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SCIENTIFIC ARTICLE

Hyperglycemia assessment in the post-anesthesia care unit

Vinicius Rodovalho Pereira, Rodrigo Akio Azuma, Bruno Emanuel Oliva Gatto, João Manoel Silva Junior*, Maria Jose Carvalho Carmona, Luiz Marcelo Sá Malbouisson

Universidade de São Paulo (USP), Faculdade de Medicina, Hospital das Clínicas de São Paulo, São Paulo, SP, Brazil

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Abstract
Background and objectives: Hyperglycemia in surgical patients may cause serious problems. Analyzing this complication in this scenario contributes to improve the management of these patients. The aim of this study was to evaluate the prevalence of hyperglycemia in the post-anesthetic care unit (PACU) in non-diabetic patients undergoing elective surgery and analyze the possible risk factors associated with this complication.
Methods: We evaluated non-diabetic patients undergoing elective surgeries and admitted in the PACU. Data were collected from medical records through precoded questionnaire. Hyperglycemia was considered when blood glucose was $>120\,mg.dL^{-1}$. Patients with hyperglycemia were compared to normoglycemic ones to assess factors associated with the problem. We excluded patients with endocrine-metabolic disorders, diabetes, children under 18 years, body mass index (BMI) below 18 or above 35, pregnancy, postpartum or breastfeeding, history of drug use, and emergency surgeries.
Results: We evaluated 837 patients. The mean age was 47.8 ± 16.1 years. The prevalence of hyperglycemia in the postoperative period was 26.4%. In multivariate analysis, age (OR = 1.031, 95% CI 1.017–1.045); BMI (OR = 1.052, 95% CI 1.005–1.101); duration of surgery (OR = 1.011, 95% CI 1.008–1.014), history of hypertension (OR = 1.620, 95% CI 1.053–2.493), and intraoperative use of corticosteroids (OR = 5.465, 95% CI 3.421–8.731) were independent risk factors for postoperative hyperglycemia.
Conclusion: The prevalence of hyperglycemia was high in the PACU, and factors such as age, BMI, corticosteroids, blood pressure, and duration of surgery are strongly related to this complication.

* Corresponding author.
E-mail: joao.s@globo.com (J.M. Silva Junior).

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PALAVRAS-CHAVE
Cirurgia eletiva;
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Avaliação de hiperglicemia na sala de recuperação pós-anestésica

Resumo
Justificativa e objetivos: Hiperglicemia em pacientes cirúrgicos pode ocasionar graves problemas. Nesse contexto, analisar essa complicação contribui para o melhor manejo desses pacientes. O objetivo do estudo foi avaliar a prevalência de hiperglicemia na sala de recuperação pós-anestésica (SRPA) em pacientes não diabéticos submetidos a cirurgias eletivas e analisar os possíveis fatores de risco associados a essa complicação.
Métodos: Foram avaliados pacientes não diabéticos submetidos a cirurgias eletivas e admitidos na SRPA. Os dados foram coletados dos prontuários por meio de questionário pré-codificado. Foi considerada hiperglicemia quando a glicemia era > 120 $mg.dL^{-1}$. Pacientes com hiperglicemia foram comparados com os normoglicêmicos para avaliar fatores associados ao problema. Foram excluídos os pacientes com distúrbios endócrino-metabólicos, diabéticos, menores de 18 anos, índice de massa corpórea (IMC) menor do que 18 ou maior do que 35, gestação, puerpério ou aleitamento materno, antecedente de uso de drogas e cirurgias de urgência.
Resultados: Foram avaliados 837 pacientes. A média de idade foi 47,8 ± 16,1 anos. A prevalência de hiperglicemia no pós-operatório foi de 26,4%. Na análise multivariada, idade (OR = 1,031; IC 95% 1,017-1,045); IMC (OR = 1,052; IC 95% 1,005-1,101); tempo cirúrgico (OR = 1,011; IC 95% 1,008-1,014); antecedente de hipertensão (OR = 1,620; IC 95% 1,053-2,493) e uso de corticoides intraoperatório (OR = 5,465; IC 95% 3,421-8,731) representaram fatores de risco independentes para hiperglicemia no pós-operatório.
Conclusão: Hiperglicemia apresentou alta prevalência na SRPA e fatores como idade, IMC, corticoides, hipertensão arterial e tempo de cirurgia são fortemente relacionados a essa complicação.

Introduction

Although glycemic levels up to 220 $mg.dL^{-1}$ were previously considered acceptable in critically ill patients,[1] infectious and metabolic complications were reported as a consequence of hyperglycemia.[2,3]

Hyperglycemia resulting from surgical stress has long been considered an adaptive and beneficial response.[1] However, the surgical wound triggers a series of other events, which in association with hyperglycemia may be deleterious. In surgical patient, neuroendocrine responses such as release of catecholamines, stress hormones, inflammatory cascade activation, and systemic inflammatory response result in increased protein catabolism, adipose tissue mobilization, gluconeogenesis, and glycogenolysis.

Another central phenomenon in the incidence of postoperative hyperglycemia is the development of insulin resistance induced by surgical stress.[4] The sum of these effects leads to prolonged postoperative recovery, increased metabolic stress, and risk of complications.[4] In early postoperative period, adequate control of hyperglycemia results in faster surgical recovery, with less incidence of complications and lower hospital costs in patients undergoing major surgeries.[5–8]

The relationship between hyperglycemia and prognosis has recently been investigated in patients with acute neurological disease,[9,10] acute myocardial infarction,[11,12] trauma,[13] and peripheral arterial disease.[14] Intraoperative hyperglycemia is correlated with death and significant organic dysfunction in patients undergoing heart surgery.[15–17] However, there is a shortage of data sent to the post-anesthetic care unit (PACU) on non-diabetic patients undergoing elective surgeries.

Therefore, the aim of this paper was to evaluate the prevalence of hyperglycemia in non-diabetic patients undergoing elective surgeries sent to the PACU and assess the risk factors for this serious complication.

Material and methods

After approval by the Ethics Committee of the HCFMUSP, which waived the consent term as this is a non-interventional study, we retrospectively evaluated patients who underwent elective surgery between August 2012 and September 2014 at the *Hospital das Clínicas, Faculdade de Medicina da Universidade de Sao Paulo*. All patients who were admitted to the Post Anesthesia Care Unit (PACU) and had a blood glucose test were included in the study.

According to a protocol previously established in the institution, all patients have their capillary glucose measured and if two measurements have changed values, serum glucose is measured to confirm the results. A value greater than 120 $mg.dL^{-1}$ is used as a cut-off point for hyperglycemia, according to the literature,[18] and a value of 200 $mg.dL^{-1}$ as a limit for therapeutic intervention.

Inclusion criteria were age >18 years; body mass index (BMI) between 18 and 35 $kg\,m^{-2}$, and elective surgery. Exclusion criteria were the need for ICU admission in the postoperative period, gestation (puerperium or breastfeeding), endocrine-metabolic disorders, previous diagnosis of diabetes, and a known or suspected history of drug abuse.

The primary objective of this study was to assess the prevalence of hyperglycemia in PACU and the secondary was to assess the risk factors for hyperglycemia. In order to find a representative sample and come to an agreement for the sample calculation that hyperglycemia can affect about 4–5% of the population,[19] with an estimate type I error of 5% and 95% power, we considered as an optional hypothesis 5% of patients with hyperglycemia admitted to the PACU and 2% as a null hypothesis. Thus, at least 446 patients would be required for the study. However, as approved by the institution's committee, data could be collected for a period of two years, so the study was only stopped after completing this period.

The assessed data were sex, age, BMI, anesthetic technique, duration of surgery, glucose use, corticoid use, need for transfusion or intraoperative use of vasopressors, comorbidities, type of surgery, and glycemic value obtained from the charts of patients admitted to PACU.

In order to find factors related to hyperglycemia, patients with high blood glucose levels were compared with those considered normoglycemic, and logistic regression was also performed with the most relevant data from this evaluation.

Statistical analysis was performed using the SPSS 15.0 software (SPSS Inc., USA). Chi-square test, Fisher's exact test, and likelihood ratio test were used for assessing qualitative variables. Parametric continuous variables were tested using Student's t-test. Subsequently, the data were submitted to the logistic regression test.

A p-value <0.05 was considered significant in bivariate analysis for inclusion of variables in the logistic regression model. Multivariate analysis was used to identify independent predictors of hyperglycemia in PACU.

Results

During the study period, 1000 patients were eligible for analysis; however, 16.3% were excluded because they had diabetes. Thus, 837 patients were enrolled: 326 male and 511 female, mean ages of 47.8 ± 16.1 years. Mean blood glucose values were 108.6 mg.dL^{-1}. On average, patients had BMI of 26.2 kg m^{-2}. Duration of surgery was 137.2 ± 76.5 min (Table 1).

The incidence of hyperglycemia in the postoperative period was 26.4%.

Arterial hypertension was seen in patients with glucose concentration greater than 120 mg.dL^{-1}. Moreover, patients who had hyperglycemia in the early postoperative period have received more intraoperative general anesthesia, corticosteroids or vasopressors (Table 2).

In addition, older patients, those with a higher BMI and longer duration of surgery presented more hyperglycemia postoperatively (Table 3).

When using the logistic regression model, at each one-year increase in age, there is a 3.1% increase in the chance of hyperglycemia (OR = 1.031), and a 1 kg m^{-2} increase in BMI leads to an increase of 5.2% in the chance of hyperglycemia (OR = 1.052). Furthermore, duration of surgery presented a statistically significant correlation with hyperglycemia. Finally, intraoperative use of corticosteroids increased the risk of postoperative hyperglycemia by 5.46 (OR = 5.465) (Table 4).

Interestingly, intraoperative glucose administration was observed in 14.1% of the sample, there was no correlation with hyperglycemia.

In general, 11 patients (1.2% of sample) had hypoglycemia, ranging from 46 to 60 mg.dL^{-1}, requiring treatment, and nine patients (0.9% of sample) had glucose values between 200 and 299 and required insulin therapy in PACU.

Discussion

The main findings of this study were the high prevalence of hyperglycemia in the admission of patients to PACU and the fact that age, BMI, arterial hypertension, intraoperative corticoid use, and duration of surgery were independent risk factors for the occurrence of hyperglycemia in the immediate postoperative period.

An assessment of the impact of hyperglycemia on admission to intensive care units found an incidence of hyperglycemia in 27.5% of the 2713 patients included in the study. However, the study population consisted of critically ill patients with indication for intensive care hospitalization.[19] Thus, the present study is one of the few that evaluated this complication in patients of elective surgeries who were admitted to PACU.

Overall, 26.4% of patients had hyperglycemia in this study. The cut-off point was greater than 120 mg.dL^{-1}, which is compatible with that used by the American Diabetes Association[18] and by studies that seek to justify strict glycemic control in postoperative patients.[20,21]

Hyperglycemia is potentially deleterious because it acts as a procoagulant,[22] changes neutrophil functions, stimulates the release of inflammatory cytokines, increases the risk of infections, changes healing, and may be associated with increased mortality.[23,24] Therefore, evaluating this complication and associated factors is important to improve this problem management.

It was also observed in this study that age is an independent risk factor for hyperglycemia in this population. This may be explained by the fact that with aging there are changes in insulin secretion and increased peripheral resistance to its effects, which can trigger hyperglycemia.[25] After the age of 50, the fasting blood glucose level increases by 6–14 mg.dL^{-1} every 10 years.[26]

Additionally, the increase in BMI was also a risk factor for the postoperative incidence of hyperglycemia, leading to a 5.2% increase in risk for each 1 kg cm^{-2} increase in BMI. Obese patients have a high incidence of diabetes and glucose intolerance. The muscular and adipose tissue of obese patients responds less to insulin action due to a decrease in the number of receptors and a lower response created by the insulin–receptor interaction.[27] In obese patients, the cortisol production is also altered, increasing the peripheral resistance to insulin. In a study with 50,905 adults, it was shown that BMI is an independent predictor for diabetes, with three times higher prevalence in patients with BMI >24.[28]

Another factor correlated with the incidence of hyperglycemia was the use of intraoperative corticosteroids.

Table 1 Characteristics of patients.

Variable	Mean	SD	Median	Minimum	Maximum
Age (years)	47.8	16.1	47	18	90
Weight (kg)	70.0	13.1	69	42	120
Height (cm)	163.4	9.4	163	140	199
BMI ($kg\,cm^{-2}$)	26.2	4.1	26.0	17	35
Surgery duration (min)	137.2	76.5	120	10	555
Anesthesia time (min)	210.9	89.7	195	40	610
Glycemia ($mg.dL^{-1}$)	108.7	29.7	105	46	299

SD, standard deviation; BMI, body mass index.

Table 2 Comparison of categorical variables between patients with and without hyperglycemia.

Variable	Hyperglycemia				Total		*p*
	No		Yes		*n*	%	
	n	%	*n*	%			
Sex							0.51
Female	372	60.4	139	62.9	511	61.1	
Male	244	39.6	82	37.1	326	38.9	
Type of surgery							0.78
Abdominal	281	45.6	105	47.5	386	46.1	
Head and neck	88	14.3	37	16.7	125	14.9	
Ophthalmic	86	14.0	32	14.5	118	14.1	
Urological	85	13.8	25	11.3	110	13.1	
Plastic	56	9.1	17	7.7	73	8.7	
Other	20	3.2	5.0	2.3	25	3.0	
Intraoperative glucose use	84	13.6	34	15.4	118	14.1	0.52
Intraoperative corticoid use	339	55.1	193	87.3	532	63.6	<0.001
Anesthesia							0.01
General	401	65.1	164	74.2	565	67.5	
Neuraxial	215	34.9	57	25.8	272	32.5	
Intraoperative vasopressor	41	6.7	25	11.3	66	7.9	0.03
Intraoperative transfusion	2.0	0.3	0.0	0.0	2.0	0.2	0.54[a]
Comorbidities							
Arterial hypertension	169	27.4	93	42.1	262	31.3	<0.001
Dyslipidemia	36	5.8	16	7.2	52	6.2	0.46
Asthma	12	1.9	9	4.1	21	2.5	0.08
Kidney failure	15	2.4	9	4.1	24	2.9	0.21
Cirrhosis	2.0	0.3	0.0	0.0	2.0	0.2	0.54[a]
Crohn's disease	3.0	0.5	2.0	0.9	5.0	0.6	0.40[a]
CHF	3.0	0.5	2.0	0.9	5	0.6	0.40[a]
COPD	5.0	0.8	5.0	2.3	10.0	1.2	0.09[a]
Hypothyroidism	36	5.8	12.0	5.4	48	5.7	0.82
Hyperthyroidism	3.0	0.5	4.0	1.8	7.0	0.8	0.83[a]

Chi-square test.
[a] Fisher exact test; Other: neurosurgery, thoracic, vascular.

Dexamethasone is often used during anesthetic procedure as adjunctive treatment to prevent nausea and vomiting and inhibit inflammatory response. However, its use, even in a single dose, may trigger hyperglycemia by stimulating neoglucogenesis and inhibiting peripheral insulin action. One study[29] showed that intraoperative dexamethasone (10 mg) given to patients undergoing abdominal surgery increased glycemia in both diabetic and non-diabetic patients. Several other studies have also demonstrated these effects triggered by the use of corticosteroids.[30,31]

Duration of surgery was also correlated with a higher risk of hyperglycemia in PACU. This fact may be justified by the sympathetic response associated with surgical stress and the release of counterregulatory hormones, which determine

Table 3 Comparison of continuous variables between patients with and without hyperglycemia.

Variable	Hyperglycemia				*p*
	No		Yes		
	Mean	SD	Mean	SD	
Age (years)	46.1	16.5	52.5	14.3	<0.001
Peso (kg)	69.9	13.2	70.3	13.1	0.70
BMI (kg cm^{-2})	25.9	4.1	26.8	3.9	0.005
Surgery duration (min)	121.2	67.6	181.6	82.1	<0.001
Preoperative Fasting Time (h)	16.2	3.9	16.6	3.4	0.21

BMI, body mass index; SD, standard deviation.

Table 4 Multiple logistic regression.

Variable	OR	95% CI		*p*
		Inferior	Superior	
Age (per year)	1.031	1.017	1.045	<0.001
BMI (per kg m^{-2})	1.052	1.005	1.101	0.03
Intraoperative use of corticosteroids (per unit)	5.465	3.421	8.731	<0.001
General anesthesia (per unit)	1.330	0.883	2.002	0.172
SAH (per unit)	1.620	1.053	2.493	0.028
Intraoperative use of vasopressor (per unit)	1.238	0.678	2.258	0.487
Duration of surgery (per min)	1.011	1.008	1.014	<0.001

BMI, body mass index; SAH, systemic arterial hypertension.

lower insulin secretion and peripheral tissue resistance to the action of insulin and produce hyperglycemia. The length and duration of the surgical intervention determine a great variation in the contribution of counterregulatory hormones, such as glucagon, epinephrine, norepinephrine, cortisol and GH, in order to influence glycemic homeostasis.[32–34]

It is important to note that in the present study, incidence of hypoglycemia was observed in 1.2% of patients, which makes intraoperative glycemic control essential, as anesthesia masks the hypoglycemia symptoms. A large study[35] drew attention to the problem related to hypoglycemia and associated complications.

However, some limitations in this study should be reported, such as lack of information on some variables. First, it was not possible to distinguish transient elevation of blood glucose or glucose intolerance. Glycosylated hemoglobin (A1C test) could help in this differentiation.[19]

Furthermore, in this study, no outpatient control medications were evaluated in asthmatic patients, mainly regarding the use of inhaled or systemic corticosteroids, and the severity profile of patients.

Regarding intraoperative use of corticosteroids, there was no distinction between the type of corticosteroid used (dexamethasone or hydrocortisone) or correlation between the used dose and risk of hyperglycemia.

Evaluation regarding the type of anesthesia and size of surgery was very broad, without details on the effect of each anesthetic agent and the correlation between the dose used and duration time. These limitations, however, are inherent to this type of study, which is an analysis with many variables.

However, we note the high prevalence of hyperglycemia in PACU, so measurement of glycemia either capillary or another method is crucial due to the great range of factors correlated with the occurrence of this problem in the postoperative period. On the other hand, the data showed an increased prevalence of hyperglycemia in older patients with high BMI. These findings are significant and suggest the need for further studies on the subject, mainly focusing on strict glycemic control in this type of patients from intraoperative period to hospital discharge.

Conflicts of interest

The authors declare no conflicts of interest.

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