Effects of Temperature and Time Delay on Arterial Blood Gas and Electrolyte Measurements

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Objective: *To determine the changes in pH, PaO_2, $PaCO_2$ and Na, K, Cl in arterial blood samples stored at room temperature or on ice, at 0, 15, 30, 45 and 60 minutes.*
Material and Method: *Arterial blood samples were collected in heparinized capillary tubes and stored at room temperature (24-26°C) and on ice (0-4°C). ABG and electrolytes were measured at 0, 15, 30, 45 and 60 minute intervals.*
Results: *There were significant decreases in the pH, PaO_2, Na, Cl and significant increases in $PaCO_2$ and K over time in both groups. The changes were greater and faster at room temperature. The significant decrease in pH over time was not found until 30 minutes at room temperature and 45 minutes on ice. There were significant decreases in PaO_2, concurrent with significant increases in $PaCO_2$ from 15 minutes onwards in both groups. Both Na and K exhibited a significant change at 60 minutes in the room temperature group. Significant decreases of Cl over time were not found until 15 minutes at room temperature, and 30 minutes on ice.*
Conclusion: *For ABG and electrolytes analysis, the blood sample should be analyzed within 15 minutes and be stored at either room temperature or on ice.*

Keywords: *Arterial blood gas, pH, PaO_2, $PaCO_2$, Electrolytes*

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Arterial blood gas (ABG) and electrolytes analysis are essential to the laboratory examination in the diagnosis, assessment and management of critically ill patients, especially those who have respiratory problems. The blood samples should be analyzed immediately after sampling[1,2]. Various pre-analytical factors, including the processes involved with sampling and handling the specimen prior to the analysis can affect the measurement of blood gas parameters[3-6]. The effects of syringe material, sample storage time, and temperature on ABG have been shown in multiple studies with conflicting evidences[7-14]. There have been no studies regarding these effects on electrolytes.

The aim of the present study was to assess the changes of ABG (pH, PaO_2, $PaCO_2$) and electrolytes (Na, K, Cl) in arterial blood samples stored in glass capillary tubes at room temperature or on ice, evaluated at 0, 15, 30, 45 and 60 minutes. The most suitable temperature and time for the storage of the blood sample prior to the analysis were consequently determined.

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Material and Method

Arterial blood samples were obtained from arterial lines of pediatric patients, who were older than 1 year-old, in the pediatric intensive care unit (PICU) at Queen Sirikit National Institute of Child Health. Patients with unstable hemodynamic status, dyshemoglobinemia, severe leukocytosis and thrombocytosis were excluded. The blood samples were drawn into 9 heparinized glass capillary tubes which were sealed at both ends with rubber caps. One capillary tube was analyzed immediately. The remaining tubes, 4 in each group, were stored either on ice (0°C) or at room temperature (24-26°C). ABG (pH, PaO_2, $PaCO_2$) and electrolytes (Na, K, Cl) were then measured at 15,

30, 45 and 60 minutes after the initial sampling. All analyses were performed by the Automatic Blood Gas Analyzer (OMNI C; Roche, Switzerland).

The results were expressed as mean ± SD. Statistical analysis of the changes in parameters over time were assessed by repeated measured analysis of variance. Comparisons between both storage temperatures during the same time period were made using Student's t-test. A p-value of less than 0.001 was considered statistically significant. A sample size of 30 was calculated based on the formula:

$$n/group = (Z_{\alpha} + Z_{\beta})^2 \sigma_d^{\ 2} / \Delta^2$$

Results

A total of 30 blood samples were collected from 30 patients. The mean ± SD of ABG and electrolytes of both groups at 0, 15, 30, 45 and 60 minutes are shown in Table 1 and 2 respectively. There were significant changes in ABG and electrolytes over time within each group. The pH, PaO_2, Na and Cl significantly decreased

Table 1. ABG (pH, PaO_2, $PaCO_2$) at 0, 15, 30, 45 and 60 minutes*

ABG	Time (minutes)	Room temperature	p-value	On ice	p-value
pH	0	7.390 ± 0.049		7.390 ± 0.049	
	15	7.390 ± 0.050	1.000	7.390 ± 0.050	1.000
	30	7.387 ± 0.050	< 0.001	7.389 ± 0.050	0.011
	45	7.376 ± 0.050	< 0.001	7.377 ± 0.050	< 0.001
	60	7.364 ± 0.057	< 0.001	7.373 ± 0.049	< 0.001
PaO_2	0	127.93 ± 18.46		127.93 ± 18.46	
(mmHg)	15	119.60 ± 18.41	< 0.001	124.05 ± 18.55	< 0.001
	30	113.69 ± 18.28	< 0.001	120.74 ± 18.71	< 0.001
	45	107.67 ± 18.21	< 0.001	116.84 ± 18.87	< 0.001
	60	102.34 ± 17.71	< 0.001	114.65 ± 18.72	< 0.001
$PaCO_2$	0	41.50 ± 4.35		41.50 ± 4.35	
(mmHg)	15	41.91 ± 4.42	< 0.001	41.75 ± 4.38	< 0.001
	30	42.55 ± 4.44	< 0.001	42.14 ± 4.40	< 0.001
	45	44.46 ± 4.52	< 0.001	43.30 ± 4.40	< 0.001
	60	44.97 ± 4.51	< 0.001	43.84 ± 4.47	< 0.001

*Value are expressed as mean ± SD

Table 2. Electrolytes (Na, K, Cl) at 0, 15, 30, 45 and 60 minutes*

Electrolytes(mEq/L)	Time (minutes)	Room temperature	p-value	On ice	p-value
Na	0	138.52 ± 4.04		138.52 ± 4.04	
	15	138.32 ± 3.74	1.000	138.42 ± 3.90	1.000
	30	138.29 ± 3.76	1.000	138.34 ± 3.87	0.809
	45	138.10 ± 3.89	0.417	138.27 ± 3.85	0.057
	60	137.98 ± 3.81	< 0.001	138.06 ± 3.93	0.005
K	0	3.85 ± 0.31		3.85 ± 0.30	
	15	3.86 ± 0.31	1.000	3.84 ± 0.30	1.000
	30	3.86 ± 0.30	1.000	3.85 ± 0.29	1.000
	45	3.88 ± 0.30	0.053	3.88 ± 0.30	0.798
	60	3.90 ± 0.31	< 0.001	3.89 ± 0.30	0.195
Cl	0	105.09 ± 3.67		105.09 ± 3.64	
	15	104.68 ± 3.57	< 0.001	104.72 ± 3.59	0.002
	30	104.51 ± 3.62	< 0.001	104.52 ± 3.55	< 0.001
	45	104.46 ± 3.59	< 0.001	104.50 ± 3.59	< 0.001
	60	104.38 ± 3.75	< 0.001	104.42 ± 3.75	< 0.001

*Value are expressed as mean ± SD

while both the $PaCO_2$ and K significantly increased. The changes were higher and more rapid at room temperature (Table 3). However, the mean values of ABG and electrolytes were not significantly different between the two groups during the same time period.

The decreases in pH were statistically significant from 30 minutes onwards at room temperature and from 45 minutes onwards on ice (Fig. 1). There were significant decreases in PaO_2, concurrently with significant increases in $PaCO_2$ from 15 minutes onwards in both groups (Fig. 2 and 3).The decreases in Na and increases in K were statistically significant at 60 minutes in the room temperature group, but not in the iced group (Fig. 4 and 5). There were significant decreases in Cl from 15 minutes onwards at room temperature and from 30 minutes onwards on ice (Fig. 6).

Discussion

Considerable changes of ABG can occur when the analysis is delayed, as the metabolism of blood cells, both aerobic and anaerobic, continues in stored

Table 3. Rate of changes (per hour) in ABG and electrolytes

	pH (unit/hour)	PaO_2 (mmHg/hour)	PCO_2 (mmHg/hour)	Na (mEg/L/hour)	K (mEg/L/hour)	Cl (mEg/L/hour)
Room temperature	0.026	25.60	3.47	0.54	0.05	0.70
On ice	0.017	13.27	2.34	0.46	0.04	0.66

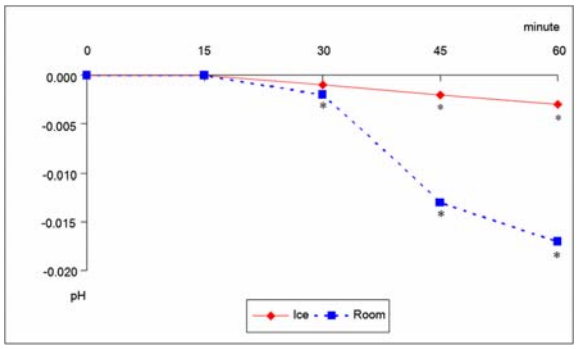

Fig. 1 Changes in pH of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

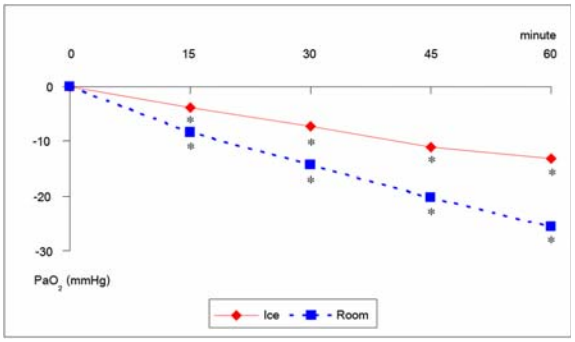

Fig. 2 Changes in PaO_2 of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

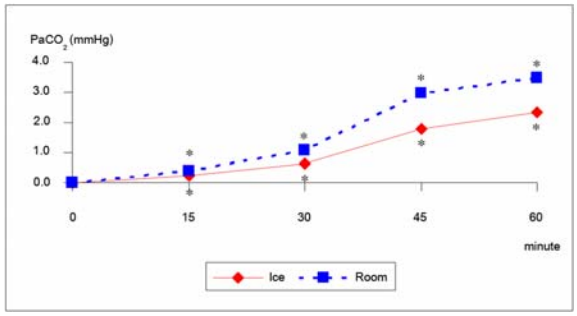

Fig. 3 Changes in $PaCO_2$ of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

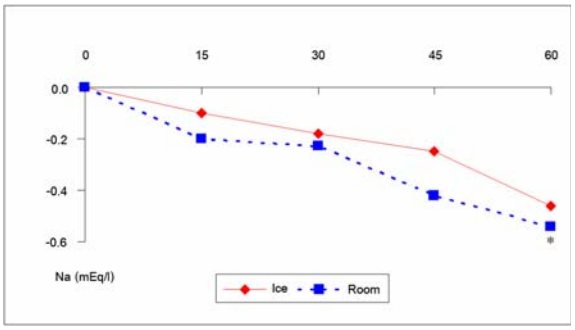

Fig. 4 Changes in Na of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

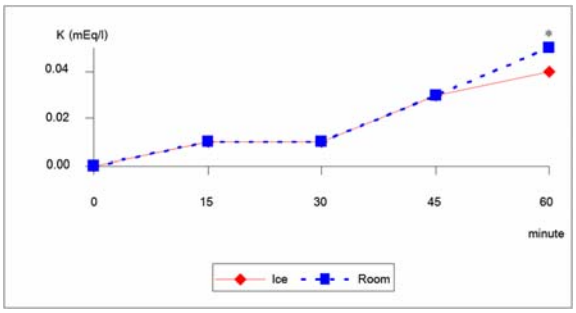

Fig. 5 Changes in K of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

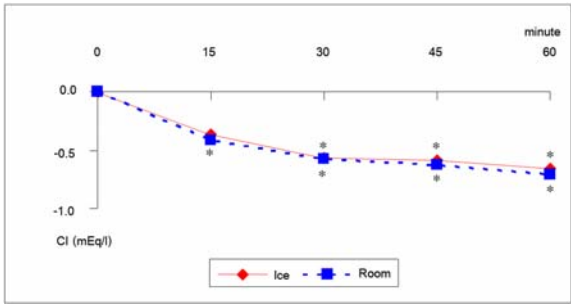

Fig. 6 Changes in Cl of blood samples stored at room temperature and on ice
*Indicates a statistically significant change from baseline ($p < 0.001$)

blood[5-7]. Leukocytes and platelets are mainly responsible for the oxygen consumption, whilst mature red blood cells contribute little due to 90 percent of their metabolism being anaerobic[15-17]. The CO_2 production from both aerobic and anaerobic metabolism leads to an increase in PCO_2 and a decrease in pH. In addition, lactate generated via anaerobic pathway may contribute to a decrease in pH. The expected changes are the decreases in PO_2 and pH and the increase in PCO_2[7,8]. To minimize these changes, it has been suggested that arterial blood should be placed on ice prior to the analysis[3-6,8,10,13]. The American Association for Respiratory Care Clinical Practice Guideline stated that the specimen should be analyzed within 10-15 minutes of drawing if held at room temperature or within 1 hour for the iced sample[1]. The Clinical and Laboratory Standards Institute (formerly the National Committee for Clinical Laboratory Standards) recommends that samples taken in plastic syringes should not be iced, but instead kept at room temperature and analyzed within 30 minutes. If the analysis is delayed more than 30 minutes, glass syringes and coolant immersion are recommended[19].

The present study demonstrates corresponding results to many previous studies that the changes were greater and faster in samples stored at room temperature than on ice[3-5,8-10,12,18]. Biswas et al reported that PO_2 decreased significantly by 20 minutes at 4°C (refrigerator) and 22°C (room temperature), but not until 60 minutes at 0°C (crushed ice). In addition, there was no significant change in pH and PCO_2 for up to 30 minutes at 4°C and 22°C and up to 60 minutes at 0°C[3]. Nanji et al found that the changes in pH, PO_2 and pCO_2 were greater in samples kept at room temperature, with a significant difference from 20 min onwards[10]. Pretto et al have shown that PO_2 declined at an average rate of 0.33 mmHg/minute (19.8 mmHg/hour) on ice and 1.37 mmHg/minute (82.2 mmHg/hour) at 22°C. The changes in PCO_2 were less dramatic than those of PO_2 with the average increment of 0.71 kPa (5.3 mmHg) over 2 hours[12]. In contrast, Dent et al found an average increment in PCO_2 of 0.17 kPa/hour (1.27 mmHg/hour) at room temperature and 0.09 kPa/hour (0.67 mmHg/hour) on ice, without any significant change of PO2[9].

In the present study, a glass capillary tube was used during storage of blood owing to the small amount of blood required and the advantages of using glass[4,5,9,12,14]. The PO_2 significantly decreased at the rate of 25.60 and 13.27 mmHg/hour at room temperature and on ice, respectively. The rates of PCO_2 change were 3.47 mmHg/hour in room temperature group and 2.34 mmHg/hour in the iced group. The pH changed at the rate of 0.017 unit/hour at room temperature and 0.003 unit/hour on ice.

Nevertheless, there was no significant difference between the mean values of ABG in both temperature groups at the same time. The earliest significant differences were the PO_2 and PCO_2 changes at 15 minutes.

Furthermore, the changes in electrolytes (Na, K and Cl) were also greater at room temperature. There were significant changes of Na and K at 60 minutes in the room temperature group, but not in the iced group. The change in K probably resulted from the pH change. Significant decreases of Cl were found from 15 minutes onwards at room temperature and from 30 minutes onwards on ice.

Conclusion

There are statistically significant changes in ABG and electrolytes over time whenever the analysis is delayed. The changes are greater and occur faster at room temperature than on ice. For accurate ABG and

electrolytes measurements, the blood sample should be analyzed within 15 minutes and stored at either room temperature or on ice.

Potential conflicts of interest

None.

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ผลกระทบของอุณหภูมิและเวลาต่อการตรวจวิเคราะห์ค่าก๊าซและสารเกลือแร่ในเลือดแดง

พนิดา ศรีสันต์, ธีรศักดิ์ อุดมศรี, ประวิทย์ เจตนชัย, สรศักดิ์ โล่ห์จินดารัตน์, วิบูลย์ กาญจนพัฒนกุล

วัตถุประสงค์: *เพื่อศึกษาการเปลี่ยนแปลงของค่าก๊าซในเลือดแดง (pH, PaO_2, $PaCO_2$) และสารเกลือแร่ (Na, K, Cl) ในเลือดที่เก็บไว้ในอุณหภูมิห้องและแช่น้ำแข็ง ณ เวลาต่างๆ (15, 30, 45 และ 60 นาที) เปรียบเทียบกับค่าที่ได้จากการตรวจทันที*

วัสดุและวิธีการ: *นำเลือดแดงของผู้ป่วยมาใส่ Heparinized capillary tubes แล้วนำไปเก็บไว้ที่อุณหภูมิห้อง (24-26^{0}C) และแช่น้ำแข็ง (0–4^{0}C) ทำการวิเคราะห์ค่า pH, $PaCO_2$, PaO_2 และ Na, K, Cl ด้วยเครื่องตรวจวิเคราะห์อัตโนมัติ ณ เวลานาทีที่ 15, 30, 45 และ 60 เปรียบเทียบกับการตรวจที่นาทีที่ 0*

ผลการศึกษา: *เมื่อเวลาผ่านไปค่า pH, PaO_2, Na และ Cl จะลดลง ขณะที่ค่า $PaCO_2$ และ K จะสูงขึ้นทั้งในอุณหภูมิห้องและแช่น้ำแข็ง โดยเลือดที่เก็บไว้ในอุณหภูมิห้องจะมีการเปลี่ยนแปลงมากกว่า เมื่อเปรียบเทียบกับการตรวจทันที พบว่าค่า pH จะเปลี่ยนแปลงอย่างมีนัยสำคัญทางสถิติตั้งแต่นาทีที่ 30 ในอุณหภูมิห้องและนาทีที่ 45 เมื่อแช่น้ำแข็ง ขณะที่ค่า $PaCO_2$ และ PaO_2 พบการเปลี่ยนแปลงอย่างมีนัยสำคัญทางสถิติตั้งแต่นาทีที่ 15 ในทั้งสองสภาวะ สำหรับค่า Na และ K พบการเปลี่ยนแปลงอย่างมีนัยสำคัญทางสถิติที่นาทีที่ 60 ในอุณหภูมิห้อง พบการเปลี่ยนแปลงของค่า Cl อย่างมีนัยสำคัญทางสถิติตั้งแต่นาทีที่ 15 ในอุณหภูมิห้องและนาทีที่ 30 เมื่อแช่น้ำแข็ง*

สรุป: *การวิเคราะห์ค่า ABG และ Electrolyte ในเลือดแดงควรทำภายใน 15 นาที โดยสามารถเก็บเลือดไว้ที่อุณหภูมิห้องหรือแช่น้ำแข็ง เพื่อให้ได้ค่าที่ใกล้เคียงกับการตรวจทันที*