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ORIGINAL ARTICLE

Carbon dioxide absorption during retroperitoneoscopic adrenalectomy: comparison between monolateral and synchronous bilateral approaches

Valter Perilli[1,2] · Paola Aceto[1,2] · Giovanni Punzo[1,2] · Celestino Pio Lombardi[2,3] · Rocco Bellantone[2,3] · Liliana Sollazzi[1,2]

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Abstract

Synchronous posterior retroperitoneoscopic bilateral adrenalectomy (PR-BilA) is a novel technique proposed for the definitive cure of hypercortisolism when a surgical approach is indicated. The aim of the present prospective cohort study was to compare the carbon dioxide (CO_2) absorption in patients undergoing PR-BilA with those undergoing single posterior retroperitoneoscopic adrenalectomy (PRA). Twenty-nine patients undergoing PR-BilA or PRA were consecutively enrolled. Anaesthesia was standardised. In both groups, CO_2 elimination (VCO_2), CO_2 dissolved in arterial blood ($PaCO_2$), end-tidal CO_2 ($EtCO_2$), and volume per minute (VM) were measured at the following time points: after anaesthesia induction and before CO_2 insufflation (T1), 5 min after CO_2 insufflation (T2), at the time of maximum VCO_2 (T3), and at desufflation (T4). VCO_2 was continuously measured using a metabolic monitor. ANOVA for repeated measures was used for statistical analysis. With respect to VCO_2, a significant group × time interaction was found ($p=0.03$). Post hoc analysis revealed that VCO_2 was significantly increased at T4 compared with T1 in both groups ($p=0.02$ and $p=0.0001$ in the PRA and PR-BilA groups, respectively). Regarding $PaCO_2$, ANOVA analysis showed a significant group effect ($p=0.01$), with higher values in the PR-BilA group. $EtCO_2$ and VM did not differ between the two groups. We found that the CO_2 absorption was increased in both groups at the end of surgery, in the presence of a higher trend in $PaCO_2$ values during PR-BilA. Therefore, PR-BilA may be considered a safe surgical approach with respect to CO_2 absorption, when a mild degree of hypercapnia may be accepted.

Keywords Carbon dioxide absorption · Retroperitoneoscopic adrenalectomy · Hypercapnia · Monitoring · Safety

Introduction

In recent years, the bilateral adrenalectomy with a posterior retroperitoneoscopic (PR-BilA) approach has been proposed for the definitive cure of hypercortisolism in persistent or recurrent Cushing's disease following failed hypophysectomy, ectopic ACTH production, or in non-resectable, corticotrophin-secreting neoplasms and primary adrenal bilateral disease [1, 2]. This novel surgical approach immediately gained interest in the endocrine surgical community as an alternative, safe, and efficacious option in patients requiring bilateral adrenalectomy, since unlike the most commonly used transperitoneal bilateral approach, it eliminates the need to reposition the patient after completing the operation on the first side [3–5]. Moreover, PR-BilA makes it possible to perform a simultaneous BilA, with two surgical teams operating on the two different sides of the patient at the same time, consequently further reducing the operative time and surgical stress on the patient [4–7]. The main limitations of this procedure are related to the need to have two different well-trained surgical teams working simultaneously. Furthermore, the absorption of carbon dioxide (CO_2) from the retroperitoneal space when both adrenal glands are removed at the same time has not yet been well studied. To the best of our knowledge, measurement of CO_2 adsorption

✉ Paola Aceto
pa.aceto@gmail.com

[1] Department of Anaesthesiology and Intensive Care Medicine, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy

[2] Università Cattolica del Sacro Cuore, Rome, Italy

[3] Division of Endocrine and Metabolic Surgery, Department of Surgery, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy

during synchronous posterior retroperitoneoscopic bilateral adrenalectomy has yet to be reported in the literature.

The aim of the present prospective cohort study was to compare the CO_2 absorption in patients undergoing synchronous PR-BilA with those undergoing single posterior retroperitoneoscopic adrenalectomy (PRA).

Materials and methods

After obtaining Ethic Committee approval and informed patient consent, 29 patients undergoing posterior retroperitoneoscopic adrenalectomy (PRA, $n = 18$) or synchronous retroperitoneoscopic bilateral adrenalectomy (PR-BilA, $n = 11$) were consecutively enrolled. Exclusion criteria were: known allergies to drugs used in the study protocol, patients with a BMI > 30 kg/m^2, ASA physical status > 2, diagnosis of chronic obstructive pulmonary disease (COPD) confirmed at the time of preoperative anaesthesiological assessment by spirometry according to the GOLD revision [i.e., the presence of a post-bronchodilator (forced expiratory volume in the first second of expiration/forced vital capacity) FEV1/FVC < 0.70] [8], or mild to severe cardiac diseases (NYHA class ≥ 2), all of whom were converted to the open surgical approach.

Standardised general anaesthesia was used in all patients. Induction of anaesthesia was performed with propofol (2–3 mg/kg), fentanyl (2–3 mcg/kg), and rocuronium (0.6 mg/kg). For anaesthesia maintenance, sevoflurane at the bispectral index (BIS)-guided concentration and additional fentanyl (50–100 mcg) boluses were administered. The BIS (BIS VistaTM, Aspect Medical System Inc, Norwood, MA, USA) was maintained between 40 and 60 during surgery. For intraoperative curarisation, rocuronium boluses were given to patients to maintain a post-tetanic count ≤ 2 using neuromuscular monitoring (neuromuscular transmission mechanosensor, GE Healthcare, UK). Controlled ventilation was initially set up in all patients at 6–8 mL/kg, with a respiratory rate of 12–14 breaths per minute; successively, tidal volume and/or respiratory rate were adjusted throughout surgery to maintain end-tidal CO_2 ($EtCO_2$) ≤ 45 mmHg, plateau pressure ≤ 25 cmH_2O, and pH no lower than 7.28. $EtCO_2$ was continuously measured using a mainstream infrared analyser in the anaesthesia machine (Dräger Primus®, Dräger Medical, Lübeck, Germany). Serial blood samples from a radial artery catheter were performed to check pH values. CO_2 elimination (VCO_2) was continuously measured using a metabolic monitor (Deltatrac™, Datex-Ohmeda Division, Instrumentarium Corp, Teollisuuskatu 29, Helsinki, FIN 00031, Finland) [8].

In both groups, CO_2 dissolved in arterial blood ($PaCO_2$), $EtCO_2$, and VCO_2 were measured every 20 min during surgery, and the following time points were used for comparisons between the two groups: after induction of anaesthesia and before CO_2 insufflation (T1), 5 min after CO_2 insufflation (T2), at the time of maximum VCO_2 as measured by a metabolic monitor (T3) and at desufflation (T4).

Central body temperature, as measured by an oesophageal probe, was maintained within the normal range using an air-forced warming system (Bair Hugger Model 505, Arizant Healthcare Inc, MN, USA) and a fluid warming device (enFlowR, BD, USA).

The pneumoperitoneum pressure was maintained at 20 mmHg throughout the procedure. Extubation was performed when the patients were fully awake, with train-of-four > 90% and $EtCO_2$ < 40 mmHg.

Statistical analysis

The Shapiro–Wilk test was used to assess the normality of data distribution for each of the variables. A Student's *t* test or Mann–Whitney *U* test was performed to compare parameters between the two groups (group 1: PRA; group 2: PR-BilA), as appropriate. Categorical variables were analysed using Fisher's exact test. ANOVA for repeated measures was used to analyse differences in $PaCO_2$, VCO_2, $EtCO_2$, and volume per minute (*V*M) between the two groups at different time points (T1, T2, T3, T4). Post hoc analysis with Bonferroni correction was performed only when a correlation (group × time) was statistically significant. A significance level of $p < 0.05$ was used.

All analyses were performed using the Statistica version 6.1 software (StatSoft, Tulsa, Oklahoma, USA).

Results

One patient was excluded due to conversion to open surgery. The final sample included 17 patients undergoing monolateral retroperitoneoscopic adrenalectomy (PRA) and 11 patients undergoing synchronous bilateral retroperitoneoscopic adrenalectomy (PR-BilA). The demographic parameters were similar in the two groups (Table 1).

With respect to VCO_2, ANOVA analysis showed that the difference between the groups was not statistically significant ($F(1,26) = 3.5$ (1,3); $p = 0.07$), whereas time ($F(3,78) = 32.1$ (1,26); $p = 0.0001$) and interaction group per time ($F(3,78) = 3.1$ (1,78); $p = 0.03$) were both significant. Post hoc analysis revealed that the increase in VCO_2 from T2 to T3 was significant in both groups ($p = 0.003$ in group 1 and $p = 0.0001$ in group 2) and that VCO_2 was significantly increased at T4 compared with T1 in both groups ($p = 0.02$ in group 1 and 0.0001 in group 2) (Fig. 1).

Regarding $PaCO_2$, ANOVA analysis showed a significant group ($F(1,26) = 7.6$ (1,3); $p = 0.01$) and time

Table 1 Characteristics of patients undergoing PRA (group 1) and PR-BilA (group 2)

	Group 1 ($n=17$)	Group 2 ($n=11$)	p
Gender (males/females)	5/12	2/9	0.50
Age (years)	46.5 ± 11.1	41.6 ± 13.4	0.19
BMI (kg/m^2)	24.6 ± 2.5	24.4 ± 2.9	0.85
Operative time (min)	111 ± 20	152 ± 38	0.01
Anaesthesia duration (min)	137 ± 19	204 ± 46	0.0005
Extubation time (min)	13 ± 11	42 ± 13	0.0001
Postoperative hospital stay length (days)	3.2 ± 0.8	3.4 ± 0.5	0.36
Preoperative diagnosis			
ACTH-dependent Cushing's disease	0	11	
ACTH-independent Cushing's disease	17	0	

Values are shown as mean ± SD or numbers

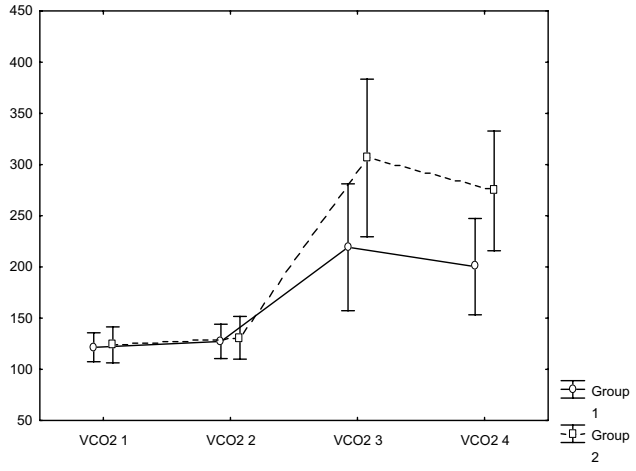

Fig. 1 Trend of VCO_2 throughout surgical procedure

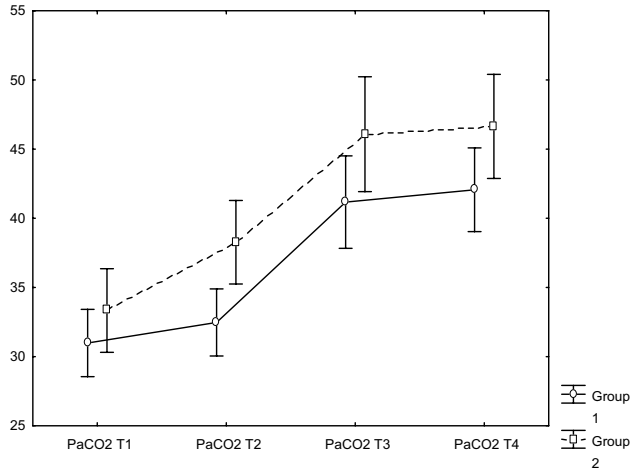

Fig. 2 Trend of $PaCO_2$ during the surgical procedure

($F(3,78)=47.8$; $p=0.0001$) effect, whereas the group per time interaction was not significant ($F(3,78)=0.70$; $p=0.55$) (Fig. 2).

ANOVA analysis of $EtCO_2$ values showed that neither group ($F(1,26)=1,90$; $p=0.18$) nor group per time interaction ($F(3,78)=16.8$; $p=0.56$) was statistically significant, whereas time was significant ($F(3,78)=32.0$; $p=0.0001$) (Fig. 3).

ANOVA analysis of VM showed that neither group ($F(1,26)=0.33$; $p=0.57$) nor group per time interaction ($F(3,78)=0.18$; $p=0.91$) was statistically significant, whereas time was significant ($F(3,78)=19.8$; $p=0.0001$) (Fig. 4).

No patients showed a pH < 7.28 with the ventilation setting adopted during the intraoperative period.

It was not necessary to raise the pneumoperitoneum pressure over 20 mmHg in any of the patients.

At the end of surgery, a mild subcutaneous emphysema was registered in 11 of the 17 patients (64.7%) who underwent PRA and in 5 of the 11 (45.4%) who underwent

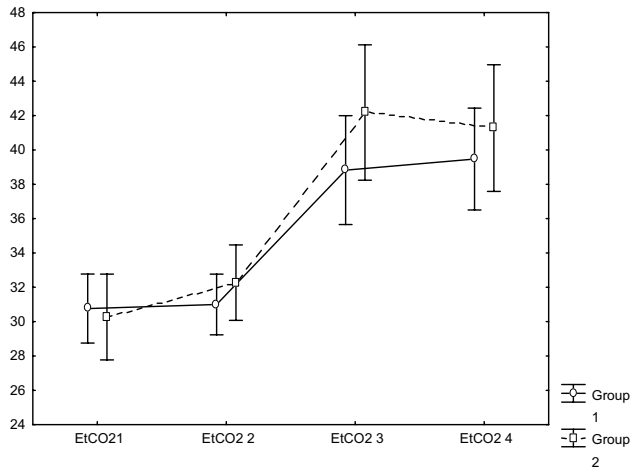

Fig. 3 Trend of $EtCO_2$ throughout surgical procedure

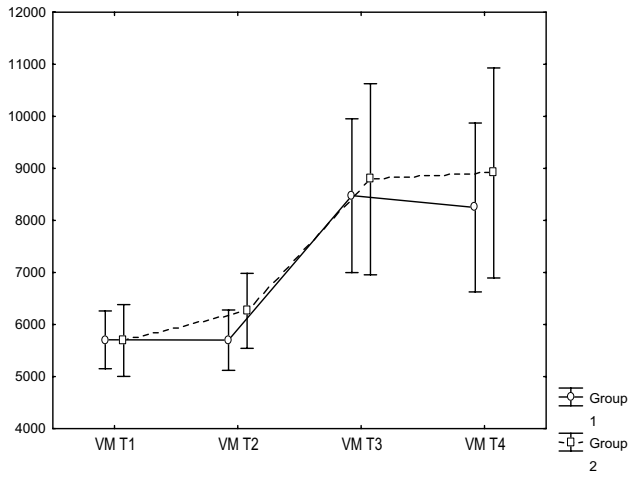

Fig. 4 Trend of VM (ventilation per minute) throughout surgical procedure

PR-BilA ($p = 0.44$). The subcutaneous emphysema did not cause any clinically relevant ailment and spontaneously disappeared during the first 12 postoperative hours in all patients.

No other intraoperative or postoperative adverse events, including those linked to CO_2 absorption (e.g., tachycardia, arrhythmias, headache, palpitations, irritation), were observed during the study period ranging from the day of surgery to discharge from the hospital.

Discussion

In the present study, we found that the CO_2 absorption was increased in both groups at the end of surgery, in the presence of a higher trend in $PaCO_2$ values during PR-BilA. Therefore, PR-BilA may be considered a safe surgical approach with respect to CO_2 absorption, when a mild degree of hypercapnia may be accepted.

Previous studies have demonstrated the safety of PRA compared with transperitoneal adrenalectomy (TPA) [1, 9], despite the higher CO_2 absorption registered in this approach, which could make it necessary to increase mechanical ventilation to avoid respiratory acidosis [10].

The CO_2 absorption from a close cavity depends on the insufflation pressure, the extension of the absorbing area, and the duration of surgery, in addition to the perfusion of the walls and the diffusivity of the gas [11]. In the present study, the insufflation pressure was maintained constantly at 20 mmHg in both groups of patients. Regarding the absorption area, the synchronous bilateral approach involves creation of two virtual cavities, instead of one, in the retroperitoneal space [4, 5, 12]. The larger absorption area, together with the longer duration of surgery, could explain the higher CO_2 absorption absolute values found in patients undergoing PR-BilA compared with those undergoing PRA, even though this difference did not reach statistical significance. In both groups, we maintained the prefixed target of $EtCO_2 < 45$ mmHg in most of the patients by increasing the mechanical ventilation; however, in such patients, we were forced to accept higher values of $EtCO_2$ to respect the limit of plateau pressure of 25 cmH_2O. Definitively, we preferred to accept a certain degree of hypercapnia instead of performing an overly aggressive mechanical ventilation. For this reason, a higher trend in $PACO_2$ values was observed in patients undergoing PR-BilA.

Nevertheless, the difference in $PaCO_2$ trend registered between the two groups did not affect patient outcome. In fact, with the exception of mild subcutaneous emphysema that was observed with a similar prevalence in patients undergoing PRA, no other complications related to the higher CO_2 absorption were detected in the PR-BilA group.

Finally, VCO_2 did not return to baseline in either group at the end of surgery; therefore, time to extubation was significantly higher in patients undergoing PR-BilA compared with those undergoing PRA. This was likely due to the greater amount of CO_2 absorbed from the two retroperitoneal cavities, which required a more prolonged mechanical ventilation to obtain $ETCO_2$ values < 40 mmHg.

Interestingly, the use of a retroperitoneal lavage with saline containing adrenaline has been proposed in patients undergoing retroperitoneal laparoscopic surgery to reduce CO_2 absorption [13]. This method may prevent the occurrence of hypercapnia and associated complications; however, it cannot be applied in the case of long surgical procedures or in patients with widespread subcutaneous emphysema. Another issue could be the improper implementation of this technique, which may cause systemic adrenaline absorption with serious adverse effects.

The main limitations of the present study were its observational design and the small sample size, which led to possible bias. Another limitation was the longer mean operative time in the PR-BilA group compared with the PRA group, which may be mainly attributed to the fact that the two surgical teams are sometimes not perfectly simultaneous in performing the procedure due to different technical difficulties at each site.

In conclusion, PR-BilA may be considered a safe surgical approach with respect to CO_2 absorption in patients without COPD. It is well known that in cases of minimum bleeding, raising the work pressure can help the surgeon to stop such bleeding. Even though it did not apply to our study, a pressure increase over 20 mmHg could be detrimental to COPD patients; therefore, we suggest avoidance of PR-BilA in COPD patients, at least with bigger tumours, since they are not ideal candidates for this surgical approach due to their defective CO_2 clearance. These patients may meet a

difficult weaning from mechanical ventilation in the postoperative period.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Research involving human participants and/or animals The present manuscript is in compliant with ethical standard. This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all the patients included in the study.

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