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Point-Of-Care Blood Glucose Measurements Accuracy in the General Intensive Care Unit

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Abstract: The point-of-care testing (POCT) of capillary blood have become widely used in Intensive Care Units (ICUs) measuring capillary point-of-care blood glucose in this setting is becoming increasingly controversial. The international studies evaluated the accuracy of POCT glucose meter using other sources of blood than the capillary blood are limited. This study was aimed to determine the point-of-care blood glucose measurements accuracy in the general intensive care unit. A prospective descriptive comparative research design was used. Two general intensive care units of Alexandria Main University Hospital were included in the study. A convenience sample of 100 newly admitted adult critically ill patients were included. One developed tool "Blood glucose monitoring record" was used. Results revealed that the mean difference between arterial blood glucose (BG) values obtained by glucose meter and laboratory analysis was 15.92±27.21mg/dl. The mean difference between venous BG values obtained by glucose meter and laboratory analysis was 15.71±33.91 mg/dl. The mean difference between arterial blood glucose (BG) values obtained by laboratory analysis and capillary BG values obtained by glucose meter was 23.39±91.91 mg/dl (the highest mean difference). The mean difference between venous BG values obtained by the laboratory analyzer and the mean capillary BG value obtained by glucose meter was 18.75±35.80 mg/dl. The differences between the laboratory glucose values and capillary glucose meter values were statistically significant ($p \leq 0.001$). The greatest level of underestimation of blood glucose values was with the capillary glucose meter values when compared with the arterial and venous laboratory values where it underestimates 34.5% of the arterial laboratory values and 28.3% of the venous laboratory values. In Conclusion: Analysis of the same blood samples using different methods and compared against each other, shown a significant difference between BG values. The blood samples analyzed using POC glucose meter provide BG values that are significantly lower than the BG values analyzed using the laboratory analyzer particularly at the hyperglycemic range of BG level. Recommendation: The POCT using capillary blood should not be used in critically ill patients, particularly those who have upper extremity edema.

Key words: Point-Of-Care Testing · Blood Glucose Testing · Accuracy Of Bedside Blood Glucose Values · Critically Ill Patients

INTRODUCTION

Critical illness is often associated with several physiological derangements. Altered glucose metabolism is a hallmark of the human body's response to critical illness. During critical illness patients may have three forms of deviation from the normal glucose level including hyperglycemia [1-3], hypoglycemia [4] and high glycemic variability [5]. Maintaining normoglycemia while preventing hypoglycemia and reducing glycemic variability are key components of glycemic control strategies used in ICUs [6]. Monitoring BG levels on admission to the ICU and on ongoing basis is crucial for glycemic control and detection of hypoglycemic events and reducing glycemic variability [7]. Critical care nurses have pivotal role in providing accurate and reliable measurements of the patient's BG level necessary for the appropriate decision regarding the glycemic control

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strategy [8, 9]. Although laboratory analysis is the most accurate method for evaluating BG levels, its remote location and the consumed time makes point-of-care testing (POCT) of BG in whole blood an ideal alternative specifically when frequent monitoring of glucose is important [10].

The POC testing of capillary blood have become widely used in ICUs, measuring capillary POC BG in this setting is becoming increasingly controversial. Previous literature has raised questions about disparity between these measured values and those obtained from laboratory analysis of blood from venous or arterial sources, particularly in the ICUs [11]. Critically ill patients may experience pathophysiological conditions that could affect the accuracy of capillary BG values [12, 13]. The source of the sample used for BG testing plays an important role in the accuracy of the measured glucose [14]. The use of arterial or venous blood samples for POC glucose measurement can best reflects the reference plasma glucose than does capillary blood in the setting of critical illness [15-17].

Research studies [9, 11, 18-20] on the accuracy of capillary blood glucose testing have shown that the capillary blood sample is unsuitable to be used for glucose testing in critically ill patients as this may result in underestimation or overestimation of blood glucose levels. Ellis *et al*. [19] found that the POC arterial BG values in patients receiving no more than two vasopressors show better accuracy than the arterial blood. Other studies [18, 20] revealed that the use of arterial blood samples for POCT of BG show better accuracy and correlation with the laboratory glucose values than the capillary blood samples but still have unacceptable agreement with the standard laboratory glucose values. Argolla *et al*. [20] found that the POCT of BG using venous blood samples in critically ill patients shows better correlation with the central laboratory glucose values than the capillary blood. On the other hand, Preriera *et al*. [21] found that the POCT using venous blood in critically ill patients had the poorest agreement with the laboratory glucose values. The international studies evaluated the accuracy of POCT glucose meter using other sources of blood than the capillary blood are limited. Up to our knowledge, there is no national studies evaluated the accuracy of POCT device with other blood sources.

Aim of the Study: The aim of this study is to determine to determine the point-of-care blood glucose measurements accuracy in the general intensive care unit.

Research Question: What is the point of care blood glucose measurements accuracy in the general intensive care unit*?*

MATERIALS AND METHODS

Materials

Design: A prospective descriptive comparative research design was used to conduct this study.

Setting: This study was conducted at two general intensive care units of Alexandria Main University Hospital-namely; unit I and unit III. Unit I and Unit III bed capacity is 8 and 15 beds respectively. These ICUs are equipped to provide care for patients who have life threatening problems.

Subjects: A convenience sample of 100 adult critically ill patients who were admitted to the previously mentioned settings within 24 hours, of either sex, aged 18-60 years and undergoing scheduled BG monitoring were included in this study. This estimation of sample size is based on the power analysis (Epi-Info program). A 300 arterial, 300 venous and 300 capillary blood samples were obtained from critically ill patients to be analyzed using glucose meter and 300 arterial and 300 venous blood samples were obtained to be analyzed using the central laboratory analyzer.

Exclusion Criteria: Patients who were receiving intravenous glucose infusion at the time of sampling and patients receiving total parenteral nutrition were excluded from this study. The sampling sites with preexisting infection, burn, hematoma, dialysis shunt, inflammation, bruising, open lesion, recently punctured and show poor hand collateral circulation as evidenced by negative Allen's test (in case of arterial sampling from radial artery) were excluded from this study.

Tool: Blood glucose monitoring record was developed by the researcher after reviewing the related literature [10-12, 16, 18, 19, 21, 23]. This tool comprises three parts. Part I includes the Bio-demographic data such as age, sex, admission diagnosis, glycemic control strategies, Part II includes patients' clinical data; hemodynamic parameters such as pulse, MAP and body temperature, sampling site color, temperature, capillary refill time and presence of peripheral edema at the extremity used for sampling, hemoglobin level, hematocrit and serum bilirubin level, partial pressure of arterial oxygen (PaO_2), partial pressure

of arterial carbon dioxide ($PaCO_2$), pH level and medications affecting peripheral perfusion. Part III includes BG reading record.

Method: An approval to conduct this study was obtained from hospital responsible authorities. The developed tool was tested for content validity by five experts in the study field. A pilot study was carried out on ten critically ill patients (not included in the study sample) to assess the clarity and applicability of the tool. No modifications were done. The reliability of the tool was assessed using Cronbach alpha reliability (r = 0.91).

Data Collection: Data were collected by the researcher during 6 months starting from June 2015 to November 2015.

Patients' bio-demographic data were obtained from patients health records upon admission. Patients' clinical data were assessed daily before obtaining the blood samples for glucose analysis.

Sampling site was assessed daily before obtaining the blood samples Patients' hemoglobin, hematocrit and serum bilirubin levels and patients' medications were obtained daily from patients' health records before obtaining the blood samples for glucose testing. The values of arterial blood gases pH, PaO_2, $PaCO_2$ at the time of BG testing were obtained after analyzing the arterial blood sample by the researcher or the nurse responsible for providing patient's care using the point of care blood gas analyzer.

An arterial, venous and capillary blood samples were obtained simultaneously daily in the morning at the time of routine sampling. The best site for arterial, venous and capillary puncture was selected. The arterial, venous and capillary blood samples were analyzed by the researcher using glucose dehydrogenase (ACCU-CHEK Active) glucose meter after performing the appropriate calibration according to the manufacturer's directions before starting data collection.

The arterial, venous and capillary BG values were recorded immediately after analysis using glucose meter. The same samples; arterial and venous blood were sent by the researcher for laboratory glucose analysis in the clinical pathology lab.

The level of agreement between BG values obtained by POC glucose meter and the reference laboratory analyzer based on the guidelines of the international organization for standardization (ISO) 15197 2003 which stated that 95% of the glucose meter BG values should be within ± 15 mg/dl of the reference laboratory glucose value at a concentration of below 75 mg/dl and within ± 20% of the reference laboratory glucose value at a concentration equal to or above 75 mg/dl [24, 25].

Ethical Considerations: An informed written consent was obtained from conscious patients. Witness consent was obtained for unconscious patients. The anonymity, confidentiality and privacy of responses, voluntary participation and right to withdraw from the study were emphasized before inclusion in the study sample.

Statistical Analysis: SPSS package version 20 was used for statistical analysis. Descriptive statistical analysis for all study variables was conducted. Student t-test and Chi-Square test were used to compare two sample means.

RESULTS

Fig. 1 and 2 and table 1 show the distribution of studied critically ill patients according to bio-demographic data. 58% of the studied patients were males. Approximately half of the studied patients aged between 50 and 60 years. A 34% and 24% of the studied patients had neurological alteration and respiratory alteration.

Table 2 shows the distribution of studied critically ill patients according to administration of hypoglycemic agents. 20% of the studied patients were diabetics. A 24% of the studied patients were receiving insulin infusion.

Table 3 shows the distribution of studied critically ill patients according to administration of pharmacological agents. 37, 17, 24, 12 and 34% of the studied patients were receiving noradrenaline infusion, corticosteroids, antibiotics, mannitol and acetaminophen respectively.

Table 4 shows the distribution of patients' clinical data at the time of BG measurements. 50.4, 67, 52, 75.3 and 73.4% of the studied BG values were obtained from patients with normal pulse rate, normal MAP, normal body temperature, low hemoglobin level and low hematocrit level respectively. 52, 54 and 54.3% of the studied BG values were obtained from patients who had pH values above the normal range, high PaO_2 and low $PaCO_2$ values respectively. 70.3, 37.7, 48 and 76.7% of the studied BG values were obtained from pale, cold, edematous extremity and extremities with delayed capillary refill time respectively.

Table 5 shows the comparison between BG values obtained by glucose meter and laboratory analysis. The mean difference between arterial BG values obtained by glucose meter and laboratory analysis was 15.92±27.21 mg/dl. The mean difference between venous BG values

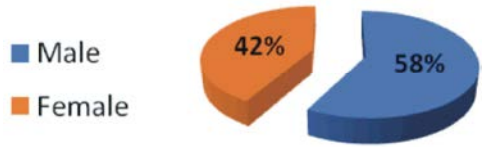

Fig. 1: Distribution of the studied critically ill patients according to their sex

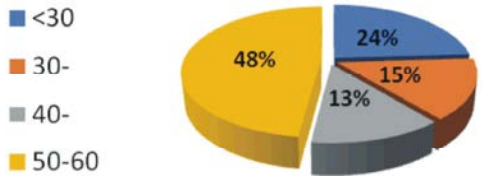

Fig. 2: Distribution of the studied critically ill patients according to their age group

Table 1: Distribution of studied critically ill patients according to body system alterations

		Studied patient's (N=100)	
Body system alterations		No	%
Cardiovascular		15	15.0
Respiratory		24	24.0
Renal		12	12.0
Neurological		34	34.0
Endocrine		3	3.0
Others	GIT	5	5.0
	Sepsis	9	9.0
	Trauma	12	12.0
	Poisoning	24	24.0

DM diabetes Millets HTN hypertension

* The total is more than 100%

Table 2: Distribution of studied patients according to administration of hypoglycemic agents

		Studied patients					
		Diabetics (N=20)		Non-diabetics (N=80)		Total (N=100)	
Hypoglycemic agent		No	%	No	%	No	%
IV insulin infusion	Yes	15	75.0	9	11.25	24	24.0
	No	5	25.0	71	88.75	76	76.0
Subcutaneous insulin	Yes	0	0.0	4	5.00	4	4.0
	No	20	100.0	76	95.00	86	86.0

Table 3: Distribution of studied critically ill patients according to administration of pharmacological agents

		Studied patients (N=100)					
		Yes		No		Total	
Pharmacological agents		No	%	No	%	No	%
Medications affecting peripheral perfusion	Noradrenaline	37	37.0	63	63.0	100	100
Medications affecting glucose metabolism	Corticosteroids	17	17.0	83	83.0	100	100
	Antibiotics	24	24.0	76	76.0	100	100
Substances interfering with GDH based glucose meter performance	Mannitol	12	12.0	88	88.0	100	100
	Acetaminophen	34	34.0	66	66.0	100	100

Table 4: Distribution of the clinical data at time of blood glucose measurement

Clinical data			Blood glucose measurement occasions (N=300) No	%
Hemodynamic parameters	Pulse rate	Bradycardia	8	2.6
		Normal pulse rate	151	50.4
		Tachycardia	141	47.0
	MAP	Normal	201	67.0
		Above normal	59	19.7
		Below normal	40	13.3
Hematological & biochemical parameters	Hb level	Normal	72	24.0
		Above normal	2	0.7
		Below normal	226	75.3
	HCT %	Normal	77	25.6
		Above normal	3	1.0
		Below normal	220	73.4
	* Serum bilirubin	Normal	15[@]	34.9
		Above normal	28	65.1
Acid base related parameters	pH	<7.35	43	14.3
		7.35-7.45	101	33.7
		>7.45	156	52.0
	PaO_2	<80 mmHg	70	23.3
		80-100 mmHg	68	22.7
		>100 mmHg	162	54.0
	$PaCO_2$	< 35 mmHg	163	54.3
		35-45 mmHg	106	35.3
		>45	31	10.3
Peripheral perfusion related parameters	Color of extremity used for sampling	Pink	41	13.7
		Pale	211	70.3
		Erythematous	48	16.0
	Temperature of extremity used for sampling	Warm	139	46.3
		Cold	113	37.7
		Hot	48	16.0
	Capillary refill time	≤ 2	70	23.3
		> 2	230	76.7
	Presence of peripheral edema	Yes	143	47.7
		No	157	52.3

*The total number of serum bilirubin monitored in the studied critically ill patients was 43 as it wasn't analyzed daily with the routine investigations.

Table 5: Comparison between the mean blood glucose values obtained by glucose meter and laboratory analysis

Laboratory analysis / glucose meter	Mean values	Mean difference ± SD	Test of significance
Arterial lab (N=300) /	152.7±82.63	15.92 ±27.21	t = 10.13
Arterial meter (N=300)	137.2±11.70		p ≤ 0.001*
Venous lab (N=300) /	149±87.32	15.71±33.91	t = 8.14
Venous meter (N=300)	132.16±11.62		p ≤ 0.001*
Arterial lab (N=300) /	152.7±82.63	23.39 ±91.91	t = 4.40c
Capillary meter (N=300)	129.76±11.60		p ≤0.001*
Venous lab (N=300) /	149±87.32	18.75±35.80	t = 9.07
Capillary meter (N=300)	129.76±11.60		p ≤ 0.001*

obtained by glucose meter and laboratory analysis was 15.71±33.91 mg/dl. The mean difference between arterial BG values obtained by laboratory analysis and capillary BG values obtained by glucose meter was 23.39±91.91 mg/dl (the highest mean difference). The mean difference between venous BG values obtained by the laboratory analyzer and the mean capillary BG value obtained by glucose meter was 18.75±35.80 mg/dl. The differences between arterial laboratory glucose values and arterial glucose meter values, venous laboratory glucose values and venous glucose meter values, arterial laboratory glucose values and capillary glucose meter values and venous laboratory glucose values and capillary glucose meter values were statistically significant ($p \leq 0.001$).

Table 6: Distribution of blood glucose readings according to predetermined level of agreement (ISO 15917 2003)

			BG readings							
			Arterial (lab / meter)		Venous (lab / meter)		Arterial/Capillary (lab /meter)		Venous /Capillary (lab / meter)	
Predetermined level of agreement			No	%	No	%	No	%	No	%
(BG value <75)	Within limits		4	66.7	13	81.2	2	33.3	8	50
	Outside limits	Below level	0	0.0	0	0.0	2	33.3	1	6.3
		Above level	2	33.3	3	18.8	2	33.3	7	43.8
	Total		6	100	16	100.0	6	100.0	16	100.0
(BG value ≥75)	Within limits		248	84.4	228	80.3	188	63.9	191	67.3
	Outside limits	Below level	44	15.0	52	18.3	102	34.7	84	29.6
		Above level	2	0.6	4	1.4	4	1.4	9	3.2
	Total		294	100	284	100.0	294	100.0	284	100.0

Table 7: Distribution of BG readings according to predetermined level of agreement (ISO 15917 2003)

		BG readings			
Predetermined level of agreement		Arterial Lab/ arterial meter	Venous Lab/ venous meter	Arterial Lab/ Capillary meter	Venous Lab/ Capillary meter
Within limit of agreement with laboratory BG values	No	252	240	190	199
	%	85.7	84.5	63.3	66.3
Under estimation of laboratory BG values	No	44	52	104	85
	%	13	18	34.5	28.3
Over estimation of laboratory BG values	No	4	7	6	16
	%	1.3	12.7	2.2	5.4
Total	No	300	300	300	300
	%	100.0	100.0	100.0	100.0

Table 6 displays the distribution of BG values according to predetermined level of agreement as stated by (ISO 15197 2003). Regarding the level of agreement between glucose meter values and laboratory glucose values which are less than 75 mg/dl, this table depicts that, 66.7% of the obtained arterial POC BG values showed acceptable level of agreement when compared with the standard arterial laboratory BG values. 81.2% of the venous POC BG values showed acceptable level of agreement when compared with the standard venous laboratory BG values. 33.3% of the capillary POC BG values showed acceptable level of agreement when compared with the standard arterial laboratory BG values and 50% of them showed acceptable level of agreement when compared with the standard venous laboratory blood glucose values.

Regarding the level of agreement between glucose meter values and laboratory glucose values which are equal to or more than 75 mg/dl, it can be noted from this table that 84.4% of the arterial POC BG values showed acceptable level of agreement when compared with standard arterial laboratory BG values. 80.3% of the venous POC BG values showed acceptable level of agreement when compared with the standard venous laboratory BG values. 63.9% of the capillary POC BG values showed acceptable level of agreement when compared with the standard arterial laboratory BG values and 67.3% of them showed acceptable level of agreement when compared with the standard venous laboratory BG values.

In relation to glucose meter BG values that fall outside the level of agreement with laboratory glucose values equal to or more than 75mg/dl, this table depicts that the glucose meter underestimated the laboratory glucose values with 15% of the arterial POC BG values fall below the acceptable level of agreement when compared with the standard arterial laboratory glucose values. 18.3% of the venous POC BG values fall below the acceptable level of agreement when compared with the standard venous laboratory glucose values. About 34.7% of the capillary POC BG values fall below the acceptable level of agreement when compared with the standard arterial laboratory glucose values and 29.6% of them fall below the acceptable level of agreement when compared with the standard venous laboratory glucose values. This means that the greater level of glucose meter underestimation of the laboratory blood resulted from POC glucose testing using the capillary blood.

Table 8: The mean differences between laboratory analysis and glucose meter blood glucose values according to the ranges of blood glucose

		Differences between blood glucose values					
		Arterial lab - arterial meter			Arterial lab - capillary meter		
Arterial laboratory blood glucose ranges		Mean difference	t	Sig.	Mean difference	t	Sig.
Hypoglycemia (n=6)	<70 mg/dl	8.83	1.179	0.29	38.33	5.50*	<0.00*
Normoglycemia (tolerable glycemia) (n=184)	70-139 mg/dl	7.83	8.857*	<0.00*	11.41	2.46*	<0.00*
Normoglycemia (target BGL) (n=51)	140 -180 mg/dl	15.31	7.231*	<0.00*	27.67	4.09*	<0.00*
Hyperglycemia (n=59)	>180 mg/dl	34.19	7.492*	<0.00*	56.53	9.98*	<0.00*

t: Paired t-test; Sig: significance; *: Statistically significant at $p \leq 0.05$; BGL: blood glucose level

Table 9: The mean differences between laboratory analysis and glucose meter blood glucose values according to the ranges of blood glucose

			Difference between blood glucose values					
			Venous lab - venous meter			Venous lab - capillary meter		
Venous laboratory blood glucose ranges			Mean difference	t	Sig	Mean difference	t	Sig
Hypoglycemia	<70 mg/dl	(N= 10)	2.80	0.867	0.490	15.40	1.893	0.09
Normoglycemia	70-139 mg/dl	(N=193)	5.03	4.480	<0.001*	8.30	6.275	<0.00*
	140 -180 mg/dl	(N=43)	19.77	7.761	<0.001*	28.95	9.575	<0.00*
Hyperglycemia	>180 mg/dl	(N=54)	42.09	7.044	<0.001*	49.28	6.653	<0.00*

t: Paired t-test; Sig: significance; *: Statistically significant at $p \leq 0.05$; BGL: blood glucose level

Table 7 shows the distribution of BG readings according to predetermined level of agreement as stated by (ISO 15917 2003). In relation to the total level of agreement between BG values obtained by glucose meter and BG values obtained by laboratory analyzer, this table reveals that 85.7% of the arterial POC BG values fall within the acceptable level of agreement when compared with the standard arterial laboratory glucose values. Regarding the agreement between venous POC BG values and venous laboratory glucose values, this table illustrates that 84.5% of the venous glucose meter fall within the acceptable level of agreement when compared with the standard venous laboratory glucose values.

In relation to the agreement between capillary glucose meter and the laboratory glucose values, this table reveals that 63.3% of the capillary POC BG values fall within the acceptable level of agreement when compared with the standard arterial laboratory glucose values and 66.3% of them fall within the acceptable level of agreement when compared with the standard venous laboratory glucose values. Regarding the glucose meter values underestimating the laboratory glucose values, this table depicts that the greater level of underestimation was with the capillary glucose meter values when compared with the arterial and venous laboratory values where it underestimates 34.5% of the arterial laboratory values and 28.3% of the venous laboratory values.

Concerning the mean difference between the arterial BG values obtained by the arterial lab and arterial meter, Table 8 shows that the lowest mean difference between the arterial BG values obtained by the arterial lab and arterial meter (8.83 mg/dl) was at the hypoglycemic range. While the highest mean difference (34.19 mg/dl) was at the hyperglycemic range. Regarding the mean difference between the arterial BG values obtained by the arterial lab and capillary meter, table 8 depicts that the lowest mean difference between the arterial BG values obtained by the arterial lab and capillary meter (11.41mg/dl) was at the normoglycemic range. While the highest mean difference (56.53 mg/dl) was at the hyperglycemic range. The mean differences are statistically significant ($p \leq 0.001$) except at the hypoglycemic range.

Concerning the mean difference between the venous BG values obtained by the venous lab and venous meter, Table 9 demonstrates that the lowest mean difference between the venous BG values obtained by the venous lab and venous meter (2.8 mg/dl) was at the hypoglycemic range. While the highest mean difference (42.09 mg/dl) was at the hyperglycemic range. Regarding the mean difference between the venous BG values obtained by the venous lab and capillary meter, Table 9 illustrates that the lowest mean difference between the venous BG values obtained by the venous lab and capillary meter (8.30 mg/dl) was at the normoglycemic range. While the highest mean difference (49.28 mg/dl) was at the hyperglycemic range. The mean differences are statistically significant ($p \leq 0.001$) except at the hypoglycemic range.

DISCUSSION

Accurate measurement of BG is essential for appropriate management of stress hyperglycemia, hypoglycemia and glycemic variability associated with critical illness and their poor clinical outcomes [26, 27]. The findings of the current study reveal that the mean difference between BG values obtained by POC glucose meter testing of different blood sources was not statistically significant. The mean difference between BG values obtained using central laboratory devices (CLD) was also not statistically significant. However, when BG values obtained using the two methods of BG testing compared against each other, the mean difference between them was statistically significant. The CLD mean BG values were significantly higher than the POC mean BG values. This can significantly affect treatment decision.

The difference between BG values may be attributed to; firstly, the method of BG testing. The methods used in the current study include the CLD and POC glucose meter. The CLD tested the glucose level in plasma where the glucose concentration is higher than the whole blood tested using POC glucose meter which provide an estimation of the plasma glucose level. Secondly, the different sources of blood samples used for POCT of BG were obtained from a group of patients most likely have conditions that may contribute to the difference between POC and CLD BG values such as inadequate peripheral perfusion secondary to infusion of vasopressor medications and the presence of sampling site edema. The highest mean POC BG values were obtained from testing arterial blood sample as it carries the glucose supply to the tissues followed by venous sample and capillary sample last. Decreased mean capillary BG value may be related to increased glucose extraction by the tissues to compensate for decreased peripheral perfusion and decreased glucose supply and dilution by peripheral edema.

These findings are in line with Cook *et al*. [8] who compared the differences in BG values obtained from POC glucose meter and laboratory analysis in critically ill patients. This study revealed that, the difference between POC venous and capillary glucose values was not statistically significant. There is a significant difference between venous and capillary POC values and venous laboratory glucose values in critically ill patients. Huysal *et al*. [28] evaluated the performance of Care Sens POCT devices for glucose testing in the routine hospital setting and found that, there is a significant difference between venous laboratory glucose values and capillary POC values. Lonjaret *et al*. [18] assessed the accuracy capillary glucose meter measurement in critically ill patients. They recorded that the mean arterial laboratory glucose values are higher than the mean arterial and capillary glucose meter values. Argollo *et al*. [20] studied the differences between the portable BG meter readings in different sampling access and laboratory analysis in medical and surgical critically ill patients and concluded that the mean venous laboratory glucose values are higher than the arterial and capillary glucose meter values in critically ill patients.

Contrary to these findings, Yaraghi *et al*. [26] compared the capillary, venous POC glucose values and CLD glucose values in comatosed poisoned patients and found that, there is no significant differences between venous glucose values obtained by CLD and venous and capillary glucose POC BG values. Sudan [27] studied the difference between BG values obtained by POC glucose meter and CLD in diabetic patients. This study results depicted that, the mean venous laboratory glucose values were higher than the mean capillary glucose values there is no significant difference between venous laboratory glucose values and capillary POC values.

Dubose *et al*. [29] compared capillary glucose measurements and the traditional laboratory analysis of BG in both shocked and non-shocked patients. Their study revealed that the mean arterial and venous laboratory glucose values were lower than the mean capillary glucose values. The accuracy of BG results obtained from POC glucose meter is quantified based on the ISO 15197 guidelines [24, 25]. Findings of the current study reveal that the POC glucose meter values obtained from testing different sources of blood failed to fulfill the accuracy criteria of the acceptable level of agreement stated by the ISO 15197 (2003) for both laboratory blood glucose values < 75 mg/dl and ≥ 75 mg/dl with the best agreement found with the arterial samples followed by venous samples. The worst agreement is with the capillary samples. This may be explained by that in patients with upper extremity edema or receiving vasopressors, the glucose available for tissue is reduced due to altered blood flow. This altered blood flow increase tissue glucose extraction to compensate for decreased perfusion which in turn decreases BG concentration. This means that the POC glucose meter is not reliable for use when aiming to control BG level in critically ill patients.

This is in agreement with Huysal *et al*. [28] findings which revealed that the capillary POC glucose values fail to meet the minimum accuracy criteria of the reference

venous laboratory glucose values in hospitalized patients. As well, Garingarao *et al*. [9] studied the accuracy of POC BG measurements in critically ill shocked patients. This study finding revealed that the capillary and venous POC glucose values fail to meet the minimum accuracy criteria of the reference venous and arterial laboratory glucose values in hypotensive critically ill patients. In addition, Ellis *et al*. [19] compared the capillary and arterial glucose values measured via POCT with arterial glucose values measured through the laboratory analyzer in patients receiving vasopressors. This latter study showed that the capillary and arterial glucose meter values fail to fulfill accuracy criteria in patients receiving vasopressors when compared to arterial laboratory values. Moreover, Lonjaret *et al*. [18] findings revealed that the capillary and POC glucose values fail to meet the minimum accuracy criteria of the reference venous and arterial laboratory glucose values in critically ill patients. On the contrary, Ellis *et al*. [19] findings revealed that the arterial POC glucose values fail to fulfill the ISO criteria in patients who have undergone cardiac surgery and received no more than two vasopressor medications.

The current study shows that the POC glucose meter values obtained using blood from different sources underestimate the CLD BG values which were more obvious at the BG levels more than 75 mg/dl. This may be due to that, the blood samples tested using glucose meter in the current study were obtained from a group of patients having special conditions such as peripheral edema and undergoing pharmacological management as receiving vasopressor medications. These conditions may affect the accuracy POC BG values specifically when using the arterial and capillary blood samples. This is in agreement with Garingarao *et al*. [9] findings which revealed that, the capillary glucose meter values underestimate the venous laboratory glucose values in hypotensive critically ill patients on vasopressors. As well Lonjaret *et al*. [18] findings revealed that the arterial and capillary glucose meter values underestimate the arterial laboratory glucose values. Also, Ellis *et al*. [19] findings revealed that the capillary and arterial glucose meter values are inaccurate in patients receiving vasopressors.

Contrary to the current study, Cook *et al*. [8] findings revealed that the venous and capillary glucose meter values overestimate the venous laboratory glucose values in critically ill patients. Dubose *et al*. [29] findings revealed that the capillary glucose meter values overestimate the venous laboratory glucose values in critically ill patients.

The current study results reveal that, the mean differences between CLD glucose values and POC glucose meter values obtained from different blood sources were statistically significant at the normoglycemic and hyperglycemia range of BG values. This means that the hyperglycemia may go undetected in such group of patients resulting in delay or interruption in administration of insulin therapy. In addition, false diagnosis of hypoglycemia may occur. Despite these results, the mean difference between arterial laboratory and capillary POC glucose values was statistically significant at the hypoglycemic range of BG values. This is in agreement with Garingaroa *et al*. [9] findings which revealed that, the inaccurate capillary glucose meter values in normotensive and hypotensive patients at the normoglycemic range underestimate the venous laboratory glucose values. Moreover, Lonjaret *et al*. [18] study findings revealed that, the capillary POC glucose values underestimated the arterial laboratory glucose values at the tolerable and normoglycemic range of blood glucose.

CONCLUSION

Analysis of different blood sources using the same method has shown no significant difference between BG values. However, when the same blood samples analyzed using different methods and compared against each other, they shown significant difference between BG values. The blood samples analyzed using POC glucose meter provide BG values that are significantly lower than the BG values analyzed using the laboratory analyzer particularly at the hyperglycemic range of BG level. Although none of the blood sources fulfill the accuracy criteria stated by ISO 15197, the arterial blood samples show better accuracy than the other blood sources when compared with the laboratory BG values.

Recommendations: The POCT using capillary blood should not be used in critically ill patients, particularly those who have upper extremity edema. Use the venous blood samples as an alternative to arterial blood for POC glucose meter testing of BG in patients having conditions that affect peripheral perfusion.

REFERENCES

1. Preiser, J.C., C. Ichai, J.C. Orban and A.B.J. Groeneveld, 2014. Metabolic response to the stress of critical illness. British Journal of Anaesthesia, 113(6): 945-54.

2. Xiu, F., M. Stanojcic, L. Diao and M.G. Jeschke, 2014. Stress Hyperglycemia, Insulin Treatment and Innate Immune Cells. International Journal of Endocrinology, 14: 1-9.
3. Corl, D.E.G.L., A. Hoofnagle, G.S. Baird, L.D. Suhr and B.E. Wisse, 2015. Measuring pointof care blood glucose in critically ill patients. Nursing Critical Care Journal, 10(4): 22-30.
4. Lacherade, J.C. and J.C. Preiser, 2009. An overview of Hypoglycemia in the Critically Ill. Journal of Diabetes Science and Technology, 3(6): 1242-46.
5. Devries, J.H., 2013. Glucose Variability: Where It Is Important and How to Measure It. Diabetes Journal, 62: 1405-6.
6. Nya-Ngatchou, J.J., D.C. Onstad, T.Y. Tylee, L.S. Rachel and T.B. Wisse, 2014. Point of care blood glucose measurement errors overestimate hypoglycaemia rates in critically ill patients. Diabetes Metabolism Research Reviews, 2014: 1.
7. Badawi, O., M.D. Waite, S.A. Fuhrman and I.H. Zuckerman, 2012. Association, between intensive care unit acquired dysglycemia and in-hospital mortality. Journal of Critical Care Medicine, 40(12): 3181-4.
8. Cook, A., D. Laughlin, M. Moore, D. North, K. Wilkins, G. Wong, A.W. Scroggs and L. Halvorsen, 2009. Differences in glucose values obtained from point of care glucose meters and laboratory analysis in critically ill patients. American Journal of Critical Care, 18(1): 65-70.
9. Garingarao, C.G.P., M. Buenaluz-Sedurante and C.A. Jimeno, 2014. Accuracy of Point-of-Care Blood Glucose Measurements in Critically Ill Patients in Shock. Journal of Diabetes Science and Technology, 8(5): 937-43.
10. Lacara, T., C. Domagtoy, D. Lickliter, K. Quattrocchi and L. Snipes, 2007. Comparison of point of care and laboratory glucose analysis in critically ill patients. American Journal of Critical Care, 16(4): 36-44.
11. Critchell, C.D., V. Savarese, A. Callahan, C. Aboud, S. Jabbour and P. Marik, 2007. Accuracy of bedside capillary blood glucose measurements in critically ill patients. Journal of Intensive Care Medicine, 33: 2079-84.
12. Pitkin, A.D., P.J. Rice and P.M. Rice, 2009. Challenges to Glycemic Measurement in the Perioperative and Critically Ill Patient: a review. Journal of Diabetes Science and Technology, 3(6): 1271-1278.
13. Herpe, T.V. and D. Mesotten, 2012. Blood Glucose Measurements in Critically Ill Patients. Journal of Diabetes Science and Technology, 6: 1.
14. Samokhvalov, A. and R. Farah, 2012. Glycemic control in the intensive care unit: between safety and benefit. IMAJ, 14: 261-3.
15. Rajendran, R. and G. Rayman, 2014. Point of care blood glucose testing for diabetes care in hospitalized patients: an evidence-based review. Journal of Diabetes Science and Technology, 8(6): 1081-5.
16. Dungan, K. and J. Chapmann, 2007. Glucose Measurement: Confounding Issues in Setting Targets for Inpatient Management. Journal of Diabetes Care, 30(2): 403-5.
17. Eastham, J.H., D. Mason, D.L. Barnes and J. Kollins, 2009. Prevalence of interfering substances with point-of-care glucose testing in a community hospital. American Journal of Health System Pharmacists, 66: 167-9.
18. Lonjaret, L. and V. Claverie, 2012. Relative Accuracy of arterial and capillary glucose meter measurement in critically ill patients. Journal of Diabetes and Metabolism, 38: 231.
19. Ellis, M.F.B.K., M. Cornell, K. Decker, K. Farrell, L. McGugan, G.P. Porter, H. Shearin, Y. Zhao and B.B. Granger, 2013. Suitability of Capillary Blood Glucose Analysis in Patients Receiving Vasopressors. American Journal of Critical Care, 22: 423-9.
20. Argollo, A.P., T.N. Faustino, T.N. Faustino and L.C. Pedreira, 2010. Portable blood glucose meter values using different sampling ways: a validity study. Rev Bras TerIntensiva Journal, 22(4): 351-57.
21. Pereira, A.J., T.D. Corrêa, F.B. Almeida, R.O. Deliberato, M.D. Lobato, N. Akamine, E. Silva and L.B. Cavalcanti, 2015. Inaccuracy of venous point of care glucose measurements in critically ill patients: A Cross-Sectional Study. Plos One Journal, 10(6): 2-9.
22. Tang, Z., Z. Du, R.F. Louie and G.J. Kost, 2000. Effects of pH on Glucose Measurements With Handheld Glucose Meters and a Portable Glucose Analyzer for Point-of-Care Testing. Journal of Arch Pathology Lab Medicine, 124: 577-82.
23. Marik, P.E. and R. Bellomo, 2013. Stress hyperglycemia: an essential survival response. Journal of Critical Care, 17: 1-6.

24. Tirimacco, R.K.G., R. Erasmus, A. Mosca, S. Sandberg, L.D. Watson, B. Goldsmith and P. Gillery, 2013. Glucose meters fit for clinical purpose. Journal of Clinical Chemistry Lab Medicine, 51(5): 943-52.
25. Teodorczyk, M., S. Nandagopalan, P. Maguire and J. Stegmann, 2013. System accuracy of blood glucose monitoring devices according to the current and proposed ISO 15197 Standards. Journal of Diabetes Science and Technology, 7(3): 796.
26. Yaraghi, A., N.E. Mood and L.K. Dolatabadi, 2015. Comparison of capillary and venous blood glucose levels using glucometer and laboratory blood glucose level in poisoned patients being in coma. Journal of Advanced Biomedical Research, 4: 1-5.
27. Sudan, K., 2014. Comparison between glucometer and chemical analyzer for measuring blood glucose of diabetic patients. International Journal of Current Research, 6(5): 6610-12.
28. Huysal, K., Y.U. Budak, H. Demirci and M.A. Önelge, 2015. Evaluation of CareSens POCT devices for glucose testing in the routine hospital setting. Journal of Clinical and Diagnostic Research, 9(10): 4-6.
29. Du Bose, J.J., K. Inaba, B.C. Branco, G. Barmparas, L. Lam, B.G.R. Teixeira, H. Belzberg and D. Demetriades, 2012. Discrepancies between capillary glucose measurements and traditional laboratory assessments in both shock and non-shock states after trauma. Journal of Surgical Research, 178: 820-25.