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# Evaluation of Dependence of the Gradient between Arterial and End-tidal $Pco_2$ on The Fraction of Inspired Oxygen

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**Abstract:** Hypocarbia and/or hypercarbia are implicated as a causative factor in periventricular leukomalacia, intra-ventricular hemorrhage, and chronic lung disease. A (40) Patients were studied on mechanical ventilation were divided into four groups according to $FiO_2$ level administration. In the present study there was statistically significant increase in Hb in group II in the 2nd day compared with the 1st day. Otherwise, there was no statistically significant difference throughout the study. The present study showed that there was statistically significant increase in pH in group IV in the 2nd day compared with 1stday. Otherwise, there was no statistically significant difference throughout the study. The present study showed that there was statistically significant increase in $P_aO_2$ in group I compared with group III in the 1st day. In addition, there was statistically significant increase in groups I and II compared with group IV in the 2nd day. Moreover, there was statistically significant increase group II and III in 2nd day compared with 1st day. Additionally, there was statistically significant increase in Δ change of groups II and III compared with and group IV. The present study showed that there was statistically significant increase in $EtCO_2$ in group I compared with group IV in the 2nd day. Otherwise, there was no statistically significant difference throughout the study. The present study showed that there was statistically significant increase in MABP in group I, and II compared with group III, IV in 1st day respectively. Also, there was statistically significant increase in group IV in the 2nd day compared with 1st day, Moreover, There was statistically significant decrease in Δ change in group I, II and III compared with group IV. The present study showed that there was significant positive correlation between $EtCO_2$ and $PaCO_2$ in group I and group III in the 1st day of follow up. Also, significant positive correlation in % of change in group I compared with other groups.

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**Keywords:** ABGs, PaCO2, $EtCO_2$, MABP

## 1. Introduction

Arterial blood gases (ABGs) analysis is essential for monitoring the adequacy of ventilation and oxygenation in ventilated babies. It is often difficult to obtain ABGs frequently especially where resources are limited. [1]

Arterial blood sampling leads to blood loss, pain, stress and arteriospasm and hence need for noninvasive monitoring. Pulse oximetry provides the non-invasive method of assessing the oxygenation pediatric intensive care unit (PICU) patients. [2]

It is necessary to have a reliable, non-invasive method for detecting hypocarbia and hypercarbia. [3] Both hypocarbia and hypercarbia are detrimental to the infants and have been implicated as a causative factor in periventricular leukomalacia (PVL), intra-ventricular hemorrhage (IVH) and chronic lung disease (CLD). [4]

Maintaining the Partial arterial Carbone Dioxide tension ($PaCO_2$) within the desired range by frequent arterial sampling can increase the need for multiple transfusions in these infants. [5]

End-tidal carbon dioxide ($EtCO_2$) measurement by capnography is a continuous and non-invasive indirect measurement of blood carbon dioxide tensions. [6]

Capnography is done by either side-stream or main-stream gas sampling. The technique, which measures the concentration of Carbone Dioxide $CO_2$ in exhaled gas, has been used extensively in adults and children. [7]

The reliability of mainstream capnography has also been reported in infant. [8]

The End-tidal carbon dioxide monitoring has some clear advantages over the transcutaneous $CO_2$ monitoring, such as a much faster response time to

changes in blood $CO_2$ levels, internal calibrating ability and no thermal injury to the fragile skin of the patients. [9]

This noninvasive method can reduce the blood loss and pain associated with arterial blood gas sampling. [10]

The End-tidal carbon dioxide is usually lower compared to corresponding $PaCO_2$. The lower value for the end-tidal measurement may be attributable to gas mixing proximal to the endotracheal tube. [10]

End-tidal carbon dioxide measurement from gas sampled distally to the endotracheal tube-ventilator connection more closely matches the arterial value. [11]

The severity of lung disease, the ventilation index and the oxygenation index had negligible influences on the degree of bias. [12]

The normal range of carbon dioxide to be maintained during assisted ventilation is 35 mmHg to 55 mmHg. [13]

The upper limit of benign $PaCO_2$ levels is less clear. In a randomized trial of permissive hypercapnia, mild hypercapnia ($PaCO_2$ 45-55 mmHg) did not increase the incidence of IVH in infants. [14]

The goal of mechanical ventilation should be avoiding hypocapnia or hypercapnia, rather than achieving a specific level or range of $PaCO_2$. Hence, the continuous noninvasive monitoring of $CO_2$ by capnometry is helpful in these vulnerable infants. [15]

The vasodilating effect of $O_2$ on pulmonary blood vessels and its effect on $EtCO_2$ - $PaCO_2$ gradient is crucial for the viability if $EtCO_2$ in different $FiO_2$ i.e. different pulmonary diseases severity.

**Aim of the Work**

This study aimed to assess the dependence of the gradient between arterial and End-tidal $PCO_2$ on the fraction of inspired oxygen in patients in pediatric intensive care unit.

## 2. Patients and Methods

**Patients**

This Prospective study was carried out upon 40 patients (20 males and 20 females) aged from 1.5 to 132 months on mechanical ventilation admitted in pediatric intensive care unit (PICU), pediatric department, Tanta university hospital.

The duration of research was 14 months from October 2013 to December 2014. A written informed consent was obtained from the guardians of all patients of the study. The study was approved by the Ethics Committee of Faculty of Medicine, Tanta University

**Patients were divided in to four groups:**

All studied Patients on mechanical ventilation were divided into four groups according to $FiO_2$ level administration.

**Group I:** Patients on 21% $FiO_2$ (ten patients)
**Group II:** Patients on 40% $FiO_2$ (ten patients)
**Group III:** Patients on 60%$FiO_2$. (ten patients)
**Group IV:** Patients on 90% $FiO_2$.( ten patients)

**Inclusion criteria:**

Patients included in the study were those on pressure controlled mandatory ventilation under sedation and muscle relaxant.

**Exclusion criteria:**

Patients with structural cardio pulmonary malformation.

Patients who died or weaned from mechanical ventilation during duration of study.

**Methods**

All the studied patients were subjected to the following:

**(1) Clinical:**

(a) - Detailed history taking with special emphasis on:

(b)- Complete physical examination including:

**(2) Laboratory tests:**

Routine tests were carried out on admission to PICU.

Complete Blood Count. (CBC) (ERMA ING full automatic blood counter model PCE 210 N TOKYO, JAPAN)

**(3) Monitoring of the patients during mechanical ventilation:**

Assessment of sedation:

(a) Pulse oximetry:

Pulse oximeter was used for continuous monitoring of oxygen saturation (Datex Cardiocap II monitor, Datex Division of Instrumentation Corp., Helsinki, Finland).

(b) ABGs:

Arterial Blood gases simultaneously were measured with $EtCO_2$. By Blood gas analyzer (GASTAT-602i/ Japan).

(c) $EtCO_2$:

Exhaled $CO_2$ was continuously monitored (Nihon KoHden monitor, Tokyo, Japan).

(d) Monitoring and recording of ventilatory parameters:

Simultaneously with $EtCO_2$ and $PaCO_2$ measurement, Ventilatory setting and main arterial blood Pressure (MABP) were recorded.

**Statistical analysis of the data:** [16]

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. [17]

Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Comparison between different groups regarding categorical variables was tested using Chi-square test. When more than 20% of the cells have expected count less than 5, correction for chi-square was conducted using Monte Carlo correction. The distributions of quantitative variables were tested for normality using Kolmogorov-Smirnov test, Shapiro-Wilk test and D'Agstino test, If it reveals normal data distribution, parametric tests was applied.

If the data were abnormally distributed, non-parametric tests were used. For normally distributed data, comparison between more than two population were analyzed F-test (ANOVA) to be used and Post Hoc test (Turkey) , also paired t-test is used to analyse two paired data. For abnormally distributed data, Kruskal Wallis test was used to compare between different groups and pair wise comparison was assessed using Mann-Whitney test. To compare between the different periods Wilcoxon signed ranks test was applied, Significance of the obtained results was judged at the 5% level.

## 3. Results

Table (1) shows that regarding MABP:

There was statistically significant increase in MABP in group I, and II compared with group III, IV in 1st day respectively.

There was statistically significant increase in group IV in the 2nd day compared with 1st day.

There was statistically significant decrease in Δ change in group I, II and III compared with group IV.

Table (1): Comparison Between The studied Groups According to Mean Arterial Blood Pressure (mmHg) at Different Periods of Follow up

| MABP | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day | | | | | | |
| Min. – Max. | 42.0 – 67.0 | 38.0 – 62.0 | 33.0 – 60.0 | 33.0 – 48.0 | | |
| Mean ± SD | 50.40 ± 8.64 | 51.40 ± 8.93 | 47.50 ± 8.76 | 40.30 ± 4.88 | F= 3.943* | 0.016* |
| Median | 46.50 | 50.0 | 46.50 | 40.50 | | |
| Sig. bet. grps | $p_1$= 0.992, $p_2$= 0.848, $p_3$= 0.036*, $p_4$=0.697, $p_5$=0.018*, $p_6$=0.201 | | | | | |
| 2nd day | | | | | | |
| Min. – Max. | 32.0 – 60.0 | 39.0 – 52.0 | 39.0 – 61.0 | 40.0 – 64.0 | | |
| Mean ± SD | 43.40 ± 8.80 | 47.10 ± 3.60 | 47.50 ± 6.38 | 47.90 ± 7.39 | F= 0.929 | 0.437 |
| Median | 42.0 | 47.50 | 48.50 | 46.50 | | |
| Mean diff. ($p_7$) | ↓7.0(0.128) | ↓4.30(0.234) | ↑0.0(1.000) | ↑7.60*(0.008*) | | |
| Δ change | | | | | | |
| Min. – Max. | -52.24 – 19.05 | -35.0 – 28.95 | -26.67 – 24.49 | -9.09 – 52.38 | | |
| Mean ± SD | -11.48 ± 22.69 | -5.32 ± 20.59 | 2.17 ± 17.36 | 19.60 ± 17.34 | $^{KW}\chi^2$= 10.080* | 0.018* |
| Median | -11.84 | -9.0 | 4.51 | 18.52 | | |
| Sig. bet. grps | $p_1$= 0.597, $p_2$= 0.151, $p_3$= 0.007*, $p_4$=0.364, $p_5$=0.021*, $p_6$=0.045* | | | | | |

F: F test (ANOVA), Sig. bet. grps was done using Post Hoc Test (Tukey)
KWχ2: Chi square for Kruskal Wallis test, Sig. bet. grps was done using Mann Whitney test
p1: p value for comparing between group I and group II, p2: p value for comparing between group I and group III
p3: p value for comparing between group I and group IV, p4: p value for comparing between group II and group III
p5: p value for comparing between group II and group IV, p6: p value for comparing between group III and group IV
p7: p value for Paired t-test for comparing between 1st day and 2nd day, *: Statistically significant at $p \leq 0.05$
MABP: Mean Arterial Blood Pressure, n: Number

Table (2) shows that regarding Hb:

There was statistically significant increase in Hb in group II in the 2nd day compared with the 1st day.

Otherwise, there was no statistically significant difference throughout the study.

Table (2): Comparison Between The studied Groups According to Hemoglobin (gm/dL) at Different Periods of Follow up

| Hb | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day | | | | | | |
| Min. – Max. | 5.50 – 14.10 | 7.70 – 11.30 | 7.90 – 13.60 | 8.70 – 11.60 | | |
| Mean ± SD | 9.70 ± 2.49 | 9.85 ± 1.18 | 10.79 ± 1.99 | 10.26 ± 1.13 | F= 0.743 | 0.533 |
| Median | 9.35 | 10.0 | 10.25 | 10.60 | | |
| 2nd day | | | | | | |
| Min. – Max. | 8.90 – 12.80 | 8.90 – 12.0 | 8.90 – 10.80 | 8.90 – 11.20 | | |
| Mean ± SD | 10.57 ± 1.27 | 10.64 ± 0.89 | 9.92 ± 0.63 | 10.19 ± 0.70 | F= 1.379 | 0.265 |
| Median | 10.70 | 10.85 | 10.0 | 10.05 | | |
| Mean diff. ($p_1$) | ↑ 0.870(0.179) | ↑0.790* (0.015*) | ↓0.870(0.179) | ↓0.070(0.871) | | |
| Δ change | | | | | | |
| Min. – Max. | -16.82 – 67.27 | -4.59 – 26.44 | -24.26 – 24.05 | -16.82 – 18.18 | | |
| Mean ± SD | 14.12 ± 25.72 | 8.74 ± 9.18 | -5.42 ± 17.46 | 0.46 ± 13.42 | $KW\chi^2$= 5.294 | 0.152 |
| Median | 11.87 | 9.63 | -11.18 | - 4.34 | | |

F: F test (ANOVA), KWχ2: Chi square for Kruskal Wallis test
p1: p value for Paired t-test for comparing between 1st day and 2nd day, *: Statistically significant at p ≤ 0.05, Hb: Hemoglobin
n: Number

Table (3) shows that regarding to Blood pH:
There was statistically significant increase in pH in group IV in the 2nd day compared with 1st day.
Otherwise, there was no statistically significant difference throughout the study.

Table (3): Comparison Between The studied Groups According to Blood pH at Different Periods of Follow up.

| pH | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day | | | | | | |
| Min. – Max. | 7.21 – 7.54 | 7.22 – 7.43 | 7.22 – 7.48 | 7.16 – 7.41 | | |
| Mean ± SD | 7.37 ± 0.09 | 7.31 ± 0.07 | 7.32 ± 0.08 | 7.27 ± 0.08 | F= 2.575 | 0.069 |
| Median | 7.36 | 7.31 | 7.31 | 7.25 | | |
| 2nd day | | | | | | |
| Min. – Max. | 7.25 – 7.42 | 7.22 – 7.44 | 7.27 – 7.44 | 7.27 – 7.51 | | |
| Mean ± SD | 7.35 ± 0.05 | 7.34 ± 0.07 | 7.36 ± 0.07 | 7.35 ± 0.07 | F= 0.156 | 0.925 |
| Median | 7.36 | 7.35 | 7.39 | 7.35 | | |
| Mean diff. ($p_1$) | ↓0.03 (0.464) | ↑0.03 (0.275) | ↑0.04 (0.300) | ↑0.08 (0.003*) | | |
| Δ change | | | | | | |
| Min. – Max. | -2.29 – 1.66 | -0.96 – 3.05 | -1.89 – 2.77 | -0.27 – 2.49 | | |
| Mean ± SD | -0.33 ± 1.40 | 0.43 ± 1.16 | 0.60 ± 1.69 | 1.15 ± 0.88 | $KW\chi^2$= 5.460 | 0.141 |
| Median | 0.20 | 0.27 | 0.48 | 1.44 | | |

F: F test (ANOVA), KWχ2: Chi square for Kruskal Wallis test
p1: p value for Paired t-test for comparing between 1st day and 2nd day
*: Statistically significant at p ≤ 0.05, pH= power of hydrogen, n: Number

Table (4) shows that regarding $PaO_2$:

There was statistically significant increase in $PaO_2$ in group I compared with group III in the 1st day.

There was statistically significant increase in groups I and II Compared with group IV in the 2nd day.

There was statistically significant increase group II and III in 2nd day compared with 1st day.

There was statistically significant increase in Δ change of groups II and III compared with group IV.

Table (4): Comparison Between The studied Groups According to Partial Arterial Oxygen Tension (mmHg) at Different Periods of Follow up..

| $PaO_2$ | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day | | | | | | |
| Min. – Max. | 52.0 – 92.0 | 54.0 – 72.0 | 45.0 – 75.0 | 45.0 – 92.0 | | |
| Mean ± SD | 71.90 ± 13.38 | 60.50 ± 6.64 | 59.0 ± 10.88 | 70.90 ± 15.15 | F= 3.208* | 0.034* |
| Median | 71.0 | 59.50 | 59.0 | 71.0 | | |
| Sig. bet. grps | $p_1$= 0.162, $p_2$= 0.042*, $p_3$= 0.998, $p_4$=0.992, $p_5$=0.227, $p_6$=0.135 | | | | | |
| 2nd day | | | | | | |
| Min. – Max. | 63.0 – 90.0 | 55.0 – 91.0 | 51.0 – 82.0 | 45.0 – 75.0 | | |
| Mean ± SD | 77.90 ± 9.19 | 77.30 ± 10.49 | 69.80 ± 9.22 | 63.90 ± 9.75 | F= 4.739* | 0.007* |
| Median | 77.0 | 77.50 | 73.0 | 66.0 | | |
| Sig. bet. grps | $p_1$= 0.999, $p_2$= 0.258, $p_3$= 0.013*, $p_4$=0.322, $p_5$=0.019*, $p_6$=0.530 | | | | | |
| Mean diff. ($p_7$) | ↑6.0 (0.182) | ↑16.80 (0.002*) | ↑10.80 (0.021*) | ↓7.0 (0.216) | | |
| Δ change | | | | | | |
| Min. – Max. | -12.22 – 40.38 | -11.29 – 65.45 | -16.44 – 68.89 | -40.22 – 22.22 | | |
| Mean ± SD | 11.03 ± 20.41 | 29.11 ± 22.48 | 21.15 ± 23.47 | -6.46 ± 21.98 | $^{KW}\chi^2$= 10.425* | 0.015* |
| Median | 3.30 | 29.33 | 22.24 | -5.72 | | |
| Sig. bet. grps | $p_1$= 0.121, $p_2$= 0.450, $p_3$= 0.151, $p_4$=0.364, $p_5$=0.003*, $p_6$=0.016* | | | | | |

F: F test (ANOVA), Sig. bet. grps was done using Post Hoc Test (Tukey)
KWχ2: Chi square for Kruskal Wallis test, Sig. bet. grps was done using Mann Whitney test
p1: p value for comparing between group I and group II, p2: p value for comparing between group I and group III
p3: p value for comparing between group I and group IV, p4: p value for comparing between group II and group III
p5: p value for comparing between group II and group IV, p6: p value for comparing between group III and group IV
p7: p value for Paired t-test for comparing between 1st day and 2nd day, *: Statistically significant at $p \leq 0.05$
$PaO_2$: Partial Arterial Oxygen Tension, n: Number

Table (5) shows that regarding $PaCO_2$:

There was statistically significant increase in $PaCO_2$ in group I compared with group II in the 1st day.

There was statistically significant increase in group I compared with group III in the 2nd day.

Table (5): Comparison Between The studied Groups According to Partial Arterial Carbon Dioxide Tension (mmHg) at Different Periods of Follow up.

| $PaCO_2$ | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day | | | | | | |
| Min. – Max. | 28.0 – 72.0 | 29.0 – 50.0 | 29.0 – 50.0 | 29.0 – 50.0 | | |
| Mean ± SD | 47.40 ± 14.82 | 36.30 ± 6.52 | 37.20 ± 6.92 | 36.50 ± 7.31 | F= 3.187* | 0.035* |
| Median | 49.0 | 35.50 | 37.0 | 34.0 | | |
| Sig. bet. grps | $p_1$= 0.04*1, $p_2$= 0.097, $p_3$= 0.068, $p_4$=0.997, $p_5$=1.000, $p_6$=0.998 | | | | | |
| 2nd day | | | | | | |
| Min. – Max. | 35.0 – 64.0 | 30.0 – 50.0 | 28.0 – 48.0 | 31.0 – 49.0 | | |
| Mean ± SD | 46.30 ± 10.47 | 40.70 ± 6.36 | 37.0 ± 7.10 | 38.60 ± 4.86 | F= 2.943* | 0.046* |
| Median | 43.0 | 41.50 | 38.50 | 39.50 | | |
| Sig. bet. grps | $p_1$= 0.352, $p_2$= 0.041, $p_3$= 0.117, $p_4$=0.689, $p_5$=0.923, $p_6$=0.963 | | | | | |
| Mean diff. ($p_7$) | ↓1.10 (0.740) | ↑1.10 (0.740) | ↓4.40 (0.062) | ↑2.10 (0.171) | | |
| Δ change | | | | | | |
| Min. – Max. | -29.82 – 31.25 | -14.29 – 41.38 | -32.56 – 45.45 | -11.11 – 30.0 | | |
| Mean ± SD | 2.43 ± 22.51 | 13.89 ± 19.41 | 1.13 ± 20.59 | 7.56 ± 13.38 | $^{KW}\chi^2$= 2.815 | 0.421 |
| Median | 4.21 | 12.85 | 0.0 | 4.30 | | |

F: F test (ANOVA), Sig. bet. grps was done using Post Hoc Test (Tukey)
KW$\chi$2: Chi square for Kruskal Wallis test, Sig. bet. grps was done using Mann Whitney test
p1: p value for comparing between group I and group II, p2: p value for comparing between group I and group III
p3: p value for comparing between group I and group IV, p4: p value for comparing between group II and group III
p5: p value for comparing between group II and group IV, p6: p value for comparing between group III and group IV
p7: p value for Paired t-test for comparing between 1st day and 2nd day, *: Statistically significant at $p \leq 0.05$
$PaCO_2$:Partial Arterial Carbon Dioxide Tension, n: Number

Table (6) shows that regarding $EtCO_2$:

There was statistically significant increase in $EtCO_2$ in group I compared with group IV in the 2nd day.

Otherwise, there was no statistically significant difference throughout the study.

Table (6): Comparison Between The studied Groups According to End-tidal Carbon Dioxide(mmHg) at Different Periods of Follow up.

| Et $CO_2$ | Group I (n = 10) | Group II (n = 10) | Group III (n = 10) | Group IV (n = 10) | Test of sig. | p |
|---|---|---|---|---|---|---|
| 1st day<br>Min. – Max.<br>Mean ± SD<br>Median | <br>27.0 – 47.0<br>36.20 ± 6.84<br>35.50 | <br>31.0 – 50.0<br>38.10 ± 6.95<br>35.50 | <br>19.0 – 50.0<br>34.70 ± 9.84<br>32.50 | <br>19.0 – 41.0<br>29.90 ± 7.55<br>29.50 | F=<br>1.973 | 0.135 |
| 2nd day<br>Min. – Max.<br>Mean ± SD<br>Median | <br>28.0 – 45.0<br>38.60 ± 5.13<br>38.0 | <br>22.0 – 50.0<br>37.10 ± 7.84<br>37.0 | <br>29.0 – 47.0<br>35.90 ± 7.13<br>32.0 | <br>19.0 – 42.0<br>29.30 ± 6.60<br>29.50 | F=<br>3.697* | 0.020* |
| Sig. bet. grps | $p_1$= 0.959, $p_2$= 0.807, $p_3$= 0.020*, $p_4$=0.978, $p_5$=0.064, $p_6$=0.146 | | | | | |
| Mean diff. ($p_7$) | ↑2.40 (0.397) | ↓1.0 (0.776) | ↑1.20 (0.709) | ↓0.60 (0.867) | | |
| Δ change<br>Min. – Max.<br>Mean ± SD<br>Median | <br>-19.15 – 50.0<br>9.96 ± 25.14<br>6.94 | <br>-50.0 – 61.29<br>0.56 ± 29.26<br>-3.48 | <br>-25.64 – 131.58<br>11.26 ± 44.84<br>-3.0 | <br>-48.78 – 73.68<br>5.56 ± 40.87<br>-11.15 | $^{KW}\chi^2$=<br>0.821 | 0.844 |

F: F test (ANOVA), Sig. bet. grps was done using Post Hoc Test (Tukey), KWχ2: Chi square for Kruskal Wallis test
p1: p value for comparing between group I and group II, p2: p value for comparing between group I and group III
p3: p value for comparing between group I and group IV, p4: p value for comparing between group II and group III
p5: p value for comparing between group II and group IV, p6: p value for comparing between group III and group IV
p7: p value for Paired t-test for comparing between 1st day and 2nd day, *: Statistically significant at p ≤ 0.05
Et $CO_2$ :End-tidal Carbon Dioxide, n: Number

Table (7) shows that regarding Correlation between Et$CO_2$ with Pa$CO_2$:

There was significant positive correlation between Et$CO_2$ and Pa$CO_2$ in group I and group III in the 1st day of follow up.

There was significant positive correlation in % of change in group I compared with other groups.

Table (7): Correlation Between Et$CO_2$ with Pa$CO_2$

| Et$CO_2$ vs. Pa$CO_2$ | | Group I | Group II | Group III | Group IV |
|---|---|---|---|---|---|
| 1st day | r | 0.737* | 0.294 | 0.710* | -0.215 |
| | p | 0.015 | 0.410 | 0.021 | 0.552 |
| 2nd day | r | 0.243 | 0.478 | -0.064 | 0.098 |
| | p | 0.499 | 0.163 | 0.861 | 0.788 |
| % of change | $r_s$ | 0.758* | 0.353 | 0.468 | -0.467 |
| | p | 0.011 | 0.318 | 0.172 | 0.174 |

r: Pearson coefficient, rs: Spearman coefficient, *: Statistically significant at p ≤ 0.05,
Et$CO_2$:End-Tidal Carbon Dioxide, Pa$CO_2$:Partial Arterial Carbon Dioxide Tension

Table (8) shows that regarding Length of Stay in PICU to Predict mortality.

There was no statistically significant in LOS in PICU in between the studied groups to predict mortality.

Table (8): Comparison Between The studied Groups According to Length of Stay in PICU (days) According to Survival

| LOS | Group I | Group II | Group III | Group IV |
|---|---|---|---|---|
| Died | (n = 3) | (n = 3) | (n = 4) | (n = 4) |
| Min. – Max. | 11.0 – 15.0 | 8.0 – 14.0 | 8.0 – 18.0 | 11.0 – 15.0 |
| Mean ± SD | 13.0 ± 2.0 | 10.67 ± 3.06 | 12.75 ± 4.57 | 13.25 ± 1.71 |
| Median | 13.0 | 10.0 | 12.50 | 13.50 |
| Survived | (n = 7) | (n = 7) | (n = 6) | (n = 6) |
| Min. – Max. | 8.0 – 22.0 | 8.0 – 22.0 | 8.0 – 22.0 | 8.0 – 16.0 |
| Mean ± SD | 12.14 ± 4.88 | 13.71 ± 4.96 | 14.0 ± 5.33 | 12.33 ± 3.27 |
| Median | 10.0 | 13.0 | 14.0 | 13.0 |
| t | 0.286 | 0.969 | 0.383 | 0.510 |
| p | 0.782 | 0.361 | 0.712 | 0.624 |
| t: Student t-test, #: Excluded from the comparison, LOS: Length Of Stay | | | | |

## 4. Discussion

When a critically ill child is admitted in PICU the main questions is what will be his prognosis?

Child mortality in critically depends on: the underlying disease, the cause of admission, clinical severity status and complications of the disease, and the treatments given and procedures performed. [18]

Many studies have analyzed the factors that can predict the risk of early death and prolonged hospitalization in PICU, and have developed numbers of investigations and clinical severity scores. [19]

Capnography is a useful monitoring tool during mechanical ventilation and is the standard of care for confirmation of endotracheal tube placement [20] and for monitoring in the operating room setting. [21]

Capnography is also useful for monitoring the integrity of the ventilator circuit for early detection of mishaps such as inadvertent extubation. [22]

There is less agreement about the utility of continuous capnography for ventilated intensive care unit patients. Advocates of capnography feel that $EtCO_2$ may be used as a surrogate of $PaCO_2$, which would provide a quick and noninvasive assessment of the adequacy of ventilation. [23]

Hypocarbia and/or hypercarbia are implicated as a causative factor in periventricular leukomalacia. [24] Intra-ventricular hemorrhage and chronic lung disease. [25]

Furthermore, extreme fluctuations in partial pressure of arterial carbon dioxide ($PaCO_2$) and higher max $PaCO_2$ are associated with worse neurodevelopmental outcomes. [26] Hence, prevention of extreme hypocarbia and/or hypercarbia in infants is essential. [27]

Arterial blood gas sampling and monitoring that require central or peripheral arterial catheters, which are not without risks – there have been incidences of digital ischemia and arterial spasm.[28]

End-tidal carbon dioxide measurement is a continuous and non-invasive indirect measurement of blood carbon dioxide tensions with fast response time to changes in blood $CO_2$ levels and internal calibrating ability.

The principal determinants of $EtCO_2$ are alveolar ventilation, pulmonary perfusion (cardiac output), and $CO_2$ production. [29]

The objective of this study was to assess the dependence between arterial and end-tidal $PCO_2$ to the fraction of inspired oxygen in PICU.

This study was carried out on 40 children who was admitted in PICU and in need of MV divided to four groups; Group I: Patients on 21% $FiO_2$, Group II: Patients on 40% $FiO_2$,Group III: Patients on 60%$FiO_2$, and Group IV: Patients on 90% $FiO_2$.

In the present study there was statistically significant increase in Hb in group II in the 2nd day compared with the 1st day. Otherwise, there was no statistically significant difference throughout the study.

This was in accordance with Landrigan et al. [30] who found that, there was significant increase in Hb.

However, Mazzella et al. [31], and Stefanescu et al. [32] found that significant decrease Hb in patients. Meaning that, significant improvement.

The present study showed that there was statistically significant increase in pH in group IV in the 2nd day compared with 1stday. Otherwise, there was no statistically significant difference throughout the study.

This was in accordance with Mayordomo et al. [33] who found that significant increase in pH in patients. Also, Thia et al., [34] found that children with bronchiolitis, there was a significant increase pH.

The present study showed that there was statistically significant increase in $P_aO_2$ in group I compared with group III in the 1st day. In addition, there was statistically significant increase in groups I

and II compared with group IV in the 2nd day. Moreover, there was statistically significant increase group II and III in 2nd day compared with 1st day. Additionally, there was statistically significant increase in Δ change of groups II and III compared with group IV.

This was in agreement with study of Hwang et al.[35] who found that significantly increase $PaO_2$. This may be explained by improvement of $PaO_2$ Meaning that, significant improvement in group I, II and III.

This was against Pillow et al. [36] and Huang et al., [37] who found that there was significant decrease $P_aO_2$ between group I and III . Meaning that, significant deteriorations.

The present study showed that there was statistically significant increase in $PaCO_2$ in group I compared with group II in the 1st day. Also, there was statistically significant increase in group I compared with group III in the 2nd day.

This was in accordance with Kugelman et al., [38] who found that there was significant increase $P_aCO_2$.

This was against Rozycki et al. [39] and Essouri et al., [40] who found that the level of $PaCO_2$ not significant and did not affect the accuracy of $EtCO_2$.

The present study showed that there was statistically significant increase in $EtCO_2$ in group I compared with group IV in the 2nd day. Otherwise, there was no statistically significant difference throughout the study.

This was in accordance with Courtney et al. [41] who found increase in $EtCO_2$ compared in patients with lower respiratory tract infection on MV.

The present study showed that there was statistically significant increase in MABP in group I, and II compared with group III, IV in 1st day respectively. Also, there was statistically significant increase in group IV in the 2nd day compared with 1st day, Moreover, There was statistically significant decrease in Δ change in group I, II and III compared with group IV.

This denoted the severer conditions with groups III and IV (needs more $FiO_2$). Also, the improvement in group IV as time pass.

The present study showed that there was significant positive correlation between $EtCO_2$ and $PaCO_2$ in group I and group III in the 1st day of follow up. Also, significant positive correlation in % of change in group I compared with other groups.

This was in accordance with Amuchou Singh et al. [42] who evaluated the correlation between $EtCO_2$ and $PaCO_2$. Likewise, they found a positive correlation between the two parameters. Also, found a positive correlation between the changes in $PaCO_2$ and the simultaneous changes in $EtCO_2$, showing that the trends $PaCO_2$ and $EtCO_2$ were close.

Also, Hasani et al. [43] carried out a study on patients and examined levels of $PaCo_2$ and $EtCO_2$. They stated that there is a significant direct positive relationship between the aforementioned two parameters.

However, Whitesellf et al., [44] failed to demonstrate such a relationship. That may be explained by that $FiO_2$ was not well controlled and the range examined was narrow.

Whether the $EtCO_2$–$PaCO_2$ gradient change more according to the severity of the lung disease is a matter of debates. Other investigators reported different results. Tingay et al. [45] found that the $EtCO_2$ bias was independent of severity of lung disease; while Rozycki et al. [39 ] reported that measures of degree of lung disease had little influence on the degree of bias.

But $EtCO_2$ monitoring should not replace ABGs measurements to monitor ventilation in patients was admitted to PICU Because ABGs, although invasive, provides more information including oxygenation, ventilation, and acid-base balance. [46]

Nevertheless, ABGs provide information about only one moment in time versus $EtCO_2$, which displays continuous information about ventilation. [47]

The good correlation between the changes in $PaCO_2$ and the simultaneous changes in $EtCO_2$, capnography could serve as a complementary tool for trending assessment of $CO_2$ levels when they were within the range of 30 to 50 mmHg.

It is better to perform periodic check of blood gases to make sure it is within accordance of $PaCO_2$, and to obtained arterial blood gases when the end-tidal monitor showed readings beyond these limits.

This protocol may reduce the amount of barotrauma by allowing more prompt adjustments of the ventilatory settings in response to changes in $EtCO_2$-$PaCO_2$. In addition, it may also reduce the exposure time to Hypocarbia and Hypercarbia and therefore decrease the brain injury; and finally it may reduce the number and total volume of blood samples required for gas measurement.

**Conclusions**

It is concluded that:

- There was eligibility to use $EtCO_2$ as positive correlate to $PaCO_2$ in the clinical assessment of pediatric patients with respiratory distress.
- The use of $EtCO_2$ monitoring does not replace blood gas assessment it could serve as an important adjunct in the clinical management of pediatric patients even with significant pulmonary disease.
- There were potential benefits to the continuous monitoring of exhaled $CO_2$ in an intensive care unit. Not only can continuous assessment of the

patient's ventilatory status, but also allow for early warning in case of a loss of integrity of the ventilator circuit or inadvertent extubation, optimize mechanical ventilation and aid in weaning from the ventilator.

- Capnography could be a useful early indicator of changes in a patient's cardiopulmonary status due to alterations in pulmonary blood flow, respiratory effort, effective minute ventilation, and/or respiratory compliance.
- The agreement was negatively influenced by the severity of pulmonary disease.

**Recommendations**

**It is recommended to:**

- Define the utility of $EtCO_2$ as a measure of blood gas $PaCO_2$ in pediatrics patients with moderate to severe respiratory distress and assessment of ventilatory setting.
- Use the two reading ($EtCO_2$ and $PaCO_2$) through 10 minutes because of the minute to minute fluctuation in $CO_2$ levels.
- Perform more studies to declare the level of agreement between $VPCO_2$ and $EtCO_2$ to determine if $EtCO_2$ could replace $PaCO_2$.

**Limitations**

The limitations during the study included that:

- Difficulties in collecting arterial blood samples.
- Difficulties in the timing of measurement of $EtCO_2$ and $PaCO_2$ simultaneously.

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