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END-TIDAL CARBON DIOXIDE MONITORING IN THE NEONATAL VENTILATED PATIENTS USING CAPNOGRAPHY TECHNIQUE

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ABSTRACT

Objective: To determine the accuracy and precision of end-tidal carbon dioxide monitoring through capnography in ventilated neonates.

Study Design: Quasi-experimental study.

Place and Duration of Study: Neonatal Intensive Care Unit (NICU) of Pak Emirates Military Hospital Rawalpindi, from Jun 2019 to Dec 2019.

Methodology: End-tidal partial pressure of carbon dioxide (PCO_2) and capillary blood pairs were obtained from 100 ventilated neonates. The patients were monitored by mainstream capnography. A total of 400 observations were made using four paired samples of end-tidal carbon dioxide and capillary blood from each patient.

Results: Four hundred end-tidal carbon dioxide and capillary blood pairs from 100 neonates were analyzed for PCO_2. Little difference was found at each time point. However, the mean difference was found little higher at time point 4 between end tidal (53.8 ± 10.4) and capillary blood gas (58.9 ± 10.5). We found significant correlation at each time point (ICC 1st = 0.99, ICC 2nd = 0.99, ICC 3rd = 0.99, ICC 4th = 0.97, $p<0.001$).

Conclusion: End-tidal carbon dioxide monitoring is an easy, noninvasive method that gives reliable values of partial pressure of carbon dioxide which are comparable to the capillary blood partial pressure of carbon dioxide.

Keywords: Capnography, End-tidal carbon dioxide ($ETCO_2$), Partial pressure of carbon dioxide (PCO_2).

INTRODUCTION

Monitoring neonates, while on mechanical ventilator, is of prime importance in order to assess ventilation and oxygenation adequacy. Pulse oximetry is widely used as a non-invasive method for continuous monitoring of oxygenation. However, oxygen saturation may be normal even in the presence of inadequate ventilation[1]. Ventilation is intermittently assessed via arterial, capillary or venous blood gas analysis for PCO_2 rather than continuous readings. These methods are invasive leading to excessive blood loss and only give a snapshot of PCO_2[2]. Fluctuations in PCO_2 are relatively common in ventilated neonates. Their incidence is variable in various studies. Brown *et al*, reported an incidence of less than 2% for PCO_2 less than 30mm Hg and 19.5% for PCO_2 more than 55mm Hg[3]. Hypocarbia and hypercarbia both have adverse effects on neonates. Hypercarbia can lead to intraventricular hemorrhage, necrotizing enterocolitis, moderate to severe bronchopulmonary dysplasia and adverse neurodevelopmental outcome[4]. Whereas, hypocarbia causes cerebral vasoconstriction leading to ischemic brain injury. Thus, large gaps in the monitoring of carbon dioxide may cause short and long term complications in ventilated neonates[5]. Therefore, the concept of $ETCO_2$ monitoring evolved leading to the use of non-invasive modalities to monitor PCO_2 in ventilated patients[6]. $ETCO_2$ is the PCO_2 that indicates indirectly the amount of carbon dioxide in the arterial blood[7]. This is a continuous and non-invasive method of monitoring that is based on the principle that carbon dioxide will be detected during expiration from a correctly placed endotracheal tube (ETT). Monitoring of $ETCO_2$ is important for assessing disease severity and response to treatment. On the other hand, capnography is a non-invasive method for monitoring $ETCO_2$ in ventilated

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patients and is highly recommended[8]. Despite its importance, researchers like Aminiahidashti *et al*, proclaim that capnography has not reached its full potential and recommend further research to evaluate its use in specific clinical conditions and diseases[9]. Capnographic PCO_2 via $ETCO_2$ in intubated neonates has been proven to have a good correlation with arterial PCO_2[10].

Capnography is used in the monitoring of ventilated patients and is considered standard of care, but limited local data in present in literature in its efficacy and accuracy in newborns. Thus, the present study is an attempt to measure and validate accuracy of end-tidal PCO_2 using capnography.

METHODOLOGY

This was a quasi experimental study undertaken in the Neonatal Intensive Care Unit of Pak Emirates Military Hospital, Rawalpindi over 6-month period from June to December, 2019. Using PASS v11, Intraclass Correlation, 80% power of the test, 95% confidence interval, 4 observations per subject, correlation of Ho: 0.73[2] vs H1: 0.81, calculated sample size was 92 subjects. The study was carried out on 100 neonates, including preterm and term patients, who were ventilated for various reasons. Non-probability purposive sampling technique was adopted. Informed consent was taken from the parents. Patients suffering from congenital heart disease, gross structurally anomalous babies, gestational age less than 26 weeks and corrected gestational age more than 42 weeks were excluded from the study. Simultaneous end-tidal and capillary blood PCO_2 pairs were obtained. Uncuffed endotracheal tubes were used with less than 10% leak. Position of ETT was confirmed via chest x-ray. Neonates were ventilated using pressure limited, time cycled ventilation in either assist control mode or synchronous intermittent mandatory ventilation mode. Exhaled PCO_2 was continuously monitored using a mainstream cap-nometer: HEYER VizOR 12 Patient Monitoring System with Main-Stream Multi Gas IRMA CO_2, AX+. A total of 400 observations were made using four paired samples of end-tidal and capillary blood PCO_2 from each patient at different times, with intervals of at least 12 hours between any two readings. The study was approved by the local ethics committee of the hospital (Letter reference no: A/28). A capillary blood specimen was collected in a preheparinised capillary and analyzed in OPTI™ CCA-TS Analyzer made in USA as point of care in NICU within 5 minutes of sampling and partial pressure CO_2 (mmHg) was measured. Continuous end-tidal capnographic monitoring of PCO_2 (mmHg) with readings recorded at the onset of capillary blood sampling. Data were analyzed using Statistical Program for Social Sciences (SPSS) version 22. Data were expressed as mean and standard deviation (SD).

RESULTS

A total of 400 end-tidal and capillary blood pairs were analyzed from 100 newborns that required ventilation for various diseases. The mean gestational age of the newborns was 34.4 ± 3.9 weeks with a mean birth weight of 2149.8 ±

Table-I: Descriptive statistics for demographics.

Demographics	**n (%)**
Gestational age (weeks) Mean ± SD	34.4 ± 3.9
Weight (gram) Mean ± SD	2149.8 ± 888.7
Gender	
Male	50 (50%)
Female	50 (50%)
Indoor/Outdoor	
Indoor	88 (88%)
Outdoor	12 (12%)
Disease	
Respiratory Distress Syndrome	17 (17%)
Transient Tachypnea of Newborn	4 (4%)
Meconium Aspiration Syndrome	8 (8%)
Inborn Errors of Metabolism	4 (4%)
Apnea	8 (8%)
Early Onset Neonatal Sepsis	5 (5%)
Late Onset Neonatal Sepsis	12 (12%)
Acute Kidney Injury	4 (4%)
Seizures	10 (10%)
Hypoxic Ischemic Encephalopathy	12 (12%)
Pneumothorax	2 (2%)
Surgical Post-Operative patients	6 (6%)
Pneumonia	8 (8%)

888.7g. The commonest indication for ventilation was respiratory distress syndrome (17%) followed by late onset neonatal sepsis and hypoxic ischemic encephlopathy, 12% each (table-I).

There was a little mean difference found at each time point which cannot be considered as clinically significant. Although little higher in capillary gas as 58.9 at 4th time point and 53.8 in end-tidal (table-II).

Table-II: Mean ± SD difference between End-tidal and Capillary Gas CO_2.

Time Points	End-tidal	Capillary Gas	Paired Difference
1st	53.4 ± 11.5	58.2 ± 11.7	4.8 ± 1.6
2nd	50.9 ± 10.1	55.7 ± 10.2	4.9 ± 1.3
3rd	47.9 ± 10.2	52.9 ± 10.6	5.0 ± 1.5
4th	53.8 ± 10.4	58.9 ± 10.5	5.1 ± 2.6

The scatterplot of the end-tidal and capillary gas shown in the figure. The plot indicates that there is no variability in the relationship between the two values of CO_2. The overall correlation between the two measurements was also good (r=0.99, p<0.001).

The correlation between the two values of CO_2 in neonates is shown in table-III. The r-value for all four time points is significant, with the first three time points showing r-values of 0.991; whereas, time point four is exhibiting r-value of 0.968, which is also quite significant. This indicates that there exists a strong correlation between the two values of CO_2.

We found intraclass correlation (table-IV) of around 0.90 at each time point either by gender or overall. A significant correlation was found, overall; at 1st time point (ICC=0.91, p-value <0.001) and at last time point it was found (ICC=0.87, p-value <0.001).

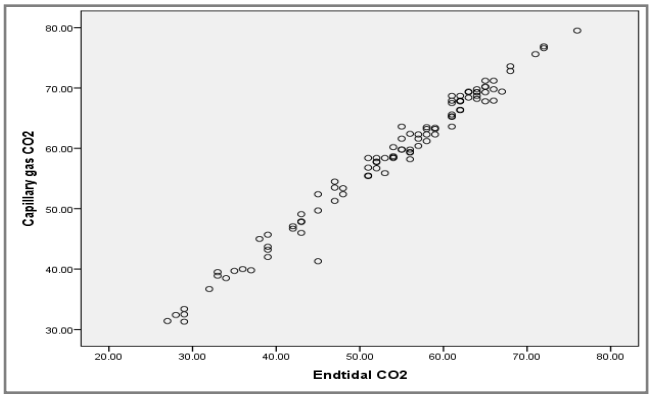

Figure: Scatter plot between End-tidal CO_2 and capillary gas CO_2.

Table-III: Correlation between End-tidal and Capillary gas CO_2.

	End-tidal CO_2 (1st Time)	End-tidal CO_2 (2nd Time)	End-tidal CO_2 (3rd Time)	End-tidal CO_2 (4th Time)
Capillary gas CO_2 (1st Time)	0.991***			
Capillary gas CO_2 (2nd Time)		0.992***		
Capillary gas CO_2 (3rd Time)			0.991***	
Capillary gas CO_2 (4th Time)				0.968***

***p<0.001

Table-IV: Intraclass correlation between End-tidal and capillary gas by gender.

Time Points	Male	Female	Overall
1st	0.92 (p<0.001)	0.91 (p<0.001)	0.91 (p<0.001)
2nd	0.90 (p<0.001)	0.88 (p<0.001)	0.89 (p<0.001)
3rd	0.91 (p<0.001)	0.87 (p<0.001)	0.89 (p<0.001)
4th	0.85 (p<0.001)	0.88 (p<0.001)	0.87 (p<0.001)

DISCUSSION

Continuous monitoring of exhaled PCO_2 in a ventilated newborn is a viable option to ensure adequate ventilation. Neonates ventilated in NICUs are monitored closely for efficacy of ventilation in an attempt to reduce complications associated with hypocarbia and hypercarbia. The importance of monitoring exhaled PCO_2 has been included in many international practice guidelines such as the American Society for Anesthesia and the American Heart Association. Despite the level of awareness and the regulatory

and organizational guidance, exhaled PCO_2 monitoring is often underutilized. Continuous non-invasive monitoring of PCO_2 is a good tool and can be performed easily in neonates to avoid invasive blood gas sampling[11]. Different modalities are currently being employed to assess the level of PCO_2 and in turn alveolar ventilation including blood gas analysis (arterial/venous/capillary), capnography, and transcutaneous measurements. These all differ in their accuracy, side effects, capacity to facilitate continuous assessment and availability. Arterial/capillary blood gas analysis although considered gold standard is invasive. On the other hand, $ETCO_2$ is simple, non-invasive and provides continuous readings. In our study we found strong correlation between $ETCO_2$ and capillary gas PCO_2, indicating that capnography is effective in neonates. Our results find support from research conducted in Japanese neonatal intensive care units[12], which found that noninvasive PCO_2 monitoring in preterm and term infants was quite accurate. Razi *et al*, also compared $ETCO_2$ with blood gases in ventilated adult patients and found a good correlation[13,14]. Another Chinese study done in ventilated newborn also proved a good correlation and consistency between $ETCO_2$ and PCO_2 in arterial blood[15]. However, some researchers argue that $ETCO_2$ may not accurately predict PCO_2. They are of the view that capnography has technical and physiological limitations in neonates mainly due to high respiratory rate and low tidal volume which require mainstream sensors with fast response times and minimal dead-space; otherwise measuring $ETCO_2$ can be misleading[16]. Watkins *et al*. have reported poor correlation between $ETCO_2$ and PCO_2 in blood in 19 infants with pulmonary diseases[17]. Canto *et al*, also reported that $ETCO_2$ did not have a good correlation with blood PCO_2 in 9 ventilated newborns with severe lung illnesses[18]. Similarly, Chandrakantan reported that $ETCO_2$ underestimates the actual PCO_2[19]. Likewise, according to another study $ETCO_2$ is less accurate in the infant populations especially with extremely low birth weights. Therefore, patient's age and body weight, as well as the type of circuit and the site of carbon dioxide sampling, all are important factors influencing the accuracy of $ETCO_2$[20]. Some new studies have also been done in which an epidural catheter was inserted at the distal end of the endo-tracheal tube, thus bringing the sampling close to the alveoli and decreasing the influence of dead space which is normally more in neonates and infants[10]. Nevertheless, neonatal intensive care units can still use $ETCO_2$ as primary means of PCO_2 monitoring.

CONCLUSION

We concluded that $ETCO_2$ correlates with the capillary blood levels of carbon dioxide and should be employed as a useful adjunct in monitoring of critical neonates in NICUs. Further studies may still be needed in order to counteract the bias in terms of technique, body weight and age of the patients.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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