Original article

# Comparison between arterial and capillary blood glucose monitoring in patients with shock

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## ABSTRACT

*Background:* The accuracy of bedside glucometry using capillary blood is contentious in patients admitted to intensive care units. We aimed to compare the accuracy of capillary bedside glucometry with arterial samples in critically ill patients with shock through a prospective case–control study.
*Methods:* Study group consisted of 100 patients with shock on vasopressor support and control group had 100 normotensive patients. Arterial and capillary samples were taken simultaneously and were tested immediately at the bedside. Results of the paired measurements were analyzed as a scatter plot by Bland and Altman method and were expressed as a correlation coefficient. Values were considered to disagree significantly when the difference exceeded 20%.
*Results:* Mean arterial and capillary sugars (mg/dl) in study and control groups were $164.7 \pm 70$ and $157.4 \pm 68.9$, and $167.1 \pm 62.2$ and $167.5 \pm 61$, respectively. On Bland–Altman analysis, 6% in study group and 5% in control group were out of range (acceptable limit <5%). Correlation between capillary and arterial values was less in the study group ($r = 0.917$, $p < 0.001$ vs $r = 0.979$, $p < 0.001$). In addition, the disagreement between capillary and arterial values was more than 20% in 18% of the patients in the study group vs 3% in control group ($p = 0.015$) (ISO standard <5%).
*Conclusions:* Capillary blood glucose monitoring is reliable only in a selected group of ICU patients. Hence, caution must be exercised especially in patients with shock in whom arterial blood may be preferred.

## 1. Introduction

Blood glucose monitoring is a vital component in management of a critically ill patient. These patients are prone to wide fluctuations in blood glucose levels making it mandatory to monitor blood glucose levels at frequent intervals. Blood glucose measurement can be accomplished by sending a venous or arterial sample to laboratory or by blood gas analyzer. The drawback of this method is the higher cost, longer time required to obtain the results and problem of iatrogenic blood loss and resultant anemia. Alternatively, blood glucose can also be estimated at the bedside with handheld glucometers applying the principal of reflectance glucometry. Although bedside glucometry using capillary blood is a well established method for ambulatory and hospital ward patients, the accuracy of this method is contentious in the critically ill patients admitted to intensive care units (ICU) with several studies reporting arterial samples to be more reliable than the capillary ones [1–3]. However, these studies had mixed ICU patients, not differentiating patients with shock on vasopressor support. Patients with shock, on

vasopressor support have peripheral hypoperfusion due to low perfusion index. Peripheral vasoconstriction can lead to increased glucose extraction by the tissues because of low capillary flow and increased glucose transit time. Hence, estimation of blood glucose from capillary blood may be unreliable in patients with septic shock. This may not apply to other critically ill patients who are not in shock. Therefore, clubbing of these patients with those with septic shock may not be appropriate when assessing the efficacy of capillary blood in monitoring blood glucose levels. Therefore, we undertook this study to compare the accuracy of arterial and capillary bedside glucometry among critically ill patients in shock.

## 2. Methods

We conducted a prospective case–control study, in a 16 bed medical and neurology ICU of a tertiary care hospital. A total of 200 patients were enrolled over an eight month period. Study group consisted of 100 consecutive patients with shock on vasopressor support. Patients in shock were defined as those requiring equal to or more than 0.1 µg/kg/min of noradrenaline to maintain the target mean arterial pressure of more than 70 mm Hg. As noradrenaline is the predominant vasopressor used in our ICUs, it was used in all these patients with shock. The control group had 100 consecutive patients who were not on any vasopressor support. Patients with

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severe limb edema and those with severe acidosis (pH<7.1) were excluded from the study. In addition, patients on more than one vasopressor and those not consenting for the study were also excluded.

### 2.1. Measurements

Two samples (one arterial and other capillary) were tested simultaneously (within 2 min) from each patient. Samples were obtained within 24 h of ICU admission. Capillary blood samples were obtained by finger prick after proper sterilization. Blood glucose was tested by reflectance glucometry at the bedside using the One Touch Ultra Blood Glucose Monitoring System (LifeScan, Johnson & Johnson). To insure independence between all glucose measurements, only one sample pair was obtained from each patient and no cross-over between the two groups was allowed.

Apart from the patient demographics, data were also collected regarding the diabetes status, and insulin requirement. Severity of disease was assessed according to acute physiology and chronic health evaluation (APACHE) II score.

Study was duly approved by the Institute's Ethical Committee and informed consent was taken from the patient or relatives, as appropriate.

#### 2.1.1. Statistical analysis

We used SPSS version 14.0 (SPSS Inc, Chicago, Ill) for the statistical analysis. The means of continuous variables was compared using Students $t$-test and the categorical variables were compared using chi-square test or Fishers exact test as appropriate. Statistical significance was set at a two-sided p value of less than 0.05. A Pearson correlation coefficient (r) was used to evaluate the relationship between the mean arterial and capillary glucose measurement. Agreement between the two samples was determined using the method of Bland and Altman [4]. We used the method of Bland and Altman [4] to plot the average of each arterial and capillary glucose pair against the arterial–capillary glucose difference. The horizontal line labeled "Mean" indicates the mean of the arterial and capillary glucose differences; this is known as the line of agreement. It is bounded by two parallel lines, known as the limits of agreement, which are drawn at 2 SDs above and below the line of agreement. In addition, the accuracy of arterial and capillary samples was evaluated according to the International Organization for Standardization (ISO; less than 15 mg/dl difference for glucose values less than 75 mg/dl and less than 20% difference for glucose values more than 75 mg/dl).

### 3. Results

Data from 100 patients in each group were analyzed. The patient characteristics are compared in Table 1. Patients in both groups were comparable with respect to age, sex ratio, diabetes status and need for insulin infusion. Understandably, patients in study group were sicker as assessed by APACHE II score. Most of the patients in the study group

**Table 1**
Comparison between the study and control groups.

| Parameter of interest | Study group (n = 100) | Control group (n = 100) | P value |
|---|---|---|---|
| Mean age, years | 63 ± 17.5 | 63.9 ± 16.9 | 0.718 |
| Sex, males | 64 | 60 | 0.662 |
| Diabetics | 35 | 38 | 0.659 |
| Patients on insulin infusion | 31 | 30 | 0.878 |
| Mean APACHE II score | 26.1 ± 9.3 | 18.6 ± 6.4 | 0.000[a] |
| Mean arterial sugar, mg/dl | 164.7 ± 70 | 167.1 ± 62.2 | 0.803 |
| Mean capillary sugar, mg/dl | 157.4 ± 68.9 | 167.5 ± 61 | 0.276 |
| Mean arterial capillary difference, mg/dl | 7.28 ± 28.2 | −0.43 ± 12.8 | 0.014[a] |

[a] Statistically significant.

(96%) were admitted to ICU for management of shock, but the majority (42%) of patients in the control group were admitted in ICU for respiratory failure followed by 32% with altered sensorium (low Glasgow coma score), 22% with sepsis, 2% with seizures and 2% with cardiac arrhythmias. As the study was conducted in medical and neurology ICUs, most of our patients with shock had septic shock (89%) and only a few patients had hypovolumic (9%) and cardiogenic shock (2%).

For the study group, the Bland–Altman analysis (Fig. 1) showed a mean absolute difference, between arterial and capillary samples, of 7.28 mg/dl, with limits of agreement of 63.7 (mean + 2 SD) and −49.1 mg/dl (mean − 2 SD). Based on the Bland–Altman analysis, 6/100 (6%) data points were outside the limits of agreement (acceptable limit<5%). On the other hand, for the control group, the Bland–Altman analysis (Fig. 2) showed a mean absolute difference, between arterial and capillary samples, of −0.43 mg/dl, with limits of agreement of 25.2 (mean + 2 SD) and −26.1 mg/dl (mean − 2 SD). Based on the Bland–Altman analysis, 5/100 (5%) data points were outside the limits of agreement (acceptable limit<5%).

There was a significant correlation between the arterial and capillary measurements in both the groups but correlation was stronger in the control group, r = 0.917, p<0.001 for study group vs r = 0.979, p<0.001 for the control (Figs. 3 and 4). According to the ISO criteria, 18/100 (18%) of our values were inaccurate in the study group as compared to only 3/100 (3%) in the control group (p = 0.001), ISO standard less than 5% disagreement.

### 4. Discussion

Even though methods of varying accuracy exist for obtaining blood glucose, measurement of blood glucose using arterial samples is recommended in adult critically ill patients [5]. Through this case–control study we could show that there was a good correlation between arterial and capillary glucose measurements in all critically ill patients, but the accuracy of capillary samples did not conform to the ISO standards in the patients with shock on vasopressor support. On the other hand, in patients without shock, capillary glucose measurement was accurate and conformed to the ISO standards. This is particularly important as it emphasizes the fact that capillary measurements can be reliably applied in this subgroup of critically ill patients. The implications of these findings for titration of insulin therapy are obvious. As the turnaround time for glucose determination by the laboratory testing is too long for fast adjustment of the rate of insulin infusion as required in a glucose regulation protocol, bedside capillary glucometry can be recommended in critically ill
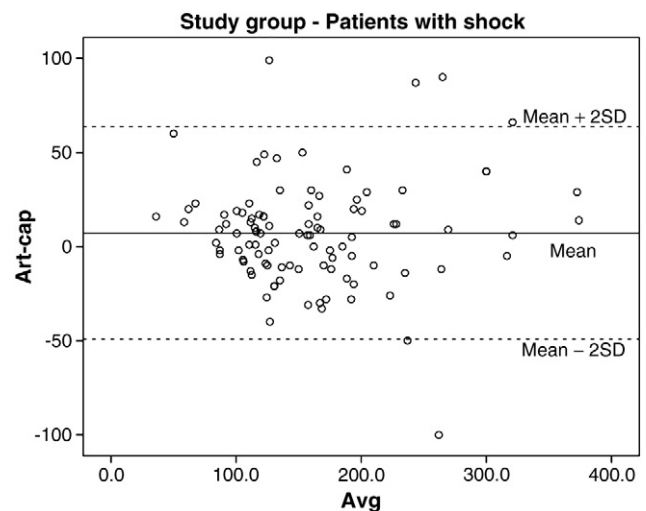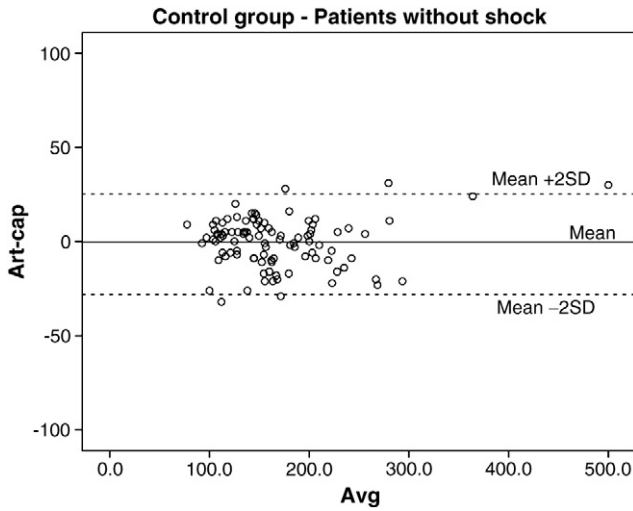

**Fig. 1.** Bland–Altman analysis for the study group.

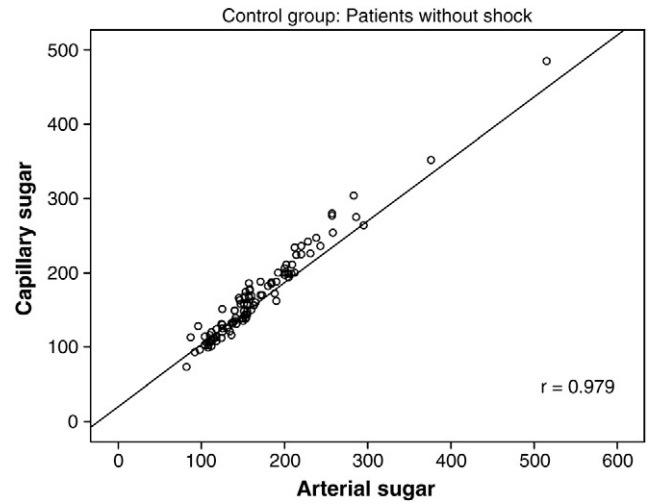**Fig. 2.** Bland–Altman analysis for the control group.



**Fig. 4.** Linear regression analysis for control group.

patients not in shock. This can aid in avoiding inappropriate adjustments to insulin therapy and episodes of undetected hypoglycaemia.

Use of vasopressors has been shown to be an independent factor determining inaccuracy of capillary glucose estimation [1]. Our results are in accordance with other studies which have shown that capillary glucose monitoring may not be accurate in patients with shock [6,7]. Despite several studies showing increased discordance in patients with shock, no study, to the best of our knowledge, has compared arterial and capillary glucose measurements in patients with shock in a case–control manner [1,6,7]. Erroneous measurement of glucose levels in shock patients may be attributed to various factors including reduced glucose extraction due to local cell death, low capillary flow and increased glucose transit time [8,9], which may not be present in other critically ill patients.

The difference between the two groups according to Bland–Altman analysis, was not very marked, 6% outliers in the study group vs 5% in the control group. This could be explained by the fact that in the patients with shock, the group variation was much higher, as compared to the control group (Figs. 1 and 2), leading to a much wider limits of agreement. Hence, most of the values were between these limits, even though there was a marked difference between the arterial and capillary values. To overcome this shortcoming, other standards like ISO were used which could highlight the differences between arterial and capillary values in the study group.
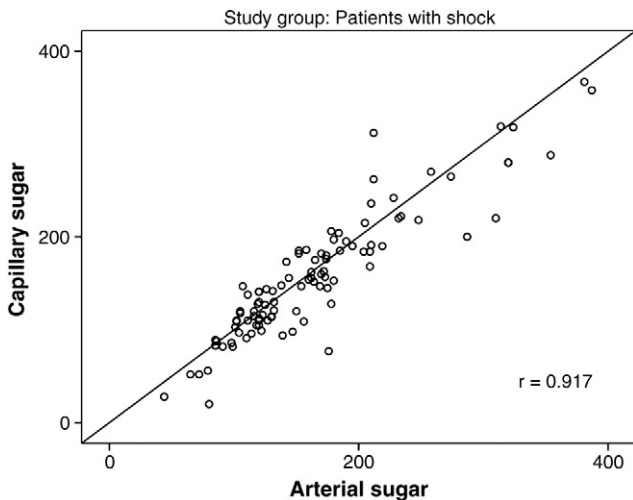
Previously it has been shown that the bedside capillary glucose monitoring may not be accurate in critically ill patients and may not conform to the Clinical and Laboratory Standards Institute (CLSI) standards of correlation of more than 0.9751 [1]. Critchell and colleagues observed that the correlation between the capillary and laboratory samples was 0.911 in critically ill patients as compared to the CLSI standard of 0.9751. But they had included patients with limb edema and patients with shock in their study cohort which may have affected their results. We excluded patients with limb edema and severe acidosis from the study as these two factors have been shown to affect glucose measurement [1,10]. In our study, we observed a correlation of 0.917 in the patients with shock as compared to a correlation of 0.979 in the patients without shock, which conforms to the CLSI standards.

Capillary glucometry in normotensive critically ill patients showed good correlation and high level of agreement (according to Bland–Altman analysis) with arterial samples and conformed to CLSI and ISO standards. It is easy to apply, cost-effective, with no lag time and without any iatrogenic blood loss. Hence, it can be reliably used in this subgroup of critically ill patients.

Our study is limited by the fact that very few of our patients were in the hypoglycemic range (glucose<40 mg/dl). This could be attributed to the fact that all the measurements were done in ICU patients with frequent glucose monitoring hence, the incidence of hypoglycaemia was understandably less, especially in the non-septic group. In addition, the affect of dose and duration of vasopressor support could not be ascertained.

## 5. Conclusions

Capillary blood glucose monitoring is reliable only in a selected group of ICU patients. Hence, caution must be exercised especially in patients with shock in whom arterial blood may be preferred.

**Learning points**

- Capillary blood glucose monitoring can be applied reliably only in a selected group of ICU patients.
- In patients with shock on vasopressor support arterial blood may be preferred for glucose monitoring.

**Conflict of interest statement**

None.



**Fig. 3.** Linear regression analysis for the study group.

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