did not reduce mortality rates, and increased the risk of hypoglycemia (5,10,17,19,20). There is no consensus in the literature about the glycemic control protocol necessary for the management of SH in critical neurosurgical patients. It is suggested in some studies that the BG level of these patients should be kept at 80-100mg/dl (5, 7), while some say it should be kept under 180mg/dl (10,21). The American Diabetes Association (ADA) recommends that when critical patients' BG level rises to 180mg/dl or above insulin should be used, and that BG levels should be kept between 140 and 180mg/dl (22-24).

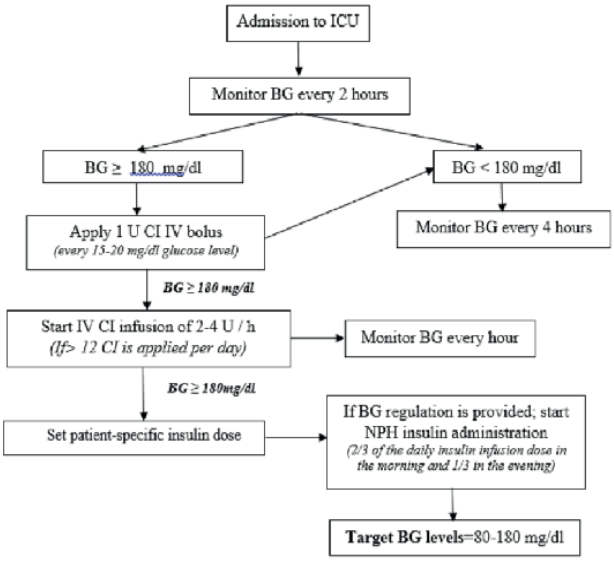
In the neurosurgical ICU where the research was conducted, a glycemic control protocol was implemented which aimed to keep the BG levels of all hyperglycemic patients, whether diabetic or not, to between 80 and 180mg/dl. It was the aim of this study to determine the rate of SH in non-diabetic critical neurosurgical patients and the effect of SH on patient outcomes, and to evaluate the glycemic control protocol implemented in the neurosurgical ICU.

MATERIAL and METHODS

Study Design, Population and Sample

This retrospective study was conducted in the neurosurgical intensive care unit (ICU) of a university hospital in Istanbul, Turkey. In this ICU, a nurse-controlled glycemic control protocol began to be implemented in 2010 (Figure 1). For this reason, the research sample was made up of the files of 125 patients who were admitted to the neurosurgical ICU from the hospital's emergency unit in 2010 and the three following years, who received treatment and care there for at least three days, and who were aged 18 or more.

The research included the files of patients whose venous BG values were measured randomly on admittance to the emergency unit or to the ICU, who did not have DM, whose glycosylated hemoglobin (HbA1c) values were <6.5%, who were not being fed parenterally, and whose BG was being monitored in the ICU at least once a day. Those with multiple traumas (four patients) or DM (four patients), those without an HbA1c value (two patients) or with a value of ≥6.5% (two patients), those who had received steroid treatment in the emergency unit (two patients), a total of 14 patients, were excluded from the study. Also excluded were patients who were not diagnosed with DM when admitted to the hospital but who had an Hb1Ac value of ≥6.5% (n=15 patients), who, according to the diagnosis criteria of the ADA, are accepted as diabetic (22,23). Thus, the research was completed with the file data of 111 patients.



IV= Intravenous; BG= Blood glucose; CI= Crystallized insulin; ICU: Intensive care unit NPH= neutral protamine Hagedorn (Intermediate acting insulins)

Figure 1. Glycemic control protocol applied in the neurosurgical intensive care unit

Data Collection Tool

The researchers collected data between August 2013 and February 2014, using a data collection form consisting of two sections, created in line with the relevant literature (1,2,5,7,10,11,18,22,23). The first section of the form consisted of questions on descriptive and clinical characteristics such as the patient's age, gender, diagnosis, entry GCS score, ICU length of stay, and developing complications. The second section had a chart, on which BG levels, frequency of BG monitoring, administration of insulin, occurrence of hypoglycemia, and glycemic control measures applied were recorded.

Data Collection

After obtaining the necessary permission for the research, the file numbers of patients who met the research criteria were determined from the electronic records, and the relevant patient files were retrieved from the archive. First of all, information was collected from the doctors' and nurses' anamnesis forms and from laboratory findings on the patient's DM history, HbA1c values, and BG values.

The patients' admission blood glucose (ABG) values from when they were admitted to the emergency unit before admission to the ICU were recorded on the form. SH and other hyperglycemia were assessed according to these values. Glycemic thresholds, used to identify SH in critical patients, showed a difference. In some studies, random BG values taken on admission to the ICU or in the emergency unit were defined to be ≥ 200 mg/dl (1,4,8), >180 mg/dl (3) or >140 mg/dl (6), while in others, fasting BG values of >126 mg/dl were defined when taken in the morning of the second day after admission to the ICU (25). In the present study, taking ADA recommendations into account (22,23), a random BG value of >140 mg/dl taken in the emergency

unit or on admission to the ICU was defined as SH, while a BG value of >140 mg/dl seen in the ICU was defined as hyperglycemia. In line with same recommendations (22,23), BG falling below 70 mg/dl in patients who were receiving insulin treatment was defined as hypoglycemia.

In the neurosurgical ICU where the research was conducted, a glycemic control protocol was implemented which aimed to keep patients' BG levels to between 80 and 180mg/dl (Figure 1). BG monitoring frequency, administration of insulin and outcomes were assessed according to this protocol. The same protocol is still in use in that ICU.

Ethical Considerations

This study was conducted in accordance with the principles set out in the Declaration of Helsinki. Before commencing the research, written permission was obtained from the neurosurgical department of the hospital where the study was to be conducted, and from the clinical research ethics committee of a university in Istanbul, Turkey (2013/18222).

Data Analyses

Data analysis was performed using the statistics program SPPS 20 (IBM Corp. Released 2011, Armonk, NY: IBM Corp.) Numerical values, percentages, means, standard deviations, and maximum and minimum values were given for categoric and continuous variables in the descriptive statistics. In comparing categoric variables, Pearson, Yates correction and Fisher chi-squared tests were used. Significance level was evaluated at a confidence interval of 95% ($p<0.05$).

RESULTS

The patients' mean age was 55.74 years, 46.8% were aged 60 years or more, and 62.2% were male; the GCS scores of 42.3% of the patients at admission to the ICU was between 3 and 8. The patients were admitted to the

Table 1. Descriptive and clinical characteristics of patients

Characteristics	n	%
Age (year)* (n=111)		
18-38	18	16.2
39-59	41	37.0
≥ 60	52	46.8
Gender (n=111)		
Female	42	37.8
Male	69	62.2
GKS score during admission to the ICU (n=111)		
3-8	47	42.3
9-12	27	24.4
13-15	37	33.3
Diagnosis (n=111)		
Cranial tumor	37	33.3
Aneurysmal subarachnoid hemorrhage	37	33.3
Intracranial hematoma	30	27.1
Traumatic brain injury	7	6.3
BG measurement method (n=111)		
Arterial and capillary	94	84.7
Arterial, venous and capillary	17	15.3
BG measurement frequency (n=111)		
1 times/day	15	13.5
2 times/day	85	76.6
> 4 times/day	11	9.9
Insulin therapy (n=111)		
Yes	29	26.1
No	82	73.9
Insulin treatment ordered by the doctor ¥ (outside the protocol) (n=14)		
If BG = 180-199 mg/dl, 4 U CI	9	64.3
If BG = 200-249 mg/dl, 6 U CI	8	57.1
If BG = 250-299 mg/dl, 8 U CI	5	35.7
If BG = 300-399 mg/dl,10 U CI	2	14.3
Stress hyperglycemia (n=111)		
Yes (BG > 140 mg/dl)&	53	47.7
No (BG ≤ 140 mg/dl)	58	52.3

BG=Blood glucose; CI=: Crystalline insulin; GCS=Glasgow Coma Scale; ICU= Intensive care unit

* Average age= ($\bar{x}$ =55.74 ±17.09 years; Min-Max= 18-92 years); ¥ There are multiple applications; &The BG levels of 21 patients (18.9%) are in the range of 182-355 mg/dl

Table 2. Comparison of patients' descriptive characteristics and development of stress hyperglycemia

Characteristics	Stress hyperglycemia Yes n (%)	No n (%)
Age (year)* (n=111)		
18-38	6 (33.3)	12 (66.7)
39-59	19 (46.3)	22 (53.7)
≥ 60	28 (53.8)	24 (46.2)
χ2 / p value	2.307 / 0.316	
Gender (n=111)		
Female	23 (54.8)	19 (45.2)
Male	30 (43.5)	39 (56.5)
χ2 / p value	0.918 / 0.338	
GKS score during admission to the ICU (n=111)		
3-8	29 (61.7)[a]	18 (38.3)
9-12	14 (51.9)[a]	13 (48.1)
13-15	10 (27.0)[b]	27 (73.0)
χ2 / p value	10.218 / **0.006**	
Diagnosis (n=111)		
Cranial tumor	17 (45.9)[a,b]	20 (54.1)
Aneurysmal subarachnoid hemorrhage	11 (29.7)[b]	26 (70.3)
Intracranial hematoma	19 (63.3)[a]	11 (36.7)
Traumatic brain injury	6 (85.7)[a]	1 (14.3)
χ2 / p value	11.828/ **0.008**	

GCS=Glasgow Coma Scale; ICU= Intensive care unit; χ^2= Pearson's chi-squared test; χ^{2Y} = Yates corrected chi-square test

Table 3. Comparison of patient outcomes and development of stress hyperglycemia

Outcomes		Stress hyperglycemia Yes	No
Target BG			
Achieved (80-180 mg/dl)	101 (91.0)	44 (48.2)	57 (52.8)
Not achieved (180-240 mg/dl)	10 (9.0)	9 (90.0)	1 (10.0)
χ^{2F} / p value		p= **0.006**	
Hyperglycemia (mg/dl) (n=111)			
Yes (BG > 140 mg/dl)	38 (34.2)	28 (73.7)	10 (26.3)
No (BG ≤140 mg/dl)	73 (65.8)	25 (34.2)	48 (65.8)
χ^{2Y} / p value		14.039 / **<0.001**	
Hypoglycemia			
Yes (40-70 mg/dl)	5 (17.2)	3 (60.0)	2 (40.0)
No	24 (82.8)	19 (79.2)	5 (20.8)
χ^{2F} / p value		p=0.569	
Infection			
Yes	55 (49.5)	28 (50.9)	27 (49.1)
No	56 (50.5)	25 (44.6)	31 (55.4)
χ^{2Y} / p value		0.437 / 0.509	
Electrolyte imbalance			
Yes	52 (46.8)	28 (53.8)	24 (46.2)
No	59 (53.2)	25 (42.4)	34 (57.6)
χ^{2Y} / p value		1.458 / 0.227	
Death			
Yes*	21 (18.9)	11 (52.4)	10 (47.6)
No**	90 (81.1)	42 (46.7)	48 (53.3)
χ^{2Y} / p value		0.053 / 0.818	
Length of stay in the ICU (day) (n=111)			
≤ 5 days	30 (27.0)	12 (40.0)	18 (60.0)
> 5 days	81 (73.0)	41 (50.6)	40 (49.4)
χ^{2Y} / p value		0.609 / 0.435	

BG=Blood glucose; ICU= Intensive care unit; χ^{2Y}= Yates corrected chi-square; χ^{2F}= Fisher's exact test
* BG=166.05±63.36 mg/dl, **BG=143.81±32.88 mg/dl, p<0.05

ICU with diagnoses of cranial tumor, aneurismal SAH, intracranial hematoma and TBI. Arterial and capillary BG was measured twice a day in 76.6% of the patients in the ICU, and insulin was administered to only 26.1%. SH was seen in 47.7% of the patients. It was found that the BG levels of 18.9% of those who developed SH ranged between 182 and 355 mg/dl (Table 1).

Of the patients' descriptive characteristics, a significant correlation with SH was found only in their GCS score and diagnoses. Compared with those with a GCS score of 13-15, the development of SH in those with a GCS score of below 13 was significantly higher. Compared with those with aneurismal SAK, SH developed at a significantly higher rate in those with a diagnosis of intracranial hematoma and TBI ($p<0.05$, Table 2).

While in intensive care, the BG levels of most of the patients (91.0%) were within the target range of the glycemic control protocol of 80-100 mg/dl. It was found that 90% of those who did not achieve glycemic control (BG= 180-240 mg/dl) were patients who developed SH ($p<0.05$, Table 3). It was found that 34.2% of patients in the ICU developed hyperglycemia (BG > 140mg/dl), and 73.7% of these were patients who developed SH ($p<0.05$, Table 3). It was found that extra insulin was administered to some of these patients outside the protocol on the doctor's orders (Table 2). During ICU hospitalization, 17.2% of the patients developed hypoglycemia (BG = 40-70 mg/dl), 49.5% developed an infection, and 46.8% developed an electrolyte imbalance, while 18.9% died (Table 3). Most of the patients (73%) remained in the ICU for more than five days. No correlation was found between SH and hypoglycemia, infection, electrolyte imbalance, mortality or length of stay in the ICU ($p>0.05$, Table 3). However, the rates of hypoglycemia, infection, electrolyte imbalance and mortality were higher in those who developed SH, and their stay in the ICU was longer, although these were not statistically significant(Table 3). It was found that the BG values of those who died (166.05±63.36 mg/dl) were significantly higher than the values of those who alive (143.81±32.88 mg/dl) ($p<0.05$, Table 3).

DISCUSSION

In this retrospective study, conducted to determine the effect on patient outcomes of the rate of SH in non-diabetic critical neurosurgical patients and to assess the glycemic control protocol implemented in the ICU, it was found that SH rates were high in patients with intracranial hematoma and TBI, and that hyperglycemia continued in most SH patients during the ICU hospitalization.

Similar to the literature, in which it is reported that SH occurs in 50.3% of critical neurosurgical patients (9), an SH rate of 47.7% was found in the present study. The rates of SH in patients aged 60 and over (53.8%) and in females (54.8%) were higher, although this was not statistically significant. In similar studies also, it is reported that ischemic patients who develop SH are older (25), that the rate of SH is significantly higher in ischemic and hemorrhagic stroke patients aged 60 and over (55.7%) (6), and that gender and SH are not correlated (4,16). In the present study, it was found that SH rates were significantly increased in those with a GCS of below 13, and that in those with a GCS of between 3 and 8, it was still higher (61.7%). In similar studies which also showed that lower GCS scores significantly increased SH rates, SH was seen in 63.6% of TBI patients with a GCS of ≤8 (4), and in 54.9% of patients with spontaneous intracerebral hemorrhage (ICH) (16).

It was found in the study that SH rates differed according to diagnosis, and that the SH rate was significantly higher in those with intracranial hematoma and TBI (63.3% and 85.7% respectively) than in those with aneurismal SAH (29.7%). These rates are different from other retrospective studies, which report SH in 50.3% of aneurismal SAH patients (9), 35% of patients with intracerebral hemorrhage (16), and 24.3% of patients with severe TBI (8). The difference may arise from the definition of SH with different ABG values. Different from these studies in which SH was defined as an ABG of >160 mg/dl (16), ≥ 200mg/dl (8) or a glycemic gap of >26.7 mg/dl (9), in the present study, SH was defined as an ABG of >140 mg/dl. In the latest ADA guideline (24), BG values of over 140 mg/dl in hospitalized patients are defined as hyperglycemia, similar to the present study. These differences show the need for multi-centered prospective studies and meta-analyses to determine the optimal BG threshold to be used to define SH in critical neurosurgical patients.

It has been reported that SH increases the risk of infection by putting pressure on the immune response (2,26). It was found that SH in non-diabetic critical orthopedic trauma patients significantly increased surgical site infection (SSI) rates (26). On the other hand, in a study with trauma patients, no significant correlation was found between SH and sepsis, urinary tract infection (UTI) or wound infection (1). In the literature, only one study (8) was found assessing the effect of SH on infection. In that retrospective study, it was found that SH was not correlated with sepsis or UTI in TBI patients, although it was emphasized that the small number of patients who developed sepsis and UTI may have affected the result (8). Similarly in the present study, it was found that the rates of infection in patients were similar, whether they developed SH or not, and that SH did not have a significant effect on infection. In our study, infection data was collected from the records on doctors' and nurses' monitoring forms. Separate data could not be obtained on the type or agent of infection. New prospective studies eliminating these deficiencies which arise from the retrospective collection of data may contribute to a better understanding of the relationship between SH and infection.

In critical neurosurgical patients, imbalances of electrolytes such as potassium, magnesium and in particular sodium are seen to be common (27,28). In a study with acute cerebrovascular stroke (CVS) patients, it was found that SH occurred in 13% of patients who

developed hyponatremia, hypokalemia or hyperkalemia (47%), but a correlation between SH and electrolyte imbalance was not investigated (27). One study evaluating this relationship was found in the literature (6). Similar to that study, conducted with acute stroke patients (6), no significant correlation was found in the present study between SH and electrolyte imbalance. In addition, similar to that study (6), it was found in the present study that SH did not significantly increase the length of stay in the ICU. Similarly, Rau et al. (4) found that SH did not lengthen the hospital stay of TBI patients.

In the long term, SH, which occurs in acute and sudden onset diseases and which is accepted as an indicator of the severity of an illness, is accepted as a protective mechanism which increases survival rates (2,8). However, studies have shown that the acute rise in BG levels which causes SH impairs neurological and functional outcomes because of oxidative stress and an increase in lactic acid, which has a neurotoxic effect (2,12,13,28), and that mortality rates are increased (1,4,8,29). In the present study, it was found that SH did not significantly increase the mortality rate, but patients who developed SH formed more than half (52.4%) of those who died. Similarly, Kongwad et al. (16) found that 56.3% of ICH patients who developed SH (ABG >160 mg/dl) died in hospital, but that SH did not have a significant effect on hospital mortality. Also, in a study comparing the ABG values of head trauma patients who died (25%) and who were discharged, it was found that the ABG level was not correlated with mortality, and that the mean ABG value of each group was >180 mg/dl (15). Different to this, there are also meta-analysis studies in the literature which show that SH increases short-term and long-term mortality rates in critical neurosurgical patients with ICH and SAH (13,14). In addition, it has been reported in some retrospective and prospective studies in the literature that SH significantly increases mortality rates in patients with aneurismal SAH (9) and acute stroke (6, 25, 27), independent of age, gender, and the severity of the injury. This may be affected by the diagnosis of SH with different BG levels in these different results apart from the study by Tshituta et al. (6), from those in the present study. This idea is supported by the mortality rates of 71% (27) in the study which defined SH as an ABG of more than 110 mg/dl, 41.4-42.7% in studies which defined it as 200 mg/dl or more (4, 8), and 51.9% in the study which, like the present study, defined it as an ABG of >140 mg/dl. Also, the difference in mortality rates may be caused by performing these studies with patients with a high mortality rate for such reasons as TBI, aneurismal SAK or stroke and the exclusion of factors which increase mortality such as further bleeding or multiple traumas. The information in the literature that the severity of stroke (6,25), the amount of bleeding and a low GCS score (16) increase rates of both SH and mortality, making it easier to determine the effect of SH in patients with a high risk of mortality (4), draws attention to the multifactorial nature of the effect of BG in mortality.

It was found in the study that the BG values of patients who died, 166.05 mg/dl, was significantly higher than that of survivors, 143.81mg/dl. It has been reported in similar studies that the BG values of spontaneous ICH patients, 177.2 mg/dl, and acute stroke patients, 154 mg/dl, who died was significantly raised (6). In a study with glioma patients, the rate of readmission to hospital or death within 30 days of discharge in patients with a mean BG level of 167mg/dl or more was reported to be significantly greater (29). In the present study, data from the patients' files on their length of stay in hospital was limited, and therefore the effect of SH on mortality or patient outcome after discharge was not assessed. The research finding that the glucose values of neurosurgical patients who died were significantly higher and information from the current literature shows the importance of glycemic control in these patients.

Studies which show that hyperglycemia makes neurological outcomes worse in critical neurosurgical patients because of secondary brain injury (7,10,11) call attention to the importance of glycemic control in this patient group. Glucose management is an important element of critical care (21). The Agency for Healthcare Research and Quality has accepted glycemic control as an indicator of quality in health care (29). Since a study (18) in 2001, which reported that IGC, which was aimed at keeping the BG levels of critical patients within the range of 80-110 mg/dl, reduced complication and mortality rates, many studies have been conducted on this topic. Of these studies, the multi-centered GLUCONTROL (30) and NICE-SUGAR (31) studies showed that IGC increased the risk of hypoglycemia and the rates of mortality from hypoglycemia. Also, in meta-analysis studies with neurosurgical patients, it is reported that IGC did not reduce mortality in critical neurosurgical patients, but affected neurological outcomes negatively by increasing the risk of hypoglycemia (5,10,16,19,20).

The central nervous system depends on glucose as a source of energy, so that it is important in neurosurgical patients to prevent hypoglycemia, resulting in neuroglycopenia (10,19). Shan et al. (5) reported that serious hypoglycemia in neurosurgical patients lasting for more than 30 minutes causes irreversible brain damage because of cerebral cell necrosis, and increases intracranial pressure as a result of increased cerebral blood flow. These findings raise the question of implementing glycemic control protocols which aim to keep BG levels between 80 and 100 mg/dl in patients such as critical neurosurgical patients, where hypoglycemia is definitely unwanted (5,10,20,21). In the ICU where the research was conducted, a nurse-controlled glycemic control protocol was being implemented which aimed to keep the BG levels of patients within the range of 80-180 mg/dl. Despite this protocol, it was found in the research that there were patients (9%) who did not achieve glycemic control or who developed hypoglycemia (17.2%), and that most of these were patients who developed SH. Administration of extra insulin under a doctor's order to patients whose BG values do not fall below 180 mg/

dl with the glycemic control protocol may be effective in development of hypoglycemia. Also, an important finding from the research was that the BG values of 73.7% of SH patients in the ICU were above 140 mg/dl, and that despite the protocol, it rose to 240 mg/dl in some patients. These findings suggest that the protocol is ineffective in managing SH.

In the current literature, there is no evidence-based knowledge on the type of hyperglycemia (SH or diabetic hyperglycemia) which is benefited by a protocol which aims to keep the BG levels of critical patients to between 80 and 180 mg/dl (8). This shortcoming of the literature has a negative effect on SH control and prevention of SH-induced complications. Studies reporting that the mortality rate is higher in the firts 72 hours in those with a BG level of 143 mg/dl or more after acute cerebral ischemia (32), and that the neurological outcomes are worse in patients with acute cerebellar bleeding whose ABG is 140 mg/dl and above (11), show the importance of intervention in SH before BG exceeds 180 mg/dl. Tshituta et al. (6) reported that it was recommended to keep the BG of critical neurosurgical patients below 180 mg/dl, but that there was no evidence concerning the necessary optimal glucose value to improve patient outcomes. Studies showing that negative effects such as deterioration of neurological function and mortality caused by SH in critical neurological patients is not seen in hyperglycemia caused by DM (4,8) suggest that SH may be more harmful than diabetic hyperglycemia in these patients. Moradi et al. (3) state that SH in patients admitted to the emergency unit for reasons such as head trauma, SAH or cerebrovascular accident increases the risk of later DM by 3.4 times. It was found in the same study that in the third month after discharge from hospital, the HbA1c values of those who developed SH were higher, and 26.8% of them developed DM. This information shows the need for evidence-based studies focusing on the management of SH in critical neurosurgical patients.

One of the most important limitations of this retrospective study is that the correctness of the data is limited by the correctness of the sources. Another important limitation is that no detailed information could be obtained from the files on the patients' cause of death or patient outcomes. This deficiency may have had a negative effect on determining the correlation of mortality and patient outcomes to SH. Levels of catecholamine and cortisol, which show the severity of the response to the stress experienced by patients, were not measured, and this is a limitation of the study, preventing a determination that hyperglycemia was definitely stress-induced. Measurement of these steroid hormones might help in determining whether the hyperglycemia which occurred was stress-induced, and understanding better the relation between SH and patient outcomes.

CONCLUSION

In this study, the rate of SH was found to be high in critical neurosurgical patients, particularly those with TBI and cranial hematoma, and in those with a GCS score of less than 13. The research findings showed that SH did not increase infection, electrolyte imbalance or mortality neither rates, nor did it lengthen ICU stay. In addition, the research showed that the hyperglycemia of most patients who developed SH continued in the ICU, and that most patients whose BG levels could not be kept below 180mg/dl by the glycemic control protocol were patients who developed SH. In the future, multi-centered and prospective studies may be conducted to investigate glycemic control protocols which are effective in the control of the SH which affects critical neurosurgical patients and the optimal BG values to improve patient outcomes.

Competing interests: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: This study was approved by the Istanbul University Cerrahpaşa Medicine Faculty Clinical Researches Ethics Committee (Number/date: 18222/2013).

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