Intensive Care Med (2002) 28:870–876
DOI 10.1007/s00134-002-1323-5

ORIGINAL

S. McLellan
T. Walsh
A. Burdess
A. Lee

Comparison between the Datex-Ohmeda M-COVX metabolic monitor and the Deltatrac II in mechanically ventilated patients

Received: 30 May 2001
Accepted: 2 April 2002
Published online: 15 June 2002

No support to declare

S. McLellan (✉) · T. Walsh · A. Burdess
A. Lee
Department of Anaesthetics,
Critical Care & Pain Medicine,
Royal Infirmary of Edinburgh,
Edinburgh EH3 9YW, Scotland, UK
e-mail: stu.mclellan@ed.ac.uk
Tel.: +44-31-5363652
Fax: +44-31-5363672

Abstract *Objective:* To compare the M-COVX and the Deltatrac II metabolic monitors under clinical conditions. *Design:* Prospective clinical comparison. *Setting:* A general Intensive Care Unit of a university hospital. *Patients:* Twenty mechanically ventilated critically ill patients. *Interventions:* The monitors were compared at FiO_2 0.3, 0.5, and 0.7 in each patient where possible. *Measurements and results:* Pulmonary gas exchange measurements were recorded using the two monitors sequentially ($Deltatrac_{before}$, M-COVX, $Deltatrac_{after}$). Each measurement consisted of five consecutive 1-min readings of VO_2 and VCO_2. We compared the $Deltatrac_{before}$ with the $Deltatrac_{after}$ and the mean of the Deltatrac with the M-COVX. There was no clinically significant bias between the two monitors for VO_2 or VCO_2 but the limits of agreement (LOA) were wide (bias ±95% LOA: VCO_2 –13±30 ml/min, –8±36 ml/min, 7±50 ml/min; VO_2 –7±50 ml/min, –5±56 ml/min, 6±64 ml/min, at FiO_2 0.3, 0.5, and 0.7, respectively). The Deltatrac before and after measurements displayed good agreement for VCO_2 but poorer agreement for VO_2 (bias±95% LOA: VCO_2 0±18 ml/min, –6±16 ml/min, –1±12 ml/min; VO_2 2±12 ml/min, 3±38 ml/min, 10±42 ml/min, at FiO_2 0.3, 0.5, and 0.7, respectively). Using within-patient standard deviation as a measure of reproducibility suggested that for VO_2 the M-COVX performed better than the Deltatrac at high FiO_2, and for VCO_2 Deltatrac was better at lower FiO_2. *Conclusions:* The M-COVX is a suitable integrated device for measuring metabolic gas exchange in ventilated patients.

Keywords Pulmonary gas exchange · Indirect calorimetry · Oxygen consumption · Carbon dioxide/metabolism · Reproducibility of results · Artificial respiration

Introduction

Measurement of respiratory gas exchange in the Intensive Care Unit (ICU) has become feasible due to the development of automated instruments. Direct gas exchange measurements to assess metabolism are desirable because pulmonary artery catheter calculations are often inaccurate [1]. Clinical applications vary from the assessment of energy expenditure to the comprehensive analysis of ventilation and oxygen transport in critically ill patients. The accurate measurement of respiratory gas exchange in the critically ill mechanically ventilated patient poses several problems that include high-inspired oxygen concentrations, leaks resulting from positive airway pressures, and humidity [2, 3, 4, 5, 6, 7].

Most metabolic monitors are bulky, expensive, and do not integrate with ICU monitoring systems. We set out to evaluate a new compact modular metabolic monitor, the M-COVX (Datex-Ohmeda, Helsinki, Finland), in clinical conditions by comparing it to the Deltatrac II, which has been validated for use in the critically ill [8, 9].

Materials and methods

Patients

The study was approved by the regional hospital Ethics Committee. Twenty patients were studied after informed assent was obtained from the next of kin. All patients were receiving mechanical ventilation with a FiO_2 ≤0.5 using a Drager Evita ventilator with active humidification.

All patients were receiving sedation (either an infusion of propofol or alfentanil, or both). Patients were clinically stable before observations were made, arbitrarily defined as less than 20% variation in heart rate, arterial pressure, central venous pressure, and arterial oxygen saturation over a 30-min period immediately preceding the study.

Deltatrac II metabolic monitor

We compared the new system with the Deltatrac II metabolic monitor, which is an open system indirect calorimeter that can measure oxygen uptake (VO_2) and carbon dioxide elimination (VCO_2) in both mechanically ventilated and spontaneously breathing patients. A thorough description of the technical principles of the Deltatrac can be found elsewhere [9]. Briefly, it consists of an infrared CO_2 analyser, a fast differential paramagnetic O_2 analyser, and a constant flow generator. During mechanical ventilation the Deltatrac is connected to the exhaust port of the ventilator and all the expiratory gas is collected into a mixing chamber. The mixed expiratory gas is then drawn through a fixed-flow generator that entrains air to a total constant flow rate. VCO_2 is calculated by multiplying the constant flow by the fraction of CO_2 in the entrained air/expiratory gas mixture. VO_2 is derived from the respiratory quotient (RQ), which is calculated using the Haldane transformation. The results are expressed as an average of the last 60 s. As the calculations are based on mixed expiratory gas and a significant volume of gas is contained within the mixing chamber and collecting tubing, the results are better regarded as a moving average of the previous 3–5 min; the exact time period is determined by the patient's minute volume.

M-COVX metabolic module

The M-COVX metabolic module is a metabolic monitor designed for use with mechanically ventilated patients only. It has a fast differential paramagnetic O_2 analyser, an infrared analyser for CO_2, and a pneumotachograph to measure inspired and expired volumes. The pneumotachograph and gas sampling ports are housed in a disposable connector, called the D-lite sensor [10]. The D-lite sensor is sited close to the patient, between the Y-piece of the ventilatory circuit and the endotracheal tube. The signals from the pneumotachograph and the gas analysers are synchronised to allow breath-by-breath estimations of gas exchange. The results are expressed as an average of the last 60 s. To make the results less sensitive to errors in volume measurements, the M-COVX monitor uses the Haldane transformation to calculate both VO_2 and VCO_2. It is usual practice to measure expiratory volumes and apply the Haldane transformation to estimate inspiratory volumes (see above with regard to the Deltatrac monitor). Conversely, the M-COVX monitor uses inspiratory volumes, as these are the more reliable measurement; expiratory volumes are dependent upon assumptions of expired temperature (assumed to be 35 °C) and humidity (assumed to be 100%).

Measurements

We planned to perform pulmonary gas exchange measurements at three different values of FiO_2 (FiO_2 0.3, 0.5, and 0.7) where possible. The measurements were conducted at the lowest FiO_2 first, increasing thereafter. The measurements consisted of five consecutive 1-min readings of VO_2 and VCO_2. Data were recorded manually.

The two monitors were used sequentially not simultaneously. The reasons for this are discussed later. To minimise the effect of physiological variability, pulmonary gas exchange measurements were performed first with the Deltatrac, then with the M-COVX, and repeated again with the Deltatrac. This protocol sequence allowed the M-COVX to be compared with the mean of the two Deltatrac measurement periods ($[Deltatrac_{Before} + Deltatrac_{After}]/2$). It also allowed the two data sets obtained with the Deltatrac to be compared as an internal control.

After the sequence Deltatrac, M-COVX, Deltatrac had been completed the FiO_2 was increased. All other ventilator settings were kept constant. At least 10 min were allowed to elapse before additional data were collected to allow steady state to be re-established. The sequence was then repeated at the new FiO_2.

The accuracy of the Deltatrac was checked at the start of the study by a quantitative alcohol-burning test. Before each use the Deltatrac was allowed to warm up for 30 min and then gas and pressure calibrations were performed, according to the manufacturer's instructions.

The M-COVX was ready for use within 5 min of switching it on. Gas calibrations were performed every 6 months as per the manufacturer's instructions.

To attempt to detect any physiological variability over the study period arterial blood gases and plasma lactate concentrations were measured before and after the data collection period. Axillary body temperature was also recorded before and after the study.

Analysis of data

Mean VO_2, VCO_2, and RQ values were calculated for each 5 min measurement period. We compared the agreement between the two monitors using the Bland and Altman technique to estimate the bias and the limits of agreement (LOA) for the mean VO_2, VCO_2, and RQ values [11].

We could not assume that the VO_2 and VCO_2 of individual patients remained constant throughout the study period, so the repeatability of the two monitors could not be assessed since this approach would attribute all differences to measurement error. We therefore compared the reproducibility of the two monitors by comparing the within-patient standard deviation (WPSD) of the VO_2 and VCO_2 measurements. This was possible because all the gas exchange data had been recorded at 1-min intervals. The WPSD was used as a measure of the dispersion of the measurements that resulted from both measurement errors and physiologic variations. Assuming physiologic variability of gas exchange was the same for the two monitors, the ratio of the WPSDs for the two monitors enabled the dispersion attributable to measurement error alone to be compared. The WPSD of VO_2 and VCO_2 was calculated using one-way analysis of variance.

Differences in plasma hydrogen ion concentration (H^+), plasma lactate concentration (lactate), arterial $PaCO_2$, and axillary body temperature at the start and end of the study were compared using the paired *t*-test.

Results

Patients

The clinical features of the patients and ventilatory settings used are shown in Table 1. In most patients

Table 1 Patient demographics, diagnoses, ventilatory settings, and sedation scores. [*RR* respiratory rate, V_T tidal volume, *IPPV* intermittent positive pressure ventilation, *SIMV* synchronised intermittent mandatory ventilation, *ASB* assisted spontaneous breathing (essentially pressure support ventilation)]

Patient number	Age	Sex	Diagnosis	Ventilatory mode	Set respiratory pattern ($RR \times V_T$)	Spontaneous respiratory pattern ($RR \times V_T$)	PEEP	Sedation score[a]
1	15	F	Fulminant hepatic failure	IPPV	15×0.6	0	5	P
2	68	M	Respiratory failure	SIMV	10×0.8	0	10	5
3	82	F	Respiratory failure	IPPV	15×0.7	0	10	P
4	49	M	Pancreatitis	SIMV	10×0.7	0	14	4
5	41	F	Gastro-intestinal bleed	ASB	0	15×0.45	5	5
6	73	M	Pneumonia	ASB	0	30×0.35	6	3
7	40	F	Budd Chiari syndrome	IPPV	10×0.5	0	5	P
8	75	F	Pneumonia	SIMV	6×0.7	0	0	5
9	61	F	Pneumonia	SIMV	10×0.7	14×0.4	7	3
10	64	M	Pneumonia + alcoholic liver disease	IPPV	10×0.7	0	4	P
11	71	F	Left ventricular failure	SIMV	8×0.7	0	8	4
12	22	F	Fulminant hepatic failure	IPPV	10×0.6	0	2	P
13	46	F	Pneumonia	ASB	0	19×0.4	8	5
14	26	M	Fulminant hepatic failure	SIMV	10×0.65	0	3	P
15	27	M	Head injury	SIMV	10×0.8	0	4	5
16	45	F	Fulminant hepatic failure	ASB	0	22×0.4	5	4
17	47	M	Fulminant hepatic failure	IPPV	15×0.8	0	2	P
18	45	F	Fulminant hepatic failure	SIMV	2×0.6	22×0.2	5	2
19	75	F	Abdominal aortic aneurysm repair	SIMV	10×0.6	10×0.3	3	2
20	51	F	Pneumonia	SIMV	14×0.7	0	0	5

[a] Sedation score: 1 agitated, 2 awake, 3 responds to speech, 4 responds to stroke, 5 responds to pain, 6 no response, P paralysed

Table 2 Change in plasma hydrogen ion concentration (H^+), $PaCO_2$, plasma lactate concentration (lactate), and body temperature (axillary) over the study period (change = post-sample – pre-sample). (*NS* not significant)

Patient number	(H^+) mmol/l	$PaCO_2$ kPa	(Lactate) mmol/l	Temperature °C
1	–4	–0.24	0.78	0.2
2	–0.1	–0.2	–0.05	0
3	–0.1	0.12	0.15	0
4	3.4	0.59	0.03	0.2
5	–1.7	–0.34	0.51	–0.1
6	0	–1.25	–0.18	0.4
7	–5.3	–0.35	–0.36	0
10	3.3	0.56	0.06	0.3
11	0.1	–0.03	–0.05	–0.2
12	3.8	0.43	0.06	0.3
13	–1.7	–0.2	0.05	–0.1
14	0.5	0.55	0.09	0.8
15	3.2	0.15	0	0.6
16	–0.4	0.01	–0.08	0.3
17	3.2	0.28	–0.15	0.1
18	3.5	0.9	–0.2	0.2
19	–1.4	–0.76	0.35	0.9
20	2.5	–0.42	0.21	0
Mean	0.49	0.00	0.07	0.22
SD	2.7	0.53	0.27	0.31
P value	NS	NS	NS	0.008

there were only minor changes in (H^+), $PaCO_2$ and (lactate) over the study period, Table 2. A small, but statistically significant, increase in axillary body temperature was observed for the group over the study period, Table 2.

Deltatrac II metabolic monitor calibrations

Burning ethanol can be used to check absolute values of VCO_2 and VO_2 measured with the Deltatrac II monitor. From stoichiometric equations burning 5 ml of 100% ethanol produces 3,820 ml CO_2. We performed 12 quan-

titative ethanol burns as per the manufacturer's instructions. CO_2 production was 3,913±94 ml and RQ was 0.67±0.02 (values represent mean±1 SD).

Agreement between the methods

Four patients were being ventilated with an FiO_2 >0.3 at the time of recruitment to the study. No gas exchange measurements were obtained at FiO_2 0.3 in these cases. Two patients (nos. 8 and 9) were excluded from further analysis because of labile pulmonary gas exchange measurements (>150% variability of VO_2 measurements with the Deltatrac monitor).

Figure 1 illustrates typical results obtained with the measurement protocol in an individual patient at FiO_2 0.3.

Bland and Altman plots for the VCO_2 and VO_2 data are shown in Figs. 2 and 3, respectively. Overall, there was no statistically significant bias between the methods of measurement for VCO_2 or VO_2.

For RQ, the bias±95% limits of agreement were: –0.01±0.1, –0.04±0.18, and –0.03±0.2 for Deltatrac before vs after measurements, and –0.06±0.14, –0.02±0.24, and 0.00±0.28 for Deltatrac mean vs M-COVX measurements, at FiO_2 0.3, 0.5, and 0.7, respectively.

Reproducibility

The WPSD for the VCO_2 and VO_2 measurements made with each monitor are shown in Table 3.

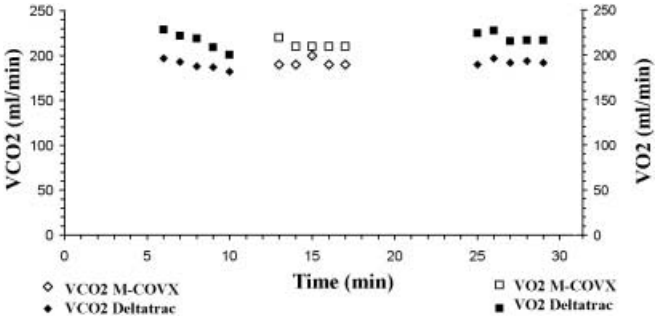

Fig. 1 Diagram of the study protocol performed in an individual patient at FiO_2 0.3. A measurement period was conducted with each monitor; this consisted of five consecutive 1-min readings of VCO_2 and VO_2. The monitors were used in sequence (Deltatrac, M-COVX, Deltatrac) and the sequence was performed at FiO_2 0.3, 0.5, and 0.7 where possible

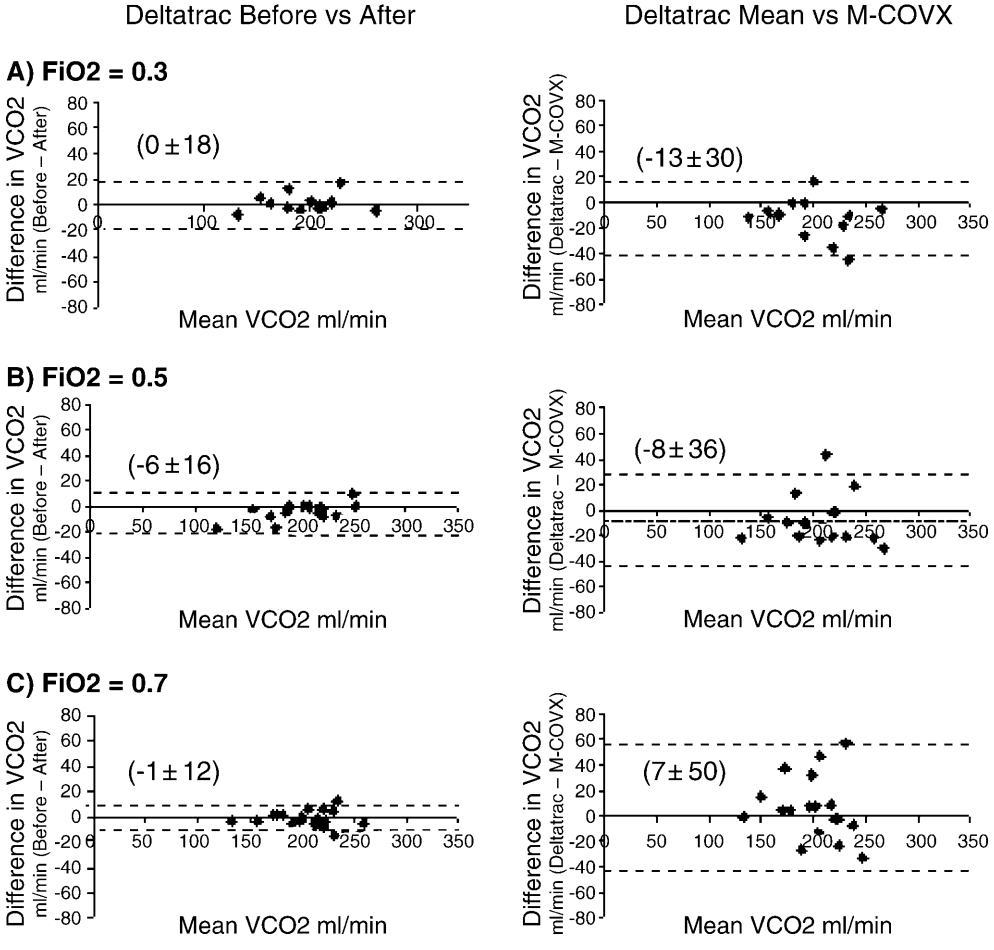

Fig. 2 Bland and Altman plots of *Deltatrac Before vs After* VCO_2 measurements and *Deltatrac Mean vs M-COVX* VCO_2 measurements at FiO_2 **A** 0.3, **B** 0.5, and **C** 0.7. Figures in parentheses represent bias ±95% limits of agreement. (*dotted line* bias, *dot/dashed line* 95% limits of agreement)

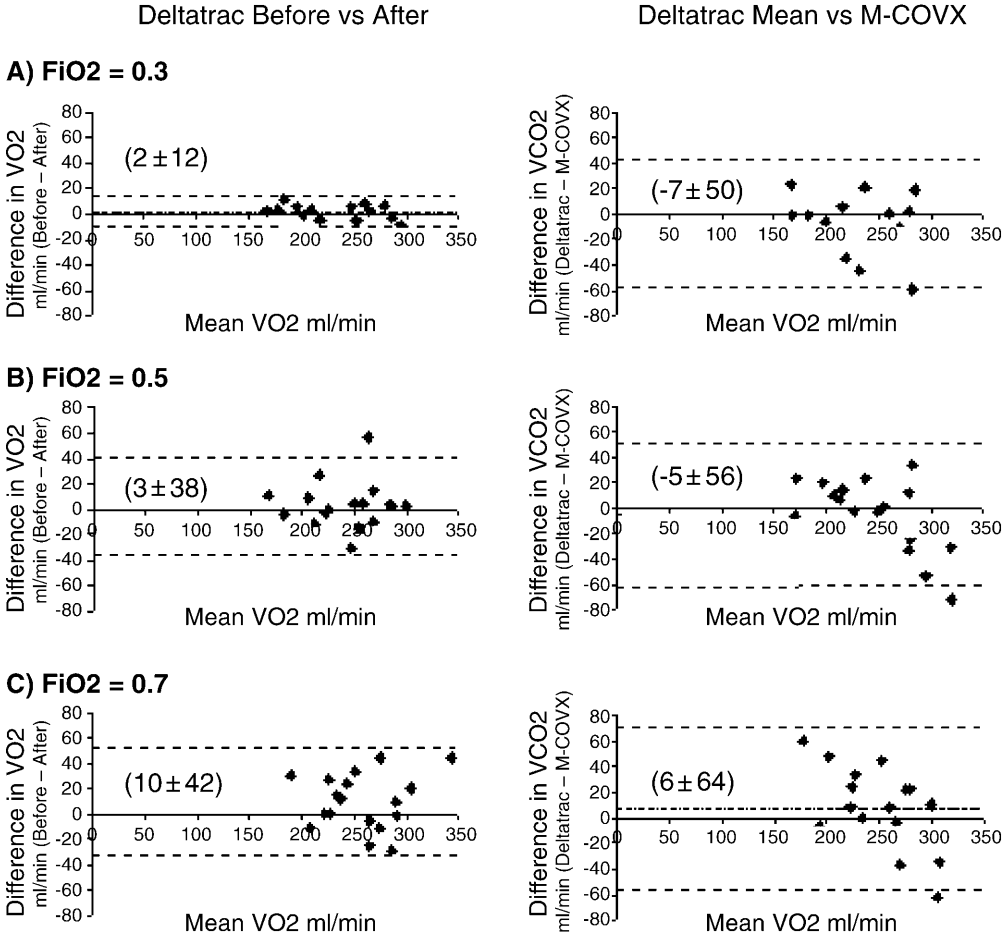

Fig. 3 Bland and Altman plots of *Deltatrac Before vs After* VO_2 measurements and *Deltatrac Mean vs M-COVX* CO_2 measurements at FiO_2 **A** 0.3, **B** 0.5, and **C** 0.7. Figures in parentheses represent bias ±95% limits of agreement. (*dotted line* bias, *dot/dashed line* 95% limits of agreement)

Table 3 Within-patients standard deviation (WPSD). Values expressed as ml/min

FiO_2	VCO_2			VO_2		
	Deltatrac before	M-COVX	Deltatrac after	Deltatrac before	M-COVX	Deltatrac after
0.3	6.78	11.65	5.27	10.7	10.7	14.32
0.5	7.43	14.75	7.67	17.03	17.56	18.5
0.7	9.21	9.79	9.66	30.65	15.68	24.34
Pooled	10.16	15.25	9.62	27.25	19.09	24.42

Discussion

We found that the bias between the M-COVX and Deltatrac metabolic monitors was clinically insignificant for both VO_2 and VCO_2. The limits of agreement between the two monitors were wide, particularly for VO_2 at high FiO_2. The relative reproducibility of VO_2 measurements was better for the M-COVX particularly at high FiO_2; VCO_2 measurements had better reproducibility with the Deltatrac, particularly at low FiO_2.

This was a clinical study and pulmonary gas exchange was subject to physiological variation. Increased variability of pulmonary gas exchange variables is seen using assisted modes of ventilation (such as synchronised intermittent mandatory ventilation and assisted spontaneous breathing). We deliberately chose to include various modes of ventilation because it is often desirable to assess respiratory gas exchange in patients receiving such modes, for example, during weaning. Measurement differences due to physiological variability would have been reduced if both monitors had been used simultaneously, but this would have introduced inaccuracy attributable to gas sampling. To measure pulmonary gas exchange the Deltatrac monitor uses a gas dilution technique that requires the collection of all the expiratory gases from the patient. The M-COVX monitor, in con-

trast, uses a pneumotachograph and a side-stream gas analyser. Simultaneous use of both monitors would have resulted in underestimation of VCO_2 and VO_2 by the Deltatrac monitor because of sampling of the expiratory gases by the M-COVX monitor (the degree of underestimation varying with the expired minute volume). A possible solution would have been to redirect the outflow from the M-COVX gas analyser back to the expiratory limb of the breathing attachment. This would have minimised errors in VCO_2 measurements made by the Deltatrac, but would have introduced significant errors (>10%) in VO_2 measurements, because the M-COVX gas analyser mixes the sampled expiratory gases with air from the oxygen reference channel. The effect of errors could have been reduced by correction factors but this would introduce assumptions. We therefore compared the two metabolic monitors sequentially and tried to minimise spontaneous variation in pulmonary gas exchange. All patients were being ventilated with a Drager Evita ventilator and were studied at the same time of day (1100–1700 hours). Only patients who were cardiovascularly stable were recruited to the study and interventions were kept to a minimum. In particular, none of the patients received physiotherapy during the study period and the administration of nutritional support and sedation was kept constant.

Axillary body temperature, $PaCO_2$, and (H^+) and (lactate) were recorded at the beginning and end of the study period. The only statistically significant change was in axillary body temperature. The reason for this small increase was unclear. Previous studies have shown that VO_2 alters by about 10% per degree Celsius in critically ill patients [12, 13]. It is therefore possible that this physiological change could have caused a systematic error.

We used an abbreviated protocol consisting of five consecutive 1-min readings of VO_2 and VCO_2. This time period was chosen as a compromise between maximising the number of data points (and therefore the accuracy of the VO_2 and VCO_2 measurements) and minimising the duration of the study to limit any physiological variation. This abbreviated protocol has been validated for use in stable sedated critically ill patients [14].

Bias

Overall there was no clinically significant bias between the Deltatrac and M-COVX for VO_2 or VCO_2. This indicates that both monitors measured the same physiological variable and that there were no systematic differences between the methods. This lack of systematic bias in VO_2 also suggested that the importance of the measured temperature change was small.

Limits of agreement and reproducibility

Comparisons of Deltatrac data before and after M-COVX measurements acted as an internal control and were expected to be similar. Deltatrac VCO_2 measurements made before and after M-COVX demonstrated very good agreement. The Deltatrac demonstrated very good reproducibility for VCO_2 suggesting that carbon dioxide production and alveolar minute ventilation were relatively constant over the entire study period. This was further supported by the lack of clinically or statistically significant changes in arterial blood gas data.

VO_2 measurements performed with the Deltatrac displayed good agreement at FiO_2 0.3 but poorer agreement at higher FiO_2 illustrated by the wider limits of agreement. Slight fluctuations in FiO_2, especially at high FiO_2 may result in significant errors in VO_2 measurement. The Drager Evita ventilator uses a solenoid blender to achieve the desired FiO_2. Solenoid blenders deliver a more stable FiO_2 than mechanical blenders although fluctuations still occur [8]. This may explain the discrepancy between the precision of the VCO_2 and VO_2 measurements obtained with the Deltatrac. Breath-by-breath methods, such as the M-COVX, may be less susceptible to FiO_2 fluctuations since instantaneous FiO_2 fractions are followed and used in the calculations.

The wide limits of agreement of the Deltatrac before and after VO_2 readings prevented a useful comparison between the Deltatrac and M-COVX monitors (for VO_2); the observed disagreement could have been attributable to errors with either monitor. We used a recognized method of comparing the reproducibility of two techniques in order to assess which had most measurement error [1, 15, 16]. The ratios of WPSD values for the Deltatrac before and after measurements were close to 1 for both VO_2 and VCO_2 as would be expected. Comparing Deltatrac with M-COVX suggested that for VO_2 the machines had similar reproducibility at FiO_2 0.3–0.5, but M-COVX had less variability at high FiO_2. Conversely for VCO_2 reproducibility was better for Deltatrac at FiO_2 0.3–0.5, and the devices performed similarly at FiO_2 0.7.

In conclusion, we compared measurements of pulmonary gas exchange in ventilated critically ill patients using two very different metabolic monitors, the Deltatrac and the M-COVX (a new breath-by-breath device). We found no clinically significant bias in VCO_2 or VO_2 over the FiO_2 range 0.3–0.7. The limits of agreement were wide, particularly for VO_2, because of a combination of physiological variation and true measurement error. Reproducibility measurements suggested that for VO_2 M-COVX performed better than Deltatrac at high FiO_2 (0.7), and for VCO_2 Deltatrac was better at lower FiO_2 (0.3–0.5). Reproducibility was similar under other conditions. The M-COVX can be used clinically with adequate reproducibility and accuracy for measuring respiratory gas exchange in ventilated critically ill patients.

Appendix

The Deltatrac II metabolic monitor calculations are as follows:

$$VCO_2 = Q \times FDCO_2$$

Where Q = constant flow rate (45 l/min)

$$FDCO_2 = fraction of CO_2 in the diluted \text{ exp}iratory gas$$

$$RQ = (1 - FiO_2)(FECO_2 - FiO_2)/(FiO_2 - FEO_2)$$

FiO_2 and $FiCO_2$ are measured from the ventilator's inspiratory limb. FEO_2 and $FECO_2$ are measured from the mixing chamber.

$$VO_2 = VCO_2/RQ$$

The M-COVX metabolic monitor calculations were as follows:

$$VO_2 = (FiO_2 - H \times FEO_2) \times V_I$$

$$VCO_2 = (FECO_2 \times H - FiCO_2) \times V_I$$

Where $H = (1\text{-}FiO_2\text{-}FiCO_2)/(1\text{-}FEO_2\text{-}FECO_2)$

$$V_I = inspiratory \min ute volume$$

At FiO_2 >0.65 expiratory volumes are more reliable than inspiratory volumes and the following formulae are used:

$$VO_2 = (FiO_2/H - FEO_2) \times V_E$$

$$VCO_2 = (FECO_2 - FiCO_2/H) \times V_E$$

Where V_E = expiratory minute volume.

References

1. Walsh TS, Hopton P, Lee A (1998) A comparison between the Fick method and indirect calorimetry for determining oxygen consumption in patients with fulminant hepatic failure. Crit Care Med 26:1200–1207
2. Dietrich KA, Romero MD, Conrad SA (1990) Effects of gas leak around endotracheal tubes on indirect calorimetry measurement. J Parenter Enteral Nutr 14:408–413
3. Browning JA, Linberg SE, Turney SZ, Chodoff P (1982) The effects of a fluctuating FiO_2 on metabolic measurements in mechanically ventilated patients. Crit Care Med 10:82–85
4. Welch HG, Pedersen PK (1981) Measurement of metabolic rate in hyperoxia. J Appl Physiol 51:725–731
5. Ultman JS, Bursztein S (1981) Analysis of error in the determination of respiratory gas exchange at varying FiO_2. J Appl Physiol 50:210–216
6. Selby AM, McCauley JC, Schell DN, O'Connell A, Gillis J, Gaskin KJ (1995) Indirect calorimetry in mechanically ventilated children: a new technique that overcomes the problem of endotracheal tube leak. Crit Care Med 23:365–370
7. Bracco D, Chiolero R, Pasche O, Revelly JP (1995) Failure in measuring gas exchange in the ICU. Chest 107:1406–1410
8. Tissot S, Delafosse B, Bertrand O, Bouffard Y, Viale JP, Annat G (1995) Clinical validation of the Deltatrac monitoring system in mechanically ventilated patients. Intensive Care Med 21:149–153
9. Takala J, Keinanen O, Vaisanen P, Kari A (1989) Measurement of gas exchange in intensive care: laboratory and clinical validation of a new device. Crit Care Med 17:1041–1047
10. Merilainen P, Hanninen H, Tuomaala L (1993) A novel sensor for routine continuous spirometry of intubated patients. J Clin Monit 9:374–380
11. Bland JM, Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1:307–310
12. Manthous CA, Hall JB, Olson D, Singh M, Chatila W, Pohlman A, Kushner R, Schmidt GA, Wood LD (1995) Effect of cooling on oxygen consumption in febrile critically ill patients. Am J Respir Crit Care Med 151:10–14
13. Chiolero R, Revelly JP, Tappy L (1997) Energy metabolism in sepsis and injury. Nutrition 13:45S-51S
14. Frankenfield DC, Sarson GY, Blosser SA, Cooney RN, Smith JS (1996) Validation of a 5-min steady state indirect calorimetry protocol for resting energy expenditure in critically ill patients. J Am Coll Nutr 15:397–402
15. Bland JM, Altman DG (1996) Measurement error. BMJ 312:1654–1654
16. Hanique G, Dugernier T, Laterre PF, Roeseler J, Dougnac A, Reynaert MS (1994) Evaluation of oxygen uptake and delivery in critically ill patients: a statistical reappraisal. Intensive Care Med 20:19–26