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Recommended Citation

Khan, F. A., Khan, M., Abbasi, S. (2007). Arterial to end-tidal carbon dioxide difference in neurosurgical patients undergoing craniotomy: a review of practice. *Journal of Pakistan Medical Association*, 57(9), 446-448.

Available at: https://ecommons.aku.edu/pakistan_fhs_mc_anaesth/181

Arterial to End-Tidal Carbon Dioxide Difference in Neurosurgical Patients undergoing Craniotomy: A Review of Practice

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Abstract

Objective: To see if PETCO₂ reflects PaCO₂ with acceptable accuracy.

Methods: In this audit the anaesthetic chart of fifty consecutive patients, age 12 years and above undergoing craniotomy for intracranial pathology, were reviewed.

Results: The difference between end tidal carbon dioxide (ETCO₂) value corresponding to the time of taking the arterial sample and the PaCO₂ was calculated. The mean end tidal CO₂ was 29.3± 2.8 and the mean PaCO₂ was 32.63± 4.5. The mean difference between the two values was calculated as 4.09 ± 3.0. The regression coefficient was 0.496, which showed a moderate association. A wide variability was observed in the results.

Conclusion: Based on our results we recommend that arterial samples should be taken to determine PaCO₂ in neurosurgical patients where maintenance of cerebral blood flow is crucial e.g. cerebral aneurysm surgery (JPMA 57:446:2007).

Introduction

Both PaCO₂ and PETCO₂ are indicators of ventilatory adequacy. It is important to know the PaCO₂ in neuroanaesthesia because of its effect on cerebral blood flow. PETCO₂ has been used as a non-invasive estimate of PaCO₂.¹ The usual reported difference between PaCO₂ and PETCO₂ in healthy awake patients is 3.6 to 4.6 mm of Hg² but a significant variability has been observed in mechanically ventilated neurosurgical ICU patients³ and in patients undergoing craniotomy in different positions.⁴ There has also

been some controversy in recent anaesthetic literature whether end tidal CO₂ (PETCO₂) is an accurate reflection of PaCO₂.^{3,5}

This audit was undertaken to review our routine practice of obtaining PaCO₂ during craniotomy procedures and comparing it with the PETCO₂ at the same time. The objective was to see whether PETCO₂ reflected the PaCO₂ with acceptable accuracy.

Methods

Since the last three years our routine practice in

neuroanaesthesia is to take an arterial blood sample from the arterial line one hour after start of surgery in patients undergoing craniotomy and to note the end tidal carbon dioxide concentration simultaneously. The readings for ETCO_2 are routinely noted on the patient perioperative charts.

In craniotomy patients the ETCO_2 value corresponding to the time of taking the arterial sample is specifically noted on our anaesthetic chart. A file note is also made on ventilatory and haemodynamic parameters at the time of obtaining the sample. The PETCO_2 is taken as the maximal terminal value at end expiration. The charts of the last 50 consecutive patient's age 12 years and above, undergoing craniotomy were reviewed to look for the difference between the two values and to see whether the PETCO_2 value could be substituted for PaCO_2 . The difference between the two value P (a-ET) CO_2 was calculated manually for each sample. The other values routinely noted at the time of sampling were heart rate, systolic and mean arterial pressure (SAP, MAP), respiratory rate, tidal volume and inspired oxygen. These patients were undergoing craniotomy for different pathologies.

The institutional ethical committee was consulted and no permission was required for this review of practice.

All these patients had undergone craniotomy in supine position and had no significant lung disease. The patient's lungs were ventilated on Aestiva/5 machine ventilator. Volume controlled ventilation was used and the initial ventilatory setting was to achieve a PETCO_2 of 30-32mm of Hg. Carbon dioxide sampling was done on a side stream sample with the Datex AS/3 monitors. Arterial blood gas samples were taken from the radial artery catheter, which is standard monitoring in a craniotomy at our institution. The sample was sent to the laboratory immediately and was analyzed on NOVA stat profile Ultra (Nova Biomedical International, USA). These results were not corrected for patient's temperature.

Values were entered on the SPSS 13.0 statistical program. Data is presented as mean SD and range of values. Confidence intervals for mean difference between ETCO_2 and PaCO_2 was also calculated. Regression analysis between PaCO_2 and PETCO_2 and its standard error was also calculated.

Results

All patients underwent craniotomy in supine position. The mean age of the patients was 36.05 ± 18.0 years. The median age was 33.5 years. Age range was 12-71 years. 95 CI were 30.2 to 41.8. The mean weight was

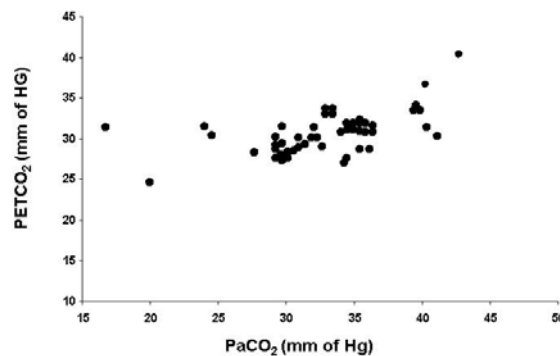


Figure 1. Regression analysis comparing PaCO_2 to End-Tidal PCO_2 (PETCO_2) $n = 50$
Each ? represents PETCO_2 and PaCO_2 difference in individual patients.

62.6 ± 17.0 kgs.

There were 30 males and 20 females. The mean ETCO_2 was 29.30 ± 2.8 (range 23-40 mm of Hg). The mean PaCO_2 was 32.63 ± 4.5 mm of Hg (range 16.8 - 42.5). The mean difference between ETCO_2 and PaCO_2 was 4.09 ± 3.08 with 95% CI = 3.21-4.97 (range 2.7 to 15.2). The regression coefficient was calculated as: 0.496, SE = 3.96. The regression analysis between PaCO_2 and ETCO_2 is shown in Figure 1.

The values differed by less than 6 mm of Hg in 41 patients (82%). The difference was more than 6 mm of Hg in nine (18%) patients. In two patients (4%) a negative correlation was observed.

Discussion

Capnometry is the measurement of the concentration or partial pressure of carbon dioxide at the patient's airway during the entire ventilatory cycle. It provides a numerical measurement of inspired and end tidal CO_2 .⁶ The end-tidal CO_2 or PETCO_2 closely approximates the arterial PCO_2 in normal lungs. The two common causes of more than normal difference are ventilation/perfusion mismatch and poor sampling of gas at patient's end. End tidal CO_2 measurement is currently the standard of care where general anaesthesia is administered.

The average P (a-ET) CO_2 gradient was determined as 4-6 mm of Hg in patients with normal lungs by Nunn et al.⁷ Other investigators have come up with similar figures: Takki et al, 3-5 mm of Hg⁸, Weingner 4 ± 2 mm of Hg⁹, and Ashrog, 5 ± 2 mm of Hg.¹⁰ No correlation was found with age and systolic arterial pressure. In respiratory failure patients, the average P (a-ET) CO_2 gradient was found to be 18 mm of Hg.¹¹

Several other factors have been shown to affect this relationship e.g. positioning¹², site of measurement i.e.

main stream versus side stream measurement¹³, and pregnancy.¹⁴ The relationship appears to be unaffected by temperature or oxygenation.¹⁵

The measurement of arterial PaCO₂ is of special importance in neuroanaesthesia because of its effect on cerebral circulation.¹⁵ In order to have a noninvasive measure of PaCO₂ several authors have investigated this relationship between PaCO₂ and end tidal CO₂ in neuroanaesthesia with mixed results. Sharma¹⁶ found this mean difference to be 5 ± 2 mm of Hg, but with large individual variations between -14 to 10 ± 19 mm of Hg. Kerr looked at head injured patients and found a mean difference of 6 ± 6 mm of Hg.¹⁷ Russell and Greybell³ found the mean difference to be 7 ± 3 mm of Hg in neurosurgical patients in the operating room and 7 ± 4 mm of Hg in ICU. They found a correlation coefficient of 0.63. Isert⁴ found this difference to be 4 ± 4 mm of Hg and observed that end tidal CO₂ correlated with PaCO₂ in 82% cases. Excellent correlation was shown by Mackersie et al who looked at data of 36 patients with known or suspected severe head injury.⁵ Grenier et al¹² showed a poor correlation and recommended arterial blood gas in addition to capnography. Ferber et al¹⁸ also showed poor correlation in patients undergoing craniotomy for head injury.

In our data the mean difference was 4.09 (± 3.08) CI. These results are very similar to those shown by Isert et al.⁴ We also found a wide variability with the lowest value as -2.7 and the highest as +15.2. We found an r value (regression coefficient of 0.496). This only shows a moderate association and not a strong one.¹⁹

Eighty two percent of our values differed by less than 6 mm of Hg. Negative correlation was observed in only 2 patients (4%). Negative values have also been reported by other investigators in neuroanaesthesia^{3,4}, and slow emptying of alveoli with long time constant has been hypothesized as the mechanism¹² but this concept has been challenged. A higher incidence of negative values have been reported in children, in laparoscopic surgery or after cardiac surgery,^{2,20,21} and in pregnancy.¹⁴ Negative correlation was seen in 20% of patients undergoing sub-arachoid haemorrhage surgery.¹⁸ Both our patients in whom negative values were reported had a history of hypertension but did not have any respiratory disease. The haemodynamic parameters were stable at the time of sampling.

In summary we observed that a relationship between PaCO₂ and end tidal CO₂ was predictable in only 49% of patients. A wide variability was seen in the results. Hence based on this audit we would recommend that arterial blood samples should be taken to determine PaCO₂ in

neurosurgical patients undergoing craniotomy where maintenance of cerebral blood flow is crucial e.g. during cerebral aneurysm surgery or patients with large intracranial tumours. In neurosurgical patients undergoing surgery for small superficial tumours with minimal disruption of cerebral blood flow and intracranial pressure, the cost benefit analysis may not favour arterial sampling.

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