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Original Article

Frequency of serum blood glucose monitoring after hyperkalaemia treatment using insulin and dextrose☆

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الملخص

أهداف البحث: يتم إعطاء الدكستروز بشكل متزامن مع الأنسولين كنظام علاجي عند علاج المرضى الذين يعانون من ارتفاع نسبة بوتاسيوم الدم وذلك لتجنب انخفاض سكر الدم. لا يزال معدل حدوث انخفاض سكر الدم في الساعات الست الأولى بعد هذا النظام العلاجي مرتفعًا نسبيًا، مما يستلزم إجراء متابعة متكررة لنسبة سكر الدم لمنع إصابة المريض. كان الهدف من هذه الدراسة هو تقييم وتيرة متابعة سكر الدم بعد هذا النظام.

طرق البحث: دراسة متعددة المراكز بأثر رجعي لتقييم المرضى البالغين (١٨ عامًا) الذين تم تنويمهم بسبب ارتفاع نسبة بوتاسيوم الدم (البوتاسيوم > ٥ مل مكافئ/مل) وتمت معالجتهم باستخدام الأنسولين بالإضافة إلى محلول الدكستروز عن طريق الوريد. تم استبعاد المرضى في حال عدم تلقيهم الدكستروز خلال ٦٠ دقيقة من العلاج بالأنسولين. كان الهدف الأساسي هو عدد المرات التي تم فيها قياس مستوى سكر الدم خلال ست ساعات من النظام. كانت الأهداف الثانوية هي قياس الوقت بين حقن الأنسولين وقراءات سكر الدم ومعدل حدوث انخفاض سكر الدم (جلوكوز الدم >٧٠ ملغ / ديسيلتر).

النتائج: كانت عدد الحالات المتاحة للتحليل ٥٢١ حالة. عدد قراءات سكر الدم على النحو التالي: ١٩٢ حالة (٣٦.٩٪) كان لها على الأقل قراءة متابعة واحدة، ٣٠ حالة كان لها على الأقل قراءتي متابعة (٥.٨٪)، وست حالات بها على الأقل ثلاث قراءات متابعة (١.٢٪). كا. متوسط الوقت للحصول على قراءات سكر الدم الأولى والثانية والثالثة: ٣ ساعات (الانحراف الربيعي ١.٧ – ٤ ساعات) و ٣.٩ ساعات (الانحراف الربيعي ٥.١ – ٣.٢ ساعة) و ٤ ساعات (الانحراف الربيعي ٥.١ – ٣.٢ ساعة) على التوالي. كانت نسبة حدوث انخفاض سكر الدم ٤.٨٪.

الاستنتاجات: أوضحت الدراسة أن وتيرة متابعة مستوى سكر الدم بعد العلاج بالأنسولين كانت منخفضة وغير متسقة. سلطت هذه الدراسة الضوء على أهمية اعتماد بروتوكولات تتضمن المزيد من المتابعة المتكررة لنسبة سكر الدم.

الكلمات المفتاحية: انسولين؛ ديكستروز؛ جولوكوز؛ ارتفاع بوتاسيوم الدم؛ انخفاض سكر الدم

Abstract

Objectives: In patients with hyperkalaemia, dextrose is administered alongside insulin treatment to prevent hypoglycaemia. However, the incidence of hypoglycaemia in the first 6 hours following this regimen remains high, and frequent blood glucose monitoring is essential. This study evaluates the frequency of blood glucose monitoring following this insulin regimen.

Methods: This retrospective, multicentre study evaluated adult patients (≥18 years) who had been hospitalised for hyperkalaemia (K ≥ 5 mEq/mL) and managed using intravenous insulin and dextrose. We excluded patients if dextrose was not administered within 60 minutes of insulin therapy. The primary outcome was the frequency of serum blood glucose monitoring within 6 hours of the regimen. Secondary outcomes were the time between insulin treatment and follow-up measurements, and the incidence of hypoglycaemia (blood glucose <70 mg/dL).

Results: In total, 521 hyperkalaemia episodes were available for analysis; 192 (36.9%) had at least one reported follow-up measurement, 30 had at least two follow-up measurements (5.8%), and six had at least three follow-up measurements (1.2%). The median times

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of obtaining the first, second, and third blood glucose measurements were 3 h (interquartile range [IQR]: 1.7 −4 h), 3.9 h (IQR: 3.2−5.1 h), and 4 h (IQR: 3.2−5.1 h), respectively. The incidence of hypoglycaemia among the episodes with follow-up was 4.8%.

Conclusions: The frequency of serum blood glucose monitoring following insulin therapy was low and inconsistent. This study emphasised the importance of adopting protocols incorporating more frequent blood glucose monitoring.

Keywords: Dextrose; Glucose; Hyperkalaemia; Hypoglycaemia; Insulin

Introduction

Hyperkalaemia is a life-threatening electrolyte abnormality commonly encountered in the emergency department (ED).[1] It requires immediate management to minimise the risk of mortality, which is approximately 10% of the admitted patients.[2] Different strategies can be used to manage hyperkalaemia. Shifting potassium inside cells by administering insulin is one of the most common approaches taken by ED clinicians. The American Heart Association recommends administering 10 units of intravenous (IV) insulin, as well as 25 g of IV dextrose to minimise the risk of hypoglycaemia.[3]

Recent studies have evaluated the incidence of hypoglycaemia after insulin plus dextrose treatment of hyperkalaemia because hypoglycaemia may be linked to patient-oriented outcomes, including higher mortality and increased length of hospital stay.[4] The incidence of hypoglycaemia ranges from 6.4% to 28.9% and can develop up to 6 hours after insulin plus dextrose administration.[5,6] Different strategies have been evaluated to minimise the risk of hypoglycaemia and thus prevent patient harm. However, the results are controversial, and hypoglycaemia remains a concern. Pierce et al. investigated whether reducing the insulin dose from 10 to 5 units decreased the risk of hypoglycaemia. They found no significant differences between the two dosing regimens. Similarly, Farina et al. reported that administering 50 g of dextrose instead of 25 g did not decrease the incidence of hypoglycaemia.[6–9]

As hypoglycaemia shows a high incidence after insulin plus dextrose treatment and there is no effective strategy to minimise the risk, clinicians must monitor blood glucose for up to 6 hours from the time of insulin administration. To our knowledge, no studies have evaluated the frequency of blood glucose monitoring following insulin administration. Thus, the aim of this study was to evaluate the frequency of blood glucose monitoring in patients receiving insulin plus dextrose to treat hyperkalaemia. We hypothesised that the frequency of blood glucose monitoring is low.

Materials and Methods

Study design and setting

A multicentre retrospective chart review study was conducted in two hospitals in KSA. Both were large tertiary hospitals in the western region with capacities of 1067 and 420 beds, respectively. There was no protocol in place for the management of hyperkalaemia in either hospital. Ethical approval was obtained from the two hospitals' research ethics committees.

Patient selection

The electronic databases at both hospitals, as well as the patient medical records, were used to screen for inclusion criteria. Adult patients (aged ≥18 years) admitted between January 2018 and December 2019 were included if they had received a regimen of IV insulin plus IV dextrose to manage hyperkalaemia (potassium level ≥5 mEq/mL). Patients who did not receive IV dextrose within 60 minutes of IV insulin were excluded.

Data collection

After proper data collection training, the data of eligible patients were extracted using a standardised data collection tool. The obtained data were then de-identified and saved into a password-protected file. To identify eligible patients, potassium levels ≥5 mEq/mL were used to generate reports from the electronic database between January 2018 and December 2019. Moreover, the patients' medical records were reviewed to confirm that the regimen was ordered to manage hyperkalaemia. The collected data included age, sex, weight, height, body mass index (BMI), episode location, presence of diabetes or renal failure, need for dialysis, baseline potassium level, baseline blood glucose level, type and dose of insulin, time between insulin and dextrose, dextrose dose, and any follow-up blood glucose measurements obtained via finger stick blood sugar test or basic metabolic panel.

Outcomes

The primary outcome was the frequency of blood glucose measurement within 6 hours of insulin therapy. The secondary outcomes were the time between insulin and follow-up blood glucose measurements, the frequency of blood glucose measurement in each location, and the incidence of hypoglycaemia (blood glucose <70 mg/dL).

Statistical analysis

Standard descriptive statistics using mean and standard deviation were used to analyse normally distributed continuous data, while median and interquartile range (IQR) were used to analyse non-normally distributed continuous data. Frequency counts and percentages were used in cases of categorical variables. All statistical evaluations were

performed using SPSS version 24 (IBM Corp., Armonk, NY, USA).

Results

The medical records of 819 patients with hyperkalaemia were screened for eligibility. Of these, 331 patients developed 521 episodes of hyperkalaemia that met the inclusion criteria. None of the remaining patients met the inclusion criteria because the insulin plus dextrose regimen was not administered to manage elevated potassium levels. Dextrose was administered concomitantly with insulin in all episodes of hyperkalaemia. Accordingly, none of the 521 episodes was excluded from the final analysis.

Approximately half the patients were male (52%), and the mean age was 62 years (±16.2 years). The mean weight and BMI were 73.4 kg (±18.6 kg) and 28 kg/m^2 (±7.1 kg/m^2), respectively. The baseline characteristics of the 521 episodes are summarised in Table 1. Among the 331 patients, the percentage of diabetes (81%), renal insufficiency (82%), and dialysis (25%) was recorded. The median baseline potassium level was 5.7 mEq/L (IQR: 5.4−6.1 mEq/L), and the median baseline blood glucose level was 152 (IQR: 111.6−227.7) mg/dL. Most (91%) follow-up blood glucose level measurements were obtained using a finger stick blood sugar test. Regular insulin (99%) was the most common type used. The predominantly administered dose of insulin was 10 units (90%), and 25 g of dextrose was administered in all cases except one, in which 50 g was given. The number of hyperkalaemia episodes managed in the ED, intensive care unit (ICU), and general floor were 217 (42%), 43 (8%), and 261 (50%), respectively.

Main results

In 329 episodes (63.1%), no follow-up blood glucose measurement was carried out, while one, two, and three follow-up blood glucose measurements were performed in 192 (36.9%), 30 (5.8%), and six (1.2%) episodes, respectively. The median times to the first, second, and third follow-up blood glucose measurements were 3 h (IQR: 1.7−4 h), 3.9 h (IQR: 3.2−5.1 h), and 4 h (IQR: 3.2−5.1 h), respectively (Table 2). The frequencies of follow-up blood glucose monitoring in each location were as follows: 57 episodes in the ED had at least one follow-up blood glucose measurement (26.3%), while 10 episodes had more than one (4.6%). In the ICU, 19 episodes had least one follow-up measurement (44.2%) and two had frequent follow-up measurements (4.6%). The general floor had the highest percentage of follow-up blood glucose measurements, with 116 episodes having at least one follow-up measurement (44.4%) and 24 having more than one (9.2%) (Table 3). The incidence of hypoglycaemia among all episodes with blood glucose measurement after the regimen was 4.8%.

Table 1: Baseline characteristics.

Baseline characteristics (*N = 521)	
Age, years (mean, SD)	62 ± 16.2
Female sex, n (%)	250 (48%)
Weight, kg (mean, SD)	73.4 ± 18.6
BMI, kg/m^2 (mean, SD)	28 ± 7.1
Diabetes, n (%)	421 (80.8)
Renal insufficiency, n (%)	427 (82)
Dialysis, n (%)	128 (24.6)
Baseline potassium level, mEq/L (median, IQR)	5.7 (5.4−6.1)
Baseline blood glucose level, mg/dL (median, IQR)	152 (111.6−227.7)
Regular insulin, n (%)	518 (99.4)
10 units of Insulin, n (%)	471 (90.4)
25 g of dextrose, n (%)	520 (99.8)

BMI, Body mass index; IQR, Interquartile range; SD, Standard deviation.
*Refers to the number of episodes of hyperkalaemia.

Discussion

The main finding of the current study was the low frequency of blood glucose monitoring following insulin plus dextrose treatment. While many studies have concluded that frequent blood glucose monitoring is important, our study found that almost two-thirds (63%) of cases in which insulin plus dextrose was administered, no follow-up glucose measurement was performed within 6 hours. Furthermore, the percentage of patients with frequent blood glucose measurements was much lower (5.8%). These results show that the current practices for managing patients with hyperkalaemia using insulin plus dextrose must be improved.

Hypoglycaemia following insulin therapy for hyperkalaemia has been an interesting area for research in recent years because it can lead to poor patient outcomes. Brodovicz et al. assessed the impact of hypoglycaemia on mortality and length of stay among hospitalised patients who received insulin. They reported that patients who developed

Table 2: Study outcomes.

Episodes with at least one follow-up blood glucose reading:	
Frequency, n (%)	192 (36.9)
Source, FSBS, n (%)	173 (90.1)
Time between insulin administration and first reading in minutes, median (IQR)	180 (100−240)
Hypoglycaemia, n (%)	9 (4.7)
Episodes with at least two follow-up blood glucose readings:	
Frequency, n (%)	30 (5.8)
Source, FSBS, n (%)	29 (96.7)
Time between insulin administration and second reading in minutes, median (IQR)	235 (190−308)
Hypoglycaemia, n (%)	2 (5.9)
Episodes with at least three follow-up blood glucose readings:	
Frequency, n (%)	6 (1.2%)
Source, FSBS, n (%)	5 (83.3)
Time between insulin administration and third reading in minutes, median, IQR	239 (194−308)
Hypoglycaemia, n (%)	0 (0)
Total:	
Frequency, n	228
Source, FSBS, n (%)	207 (90.8%)
Hypoglycaemia, n (%)	11 (4.8)

FSBS, Finger-stick blood sugar test; IQR, Inter quartile range.

Table 3: Frequency of blood glucose monitoring at each location.

Episode location	Episodes without follow-ups	Episodes with at least one follow-up	Episodes with at least two follow-ups	Episodes with at least three follow-ups
Emergency department (n = 217)	160 (73.7%)	57 (26.3%)	9 (4.1%)	1 (0.5%)
Critical care (n = 43)	24 (55.8%)	19 (44.2%)	1 (2.3%)	1 (2.3%)
General floor (n = 261)	145 (55.6%)	116 (44.4%)	20 (7.7%)	4 (1.5%)

hypoglycaemia had a significantly higher inpatient mortality rate (6.5% vs. 3.8, $p < 0.0001$) and longer length of stay (median: 8.2 vs 5.2 days, $p < 0.0001$) than patients who did not develop hypoglycaemia.[4] Two other factors complicate the issue: the high incidence of hypoglycaemia and the timeframe in which patients may develop it. The incidence of hypoglycaemia has ranged from 6.4% to 28.9% in previous studies.[5,6] The median time for hypoglycaemia development is approximately 2–3 hours; however, Pierce et al. found that patients can develop hypoglycaemia up to 7.5 hours after insulin therapy.[7] Accordingly, many studies have explored strategies that could minimise the risk of hypoglycaemia, such as reducing insulin dose, increasing dextrose dose, identifying hypoglycaemia predictors, and anticipating the extent of blood glucose reduction.

Few studies have evaluated whether reducing the insulin dose minimises the rate of hypoglycaemia.[7] Brown et al. found that weight-based insulin dosing (0.1 unit/kg) did not significantly reduce the hypoglycaemia rate compared to conventional dosing ($p = 0.05$).[5] Wheeler et al. reported similar rates of hypoglycaemia between the weight-based regimen and 10 units of IV insulin ($p = 0.05$).[9] Other researchers adjusted the dextrose dosing to mitigate the risk of hypoglycaemia. Farina et al. evaluated the effect of higher dextrose dose (50 g) and found that the results were similar to those with the usual 25 g of dextrose ($p = 0.11$).[8] In an alternative method, Cocoa et al. reported a low rate of hypoglycaemia (6.1%) in patients who received a standardised protocol consisting of 10 units of insulin plus 50 g of dextrose continuously infused over 4 hours. However, it is difficult to draw a conclusion since this study had no comparator group.[10]

Predictors of hypoglycaemia have also been studied; however, the evidence is conflicting. The reported predictors of hypoglycaemia include: no prior history of diabetes mellitus or antidiabetic medications,[11] lower body weight,[12] higher serum creatinine,[13] and female sex.[9] The only predictor to be reported in most studies was low baseline blood glucose level.[5,9–11,13–15] In attempts to identify patients at high risk of hypoglycaemia, two studies have evaluated the extent of blood glucose reduction following insulin plus dextrose therapy. Both studies revealed that the extent of blood glucose reduction is unpredictable.[5,15]

Previous studies have shown that there is no effective strategy to mitigate the risk of hypoglycaemia when using insulin plus dextrose therapy to manage hyperkalaemia, and that frequent blood glucose monitoring is required to avoid hypoglycaemia. The Institute for Safe Medication Practices recommends monitoring blood glucose levels for up to 6 hours after insulin therapy.[16] The current study revealed that the frequency of blood glucose monitoring is low and inconsistent, even in tightly controlled environments such as the ICU. In fact, the median times to obtain the second and third blood glucose measurements were similar (3.9 and 4 h, respectively). The time course of blood glucose measurement following insulin plus dextrose regimen has been described in previous studies.[5,15] The regimen results in a transient increase in blood glucose level after the first dextrose administration, followed by a subsequent reduction. Considering the baseline blood glucose level, it seems that blood glucose measurement within the first hour is unnecessary; however, consideration should be given to hourly monitoring for at least 5 additional hours thereafter.

We hypothesised that the frequency of second and third blood glucose measurements would be higher in the ICU and general floor than in the ED as the median length of stay in the ED ranges between 2.4 and 4.5 hours. However, our results showed that the frequency of the second and third blood glucose measurements was comparatively low, irrespective of location. To our knowledge, the incidence of hypoglycaemia in the current study was lower than in all previous studies, perhaps because previous studies have included patients with at least one follow-up blood glucose measurement, while our study included patients who received the regimen but did not necessarily have their blood glucose measured. In fact, 63% of the episodes had no follow-up blood glucose readings. Accordingly, the true incidence of hypoglycaemia may have been underestimated in our study.

The study had several other limitations. Firstly, it employed a retrospective design; therefore, the accuracy of the collected data was limited to that of the medical records. Secondly, some confounders that could have affected the incidence of hypoglycaemia were not controlled, namely concomitant medications, insulin dose, and dextrose-containing infusions. Thirdly, the reported incidence of hypoglycaemia may have been underestimated because of infrequent blood glucose monitoring. Finally, the data were collected from large academic medical centres in KSA, and the results may not reflect practice in other environments.

Conclusions

The current study revealed that blood glucose monitoring was infrequent following IV insulin plus dextrose for hyperkalaemia, irrespective of treatment location. Future studies evaluating the reasons for inadequate monitoring of blood glucose levels are needed. The results emphasised that clinicians must adopt frequent and regular blood glucose monitoring to avoid patient harm.

Recommendations

When managing hyperkalaemia with insulin plus dextrose, clinicians should adopt protocols that incorporate frequent blood glucose monitoring at regular intervals to avoid patient harm.

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Conflict of interest

The authors have no conflicts of interest to declare.

Ethical approval

This study was approved by the ethical review committee of King Abdulaziz University Hospital (approval No. 711−18; dated 1.1.2019) and the ethical review committee of King Fahad Armed Forces Hospital (No. Rec 291; dated 15.4.2019).

Authors' contributions

AMA conceived and designed the study, analysed and interpreted the data, and wrote the final draft. SAA analysed and interpreted the data, wrote the initial and final drafts of the article, and provided logistic support. All authors critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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