

Information about the Critically Appraised Topic (CAT) Series

The objective of the Doctor of Nursing Practice (DNP) program at George Mason University is to prepare graduates for the highest level of nursing practice. Emphasis is placed on evaluating and applying the evidence that supports practice, understanding and creating practice delivery systems based on patient outcomes, and assuming leadership roles in practice settings. Graduates of the program will be able to assume many roles in the health care system, including direct patient care, clinical nursing faculty, practice management, and policy development.

All DNP students take an evidence-based practice course titled Evidence Based Practice in Nursing and Healthcare (NURS 883). This hallmark course for the DNP program builds on knowledge of research methodologies to analyze the selection and evaluation of research underlying evidence based practice. Emphasis is placed on the translation of research in practice, the evaluation of practice and the improvement of the reliability of health care practice and outcomes.

The first assignment students complete is a Critically Appraised Topic (CAT). CATs are mini-systematic reviews and considered a snapshot of the literature on a topic of interest. Students critically appraise literature related to a focused clinical question and summarize the best available research evidence on the topic of interest. CATs conclude with clinical bottom lines for practitioners to quickly take away for consideration in practice.

The CATs published in MARS (Mason Archival Repository Service; mars.gmu.edu) are submitted by students after they have been reviewed, revised, and approved by their instructor. All CATs are current at the time of original publication but will not be updated over time.

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Methods of Non-Invasive Carbon Dioxide Monitoring CAT

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Methods of Non-Invasive Carbon Dioxide Monitoring

Critically Appraised Topic

Purpose: To determine which method of noninvasive carbon dioxide (Co₂) monitoring - transcutaneous or end-tidal Co₂ - more accurately reflects arterial Co₂ levels facilitating identification of hypoventilation as evidenced by hypercarbia in adults receiving anesthesia in the peri-procedural setting?

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Clinical Scenario: Arterial blood sampling sets the standard for Co₂ monitoring in the peri-procedural setting. However, arterial blood gas (ABG) sampling is an invasive procedure and provides only intermittent estimates of Co₂ levels. Improved ventilatory optimization in the peri-procedural setting would be better achieved using a technology that provides continuous estimates of this non-static variable. Two non-invasive Co₂ measurement systems - end-tidal Co₂ (PETCo₂) and transcutaneous Co₂ (TcPCo₂) - are currently used clinical practice to provide these estimates. Due to the costs of implementing non-invasive Co₂ monitoring systems throughout all peri-procedural areas, it is critical to determine which system provides the most accurate, timely and actionable data as compared to the “gold standard” ABG.

PICOT Question: Which method of noninvasive carbon dioxide monitoring - transcutaneous or end-tidal Co₂ - more accurately reflects arterial Co₂ levels facilitating identification of hypoventilation as evidenced by hypercarbia in adults receiving anesthesia in the peri-procedural setting?

Search Strategies and Results: CINAHL, MEDLINE, and COCHRANE databases were searched with the following keywords and phrase: 1.) Co₂ monitoring, 2.) adult and 3.) transcutaneous. A subsequent search parameter narrowed results by using the key phrase: carbon dioxide monitoring. This key phrase search resulted in the identification of 43 articles written between 1981 and 2012 for review. Of the 43 articles found, 14 articles pertinent to the PICOT question were identified. The reference sections of these articles were hand searched with no additional pertinent articles identified. Three prospective observational studies were appraised as the highest level evidence available at this time based on both the Department of Health and Human Services (DHHS) & Oxford Levels of Evidence and were selected for this topic appraisal.

Chosen Articles:

Casati, A., Squicciarini, G., Malagutti, G., Bariarello, M., Putzu, M., & Fanelli, A. (2006).

Transcutaneous monitoring of partial pressure of carbon dioxide in the elderly patient: a prospective, clinical comparison with end-tidal monitoring. *Journal of Clinical Anesthesia*, 18(6), 436-440. <http://dx.doi.org/10.1016/j.jclinane.2006.02.007>

De Oliveira, Jr., G. S., Ahmad, S., Fitzgerald, P. C., & McCarthy, R. J. (2010). Detection of hypoventilation during deep sedation in patients undergoing ambulatory gynaecological hysteroscopy: a comparison between transcutaneous and nasal end-tidal carbon dioxide measurements. *British Journal of Anaesthesia*, 104(6), 774-778.

<http://dx.doi.org/10.1093/bja/aeq092>

Griffin, J., Terry, B. E., Burton, R. K., Keller, B. P., Landrum, A. L., Johnson, J. O., & Tobias, J. D. (2003). Comparison of end-tidal and transcutaneous measures of carbon dioxide during general anaesthesia in severely obese adults. *British Journal of Anaesthesia*, 91(4), 498-501. <http://dx.doi.org/10.1093/bja/aeg217>

Clinical Appraisal:

Casati et al (2006) conducted a prospective, observational correlational study (DHHS & Oxford Level 3) that included 17 consecutive patients all age ≥ 60 undergoing general anesthesia for surgery in an acute care hospital. Both non-invasive modalities and arterial Co₂ testing were employed in all 17 cases with the intent to compare both the accuracy and the mean bias estimation of PETCo₂ and TcPCo₂ monitoring to arterial PaCo₂ levels derived from intermittent arterial blood samples. For the noninvasive monitoring modalities, the absolute values of the differences between the PaCo₂ & PETCo₂ was 3mmHG or less in 7 (15%) of the 45 sample sets and the absolute values of the differences between the PaCo₂ and the TcPCo₂ was less than 3mmHg or less in 21 (46%) of the 45 sample sets ($p=0.003$). The Pearson's correlation of PETCo₂ to PaCo₂ was $r^2=0.50$ and TcPCo₂ to PaCo₂ was $r^2=0.73$. The mean bias arterial versus TcPCo₂ was 2 ± 4 mmHg (95% CI, -6 to 9mmHg) and the mean bias arterial versus PETCo₂ was 6 ± 5 (95%CI, -3 to 16 mmHg, $p = 0.0005$). These statistically significant results support the conclusion that transcutaneous Co₂ monitoring provided a more accurate estimation of PaCo₂ (measure of ventilatory adequacy) than PETCo₂ in healthy elders over 60 years of age undergoing general anesthesia.

The design of this study did not provide for a control group – testing of both noninvasive Co₂ systems and comparison against arterial blood samples was conducted concurrently on the same study group. Although the patient group in this study was homogeneous for age, type of surgery and anesthesia, and ASA score, the group was selected by convenience sampling and as noted by the Centre for Clinical Effectiveness, Monash Institute of Health Services Research, correlational studies are “fast and cheap [and] hypothesis generating... [but they] are highly susceptible to bias” (The Center for Clinical Effectiveness, Monash Institute of Health Services Research, 2006, p. 24). Further, aside from control of patient homogeneity as noted, it was unclear what additional measures were taken to control for confounding variables. While the sample group was small (group $n = 17$), the sample data set $n = 45$. A thorough discussion of appropriate descriptive and inferential statistical analysis with clear description of quantitative results was provided by the author. While the results of this study did support that TcCO₂ monitoring was a more accurate measure of PaCo₂/hypoventilation in surgical patients age 60 years and over, the following limitations exist: differences in patient groups (age, co-morbidities), surgical and anesthesia type and the complexities of the transcutaneous monitoring technology especially related to placement, calibration and maintenance of the limits the applicability of these findings to all adult peri-procedural patients.

De Oliveira, Jr. et al (2010) conducted a prospective, blinded, observational correlational study (DHHS & Oxford Level 3) that included 40 healthy females undergoing hysteroscopy with monitored anesthesia/sedation (MAC) at a tertiary care hospital. Both noninvasive Co₂ monitoring systems (PETCo₂ & TcPCo₂) and arterial blood gas sampling (PaCo₂) were employed to permit simultaneous comparison of results obtained from the same group of subjects. The intent was to determine which non-invasive modality most accurately identified hypoventilation resulting in hypercarbia as defined as a value of PaCo₂ > 6.65 kPa. For the non-invasive monitoring modalities, the mean absolute difference between PaCo₂ & TcPCo₂ was 0.43 compared to the absolute mean difference between the PaCo₂ & PETCo₂ ($p=0.002$); the mean bias of TcPCo₂ & PaCo₂ = 0.23 (CI, 0.07 to 0.4) and the mean bias of PETCo₂ & PaCo₂ = -0.93 (CI, -1.24 to 0.63). Overall, twelve of the subjects demonstrated PaCo₂ values > 6.65 kPa. Of this group, TcPCo₂ recorded values >6.65 kPa in 8 of the 12 where PETCo₂ identified a PaCo₂ > 6.65 kPa in only 1 of the 12 subjects. These statistically significant results support

the conclusion that transcutaneous Co₂ monitoring provided a more accurate estimation of PaCo₂ (measure of ventilatory adequacy) and was more likely to identify hypercarbia/hypoventilation in healthy females undergoing MAC anesthesia than is PETCo₂ monitoring.

Once again, this study design did not provide for a control group – testing of both noninvasive Co₂ systems and comparison against arterial blood samples was conducted concurrently on the same study group. Although the patient group in this study was homogeneous for gender, type of surgery and anesthesia, and ASA score, the study sample was one of convenience. A power analysis with sample size calculation using the PASS 2008 identifying an $n = 40$ to achieve an 80% power to detect a difference of 1.06kPa between the two noninvasive modalities was utilized. It was unclear what, if any, additional measures to promote internal & external validity and control of confounding variables were employed beyond anesthesia provider blinding to the use of TcPCo₂ and attempts to assure group homogeneity. A thorough discussion of appropriate descriptive and inferential statistical analysis with clear description of quantitative results was provided by the author. While the results of this study did support that TcCo₂ monitoring was a more accurate measure of arterial Co₂ level and more accurately identified hypercarbia related to hypoventilation in adult, female surgical patients, the following limitations exist: differences in patient groups (age range, co-morbidities), surgical and anesthesia type and the complexities of the transcutaneous monitoring technology especially related to placement, calibration and maintenance of the device limits the applicability of these findings to all adult peri-procedural patients.

Griffin, J. et al (2003) conducted a prospective, observational correlational study (DHHS & Oxford Level 3) that included 30 adults [7 men/23 females; age 18-54 years; BMI > 40] undergoing open vertical ringed gastric bypass roux en y procedure under general anesthesia with tracheal intubation in an acute care hospital. Both TcPO₂ and PETCo₂ modalities were utilized with the intent to compare the accuracy of the non invasive measures in estimating the PaCo₂. The results of the absolute difference analysis of the TcPCo₂:PaCo₂ measurements versus the PETCo₂:PaCo₂ measurements were as follows: the TcPCo₂ was closer to the arterial Co₂ in 25 out of 30 patients. The PETCo₂ was closer to the arterial Co₂ in 4 out of 30 patients and for 1 out of 30 patients, the results were equivocal. Further, the absolute difference between the PETCo₂ and the TcPCo₂ measurements were also compared when the differences in the non-invasive measurements differed from the actual arterial Co₂ by 0.5kPa and 10kPa. The average data set analysis indicated that: 90% of TcCo₂ readings were 0.5kPa or less from the PaCo₂ value. 30% of PETCo₂ readings were 0.5kPa or less from the PaCo₂ value ($p < 0.00025$) and 100% of TcCo₂ readings were 1.0kPa or less from the PaCo₂ value ($p < 0.05$). These statistically significant results support the conclusion that noninvasive TcCO₂ monitoring was a more accurate measure of arterial Co₂ (as a measure of ventilatory adequacy) than PETCo₂ in adult patients with a BMI > 40.

This study design did not provide for a control group. Testing of TcCo₂ and PETCo₂ modalities were conducted concurrently on the same group of subjects. The study patients were selected via convenience sampling and were homogenous only in regard to procedure, anesthesia and cut point of BMI >40. It was not clear if additional measures were taken to control for confounding variables. Appropriate descriptive statistical testing with analysis and results were described by the author. Again, while the results of this study does support that TcCO₂ monitoring was a more accurate measure of PaCo₂/hypoventilation in a mixed group of adult patients with a BMI >40 undergoing gastric bypass, the following limitations exist: differences in patient groups (age, co-morbidities), surgical and anesthesia type and the complexities of the transcutaneous monitoring technology especially related to placement, calibration and maintenance of the device limits the applicability of these findings to all adult peri-procedural patients.

Conclusion/Clinical Bottom Line:

The resultant data supports the conclusion that transcutaneous Co₂ monitoring provides a more accurate estimate of arterial Co₂ levels compared to end-tidal Co₂ monitoring within the subject parameters as defined for each study. However, selection of the subjects in each of these sample groups was specifically defined based on characteristics such as demographics (age/sex), co-morbidity, surgical procedure or anesthesia type and, as such, it cannot be assumed that the results are generalizable to all adult peri-procedural patients. Further, as factors other than arterial Co₂ levels effect ventilatory adequacy, there was insufficient evidence to support that TcPCo₂ monitoring was more accurate in identifying hypoventilation than PETCo₂ monitoring. Randomized controlled trials are needed not only to compare the accuracy of non-invasive Co₂ estimates to arterial Co₂ levels in a wider variety of adult peri-procedural patients but are also needed to evaluate the accuracy of TcPCo₂ monitoring in identifying hypoventilation which results in hypercarbia.

References

- Casati, A., Squicciarini, G., Malagutti, G., Bariarello, M., Putzu, M., & Fanelli, A. (2006). Transcutaneous monitoring of partial pressure of carbon dioxide in the elderly patient: a prospective, clinical comparison with end-tidal monitoring. *Journal of Clinical Anesthesia, 18*(6), 436-440. <http://dx.doi.org/10.1016/j.jclinane.2006.02.007>
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