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Continuous intra-arterial blood gas monitoring during oesophagectomy

Purpose: To evaluate the clinical usefulness of the continuous intra-arterial blood gas (CIABG) monitoring system, Paratrend 7™, during differential lung ventilation (DLV) in 12 patients undergoing oesophagectomy.

Methods: Anaesthesia was induced with propofol and was maintained with isoflurane, oxygen and air, supplemented by an epidural infusion of mepivacaine. Arterial samples for estimation of blood gases (ABG) were taken just before and 5, 10, 20, 30, 60, and 90 min after the pleura was opened. The pH, PO_2, and PCO_2 values displayed by the CIABG monitor, which were recorded prior to the arterial blood sampling, were compared with the results of ABG analysis.

Results: Eighty-four blood samples were obtained and the ranges for the measured variables were PCO_2 24.8-57.4 mmHg, PO_2 47–449 mmHg, and pH 7.30–7.49. The correlation between CIABG and ABG measurements was strong and significant (r values : PCO_2 0.80, PO_2 0.93, pH 0.94). The overall bias ± precision between the two methods was PCO_2 0.9 ± 3.1 mmHg, PO_2 –1 ± 40 mmHg, %PO_2 0.8 ± 21.6 %, pH 0.00 ± 0.02. For PO_2 values < 150 mmHg, the biases ± precision were PO_2 –5 ± 17 mmHg, %PO_2 –2.1 ± 20.7%.

Conclusion: The agreement between CIABG and ABG measurements was better for PCO_2 and pH than for PO_2. Although the CIABG system is clinically useful for monitoring trends in blood gas changes, the accuracy of the PO_2 value may be unacceptable during DLV because the error is theoretically < 34 mmHg with 95% reliability in the clinically important range of PO_2, < 150 mmHg.

Objectif : Évaluer l'utilité clinique du système de monitorage continu des gaz sanguins par voie intra-artérielle (CIABG), Paratrend 7®, durant la ventilation à un poumon chez 12 patients subissant une oesophagectomie.

Méthodes : Après induction au propofol, l'anesthésie a été maintenue à l'isoflurane avec air et oxygène, complétée d'une infusion péridurale de mépivacaïne. Des gaz artériels (ABG) ont été prélevés immédiatement avant l'ouverture de la plèvre de même qu'à 5, 10, 20, 30, 60 et 90 min après son ouverture. Les valeurs du pH, PO_2 et PCO_2 indiquées par le système de monitorage (CIABG), et enregistrées avant l'échantillonnage artériel, ont été comparées avec celles des gaz artériels.

Résultats : Quatre-vingt-quatre échantillons sanguins ont été prélevés et l'éventail des variables mesurées a été: PCO_2 24,8–57,4 mmHg, PO_2 47–449 mmHg et pH 7,30–7,49. La corrélation entre les mesures effectuées par CIABG et celles effectuées par ABG a été très bonne et significative (valeurs de r: PCO_2 0,8, PO2 0,93, pH 0,94). La tendance globale ± la précision entre les deux méthodes a été: PCO_2 0,9 ± 3,1 mmHg, PO_2 -1 ± 40 mmHg, % PO_2 0,8 ± 21,6%, pH 0,00 ± 0,02. Pour des valeurs de PO_2<150 mmHg, la tendance ± la précision ont été pour la PO_2 de -5 ± 17 mmHg et pour le % PO_2 de -2,1 ± 20,7%.

Conclusion : La concordance entre les mesures par CIABG et celles par ABG était meilleure pour la PCO_2 et le pH que pour la PO_2. Même si le système CIABG est utile cliniquement pour la surveillance des tendances de variations des gaz sanguins, la précision des valeurs de PO_2 peut être inacceptable durant la ventilation à un poumon parce que l'erreur est théoriquement de < 34 mmHg avec 95% de fiabilité dans la gamme de PO_2 cliniquement importante soit < 150 mmHg.

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Accepted for publication November 29, 1997.

THE Paratrend 7™ (Pfizer Biomedical Sensors, UK), the only continuous intra-arterial blood gas (CIABG) monitoring system commercially available, is a multiparameter intravascular sensor system for on-line continuous measurement of pH, PCO_2, PO_2 and temperature. The objective of the present study was to evaluate the clinical usefulness of the CIABG system during oesophagectomy with differential lung ventilation (DLV).

Materials and methods

Of 13 patients scheduled to undergo oesophagectomy with right thoracotomy, 12 with ASA physical status 1 or 2 were included in this study. One patient with pneumonia who may have required two-lung ventilation was excluded. The study was approved by the University's Ethical Committee and informed consent was obtained from all patients.

Anaesthesia was induced with 2 $mg \cdot kg^{-1}$ propofol *iv* and was maintained with isoflurane 0.5-1.5%, oxygen and air (FIO_2 = 0.8), supplemented by a continuous epidural infusion of mepivacaine. Tracheal intubation was facilitated with 0.2 $mg \cdot kg^{-1}$ vecuronium *iv* and a left-sided double-lumen endotracheal tube (Broncho-cath®, Mallinckrodt Inc, Argyle, NY) was used for DLV.

The intravascular sensor was advanced through a 20-gauge arterial catheter placed in the radial artery to a length of 15 cm. The monitoring system was calibrated to the conventional blood gas analysis according to the manufacturer's recommendation. The data collected by the monitoring system were corrected to the corresponding values at 37°C.

Just before the pleura was opened, one-lung ventilation was commenced. The dependent lung was ventilated with a tidal volume of 6–8 $ml \cdot kg^{-1}$ and the respiratory rate was increased by 20–50% to keep $PaCO_2$ at approximately 40 mmHg. If severe hypoxaemia (SpO_2 ≤90%) was recognised during one-lung ventilation, major causes of hypoxaemia (e.g., double-lumen tube malposition, poor haemodynamic status) were eliminated and, if required, differential lung CPAP/PEEP and/or intermittent non-dependent lung ventilation[1] were performed. The monitoring system was recalibrated at the beginning of the intra-abdominal procedure (reconstruction using the stomach) in the supine position. The lungs were ventilated at a constant tidal volume (VT = 10 $ml \cdot kg^{-1}$) using an FIO_2 of 0.5. The respiratory rate was adjusted to maintain normocapnia.

Arterial blood for conventional blood gas analyses (ABG) was sampled and analysed without delay on a laboratory blood gas analyser (STAT Profile 5™ gas analyser, NOVA Biomedical, USA) just before the pleura was opened, and 5, 10, 20, 30, 60, and 90 min after opening the chest and 30, 60, 90, and 120 min after abdominal surgery was started. Just before arterial blood sampling, the CIABG data were recorded for the comparison with ABG data using a correlation analysis and the method of Bland and Altman.[2]

Results

The ranges of the ABG variables were PCO_2: 24.8–57.4 mmHg and 30.3–46.6 mmHg, PO_2: 47–449 mmHg and 72–255 mmHg, and pH: 7.30–7.49 and 7.34–7.47, respectively (thoracic and abdominal). In the early stage of DLV, the PaO_2 decreased abruptly from 386 ± 49 mmHg to 172 ± 84 mmHg and remained at approximately 150–200 mmHg thereafter.

The correlation between CIABG and ABG measurements was strong and significant for each parameter. The precision of the % PO_2 measurements was twice as great in the thoracic part of the operation as in the abdominal part (Table I).

The % bias and the % precision of the PO_2 measurements were markedly increased at five minutes after opening the chest, however these changes were temporary. The % precision of the PO_2 data collected during the latter part of the thoracic procedure was approximately twice as great as that of the data collected during the abdominal procedure (Table II). Two sensors showed signs of the formation of clots covering the sensor tip[3] during intra-abdominal procedure but such signs were not found in any patient during the intra-thoracic procedure.

Discussion

We have assessed the agreement between CIABG and ABG data by utilising the method of Bland and Altman.[2] The bias and the precision values of PCO_2 and pH during DLV in the present study were similar to those reported in other situations such as intensive care[4] and open heart surgery.[5] As the lungs of our patients were ventilated to maintain $PaCO_2$ at approximately 40 mmHg, dynamic changes in the $PaCO_2$ or pH were not observed during DLV. Adjusting the respiratory rate to keep the $PaCO_2$ constant may have resulted in acceptable accuracy in the $PaCO_2$ and pH measurements.

Although the bias of each parameter was within acceptable limits,[6] the precision of the PO_2 values during the intra-thoracic procedure was larger than the precision in published reports[4,5] as well as being larger than that during the intra-abdominal procedure in our study. Even in the clinically important range of PO_2, < 150 mmHg, the error will be theoretically < 34 mmHg with

TABLE I Statistical comparison of the continuous intra-arterial blood gas monitoring values with simultaneous arterial blood gas analysis.

	PCO_2 (mmHg)	PO_2 (mmHg)	pH (pH unit)	$\%PO_2$ (%)	$PO_2 < 150$ mmHg (mmHg)	$\%PO_2$ ($PO_2 < 150$ mmHg) (%)
Thoracic part						
Linear regression						
Slope	0.71	0.96	1.07			
Intercept	12.67	6.60	-0.53			
Pearson's r value	0.80	0.93	0.94			
P	< 0.001	< 0.001	< 0.001			
Bias	0.9	-1	0.00	0.8	-5	-2.1
Precision	3.1	40	0.02	21.6	17	20.7
Abdominal part						
Linear regression						
Slope	0.67	1.02	0.80			
Intercept	12.29	-4.13	1.50			
Pearson's r value	0.61	0.87	0.59			
P	< 0.001	< 0.001	< 0.001			
Bias	0.6	0	-0.01	-0.2		
Precision	3.1	21	0.04	11.8		

TABLE II Sequential changes of the bias and the precision between the continuous intra-arterial blood gas monitoring and the arterial blood gas analysis.

		Base line	*T5*	*T10*	*T20*	*T30*	*T60*	*T90*	*A30*	*A60*	*A90*	*A120*
PCO_2	bias	0.5	1.7	1.1	0.6	0.3	1.3	0.8	0.2	0.5	1.0	0.7
	precision	2.3	4.9	2.3	4.0	2.8	2.4	3.0	2.8	3.1	3.4	3.4
$\%PO_2$	bias	1.6	22.8	4.4	-3.1	-2.1	-10.6	-7.5	-0.2	0.8	-1.4	0.1
	precision	8.9	27.2	12.3	12.1	24.7	21.2	23.6	9.3	14.3	11.9	12.5
pH	bias	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.01	-0.02	-0.03
	precision	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.04	0.05

Base line, T5, T10, T20, T30, T60, T90; Just before and 5, 10, 20, 30, 60, 90 min after opening the pleura.
A30, A60, A90, A120; 30, 60, 90, 120 min after starting the abdominal part of the surgery.

95% reliability, suggesting that the true PO_2 may be in the range of plus or minus 34 mmHg of the monitored PO_2 (PO_2 (P7)). Although the strong correlation between CIABG and ABG for each parameter indicates that the CIABG system is clinically useful for monitoring trends in blood gas changes, the accuracy of the PO_2 (P7) value may be unacceptable during DLV.

The precision of the PO_2 measurements made during DLV may have been influenced by the response time of the sensor. Venkatesh *et al.*[4] measured the 90% response time for PO_2 and estimated that it was 70 sec, suggesting that it takes more than one to two minutes for CIABG readings to equilibrate to the true PaO_2 when PaO_2 changes rapidly such as the change in the FIO_2 and maybe during DLV. The large bias in the PO_2 data in the initial stage of one-lung ventilation may also be a result of the slow response time of the sensor. The PaO_2 is largely reduced after the induction of one-lung ventilation, so PO_2 (P7) also decreases after the change in the true PaO_2.

In conclusion, the agreement of data between CIABG and ABG was acceptable for pH and PCO_2. The accuracy of the PO_2 value of the CIABG system may be unacceptable due to the slow response time of the sensor when arterial blood gas values are rapidly fluctuating, although the strong correlation between CIABG and ABG data suggests that the CIABG system is clinically useful for monitoring trends in blood gas changes. Occasional blood sampling may be required for checking CIABG monitoring during DLV.

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