Brief Reports

Difference between arterial and end-tidal carbon dioxide pressures during laparoscopy in paediatric patients

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Purpose: To assess the effect of pneumoperitoneum on $P_{(a-ET)}CO_2$ gradient in children.

Methods: Sixty one ASA I and II children (10.7 ± 3.0 yr, 38.4 ± 14.2 kg, mean ± SD), scheduled for visceral or urological laparoscopic procedures, were studied. They were anaesthetized, intubated, paralysed and their lungs ventilated with constant ventilator settings to obtain $P_{ET}CO_2$ values between 4.3 and 4.8 kPa. Intra-abdominal pressure was maintained between 8 and 14 mmHg. The following measurements were performed at steady state, before the pneumoperitoneum (T_1) and 15 min later (T_2): heart rate, systolic and diastolic arterial pressure; peak airway and intra-abdominal pressure; P_aCO_2 corrected for the patient's temperature; $P_{ET}CO_2$ drawn between the micropore filter and the ventilator tubes, corrected for BTPS conditions; $P_{(a-ET)}CO_2$. Values between -1.0 and +1.0 mmHg were considered nil; patient position (horizontal or head-down tilt) : all patients were horizontal at T_1.

Results: Arterial pressure, heart rate and peak airway pressure increased at T_2: P_aCO_2 and $P_{ET}CO_2$ increased by 14%. The incidence of negative gradients increased from 54 to 67% although mean $P_{(a-ET)}CO_2$ remained clinically unchanged. No difference was found in $P_{(a-ET)}CO_2$ gradient, whatever the position and intra-abdominal pressure. The 95% confidence intervals for $P_{(a-ET)}CO_2$ were [-5.6 ; +3.2] at T_1 and [-8.8 ; +4.8] at T_2.

Conclusion: $P_{ET}CO_2$ often overestimates P_aCO_2 during laparoscopy in children, by up to 8.8 mmHg . Arterial blood gas analysis should be performed during long procedures to avoid hyperventilation.

Objectif : Évaluer l'effet du pneumopéritoine sur le gradient $P_{(a-ET)}CO_2$ chez les enfants.

Méthodes : Soixante et un enfants ASA I et II (10,7 ± 3 ans; 38,4 ± 14,2 kg, moyenne ± écart type) devant subir une laparoscopie viscérale ou urologique ont participé à l'étude. Ils ont été anesthésiés, intubés, curarisés et leurs poumons ont été ventilés selon des réglages constants afin d'obtenir des valeurs de $P_{ET}CO_2$ entre 4,3 et 4,8 kPa. La pression intra-abdominale a été maintenue entre 8 et 14 mmHg. Les mesures suivantes ont été faites à l'état d'équilibre, avant le pneumopéritoine (T_1) et 15 min plus tard (T_2) : rythme cardiaque, pression artérielle systolique et diastolique; pression de pointe ventilatoire et pression intra-abdominale; P_aCO_2 ajustée pour la température du patient; $P_{ET}CO_2$ prélevée entre le filtre micropore et les tubes du ventilateur, ajustée selon les conditions BTPS; $P_{(a-ET)}CO_2$. Les valeurs entre −1,0 et +1,0 mmHg ont été considérées comme nulles; la position du patient (horizontale ou inclinée avec la tête vers le bas) : tous les patients étaient en position horizontale au T_1.

Résultats : La pression artérielle, le rythme cardiaque et la pression de pointe ventilatoire ont augmenté à T_2 : P_aCO_2 et $P_{ET}CO_2$ augmentent de 14 %. L'incidence de gradients négatifs s'accroît de 54 % à 67 % bien que la moyenne de $P_{(a-ET)}CO_2$ demeure cliniquement inchangée. Aucune différence n'a été observée dans le gradient $P_{(a-ET)}CO_2$, quelle que soit la position et la pression intra-abdominale. Les intervalles de confiance à 95 % pour $P_{(a-ET)}CO_2$ étaient de [-5,6; +3,2] à T_1 et de [-8,8; + 4,8] à T_2.

Conclusion : $P_{ET}CO_2$ surestime souvent P_aCO_2, pendant la laparoscopie chez les enfants, de valeurs allant jusqu'à 8,8 mmHg. L'analyse des gaz artériels devrait être réalisée pendant les interventions de longue durée afin d'éviter l'hyperventilation.

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Presented, in part, at the 5th Annual Congress of the European Society of Anaesthesiologists, Lausanne, May 3-6th, 1997.
Accepted for publication February 25, 1998.

LAPAROSCOPIC surgery is routinely performed in children. Analysis of expired CO_2 is an important part of anaesthetic monitoring and negative $P_{(a-ET)}CO_2$ values have been reported in adults.[3] Paediatric laparoscopy increases CO_2 loading by transperitoneal absorption, and decreases both thoracic compliance and FRC.[1]

End-tidal carbon dioxide pressure ($P_{ET}CO_2$) may be less accurate in children than in adults: small tidal volumes and high fresh gas flows lead to dilution of $_{ET}CO_2$ and underestimation of P_aCO_2 by $P_{ET}CO_2$.[2] Laparoscopy could increase the discrepancy between P_aCO_2 and $P_{ET}CO_2$ in children, with negative or zero $P_{(a-ET)}CO_2$ gradients. No such findings have yet been reported in children.

The purpose of this study was, therefore, to assess the effect of pneumoperitoneum on $P_{(a-ET)}CO_2$ gradient during laparoscopic surgery in children.

Methods

Eighty-three children, ASA physical status I or II, were enrolled after approval by the local ethics committee. Children had fasted for six hours and were premedicated by flunitrazepam. They were scheduled for visceral or urological procedures via laparoscopy. Patients with cardiopulmonary abnormality and those in whom ventilatory settings were modified during the study were excluded. All children were monitored as usual. Heating blankets and isothermal mittens were used to prevent hypothermia.

Anaesthesia was induced either intravenously or with halothane (up to 3%). After tracheal intubation, anaesthesia was maintained with isoflurane 1% and N_2O 50% in O_2, opioids and atracurium for muscle relaxation. Mechanical ventilation was maintained with a Siemens® *SV 900 D* and a paediatric circle circuit. Tidal volume and respiratory rate were adjusted to obtain $P_{ET}CO_2$ values between 32 and 36 mmHg. Fresh gas flow was more than twice the minute ventilation. Inspiratory/expiratory ratio was ½ or 1/3. None of these settings was thereafter modified. Intra-abdominal pressure was maintained between 8 and 14 mmHg.

All measurements were performed at steady state, before the pneumoperitoneum (T_1) and 15 min later (T_2):

1 Heart rate, systolic and diastolic arterial pressure.

2 Peak airway and intra-abdominal pressure.

3 P_aCO_2 in blood drawn from the radial artery after Allen's test. The samples were analysed within ten minutes by a Ciba-Corning® model 820 analyser.

4 $P_{ET}CO_2$: recorded by a Capnomac Ultima (Datex®) infrared sidestream capnometer, calibrated according to the manufacturer's recommendations. The sampling site was between the micropore filter (dead space 25 ml) and the ventilator circuit (sampling rate 200 $ml \cdot min^{-1}$).

5 $P_{(a-ET)}CO_2$ gradient computed as P_aCO_2 - $P_{ET}CO_2$ corrected for BTPS conditions. Regarding measurement errors, gradients between -1.0 and +1.0 mmHg were considered to be zero.

6 The position of the patient at T_2 (supine or head-down tilt).

Statistical analysis was with Student's t test upon differences for comparisons between T_1 and T_2 and [2] or Fisher's exact test for qualitative data. All values are expressed as mean ± standard deviation. A P value < 0.01 was considered clinically significant.

Results

Sixty-one patients were studied (age 10.7 ± 3.0 yr, range 3.3 to 15.0 yr, weight 38.4 ± 14.2 kg, range 14 to 77 kg). All patients were in the horizontal supine position at T_1. At T_2, 32 were still horizontal and 29 were in the Trendelenburg position (-15 head-down tilt).

Relevant data are summarized in Table I. Arterial pressure, heart rate and peak airway pressure increased. $P_{ET}CO_2$ and P_aCO_2 increased by 14%. The mean $P_{(a-ET)}CO_2$ gradient varied from -1.2 ± 2.2 mmHg to -2.0 ± 3.4 mmHg (P = 0.05, clinically non significant). The 95% confidence intervals for $P_{(a-ET)}CO_2$ are [- 5.6 ; + 3.2] at T_1 and [- 8.8 ; + 4.8] at T_2. The incidence of negative gradients increased at T_2 (Table II). Intra-abdominal pressure (10 or > 10 mmHg) and the position at T_2 did not affect $P_{(a-ET)}CO_2$ variations.

Conclusions

The $P_{(a-ET)}CO_2$ values were often negative in these healthy ventilated children during general anaesthesia, especially after peritoneal insufflation.

Negative $P_{(a-ET)}CO_2$ values have been found previously in anaesthetized children.[2] Several factors have been suggested of which the first is the gas sampling site. In ventilated children, $P_{ET}CO_2$ is lower when gas sampling is proximal (near the micropore filter) than when it is distal (near carina): distal $P_{ET}CO_2$ is higher than P_aCO_2 in 26.6% of cases.[2] Thus, distal measurements favour negative gradients. This was not the case here. The second factor is linked to rebreathing.4 The circuits we used do not permit rebreathing. It is doubtful that these factors contributed to the negative values we observed. Overestimation of P_aCO_2 by $P_{ET}CO_2$ (up to 8.8 mmHg) may lead to hyperventilation which may be deleterious.

TABLE I. Haemodynamic data, temperature, arterial pH and CO2, PETCO2

	T1	*T2*
Arterial pressure (mmHg)		
systolic	100 ± 12	115 ± 14 *
diastolic	54 ±13	67 ± 12 *
mean	71 ± 11	85 ± 12 *
Heart rate (min^{-1})	78 ± 14	84 ± 17 *
Body temperature (C)	36.5 ± 0.5	36.5 ± 0.6
Peak airmay pressure (mmHg)	15.4 ± 4.3	17.5 ± 4.0 *
Arterial pH	7.47 ± 0.04	7.43 ± 0.05
P_aCO_2 (mmHg)	27.5 ± 3.0	31.0 ± 5.1 *
$P_{ET}CO_2$ (mmHg)	28.7 ± 3.4	33.1 ± 4.4 *
$P_{(a-ET)}CO_2$(mmHg)	-1.2 ± 2.2	-2.0 ± 3.4

* : $P < 0.01$, T_2 *vs* T_1

TABLE II $P_{(a-ET)}CO_2$ values at steady state before (T_1) and during (T_2) pneumoperitoneum: negative (-1.0 mmHg), positive (> +1.0 mmHg) or nil (between -1.0 and +1.0 mmHg)

	T_2 $P_{(a-ET)}CO_2$			
T_1 $P_{(a-ET)}CO_2$	*Negative (68%)**	*Nil*	*Positive*	*Total*
Negative (57%)*	26	3	4	33 (54%)*
Nil1	3	5	1	19
Positive	2	3	4	9
Total	41 (67%)*	11	9	61

* : $P < 0.01$ T_2 *vs* T_1

Temperature correction of blood gas values may explain the negative mean $P_{(a-ET)}CO_2$ gradient at T_1. P_aCO_2 values would, otherwise, have been overestimated in our hypothermic patients. This correction must be used when gas and blood samples are compared.[5] Bures et al. found that not correcting blood gas values led to overestimate mean $P_{(a-ET)}CO_2$ by 4.9 mmHg during adult laparoscopy and that CO_2 load or increased CO_2 production may favour a decrease in $P_{(a-ET)}CO_2$.[6] These findings are consistent with Piiper's studies.[7] He found that $P_{(a-ET)}CO_2$ became more negative with increasing P_aCO_2. Similarly, negative $P_{(a-ET)}CO_2$ values have been found during exercise, where CO_2 production is higher than at rest.[8] This was not the case in our hypocarbic patients, whose cardiac index might have remained unchanged or decreased.[9]

The influence of posture and intra-abdominal pressure was not clinically important in our study, probably because head-down tilt (-15°) and intra-abdominal pressure (≤14 mmHg) were moderate.

In conclusion, negative $P_{(a-ET)}CO_2$ values before and during pneumoperitoneum may occur frequently in children. They may lead to hyperventilation in some patients. Arterial blood gas analysis might be indicated during long procedures to prevent hyperventilation. Explanations for these negative values are ambiguous, further studies should be carried out in children, especially during laparoscopic procedures.

References

1 *Sfez M.* Anesthésie pour coeliochirurgie en pédiatrie. Ann Fr Anesth Réanim 1994; 13: 221–3.

2 *Badgwell JM, McLeod ME, Lerman J, Creighton RE.* End-tidal PCO_2 measurements sampled at the distal and proximal ends of the endotracheal tube in infants and children. Anesth Analg 1987; 66: 959–64.

3 *Bhavani Shankar K, Moseley H, Kumar Y, Vemula V, Krishnan A.* Arterial to end-tidal carbon dioxide tension difference during anaesthesia for tubal ligation. Anaesthesia 1987; 42: 482–6.

4 Rich GF, Sconzo JM. Continuous end-tidal CO_2 sampling within the proximal endotracheal tube estimates arterial CO2 tension in infants. Can J Anaesth 1991; 38: 201–3.

5 *Scheid P, Piiper J.* Blood/gas equilibrium of carbon dioxide in lungs. A critical review. Respir Physiol 1980; 39: 1–31.

6 *Bures E, Fusciardi J, Lanquetot H, Dhoste K, Richer J-P, Lacoste L.* Ventilatory effects of laparoscopic cholecystectomy. Acta Anesthesiol Scand 1996; 40: 566–73.

7 *Piiper J.* Blood-gas equilibrium of carbon dioxide in lungs: a continuing controversy. J Appl Physiol 1986; 60: 1–8.

8 *Wilmore JH, Farrell PA, Norton AC,* et al. An automated, indirect assessment of cardiac output during rest and exercise. J Appl Physiol 1982; 52: 1493–7.

9 *Raux O, Castro-Marin M, Rochette A,* et al. Hemodynamic changes associated with laparoscopic surgery in children. Anesthesiology 1995; 83: A1155.