Correlation of the capillary and venous blood glucose levels using glucometer with fully automated chemistry analyzer for stress hyperglycemia among critically ill patients

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ABSTRACT

Objective: To correlate venous and capillary blood glucose measurements using glucometer with fully automated chemistry analyser in stress hyperglycemia among critically ill patients.

Material and Methods: This cross-sectional study was conducted at Combined Military Hospital, Rawalpindi from August 2018 to January 2019 and blood specimens were analysed in Department of Chemical Pathology and Endocrinology Armed Forces Institute of Pathology Rawalpindi. Blood samples were collected from thirty-five non-diabetic patients of both genders admitted to Intensive Care Unit (ICU), Coronary Care Unit (CCU) and High Dependency Unit (HDU) of CMH, Rawalpindi. Venous and capillary blood glucose were measured using glucometer. Venous plasma glucose was analysed on fully automated chemistry analyser ADVIA 1800 by spectrophotometric kinetic method using Hexokinase.

Results: Mean (± Standard deviation) of Capillary Blood Glucose (CBG) was 160 (± 34.1) mg/dl, of Venous Blood Glucose (VBG) was 145.4 (± 33.9) mg/dl, and of fully automated chemistry analyser was 121 (± 35.4) mg/dl. Mean values of blood glucose showed significant difference ($p<0.001$) by three methods mentioned above. The CBG and VBG were found significantly correlated ($r=0.91$; $p<0.001$), similarly CBG and blood glucose levels (BGL) measured on automated chemistry analyser were also significantly correlated ($r=0.79$; $p<0.001$) as well as VBG and BGL measured on automated chemistry analyser ($r=0.87$; $p<0.001$)

Conclusion: A significant positive correlation was found between capillary and venous blood glucose measured by glucometers as well as between these two parameters and blood glucose measures on automated chemistry analyser but the means of these three values differ significantly. This warrants cautious use of glucometers for the detection of stress hyperglycaemia.

Keywords: Blood glucose monitoring, Critically ill patients, Glucometer, Stress hyperglycemia

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INTRODUCTION

Stress hyperglycemia is a transient or temporary increase in blood glucose during acute physiological or mental stress in the absence of glucose homeostasis dysfunction [1]. According to the guidelines of The American Diabetes Association (ADA) stress hyperglycemia is defined as having a random glucose level > 140 mg/dL at any given time in hospitalized patients [2]. Stress hyperglycemia occurs commonly among patients suffering with critical illness and trauma [3]. Multiple causes of stress hyperglycemia are present but mostly proposed include excessive counter-regulatory hormones (corticosteroid, growth hormone, catecholamines, glucagon) and release of cytokines interleukin (IL)-1 and tumour necrosis factor (TNF)-alpha [4]. In critical illness, intricate interactions between cytokines and counter-regulatory hormones cause excessive production of glucose [5]. These hormones such

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as cortisol causes elevation in blood glucose through stimulation of gluconeogenesis and reduction in glucose utilization because of impaired insulin release and action, resulting in stress hyperglycaemia [6]. Pro-inflammatory cytokines that are released in response to acute stress increases insulin resistance by interfering with insulin signaling. Exogenous factors, such as parenteral and enteral nutrition, vasopressors, dextrose, and corticosteroids, further aggravate this hyperglycemia [7].

Prevalence of stress hyperglycemia has been variedly reported from 16.8% to 79.8% in critically ill patients e.g. 16.8% by Khalfallah *et al* [8],16.9% in children admitted with febrile seizures as demonstrated in study by Costea *et al* [9] and a frequency of 18% was reported by Satti *et al* at Combined Military Hospital Quetta in patients admitted in Medical Intensive Care Unit [10]. Effective glycemic control in critically ill patients has been shown to result in marked improvements in clinical outcome.

Measured glucose level depends on the kind of sample used for analysis (plasma vs blood), the site of blood (capillary, venous or arterial) and chemical analysis used for the test. General rule of glucose concentration level from high to low according to sampling site is artery, capillary, and then venous blood [11]. There is a higher glucose concentration in the plasma than whole blood. The reason behind this is that there is higher water content in plasma resulting in increased glucose concentration. Laboratory blood glucose measurement using plasma is said to be more accurate and reliable than the point of care glucose measurement using glucometers [12]. In a critically ill patient, various stresses such as fasting and a hypermetabolic state, results in significant variation between glucose values [13]. There is also concern regarding accuracy and reproducibility of results using capillary samples due to hypotension and oedema giving inaccurate results in critically ill patients [14].

Despite these limitations, point of care testing using glucometer in critically ill patients is a routine practice and limited local data was available regarding use of an appropriate sample and method used for the detection of stress hyperglycaemia. Present study has, therefore, been designed to determine the difference in glucose values by glucometer which is point of care testing and the main clinical laboratory for ICU patients having stress hyperglycemia and whether the site of blood sampling had a significant impact on glucose values.

MATERIAL AND METHODS

This Cross-sectional study was conducted at Department of Chemical Pathology and Endocrinology, Armed Forces Institute of Pathology from August 2018 to January 2019 after approval from Institutional Review Board (IRB) of AFIP Rawalpindi (FC-CHP15-6/READ-IRB/17/315) Sample size was calculated according to following formula

$$N = [(Z\alpha+Z\beta)/C]2 + 3 \text{ [15]}$$

Correlation coefficient " r= 0.93" from a regional study [16] was used to find sample size of our study. Sample size calculated was 7 which was too small to conduct a study. As sample size larger than 30 is appropriate for most research, we used sample size 35 for our study. Sample size calculation was done with the help of statistician. Using non-probability consecutive sampling technique, a total of 31 non-diabetic patients admitted in ICU, CCU and HDU of Combined Military Hospital Rawalpindi were included in the study. Patients with diabetes and those who have received pre-sampling intravenous dextrose solution or glucocorticoids were excluded. HbA1c was used to exclude patients with pre-existing diabetes. Stress hyperglycemia is considered as random plasma glucose concentration of >7.8 mmol/L (140 mg/dl) in the hospital setting in first 24 to 48 hours after admission, therefore blood samples were collected in first 24 hours of admission. Venous blood was collected in EDTA and sodium fluoride tubes for Glycated Haemoglobin (HbA1c) and glucose analysis respectively. Plasma was then separated within 45 minutes of collection by centrifugation at 3000 Revolution

per minute (RPM) for 3 minutes. Capillary blood samples were obtained with finger prick. Venous blood glucose (VBG) was measured on glucometer as well as by fully automated Clinical Chemistry Auto-analyser ADVIA 1800® (SIEMENS Germany) by Hexokinase method. Capillary blood glucose (CBG) was measured using glucometer. HbA1c was measured on fully automated chemistry analyser ADVIA 1800® (SIEMENS Germany) by immunoturbidimetric method. Quality control was maintained utilizing 2 levels of controls (Roche) in each run with inter-assay and intra assay CV (Coefficient of Variation) of 3.4%. During the study period Proficiency Testing (PT) was carried by External Quality Assessment Scheme (EQAS BioRad) was run monthly and it was within acceptable Z value (2.0) for study glucose. Aim was to ensure accuracy and authenticity of data generated for the study being carried out. Descriptive statistics were used to analyse qualitative and quantitative variables. Qualitative variables like gender and disease were expressed in frequency and percentage. Quantitative variables like age, blood pressure, pulse, capillary blood glucose, venous blood glucose measured by glucometer and venous blood glucose measured in laboratory were expressed in mean and SD. Statistical analysis was done using paired t test, One-way analysis of variance (ANOVA) and Pearson's correlation analysis.

RESULTS

Thirty-five patients were included in the study, 23 (65.7%) were males and 12 (34.3%) were females. Mean age was 56.2 ± 13.5 years, range 18-70 years). Mean age of the females and males were 54.74 ± 14.95 and 59 ± 10.2 years, respectively. There was no significant difference between the age of two genders p = 0.328). It was observed that 48% of the patients having stress hyperglycemia had cardiovascular disease. In Table-I mean, SD and range of blood pressure, pulse and HbA_{1C} of all patients are shown.

Based on the obtained results, mean of capillary blood glucose, venous blood glucose measured by glucometer and venous blood glucose measured on automated analyser are 160.67 ± 34.1, 145.37 ± 33.9 and 121.04± 35.4 respectively. Performing paired t test and Pearson correlation on the obtained data showed significant difference (p< 0.001) and positive correlation as given in Table-II.

There was a good correlation between CBG and VBG (r=0.912; (p < 0.001) (Figure-I). Correlation between CBG and BGL on automated chemistry analyzer was also quite significant (r=0.796;p <0.001) (Figure-II). The correlation rate between VBG and BGL on automated chemistry analyzer was also statistically significant (r=0.83; p < 0.001) (Figure-III).

One way ANOVA test also showed significant difference in the mean of blood glucose level measured by glucometer and lab testing (p=0.036).

Table-I: Values for selected non-study variables in 35 critically ill patients.

Variables	Mean± SD	Range
SBP mmHg	134.4 ±29.1	90-196
DBP mmHg	82.3±13.4	46-100
PULSE /min	79.3±13.4	52-131
HbA1C %	5.8±0.44	4.9-6.5

SBP= Systolic blood pressure, DBP= Diastolic blood pressure

Table-II: Comparison of different glucose estimation methods.

	Paired differences and Correlation			
	Mean ± SD	p value	r	p-value
GCBG vs GVBG	160.77 ± 34.06 vs 145. 37 ± 33.97	0.000	0.912	0.000
GCBG vs BGL	160.77 ± 34.06 vs 121.04 ± 35.37	0.000	0.796	0.000
GVBG vs BGL	145.37 ± 33.97 vs 121.04 ± 35.37	0.000	0.838	0.000

*P < 0.05 was considered significant. BGL, blood glucose laboratory; GCBG, glucometric capillary blood glucose; GVBG, glucometric venous blood glucose

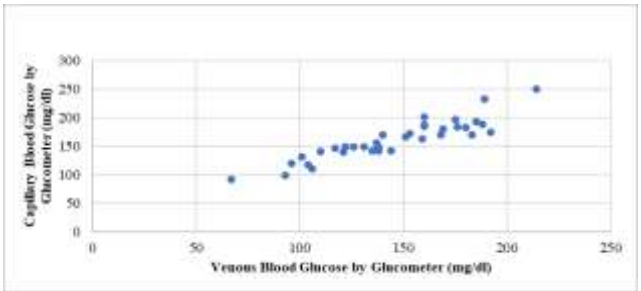

Figure-I: Correlation between capillary blood glucose and venous blood glucose by glucometer mg/dl (r = 0.912).

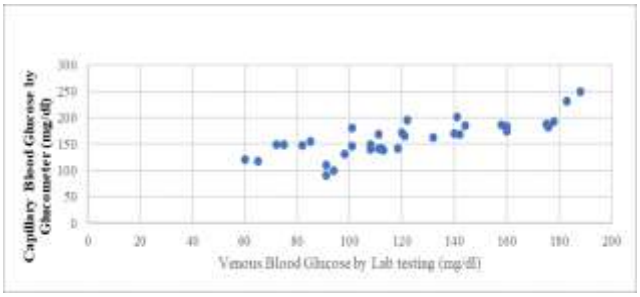

Figure-II: Correlation between capillary blood glucose and laboratory venous blood glucose mg/dl (r = 0.796).

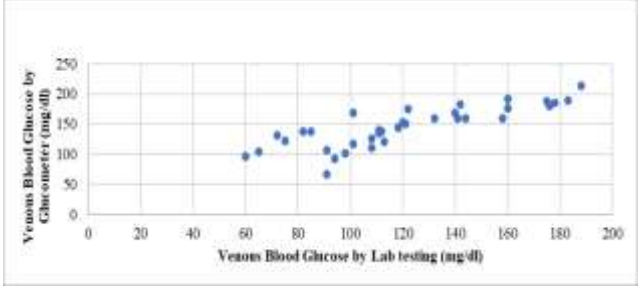

Figure-III: Correlation between venous blood glucose by glucometer and laboratory venous blood glucose mg/dl (r = 0.83).

DISCUSSION

Use of capillary blood glucose estimation using glucometer and treatment decisions on its basis is routine practice in critical care setting now-a-days. We estimated BGL with three different types of samples; CBG, VBG and venous plasma on automated analyser in the lab. The reason of conducting the current study was to compare these three types of samples and to correlate the results of glucometer with laboratory estimated values on clinical chemistry analyser. In comparison to the laboratory, we established that our glucometers yielded higher glucose levels in capillary and venous samples. These results are comparable to the observations stated by Boyd *et al* in 2005 and Critchell *et al* in 2007 [17]. According to the results obtained from our study, the mean of CBG, VBG and BGL on automated chemistry analyser had significant difference in both methods. In Boyd *et al*.'s study [18], samples of venous and capillary blood were taken from 20 patients in the emergency room and the glucose levels in both samples were checked by a glucometer and in the laboratory. Significant difference was obtained. Similar to our study, Patel *et al* showed that venous plasma glucose measured in laboratory is lower than mean capillary blood glucose analysed by glucometer. Adnan *et al* suggested that there was a significant inter method mean difference. This difference was not significant at normal glucose values but increases gradually with a rise in blood glucose levels and was significant at higher glucose levels. Our study results were in contrast to the study conducted by Lacara *et al* [19] which indicated no significant difference between glucose values of laboratory and point of care testing (POCT) glucometer values. Mean laboratory glucose level was 135 (SEM 5.3, range 58–265) mg/dL. In point-of-care testing, bias ± precision and root-mean-square differences were 2.1 ± 12.3 and 12.35, respectively, for fingerstick blood and 0.6 ± 10.6 and 10.46 for catheter blood. In a study conducted by Sharma *et al* [20], strong correlation (r=0.93) was observed between capillary blood glucose measured by glucometer and venous blood glucose measured in laboratory in Neurosurgical patients. Yarghai *et al* [15] also showed that no significant difference was present in between venous blood glucose and capillary blood glucose measured by POC glucometer. We found a strong correlation between CBG and VBG (r=0.92) while in Yarghai *et al* also showed a similar strong correlation (r= 0.93). Our observed correlation between CBG and BGL on automated chemistry analyser was somewhat less strong (r=0.796), similar to Yarghai *et al* who found a correlation coefficient of 0.78. The strength of correlation between the VBG and BGL on automated chemistry analyzer (r=0.83) was quite similar to

that found by Yarghai *et al* (r= 0.81). Thus, if laboratory measured venous blood glucose was considered as the reference standard, the level of VBG and CBG greatly differ to it and so glucometer should be used very cautiously in critically ill patients with stress hyperglycemia. In another study on 97 healthy volunteers conducted by Funk *et al* [21] capillary and venous blood samples were taken simultaneously from individuals and the blood glucose level of the two samples was measured by a glucometer. A weak correlation was obtained between the levels of venous and capillary blood glucose. Petersen *et al* [22] compared venous, arterial and capillary blood glucose levels using blood gas instrument, glucometer and main clinical laboratory instruments and suggested that all methods (blood gas, POCT, and central laboratory) were highly correlated to each other and to the reference method except for glucose meter testing using capillary sampling which had significantly weaker correlations similar to our study. In a study conducted by Dubose *et al* [23], capillary and venous blood glucose levels of patients with and without shock were correlated, and a slight difference was observed between both groups. In 2010, Fekih Hassen [24] studied 43 hyperglycemic patients older than 18 years admitted to the intensive care unit. There was difference of venous and capillary blood glucose levels in these patients and capillary sampling was not recommended to determine blood glucose level. The major difference between our study and some of the previous studies could be attributed to the difference in clinical setting and the types of population studies. For example, in the study by Yarghai *et al*, blood glucose level of poisoned patients in coma was measured by these methods while in Funk *et al*, only healthy population was studied. In Matthew *et al* and Adnan *et al* [25], only patients with diabetes were studied. The subjects selected in the study by Patel *et al* [26] were all adults, who came for checkup in Out Patient Department (OPD) of a tertiary care level hospital. Furthermore, we observed that 48% of the patients having stress hyperglycemia had cardiovascular disease. As hyperglycemia is a risk factor for adverse outcomes during acute illness and is related to increased mortality and morbidity [27], this warrants stringent glucose level monitoring in critically ill patients by a suitable methodology.

According to the results obtained in our study, level of blood glucose measured by glucometer is significantly different from blood glucose measured by laboratory. So in critical settings, there is a substantial difference in blood glucose values by laboratory and from venous blood glucose determined by glucometer. So, venous blood glucose estimation by glucometer is not recommended for use in such settings.

CONCLUSION

Glucometer estimations in critically ill patients can differ significantly from venous blood specimen measured on automated chemistry analyser in the laboratory. Measuring the glucose level in venous blood sample by laboratory is an acceptable and recommended method. Glucose measurement in capillary blood sample using glucometer should be done cautiously in critically ill patients with periodic venous blood testing.

LIMITATIONS OF THE STUDY

Sample size of this study was very small. Only 35 subjects were included in our study, so a larger study is essential for validation of the conclusion drawn in this study.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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Declared none

AUTHORS CONTRIBUTION

Azooba Fatima: Manuscript writing, literature search, study design, data analysis

Ayesha Hafeez: Conception of work, draft, final approval

Aamir Ijaz: Conception of work, data analysis, drafting

Mehreen Hassan: Data collection

REFERENCES

1. Scheen M, Giraud R, Bendjelid K. Stress hyperglycemia, cardiac glucotoxicity, and critically ill patient outcomes current clinical and pathophysiological evidence. Physiol Rep. 2021; 9(2): e14713. DOI: https://doi.org/10.14814/phy2.14713
2. American Diabetes Association. Classification and diagnosis of diabetes: standards of medical care in diabetes 2019. Diabet Care 2019; 42: S13–S28.
3. Li L, Zhao M, Zhang Z, Zhou L, Zhang Z, Xiong Y. *et al*. Prognostic significance of the stress hyperglycemia ratio in critically ill patients. Cardiovasc Diabetol. 2023; 22: 275. DOI: https://doi.org/10.1186%2Fs12933-023-02005-0
4. Alhatemi G, Aldiwani H, Alhatemi R, Hussein M, Mahdai S, Seyoum B. Glycemic control in the critically ill: Less is more. Cleve Clin J Med. 2022; 89(4):191-9. DOI: https://doi.org/10.3949/ccjm.89a.20171
5. Angelousi A, Margioris AN, Tsatsanis C. ACTH action on the adrenals. In: Feingold KR, Anawalt B, Boyce A, Chrousos G, de Herder WW, Dungan K, editors. Endotext [Internet]. MDText.com, Inc.; South Dartmouth (MA): Jun 13, 2020.
6. Thau L, Gandhi J, Sharma S. Physiology, Cortisol. [Updated 2023 Aug 28]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538239
7. Vedantam D, Poman D S, Motwani L, Asif N, Patel A, Anne KK*, et al*. Stress-induced hyperglycemia: Consequences and management. Cureus 2022. 14(7): e26714. DOI: https://doi.org/10.3949/ccjm.89a.20171
8. Khalfallah M, Abdelmageed R, Elgendy E, Hafez YM. Incidence, predictors and outcomes of stress hyperglycemia in patients with ST elevation myocardial infarction undergoing primary percutaneous coronary intervention. Diab Vasc Dis Res. 2020; 17(1): 1479164119883983. DOI: https://doi.org/10.1177/1479164119883983
9. Costea RM, Maniu I, Dobrota L, Neamtu B. Stress hyperglycemia as predictive factor of recurrence in children with febrile seizures. Brain Sci. 2020; 10(3): 131. DOI: https://doi.org/10.3390/brainsci10030131
10. Satti SA, Khattak AL, Tariq AM, Majoka SM, Naeem A, Din RU. The frequency of stress hyperglycemia and mortality in patients with hyperglycemia in medical intensive care unit. Pak Armed Forces Med J. 2021; 71(3): 753–56. DOI: https://doi.org/10.51253/pafmj.v71i3.3298
11. Yang C, Chang C, Lin J. A comparison between venous and finger-prick blood sampling on values of blood glucose. Int Proceedings Chemical, Biologic Environment Engineering. 2012; 39: 206-10.
12. Sirohi R, Singh RP, Chauhan K. A comparative study of venous and capillary blood glucose in a tertiary care hospital. Indian J Pub Health Res Development. 2020; 11(7): 673-7.
13. Sharma K, Mogensen KM, Robinson MK. Pathophysiology of critical illness and role of nutrition. Nutr Clin Pract. 2019; 34(1): 12-22. DOI: https://doi.org/10.1002/ncp.10232
14. Finfer S, Wernerman J, Preiser JC, Cass T, Desaive T, Hovorka R, et al. Clinical review: Consensus recommendations on measurement of blood glucose and reporting glycemic control in critically ill adults. Crit Care. 2013; 17: 229. DOI: https://doi.org/10.1186/cc12537
15. Hulley SB, Cummings SR, Browner WS, Grady D, Newman TB. Designing clinical research: an epidemiologic approach. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013. Appendix 6C, page 79.
16. Yaraghi A, Mood NE, Dolatabadiali LK. Comparison of capillary and venous blood glucose levels using glucometer and laboratory blood glucose level in poisoned patients being in coma. Adv Biomed Res. 2015; 4: 247. DOI: https://doi.org/10.4103/2277-9175.170242
17. Critchell CD, Savarese V, Callahan A, Aboud C, Jabbour S, Marik P. Accuracy of bedside capillary blood glucose measurements in critically ill patients. Intensive Care Med. 2007; 33(12): 2079-84. DOI: https://doi.org/10.1007/s00134-007-0835-4
18. Boyd R, Leigh B, Stuart P. Capillary versus venous bedside blood glucose estimation. Emerg Med. 2005;22:177–9. DOI: https://doi.org/10.1136/emj.2003.011619
19. Lacara T, Domagtoy C, Lickliter D, Quattrocchi K, Snipes L, Kuszaj J, *et al*. Comparison of point-of-care and laboratory glucose analysis in critically ill patients. Am J Crit Care. 2007; 16(4): 336-46.
20. Jyoti S, Renu B Singh, Seema. Correlation of venous blood sugar measured by lab method and capillary blood sugar measured by glucometer in neurosurgical patients receiving dexamethasone. Asian J Neurosurg. 2023; 19 (1); 21-25. DOI: https://doi.org/10.1055/s-0043-1775569
21. Funk DL, Chan L, Lutz N, Verdile VP. Comparison of capillary and venous glucose measurements in healthy volunteers. Prehosp Emerg Care. 2001; 5: 275–7. DOI: https://doi.org/10.1080/10903120190939788
22. Petersen JR, Graves DF, Tacker DH, Okorodudu AO, Mohammad AA, Cardenas VJ Jr. Comparison of POCT and central laboratory blood glucose results using arterial, capillary, and venous samples from MICU patients on a tight glycemic protocol. Clin Chim Acta. 2008; 396:10-3. DOI: https://doi.org/10.1016/j.cca.2008.06.010
23. Du Bose JJ, Inaba K, Branco BC, Barmparas G, Lam L, Teixeira PG, *et al*. Discrepancies between capillary glucose measurements and traditional

laboratory assessments in both shock and nonshock states after trauma. J Surg Res. 2012; 178: 820–6. DOI: https://doi.org/10.1016/j.jss.2012.04.003

24. FekihHassen M, Ayed S, Gharbi R, Ben Sik Ali H, S. Marghli S, Elatrous S. Bedside capillary blood glucose measurements in critically ill patients: Influence of catecholamine therapy. Diabetes Res Clin Pract. 2010; 87: 87–91. DOI: https://doi.org/10.1016/j.diabres.2009.09.018
25. Adnan M, Imamb F, Shabbira I, Alia Z, Rahata T. Correlation between capillary and venous blood glucose levels in diabetic patients. Asian Biomed. 2015 Mar 23;9(1):55-9. DOI: https://doi.org/10.5372/1905-7415.0901.368
26. Patel N, Patel K. A comparative study of venous and capillary blood glucose levels by different methods. GCSMC J Med Sci. 2015;4(1):53-6.
27. Bar-Or D, Rael L T, Madayag RM, Banton K.L, Tanner A, Acuna DL, *et al*. Stress Hyperglycemia in Critically Ill Patients: Insight Into Possible Molecular Pathways. Front Med 2019; 6: 54. DOI: https://doi.org/10.3389/fmed.2019.00054