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ORIGINAL ARTICLE

A study of partial pressure of arterial carbon dioxide and end-tidal carbon dioxide correlation in intraoperative and postoperative period in neurosurgical patients

Pallavi Gaur, Minal Harde, Pinakin Gujjar, Devanand Deosarkar, Rakesh Bhadade[1]

Departments of Anaesthesiology and [1]Medicine, Topiwala National Medical College and BYL Nair Charitable Hospital, Mumbai, Maharashtra, India

ABSTRACT

Background and Aim: Monitoring carbon dioxide (CO_2) is of utmost importance in neurosurgical patients. It is measured by partial pressure of arterial CO_2 ($PaCO_2$) and end-tidal CO_2 ($ETCO_2$). We aimed to study the correlation between $PaCO_2$ and $ETCO_2$ in neurosurgical patients in the intraoperative and postoperative period on mechanical ventilation in Postanesthesia Care Unit (PACU).

Methodology: This was prospective observational study done at tertiary care teaching public hospital over a period of 1 year. We studied 30 patients undergoing elective craniotomy intraoperatively and in the postoperative period on mechanical ventilation for 24 h. Serial measurement of $ETCO_2$ and $PaCO_2$ at baseline, hourly intraoperatively and every 6 hourly in the PACU were studied. Data analysis was done using SPSS software version 20.

Results: The mean $PaCO_2$–$ETCO_2$ gradient intraoperatively over 4 h is 3.331 ± 2.856 and postoperatively over 24 h is 2.779 ± 2.932 and lies in 95% confidence interval. There was statistically significant correlation between $PaCO_2$ and $ETCO_2$ intraoperatively baseline, 1 h, 2 h, 3 h, and 4 h with Pearson's correlation coefficients of 0.799, 0.522, 0582, 0.439, and 0.547, respectively ($P < 0.05$). In PACU at baseline, 6 h, 12 h, 18 h, and 24 h Pearson's correlation coefficients were. 534, −0.032, 0.522, 0.242, 0.592, and 0.547, respectively, which are highly significant at three instances ($P < 0.01$).

Conclusion: $ETCO_2$ correlates $PaCO_2$ with acceptable accuracy in neurosurgical patients in the intraoperative and postoperative period on mechanical ventilation in Intensive Care Unit. Thus, continuous and noninvasive $ETCO_2$ can be used as a reliable guide to estimate arterial PCO_2 during neurosurgical procedures and in PACU.

Key words: End-tidal carbondioxide, neurosurgery, partial pressure of arterial carbon dioxide, postoperative care unit

Introduction

In neurosurgeries monitoring of arterial partial pressure of carbon dioxide ($PaCO_2$) is most vital as it affects intracranial pressure (ICP), cerebral blood flow, volume and cerebral perfusion pressure (CPP). Increase in $PaCO_2$ increases ICP thereby decreasing CPP. Raised ICP can be reduced through therapeutic hyperventilation; however, excessive hyperventilation (<20 mmHg) could result in regional cerebral hypoxia.[1,2] Hence, continuous monitoring of CO_2 is of utmost importance. End-tidal CO_2 ($ETCO_2$) is another method to estimate CO_2 continuously and noninvasively. A good alveolar ventilation-perfusion matching results in an $ETCO_2$ that closely

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Address for correspondence:
Dr. Pallavi Gaur, 5 Vinayak Nagar, Bohra Ganesh Ji Road, Udaipur, Rajasthan - 313 001, India.
E-mail: pallavigaur22@gmail.com

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correlates with $PaCO_2$; hence in patients without significant cardiopulmonary disorders, $PaCO_2$ may be estimated by using actual $ETCO_2$ measurements. The difference between $PaCO_2$ and $ETCO_2$ (P(a-ET) CO_2 gradient) is reported to be 3.6–4.6 mmHg in healthy awake patients. However, in literature various studies mention substantial variability in patients undergoing craniotomy in different positions and mechanically ventilated neurosurgical Intensive Care Unit (ICU) patients.[3-6] In addition, in diseased lungs, impaired cardiac function, increased dead space ventilation, ventilation-perfusion (V/Q) mismatch, sampling line error, and critical illness may widen the above gradient.[7,8] Nevertheless, monitoring $ETCO_2$ has many advantages such as it reduces the need for invasive arterial blood gas (ABG) sampling, allowing safe, comfortable, and continuous monitoring. A sudden change in $ETCO_2$ can prompt the clinician to measure $PaCO_2$ via an ABG sample thus before the patient is compromised, early intervention is guaranteed.[9] This also has important implication in Postanesthesia Care Unit (PACU) for more cautious postoperative care. There is lot of contradiction in the recent literature regarding $ETCO_2$ and $PaCO_2$ correlation in neurosurgical patients.[1,3-7,10,11] Hence, we decided to do the present study in Indian population.

The aim was to study the correlation between $PaCO_2$ and $ETCO_2$ in patients undergoing neurosurgery in the intraoperative as well as in the postoperative period on mechanical ventilation in PACU.

Methodology

This was prospective observational study done at a tertiary care teaching public hospital in neurosurgery operation theater and PACU after approval from the Institutional Ethics Committee and written informed valid consent. The study was conducted over a period of 1 year from June 2014 to June 2015. We studied 30 patients aged between 18 and 60 years, belonging to the American Society of Anesthesiologists (ASA) Grade 1/2 undergoing elective craniotomy (surgical duration of 4–5 h) in the supine position. In the postoperative period, we included only those patients who required mechanical ventilation for minimum 24 h period. We excluded patients with lung disease and hemodynamically unstable patients.

After adequate preoxygenation and premedication, induction was done with intravenous (IV) fentanyl 2 μg/kg and thiopentone 5 mg/kg. Vecuronium 0.08 mg/kg was used to facilitate tracheal intubation. After intubation with an appropriate-sized cuffed endotracheal tube, intermittent positive pressure ventilation was given using a volume-controlled mode with a tidal volume of 7–10 ml/kg and a respiratory rate of 10–12 breaths per minute and continous $ETCO_2$ was monitored using a side-stream capnometer (Patient Monitor 9000 Express side-stream CO_2, Penlon Limited, Abington, Oxon). Postinduction radial artery cannulated and baseline ABG were collected. Anesthesia was maintained with oxygen (40–50%), air and desflurane (minimum alveolar concentration 0.8–1.0). The first postinduction measurement of $ETCO_2$ and $PaCO_2$ was taken as a baseline and then repeated for every 1 h until the end of surgery. In the postoperative period in PACU, patients were maintained on volume-synchronized intermittent mandatory ventilation (volume SIMV) with inspired oxygen fraction (FiO_2) 40–50% and adequate sedation and analgesia with titrated doses of IV midazolam and fentanyl. Continuous $ETCO_2$ was recorded by using a sidestream capnometer which was connected by angle piece connector in between the endotracheal tube and breathing circuit. After stabilizing the patient in PACU, a baseline measurement of $ETCO_2$ and $PaCO_2$ was recorded and thereafter every 6 hourly. Simultaneous measurement of blood pressure, heart rate, respiratory rate, central venous pressure, tidal volume, and FiO_2, peak inspiratory pressure were recorded at each sampling time. Standard calibration of sidestream CO_2 of patient monitor 9000 express was done with the same gas mixture before induction of each case as per the specifications of manufacturer.[12]

Statistical analysis

We calculated sample size with reference to Husaini and Choy, 2008, by taking into consideration Pearson's correlation between $PaCO_2$ and $ETCO_2$, with Type I error of 0.05 and Type II error of 0.20, with power equal to 0.80, which came to be 21.[1]

We decided to go ahead with a sample size of 30, which was appropriate for the study design and institutional settings. Quantitative data are presented with the help of mean, median, standard deviation (SD), interquartile range (IQR), minimum and maximum values. Qualitative data are presented with the help of frequency and percentage table. Data were initially analyzed using Pearson's correlation to assess the relationship between $PaCO_2$ and $ETCO_2$ at different stages of the operation. $P < 0.05$ was considered statistically significant with 95% confidence interval (CI).

Data analysis is done with the help of IBM Corp. Released 2011. IBM SPSS Statistics for windows, Version 20.0. Armonk, NY:IBM Corp.

Results

We analyzed 30 patients in the age group of 18–60 years with youngest being 23 years old and oldest 59 years and 11 of them belonged to the age group of 31–40. Among these 60% (18) were male and rest 40% (12) female with ASA Grade 1 as 40% (12) and ASA Grade 2 60% (18). There was no significant correlation of $PaCO_2$ and $ETCO_2$ values and demographic data, ASA grades. The various neurosurgeries included in the study with percentage distribution are depicted in Figure 1 with no significant correlation between diagnosis and correlation between $PaCO_2$ and $ETCO_2$. The parameters $ETCO_2$ and $PaCO_2$ and P(a-ET) CO_2 gradient at regular intervals were recorded with mean, SD, median, IQR, minimum and maximum values as depicted in Table 1. The mean P(a-ET) CO_2 gradient at each time interval in both intraoperative and the postoperative period is represented in Table 1, Figures 2 and 3. The mean of

P(a-ET) CO_2 gradient intraoperatively over 4 h is found to be 3.331 ± 2.856 and postoperatively over 24 h 2.779 ± 2.932 and lies in 95% CI. Correlations between $PaCO_2$ and $ETCO_2$ at different intervals during intraoperative period and in PACU are depicted in Tables 2 and 3. Data are analyzed by using Pearson's correlation to study the relationship between $PaCO_2$ and $ETCO_2$ at regular intervals. Table 2 shows correlation between $PaCO_2$ and $ETCO_2$ intraoperatively with statistically significant Pearson's correlation coefficients. Table 3 shows the correlation between $PaCO_2$ and $ETCO_2$ postoperatively in PACU, displaying highly significant correlation at three occasions however not significant at two occasions.

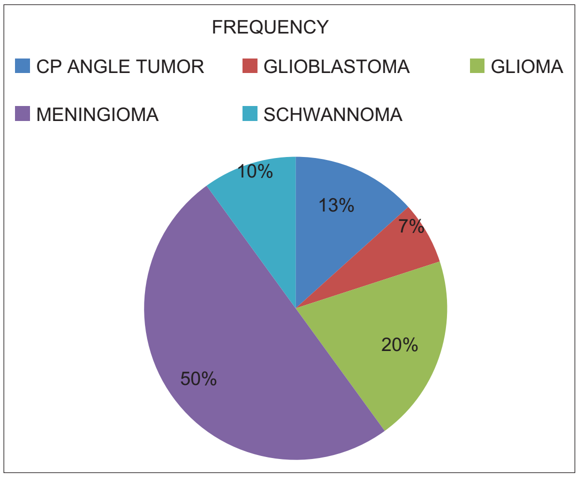

Figure 1: Distribution of study group as per diagnosis

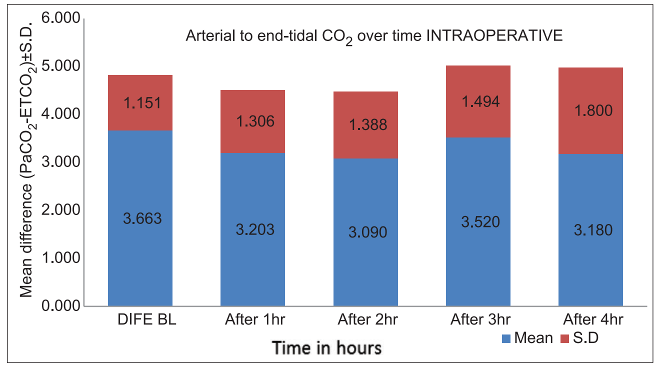

Figure 2: The arterial to end-tidal carbon dioxide differences over time for intraoperative period (mean ± standard deviation)

Table 1: Arterial and end-tidal carbon dioxide values in intraoperative and postoperative period

Parameters (in general)	*n*	Mean±SD	Median	IQR	Minimum	Maximum
$PaCO_2$ baseline/intraoperatively	30	37.130±1.847	37.600	1.775	32.800	39.800
$PaCO_2$ after 1 h	30	36.737±1.490	36.800	2.375	34.500	39.900
$PaCO_2$ after 2 h	30	36.490±1.608	36.800	1.675	32.100	38.900
$PaCO_2$ after 3 h	30	36.620±1.555	36.600	2.900	33.800	39.700
$PaCO_2$ after 4 h	30	36.613±1.814	36.800	2.450	32.700	39.900
$PaCO_2$ (PACU) baseline	30	37.337±0.989	37.400	1.775	35.400	38.800
$PaCO_2$ (PACU) 6 h	30	38.223±1.188	38.200	1.050	36.400	42.400
$PaCO_2$ (PACU) 12 h	30	38.517±1.562	38.800	2.350	34.200	41.200
$PaCO_2$ (PACU) 18 h	30	38.073±1.847	37.600	2.650	35.300	42.400
$PaCO_2$ (PACU) 24 h	30	37.110±1.325	36.600	1.800	35.400	39.900
$ETCO_2$ baseline/intraoperatively	30	33.467±1.776	34.000	3.000	29.000	37.000
$ETCO_2$ after 1 h	30	33.533±1.074	34.000	1.250	32.000	35.000
$ETCO_2$ after 2 h	30	33.400±1.404	33.500	1.250	31.000	36.000
$ETCO_2$ after 3 h	30	33.100±1.213	33.000	2.000	31.000	35.000
$ETCO_2$ after 4 h	30	33.433±1.960	34.000	2.000	30.000	38.000
$ETCO_2$ PACU baseline	30	35.067±1.484	36.000	2.000	32.000	37.000
$ETCO_2$ after 6 h	30	35.500±0.938	35.000	1.000	34.000	38.000
$ETCO_2$ after 12 h	30	35.400±1.499	36.000	2.250	32.000	38.000
$ETCO_2$ after 18 h	30	34.867±1.306	35.000	1.000	33.000	38.000
$ETCO_2$ after 24 h	30	34.533±1.137	34.000	2.000	33.000	37.000
Difference baseline	30	3.663±1.151	3.550	1.255	1.500	6.800
After 1 h	30	3.203±1.306	3.650	1.425	−0.400	5.600
After 2 h	30	3.090±1.388	2.800	1.300	0.900	6.600
After 3 h	30	3.520±1.494	3.800	1.950	0.600	5.800
After 4 h	30	3.180±1.800	3.200	1.650	−0.300	8.100
Difference PACU/baseline	30	2.270±1.214	2.200	1.325	0.300	6.200
After 6 h	30	2.723±1.473	2.600	2.050	0.600	7.400
After 12 h	30	3.117±1.490	2.800	2.025	0.800	6.700
After 18 h	30	3.207±1.976	2.600	1.975	0.400	9.400
After 24 h	30	2.577±1.179	2.400	1.775	0.400	5.300

$PaCO_2$ – Partial pressure of arterial carbon dioxide; $ETCO_2$ – End-tidal carbon dioxide; PACU – Postanesthesia Care Unit; SD – Standard deviation; IQR – Interquartile range

Table 2: Correlation between partial pressures of arterial and end-tidal carbon dioxide during craniotomy

Parameters (in general)	$ETCO_2$ baseline	$ETCO_2$ after 1 h	$ETCO_2$ after 2 h	$ETCO_2$ after 3 h	$ETCO_2$ after 4 h
$PaCO_2$ baseline					
Pearson's correlation	0.799	0.247	−0.062	0.43	0.235
Significant (two-tailed)	0.000**	0.188	0.745	0.018	0.212
n	Significant	30	30	30	30
$PaCO_2$ after 1 h					
Pearson's correlation	0.217	0.522	0.006	−0.166	−0.239
Significant (two-tailed)	0.248	0.003**	0.975	0.38	0.203
n	30	Significant	30	30	30
$PaCO_2$ after 2 h					
Pearson's correlation	−0.146	−0.015	0.582	0.015	0.031
Significant (two-tailed)	0.442	0.938	0.001**	0.939	0.871
n	30	30	Significant	30	30
$PaCO_2$ after 3 h					
Pearson's correlation	0.238	0.018	0.298	0.439	0.355
Significant (two-tailed)	0.206	0.924	0.11	0.015*	0.054
n	30	30	30	Significant	30
$PaCO_2$ after 4 h					
Pearson's correlation	−0.079	−0.299	0.29	0.269	0.547
Significant (two-tailed)	0.678	0.108	0.12	0.151	0.002**
n	30	30	30	30	Significant

*Correlation is significant at the 0.05 level (two-tailed); **Correlation is significant at the 0.01 level (two-tailed). $PaCO_2$ – Partial pressure of arterial carbon dioxide; $ETCO_2$ – End-tidal carbon dioxide

Table 3: Correlation between partial pressures of arterial and end-tidal carbon dioxide in Postanesthesia Care Unit

Parameters (in general)	$ETCO_2$				
	PACU BL	After 6 h	After 12 h	After 18 h	After 24 h
$PaCO_2$ (PACU) baseline					
Pearson's correlation	0.581	−0.024	−0.199	0.236	0.050
Significant (two-tailed)	0.001**	0.899	0.293	0.209	0.795
n	Significant	30	30	30	30
$PaCO_2$ (PACU) 6 h					
Pearson's correlation	0.226	0.054	0.144	0.122	0.057
Significant (two-tailed)	0.230	0.776	0.449	0.521	0.765
n	30	Not significant	30	30	30
$PaCO_2$ (PACU) 12 h					
Pearson's correlation	0.046	0.279	0.527	0.343	0.395
Significant (two-tailed)	0.811	0.135	0.003**	0.064	0.031
n	30	30	Significant	30	30
$PaCO_2$ (PACU) 18 h					
Pearson's correlation	0.287	0.265	0.152	0.251	0.390
Significant (two-tailed)	0.123	0.157	0.422	0.180	0.033
n	30	30	30	Not significant	30
$PaCO_2$ (PACU) 24 h					
Pearson's correlation	0.368	0.312	0.255	0.300	0.550
Significant (two-tailed)	0.045	0.093	0.174	0.108	0.002**
n	30	30	30	30	Significant

**Correlation is significant at the 0.01 level (two-tailed). $PaCO_2$ – Partial pressure of arterial carbon dioxide; $ETCO_2$ – End-tidal carbon dioxide; PACU – Postanesthesia Care Unit

Figures 4–13 show correlation between two methods of CO_2 measurement at given point of time by plotting a scatter diagram with R as the correlation coefficient between each set of values.

Discussion

$ETCO_2$ monitoring is considered the standard of care during general anesthesia and ICU care. The monitoring of $PaCO_2$ and

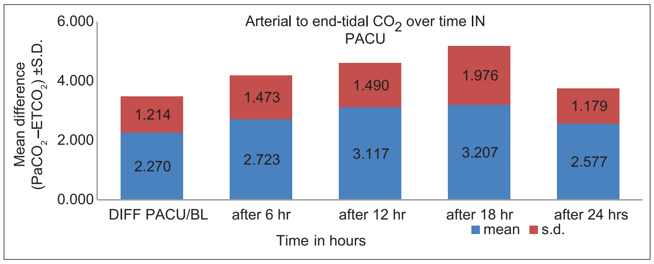

Figure 3: The arterial to end-tidal carbon dioxide differences over time for postoperative period (mean ± standard deviation)

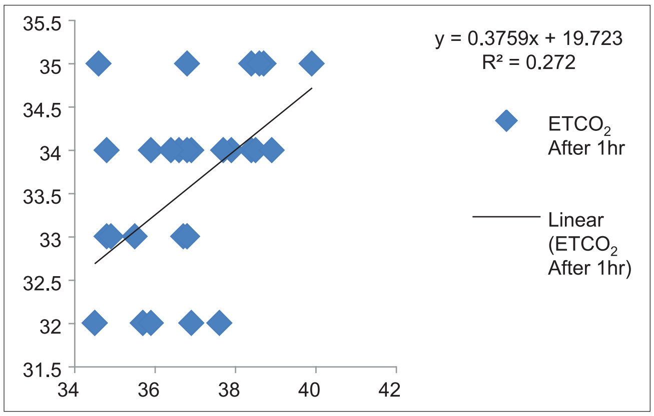

Figure 5: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 1 h ($P < 0.05$)

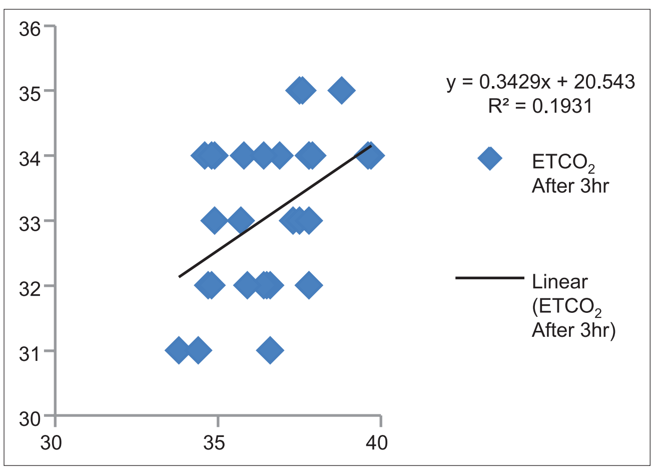

Figure 7: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 3 h ($P < 0.05$)

control in a narrow range is necessary during neurosurgical procedures as this affects and ICP dynamics and CPP.

ABG measurement of $PaCO_2$ is considered gold standard for monitoring changes in CO_2, which is invasive, expensive, and provides only intermittent measures of $PaCO_2$. $ETCO_2$ which is continuous respiratory measure of CO_2 can also reflect an indirect quantity of $PaCO_2$.[1] The $ETCO_2$ may be used as a surrogate marker for monitoring $PaCO_2$ in neurosurgical and ICU patients and thus reducing repetitive invasive ABG sampling. However, various studies have shown inconsistent results regarding this

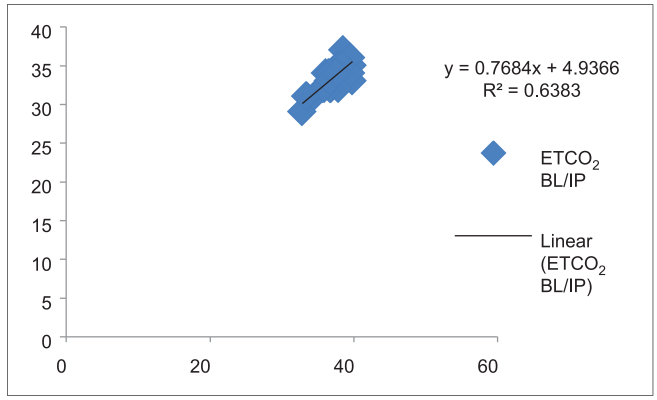

Figure 4: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide ($P < 0.05$)

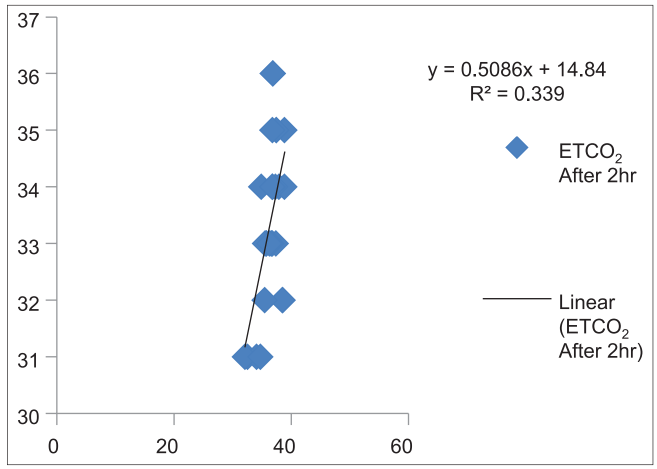

Figure 6: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 2 h ($P < 0.05$)

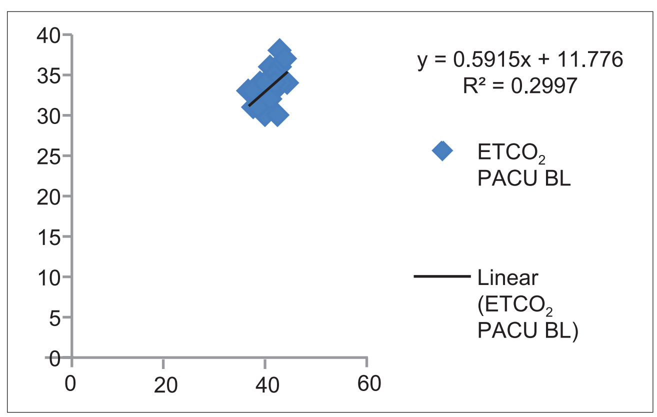

Figure 8: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 4 h ($P < 0.05$)

correlation during intraoperative period and in ICU patients. Hence, we conducted this study to evaluate the correlations in patients undergoing neurosurgeries who are also requiring postoperative ventilatory support for at least 24 h. Hence, this is the first initiative to assess the correlation of CO_2 level through invasive and noninvasive methods in the intraoperative period as well as in the postoperative period in the same set of patients.

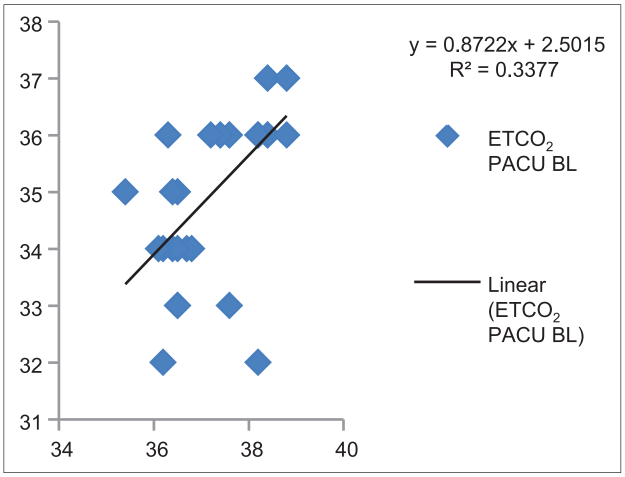

Figure 9: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide baseline in Postanesthesia Care Unit ($P < 0.05$)

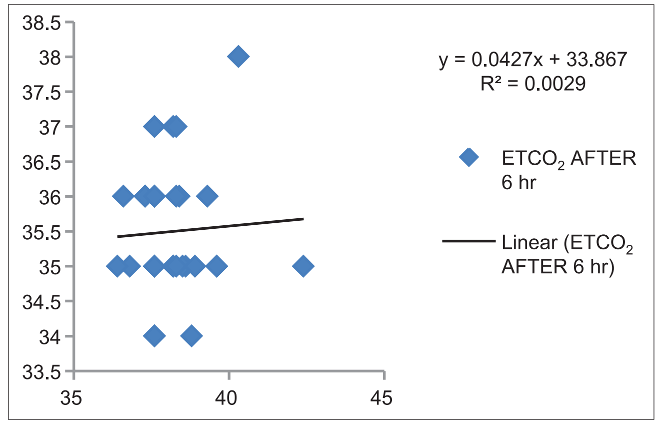

Figure 10: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 6 h in Postanesthesia Care Unit ($P > 0.05$)

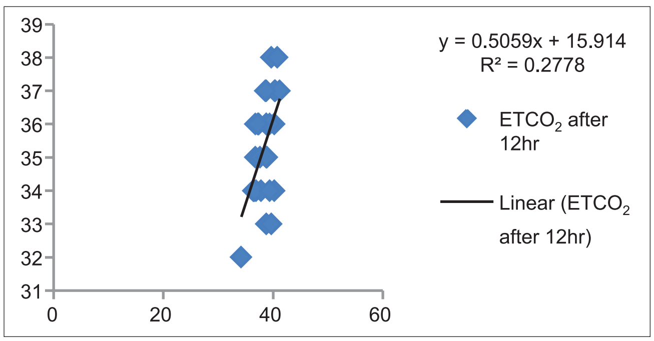

Figure 11: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 12 h in Postanesthesia Care Unit ($P < 0.05$)

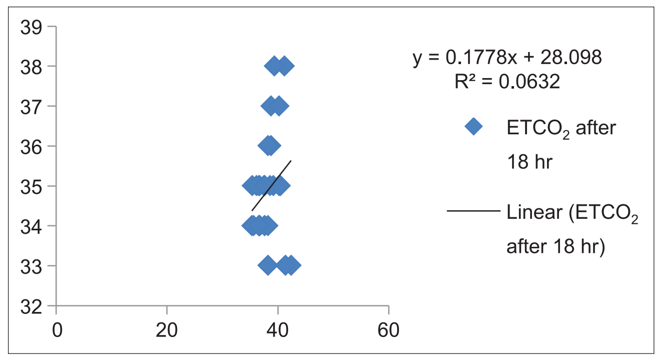

Figure 12: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 18 h in Postanesthesia Care Unit ($P > 0.05$)

Thirty patients aged between 18 and 60 years, undergoing elective craniotomy and those who required postoperative mechanical ventilation for minimum 24 h period, were studied. We found no significant correlation between $PaCO_2$ and $ETCO_2$ with respect to demographic data, ASA grading, and diagnosis. Kenichi Satoh 2015 concluded that partial pressure gradient of $PaCO_2$ to $ETCO_2$ increases with increasing age in patients undergoining surgeries in general anesthesia in supine position however we did not observe similar finding.[8]

During intraoperative period mean difference between $PaCO_2$ and $ETCO_2$ was found to be 3.31 ± 2.856 with 95% CI [Table 4 and Figure 2]. In our study, $PaCO_2$ values always exceeded $ETCO_2$ and at any point of time it never went in opposite directions. P(a-ET) CO_2 gradient lies between 3.6 and 4.6 mmHg in healthy awake patients. This gradient mainly depends on the degree of alveolar dead space.[12] Under stable physiologic conditions, with completely accurate monitoring, P(a-ET) CO_2 gradient should be close to zero, thus $PaCO_2$ values can be implicated accurately and constantly from $ETCO_2$ values. The various causes of widened gradient are V/Q mismatch and poor sampling of gas at patients end, impaired cardiac function, and critical illness.[3] Khan *et al*. 2007, Sharma *et al*. 1995, Hemmati *et al*. 2012 showed similar mean values which remained satisfactorily persistent with $ETCO_2$ for predicting $PaCO_2$ under anesthesia.[3,6,11] However, above positive gradient was not consistently found in all the patients in the study of Russell and Graybeal 1995.[4]

Table 4: Mean of gradient of partial pressures of arterial carbon dioxide and end- tidal carbon dioxide during intraoperative period

P (a-ET) CO_2	Mean±SD
Difference baseline	3.663±1.151
After 1 h	3.203±1.306
After 2 h	3.090±1.388
After 3 h	3.520±1.494
After 4 h	3.180±1.800
Total mean	3.331±1.428

SD – Standard deviation; *P* (a-ET) CO_2 – Partial pressure of arterial carbon dioxide and end-tidal carbon dioxide

During the postoperative period, the mean of P(a-ET) CO_2 gradient was found to be 2.78 ± 2.932 with 95% CI [Table 5 and Figure 3]. In these values also, there was a

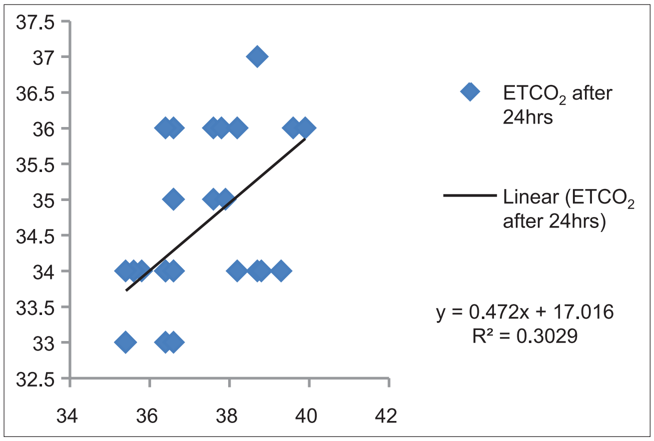

Figure 13: Correlation between partial pressure of arterial carbon dioxide and end-tidal carbon dioxide after 24 h in Postanesthesia Care Unit ($P < 0.05$)

positive gradient in all values with $PaCO_2$ exceeding $ETCO_2$ values. According to Razi *et al*. 2012, in healthy subjects there are close correlation between $PaCO_2$ and $ETCO_2$, and it is commonly accepted that $PaCO_2$ measurements vary approximately 2–5 mmHg above $ETCO_2$ values.[7] Russell and Graybeal *et al*. 1992 found a significant correlation between the gradients in total study population but not in individual patients. The direction of $PaCO_2$ change was also inaccurately predicted by $ETCO_2$ changes. $ETCO_2$ does not provide a stable reflection of $PaCO_2$ in all neuro-intensive care patients.[5]

We also calculated the correlation between $PaCO_2$ and $ETCO_2$ at given time and found out the positive correlation with each value, which was statistically significant ($P < 0.05$). During intraoperative period monitoring of each hourly value of $PaCO_2$ and $ETCO_2$, a positive significant correlation was found [Table 2]. These results are consistent with Khan *et al*. 2007, Husaini and Choy 2008, Hemmati *et al.* 2012, which showed a positive correlation at each time interval,[1,3,11] whereas Russell and Graybeal 1995 did not show positive correlation in all patients undergoing craniotomy.[4]

In the same patients in the postoperative period in ICU on volume SIMV mode for 24 h, we obtained a highly significant positive correlation ($P < 0.01$) at three occasions, however not significant at two [Table 3]. Razi *et al*. 2012 assessed in neurological patients admitted in intensive care in various modes of ventilation at a given point of time. They have found a positive correlation in each mode of ventilation (volume SIMV, continuous positive airway pressure, T-piece).[7] Kerr *et al*. 1996 studied the relationship between $PaCO_2$ and $ETCO_2$ in mechanically ventilated adults with severe head trauma and also observed $ETCO_2$ monitoring correlating well with $PaCO_2$ in patients without respiratory complications or without spontaneous breathing.[10] Russell and Graybeal 1992 did not obtain positive correlation in all ICU patients.[5] The reasons for this variability in the above gradient in our study and other

Table 5: Mean of gradient of partial pressure of arterial carbon dioxide and end-tidal carbon dioxide in Postanesthesia Care Unit

P (a-ET) CO_2	Mean±SD
Difference PACU/baseline	2.270±1.214
After 6 h	2.723±1.473
After 12 h	3.117±1.490
After 18 h	3.207±1.976
After 24 h	2.577±1.179
Total mean	2.779±1.466

PACU – Postanesthesia Care Unit; *P* (a-ET) CO_2 – Partial pressure of arterial carbon dioxide and end-tidal carbon dioxide; SD – Standard deviation

studies as well are explained by various factors such as dead space fraction, ventilation-perfusion mismatch, the site of sampling, and nonuniform alveoli CO_2 emptying patterns.[7,9] Cheifetz and Myers *et al*. 2007 have emphasized capnography as the standard of care in all respects right from operation theater to ICUs during mechanical ventilation.[9]

The present study was not without limitations as we did not study patients with major hemodynamic changes, severe lung disease, or positions other than supine. In healthy lungs and hemodynamically stable patients due to good alveolar ventilation and perfusion matching, $ETCO_2$ closely correlates with $PaCO_2$ but in above set of patients it may not correlate well, hence it is practical to verify with ABG analysis. Hence, future research should be directed in including all these patients. In addition, we used sidestream capnography intraoperatively as well as postoperatively, as mainstream was unavailable. In the PACU, we did not compare different modes of ventilation with respect to $ETCO_2$ and $PaCO_2$ correlation. Hence, above factors must be considered when generalizing the results.

Conclusions

From this study, we conclude that $ETCO_2$ reflects $PaCO_2$ with acceptable accuracy. In addition, $ETCO_2$ correlates $PaCO_2$ in patients undergoing neurosurgery in the intraoperative as well as in the postoperative period on mechanical ventilation (SIMV mode) in PACU. The above correlation is perfect in patients who are hemodynamically stable and with healthy lungs. Thus, simple, continuous, and noninvasive $ETCO_2$ can be used as a reliable guide to estimate $PaCO_2$ during neurosurgical procedures and in PACU.

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Conflicts of interest

There are no conflicts of interest.

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