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# Portable blood glucose meter values using different sampling ways: a validity study

*Valores glicêmicos oferecidos pelo glicosímetro portátil, utilizando sangue de diferentes vias de coleta: estudo de validade*

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**ABSTRACT**

**Objective**: To identify the relevant differences between portable blood glucose meter readings in different sampling accesses blood and laboratory analysis.

**Methods**: Quantitative validity study. Daily samples were collected from capillary blood, central venous access catheter and arterial catheter and the blood glucose values checked using portable blood glucose meter and laboratory analysis. The findings were analyzed with the Statistical Package for the Social Sciences – SPSS software.

**Results**: Central venous catheter samples blood glucose meter readings were found to have the best correlation with the laboratory analysis results, considered as the gold-standard.

**Conclusion**: Hemodynamically unstable patients' capillary blood samples may provide false blood glucose results, and lead to inappropriate insulin solution management. Therefore, ideal blood glucose sampling is relevant to prevent insulin solution management errors.

**Keywords:** Blood specimen collection; Critical care; Blood glucose; Intensive care units

## INTRODUCTION

Hyperglycemia is common in intensive care units (ICUs), and in acute conditions is associated to poorer outcomes. Therefore, accurate blood glucose measurement is a must for appropriate patient's therapy.[1-4]

Van den Berghe et al.[5] study became a landmark for ICU blood glucose control, showing that use of continued insulin solution, maintaining blood glucose between 80 and 110 mg/dL, significantly reduced critically ill patients' mortality and complications rates.

An insulin therapy protocol is necessary to guide this solution use, in order to keep glycemic levels within the selected range and preventing, or a least reducing, complications. This is also a simple and low cost measure that guides the nursing team on insulin solution titration.

In our ICU, insulin solution titration is guided by glycemic levels measurement mostly using a portable blood glucose meter on finger tip capillary blood samples collected with lancets. However, severely ill patients' finger tip samples were shown to provide inaccurate readings, due to poor peripheral perfusion from several causes, such as vasoactive drugs, edema and microcirculation disorders, and may lead to inappropriate insulin solution flow management.[6,7]

Other than finger tip sources may be used, as central venous and arterial sampling. Frequently the nursing team uses blood from central venous access, drawn for laboratory tests, also for portable blood glucose meter readings. This is intended to spare the patient from repeated finger punctures, maintain skin integrity and prevent secondary infection risks.

The relevance of accurate sampling is clear for proper insulin solution introduction, adjustment or withdrawal, and hypoglycemic events prevention. However, few published studies evaluated in sufficient details the accuracy of the different sampling ways.[6,8]

Usually ICU nursing teams manage insulin solution protocols based on capillary blood readings. However, these protocols do not standardize the sampling sources, being this choice upon each professional's discretion. No expert consensus statements are available to guide the professionals on the best way to obtain accurate blood glucose readings, which should be compared to the laboratory testing, the gold-standard.[6,7]

This study was aimed to compare portable blood glucose meter readings in blood samples from different sampling ways versus laboratory readings, and to identify possible significant differences.

## METHODS

This was a validity quantitative trial, conducted on a private hospital's ICU in the city of Salvador, Bahia, Brazil. This ICU has 16 beds for adult clinical and surgical patients. This unit uses continued insulin venous infusion, with blood glucose monitoring according to the Yale Protocol.[1,4]

To achieve our overall objective, the following specific objectives were established: to identify the blood glucose values using three different accesses usual in the ICU, i.e., capillary blood, arterial blood and central venous blood, using reagent test strips; to compare the portable blood glucose meter readings and laboratory analysis results; to identify the impact of vasoactive drugs, edema and reduced peripheral perfusion on the finger tip capillary blood readings and consequently on the insulin protocol management.

We elected to use as reference the central catheter venous blood glycemic values measured in the laboratory. Studies have shown that measurements using

either arterial or venous blood measurements are not significantly different.[9-11]

During the study time, 263 patients were admitted to the ICU, however only 34 complied with the inclusion criteria: adults with both central venous and arterial catheters, prescribed capillary blood glucose measurements at 6:00 a.m., and informed consent obtained from the patient or legally accepted representative in case of incapacity. The exclusion criteria included unfeasible capillary blood, arterial blood or central venous catheter collection, less than 18 years old, and consent refusal.

The data were collected between October 2008 and January 2009, using a three parts instrument to be completed each sampling, and search on the medical chart:

a) part 1 – sample characterization.

b) part 2 – independent variables; vasopressor use/dose, hematocrit, edema presence/intensity, capillary filling.

The edema was always evaluated by the same investigator, in the limb where the capillary puncture was performed and categorized in four levels: 1 (absent), 2 (mild), 3 (moderate) and 4 (severe edema).

The capillary filling was categorized as preserved when shorter than 3 seconds, and reduced when above. The capillary filling was evaluated on the sampling finger.

c) part 3 – portable blood glucose meter readings using central access, arterial catheter and capillary blood were recorded, as well as the sample analyzed at the central laboratory.

The blood samples were collected daily at 6:00 a.m. in patients with prescribed capillary blood glucose reading, thus preventing additional punctures. The blood collection from the different accesses was exclusively conducted by the investigators.

Blood was drawn from the central venous access and arterial access using syringes. First, 5 mL blood were obtained from the central venous access, and discarded. Next 10 mL were drawn from the catheter. This sample was used for portable blood glucose meter reading and also forwarded to the laboratory for blood glucose and other daily routine tests analysis.

The portable blood glucose meter used was the Roche's Accu-Check Performa® and respective reagent strips; all tests were conducted using one single device. This was calibrated before each use to assure accuracy, as it was demonstrated that lack of calibration may lead to inaccurate results.[12] Laboratory

blood glucose was measured using the hexokinase-glucose-6-phosphate dehydrogenase method with a Dade Behring's Flex® reagent cartridge.

For the arterial catheter, 3 mL blood was collected and discarded, and next 01 mL blood was collected for blood glucose processing.

The capillary puncture was conducted contra lateral to the arterial catheter, in random finger tips, avoiding those with signs of multiple previous punctures.

The samples were immediately read in the portable blood glucose meter in the order: central venous catheter, invasive arterial pressure catheter, and capillary puncture.

The data were uploaded into a Microsoft Windows Excel-2000 software document as soon as collected. Later, the data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 10.0.

Descriptive statistics were used for the demographic (age and gender) and clinic (current diagnosis, edema, capillary filling, vasoactive drugs) characteristics.

The continuous variables were: age (years); portable blood glucose meter capillary, central venous and arterial blood readings (mg/dL); laboratory evaluated venous blood glycemic values (mg/dL); vasoactive drugs doses (µg/kg/min); and extremity edema categorization. Measures of central tendency were calculated for the continuous variables: mean, median, and one single dispersion measure (standard deviation). Minimal and maximal values were also described.

Gender, current diagnosis, edema, capillary filling and vasoactive drugs use were described by frequency (%). Due to the sample's abnormality, we decided to calculate the mean, median and standard deviation.

The continuous variables correlation was evaluated with the Spearman correlation coefficient. The correlations magnitude evaluations used the reference values: weak < 0.30; moderate = 0.30 to 0.9715; strong > 0.9715 to 0.99 and perfect = 1.00. For all analysis a significance level of 5% was adopted.[13]

For continuous variables agreement analysis (portable blood glucose meter capillary, central venous and arterial blood glucose readings, and laboratory measured central venous blood glucose), the Bland & Altman test was used. This test is used for graphic presentation of variables agreement; the plot has a vertical line representing the means difference; the closer to the agreement axis are the points, the higher the variables agreement.[13,14]

To bring the statistic results closer to the clinical practice, the insulin solution titration, based on daily blood glucose values, was compared to the Yale Protocol. The reference value for this comparison was the laboratory-measured venous blood glucose.

Next, this result was fit into the corresponding cell, observing the indication for change on the insulin solution flow. If this was the same as the one triggered by the laboratory-measured venous blood glucose, it was considered as coherent clinical measure.

The project complied with the National Health Council requirements,[15] and was analyzed and approved by the hospital directory and the Ethics Committee of the Nursing College of Universidade Federal da Bahia. Protocol CPEE/UFBA no. 34/2008, FR-203944.

## RESULTS

Table 1 describes the values found and their respective means and medians, plus standard errors (SE) and standard deviations (SD).

**Table 1 – Comparison of different blood sources glycemic values using portable blood glucose meter or laboratory measurement**

| Blood sample/ analysis method | Median ± SE | Mean ± SD |
|---|---|---|
| CVC / portable blood glucose meter | 146.5 ± 13.62 | 163 ± 79.4 |
| Capillary / portable blood glucose meter | 133.5 ± 6.21 | 138.2 ± 36.2 |
| IMBP / portable blood glucose meter | 136.5 ± 7.10 | 139.2 ± 41.4 |
| CVC / laboratory | 142.0 ± 9.33 | 150.6 ± 54.4 |

SE – standard error; SD – standard deviation; CVC – central venous catheter; IMBP – invasive mean blood pressure.

Of the 34 patients, 41.2% were female and 58.8% male. Mean age was 64.9 ± 15.1, median 63 years. The main diagnoses were sepsis (14.7%), acute respiratory failure (11.6%), heart surgery (11.6%), septic shock (8.8%) and neurological surgery (8.8%).

Regarding vasoconstrictive drugs, 35.2% used continuous noradrenalin, mean dose 0.2 ± 0.4 µg/kg/min, maximal dose 1.6 µg/kg/min and minimal

0.05 µg/kg/min. Most of the sample, 85.3%, had preserved capillary filling, and 14.7% reduced; 60% of them used noradrenalin. Most of the sample had some edema: 20.6% mild; 38.2% moderate; 29.4% severe.

One hundred thirty six blood samples were used for blood glucose measurements. The Spearman and Bland-Altman tests were used to evaluate the correlation between portable blood glucose meter readings and laboratory blood glucose results, showing no significant differences between the portable blood glucose meter and laboratory measured results (Table 2).

**Table 2 – Correlation between laboratory-measured blood glucose values and portable blood glucose meter readings**

| Variables | Laboratory blood glucose value | |
|---|---|---|
| | r | p value |
| Capillary | 0.798 | 0.0001 |
| CVC | 0.856 | 0.0001 |
| IMBP | 0.852 | 0.0001 |

CVC – central venous catheter; IMBP – invasive mean blood pressure. Spearman's correlation.

The portable blood glucose meter readings that had best correlation with laboratory blood glucose results (the gold standard) were from the central venous catheter (r = 0.856; p<0.0001), followed by those from the arterial catheter (r = 0.852; p<0.0001) and finally, from capillary blood (r = 0.798; p<0.0001).

Comparing the blood glucose values and their influence on the insulin protocol management, we found that in 39.2% (n=40) of the total portable blood glucose meter readings, insulin solution would be inappropriately titrated. From these, 62.5% (n=25) were from capillary blood.

Among vasopressor users, 91.6% (n=11) would have inappropriate insulin solution management. Out of these, in 63.6% (n=7) the blood glucose values came from capillary blood.

## DISCUSSION

The Spearman's test showed that when different sources samples were compared to the laboratory-measured results, strong and significant correlation was found, with statistically significant differences.

However, the mean differences calculation showed weak and non-significant correlation, likely with relevant clinical impact, as according to the Yale Protocol would lead to changes in insulin solution titration.

This study results are similar to another trial findings, where capillary, arterial and central samples were read in portable blood glucose meters and compared to the central laboratory results (both arterial and central venous blood). The sample had 49 patients, with capillary blood collected from all patients, arterial blood from 42 and central venous blood from 7 patients.[8]

In this trial, no significant differences were found for laboratory results versus portable blood glucose meter. Also, the influence of edema and vasopressor use was not evaluated, as most of the patients had blood pressure above 60 mmHg.

A 80 patients' trial compared the blood glucose values from both capillary puncture and venous blood plasma, showing that finger tip blood glucose read by portable blood glucose meter is inaccurate in critically ill patients.[6] This study considered correlation, agreement and accuracy to express the results.

Another trial compared the capillary and arterial blood glucose read in blood glucose meter in 30 ICU patients, 10 of them vasopressor dependent, 10 with edema and 10 post-operative, showing a 56% similarity between capillary and laboratory results. Digital blood collection accuracy was rated as poor in post-operative, vasopressor-dependent (vasoactive amines doses above 5.0 µg/kg/min) and significant edema patients.[7]

Still discussing the above mentioned reference, arterial and capillary blood glucose meter readings were overestimated in approximately 5 and 9%, respectively, versus the laboratory results. The haemogasometer processed samples had no differences. In addition, in hypoglycemic patients the capillary blood reading and laboratory value proximity was only 26.3%.

In this study sample, capillary blood glucose was statistically similar to the laboratory-processed result. Additionally, 10 of this study's patients (29.4%) also had relevant edema, and 9 were post-operative. This difference may be explained by the different data processing methods, however underlines the relevance of the patient evaluation when the site for blood collection and blood glucose evaluation is decided.

Also, in this study, in 100% of the hypoglycemia cases the finger tip reading overestimated the labo-

ratory value. Similarly to other studies, this shows that the finger tip sampling trends to overestimate the reference values.[6,16]

Therefore, hypoglycemic episodes may be under diagnosed in insulin protocol patients. This is particularly relevant in ICUs, where patients are frequently intubated and/or sedated, and therefore not able to communicate hypoglycemic symptoms.

It should be emphasized that 2 of this sample's patients had blood glucose values below 70 mg/dL, and 1 had a glycemic value above 220 mg/dL, reaching 497 mg/dL, demonstrating the sample abnormality. Therefore, other studies, with more homogeneous samples, are required.

The hematocrit is known to affect portable blood glucose meter accuracy. These devices operating manuals suggest that hematocrit levels should be between 25 and 55% for reliable capillary blood readings.[8]

Nevertheless, blood glucose meters are frequently used with no considerations to the patient's hematocrit level. Patients with lower than normal hematocrit may have their blood glucose meter readings overestimated versus the laboratory values. Hematocrit values above the normal may result in underestimated values.[8]

In our study, hematocrit values did not influence the blood glucose meter readings, likely because this variable had similar values among the study subjects. The same was seen in the above mentioned trial.

In a 38 circulatory shock patients' study, blood glucose meter capillary and central venous readings were compared with laboratory measured blood glucose levels, and 30 and 18% variation was found between capillary and laboratory blood glucose, and between venous blood glucose processed by the blood glucose meter or laboratory, respectively. The patients had several shock diagnosis, and 70% of the sample required vasopressors.[17]

In this study, vasoactive drugs patients' capillary blood glucose readings were not significantly different versus laboratory-measured values. This may be due to the small number of vasoactive amine users (12 patients, 35.2% of the sample), and the low doses (0.2 μg/kg/min), therefore not leading to significant peripheral perfusion changes.

In a 85 patients' sample, how much blood glucose readings may be affected by poor tissue perfusion was measured, indicating that blood glucose meter readings were different from laboratory results in 15% of the capillary samples and 7% of total blood samples. The authors considered as discrepant values those with more than 20% differences. The blood glucose meter readings more frequently overestimated, rather than underestimated, the blood glucose values versus laboratory results. Poorer perfusion patients had the most divergent results.[18]

These results were not found in our study, probably due to the small number of poor capillary filling patients (4 patients, or 14.7% of the sample). Poor peripheral perfusion is recognized, in several studies, to influence capillary blood glucose values. However, this relationship nature is not yet known.

More studies are required involving poor peripheral perfusion patients to clearly determine its contribution to blood glucose meter readings changes. For this, possibly partial oxygen pressure ($PaO_2$), arterial blood pressure, sample source (venous, arterial, capillary), pH, temperature, blood elements (cell, protein, lipid and water contents) could be used, in addition to lactate and mixed venous saturation measurements.

As previously reported, statistically significant differences were found for blood glucose meter readings versus laboratory values. However, about 50% of edema patients had mean differences of at least 11 to 12 mg/dL between the blood glucose meter readings and the laboratory values. Additionally, these differences were identified in vasoactive amines users and reduced peripheral perfusion patients, trending to hypoglycemia. This was also found by Critchell et al. in 2007.[6] According to the insulin protocol used in our ICU, this could change the insulin solution titration.

This is because the Yale Protocol is divided into four blood glucose ranges (75-99 mg/dL, 100-139 mg/dL, 140-199 mg/dL and > 200 mg/dL). Therefore, close blood glucose values may lead to different decisions, if in the ranges' extremities. This confirms the relevance of clinical, rather than only statistic, investigation on this subject.

Outstand the data on insulin solution management in vasopressor users' disagreement (91.6%), and that most of inappropriate managements were related with finger tip punctures (63.6%). Caution is required for peripheral puncture use in circulatory shock patients, as mentioned by several previously mentioned authors also.

In this regard, Brazilian Intensive Care Medicine and Infectology societies recommend that in

septic venous insulin therapy patients, blood glucose measurements are made using either arterial or venous blood, evaluated in an haemogasometer, and if missing with a glucometer, since laboratory-confirmed.[19]

## CONCLUSION

Statistically significant correlations were found between blood glucose readings from the three different sources versus the laboratory analysis values. However, considering the sample abnormality, statistically non-significant but clinically relevant mean differences were found. It should be emphasized that the collection source with best gold standard agreement was from the central venous access, followed by from the arterial catheter.

Caution is advised for capillary blood and portable blood glucose meter use for insulin protocol management in hemodynamically unstable, with vasoactive drugs, peripheral perfusion changes or edema patients; not only the blood source but also the measuring method should be considered.

On the other hand, in clinically stable patients portable blood glucose meter is a safe, fast and easy blood glucose measuring method, for which either capillary, arterial or central venous blood are suitable.

Additional studies, with larger samples and evaluating different critically ill patients' clinical status, and also considering the results accuracy, are recommended. Another aspect to be investigated is the impact of the different blood sources glycemic values on the several available insulin protocols management.

## RESUMO

**Objetivo:** Identificar se há diferença significativa entre os resultados glicêmicos oferecidos pelo glicosímetro portátil, utilizando sangue obtido de diferentes vias de coleta e pela análise laboratorial.

**Métodos:** Estudo quantitativo de validade. Foram coletadas diariamente amostras de sangue capilar, do cateter venoso central e do catéter arterial para verificação da glicemia pelo glicosímetro, e feita análise da glicemia laboratorial. Para análise, foi utilizado o programa *Statistical Package for the Social Sciences* - SPSS.

**Resultados:** Observou-se que glicemia processada no glicosímetro portátil, com amostra de sangue do cateter venoso central, foi a que apresentou maior correlação com o valor oriundo do laboratório, considerando-se este o "padrão-ouro".

**Conclusão:** Coletas por via capilar, em pacientes graves e instáveis hemodinamicamente, podem trazer resultados glicêmicos falsos, levando a alterações indevidas da solução de insulina É preciso atentar para a via de coleta ideal da glicemia em pacientes graves, afim de que não haja erro no manuseio da solução de insulina.

**Descritores:** Coleta de amostras sanguíneas; Cuidados críticos; Glicemia; Unidades de terapia intensiva

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