Original Article

# Comparison of blood electrolytes and glucose during cardiopulmonary bypass in diabetic and non-diabetic patients

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**Background:** Cardiopulmonary bypass (CPB) during coronary artery bypass grafting is thought to contribute significantly to increased blood glucose level and altered blood electrolytes balance during the operation. In this (CABG) study, blood electrolytes and glucose during CPB in insulin-dependent diabetic and non-diabetic patients were assessed with special emphasis on the trend of the changes. **Materials and Methods:** Blood glucose and electrolytes were assessed in 30 insulin-dependent diabetic and 30 non-diabetic patients, classified as class II and III American Society of Anesthesiologist, before, during, and after CPB. Repeated-measures analysis of variance (ANOVA) was used to compare the trend of the changes during CPB for the two groups. **Results:** The trend in blood glucose level did not show any significant difference between two groups ($P = 0.59$). For other blood factors, no significant between-group difference was detected except for $PaCO_2$ ($P = 0.002$). **Conclusion:** The study suggested that the changes in blood electrolytes and the increase in blood glucose level do not differ between insulin dependent diabetic and non-diabetic patients.

**Key words:** Coronary artery bypass surgery, cardiopulmonary bypass, cardiopulmonary, hyperglycemia

## INTRODUCTION

Hyperglycemia, whether chronic, intra-operative or post-operative, have always been described to be associated with adverse outcomes such as osmotic diuresis and resultant electrolyte disorders, focal, and global neurologic ischemia, cardiac damages and, if severe, coma.[1-3] Surgical traumas contribute significantly to an increased blood glucose level during the operation, among which cardiopulmonary bypass (CPB) during coronary artery bypass grafting (CABG) is indicated to be a major cause of perioperative hyperglycemia.[4] The situation, called 'surgical diabetes', occurs in both diabetic and non-diabetic patients as a result of endogenous catecholamine release, leading to a higher rate of morbidity and mortality in both groups.[5,6]

Blood electrolytes, such as sodium, potassium, calcium, and chloride have a great role in regulating cellular membrane potential, and as a result, in metabolism and energy transfer. This role is more apparent in muscular and nervous system, emerging as neuromuscular disorders and arrhythmia when a deficit occurs.[7,8] Hypokalemia itself can induce hyperglycemia.[9] Cardiovascular depression, as a result of hypocalcemia, may arise without any significant changes in electrocardiogram (EKG).[10] Besides, a cumulative effect is supposed for more than one electrolyte deficit. This effect is especially important in patients undergoing cardiac surgery with prior cardiovascular disorders.[11] As a result, blood electrolyte changes must be considered during any surgeries and this seems to be more important in diabetic patients.

Many approaches have been suggested to reduce the risk of blood glucose changes along with blood electrolytes alteration.[12] The underlying pathophysiology of stress-induced hyperglycemia is well defined,[7] however, according to our knowledge not any previous study has accounted for all blood electrolytes being affected during CPB together. Since changes in blood glucose and electrolyte balance may induce some morbidity in patients under CPB, we aimed to compare blood electrolytes and glucose during CPB in diabetic and non-diabetic patients with special emphasis on the trend of the changes.

## MATERIALS AND METHODS

Hospital's ethic committee approved the study protocol and informed written consent was obtained from the participants, insisting on no extra charge for the patients. Two populations of 30 insulin-dependent diabetic and 30 non-diabetic patients scheduled for an elective CABG with CPB for the first time were decided as the study population. The subjects were selected among the

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class II and III American Society of Anesthesiologist (ASA) patients, being admitted to Shaheed Rajaei Cardiovascular Medical and Research Center, Tehran, Iran during October to December 2009 who aged 30 to 70 years old. Patients with uncontrolled underlying disease such as hepatic and renal disorders, weighting over 115 kg, and also type II diabetics (not insulin dependent) or those having an HbA1c over 7.5% were excluded.

It is suggested that sustain infusion of the daily dose of insulin in diabetic patients results in a better control of blood glucose during surgery,[13] as a result, patients received appropriate dose of regular insulin, according to the protocol, in a sustained infusion manner during 24 hours prior to the surgery. During the operation, if blood glucose of over 200 mg/dL was detected, a bolus of regular insulin was administered according to this protocol: 5 U/kg for blood glucose of 200-224; 10 U/kg for blood glucose of 225-249; 15 U/kg for blood glucose of 250-350 (reference for the protocol). These patients needing an extra dose of insulin infusion during operation were not included in the final analysis.

All the patients received same premedication the night before operation; 1 mg lorazepam was administered orally, once the night before the operation and once at the morning of the operation day. One hour before surgery, 0.1 mg/kg morphine was given. The anesthetic approach was also performed identically for all the patients. Anesthesia induction included 1 mg/kg midazolam, 0.5 μg/kg sufentanil, 1 - 2 mg/kg propofol, and 0.2 mg/kg cisatracurium along with 500 ml ringer solution. Anesthesia was maintained using 20 - 100 μg/kg/min propofol, 0.25 - 0.5 μg/kg/min midazolam, fentanyl 0.5 μg/kg/hour, and 2-4 μg/kg/min atracurium (reference).

Non-pulsatile CPB with a roller pump (Stöckert, Munich, Germany) was used. The extracorporeal system was primed with ringer lactate and voluven® and a membrane oxygenator (Jostra Quadrox, Maquet Cardiopulmonary AG, Hirrlingen, Germany) was used. No glucose containing solution was given before and during CPB. Heparin (3 mg/kg) intravascular was administered as anticoagulant, maintaining Activated Clotting Time (ACT) less than 480.

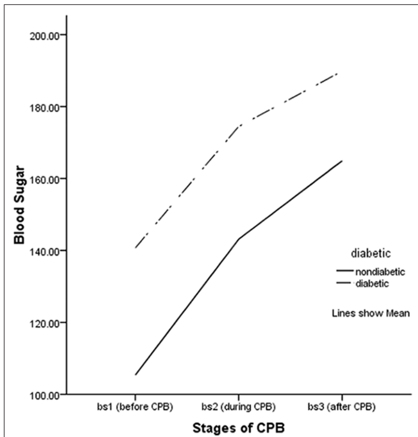
Left radial artery cannula was inserted to gather blood samples. Blood glucose, lactate, pH, $pCO_2$, bicarbonate ($HCO_3$), sodium (Na), potassium (K), chloride (Cl), and calcium (Ca) were measured at three time points: After the cannula being inserted and before the beginning of anesthesia induction; during CPB; and 5 to 10 minutes after termination of CPB. For a more accurate measurement at the second time point, three samples were collected during CPB (two before and during cold phase, and one after warm phase) and the mean value was considered as the second samples. Blood sample assessment was performed using blood gas analyzer (Technomedia, b03IE).

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software program for Windows, version 16.0 (SPSS Inc., Chicago, IL) and repeated-measures analysis of variance (ANOVA) was used to compare the changes occurring for different variables during CPB for the two groups. A $P < 0.05$ was considered as statistically significant.

## RESULTS

Thirty diabetic (15 men and 15 women) along with 30 non-diabetic (19 men and 11 women) patients were recruited in the study, showing no sex difference ($P = 0.297$). Diabetic patients aged 60.03 ± 5.67 while the mean age was 59.40 ± 9.29 in non-diabetic patients ($P = 0.751$). HbA1c, assessed for diabetic patients, showed a good diabetes control for all the patients, ranging from 5.2% to 7.3%.

Analyzed factors in blood samples are shown in Table 1. As is shown, blood glucose at the baseline and at the termination of CPB was significantly higher in diabetic group; however, the process of changes was not statistically significant [Figure 1]. Besides, although $PaCO_2$ did not differ at the baseline in the two groups, at the end of CPB a higher $PaCO_2$ was detected in non-diabetic group; repeated-measures ANOVA indicated a significant change during operation. The trend of changes for serum lactate, as an indicator of tissue perfusion, was the same in both groups ($P = 0.2$). The patients in the two groups also needed the same amount of Potassium during CPB ($P > 0.05$). For other blood factors, no significant between-group difference was detected.



CPB = Cardiopulmonary bypass; bs = Blood sugar (mg/dl)

**Figure 1:** Trend of changes in blood glucose in diabetic and non-diabetic patients

**Table 1: Blood electrolytes and glucose in diabetic and non-diabetic patients**

| Parameter | Diabetic (mean±SD) | | | Non-diabetic (mean±SD) | | | *P* value | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before CPB | During CPB | After CPB | Before CPB | During CPB | After CPB | Before CPB | After CPB | Repeated measures ANOVA |
| Glucose (mg/dl) | 140.73±49.32 | 174.50±37.20 | 189.84±55.36 | 105.37±16.80 | 143.15±29.02 | 164.93±37.32 | 0.001 | 0.04 | 0.59 |
| Lactate (meq/l) | 1.13±0.40 | 2.15±0.68 | 2.76±0.89 | 1.22±0.54 | 2.42±0.89 | 2.67±1.04 | 0.464 | 0.72 | 0.20 |
| $PaCO_2$ (mmHg) | 32.83±5.05 | 32.90±7.64 | 31.70±5.38 | 30.97±6.16 | 36.55±5.04 | 35.60±7.03 | 0.204 | 0.01 | 0.002 |
| $HCO_3$ (meq/l) | 22.03±1.81 | 20.45±2.05 | 19.40±2.47 | 21.23±3.23 | 20.48±2.43 | 19.63±2.27 | 0.242 | 0.70 | 0.32 |
| pH | 7.43±0.04 | 7.34±0.05 | 7.37±0.06 | 7.44±0.06 | 7.40±0.08 | 7.35±0.7 | 0.592 | 0.24 | 0.06 |
| Na (meq/l) | 140.97±5.19 | 134.63±4.06 | 138.03±3.65 | 141.53±4.06 | 134.80±3.68 | 138.27±4.56 | 0.639 | 0.82 | 0.90 |
| K (meq/l) | 3.35±0.35 | 4.64±0.81 | 4.10±0.65 | 3.42±0.34 | 5.16±0.77 | 4.29±0.68 | 0.392 | 0.28 | 0.54 |
| Cl (meq/l) | 106.27±4.73 | 109.20±4.10[a] | 108.80±4.08 | 105.63±5.21 | 111.13±13.0[a] | 107.40±5.82 | 0.624 | 0.28 | 0.16 |
| Ca (meq/l) | 1.75±0.30[a] | 2.12±0.31[a] | 1.92±0.50[a] | 1.61±0.30[a] | 2.22±0.38[a] | 1.86±0.45[a] | 0.065 | 0.62 | 0.16 |

[a]Mann-Whitney test, Na=Serum sodium; K=Potassium; Ca=Calcium; Cl=Chloride; $HCO_3$=Bicarbonate; $PaCO_2$=Arterial carbon dioxide pressure; CPB=Cardiopulmonary bypass; ANOVA=Analysis of variance

## DISCUSSION

According to our study, we found that although there was a significant increase in blood glucose during the operation for both diabetic and non-diabetic patients, however, the trend of changes was not different in the two groups. Besides, we did not observe any significant difference in the way other blood electrolytes changed. Changes in $PaCO_2$ was also significantly different between the two groups, however, it could not indicate any clinically significant importance.

This study aimed to investigate the changes in blood glucose levels during CPB in diabetic and non-diabetic patients. CPB is a major contributor in hyperglycemia during and after CABG.[4] This glucose tolerance is present regardless of the patients suffering from diabetes or not and is seen during the operation until weeks after.[14] Many factors are suggested to contribute to the disturbed glucose metabolism. Although insulin is infused during CPB to maintain blood glucose level, the counter regulatory hormones secreted, as a result of stress, lead to insulin resistance and hence a high blood glucose level.[15,16] Non-esterified fatty acids produced as a result of high level of heparin infusion during CPB, are suggested to have a role in hyperglycemia.[17] Another contributor is hyperthermia which is accompanied by altered insulin secretion and glucose consumption.[18]

Because of trauma-induced hyperglycemia, role of CPB in increased blood glucose during CABG is marginal[17] and the hyperglycemia will occur even in off-pump surgeries. However, as insulin secretion and glucose metabolism is disturbed in diabetic patients, we expected blood glucose to increase more rapidly to a higher level in diabetic group. Although, blood glucose level at the termination of CPB was at a higher range in diabetic patients, repeated-measure ANOVA showed a similar increasing trend in both groups [Figure 1]. This could be justified by supposing that a non-diabetic patient becomes as insulin resistant as a diabetic patient during high stress of a surgery.

Although it is indicated in other studies that electrolyte depletion occurs during CPB as a result of increased urinary excretion and intracellular shift,[19] we did not observe any significant electrolyte depletion. Polderman *et al*., also showed that induction of hypothermia leads to electrolyte loss which is more significant during rewarming phase.[20]

We observed an increase in $PaCO_2$ in non-diabetic patients which was not statistically significant ($P$ = 0.081). Within group changes was neither significant in diabetic group ($P$ = 0.289). However, the trend of changes in non-diabetic patients was significantly different from that of diabetic patients. Studies show an increase in $PaCO_2$ during CPB;[21,22] as a result this difference could be justified by our limited number of participants.

Different studies had been evaluated the role of glucose and electrolyte in patients with cardiac surgery,[23-26] however, according to our knowledge not any previous study has accounted for all blood electrolytes being affected during CPB together.

## CONCLUSION

The study suggested that the changes in blood electrolytes and the increase in blood glucose level do not differ between insulin-dependent diabetic and non-diabetic patients.

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