How useful is transcutaneous carbon dioxide monitoring in the adult emergency department?

在成人急症室中，經皮二氧化碳監測的效用如何？

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Transcutaneous carbon dioxide ($PtCO_2$) monitoring offers a potential non-invasive and continuous means to determine the arterial carbon dioxide tension ($PaCO_2$). Studies investigating the use of $PtCO_2$ monitoring in the adult emergency department (ED) are limited. To date, the lack of ED studies, especially those looking at clinical outcome and treatment alteration, some technical and cost limitations make it difficult to recommend widespread use of $PtCO_2$ monitoring in the ED. However, there is a potential future use of $PtCO_2$ monitoring in combination with peripheral venous blood gas (pVBG) values in ED patients with acute exacerbations of chronic obstructive pulmonary disease. (*Hong Kong j.emerg.med.* 2010;17:82-84)

經皮二氧化碳監測提供一個有潛力的非入侵性及連續性的方法，去確定動脈二氧化碳的張力。在成人急症室中，調查使用經皮二氧化碳監測的研究很少。至目前為止，急症室研究的缺乏，尤其是調查臨床結果及改變治療的研究、一些技術上及成本上的限制，令急症室廣泛使用經皮二氧化碳監測有困難。然而，在急症室慢性阻塞肺病急性惡化的病人中，經皮二氧化碳監測聯同周邊靜脈血液氣體的數值，將來可能是有效用的。

Keywords: Carbon dioxide, transcutaneous monitoring

關鍵詞：二氧化碳、經皮監測

Transcutaneous carbon dioxide ($PtCO_2$) monitoring offers a potential non-invasive and continuous means to determine arterial carbon dioxide tension ($PaCO_2$). It was first developed in the 1970s in the neonatal intensive care setting to reduce arterial sampling.[1] The $PtCO_2$ monitor uses a thermostatically controlled heater unit that works on the principle that a heating element in the electrode elevates the temperature of the underlying skin. Under stable hemodynamic conditions, this increases the capillary blood flow and makes the skin permeable to CO_2 diffusion. This enables it to measure the CO_2 tension of the underlying skin tissue.[2] Figure 1 is a picture of the TOSCA™ 500 model of $PtCO_2$ monitor.

A number of studies have since reported good agreement between $PtCO_2$ and $PaCO_2$ values using Bland Altman analysis[3-4] in various adult patient populations in the general ward, sleep study unit, respiratory care unit with non-invasive ventilation, critical care unit and operating theatre.[5-11]

Studies investigating the use of $PtCO_2$ monitoring in the adult emergency department (ED) are limited. To date, there are only two prospective ED trials investigating $PtCO_2$ monitoring. Kelly et al[12] compared

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Figure 1. TOSCA™ 500 monitor (Reproduced from [McVicar J, Eager R. Validation study of a transcutaneous carbon dioxide monitor in patients in the emergency department. Emerg Med J 2009;26(5):344-6] with permission from BMJ Publishing Group Ltd.)

the agreement between $PtCO_2$ and $PaCO_2$ values amongst ED patients who required an arterial blood gas (ABG) as judged by their treating physician and performed subgroup analysis based on capillary return time of >2s or <2s respectively. They reported the 95% limits of agreement of ±40 mmHg and ±11.8 mmHg in the groups with capillary return time of >2s and <2s respectively and concluded that $PtCO_2$ measurements are unreliable in patients with low perfusion states. That study was published in 1991 and used older technology than what is available today. McVicar and Eager[13] studied an ED population and reported a mean difference between the two measurements of 0.15 mmHg and 95% limits of agreement of ±6.84 mmHg. There were, however, some important limitations of their study. The sample size was relatively small (n=49) and not representative of the broad ED patient population. Patients were included only if they could give informed consent which might have excluded patients with higher degrees of hypercarbia. Also, a five minute lapse time from application of the monitor to arterial blood sampling was used in the study. Although this lapse time was more reflective of practical ED need for rapid information, it could affect the equilibration of the $PtCO_2$ monitor which usually takes 10-20 minutes.[2]

In addition to the lack of ED studies on $PtCO_2$ monitoring, we have identified other considerations that would need to be addressed before it can be adopted for widespread ED use. Studies to date, both within or outside ED, have not investigated the impact of $PtCO_2$ monitoring on treatment alteration and clinical outcome of patients with hypercarbia. The clinical decision-making process in such ED patients is likely a result of a combination of factors including clinical assessment, clinician's judgement of disease progression or improvement and the use of other laboratory or radiological investigations. Further, there is information within a blood gas analysis (e.g. pH and HCO_3) which can detect a mixed acid-base disorder in patients with suspected hypercarbia.

It is also important to know the potential technical limitations of the specific $PtCO_2$ monitor. In addition to the need for an equilibration time of 10-20 minutes[2] upon initial application of the electrode on the patient, there are other technical drawbacks. These include the need for frequent (varying from once in 4 to 12 hours) re-calibration and changing of sites of placement to prevent burns or blistering of the skin, technical inaccuracies arising from trapped air bubbles, damaged electrode membranes and improper calibration or placement techniques[14] and the 'drift' phenomenon. The 'drift' phenomenon refers to the variation of $PtCO_2$ values with time. Although the newer $PtCO_2$ monitors with optical sensors are less affected by the drift phenomenon,[15] it differs among the electrochemical models and can be up to 5% over four hours.[16] Drift can affect the agreement between $PtCO_2$ and $PaCO_2$ values. Storre et al[6] reported a drift of 1.3 mmHg/hr over four hours that changed the limits of agreement from -1.7 to 7.5 mmHg to -3.9 to 13.2 mmHg between drift corrected and drift uncorrected values respectively. This may affect the usefulness of $PtCO_2$ monitoring in the ED over prolonged periods of time. In addition, further limitations arise because the $PtCO_2$ monitor does not contact expired air. It measures carbon dioxide tension in tissues overlying a capillary bed. Hence, unlike end tidal CO_2, it cannot be used to confirm the intra-tracheal placement of the endotracheal tube or to detect ventilator disconnection. Also, its use in haemodynamically compromised

patients with poor capillary refill appears to be unreliable.[12,16] Finally, $PtCO_2$ monitoring is expensive and cost issues may limit its widespread use. McVicar et al[13] estimated the cost of the TOSCA™ 500 model of $PtCO_2$ monitor to be in the region of £7000 (US$10,700).

We have identified a potential future use of $PtCO_2$ monitoring in combination with peripheral venous blood gas (pVBG) values in ED patients with acute exacerbations of chronic obstructive pulmonary disease (AECOPD). Studies[17,18] have reported good agreement between arterial and pVBG values for pH and HCO_3 in ED respiratory patients requiring an ABG, including those with AECOPD. $PtCO_2$ and pVBG can complement each other in such patients. $PtCO_2$ values, with their good agreement with $PaCO_2$ values, can help to monitor for improvement or deterioration of their ventilatory status. In addition, pH and HCO_3 values in pVBG analyses in these patients can give insight to a concomitant metabolic acidosis. This, however, will require validation studies.

To date, the lack of ED studies, especially those looking at clinical outcome and treatment alteration, some technical and cost limitations make it difficult to recommend widespread use of $PtCO_2$ monitoring in the ED. Its future use in combination with pVBG remains to be validated.

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