SOME OBSERVATIONS ON THE USE OF THE NUNN BLOOD GAS PREDICTOR

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THE RELATIONSHIP between ventilation and the arterial pH and $p\text{CO}_2$ of healthy patients has sometimes been portrayed, together with other relevant factors, in the form of a nomogram. The use of one of these facilitates the adjustment of ventilation required to produce a desired pH and $p\text{CO}_2$, or assessment of the probable effects of existing ventilation. In 1955 Radford published a nomogram designed primarily for conscious paralysed patients and with comments on its use in other circumstances. These have been elaborated by Scurr,² Nunn,³ and Gain.⁴ Other nomograms have been presented for use in anaesthesia by Engstrom,^{5,6} and Nunn has described a blood gas predictor in the form of a slide rule.⁷ The predictions of the latter are based on the body weight, sex, metabolic rate, and ventilation of the patient. The alveolar ventilation is calculated as 0.7 of the minute volume, and the pH prediction is based on the Henderson-Hasselbalch equation. No correction for intubation is considered necessary. Some experiences with its use are reported here.

Forty healthy normothermic patients undergoing extrathoracic surgery, having been premedicated with morphine or meperidine and atropine, were induced with thiopentone and succinylcholine, intubated, and maintained under anaesthesia with a 2 L/min flow of nitrous oxide and oxygen 1 L, carrying methoxyflurane 0.75–1.0 per cent into a semi-closed circle system. BOC machines with Foregger Jumbo carbon dioxide absorbers and Jefferson ventilators were used. Ventilation was maintained at a constant rate and volume, the former varying between 12 and 20/min, the latter selected at random and measured with a Wright anemometer. Systemic blood pressure remained stable at near normal values and transfusions were not given. After an hour of stable ventilation the pH and $p\text{CO}_2$ of arterial samples were measured with minimal delay using an AME I Astrup micro-equipment pH meter and a Sigaard Anderson and Engel nomogram.

The true ventilation minute volume was taken as the anemometer reading reduced by 10 per cent as compensation for expansion of corrugated tubing. The alveolar ventilation was calculated as 0.7 of the minute volume.³ It was assumed that patients under these conditions had their metabolism reduced to 85 per cent of normal and this, together with the minute volume, sex, and body weight, was used to predict the $p\text{CO}_2$ and pH with the slide rule.

The results (Table I) are considered here from two aspects: first, the difference between the predicted values and those obtained from arterial blood samples, secondly, the usefulness of the slide rule in predicting the ventilation necessary to maintain a $p\text{CO}_2$ at approximately 40 mm Hg. The predicted $p\text{CO}_2$ was

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TABLE I

		Prediction using minute volume	Prediction using alveolar ventilation
Difference between predicted and measured pH	Average mean	+0.10	+0.11
	Standard deviation	0.05	0.046
	Standard error of mean	0.008	0.007
		$p < 0.001$	< 0.001
Difference between predicted and measured $p\text{CO}_2$	Average mean	-1.95	-2.8
	Standard deviation	4.05	4.19
	Standard error of mean	0.64	0.66
		$p < 0.001$	< 0.001

FIGURE 1 Percentage value of tidal volume used against the predicted volume necessary to maintain $p\text{CO}_2$ at 40.0 mm Hg (ordinate) versus the difference between the predicted pH, based on minute volume, and measured value from arterial blood (abscissa)

always lower than the measured value. The variation in difference could not be correlated with body weight, sex, or with rate of ventilation. However, an approximately linear relationship with the degree of hyperventilation could be demonstrated (Figs 1, 2). The hyperventilation was calculated as the percentage of the predicted value necessary to maintain a $p\text{CO}_2$ of 40 mm Hg, and as hyperventilation was increased so the measured $p\text{CO}_2$ was progressively higher than the predicted value.

It was found that to maintain a $p\text{CO}_2$ of 35–45 mm Hg, ventilation had to be increased to 105–130 per cent of the value predicted as necessary to maintain a $p\text{CO}_2$ of 40 mm Hg.

FIGURE 2 Percentage value of tidal volume used against the predicted volume needed to maintain a $p\text{CO}_2$ of 40.0 mm Hg (ordinate) versus the difference between the predicted $p\text{CO}_2$, based on minute volume, and measured value from arterial blood (abscissa)

A number of reasons, such as errors in the technique of blood gas analysis or measurement of ventilation, may account for these variations. It is considered

unlikely that there was an increasing distension of the corrugated tubing with hyperventilation because muscle relaxants were used to produce maximum pulmonary compliance and there was considerable variation in pressures required to produce similar ventilation in different patients. More probable reasons are an increase in physiological dead space above that used in the design of the predictor, and in carbon dioxide output. Methoxyflurane has been reported as responsible for only a slight trend towards metabolic acidosis⁹ or failure to disturb it significantly¹⁰. However, specific effects of this drug may in part account for the increase in ventilation above that predicted on the slide rule, which was required to maintain a $p\text{CO}_2$ at approximately 40 mm Hg.

Nunn has carefully outlined the sources of error in the use of this predictor and emphasized that it indicates what the $p\text{CO}_2$ might reasonably be expected to be and not what it is. The findings presented here suggest that this is indeed so and that, when used in the manner described, the predictor will read low for $p\text{CO}_2$ and high for pH, particularly if a hyperventilation technique is being used. The experienced anaesthetist can provide adequate ventilation in uncomplicated cases without recourse to a nomogram or blood gas analysis.⁴ The value of the Nunn predictor lies in the fact that it encourages the anaesthetist in training to correlate, in a normal case, the clinical signs of ventilation with what the $p\text{CO}_2$ and pH might possibly be, and it provides a clinical standard of ventilation for reference purposes.

SUMMARY

In 1962 Nunn described a predictor for arterial $p\text{CO}_2$ and pH. This was in the form of a slide rule and its function was based on the patient's weight, sex, metabolic rate, and ventilation. A clinical investigation of 40 healthy patients undergoing extrathoracic surgery was performed. The anaesthetic technique consisted of thiopentone, nitrous oxide, methoxyflurane, relaxant, and artificial ventilation. After one hour predicted values of $p\text{CO}_2$ and pH were compared with those measured from arterial blood samples. The predicted $p\text{CO}_2$ was always lower than the measured value, and the difference increased with the degree of hyperventilation. It was found that to maintain a $p\text{CO}_2$ of 35–45 mm Hg ventilation had to be increased to 105–130 per cent of the value predicted necessary to maintain a $p\text{CO}_2$ of 40 mm Hg. These findings were considered to be mainly due to an increase in physiological dead space, and an increase in carbon dioxide production during methoxyflurane anaesthesia.

RÉSUMÉ

En 1962, Nunn a mis au point un appareil pouvant renseigner sur la $p\text{CO}_2$ et le pH du sang artériel. Cet appareil ressemble à une règle à calcul, et son fonctionnement est basé sur le poids, le sexe, le métabolisme basal et la ventilation du malade. Nous avons fait des recherches cliniques chez 40 sujets sains qui devaient subir de la chirurgie extrathoracique. Nous avons utilisé la technique suivante : pentothal, protoxyde d'azote, méthoxyflurane, myorésolutif et ventilation artificielle. Au bout d'une heure d'anesthésie, nous avons comparé les don-

nées prédites par la règle à calcul de la $p\text{CO}_2$ et du pH avec celles qui avaient été obtenues sur des échantillons de sang artériel. La $p\text{CO}_2$ prédite était toujours inférieure à la $p\text{CO}_2$ mesurée. La différence augmentait avec l'importance de l'hyperventilation. Nous avons compris que pour maintenir une $p\text{CO}_2$ de 35 à 45 mm de mercure, il fallait augmenter la ventilation de 105 à 130 pour cent de la valeur nécessaire prédite pour maintenir une $p\text{CO}_2$ à 40 mm de mercure. Ces résultats seraient attribuables en grande partie à l'augmentation de l'espace mort physiologique et à l'augmentation de la production du CO_2 au cours de l'anesthésie au méthoxyflurane.

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